HIGHWAYS IN THE RIVER ENVIRONMENT HYDRAULIC AND ENVIRONMENTAL DESIGN CONSIDERATIONS

Basic Course
Instructor's Lesson Plans

U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration

August 1975

Technical Report Documentation Page

1. Report No. FHWA-NHI-76-N004	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle HIGHWAYS IN THE RIVER ENVIRONMENT--HYDRAULIC AND ENVIRONMENTAL DESIGN CONSIDERATIONS Basic Course Instructor's Lesson Plans		5. Report Date August 1975
		6. Performing Organization Code
7. Author(s) Messrs. E.V. Richardson, S. Karaki, K. Mahmood, D.B. Simons, and M.A. Stevens		8. Performing Organization Report No.
9. Performing Organization Name and Address Civil Engineering Department Engineering Research Center Colorado State University Fort Collins, Colorado 80523		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DOT-FH-11-8101
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Highway Administration Office of Engineering, Office of Development, National Highway Institute, Washington, D.C. 20590		13. Type of Report and Period Covered Basic Course Instructor's Lesson Plans 1974-75
		14. Sponsoring Agency Code N004

15. Supplementary Notes

FHWA Contract Manager: Mr. Roger L. Dean

16. Abstract

Through a coordinated effort between the Federal Highway Administration and Colorado State University a training course was developed to provide training in the practical application of the concepts of open channel flow, fluvial geomorphology, and river mechanics to the planning, location, design, construction, maintenance and operation of highways; and to enable the participants to apply these concepts to environmental problems associated with highway crossings and encroachments.

This two-week course was oriented to graduate engineers who have had training in basic hydraulics.

The subject publication, Basic Course Instructor's Lesson Plans, contains outlines for each of the thirty-four lessons for this course. A lesson may consist of only a lecture or it may have a lecture, problems, and discussion session. Each lesson is a unit by itself with specific objectives.

A second publication was also developed for this course on Highways in the River Environment. It is subtitled Training and Design Manual and is intended to serve as a text for the course. It is also available from the National Technical Information Service.

17. Key Words Open Channel Flow, Sediment Transport, Fluvial Geomorphology, River Mechanics, Riverbank Protection	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72) Reproduction of form and completed page is authorized

ACKNOWLEDGMENTS

The writers of these lesson plans gratefully acknowledge the review, help and guidance given by a Steering Committee consisting of: Roger L. Dean, Frank L. Johnson, Murray L. Corry, Dah-Cheng Woo, Milo Cress, Lawrence J. Harrison, Herbert Gregory, Gene R. Fiala of the Federal Highway Administration and Mainard Wacker of the Wyoming Highway Department.

The writers also wish to acknowledge the help of Professors J. F. Ruff and A. G. Mercer; Graduate Research Assistants V. M. Ponce, Larry Rundquist and Tony Melone; Mrs. Arlene Nelson, Chief of Technical Typing; and Miss Hanae Akari, Chief of Illustration, Engineering Research Center in the preparation of these lesson plans.

TABLE OF CONTENTS

TABLES

PARTIAL LIST OF SYMBOLS

A	Cross-sectional area of flow
a	Acceleration, half-distance of wave amplitude
B	Constant
C	Concentration of material in suspension in the fluid or Chezy discharge coefficient
$C/\sqrt{g}$	Chezy dimensionless discharge coefficient $C/\sqrt{g} = V/\sqrt{gRS}$
C_f	Concentration of fine sediment (washload)
C_s	Concentration of suspended sediment discharge
C_D	Coefficient of drag
C_v	Free vortex constant
C_λ	Celerity of the wave
C_T	Concentration of total bed-material discharge
c	Proportionality constant, subscript: critical conditions
d	Diameter of sediment particles
d_a	Diameter of sediment particles for which a percent of the particles are finer
d_{50}	Median diameter of sediment particles for which 50 percent are finer
D	Depth of flow
F_r	Froude number $V/\sqrt{gD}$
f	Darcy-Weisbach resistance coefficient
f_s	Seepage force
g	Acceleration of gravity
G	Gradation, measure of size distribution of sediment particles
H	Specific head $(V^2/2g + y_o)$ or for trapezoidal channels, the horizontal distance for one unit of vertical distance
H_L	Head loss (total) $H_L = h_f + h_L$
h	Head
h_f	Friction head loss
h_L	Minor loss or form loss
i	Subscript: inside, initial
k_s	Height of the roughness element
K	Arbitrary constant
L	Distance, length
ℓ	Mean scale of turbulence
M	Momentum

PARTIAL LIST OF SYMBOLS (continued)

m	Mass, subscript for model
n	Manning roughness coefficient, coordinate normal to flow direction
P	Wetted perimeter
ppm	Parts per million
Q	Discharge cubic feet per second, cfs
Q_s	Sediment discharge, lbs per sec, tons per day
q	Discharge per unit width
q_s	Sediment discharge per unit width
R	Hydraulic radius, A/P
Re	Reynolds number, VD/ν
r	Radius, cylindrical coordinate, subscript: ratio
r_o	Radius, outside of bend
r_i	Radius, inside of bend
S	Slope
S_c	Shape factor for the cross section of a river
S_f	Slope of energy grade line
S_o	Slope of the bed
S_p	Shape factor of the sediment particles
S_R	Shape factor for the reach of a river
S_w	Slope of the water surface
s	Coordinate in the direction of flow
T	Temperature, or period in wave equation
t	Time variable
V	Mean velocity in the vertical
$\overline{V}$	Mean velocity Q/A
v	Velocity at a point ($v = \overline{v} + v'$)
$\overline{v}$	Mean velocity at a point
v'	Velocity fluctuations
V_*	Shear velocity $V_* = \sqrt{gRS}$
W	Width of stream
W_e	Weber number
w	Weight, subscript: wave
x,y,z	Cartesian coordinate
y	Depth
y_o	Normal depth of flow

PARTIAL LIST OF SYMBOLS (continued)

y_c	Critical depth of flow
y_o/k_s	Relative roughness
z	Vertical distance
Z	Rouse number
α	Kinetic energy coefficient
β	Velocity (momentum) coefficient, wave front angle
γ	Specific weight of water—sediment mixture
γ_s	Specific weight of sediment, about 164.5 pounds per cubic foot
γ_w	Specific weight of water, about 62.4 pounds per cubic foot
Δ	Small increment
ΔD	Wave height
ϵ	Eddy viscosity
θ	Angle: inclination, contraction, central
κ	von Kármán universal velocity coefficient
λ	Wave length
μ	Dynamic viscosity
ν	Kinetic viscosity
ρ	Mass density of fluid
ρ_s	Mass density of sediment
Σ	Summation symbol
σ	Surface tension
π	Circular circumference-diameter ratio
τ	Shear stress
τ_o	Shear stress at the boundary
ω	Fall velocity of sediment particles

INTRODUCTION

A major aspect in highway design and construction is the crossing of streams and rivers. A concurrent problem is the encroachment of the highway onto the floodplain or even the stream channel at times. This encroachment may be at right angles to the stream or parallel to the stream, the former being the approaches to a bridge or culvert and the latter being the only feasible or economical location of the highway. In either case, the design of the crossing or encroachment must be made to insure the safety of the traveler, must protect the river environment, must not create hazards or problems to adjacent land owners and the community, and must be economical. This requires that the designer must have a basic understanding of hydraulics, hydrology, sedimentation, and fluvial geomorphology. These disciplines are encompassed in the term "river mechanics." Although there is a considerable fund of knowledge of these subjects, it is still partly an art in addition to being science. The subjects are based on sound scientific principles but there are so many variables interacting that precise formulas are not possible. The design of a river crossing or encroachment depends on the experience of the designer in addition to his knowledge of engineering science. This course is a two week intensive training session for about 35 hydraulic engineers, dealing specifically with river mechanics as it affects highways in the river environment.

COURSE OBJECTIVES

The course has two objectives: (1) to develop participant skills in the hydraulics of open channel flow, sedimentation, fluvial geomorphology, and river mechanics, and (2) to train highway engineers in the application of these skills to typical design problems of highways in the river environment.

COURSE CONTENTS

The course is based on a manual titled Highways in the River Environment--Hydraulic and Environmental Design Considerations written especially for it. The manual has eight chapters which are titled as follows:

Chapter I Introduction

Chapter II Open Channel Flow

Two weeks are required to complete this course. The first four and one-half days are spent on the first five chapters, which teach the requisite engineering skills. The rest of the time is spent in the application of these skills to typical design problems. One and one-half days are spent on single aspect problems such as scour around bridge piers or design of riprap; and two and one-half days are spent on complex design problems which consider the total problem, from site selection to design of waterway crossing with riprap requirements. In the application section of the course, the skills taught in the first part of the training are emphasized using a case history approach. The use of the skills in the solution of realistic problems emphasizes their importance and reinforces the knowledge previously gained by the participants and thus aids them in retaining what they have learned.

Basic data is a prime consideration in the design of highways in the river environment. It is often lacking, yet the designer must design the crossing with the particulars of the river and its environment in mind. Therefore, some time is spent on data requirements and methods of making do when data is lacking.

TEACHING METHOD AND MODEL SCHEDULE

The method of teaching is an integration of lecture, problem solving and discussion. Visual aids consisting of slides, movies, overhead projectors and blackboards are used freely. In general, four lectures, two problem sessions and two discussion sessions are given during an eight hour day. Each lecture, problem session or discussion lasts about 50 minutes, although adherence to a 50 minute schedule should not be rigid. Participants in groups of two or three will work the problems. Instructors and teaching aides help in the solution of the problems. It is suggested that there be one aide for every 5 to 10 students. Participants who know the material may serve as aides. At midmorning and mid-afternoon a coffee break with informal discussion is recommended.

A model schedule is given in Table I. Except for the movie on the evening of the first day, all evenings are free. In consideration of the intensive eight hour training day, the evenings should be free for self study and unstructured discussion. Although not shown on the schedule, an introductory get-together the evening preceeding the training will help open up the discussion sessions and aid the training. Also, using name cards on the desks and scrambling desk assignments each day will integrate the group, leading to more discussions and a better learning atmosphere. Finally, a dinner with a speaker on the next to last day is a fitting reward for two weeks of intensive work.

FIELD TRIP

If possible, a field trip should be scheduled on the Saturday between the two weeks of instruction. The trip to visit typical highway crossings and encroachments will aid in the understanding and utilization of the skills that were learned in the first week. The trip will set the stage for the application of these skills in the next week. However, the trip must be carefully structured and an instructor must go along to lead in the discussions. If the field trip cannot be scheduled, then an unstructured discussion of highway environment problems could be held.

PRETRAINING STUDY

Prior to attending the course, the participants should purchase or be sent the manual titled Highways in the River Environment--Hydraulic and Environmental Design Considerations, and the two volume set of books titled River Mechanics edited by H. W. Shen. The books can be ordered from: Water Resources Publications, P.O. Box 303, Fort Collins, Colorado 80521.

The material should be read for concept and ideas, not mathematical formulations. The short course will build on the material in the manual and the books to develop them into a tool for hydraulic and design problems of highways in the river environment. In addition to the manual and the two volume set of River Mechanics, the references at the end of each chapter of the manual can be used for further study.

It is suggested that the chapters in River Mechanics be read in the following order: Chapters 3, 9, 4, 5, 6, 7, 8, 11, 20, 12, 13, 14, 16, 23, 24, 19, 17, 18, and 25. In Chapter 9, it is suggested that pages 9-42 to 9-47 and 9-56 to 9-77 be skipped.

STUDENT NUMBERS AND FACULTY

It is suggested that the number of participants be limited to less than 40. For this number of participants, the faculty should consist of four instructors. It also helps to have two or three teaching aids to assist in the problem sessions.

FACILITIES AND EQUIPMENT

The course is based on the assumption that a classroom will be available. It should be large enough so that each participant will have ample space to work the assigned problems.

Standard classroom equipment is required, including chalkboards, overhead projectors and slide and movie projectors. In addition, a TV camera and playback equipment would assist in presenting some of the material.

If a field trip is taken, a bus large enough to handle the total group should be provided.

INSTRUCTIONAL MATERIALS

Instructional materials consist of the lesson plans, manual, and set of River Mechanics edited by Shen. The latter two items should be sent to the participants prior to their attendance. Participants need not bring paper as this should be furnished. Paper supplied should be white engineering graph paper with five squares to the inch (Padmaster or equivalent).

Participants should bring a slide rule and/or pocket electronic calculator.

VISUAL AIDS

Visual aids consist of 35 mm slides, a movie titled "Flow in Alluvial Channels," and overhead projections of sketches of graphs and figures. In addition, TV tapes of lectures given by instructors from Colorado State University in December 1973 to a group of highway engineers are available. A list of these tapes is given in Table II. These tapes are coded with the lesson plans.

TRAINING EVALUATION

Evaluating the participants' knowledge of the subject matter is the only way to ascertain if the objectives of the course have been met. This evaluation is done in two ways: (1) the definitely stated objectives given for each lesson plan, and (2) course evaluation tests provided in the appendix.

Except for those lesson plans that consist only of a lecture, all lesson plans include problem sessions and discussions. From these problems and discussions, the instructor can ascertain whether the objectives of that lesson have been met. If they have not been met, adjustments to the course can and must be made. Instructors must know the objectives of each lesson and make every effort during the problem sessions to determine if the objectives have been met. Instructors must be sensitive to what has been learned and what has not been learned from participants' answers to questions, skill in working problems, and questions participants ask. There is not sufficient time to administer formal evaluation exams each day. However, in the Appendix, an evaluation questionnaire is given for the participants to fill out at the end of each day. The purpose of this questionnaire is to help the participant in his subjective evaluation of the course at the end of the course. This questionnaire could be collected daily to determine progress in the course.

In addition to the instructors' use of problem and discussion sessions for day by day course evaluation, there are two other course evaluation tests given in the Appendix. One test is subjective to determine the participants' opinions of the course; the other is objective and tests the participants' knowledge of the course content. The purpose of these tests is to determine if the objectives of the course have been met. Therefore, the participants should not sign the tests. If some participants would like to know how well they have done, the tests could be numbered, allowing a grade sheet to be sent all participants for their information.

LESSON PLANS

Thirty-four lessons have been prepared for this course. The plan for each lesson follows this section. A lesson may consist of only a lecture or it may have a lecture, problem and discussion session. Each lesson is a unit by itself with specific objectives. The arrangement of the lessions and the general subject each covers is given in Table I.

REFERENCES

Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.

River Mechanics, 1971, edited by H. W. Shen.

Table I

Training Session Schedule

LESSON NO.	DAY & TIME	SESSION	CHAPTER OF MANUAL LS	PS	DS*	SECTION OF MANUAL	TOPIC
	Monday						
	8-9	Introduction					
1	9-10	Lecture	I			1.1.0-1.5.0	Introduction
	10-11	Discussion			I		
2	11-12	Lecture	I			1.6.0-1.9.0	Introduction
		Lunch					
	1-2	Lecture	II			2.1.0-2.4.0	Basic Principles
3	2-3	Problem Session		II			
	3-4	Discussion			II		
4	4-5	Lecture	III			3.1.0-3.6.0	Flow in Sand Channels
	7:30-9:00	Movie				"Flow in Alluvial Channels"	
	Tuesday						
	8-9	Lecture	II			2.5.0-2.5.3	Transitions
5	9-10	Problem Session		II			
	10-11	Discussion			II		
6	11-12	Lecture	II			2.1.0-2.5.3	Review Chap. II
	1-2	Lecture	II			2.7.0-2.7.3	Water Surface Profiles
7	2-3	Problem Session		II			
	3-4	Discussion			II		
8	4-5	Lecture	II			2.6.0, 2.8.0-2.8.2	Bends, Rapid Flow
	Evening	Review Chap. II and read Chap. III of manual					
	Wednesday						
9	8-9	Lecture	III			3.7.0-3.8.12	Sediment Properties
10	9-10	Lecture	III			3.9.0-3.9.3	Beginning of Motion
	10-11	Discussion		III			

*LS, Lecture Session; PS, Problem Session; DS, Discussion Session

LESSON NO.	DAY & TIME	SESSION	CHAPTER OF MANUAL LS	PS	DS*	SECTION OF MANUAL	TOPIC
11	11-12	Lecture	III			3.10.0-3.10.6	Sediment Transport
	1-2	Lecture	III			3.10.7-3.10.11	Sediment Transport
12	2-3	Problem Session		III			
	3-4	Discussion			III		
13	4-5	Lecture	III			3.11.0-3.11.4	Coarse Material
	Evening	Laboratory Session or open Discussion Session					
	Thursday						
	8-9	Lecture	III			3.10.12-3.10.14	Sediment Transport
14	9-10	Problem Session		III			
	10-11	Discussion			III		
15	11-12	Lecture	III			3.12.0-3.12.2	Modeling
	1-2	Lecture	IV			4.4.0-4.4.6	Fluvial Geomorphology
16	2-3	Problem Session		IV			
	3-4	Discussion			IV		
17	4-5	Lecture	IV			4.1.0-4.3.6	Fluvial Geomorphology
	Evening	Review Chap. IV and read Chap. V of manual					
	Friday						
	8-9	Lecture	V			5.1.0-5.3.3	River Mechanics
18	9-10	Problem Session		V		5.6.0-5.6.4	
	10-11	Discussion			V		
19	11-12	Lecture	V			5.4.0-5.7.2	River Mechanics
	1-2	Lecture	VI			6.1.0-6.3.5	River Training and Channel Improvement
20	2-3	Problem Session	VI				
	3-5	Discussion		VI			
	Evening	Free					
	Saturday						
	9-5	Field trip to observe highway crossings and encroachments.					

