civil engineering

An Evaluation Of Computer Models To Predict The Erosion And Deposition Of Sediment For Selected Streams In Arizona

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21 April 1982

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CR- 82108

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1.0 Identification

1.1 "An Evaluation of Computer Models To Predict The Erosion And Deposition Of Sediment For Selected Streams In Arizona" is a proposal submitted to the Arizona Department of Transportation by Professor Paul F. Ruff, Department of Civil Engineering, Arizona State University.

2.0 Problem Statement

2.1 The rapid and extensive urbanization in Maricopa and Pima Counties, Arizona has magnified many problems that, in the past, have been considered as merely annoyances. These problems are related to the flow of water in its natural channels and the accompanying phonomena of sediment transport. This phenomena includes erosion and deposition of sand, gravel and boulders along the channel bed and banks.

2.2 Engineers and developers should have a thorough knowledge of the river system that includes not only the volume of water it will carry, but the movement of sediments and the stability of the channel. This knowledge should include the stream in its natural mode and, where developements are planned, in its disturbed condition. Developments in a river system may have great repercussions caused by sediment transport, upstream and downstream of the disturbance.

2.3 Bridge failure may result from the shifting of a stream channel and scour of the abutments and around the piers. Culvert failure may be caused by deposition of sediment downstream or immediately upstream from the structure.

Sediment deposition can be instrumental in raising the water level in a stream that results in over-bank flooding.

2.4 The sediment transport phenomena is obviously of great economic importance.

3.0 Objective of the Research

3.1 The objective of this study is to evaluate the ability of computer models to satisfactorily predict the erosion and deposition in two of the river channels of Arizona.

4.0 Back ground of the Proposed Research

4.1 A sediment transport computer model consists of several modules. The most complex of these subroutines is the calculation of the sediment transport quantity and the water surface profiles.

4.2 There exists a large number of these formulas which attempt to calculate the volumetric flowrate of sediment in alluvial streams. Some of these formulas have been obtained from entirely theoretical considerations, while others were derived by the observation of stream and canal flows, and by the direct measurement of the sediment discharge. It is generally acknowledged that there are a minimum of 17 basic variables (10 independent, 7 dependent) and 7 interdependecies that must be considered in any rational sediment discharge formula that attempts to express a relationship between this multiplicity of variables. Most of the relationships are a mix of theory, observation and measurement. The formulas should only be used

for the conditions for which they were derived, for example, for very course gravel sediment, flat slope of stream bed, etc. because of the partial empherical origin of the relationships.

4.3 The calculation of water surface profiles, velocities, and so forth, is usually achieved by utilization of the U.S. Army Hydrologic Engineering Center Computer model HEC-2, "Water Surface Profiles".

4.4 The calculation of sediment transport quantities and water surface profiles was a long, difficult and tedious process until computer programs were written for their solution. Computer usage does not make these solutions more accurate, but it does make the computer output more readily available to the engineer for analysis.

4.5 The Hydrologic Engineering Center (HEC), U.S. Corps of Army Engineers, and Simons & Li & Assoc., Inc., have developed computer programs for sediment discharge analyses. The programs are designed to analyze the scour and deposition of sediments by mathematically modeling the interaction between the water-sediment mixture, sediment material composition of the stream's bed and banks, and the flow hydraulics. Both programs allow the use of any of the sediment discharge formulas to calculate the average depth of scour or sediment deposition in cross sectional areas, water surface elevations and depth of flow, velocity distributions and coefficients of kinetic energy, and so forth. HEC-6, "Scour And Deposition In Rivers And Reservoirs", and the Simons & Li program,

"Quasi-Dynamic Sediment Routing Model", are one dimensional steady flow models in which the sediment discharge formula and HEC-2 comprise the most significant and major components of the programs.

4.6 A large number of formulas have been derived for the calculation of sediment discharge. However, none of them are completely satisfactory and it is usually not possible to determine which formula gives the best or most accurate answer. The role of the computer model is to provide information, but which must be subjected to practical test before being accepted as valid information. There is no substitute for these tests.

4.7 There are no reports of computer sediment transport model verification testing in the literature. The ASCE Division journals, for example, contain no information on this subject. A major reason for this void in the literature is that very little data has been obtained in the field that is appropriate for sediment transport analysis.