LESSON NO.	DAY & TIME	SESSION	CHAPTER OF MANUAL LS	PS	DS*	SECTION OF MANUAL	TOPIC
	Sunday	Read Chap. VI of manual					
	Monday						
	8-9	Lecture	VI			6.4.0-6.4.8	Bank Protection
21	9-10	Problem Session		VI			
	10-11	Discussion			VI		
22	11-12	Lecture	VI			6.5.0-6.5.2	Degradation and Aggradation
	1-2	Lecture	VI			6.5.3	Local Scour
23	2-3	Problem Session		VI			
	3-4	Lecture	VI			6.5.4-6.6.0	Local Scour Prevention
24	4-5	Discussion			VI		
	Evening	Read Chap. VII and Sections 8.1.0 to 8.22 of Chap. VIII					
	Tuesday						
	8-9	Lecture	VIII			8.1.0-8.2.1	Hypothetical Cases
25	9-10	Discussion			VIII		
	10-11	Lecture	VIII			8.2.2	Actual Case Histories
26	11-12	Discussion			VIII		
	1-2	Lecture	VIII			8.3.0-8.7.0	Factors in Design
27	2-3	Discussion			VIII		
	3-4	Lecture	VII			7.1.0-7.6.0	Data Requirements
28	4-5	Discussion		VII			
	Evening	Read Chap. VIII					
	Wednesday						
29	8-9	Lecture	VIII			8.8.0-8.8.1	Introduction to Design Examples
	9-10	Lecture	VIII			8.8.2	Design Example 1
30	10-11	Problem Session		VIII			
	11-12	Discussion			VIII		
31	1-2	Lecture	VIII			8.8.3	Design Example 2

LESSON NO.	DAY & TIME	SESSION	CHAPTER OF MANUAL	SECTION OF MANUAL	TOPIC
			LS PS DS*		
	2-3	Lecture	VIII		
32	3-4	Problem Session	VIII	8.8.4	Design Example 3
	4-5	Discussion	VIII		
	Evening	Laboratory or Unstructured Discussion			
	Thursday				
	8-9	Lecture	VIII	8.8.5	Design Example 4
33	9-10	Problem Session	VIII		
	10-12	Discussion	VIII		
34	1-2	Lecture	I to VIII		Review
	2-3	Discussion			
	Evening	Banquet			
	Friday				
	8-10	Evaluation of Course by Exam			
	11-12	Evaluation of Course by Discussion with Participants			
	1-2	Review of Course by Lecturers			

Table II

Videotape Cassettes

"Highways in the River Environment"

TAPE NO.	LECTURER	LESSON PLAN NO.	TITLE OF LECTURE	NO. OF TAPES
3251	D.B. Simons	1	Introduction	1
3252	D.B. Simons	2	Introduction	1
3253	H.W. Shen	3	Open Channel Flow	2
3254	E.V. Richardson	4	Fundamentals of Alluvial Channel Flow	1
3255	E.V. Richardson	5	Open Channel Flow	1
3256	E.V. Richardson	6	Open Channel Flow	1
3257	A.G. Mercer	7	Open Channel Flow	1
3258	A.G. Mercer	8	Open Channel Flow	1
3259A	E.V. Richardson	9	Fundamentals of Alluvial Channel Flow	1
3259B	E.V. Richardson	10	Fundamentals of Alluvial Channel Flow	1
3260A	K. Mahmood	11	Fundamentals of Alluvial Channel Flow	1
3260B	K. Mahmood	12	Fundamentals of Alluvial Channel Flow	1
3261	D.B. Simons	13	Fundamentals of Alluvial Channel Flow	1
3260C	K. Mahmood	14	Fundamentals of Alluvial Channel Flow	1
3262	S. Karaki	15	Fundamentals of Alluvial Channel Flow	2
3263	D.B. Simons	16	Fluvial Geomorphology	1
3264	D.B. Simons	17	Fluvial Geomorphology	1
3265	E.V. Richardson	18	River Mechanics	2
3266	E.V. Richardson	19	River Mechanics	1
3267	S. Karaki	20	River Stabilization, Bank Protection and Scour	1

Table II - continued

TAPE NO.	LECTURER	LESSON PLAN NO.	TITLE OF LECTURE	NO. OF TAPES
3268	M.A. Stevens	21	River Stabilization, Bank Protection and Scour	2
3269	M.A. Stevens	22	River Stabilization, Bank Protection and Scour	1
3270	S. Karaki	23	River Stabilization, Bank Protection and Scour	1
3271	S. Karaki	24	River Stabilization, Bank Protection and Scour	1
3272	D.B. Simons	25	Hydraulic and Environmental Considerations of Highway River Crossings and Encroachments	1
3273	D.B. Simons	26	Hydraulic and Environmental Considerations of Highway River Crossings and Encroachments	1
3274	A.G. Mercer	27	Hydraulic and Environmental Considerations of Highway River Crossings and Encroachments	1
3275	S. Karaki	28	Data Needs and Collection	1
3276A	J.F. Ruff	29	Hydraulic and Environmental Considerations of Highway River Crossings and Encroachments	1
3276B	K. Mahmood	30	Design Examples	1
3277	K. Mahmood	31	Design Examples	1
3278	J.F. Ruff	32	Design Examples	2
3279	K. Mahmood	33	Design Examples	2
3280	D.B. Simons	34	Review	1

Lesson Plan 1

UNIT: Introduction

SUBJECT: Hydraulic and environmental considerations of highway crossings and encroachments. Sections 1.1.0 to 1.5.0, Chap. I of Manual

TIME: Two hours including fifteen minute break

OBJECTIVES: To stimulate interest in and lay the introductory groundwork for the application of open channel flow, fluvial geomorphology and river mechanics to the design and maintenance of highway crossings and to improve and maintain the river environment in order that the participant will be able to

I. Identify the types of rivers, river crossings and encroachments.

II. State or cite the instability of river systems.

III. Identify the effects of highway construction on the river system.

IV. Describe the potential effects of river development on highway structures.

PRESENTATION: (60 minutes)

I. Objectives of the course

   A. Define the important terms of fluvial geomorphology

      1. Sediment

      2. Rivers

      3. Geomorphology (braided--meander)

   B. Objectives of the two-week course

      1. Open channel flow

      2. Potomology

      3. Environment

II. Classification of rivers, river crossing and encroachments

   A. Types of rivers

      1. Braided

      2. Meandering

      3. Large and small

      4. Sand and rock

      5. Mountain, plains

B. Types of crossings

1. Narrow valley

2. Broad floodplain

C. Geometric properties of bridge crossings

III. Dynamics of natural rivers and their tributaries

A. Historical evidence

1. Worldwide

2. United States

3. Bed-form change

B. River response to variables

1. Long term

2. Short term

IV. Highway construction effects on river systems

A. Interdependency of roles (if rivers affect highways, highways affect rivers)

B. Importance of highways

C. Negative effects of highway crossings on rivers

D. Positive effects of highway crossings on rivers

V. Effects of rivers on highway crossings

A. Natural changes

B. Works of man

DISCUSSION SESSION: (60 minutes)

I. Types of rivers

II. Types of highway crossings

III. Types of encroachments

IV. Instability of rivers

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Slides

IV. Videotape number 3251 (See Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. River Mechanics, 1971, edited by H. W. Shen, Chaps. I, IV and V.

III. Guide to Bridge Hydraulics, 1973, Edited by C. R. Neill, Roads and Transportation Assoc., Univ. of Toronto Press.

SLIDES:

1. Meandering river
2. Bendway and crossing of a meandering river
3. Straight channel
4. Braided channel
5. Braided channel
6. Braided channel
7. Bankline change of Brahmaputra River
8. Changes in cross section, Colorado River
9. Nile River
10. Comparison of 1884 and 1968 Mississippi River channel near Commerce, Missouri
11. Bridge in slide 12 before sedimentation
12. Bridge--channel filled with sediment to bridge deck
13. Figure of sinuosity vs. slope
14. Figure illustrating Lane's channel balance relation
15. Stage vs. discharge
16. Alternate bars in a meandering channel

Lesson Plan 2

UNIT: Introduction

SUBJECT: Hydraulic and environmental considerations of highway crossings and encroachments. Section 1.6.0 to 1.9.0, Chap. I of Manual

TIME: One hour

OBJECTIVES: The participant will be able to

I. State and define the goals of this two week course.

II. State the adequacy of current knowledge of river mechanics for the design of environmentally acceptable river crossings and encroachments.

III. State the variables affecting the environment of river crossings.

PRESENTATION: (45 minutes)

I. Environmental considerations for bridge engineering
   - A. Recreation, fish, wildlife
   - B. Identification of ecosystems
     1. Types of ecosystems
     2. Use of outside experts
   - C. Landscape and architecture
   - D. Site selection
   - E. Construction
     1. Effects
     2. Control
   - F. Costs

II. Variables affecting river behavior
   - A. Variables
   - B. Basic knowledge needed
   - C. Data requirements

III. Research needed
   - A. Adequacy of current knowledge
   - B. Research
   - C. Training

IV. Goals of the two week course
   - A. Outline goals
   - B. Organization of course

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Slides

IV. Videotape number 3252 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. River Mechanics, 1971, edited by H. W. Shen, Chaps. I, IV and V.

III. Guide to Bridge Hydraulics, 1973, Edited by C. R. Neill, Roads and Transportation Assoc., Univ. of Toronto Press.

SLIDES:

1. Culvert
2. Levee system on Brahmaputra River
3. Levee system on Brahmaputra River
4. Flood on Mississippi River 1973
5. Flood on Mississippi River 1973
6. Site activities, gravel pits
7. Debris caught on bridge
8. Problem vs. type of data
9. Change in bed elevation with time
10. Flow chart--Overland loop
11. Flow chart--Channel loop
12. Mississippi River--Color Infrared
13. Mississippi River--Color Infrared

Lesson Plan 3

UNIT: Open Channel Flow

SUBJECT: Basic principles, steady uniform flow, unsteady flow. Sections 2.1.0 to 2.4.0, Chap. II of Manual

TIME: Three hours including fifteen minute break

OBJECTIVES: The participant will be able to

I. Describe the characteristics of the eight conditions of open channel flow along with the various combinations of four that can occur.

II. Apply the three basic principles of fluid mechanics to simple one-dimensional open channel flow problems.

III. Compute the velocity at a point, the mean velocity, and shear stress at the boundary.

PRESENTATION: (90 minutes)

I. Introduction
   A. Define open channel flow
      1. Emphasize the importance of the free surface
      2. Explain river mechanics
   B. Define useful terms
      1. Geometry; stage, depth of flow, water area, hydraulic radius
      2. Kinematics; velocity, acceleration, one-dimensional flow, streamline, streamtubes
      3. Dynamics; forces, pressure, momentum
      4. Others; flux, control volume, velocity distribution, wide channel, kinetic energy coefficient, momentum coefficient, Reynolds number, Froude number, Euler number
      5. Types of flow
         a. Steady, unsteady
         b. Uniform, nonuniform
      6. State of flow; laminar, turbulent, tranquil, rapid

II. Basic principles of open channel flow
   A. Describe the three basic equations
      1. Conservation of mass
      2. Conservation of linear momentum
      3. Conservation of energy

B. Discuss the shear stress and velocity distribution

1. Average shear stress
2. Local shear stress
3. Turbulent shear stress
4. Velocity distribution

C. Empirical expressions for velocity

1. Chezy
2. Manning

III. Basic principles to compute hydraulic variables

A. Water waves
B. Hydraulic jump

PROBLEM SESSION: (60 minutes)

I. Assign a problem on momentum (Problem II-1, Appendix B)
II. Assign a problem on velocity and shear (Problem II-2, Appendix B)

DISCUSSION SESSION: (30 minutes)

I. Types of flow in open channel
II. Importance of the Froude number, Reynolds number
  A. Open channel flow
  B. Models
  C. Viscous effects
III. Concept of hydraulically smooth and hydraulically rough open channel flow
IV. Manning's n

VISUAL AIDS:

I. Blackboard
II. Overhead projector for sketching
III. Videotape number 3253 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.
II. Fluid Mechanics for Engineers, 1960, M.L. Albertson, J.R. Barton and D.B. Simons, Prentice-Hall.
III. Engineering Hydraulics, 1950, edited by H. Rouse, John Wiley and Sons.

Lesson Plan 4

UNIT: Fundamentals of Alluvial Channel Flow

SUBJECT: Flow in sand channels, bed configuration, resistance to flow. Sections 3.1.0 to 3.6.0, Chap. III of Manual

TIME: One hour plus forty-five minute movie

OBJECTIVES: The participant will be able to

I. Define an alluvial channel and describe the bed configurations that can occur in them.

II. Give the range of Manning's n associated with each bed configuration.

III. Describe the effect of a change of the major variables (depth, slope and viscosity) on bed form and thus on the magnitude of resistance to flow and sediment transport.

IV. Describe how a change in bed configuration in response to changes in depth or viscosity or slope will affect the stage-discharge relation, depth of flow, water-surface profiles, and how these changes relate to his problems of highways in the river environment.

PRESENTATION: (60 minute lecture, 45 minute movie)

I. Introduction

  A. Define alluvial sand channel

  B. Define sand, give grade, size for other material

  C. Define sediment transport terms

    1. By mode (suspended, contact)

    2. By source (bed material, fine sediment)

    3. By measurement (measured, unmeasured load)

  D. Describe complexity of problem where bed configuration, resistance to flow and sediment transport are a function of many interrelated variables (D, S, M, d_{50}, G, C_f)

II. Bed configuration

  A. General description of bed configuration and importance of Froude number

B. Detailed description of each bed form
    1. Physical characteristics, flow characteristics, range in Manning's n, range in bed-material concentration of the bed configurations--with emphasis on the relationship of their formation with slope and depth along with resistance to flow
        a. plane bed without sediment movement
        b. ripples
        c. dunes
        d. transition
        e. plane bed with movement
        f. standing waves
        g. antidunes
        h. chutes and pools
    2. Describe other bed forms
        a. bars
        b. point bars
        c. alternate bars
        d. riffles and pools
C. Regimes of flow
    1. Classification of bed form in each flow regime
    2. Manning's n in each flow regime

II. Variables affecting alluvial flow
A. Number of variables and their interdependency
    1. V, D, S; M, ρ, C_T, C_f; d, G, ρ_s, w; S_R, S_c, f_s; g
    2. flow; fluid; sediment; geometry
B. Dependent and independent variables V, C_T, S, D
C. General description of how bed-form changes in response to a change in depth, slope, and fall velocity with emphasis on importance of fall velocity and variables affecting it

III. Methods for predicting bed form

IV. Response of rivers to changes in bed configuration
A. Stage-discharge relation
B. Change in Manning's n
C. Sediment transport changes
D. Backwater upstream of constrictions

V. Movie, "Flow in Alluvial Channels"

DISCUSSION SESSION: After movie, a general question and answer period

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Slides

IV. Videotape number 3254 (see Table II)

V. Movie film

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. Resistance to Flow in Alluvial Channels, 1966, D. B. Simons and E. V. Richardson, U. S. Geol. Survey Prof. Paper 422-J.

III. Forms of Bed Roughness in Alluvial Channels, 1963, D. B. Simons and E. V. Richardson, ASCE Hydr. Div. Jour., v. 87, HY3, and Trans., v. 128.

IV. River Mechanics, 1971, edited by H. W. Shen, Chap. 9.

SLIDES:

1. Bed forms in sand channels
2. Water surface profiles over a rise in the floor (Froude number)
3. Ripples in 8 ft flume
4. Side view of ripples
5. Overhead view of ripples--flow
6. Overhead view of ripples--dry
7. Dunes in 8 ft flume
8. Dunes in 8 ft flume
9. Boils on water surface for dune bed
10. Dunes in 8 ft flume
11. Sonic sounder chart of dune bed
12. Dunes in 8 ft flume
13. Washed out dunes in 8 ft flume
14. Plane bed with sediment movement
15. Water surface for plane bed flow condition
16. Water surface for plane bed flow condition showing meandering thalweg

Lesson Plan 5

UNIT: Open Channel Flow

SUBJECT: Steady rapidly varying flow (transitions); Sections 2.5.0 to 2.5.3, Chap. II of Manual

TIME: Three hours including fifteen minute break

OBJECTIVES: A review of basic principles of steady flow through reaches of stream with either a contraction, change in bed elevation, or both, in order that the participant will be able to

I. Sketch and use the specific energy and specific discharge diagrams to determine the changes in water-surface elevation for tranquil or rapid flow through a transition.

II. Calculate and define the critical depth, minimum specific head, maximum discharge and Froude number.

III. Calculate the change in water-surface elevations (neglecting friction effects) for flow through transitions.

PRESENTATION: (60 minutes)

I. Introduction

A. Define the conditions for steady rapidly varying flow and what the student is expected to learn

1. Describe the changes in water-surface elevation that occurs when width changes, bottom changes, or a bend occurs

2. Outline of this lesson

3. Importance of Froude number

4. Give assumptions and conditions

a. Flow is steady; therefore it is possible to neglect local accelerations

b. Flow is very nonuniform; change occurs over short distances; therefore convective accelerations ($\frac{\partial V}{\partial S}$) are important but friction is not (at least in the first approximation)

B. Define specific energy H

C. Three variables q, H, and y and two conditions for analyzing flow

1. q constant H and y vary
2. H constant q and y vary

II. Transitions

A. Specific head diagram

1. q is constant, y = [H]
2. Alternate depth y for all H greater than H min
3. Derive y_c, depth for H_{min} by setting dH/dy to 0
4. Show from definition of Froude number that y_c occurs when Fr = 1 how that $y_c = 2/3\ H_{min}$
5. Describe flow over a rise in bed

B. Specific discharge diagram

1. H is constant $y = f(q)$
2. Alternate depths for all $q < q_{max}$
3. Derive y_c for q_{max}
4. Give conditions for y_c
5. Describe flow for a constant width

C. Describe the requisites for critical conditions concerning the following

1. Rise in bed elevation
2. Change in width
3. Both of the above occurring simultaneously

D. Example problems will be worked in problem session

PROBLEM SESSION: (60 minutes)

I. Using blackboard do example problems in Manual

A. Increase in bed elevation (Example problem 2.A2.0)

B. Change in width (Example problem 2.A1.0)

II. Problems

A. Assign a problem on change in width (Problem II-3, Appendix B)

B. Assign a problem on increase in bed elevation (Problem II-4, Appendix B)

DISCUSSION SESSION: (60 minutes)

I. Critical conditions for channel transitions

$$\left(y_c = 2/3\ H_{min} = \frac{\sqrt[3]{q^2_{max}}}{y}\right)$$

II. Water Surface profiles in transitions
III. Waves downstream of width contractions
IV. Rapid flow in transitions and bends
V. Flow around bends in alluvial channels
VI. Difference between steady uniform flow and steady nonuniform flow

VISUAL AIDS:

I. Blackboard
II. Overhead projector for sketching
III. Videotape number 3255 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.
II. Fluid Mechanics for Engineer, 1960, M. L. Albertson, J. R. Barton, and D. B. Simons, Prentice-Hall.
III. Engineering Hydraulics, 1950, edited by H. Rouse, John Wiley and Sons.

Lesson Plan 6

UNIT: Open Channel Flow

SUBJECT: Review of material on open channel flow in lesson plans 3 and 5: Sections 2.1.0 to 2.5.3, Chap. II of Manual

TIME: One hour

OBJECTIVES: Review of previous material to be sure that participant can differentiate between steady-uniform flow, steady-rapidly varying flow, steady-gradually varying flow and be able to

I. Calculate the normal depth for steady-uniform flow using Manning equation.

II. Calculate the critical depth, alternate depths, and sequent depths.

III. Determine the correct equation to use for calculating critical depth for specific flow conditions.

IV. State the steady-rapidly varying flow conditions and the steady-gradually varying flow conditions.

PRESENTATION: (60 minutes)

I. Review (A status report of where the course is and where it is going)

A. Manning equation, stressing that

1. It is used to calculate $\overline{V}$ or y_o in steady uniform flow.

2. Friction or slope of energy grade line is involved

B. Hydraulic jump

1. Sketch on blackboard hydraulic jump

2. Give equation for y_1y_2 ratio

3. Sequent depth

C. Rapidly varying flow, stressing that resistance to flow or slope of energy grade line is not involved, at least in the first approximation

D. Review specific energy and specific discharge diagram

1. Alternate depths

2. Sequent depths

3. Calculation of critical depth conditions

$$y_c = 3 \frac{q_{max}^2}{g} \pm \frac{2}{3} H_{min}; \; Fr = 1.0$$

II. Introduction to gradually varied flow (GVF)

A. Contrast gradually varied flow to rapidly varying flow

1. Relative importance of resistance to flow and accelerations

2. Type of problems; hydraulically, transitions are short and water surface profiles are long

B. Give examples of gradually varied flow

1. Backwater upstream of bridge

2. Drawdown through bridge

C. Importance of y, y_o and y_c

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3256 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. Fluid Mechanics for Engineers, 1960, M. L. Albertson, J. R. Barton and D. B. Simons, Prentice-Hall.

III. Engineering Hydraulics, 1950, edited by H. Rouse, John Wiley and Sons.

Lesson Plan 7

UNIT: Open Channel Flow

SUBJECT: Gradually varied flow (water surface profiles); Sections 2.7.0 to 2.7.3, Chap. II of Manual

TIME: Three hours including fifteen minute break

OBJECTIVES: The participant will be able to

I. State the two processes in the analysis of gradually varied flow.

II. Calculate normal depth y_o, critical depth y_c and the actual depth y.

III. Classify and sketch the type of water surface profile given S_o, discharge, a single y and any control points consisting of changes in S_o, dams, contractions, and drop off.

IV. Calculate the depth of flow for gradually varied flow using the step method.

PRESENTATION: (60 minutes)

I. Method of analysis of GVF problems
   A. Classification of water surface profiles
   B. Numerical calculation of flow depth or water surface elevation

II. Classification of water surface profiles
   A. Overhead sketch of profile of two dimensional flow showing energy equation
   B. Overhead sketch showing Equations 2.7.2, 2.7.3, 2.7.4 and 2.7.7 and explanation of terms
   C. In Equation 2.7.7 indicate relation between y_o, y_c and y; indicate importance of S_o where S_o determines relation between y_o and y_c
   D. Five possible bed slopes; steep, mild, critical, horizontal and adverse
   E. Using a reproduction of Figure 2.7.1, explain the 12 possible classifications; emphasize
      1. The importance of the relationship for y_c, y and y_o for each S_o

2. Location of the control for each type (upstream or downstream) and its dependence on the Froude number of the flow, not on the type of curve (M, S, A, H or C)

F. Show how y_c, y_o and y are calculated

G. Sketch some water surface profiles for changes in S_o at control points using the blackboard

III. Calculations of water surface profiles

A. Restate there are two steps

1. Determining type of W. S. profile
2. Actual calculation of the depth

B. Explain the step method of calculation

PROBLEM SESSION: (60 minutes)

I. Classification problems; assign problem of sketching water surface profiles (Problem II-5, Appendix B)

II. Work Example problem 2.A3.0 in manual

DISCUSSION SESSION: (60 minutes)

I. Discuss classification of W. S. profiles in problem II-5 and Figure 2.7.2

II. Discuss the problem of backwater upstream of a river crossing and the water surface profile through the bridge opening and downstream

III. Describe the problems in calculating the W. S. profile when the normal flow alternates between rapid and tranquil

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3257 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. Fluid Mechanics for Engineers, 1960, M. L. Albertson, J. R. Barton and D. B. Simons, Prentice-Hall.

III. Engineering Hydraulics, 1950, edited by H. Rouse, John Wiley and Sons.

IV. Open Channel Hydraulics, 1959, V. T. Chow, John Wiley and Sons.

Lesson Plan 8

UNIT: Open Channel Flow

SUBJECT: Flow around bends--transitions in rapid flow; Sections 2.6.0 and 2.8.0 to 2.8.2, Chap. II of Manual

TIME: One hour

OBJECTIVES: The participant will be able to

I. Calculate the superelevation for tranquil flow around a bend.

II. Demonstrate a knowledge of the problems that can occur with rapid flow in a transition or bend by sketching in plan a profile of the shock waves that can occur.

PRESENTATION: (60 minutes)

I. Bends and tranquil flow around bends

   A. Derive basic superelevation Equation 2.6.3

   B. Derive Equation 2.6.5

   C. Place Equations 2.6.5, 2.6.7, 2.6.8, and 2.6.10 on the board and describe their essential differences

II. Rapid flow in bends and transitions

   A. Give brief history of problems and delineate that this section is not definitive, that it would take at least three hours of lecture with two hours of homework per lecture to adequately cover subject

   B. Ippen's work

   C. Magnitude of problem using examples

   D. Correspondence to flow in alluvial channels

PROBLEM SESSION: (Evening)

I. Participants review Chap. II and read Chap. III

II. Assign superelevation calculation problem (Problem II-7, Appendix B)

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3258 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. Engineering Hydraulics, 1950, edited by H. Rouse, John Wiley and Sons.

III. Open Channel Hydraulics, 1959, V. T. Chow, John Wiley and Sons.

Lesson Plan 9

UNIT: Fundamentals of Alluvial Channel Flow

SUBJECT: Properties of alluvial material and methods of measuring these properties; Sections 3.7.0 to 3.8.12, Chap. III of Manual

TIME: One hour and fifteen minutes

OBJECTIVES: The participant will be able to

I. Describe in general terms the properties of alluvial material.

II. State in terms of size points at which silts and clays become sand, sand becomes gravel, and gravel becomes cobbles.

III. Demonstrate the importance of water temperature, sediment size, and sediment shape on fall velocity.

IV. Describe in general terms a method for measuring the size characteristics (d_{50} and G) for silts--clay sizes, sand sizes, gravels and cobbles.

PRESENTATION: (75 minutes)

I. Properties of alluvial material
   - A. Size--definitions, grade scales
   - B. Shape--definitions, large shape factor, importance
   - C. Fall Velocity; variables, C_D, R, S_p; diagram
   - D. Cohesion--define, importance, problems
   - E. Angle of repose--importance

II. Methods of measuring
   - A. Size distributions--types of analysis, sieves, VA tubes, pebble count methods, and pipettes
   - B. Cohesion

III. Methods of summarizing data
   - A. Frequency curves
   - B. Median diameter
   - C. Gradation

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Slides

IV. Videotape number 3259A (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. Laboratory Theory and Methods for Sediment Analysis, 1969, H. P. Guy, U. S. Geol. Survey Techniques book 5, C-1.

III. River Mechanics, 1971, edited by H. W. Shen, Chap. 6.

SLIDES:

1. Coefficient of Drag (C_D) vs. Reynolds numbers (Re) with shape factor as third variable
2. Fall velocity vs. percent wash load
3. Sedimentation diameter distribution for various concentrations of bentonite
4. Viscosity of water dispersions of bentonite and koline
5. Trace of disc in sedimentation cylinder
6. Coefficient of drag vs. Reynolds number with density ratio as third variable
7. Diameter vs. frequency distribution
8. Normal curves with different median diameter
9. Percent cumulative vs. diameter or fall velocity
10. Peakedness of a size distribution
11. Skewness of a size distribution
12. Cobble bar--armoring
13. Cobble bar--armoring
14. Cobble bar--armoring--sand under cobbles
15. Gravel bar--armoring--sand under cobbles
16. Comparison of sieve size and pebble count analysis
17. Comparison of sieve size and pebble count analysis
18. Comparison of particle count and volumetric analysis

Lesson Plan 10

UNIT: Fundamentals of Alluvial Channel Flow

SUBJECT: Beginning of motion of sediment particles; Sections 3.9.0 to 3.9.3, Chap. III of Manual

TIME: Two hours including fifteen minute break

OBJECTIVES: The participant will demonstrate his knowledge of the beginning of motion and be able to

I. Determine the size of stone necessary to resist motion for flow conditions described by either slope, depth and width, average velocity or velocity distribution.

II. Determine critical tractive force knowing the median size of the bed material.

PRESENTATION: (60 minutes)

I. Theory of beginning of motion
   - A. Critical tractive force
   - B. Critical velocity
   - C. Fluctuating nature of A and B above

II. Methods of determining the shear stress on the bed or banks
   - A. $Y_o = \gamma RS$ (don't derive)
   - B. Velocity profile
   - C. Side slopes

III. Method of determining velocity at the stone level
   - A. Using mean velocity
   - B. Using velocity distribution

IV. Determining stone size required to resist motion

DISCUSSION SESSION: (60 minutes)

I. Question participants on how they would determine size of stone necessary to resist motion given 1) slope and depth, 2) mean velocity and 3) velocity distribution

II. Importance of filter for riprap

III. Safety factor for riprap

IV. Historical aspects of beginning of motion

V. Wave motion

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Slides

IV. Videotape number 3259B (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.

II. River Mechanics, 1971, edited by H.W. Shen, Chaps. 7, 16 and 17.

SLIDES:

1. Velocity vs. stone size

2. Diameter vs. critical tractive force

Lesson Plan 11

UNIT: Fundamentals of Alluvial Channel Flow

SUBJECT: Sediment transport; Sections 3.10.0 to 3.10.6, Chap. III of Manual

TIME: One hour

OBJECTIVES: The participant will demonstrate his knowledge of the mechanics of sediment transport and be able to

I. Describe the difference between contact discharge (bed load) and suspended sediment discharge, bed material discharge and fine sediment discharge, and total sediment discharge.

II. Describe the manner in which the magnitude of the variables in the Rouse number changes its magnitude and how these changes affect the distribution of the suspended sediment in the vertical.

PRESENTATION: (60 minutes)

I. Introduction--discussion of the importance of sediment transport for highway engineers

II. Carefully go over the terminology of sediment transport mechanics to eliminate confusion that exists

III. Derivation of suspended sediment equation

  A. Starting from Equation 3.10.3 derive Equation 3.10.11, stressing assumptions not mathematics

  B. Illustrate the effect of variables on the Rouse number and hence on the distribution of the sediment in the vertical

IV. Lay the groundwork for Lessons 12 and 14 by describing in general terms the Meyer-Peter, Muller and Einstein equations and Colby's method for determining sediment load

  A. Meyer-Peter, Muller equation; $q_B = K(\tau - \tau_o)^{3/2}$ (q_B is only the contact load)

B. Einstein determines contact load and from it a concentration C_a at level a in order to integrate the suspended sediment equation to determine total bed material discharge

C. Colby's is a graphical method based on Einstein's method for determining total bed material discharge

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3260A (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. River Mechanics, 1971, edited by H. W. Shen, Chaps. 11, 12 and 13.

III. Meyer-Peter, Muller Bed Load Equation, 1960, U. S. Bureau of Reclamation.

IV. Task Committee on Sediment Manual, 1971, ASCE Hydr. Div. Jour. HY4, v. 97.

Lesson Plan 12

UNIT: Fundamentals of Alluvial Channel Flow

SUBJECT: Sediment transport; Sections 3.10.7 to 3.10.11, Chap. III of Manual

TIME: Three hours including a fifteen minute break

OBJECTIVE: The participant will demonstrate his knowledge of sediment transport by being able to compute the bed material discharge using the Einstein equation.

PRESENTATION: (60 minutes)

I. Basic Meyer-Peter, Muller theory giving limitations and assumptions

II. Einstein bed material discharge function

A. Einstein's theory will be briefly explained showing the similarities to the Meyer-Peter, Muller equation, the use of the suspended sediment equation

B. The Einstein theory will be further explained by going through his procedure of computing the total bed material discharge step by step

PROBLEM SESSION: (180 minutes) Einstein example problem will be gone through step by step (Tables 3.10.2, 3.10.3 and 3.10.4 in the Manual)

DISCUSSION SESSION: (0 minutes) During the working of the Einstein problem it is expected that considerable discussion will take place

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3260B (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. Meyer-Peter, Muller, 1960, U. S. Bureau of Reclamation.

III. Formulas for bed load transport: Meyer-Peter, Muller, 1968, Proc. 2nd Congress, IAHR Stockholm.

IV. The bed load function for sediment discharge in open channel flows, 1950, H. A. Einstein, U. S. Department of Agriculture, Tech. Bulletin 1026.

Lesson Plan 13

UNIT: Fundamentals of Alluvial Channel Flow

SUBJECT: Coarse material streams. Sections 3.11.0 to 3.11.4, Chap. III of Manual

TIME: One hour

OBJECTIVES: The participant will be able to

I. Define what is meant by coarse material and describe its importance.

II. Define what is meant by armoring.

III. State what equation to use to determine sediment transport in coarse material channels.

IV. Determine Manning's n.

PRESENTATION: (60 Minutes)

I. Introduction

A. Define coarse bed material

B. Describe the difference between coarse bed material and sand

II. Describe and illustrate the concept of armoring

III. Present a method of estimating Manning's n and sediment transport

IV. Describe the long and short term response of coarse material stream

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Slides

IV. Videotape number 3261 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. River Mechanics, 1971, edited by H. W. Shen, Chaps. 16 and 17.

III. Some Hydraulic Characteristics of Coarse Bed Rivers, 1970, V. J. Galay, Dissertation, Univ. of Alberta.

SLIDES:

1. Armor plating
2. Close-up, armor plating of bed material
3. Diagram of flow over armor plating
4. Bed forms in sand-bed channel
5. Diagram of profile and cross-sections of meandering river

Lesson Plan 14

UNIT: Fundamentals of Alluvial Channel Flow

SUBJECT: Sediment transport Sections 3.10.12 to 3.10.14, Chap. III of Manual

TIME: Three hours with fifteen minute break

OBJECTIVES: The participant will be able to

I. Calculate bed material discharge by the Colby method, and the Meyer-Peter, Muller equation.

II. Describe the conditions for the use of the Meyer-Peter, Muller contact load equation, Einstein's total bed material discharge equation and Colby's total bed material load equation.

PRESENTATION: (60 minutes)

I. The example problem for Colby's method will be explained

II. How to use Colby's method will be given

III. The essentials of the three methods will be reviewed

IV. A comparison of the three methods will be made and recommendations made on the conditions for the use of each method

PROBLEM SESSION: (90 minutes)

I. The example problem for Colby's method will be worked (Tables 3.10.3, 3.10.5 and 3.10.6 in the Manual)

II. Example problems 3.A1.0, 3.A1.2 and 3.A1.3 from the Manual will be worked as time permits

DISCUSSION SESSION: (30 minutes including a 15 minute break)

I. The three methods of computing transport will be compared

A. Conditions for each

B. Accuracy of each

II. Data required for each equation will be discussed

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3260C (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. Meyer-Peter, Muller, 1960, U. S. Bureau of Reclamation

III. The Bed Load Function for Sediment Discharge in Open Channel Flows, 1950, H. A. Einstein, U. S. Department of Agriculture Tech. Bulletin, 1026.

IV. Discharge of Sands and Mean Velocity Relationships in Sand Bed Streams, 1964, B. R. Colby, U. S. Geol. Survey Prof. Paper 462-A.

V. Discharge Formulas, 1971, Task Committee on Sediment Manual, ASCE Hydr. Div. Jour. HY4, v. 97.

Lesson Plan 15

UNIT: Fundamentals of Alluvial Channel Flow

SUBJECT: Open channel modeling; Section 3.12.0 to 3.12.2, Chap. III of manual

TIME: One hour

OBJECTIVES: The participant will demonstrate his knowledge of modeling by

I. Stating the modeling laws.

II. Stating the conditions for dynamic similitude in open channel flow.

III. Describing the problems associated with mobile bed similitude.

PRESENTATION: (60 minutes)

I. Conditions for similarity
   - A. Needs for modeling
   - B. Constraints
   - C. Conditions for similarity
   - D. Choice of similitude parameters
   - E. Derive scaling parameters

II. Movable river models
   - A. Describe problem between rigid boundary and movable bed similitude
   - B. Distorted models
   - C. Interpretation of results of movable bed model

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Slides

IV. Videotape number 3262 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. River Mechanics, 1971, edited by H. W. Shen, Chap. 21.

III. Engineering Hydraulics, 1950, Edited by H. Rouse, Chap. II.

IV. Fluid Mechanics for Engineer, 1960, M. L. Albertson, D. B. Simons and J. B. Barton.

SLIDES:

1. Flip bucket
2. Approach channel
3. Supercritical chute flow
4. Surface waves in the channel
5. Flip bucket
6. Scour on the river bed
7. Power house upstream from the flip bucket
8. Morning Glory spillway, Dillon Dam
9. Piers on the crest of a spillway
10. Curved elbow below Morning Glory
11. Hydraulic jump/flip bucket basin
12. Flip bucket
13. Silt excluders at a canal intake
14. Closer view of the silt excluder
15. Silt excluder
16. Sediment ejector at a bend in the flume
17. Sediment bins in the flume
18. Sediment ejector across a flume
19. Radial gate flow control at tunnel outlet
20. Model of one radial gate
21. Flow around a radial gate
22. Deflectors along the side walls of radial gate
23. Upward flow deflector above the radial gate
24. Spur dike at a highway bridge opening
25. Model of a spur dike
26. Mississippi River basin model
27. Model of the Mississippi River near St. Louis, Missouri

Lesson Plan 16

UNIT: Fluvial Geomorphology

SUBJECT: Classification of alluvial channel forms and qualitative response of channels; Sections 4.4.0 to 4.4.6, Chap. IV of Manual

TIME: Three hours including fifteen minute break

OBJECTIVES: The participant will be able to

I. Qualitatively predict the response of a river to a change in slope, discharge of water, discharge of sediment and size of bed material.

II. Describe the change in slope and bed material of a channel in the longitudinal direction.

III. Classify a river based on its morphological characteristics.

PRESENTATION: (80 minutes)

I. Review channel form classification using sketches on blackboard

   A. Emphasize that straight channels are relatively rare in nature

   B. Emphasize the relative stability of meandering channel form

   C. Emphasize coexistence of straight, meandering and braided reaches on same river

   D. Emphasize the channel processes in meandering channels

II. Subclassification of river channels with channel and floodplain indicators

   A. Emphasize morphological indicators, such as: sinuosity, oxbow lakes, meander scrolls, natural levees, types of modern floodplain and type of vegetal patterns

   B. Emphasize hydraulic and hydrological indicators, such as velocity, top width, mean depth, width depth ratio, resistance to flow, cross-sectional shape and mode of sediment transport

   C. Present subclassification scheme

III. Qualitative response of rivers

A. Channel profile, bed material size and hydraulic geometry

1. Emphasize changes in longitudinal profile as possible channel response
2. Emphasize the bed material size variation in rivers along the direction of flow and its change as possible channel response
3. Emphasize at-station and downstream variation in hydraulic geometry

B. Lane's qualitative relation

1. Emphasize base level variation as a measure of natural or man-made changes
2. Emphasize direction of change in channel profile as a result of imposed variation of Q, Q_s and D_{50}

C. Prediction of changes in channel form

1. Emphasize the $SQ^{1/4}$ parameter for channel form differentiation
2. Emphasize direction of change in channel form as river's response to natural or man-made changes in Q and S

IV. Review

A. Synthesize river channel morphology

1. Emphasize rivers as a geomorphic agent
2. Emphasize interaction of water and alluvium in generating river forms
3. Emphasize role of channel form in determining channel response

B. Synthesize river channel response

1. Emphasize possible modes of channel response
2. Emphasize role of qualitative relations presented in III.B and III.C

PROBLEM SESSION: (50 minutes)

I. Complete Table in problem IV-1 in Appendix B.

DISCUSSION SESSION: (50 minutes)

I. During problem session a discussion of the solution of the problem will naturally evolve

II. Discuss Table 4.4.2 in the Manual

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3263 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.

II. River Mechanics, 1971, edited by H.W. Shen, Chaps. IV and V.

Lesson Plan 17

UNIT: Fluvial Geomorphology

SUBJECT: Basic principles of river morphology; Sections 4.1.0 to 4.3.6, Chap. IV of Manual

TIME: One hour

OBJECTIVES: The participant will be able to

I. Define fluvial process and cycles.

II. Differentiate between a braided and meandering stream.

III. Define river channel form.

PRESENTATION: (60 minutes)

I. Define geomorphology and emphasize the interaction between geologic and hydrologic variables

II. Define geological age classification of rivers and emphasize morphological changes with age

III. Define graded rivers

   A. Emphasize concept of graded river and its relation with age classification

   B. Emphasize variation of river channel about equilibrium form in graded conditions

IV. Define floodplain components (sketch on blackboard)

   A. Emphasize evolution of natural levees

   B. Identify alluvial fans as particularly unstable morphological feature

V. Define river channel form and emphasize planform differentiation of straight, meandering and braided river channels

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3264 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.

II. River Mechanics, 1971, edited by H.W. Shen, Chaps. IV and V.

Lesson Plan 18

UNIT: River Mechanics

SUBJECT: Channel geometry of rivers; Sections 5.1.0 to 5.3.3 and 5.6.0 to 5.6.4, Chap. V of Manual

TIME: Three hours including fifteen minute break

OBJECTIVES: The participant will be able to

I. Classify the three types of river bends--free, limited and forced--and in general terms describe them.

II. Predict the velocity distribution in a bend.

III. Predict the characteristics of meanders.

PRESENTATION: (60 minutes)

I. Geometry of meandering channels

  A. Define meander geometry

    1. Emphasize departure of natural channel meanders from idealized representation

    2. Empirical relations for meander geometry

  B. Characteristics of bends in alluvial channels

    1. Emphasize types of bends

    2. Emphasize method of analyses from known channel plans to obtain prevalent geometry of bends

II. Flow in alluvial channel bends

  A. Hydraulic conditions in channel bends

    1. Emphasize transverse velocity components

    2. Emphasize changes in velocity distribution due to bends

  B. Variation of depth along channel bends

    1. Emphasize the variation in channel depth in pools

    2. Emphasize the effect of bend geometry and channel order on the variation of channel depth

PROBLEM SESSION: (60 minutes)

I. Assign problems on meander geometry, and transverse and longitudinal water surface change in elevation (Problems V-1, V-2, Appendix B)

II. Problems on velocities in bend (Problems V-3, V-4, Appendix B)

DISCUSSION SESSION: (60 minutes)

I. Representation and analyses of meandering channels

II. Type of bends in alluvial rivers

III. Hydraulics of flow in river bends

IV. Transverse and longitudinal drop in water surface elevation

V. Velocity fluctuations in alluvial river channels

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Slides

IV. Videotape number 3265 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulics and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.

II. River Mechanics, 1971, edited by H.W. Shen, Chap. 20.

SLIDES:

1. Colorado River, Glen Canyon rock control, Delta from tributary
2. Sand channel, point bar, U.S. 61 crossing Buffalo Bayou near Woodville, Mississippi
3. Rock channel, Colorado River, Glen Canyon, Colorado
4. Silt, sand and clay banks, Mississippi River
5. Braided channel low flow, Missouri River at Indian Cave, Sept. 18, 1934
6. Diagram, Platte River near Brule, Nebraska
7. Diagram, meandering channel, crossings and pool
8. Braided channel, White River, Oregon
9. Radius of curvature vs. frequency of occurrence
10. Rock channel, Glacier National Park
11. Lateral distribution of velocity in a bend
12. Relative radius of curvature (r_c/W) vs. relative depth (D_{max}/W)
13. Relative radius of curvature (r_c/W) vs. relative depth (D_{max}/W) with stream order
14. (D_{max}/W) vs. concentration (ppm)
15. Discharge vs. cross-sectional area
16. Top width vs. discharge

Lesson Plan 19

UNIT: River Mechanics

SUBJECT: Roughness and mean velocity in alluvial channels. Sections 5.4.0 to 5.7.2, Chap. V of Manual

TIME: One hour

OBJECTIVES: The participant will be able to

I. Describe the variation of roughness in alluvial rivers due to flow in various components of floodplain and the river channel under various conditions.

II. Know the maximum and minimum velocities and turbulent velocity fluctuations in alluvial rivers.

PRESENTATION: (60 minutes)

I. Flow in Alluvial Rivers--variation of roughness in alluvial floodplains

  A. Emphasize roughness in channel, in floodplains, under ice conditions and variations of roughness in sand bed channels

  B. Relate basic alluvial flow concepts

II. Quantitative prediction of river channel response

  A. Emphasize methods of mathematical and physical modeling

  B. Emphasize simplified approaches to quantitative prediction

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3266 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. River Mechanics, 1971, edited by H. W. Shen, Chaps. 20, 21.

Lesson Plan 20

UNIT: River Stabilization, Bank Protection and Scour

SUBJECT: Channel improvement and river training; Sections 6.1.0 to 6.3.5, Chap. VI of Manual

TIME: Three hours including fifteen minute break

OBJECTIVE: Given that channel improvement of a river is desirable, the participants will be able to design

I. A rigid boundary open channel for a given discharge.

II. An alluvial channel for a given discharge.

III. A modified river section with a new alignment.

PRESENTATION: (50 minutes)

I. Channel improvement by excavation

A. Alignment design

B. Channel cross section

C. Stream power and sediment transport

D. Consequences with respect to the river system

E. Conditions for bank stabilization of the the improved channel

II. River Training

A. Function of jetties and jetty fields

B. Function of dikes

C. Design of jetties

D. Design of dikes

E. Relationship to bars and sediment transport

PROBLEM SESSION: (60 minutes) Participants will design a problem on channel realignment, jetty field location, spur lengths and spur spacing

DISCUSSION SESSION: (50 minutes) In the discussions of this subject, valuable information may be exchanged by the participants if a forum is provided for information exchange between participants regarding

I. Individual experiences related to channel improvement

II. Possible consequences beyond usual limits of highway interests upstream and downstream

III. Maintenance problems

IV. Construction methods and difficulties

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3267 (see Table II).

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. State of Knowledge of Channel Stabilization in Major Alluvial Rivers, 1969, edited by G. B. Fenwick, Corps of Engineers, U. S. Army.

III. River Mechanics, 1971, edited by H. W. Shen, Chap. 19.

Lesson Plan 21

UNIT: River Stabilization, Bank Protection and Scour

SUBJECT: Bank protection ; Sections 6.4.0 to 6.4.8, Chap. VI of Manual

TIME: Three hours including fifteen minute break

OBJECTIVES: The participants will be able to

I. Design proper size and gradation of riprap

II. Design a filter blanket

III. Identify other types of bank protection works

PRESENTATION: (50 minutes)

I. How banks fail
   - A. Erosion of soil particles
   - B. Excessive internal hydrostatic pressure
   - C. Undermining the toe
   - D. Liquefaction

II. Rock riprap
   - A. Advantages
   - B. Important factors in sizing riprap
   - C. Equations for design
   - D. Effective size of a well-graded rock

III. Filters
   - A. Need for filters
   - B. Gravel filters
   - C. Cloth filters

IV. Other bank protection materials
   - A. Rock and wire mattress
   - B. Sandbags
   - C. Articulated concrete mattress
   - D. Other mattresses
   - E. Exotics

PROBLEM SESSION: (60 minutes) Work out the design for riprap on the nose of the embankment given in the Manual on page 6.A4.0. The process is as follows

I. Select a suitable safety factor

II. Select a rock size and compute the safety factor

III. Select other rock sizes and compute the corresponding safety factors

IV. Interpolate the information above to get the design size

DISCUSSION SESSION: (50 minutes)

I. Interactive discussion among participants on designs and failures of bank protection

II. Discuss the meaning of safety factor

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Slides

IV. Videotape number 3268 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. River Mechanics, 1971, edited by H. W. Shen, Chap. 17.

SLIDES:

1. Car bodies on a bank
2. Car bodies used after jetties failed
3. Sacked-cement riprap
4. Successful riprap design on a river along a highway
5. Another riprapped channel but the banks are very steep
6. Hefty looking riprap on an embankment
7. Fabriform riprap

Lesson Plan 22

UNIT: River Stabilization, Bank Protection and Scour

SUBJECT: Channel degradation and scour due to contractions; Sections 6.5.0 to 6.5.2, Chap. VI of Manual

TIME: One hour

OBJECTIVE: Given channel and sediment characteristics, the participants will be able to calculate scour due to contraction at a bridge site.

PRESENTATION: (60 minutes)

I. Channel degradation and aggradation
   A. Review causes for degradation or aggradation
   B. Describe computational method

II. Scour due to contractions
   A. Stress the need for uniform acceleration in the approach section
   B. Illustrate Nordin's method of computing scour in a channel section with no overbank flow and in a section with overbank flow
   C. Give Laursen's equations for general scour and explain their applicability

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3269 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

II. River Mechanics, 1971, edited by H. W. Shen, Chap. 8.

Lesson Plan 23

UNIT: River Stabilization, Bank Protection and Scour

SUBJECT: Local scour; Section 6.5.3, Chap. VI of Manual

TIME: Two hours including fifteen minute break

OBJECTIVE: The participants will be able to calculate scour depths at bridge piers and embankments starting from basic hydraulic characteristics of river flow.

PRESENTATION: (60 minutes)

I. Local scour around embankments
   A. Illustrate consequences of local scour around embankments
   B. Provide background for scour equations
   C. Present recommended scour prediction equations

II. Local scour around piers
   A. Illustrate consequences of local scour around piers
   B. Provide background for scour equation
   C. Present recommended prediction equation

PROBLEM SESSION: (50 minutes)

I. Present illustrative examples of scour problems

II. Assign problems on computing scour (Problems VI-3 and VI-4, Appendix B) for problems)

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Slides

IV. Videotape number 3270 (see Table II)

REFERENCE: Manual, Highways in the River Environment--Hydraulic and Environmental Design Consideration, 1975, Federal Highway Administration, U.S. Department of Transportation.

SLIDES:

1. Scour of a bridge pier
2. Scour of a bridge pier
3. Debris on bridge and scour
4. Scour of a bridge pier
5. Debris on bridge and scour

SLIDES (Continued)

6. Debris on bridge pier
7. Scour on bent of approach channel
8. Scour of pier and abutment
9. Scour

Lesson Plan 24

UNIT: River Stabilization, Bank Protection and Scour

SUBJECT: Local scour prevention and protection; Sections 6.5.4 to 6.6.0, Chap. IV of Manual

TIME: Two hours

OBJECTIVE: The participants will be able to identify local scour protection methods and choose specific methods for particular given situations.

PRESENTATION: (60 minutes)

I. Local scour protection against scour around embankments

II. Local scour protection against scour around piers

DISCUSSION SESSION: (60 minutes) Participant discussion on whole subject of scour, importance for prediction, prevention or attenuation

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3271 (see Table II)

REFERENCE: Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.

Lesson Plan 25

UNIT: Hydraulic and Environmental Considerations of Highway River Crossings and Encroachments

SUBJECT: Hypothetical cases; Sections 8.1.0 to 8.2.1, Chap. VIII of Manual

TIME: Two hours including fifteen minute break

OBJECTIVES: From a presentation of hypothetical situations, the participant will be able to identify the major hydraulic and environmental problems associated with

I. Construction on alluvial fan.
II. Head cutting associated with lowered downstream control.
III. River alignment improvements downstream of crossings.
IV. Increase of sediment influx.
V. River alignment improvements at crossings or encroachments.
VI. Crossings or encroachments upstream of a dam.
VII. Crossings or encroachments downstream of a dam.
VIII. Future dam constructions.
IX. Construction on meandering rivers.
X. Tidal effects, wind effects and earthquakes.

PRESENTATION: (60 minutes)

I. Introduction of value of hypothetical cases
II. Problems with construction on an alluvial fan
III. Problems with a river experiencing head cutting
IV. Problems with alignment improvement beyond crossing site
V. Problems with sediment transport changes
VI. Problems with alignment improvement at the crossing site
VII. Problems with dams upstream of a crossing
VIII. Problems with dams downstream of a crossing
IX. Problems with meanders
X. Problems with tides, winds and earthquakes

DISCUSSION SESSION: (60 minutes) Discussion of actual cases similar or dissimilar to the ones presented in the lecture from the personal experiences of the participants

VISUAL AIDS:

I. Blackboard

II. Overhead projector with sketches from Table 8.2.1

III. Videotape number 3272 (see Table II)

REFERENCE: Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.

Lesson Plan 26

UNIT: Hydraulic and Environmental Considerations of Highway River Crossings and Encroachments

SUBJECT: Actual case histories; Section 8.2.2, Chap. VIII of Manual

TIME: Two hours

OBJECTIVES: After a presentation of actual case histories, the participant will be able to

I. Make a prediction of the most probable future alignment of a river in the vicinity of a crossing given the past alignments, flows and bed and bank materials and the floodplain topography.

II. Select the river training devices most likely to be successful in ensuring the safety of the highway crossing or encroachment.

PRESENTATION: (60 minutes)

A history of actual cases of river behavior in the vicinity ty of highway crossings and encroachments where jetties, piles, riprap, etc., were used to correct situations threatening the highway, with comments on the individual effectiveness

DISCUSSION SESSION: (60 minutes)

I. After the fact discussion of how the difficulties could have been anticipated and prevented or how they could have been more successfully overcome

II. Discussion of associated problems from the participants' experiences

VISUAL AIDS:

I. Blackboard

II. Overhead projector of sketches of Figures 8.2.1. to 8.2.12

III. Videotape number 3273 (see Table II)

REFERENCE: Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.

Lesson Plan 27

UNIT: Hydraulic and Environmental Considerations of Highway River Crossings and Encroachments

SUBJECT: Principal factors in design; Sections 8.3.0 to 8.7.0, Chap. VIII of Manual

TIME: Two hours including fifteen minute break

OBJECTIVE: Review of the material of previous sections so that the participant will be able to list at least ten of the most important factors bearing on the design of a particular crossing or encroachment.

PRESENTATION: (60 minutes) A review of the important material of previous chapters specifically relating to design including

I. Types of rivers
II. Location of the crossing
III. River characteristics
IV. River geometry
V. Hydrologic data
VI. Hydraulic data
VII. Flow alignment
VIII. Flow on the floodplain
IX. Site variables
X. Channel stability
XI. Short-term response
XII. Long-term response

DISCUSSION SESSION: (60 minutes) Discussion of additional factors not presented in the lecture, especially of environmental and social factors which are hard to quantify, with strong reliance placed on comments and inclusions from participants.

VISUAL AIDS:

I. Blackboard
II. Overhead projector for sketching
III. Videotape number 3274 (see Table II)

REFERENCE: Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.

Lesson Plan 28

UNIT: Data Needs and Collection

SUBJECT: Data needs, collection and estimation; Sections 7.1.0 to 7.6.0, Chap. 7 of Manual

TIME: Two hours

OBJECTIVES: Of the basic hydraulic, hydrologic and geologic data needed for analysis of river crossings and encroachments the participant will be able to

I. Identify basic data needed.

II. Identify other desirable data.

III. Identify data collection sources and methods.

IV. Estimate key data when unavailable directly.

PRESENTATION: (60 minutes)

I. Data Needs

  A. Basic information needed for route selection

  B. Basic information needed for design

  C. Other desirable data to aid analysis

  D. Reporting of data

II. Data Collection

  A. Usual sources for hydrologic, hydraulic, geologic data

  B. Field observation and collection of data

III. Analysis Methods of Hydrologic Data

DISCUSSION SESSION: (60 minutes) Discussion of data collection methods, instrumentation and problems

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3275 (see Table II)

REFERENCES:

I. Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.

II. Guidelines for Hydrology, Prepared by the Task Force on Hydrology and Hydraulics, AASHO Operating subcommittee on Roadway Design, 1973.

Lesson Plan 29

UNIT: Hydraulic and Environmental Considerations of Highway River Crossings and Encroachments

SUBJECT: Introduction to design examples; Sections 8.8.0 to 8.8.1, Chap. VIII of Manual

TIME: One hour

OBJECTIVES: From a presentation of the philosophy of providing design examples and a description of the river chosen for these examples the participant will be able to

I. State at least three reasons for utilizing the design examples and two of their limitations.

II. Point out the important hydraulic, hydrologic, and physical properties and dominant past behavior of the river to be used in the example.

PRESENTATION: (60 minutes)

I. Reasons for and limitations of design examples

II. Scope of the design examples

III. River and crossing chosen

A. Physical properties

B. Hydrologic properties

C. Hydraulic properties

D. Past behavior

E. Predicted future behavior

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3276A (see Table II)

REFERENCE: Manual, Highways in the River Environment--Hydraulic and Environmental Design Consideration, 1975, Federal Highway Administration, U.S. Department of Transportation.

Lesson Plan 30

UNIT: Hydraulic and Environmental Considerations of Highway River Crossings and Encroachments

SUBJECT: Design Example 1; Section 8.8.2, Chap. VIII of Manual

TIME: Three hours including fifteen minute break

OBJECTIVES: The participant will be able to select and perform at least one sound design procedure for determining

- I. The anticipated minimum bed level of a river in the vicinity of a crossing.
- II. The anticipated maximum stage for the design flood.
- III. The size of riprap required for embankment protection.
- IV. The extra stage produced by the interference of the floodplain flow by the highway approaches.
- V. The depth to be anticipated at scour piers.

PRESENTATION: (60 minutes) Design Example 1, a bridge crossing with abutments and piers in the channel, part of the flood flow (on the floodplain) does not go under the bridge because there are relief openings through the approach to the bridge; discuss relevant design details

- I. Design flows and design stage
- II. River stability
- III. Calculation of radius of curvature
- IV. Abutment protection
- V. Scour at the pier

PROBLEM SESSION: (75 minutes) Using data from Example 1, solve parts of the problem with the following changes

- I. Problem 1. Compute depth of flow for a Manning's n of .035
- II. Problem 2. Compute riprap size required for a 2 to 1 slope
- III. Problem 3. Compute depth of scour for a circular pier of the same cross-sectional area

DISCUSSION SESSION: (25 minutes)

- I. Discuss the methods presented and other methods available
- II. Discuss the design results--their reliability and reasonableness

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3276B (see Table II)

REFERENCE: Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.

Lesson Plan 31

UNIT: Hydraulic and Environmental Considerations of Highway River Crossings and Encroachments

SUBJECT: Design Example 2; Section 8.8.3, Chap. VIII of Manual

TIME: One hour

OBJECTIVE: The participant will be able to determine the effects of all the flow in Design Example 1 going through the bridge opening.

PRESENTATION: (60 minutes) The effect of having the total design flood of 110,000 cfs go through the bridge instead of 66,000 cfs

I. General discussion

II. Calculations of average velocity, shear stress, Froude number and stream power

III. General scour calculations

IV. Conclusions

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3277 (see Table II)

REFERENCE: Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.

Lesson Plan 32

UNIT: Hydraulic and Environmental Considerations of Highway River Crossings and Encroachments

SUBJECT: Design Example 3; Section 8.8.4, Chap. VIII of Manual

TIME: Three hours including a fifteen minute break

OBJECTIVES: According to conservative design procedures, the participant will be able to analyze and compute

I. The affect of having a dam upstream change flow conditions.

II. The amount of degradation to be expected downstream of a dam.

PRESENTATION: (60 minutes) Design Example 3, the same crossing situation as Design Examples 1 and 2 but with a dam upstream modifying the hydrograph and changing the sediment discharge

I. Modified hydrograph and dominant flow

II. Degradation analysis

III. Revised flood stage

PROBLEM SESSION: (60 minutes) Compute variables in Design Example 3

DISCUSSION SESSION: (60 minutes)

I. Discuss the correctness of the assumption that the slope is varying linearly on degrading and aggrading profiles

II. Discuss participants experiences with degradation

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3278 (see Table II)

REFERENCE: Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U. S. Department of Transportation.

Lesson Plan 33

UNIT: Hydraulic and Environmental Considerations of Highway River Crossings and Encroachments

SUBJECT: Design Example 4; Section 8.8.5, Chap. VIII of Manual

TIME: Three hours including fifteen minute break

OBJECTIVES: According to conservative design procedures the participants will be able to analyze and compute

I. The amount of aggradation to be expected upstream of a dam.

II. The increase in flood stage due to aggradation upstream of a reservoir.

PRESENTATION: (60 minutes) Design Example 4, same crossing situation as before but with a dam downstream causing aggradation and additional impoundment during floods

I. Aggradation analysis

II. Computation of aggradation

III. Backwater computation for flood stage

PROBLEM SESSION: (60 minutes) Compute aggradation and backwater values given for Design Example 4.

DISCUSSION SESSION: (60 minutes)

I. Discuss the correctness of the assumption that the slope is varying linearly on degrading and aggrading profiles

II. Discuss participants experiences with degradation and aggradation

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3277B (see Table II)

REFERENCE: Manual, Highways in the River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.

Lesson Plan 34

UNIT: Review

SUBJECT: Hydraulic and environmental considerations of highway crossings and encroachments. Chap. I through VIII of Manual

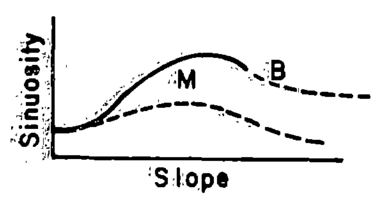
TIME: Two hours

OBJECTIVE: To review and highlight the basic relations, equations and concepts that were presented during the course. The review will emphasize the important points in the two week course so that the participant will be able to apply them to his problems.

PRESENTATION: (60 minutes)

I. River mechanic relations

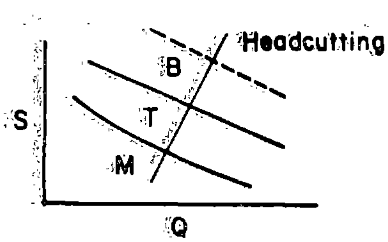
A. River form



Evaluate river form and the potential for change in form due to river development, change in climate, etc.

B. Classification of rivers

Discuss Figure 4.3.5 and Table 4.3.1 in Chap. IV of Manual describing river classification

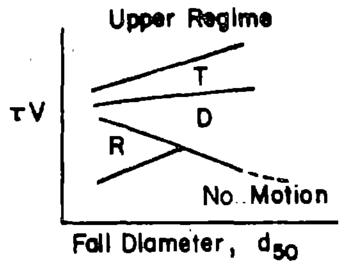


Quantitative evaluation of river form and the potential for change in river form. Also, may indicate danger of head cutting

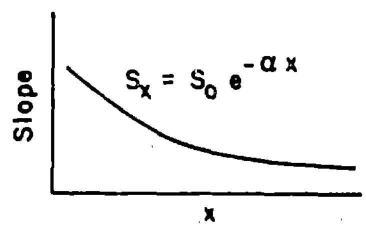
Meandering rivers $SQ^{\frac{1}{4}} \leq 0.0017$

Braided rivers $SQ^{\frac{1}{4}} \geq 0.010$

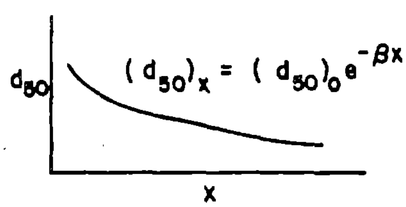
C. Relations for rivers



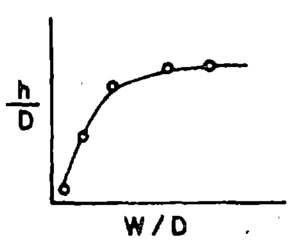
Prediction of bedforms and resistance to flow in sand bed channels



Assessment of slope variation along a river system
α = exponent of slope variation to be determined experimentally
(It is possible to evaluate relative steepness or flatness of river slope at a site)



Assessment of variation of size of bed material with distance along a river channel (It is possible to evaluate relative size of bed material in comparison with the rest of the system)



Determination of the potential for development of alternate bars (If W/D is large, then the alternate bars that may form will be of large amplitude; this is applicable if channel is straight and within the sinuous range)

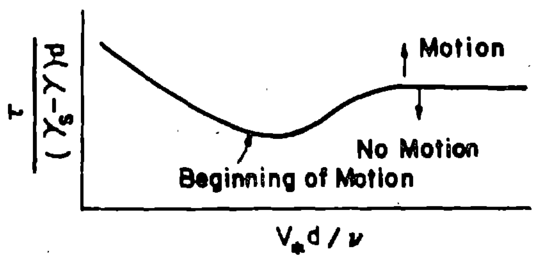
C. Relations for rivers--continued

$W = aQ^b$ $D = cQ^f$ $V = KQ^m$ $G = PQ^J$ $S = tQ^Z$ $n = rQ^y$	These channel geometry relations are useful to evaluate channel characteristics both at a station and along the river system (see page IV-27 of the Manual for coefficients and exponents in the equation)--greater refinement of the relations can be achieved by using local field data
Dominant discharge	Function of: Flow Transport Time Channel characteristics Bed and bank material
$r \alpha W_T$ $r \alpha d^n$	Radius of curvature r varies with discharge (At large discharges the thalweg may shift on to the point bar and cut a chute channel)
$Q_s \frac{d_{50}}{C_w} \alpha QS$	Qualitative evaluation of river stability and response to change of: sediment discharge, Q_s; size of bed material, d_{50}; concentration of wash load, C_w; water discharge, Q; and slope of energy gradient, S (All variables may be changing simultaneously)

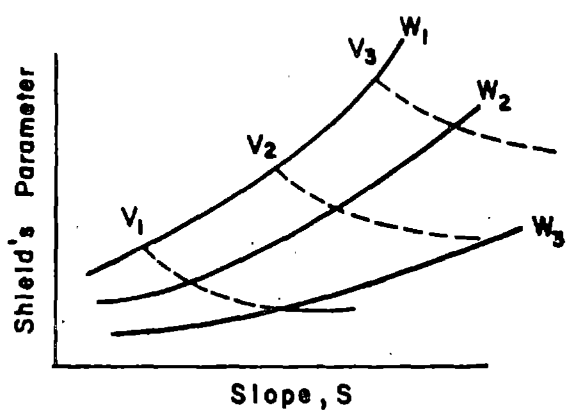
D. Remote sensing

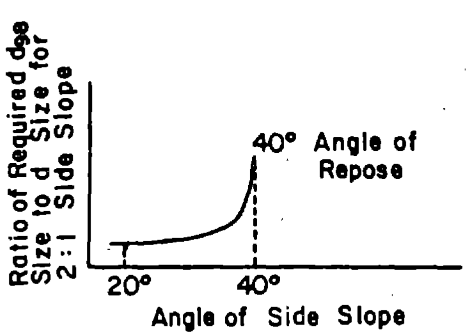
<u>Remote Sensing</u> Photography: Black & White; Color; Color Infrared; Thermal	By using aerial photos, preferably color infrared, one can identify sediment sources, places of deposition, channel instability; with sequential photography one can identify changes in river form and changes in the position of a river over time increments

II. Beginning of motion



Shields' diagram; determines the critical shear stress defining beginning of motion of particles (τ_c is widely used in transport equations) and can be used to establish a design procedure for stabilizing the bed and banks of rivers





III. Fluid mechanics

A. Continuity

$Q = AV$ (Steady flow)

Used all the time, including sometimes when it shouldn't because of time dependence

$$\frac{d(\text{Vol})}{dt} = Q_{in} - Q_{out}$$

(unsteady flow)

Inclusion of time dependence enables evaluation of effectiveness of channel storage

B. Momentum (steady)

$F_t + F_p + F_q + F_\sigma = \rho Q(V_2 - V_1)$

Useful for calculation of forces imposed by the flow

C. Energy Eq.

$$\frac{V_1^2}{2g} + \frac{p_1}{\gamma} + Z_1 = \frac{V_2^2}{2g} + \frac{p_2}{\gamma} + Z_2 + H_2$$

Can calculate loss in energy between different sections of the channel

D. Specific energy

$$H = \frac{V^2}{2g} + Z$$

For steady flow enables easy determination of water surface profiles for changes in channel cross section

E. Resistance to flow

$$n = \frac{1}{39}\,(d_{75})^{1/6}$$

(d_{75} in inches)

U.S. Geol. Survey Water Supply paper 1849 has pictorial reference of Manning's n
Calculate Manning's n from sediment size (coarse materials)
Use measured hydraulic data, Q, slope, channel geometry

F. Temperature

Change in fluid viscosity is largest effect; but water quality and growth rates of flora are affected

G. Flow distribution

Need to calculate shear stress and calculate average velocity in a vertical section

IV. Models

A. Physical models Froude model $F_m = F_p$	Used for all open channel (river) models (Sometimes distored scales are used--adjustment for roughness is necessary--lightweight sediment often used)
Reynolds model $\mathbb{R}_m = \mathbb{R}_p$	Used for closed conduit flow models where gravity is unimportant compared to viscous and pressure forces
B. Mathematical models	Used when reliable equations are available to describe flow of water and sediment (particularly valuable with physical model and when time varying phenomena are of interest--larger regions of the river can be modeled mathematically--model is limited by size of the computer)
C. River models	
1. Physical	Evaluate the performance of hydraulic structures and their interaction with the river environment (also used to verify mathematical models)
2. Mathematical	Same as for physical models, except more versatile in rapidly looking at a large number of alternatives, considering not only specific sites and structures, but their interaction with the river system and its tributaries

V. Sediment transport relations

A. Sand bed channels

Einstein's bedload function (Good for both analysis and design; Computer programs available)

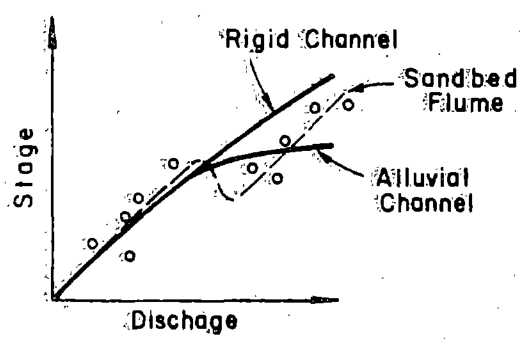
Colby Transport Relation--mostly for analysis of existing systems but can be adapted to design (Simple to use and based on large range of conditions)

B. Gravel and cobble bed channels

Meyer-Peter, Muller equation was originally developed for gravel and cobble bed channels (Has also been adapted for use for sandbed channels)

Very important to couple the water and sediment discharges for analysis of river systems and their interaction with hydraulic structures (Sediment transport relations are necessary to accomplish this)

VI. Stage-discharge relations



This stage-discharge relation helps identify not only the stage relative to discharge but the effects of different roughness elements and flow required on the stage-discharge relation

VII. Resistance to flow

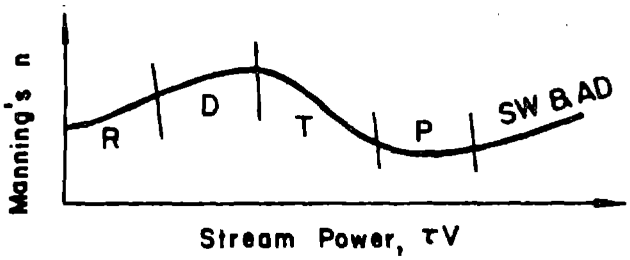
$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

Manning's equation

$$V = \frac{C}{\sqrt{g}} \sqrt{gRS}$$

Chezy's equation

VII. Resistance to flow--continued



Variation of resistance with change in bed form and regime of flow for a sand bed channel

$$n = \frac{d_{50}^{1/6}}{44.4}$$

Gravel-rock heterogeneous mixture

$$n = \frac{d_{75}^{1/6}}{39}$$

Gravel-rock armor

(d_{50} in inches)

d_{50} and d_{75} in inches

VIII. Riprap

A.

$d_m, \phi, \theta, V, S_s, S.F.$

The size of riprap required for bank protection depends on the angle of repose of the rock, ϕ, the angle of the side slope, θ, the magnitude and direction of the approach velocity, V, the specific gravity of the rock and the desired safety factor S.F.

$$d_m = \left[\frac{\sum_{i=1}^{10} d_i^{\,3}}{10} \right]^{1/3}$$

The effective size, d_m, of a rock mixture for riprap protection is computed from the gradation curve

$$d_1 = \frac{d_o + d_{10}}{2}$$

$$d_2 = \frac{d_{10} + d_{20}}{2}$$

.

.

.

$$d_{10} = \frac{d_{90} + d_{100}}{2}$$

	$\frac{d_m}{d_{50}} = 0.4G + 0.6$	The size of rock required for riprap material, d_m is related to d_{50} 50 and to the gradation coefficient G by this experimental equation
B.	$\tau_c = .047(S_s-1)d_{50}$	The critical shear stress on a plane flat bed (with a turbulent boundary layer) is related to the specific gravity and the d_{50} of the rock
C.	"CSU" method	Use for calculation of riprap on curved channel banks, embankment ends
D.	Minnesota method	Use for straight channels, side and bottom riprap Q less than 1000 cfs, man-made channels or natural channels with a flat bank side slope
E.	Corps of Engineers Manual TR 4	Use where wave action is large (sea coasts)

F. Filters for riprap

$$\frac{d_{50}(\text{filter})}{d_{50}(\text{base})} < 40$$

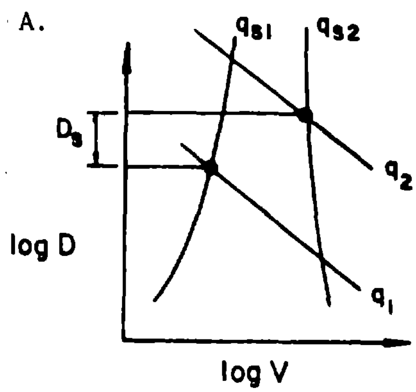
$$5 < \frac{d_{15}(\text{filter})}{d_{15}(\text{base})} < 40$$

$$\frac{d_{15}(\text{filter})}{d_{85}(\text{base})} < 5$$

These equations are used to design gravel filters to prevent the migration of base materials through the riprap and then on downstream

IX. General scour

A.



Nordin's method of computing general scour in contracted reaches (Employs Colby's relations for the transport of sand in channels)

B.

$$\frac{D_2}{D_1} = \left(\frac{w_1}{w_2}\right)^{6/7} \left(\frac{\tau_1}{\tau_2}\right)^{3/7} \left(\frac{n_2}{n_1}\right)^{6/7}$$

Straub's clear-water scour equation predicts general scour at relief structures (There is no sediment transport upstream of the bridge but scour in the bridge opening)

C.

$$\frac{D_2}{D_1} = \left(\frac{Q_t}{Q_c}\right)^{6/7} \left(\frac{w_1}{w_2}\right)^{\frac{6(2+f)}{7(3+f)}} \left(\frac{n_2}{n_1}\right)^{\frac{6f}{7(3+f)}}$$

Laursen's equations for general scour in long contractions (The value of f to be used depends on whether there is upstream sediment transport or not)

V_{*1}/w	f
< 0.5	.25
1	1
> 2.0	2.25

The value of "f" in Laursen's equation is dependent on the upstream shear velocity, V_{*1}, and on the fall velocity of the bed material, w

X. Local scour

A. Embankment

$$\frac{D_s}{D_1} = 1.1\left(\frac{a}{D_1}\right)^{0.4} F_1^{0.33}$$

$$\left(\frac{a}{D_1} < 25\right)$$

Local scour D_s caused by the vortex generated at an embankment end is related to the upstream Froude number F_1, the upstream depth D_1 and the length of abutment a

With sediment transport, gives equilibrium scour (Increase D_s by 30% with no sediment transport, and for maximum depth)

$$\frac{D_s}{D_1} = 4F_1^{0.33}$$

If the ratio a/D_1 is greater than 25, the local scour is independent of the abutment length a

B. Piers

$$\frac{D_s}{D_1} = 2.2\left(\frac{a}{D_1}\right)^{0.65} F_1^{0.43}$$

Local scour at the nose of a square-nose pier is related to the width of the pier, a, the depth of flow and Froude number upstream of the pier (Gives equilibrium scour--use 30% greater for maximum clear water scour--reduce with round nose, or streamlined piers)

DISCUSSION SESSION: (60 minutes) Open discussion of highway environment and hydraulic problems

VISUAL AIDS:

I. Blackboard

II. Overhead projector for sketching

III. Videotape number 3280 (see Table II)

REFERENCE: Manual, Highways in The River Environment--Hydraulic and Environmental Design Considerations, 1975, Federal Highway Administration, U.S. Department of Transportation.

Appendix A

DAILY EVALUATION QUESTIONNAIRE:

Table A-1 is a sample form of a daily questionnaire. The purpose of this form is for the participant in the training course to record daily his impression of the course material and lectures as they progress. This information can be turned in each day as part of the evaluation or used by the participant to aid in his subjective evaluation at the end of the course.

Table A-1

Daily Evaluation Questionnaire

Course Objective: To provide training in the practical application of the concepts of open-channel flow, fluvial geomorphology and river mechanics to the design, construction, maintenance and related environmental problems associated with highway crossings and encroachments.

Date:

Subjects:

Lecturer(s):

Note: Circle appropriate number

	Not applicable	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
1. The lecturers clearly indicated the purpose and objective of their lectures before beginning their presentations.	0	1	2	3	4	5
2. Important points were summarized at lecture conclusions.	0	1	2	3	4	5
3. Subject material and lectures were consistent with the course objective (stated above).	0	1	2	3	4	5
4. Subject material was comprehensive and lectures were arranged with good continuity.	0	1	2	3	4	5

5. Was the level of difficulty of the lectures and the manual consistent with your background and training?

/_/ Too difficult

/_/ About right

/_/ Too easy

Comments:

6. Were there any parts of the lectures or the manual that should be emphasized or deemphasized?

   Comments:

7. Was any material omitted from the lectures or the manual that you feel would have furthered your understanding at this point or would have made the learning process easier?

   Comments:

8. Was any material included that is superfluous to your understanding or your needs as a designer?

   Comments:

FINAL EVALUATION QUESTIONNAIRES:

I. Subjective Evaluation

In Tables A-II and A-III are two sample questionnaires for subjectively evaluating the training material and course. Either one of the questionnaires can be used or questions could be selected from each. The questionnaire in Table A-III is somewhat easier for statistical analysis in that a numerical value can be given to each answer. For example, the value of 1 can be given to the answer NA and 2, 3, etc. for the others up to 6 for SD. An average score of 2.3 for a question would indicate that most of the participants agree with that statement.

II. Objective Evaluation

In Table A-IV a questionnaire is given to determine what factual information the participants have gained. These questions were developed to determine if the objectives of the course have been met by actual transfer of knowledge; that is, whether the participant learned what the objectives of the course were set up to teach.

Table A-II

Subjective Course Evaluation Questionnaire No. 1

Date:

Evaluator (can be anonymous):

Note: Circle appropriate number

	Not applicable	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
1. Course objectives were clearly defined.	0	1	2	3	4	5

Comments:

2. The course subject matter was consistent with the course objectives.

a. Lectures	0	1	2	3	4	5
b. Manual	0	1	2	3	4	5

Comments:

3. There was an appropriate balance between theory and application.	0	1	2	3	4	5

Comments:

Table A-II continued

4. The course length was adequate. 0 1 2 3 4 5

Comments:

5. The training manual is

a.	Thorough and comprehensive	0	1	2	3	4	5
b.	Well organized and developed; i.e., logical presentation of subject material.	0	1	2	3	4	5
c.	Clearly written	0	1	2	3	4	5
d.	Suitable as an instructional text	0	1	2	3	4	5
e.	Suitable as a design manual	0	1	2	3	4	5
f.	In need of revision	0	1	2	3	4	5

List the sections of the manual that you feel need revision and describe the nature and extent of the modifications.

Comments:

Table A-II continued

6. a. Was the level of difficulty of the lectures and the manual consistent with your background and training?

   /_/ Too difficult

   /_/ About right

   /_/ Too easy

   Comments:

   b. Do you feel the advance reading assignments (Volume I and II of River Mechanics and selected papers) were helpful to you?

   Comments:

   c. How much of the advance materials did you read?

   /_/ None

   /_/ 20 percent

   /_/ 40 percent

   /_/ 60 percent

   /_/ 80 percent

   /_/ 100 percent

   Comments:

Table A-II continued

7. Do you believe there is a continuing need for this course?

   Comments:

8. Do you believe the course attained its training objectives?

   Comments:

9. How would you rate this course overall?

   /_/ Excellent

   /_/ Very good

   /_/ Good

   /_/ Fair

   /_/ Poor

Table A-III

Subjective Course Evaluation Questionnaire No. 2

Note: Questions are to be answered on form at the end of these questions.

1. The manual subject matter was consistent with the objectives of providing training in the practical application of the concepts of open-channel flow, fluvial geomorphology and river mechanics to the design, construction, maintenance and related environmental problems associated with highway crossings and encroachments.

2. The manual is organized and written to serve your needs as a designer.

3. The manual described fine bed material in a manner that enhanced your appreciation of the better things in life.

4. The manual is clearly written.

5. The manual is satisfactory for both training and design.

6. The level of difficulty of the manual was consistent with your background and training.

7. The manual is organized and written to serve your needs as a participant in the training course.

8. The chapter on open channel flow served as comprehensive background material for following sections in the manual.

9. The fundamentals of alluvial channel flow and sediment transport were clearly communicated.

10. The chapters on fluvial geomorphology and river mechanics clearly explained river conditions.

11. The chapter pertaining to fluvial geomorphology and river mechanics adequately explained the classification and behavior of rivers.

12. Chapters VI and VIII adequately used the fundamentals presented in earlier chapters in practical design.

13. The case histories and design examples adequately covered problems that are commonly encountered in highway river crossing design.

14. The manual clearly illustrates the need to use the fundamentals of open channel flow, geomorphology, and fluvial hydraulics in analyzing practical design problems.

Table A-III continued

15. The training course subject matter was consistent with the objectives of providing training in the practical application of the concepts on open-channel flow, fluvial geomorphology and river mechanics to the design, construction, maintenance and related environmental problems associated with highway crossings and encroachments.

16. The organization of the two week training course was satisfactory.

17. Objectives of each training session were clearly defined and communicated.

18. Instructors summarized and emphasized major points and clarified important issues and viable points.

19. Effective use was made of training session time.

20. The general quality of presentation of the lectures, laboratory sessions, and discussion was satisfactory.

21. Lectures, discussions and assignments were well integrated.

22. The standard of the work involved during assignments allowed direct correlation with in-field problems.

23. The quantity of work involved during problem sessions was satisfactory.

24. The level of the required work did not involve application of knowledge beyond that provided by your background.

25. Sufficient time was available for in-class and extra-curricula open discussion.

26. The content of class discussions were stimulating and aided in clarifying issues.

27. The relatively unstructured laboratory sessions allowing you to pursue your own interests were satisfactory.

28. The general quality of the laborating sessions was satisfactory.

29. The first week of the training session was important to an understanding of the material presented during the second week.

30. Basic theoretical considerations were clearly explained and were related to the problems of highways in the river environment.

31. Problems solved in the problem session were applicable to your field problems.

Table A-III continued

32. Participation in the field trip provided additional insight to the problems of highways in the river environment.

33. The outside lecturers were stimulating and provided information that was useful to you.

34. Facilities were adequate for this type of training course.

Table A-III continued

Answer Form for Subjective Questionnaire

Circle one for each question using the following key.

0 (NA) Not applicable
1 (SA) Strongly agree
2 (A) Agree
3 (I) Impartial
4 (D) Disagree
5 (SD) Strongly disagree

	NA	SA	A	I	D	SD
1.	0	1	2	3	4	5
2.	0	1	2	3	4	5
3.	0	1	2	3	4	5
4.	0	1	2	3	4	5
5.	0	1	2	3	4	5
6.	0	1	2	3	4	5
7.	0	1	2	3	4	5
8.	0	1	2	3	4	5
9.	0	1	2	3	4	5
10.	0	1	2	3	4	5
11.	0	1	2	3	4	5
12.	0	1	2	3	4	5
13.	0	1	2	3	4	5
14.	0	1	2	3	4	5
15.	0	1	2	3	4	5
16.	0	1	2	3	4	5
17.	0	1	2	3	4	5
18.	0	1	2	3	4	5
19.	0	1	2	3	4	5
20.	0	1	2	3	4	5
21.	0	1	2	3	4	5
22.	0	1	2	3	4	5
23.	0	1	2	3	4	5
24.	0	1	2	3	4	5
25.	0	1	2	3	4	5
26.	0	1	2	3	4	5
27.	0	1	2	3	4	5
28.	0	1	2	3	4	5
29.	0	1	2	3	4	5
30.	0	1	2	3	4	5
31.	0	1	2	3	4	5
32.	0	1	2	3	4	5
33.	0	1	2	3	4	5
34.	0	1	2	3	4	5

Table A-IV

Objective Course Evaluation Questionnaire

Note: Questions are to be answered on the form at the end of these questions.

1. A meandering stream consists of

   a. Many interlacing channels
   b. A series of S-shaped curves with point bars, pools, and crossings
   c. A long straight channel with bars alternating on opposite sides of the channel
   d. A pool connected with a stream reach
   e. None of these

2. A braided channel may result from a river having

   a. A steep slope and high velocities with banks susceptible to erosion
   b. Sandy, easily eroded banks and periods of high flows followed by periods of low flow
   c. A degrading channel with erodible banks
   d. An aggrading channel
   e. All of these

3. What will be the response of a river to a decrease in discharge resulting from a major diversion? Little or no sediment is diverted.

   a. Aggradation with a decrease in slope downstream of the diversion
   b. Degradation with a decrease in slope downstream of the diversion
   c. Nothing
   d. Aggradation with an increase in slope downstream of the diversion
   e. The bed material will become coarser

4. Rivers in nature have constant cross sections that never change with time.

   a. True
   b. False

5. Which of the following statements are true?

   a. With uniform flow the velocity does not change with time
   b. A flow may be nonuniform, steady, laminar and rapid
   c. The resistance factor (f) for hydraulically smooth turbulent flow is independent of the Reynolds number
   d. Manning's n is constant for any channel
   e. The momentum equation is a scalar

6. A bridge narrows a channel from 5,000 ft to 1,000 ft for a flow of 10,000 cfs. Depth of flow in the 5,000 ft channel was 10 ft. Neglecting friction and head losses and assuming no scour, which of the following statements are true?

   a. The bridge will not cause any backwater
   b. The depth of flow downstream of the bridge will be approximately 25 ft
   c. The specific energy at the downstream section is approximately 14 ft
   d. There will be large standing waves downstream of the bridge
   e. None of the above

Table A-IV continued

7. The slope of a channel changes from steep to mild. Which of the following statements might be true? Assume the channels are infinitely long before and after the change in slope.

   a. An M-3 curve will form on the mild slope followed by a hydraulic jump to the normal depth of flow
   b. An M-3 curve will form on the mild slope followed by a hydraulic jump to the sequent depth of the jump which is on an M-2 curve
   c. A hydraulic jump occurs on the steep slope followed by an M-1 curve which ends at the normal depth of the mild slope
   d. A hydraulic jump occurs on the steep slope followed by an S-1 curve which ends at the normal depth of the mild slope
   e. A hydraulic jump occurs at the change in slope followed by an M-1 curve to the normal depth of the mild slope

8. During a large increase in flow, the Manning's n for a channel dune bedform and median diameter of sand equal to 0.2 mm may change from

   a. 0.014 to .035
   b. 0.030 to .015
   c. 0.080 to .032
   d. .026 to .026
   e. .026 to .036

9. The Rouse number is the ratio of the fall velocity ω of the sediment particles to the shear velocity V_* of the flow. If the Rouse number increases which one of the following statements is true?

   a. The turbulence of the stream has increased in relation to the fall velocity of the sediment particles
   b. The distribution of the sediment in the vertical has become more uniform
   c. There will be a decrease in concentration of the given particles in the vertical
   d. The temperature of the water has decreased in relation to the shear velocity
   e. None of these

10. If the Froude number of the channel is greater than one, which of the following statements is true?

   a. The control of the water surface is upstream
   b. The celerity of a small wave is less than the velocity of flow
   c. The water surface will decrease for flow over a gentle rise in the bed
   d. Violent cross waves may occur at any bend or transition
   e. The confluence with another stream is of no more concern than if the flow was tranquil

11. For the following conditions the velocity at a point in the flow is d_{65} is 1.0 mm = 0.00328 ft, y = 1.0 ft, $\nu = 1.6 \times 10^{-5}$, $V_* = \sqrt{gRS} = 0.5$

   a. 2.62
   b. 11.4 fps
   c. 4.26
   d. 15.8
   e. 13.21

Table A-IV continued

12. If the velocity of flow is 12 ft/sec and $C/\sqrt{g}$ is 20, what is the average shear stress on the bed?

   a. 1.35
   b. .423
   c. .698 lbf/ft^2
   d. 1.16
   e. 0.94

13. During a runoff event in a sand channel, the bed configuration changes (relatively fast) from dunes to antidunes. Which of the following are true?

   a. The resistance to flow will increase
   b. There may be a discontinuity in the depth discharge relation with a decrease in depth for the same discharge
   c. There will be no change in the appearance of the water surface
   d. There will be a decrease in average velocity of flow
   e. None of these

For the following four questions (14-17), the discharge per foot of width in a channel is 200 cfs/ft and the depth is 20 ft.

14. The specific energy for this flow is

   a. 22.6
   b. 21.55
   c. 20.65
   d. 24.0
   e None of these

15. The critical depth for minimum specific energy for this flow is

   a. 15.04
   b. 9.83
   c. 14.37
   d. 10.72
   e. None of these

16. The maximum discharge for flow with this specific energy is

   a. 199
   b. 200
   c. 372
   d. 309
   e. None of these

17. What is the minimum width of a bridge opening for a flow of 5,000 cfs and this specific energy without causing backwater?

   a. 25.0
   b. 13.4
   c. 18.4
   d. 16.2
   e. None of these

Table A-IV continued

18. A wide channel has a slope of .0009, a Manning's n of .030, and a unit discharge of 149 cfs/ft. The corresponding depth of flow from Manning's Equation is

   a. 2 feet
   b. 4 feet
   c. 8 feet
   d. 16 feet
   e. Not within 10 percent of any one of the above

19. A meandering river

   a. Flows only in upper regime
   b. Is relatively unstable compared with a braided river
   c. Has many islands and sandbars in the channel
   d. Is an example of laminar flow
   e. None of these

20. The flow in a river is reduced, causing a reduction in depth of flow. This may cause

   a. The tributaries in the area to aggrade
   b. The tributaries in the area to degrade
   c. A reduction of sediment flow in the tributaries
   d. Increased stability of the tributaries
   e. All of these

21. A meandering river channel is steepened locally by making a series of artificial cutoffs. Subsequently, a bridge is constructed immediately upstream of the straightened section. The safety of the bridge may be affected by

   a. Increased local scour
   b. Increased bank instability
   c. The possibility of headcutting
   d. Increased velocity
   e. All of these

22. In a gravel-bed stream, a relatively straightforward method for computing the bed load is

   a. Colby's method
   b. The Meyer-Peter, Muller method
   c. Einstein's bedload function
   d. None of these

23. The wash load in alluvial channel can be computed from

   a. Colby's method
   b. The Meyer-Peter, Muller method
   c. Einstein's bedload function
   d. None of these

24. The suspended bed-material load in sand bed channels contains

   a. All sizes that are in the bed material
   b. The measured total load
   c. The load computed by Colby's method
   d. The load computed by Einstein's method
   e. None of these

Table A-IV continued

25. With a water temperature decrease of 20°F in a sand channel

    a. The fall-form velocity of the sand with movement will increase
    b. The bed will change from plane bed to dunes
    c. The fall velocity of the sand particles will not change
    d. The wash load will increase
    e. None of these

26. A good method of determining the size distribution in a cobble bed is

    a. Pipette
    b. Visual accumulation tube
    c. Standard nested sieves
    d. Pebble count
    e. None of these

27. Knowledge of the critical tractive force for alluvial particles is important in determining

    a. The size of rock necessary to protect a bank from erosion
    b. The maximum shear that particles forming the bed and bank of a channel can take without the beginning of movement
    c. The transport of gravel-sized particles
    d. In the design of stable channels
    e. All of these

28. The results of an alluvial model study of a bridge crossing

    a. Can be used to predict the depth of scour around bridge piers
    b. Can be used to find the location of scour holes and potential problem areas from either scour or deposition
    c. Can be used to predict the magnitude of the backwater effect of the bridge within one foot
    d. Are scaled to the prototype dimensions using the Reynolds number
    e. None of these

29. A filter blanket is used between riprap and the fine material forming a bank to

    a. Form a cushion for the riprap to decrease its mobility and increase its resistance to abrasion
    b. Protect the riprap from the movement of groundwater
    c. Keep the flowing water from eroding the fine material through the voids in the riprap
    d. Keep rodents and other small animals from burrowing in the bank
    e. None of these

30. Circle the statements that are true.

    a. Riprap should be well graded with maximum size as large as possible
    b. Riprap should be uniform in size
    c. Riprap should be "smoothly graded" with maximum size about 2 d_{50}
    d. Riprap size (d_{50}) for bank protection cannot be designed
    e. Filters beneath riprap are desirable but not necessary

Table A-IV continued

31. A rectangular shaped pier is 6 ft wide and 24 ft long. The flow is aligned with the pier. Approach velocity is 6 ft/sec at a depth of 5 ft. The maximum depth of scour is predicted to be

a. 6 ft
b. 9 ft
c. 12 ft
d. 15 ft
e. None of these

Table A-IV continued

Answer Form for Objective Questionnaire with correct answer marked with an x.

Circle the correct answer or answers for each question.

1.	a	b (x)	c	d	e
2.	a	b	c	d	e (x)
3.	a	b	c	d (x)	e
4.	a	b (x)	c	d	e
5.	a	b (x)	c	d	e
6.	a (x)	b	c	d	e
7.	a (x)	b	c	d (x)	e
8.	a	b (x)	c	d	e
9.	a	b	c (x)	d	e
10.	a (x)	b (x)	c	d (x)	e
11.	a	b (x)	c	d	e
12.	a	b	c (x)	d	e
13.	a	b (x)	c	d	e
14.	a	b (x)	c	d	e
15.	a	b	c	d (x)	e
16.	a	b	c	d (x)	e
17.	a	b	c	d (x)	e
18.	a	b	c	d (x)	e
19.	a	b	c	d	e (x)
20.	a	b (x)	c	d	e
21.	a	b	c	d	e (x)
22.	a	b (x)	c	d	e
23.	a	b	c	d (x)	e
24.	a (x)	b	c	d	e
25.	a	b	c	d	e (x)
26.	a	b	c	d (x)	e
27.	a	b	c	d	e (x)
28.	a	b (x)	c	d	e
29.	a	b	c (x)	d	e
30.	a	b	c (x)	d	e
31.	a	b	c (x)	d	e

Appendix B

PROBLEMS:

In this section additional problems are provided. These are problems in addition to those in the Manual. The instructor can use these problems or make up additional ones.

Problem numbers are keyed to the chapters in the Manual. That is, problems for Chapter II are number II-1, II-2..., for Chapter III are number III-1,..., and so forth.

II-1. Hydraulic Jump

Flow from a steep box culvert coming out of a horizontal apron has a discharge of 20 cfs per foot of width and a depth of 0.5 ft. Normal depth in the downstream channel is 5 ft. Calculate

a) The consequent depth
b) The length of the jump
c) The height of the end sill to cause the jump to form on the apron
d) the approximate length of the apron

Solution

a) Calculate the upstream Froude number

$$q = vy$$

$$v = q/y = 20/0.5 = 40 \text{ fps}$$

$$Fr = \frac{v}{\sqrt{gy}} = \frac{40}{\sqrt{32.2 \times 0.5}} = 10$$

b) Calculation of consequent depth; from Fig. 2.4.3, for Fr = 10

$$y_2/y_1 = 14$$

$$y_2 = 14\ y_1 = 7 \text{ ft}$$

c) Calculation of the length of the jump from Fig. 2.4.3, for Fr = 10

$$L/y_2 = 6.2$$

$$L = 6.2\ y_2 = 43.4 \text{ ft}$$

d) Calculation of the height of the end sill to cause the jump to form on the apron consequent depth $y_2 = 7$ ft normal depth downstream $y_n = 5$ ft

Height of end sill $\Delta z = y_2 - y_n = 2$ ft

e) Length of the apron; for safety, assume a design length of 60 ft

II-2. Velocity and Shear

For a stream with a slope of 20 ft/mile, and a sand bed with $D_{65} = 2.0$ mm (0.066 ft), depth of flow 5 ft and width 300 ft, Manning's n = 0.020, $\nu = 1.217 \times 10^{-5}$ ft^2/sec., determine

a) The average shear stress on the bed
b) The velocity at a depth of 1 ft from the bed
c) The mean velocity
d) Identify the type of flow

Solution

a) For a wide stream, $R = y_o$

and $\tau_o = \gamma\, y_o\, S_f$

$$S_f = \frac{20 \text{ ft/mile}}{5280 \text{ ft/mile}} = 0.003822$$

$$\tau_o = 62.4 \times 5 \times 0.003822$$

$$\tau_o = 1.19 \text{ lbs/sq ft}$$

b) The shear velocity V_* is

$$V_* = \sqrt{\frac{\tau_o}{\rho}} = \sqrt{\frac{1.19}{1.94}} = 0.784 \text{ fps}$$

The thickness of the viscous sublayer δ' is

$$\delta' = \frac{11.6\nu}{V_*} = \frac{11.6 \times 1.217 \times 10^{-5}}{0.784}$$

$$\delta' = 0.18 \times 10^{-3} \text{ ft}$$

The height of the roughness elements k_s is

$$k_s = D_{65} = 0.066 \text{ ft}$$

And $k_s/\delta' = 367$, and from Fig. 2.3.5, the correction factor x is

$$x = 1.0$$

Now $\frac{v}{V_*} = 2.5 \ln \left(30.2 \frac{xy}{k_s}\right)$ (Eq. 2.3.15)

For $y = 1.0$, $x = 1.0$, and $k_s = 0.066$

$$v = 2.5\, V_* \ln (457.6)$$

Finally, the local velocity v is

$$v = 2.5 \times 0.784 \times 6.12 =$$

$$v = 12.0 \text{ fps}$$

c) The mean velocity can be calculated with Manning's formula, for $R = y_o$

$$V = \frac{1.486}{n}\, y_o^{2/3}\, S_f^{1/2}$$

$$V = \frac{1.486}{0.020} (5)^{2/3} (0.003822)^{1/2}$$

$$V = 13.43 \text{ fps}$$

d) The type of flow can be assessed by the Froude number

$$Fr = \frac{V}{\sqrt{gy_o}} = \frac{13.43}{\sqrt{32.2 \times 5}}$$

$$Fr = 1.05$$

Therefore, the flow is supercritical

II-3. Flow Contraction Through a Bridge Opening

For the flow conditions of Problem 2.A1.0 in the manual, calculate the change in bed elevation in order for the water surface elevation (neglecting friction) to remain constant through the bridge opening. (Discharge 5000 cfs, depth upstream 10 ft, width upstream 100 ft, width at the opening 48.4 ft). What is the Froude number in the contraction?

Solution

a) For the water surface elevation to remain constant, the velocity head has to be the same in the contraction and upstream, neglecting frictional losses

Velocity upstream $V = \frac{Q}{A} = \frac{5000}{100 \times 10} = 5$ fps

Depth at the bridge opening y

$$y = \frac{Q}{V \times W} = \frac{5000}{5 \times 48.4} = 20.66 \text{ ft}$$

$$Fr = \frac{V}{\sqrt{gy}} = \frac{5}{\sqrt{32.2 \times 20.66}} =$$

$$Fr = 0.193$$

II-4. Width Contraction and Bottom Rise

Calculate the depth of flow in the following width contraction and bottom rise. Discharge is 5000 cfs, upstream width and depth are 100 and 10 ft. The contraction is to 60 ft and the bed rise is 1 ft. What is the Froude number in the contraction?

Solution

a) We know from Problem 2.A1.0 in the Manual that this contraction will not cause backwater

Discharge per unit width upstream, q_o

$$q_o = \frac{Q}{W_o} = \frac{5000}{100} = 50 \text{ cfs/ft}$$

Discharge per unit width at the contraction, q_1

$$q_1 = \frac{Q}{W_1} = \frac{5000}{60} = 83.33 \text{ cfs/ft}$$

$$q_1 = \frac{Q}{W_1} = \frac{5000}{60} = 83.33 \text{ cfs/ft}$$

b) Specific head upstream, H_o

$$H_o = \frac{q_o^2}{2gy_o^2} + y$$

$$H_o = \frac{(50)^2}{2 \times 32.2 \times (10)^2} + 10 = 10.39 \text{ ft}$$

c) Specific head at the contraction, H_1 and depth, y_1,

$$H_1 = H_o - \text{bottom rise } \Delta z$$

$$H_1 = 10.39 - 1.00 = 9.39 \text{ ft}$$

$$H_1 = \frac{q_1^2}{2gy_1^2} + y_1 = 9.39$$

And solving for y_1:

$$y_1 = 7.45 \text{ ft}$$

d) The Froude number Fr_1

$$Fr_1 = \frac{V_1}{\sqrt{gy_1}} = \frac{q_1}{y_1\sqrt{gy_1}}$$

$$Fr_1 = 0.72$$

II-5. Classification of W. S. Profiles

Sketch and label the water surface profiles for following changes in slope (assume flows reach normal depth before and after slope change)

a) Steep slope to mild slope to steep
b) Mild slope to steeper mild slope
c) Steep slope to flatter steep slope

Solution

Figure 2.7.2 in the manual shows the W. S. profiles. Discuss the conditions for hydraulic jump forming on either steep or mild slope in problem A1. The relation between the sequent depth of the hydraulic jump to the normal depth on the mild slope determines where jump will form. If the y_2 of the jump calculated for flow conditions on the steep slope is smaller than normal depth on the mild slope, jump will form on steep slope. If y_2 of the jump on the steep slope is greater than the normal depth on the mild slope, jump will form on mild slope.

II-6. Calculation of Backwater

An overflow weir raises the normal depth of flow in a lined retangular channel from 5 to 6 ft. Compute the backwater curve for these conditions, given S_o = 0.001, n = 0.018, and width of the channel 12 ft.

Solution

a) Compute the discharge Q using Manning's equation given w = 12; y_o = 5; n = 0.018; S_o = 0.001; Q = 308.4 cfs

b) The initial condition for depth is y = 6 ft

c) Assume subsequent depths, and compute the length of reach ΔL required to reach each depth

1) Compute A, V, $V^2/2g$, H, P, R and S for each depth; enter into a table
2) Compute the average value of S and the change in specific head for each reach
3) Compute $\Delta L = \frac{\Delta H}{S_o - S}$
4) Add ΔL values to obtain the total distance ΣL from start point. (See Table for detailed computation.)

y	A	V	$V^2/2g$	H	P	R	n	S	Save	ΔH	ΔL	ΣL
6.0	72.0	4.28	0.285	6.28	24.0	3.00	0.018	0.000610				0
5.8	69.6	4.43	0.305	6.10	23.6	2.95	0.018	0.000670	0.000640	0.18	500	500
5.6	67.2	4.59	0.327	5.93	23.2	2.90	0.018	0.000736	0.000703	0.17	572	1072
5.4	64.8	4.76	0.352	5.75	22.8	2.84	0.018	0.000814	0.000775	0.18	800	1872
5.2	62.4	4.94	0.379	5.58	22.4	2.78	0.018	0.000903	0.000858	0.17	1197	3069

$$A = wy = 12\,y$$

$$V = Q/A = 308.4/A$$

$$P = w + 2y$$

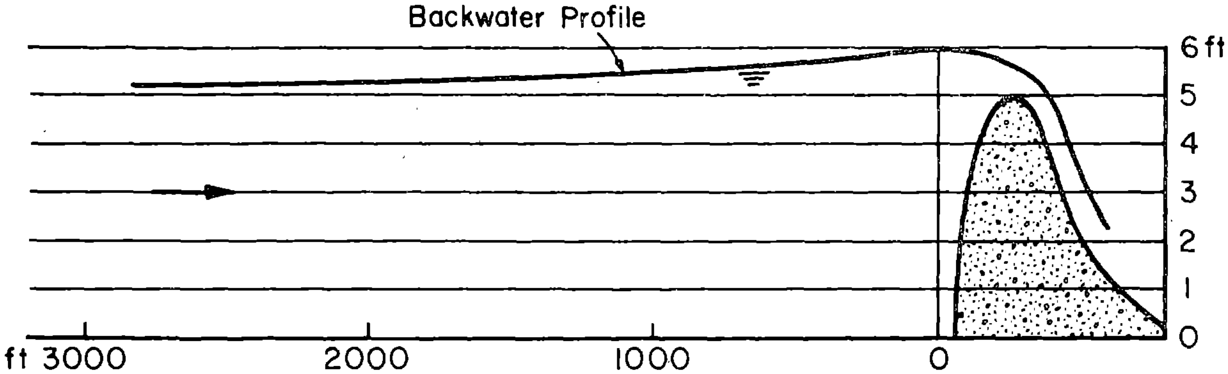
$$R = A/P$$

$$n = 0.018$$

$$S = \frac{n^2 Q^2}{2.25\, A^2 R^{4/3}} \quad \text{(Manning)}$$

$$\Delta H = H_1 - H_2$$

$$\Delta L = \frac{\Delta H}{S_o - S} = \frac{\Delta H}{0.001 - S}$$



II-7. Calculation of Superelevation

Compare the differences in superelevations that will be obtained by using equations 2.6.5, 2.6.7, 2.6.8 and 2.6.10. Assume

$r_i = 500$ ft, $r_c = 700$ ft, $r_o = 900$ ft

$V = Q/A = 10$ fps, $V_{max} = 14$ fps

a) Eq. 2.6.5

$$\Delta z = \frac{V^2}{gr_c}(r_o - r_i)$$

$$\Delta z = \frac{100}{32.2 \times 700}(900 - 500)$$

$$\Delta z = 1.774 \text{ ft}$$

b) Eq. 2.6.7

$$\Delta z = \frac{V^2}{2g} \cdot \frac{2W}{r_c}\left(\frac{1}{1 - (\frac{W}{2r_c})^2}\right)$$

$$\Delta z = \frac{100}{2 \times 32.2} \times \frac{2 \times 400}{700}\left(\frac{1}{1 - (\frac{400}{2 \times 700})^2}\right)$$

$$\Delta z = 1.774 \times 1.088$$

$$\Delta z = 1.931 \text{ ft}$$

c) Eq. 2.6.8

$$\Delta z = \frac{V^2}{2g} \cdot \frac{2W}{r_c}\left(\frac{1}{1 + \frac{W^2}{12r_c^2}}\right)$$

$$\Delta z = \frac{100}{2 \times 32.2} \times \frac{2 \times 400}{700} \left(\frac{1}{1 + \frac{(400)^2}{12 \times (700)^2}} \right)$$

$$\Delta z = 1.774 \times 0.973$$

$$\Delta z = 1.727 \text{ ft}$$

d) Eq. 2.6.9

$$\Delta z = \frac{V_{max}^2}{2g} \left(2 - \left(\frac{r_i}{r_c}\right)^2 - \left(\frac{r_c}{r_o}\right)^2\right)$$

$$\Delta z = \frac{(14)^2}{2 \times 32.2} (2 - 0.51 - 0.60)$$

$$\Delta z = 3.043 \ (0.89)$$

$$\Delta z = 2.708 \text{ ft}$$

III-1. Computation of Velocity at Grain Level

Given $V = 10$ fps, $V_* = 0.5$ fps, $k_s = 0.2$ ft. determine V on the grains at $y = k_s = 0.2$ ft

Solution

Assume a hydraulically rough flow, so the multiplication factor x is equal to 1

$$\frac{v}{V_*} = 2.5 \ln \left(30.2 \frac{xy}{k_s}\right)$$

$v = 2.5\, V_* \ln (30.2)$ for

$x = 1,\ y = k_s$

$v = 4.25$ fps

IV-1. Problem on Qualitative Response of Alluvial Channels to a Change in a Variable. Solution is Table 4.4.1 of Manual, Highways in the River Environment.

Variable	Change in Magnitude of Variable	Effect on: Regime of Flow	River Form	Resistance to Flow	Energy Slope	Stability of Channel	Area	Stage
Discharge	+	+	M→B	±	-	-	+	+
Size Bed Material	+							
Bed-Material Load	+							
Wash Load	+							
Viscosity	+							
Seepage Force	+							
Vegetation	+							

V-1. Geometry of Meandering Rivers

Given the width of a meandering channel $W = 50$ ft, estimate

a) Meander wavelength λ
b) Meander amplitude A
c) Meander width W_m
d) Mean radius of curvature r_m

Solution

From Table 5.2.1, with Leopold and Wolman's data

a) $\lambda = 10.9\, W^{1.01} = 566.7$ ft

b) $A = 2.7\, W^{1.10} = 199.6$ ft

c) $W_m = A + W = 249.6$ ft

d) $\lambda = 4.7\, r_c^{0.98}$

$$r_c = \left(\frac{\lambda}{4.7}\right)^{\frac{1}{0.98}} = 132.9 \text{ ft}$$

V-2. Calculation of the Longitudinal Drop

Given: $Q = 50{,}000$ cfs, $y_o = 10$ ft, $W = 1000$ ft, $L - 6000$ ft, $r_c = 2000$ ft, $\phi = 90° = \frac{\pi}{2}$ radians, $S_o = 0.0004$, calculate

a) The longitudinal drop Δz_o

b) The ratio of the longitudinal drop to the superelevation, K_o

Solution

a) From Eq. 5.6.2

$$\Delta z_o = \frac{V^2 L}{C^2 y_o}$$

$$V = \frac{Q}{y_o W} = \frac{50{,}000}{10 \times 1000} = 5 \text{ fps}$$

$$C = \frac{V}{\sqrt{y_o S_o}} = \frac{5}{\sqrt{0.0004 \times 10}} = 79$$

$$\Delta z_o = \frac{(5)^2 \times 6000}{(79)^2 \times 10} = 2.4 \text{ ft}$$

b) $$K_o = \frac{g\, r_c\, L}{C^2 W y_o} = \frac{32.2 \times 2000 \times 6000}{(79)^2 \times 1000 \times 10}$$

$$K_o = 6.19$$

V-3. Velocity Distribution in Bends

Given $Q = 1000$ cfs, $W = 60$ ft, $y_{max} = 6$ ft, $\Delta = 30°$, $C/\sqrt{g} = 12$, find

a) The location of the maximum average velocity

b) The depth at the location of the maximum average velocity

Solution

a) From Eq. 5.3.2

$$\Delta' = 0.42\ \Delta \frac{y_{max}}{W} \frac{\sqrt{g}}{C}$$

$$\Delta' = 0.42 \times 30 \times \frac{6}{60} \times \frac{1}{12}$$

$$\Delta' = 0.105$$

$$\Delta' \times 10^2 = 10.5$$

From Fig. 5.3.5, for $\Delta' \times 10^2 = 10.5$

V/V_{max} is a minimum for

$$2x/W = 0.4$$

$$x = \frac{0.4W}{2} = 12 \text{ ft}$$

b) From Eq. 5.3.4

$$y = y_{max}(1 - \frac{2x}{W})^2$$

$$y = 6(1 - 0.4)^2$$

$$y = 2.16 \text{ ft}$$

V-4. Radial Velocity Distribution in Bends

Given $V = 4$ fps, $r = 400$ ft, $k = 0.4$, $y_o = 2$ft, $C/\sqrt{g} = 12$, find the radial velocity at $y = 0.4$ ft

Solution

a) $\eta = \frac{y}{y_o} = 0.2$

From Fig. 5.3.6

$$F_1(\eta) = -0.80$$

$$F_2(\eta) = -0.36$$

From Eq. 5.3.5

$$V_r = \frac{1}{k^2} V \frac{y}{r}[F_1(\eta) - \frac{\sqrt{g}}{KC} F_2(\eta)]$$

$$V_r = \frac{1}{(0.4)^2} \times 4 \times \frac{0.4}{400}[- 0.80 + \frac{1}{0.4 \times 12} 0.36]$$

$$V_r = -0.018 \text{ fps}$$

VI-1. Safety Factor for Riprap Design

Given a wide channel and a depth of flow $y_o = 20$ ft, $S_o = 0.0001$, mean diameter and specific gravity of the rock 1 ft and 2.65 respectively. Calculate the factor of safety for a trial slope of $\theta = 35°$, if the friction angle $\phi = 40°$. Assume the flow angularity λ negligible.

a) Evaluation of bed shear

$$\tau_o = \gamma\, y_o S_o = 62.4 \times 20 \times 0.0001 =$$

$$\tau_o = 0.1248 \text{ lbs/sq ft}$$

b) From Eq. 6.A1.32

$$\eta = \frac{21\tau_o}{(S_s-1)\lambda D} = \frac{21 \times 0.1248}{(2.65-1)62.4 \times 1} =$$

$$\eta = 0.02545$$

c) From Eq. 6.A1.34

$$\beta = \tan^{-1}\{\frac{\eta \tan\phi}{2 \sin\theta}\}$$

$$\beta = \tan^{-1}\{\frac{0.02545 \times \tan 40°}{2 \times \sin 35°}\}$$

$$\beta = \tan^{-1}(0.01861) \cong 1°$$

$$\sin\beta = \tan\beta = 0.01861$$

d) From Eq. 6.A1.35

$$\eta' = \eta\{\frac{1+\sin\beta}{2}\} = 0.02545(\frac{1+0.01861}{2})$$

$$\eta' = 0.01296$$

e) From Eq. 6.A1.38

$$S_m = \frac{\tan\phi}{\tan\theta} = \frac{\tan 40°}{\tan 35°} = 1.198$$

From Eq. 6.A1.37

$$\xi = S_m\, \eta \sec\theta = 1.198 \times 0.02545 \times 1.22$$

$$\xi = 0.0372$$

f) From Eq. 6.A1.36

$$S.F. = \frac{S_m}{2}(\sqrt{\xi^2+4} - \xi)$$

$$S.F. = 1.17$$

VI-2. Riprap Design

Find the necessary riprap diameter for a safety factor of 1.5, if τ_o = 1 psf, ϕ = 35°, σ = 20°, S_s = 2.60, θ = 20°

Solution

a) From Fig. 6.A5.1

for $\phi = 35°$, $\theta = 20°$,
$\eta = 0.23$

b) From the Shield's criteria

$$D = \frac{21\tau_o}{(S_s-1)\gamma\eta} = \frac{21 \times 1}{1.60 \times 62.4 \times 0.23}$$

$$D = 0.91 \cong 1 \text{ ft}$$

VI-3. Local Scour around Embankments

Given a discharge of 50 cfs/ft and a depth of flow of 10 ft upstream, calculate the equilibrium depth of scour if the embankment length is 100 ft.

Solution

a) Upstream Froude number

$$Fr_1 = \frac{V_1}{\sqrt{gy_1}}$$

$$V_1 = \frac{q_1}{y_1} = \frac{50}{10} = 5 \text{ cfs}$$

$$Fr_1 = \frac{5}{\sqrt{32.2 \times 10}} = 0.278$$

b) Using Eq. 6.5.6

$$y_s = 1.1\, y_1 \left(\frac{a}{y_1}\right)^{0.40} Fr_1^{\ 0.33}$$

$$y_s = 1.1 \times 10 \times 2.51 \times 0.655 = 18.0 \text{ ft}$$

VI-4. Local Scour around Piers

Calculate the equilibrium local scour at a bridge pier with $a = 3$ ft. Use the same flow conditions as in Problem 6.B.3.

Solution

a) Upstream Froude number

$$Fr_1 = 0.278$$

b) Using Eq. 6.5.10

$$y_s = 2.2\ y_1 \left(\frac{a}{y_1}\right)^{0.65} (Fr_1)^{0.43}$$

$$y_s = 2.2 \times 10 \times (0.3)^{0.65} (0.278)^{0.43}$$

$$y_s = 5.8 \text{ ft}$$

VIII-1. Compute Depth of Flow for Data in Example 1 in Chapter VIII.
$q = 132$ cfs/ft, $n = 0.030$
$S = 0.00138$

Solution

a) $$V = \frac{1.486}{n} y^{2/3} S^{1/2}$$

$$q = \frac{1.486}{n} y^{5/3} S^{1/2}$$

$$y = \left(\frac{qn}{1.486\ S^{1/2}}\right)^{3/5}$$

$$y = \left(\frac{132 \times 0.035}{1.486 \times 0.037}\right)^{3/5} = 14.3 \text{ ft}$$

VIII-2. Riprap Design

Calculate riprap size for a 2.5 to 1 slope, using the same flow conditions in Problem VIII-1.

Solution

a) Slope 2.5:1
$\theta = 22°$

From Problem 1, $\theta = 37°$
$\tau_o = 1.0$ psf
$S_s = 2.50$

b) $$S_m = \frac{\tan\phi}{\tan\theta} = \frac{\tan 37°}{\tan 22°} = \frac{0.75}{0.40} = 1.875$$

S.F. = 1.5

$$\eta = \frac{S_m^{\ 2} - (S.F.)^2}{(S.F.)\ S_m^{\ 2}} \cos\theta$$

$$\eta = \frac{3.51 - 2.25}{(1.5)(3.51)} (0.927)$$

$$\eta = 0.222$$

c) $$D = \frac{21\tau_o}{(S_s - 1)\gamma\eta} = \frac{21 \times 1}{(1.50)62.4 \times 0.222}$$

$$D = 1.0 \text{ ft}$$