5.0 Benefits

5.1 The potential information derived from sediment transport computer models would be too expensive to obtain in any other manner. For example, the Salt River from Granite Reef Dam to its confluence with the Gila River could be modelled physically, but such an approach to predicting the erosion and deposition in the river would cost ten-fold or more the

expense of the computer model analysis. However, it must be recognized that in some stream reaches the dual analysis of the sediment transport activity by computer and physical modelling may be desirable or even required.

5.2 Accurate analysis of the movement of stream sediment would allow design engineers to confidently anticipate the reaction of a stream channel to a large flow or sequence of flows, and to constructed facilities within its banks.

5.3 Consulting engineers in Arizona have used computer sediment transport models with little confidence and no success. The evaluation of the ability of computer models to satisfactorily predict the erosion and deposition in stream channels is of major signficance to the engineering profession.

6.0 Implementation

6.1 The proposed research will provide immediate implementable results. Engineers will have at their disposal a calibrated computer model and the predicted accuracy of the computer output for the reaches of the rivers studied.

6.2. The program documentation will be completely detailed to facilitate transfer of the research results to the Department of Transportation personnel.

6.3 Seminars will be scheduled in October, March and July, to acquaint the Department of Transportation personnel with the research objectives, problem formulation and research results. It is possible that the anticipated direction of the research tasks may change because of the seminar discussions.

6.4 The results of the research will be submitted to the Hydraulics Division or the Water Resources Planning and Management Division journal, American Society of Civil Engineers for publication.

7.0 Work Plan

7.1 HEC-6 and the Simons & Li models will be evaluated to determine their ability to accurately predict the erosion and deposition in river channels.

7.2 The Aqua Fria and the Salt River have been determined to lend themselves to the objective of this research. For each of the streams, two topographic maps will be obtained of a specified reach or study site. The time interval between when the two maps were made and, therefore, between the topography depicted on the maps, will be at least one major flow of water. Hydrographs of this intervening period will be obtained for each study site. Sediment samples will be collected from the banks and the dry stream beds of the sites to be analyzed for their physical properties and particle size distribution. For each stream study, cross sections from the earlier of the two topographic maps, stream flow hydrographs, sediment field data and one of the sediment discharge formulas will be used for each computer run.

7.3 The stream's floodplain will be divided into 3 longitudinal strips: left overbank, main channel and right overbank. The average distribution of sediment load in each study reach

cross section will be calculated using each of the two computer models. The hydrograph for each stream flow occuring over the study period will be divided into a number of segments, and the sediment load at each cross section will be calculated for the interval of each hydrograph time segment. During the hydrograph intervals, because the stream's friction factor is a function of the discharge, the effects of a range of f-values will be evaluated. Existing photographs may be of some help in determining appropriate friction factors. The effect of a variable sediment load being transported into the study reach, and water temperature change will be evaluated. Sensitivity studies will also be made of the physical properties and particle size distribution of the material composing the banks and bed of the streams in this study. Numerous sediment discharge formulas will be systematically used with each of the two computer models to determine their applicability.

7.4 Summary

a. Divided each study reach into sections transverse to the flow, i.e., cross sections.

b. Partition each study reach into longitudinal strips.

c. Divide each stream flow hydrograph into a number of time, or constant discharge, intervals.

d. Select a sediment discharge formula.

e. Select f-values for the main channel and overbanks.

f. Select an appropriate water temperature.

g. Derive a relationship, using HEC-2, "Water Surface Profiles" procedures, between stream discharge and water surface elevation downstream of the study site.

h. Determine the quantity of bed load and suspended sediment load coming into the study site for each inflowing water discharge. The particle size and size distribution of the incoming sediment will be identical to the composition of the bed and banks of the study reach.

i. Analyze the computer output.

j. These specific items in the research will be systematically changed, generally one at a time, and the procedure repeated. The items to be changed, the number and their magnitude, will be determined from an analysis of the previous computer output(s).

7.5

The output of each computer run, namely, the average distribution of the sediment load across each cross section of the study reach, will be compared with the second topographic map. Topograph maps will be made of selected computer output data. This comparison of the computer model results and the surveyed river site topography will allow the most accurate evaluation of the HEC-6 and Simons & Li programs possible. A discussion will be presented for each run. Efforts will be made to improve the accuracy of the HEC-6 and Simons & Li models.

7.6 Level of Effort by Tasks. See page 9.

LEVEL OF EFFORT BY TASKS (MAN-HRS & COSTS)

Members of study team	Role in Study	Time (%) over contract Period	MAN-HRS TASK NO. 1	2	3	4	5	6	7	8	9	Total	Hourly Rate ($)	Cost ($)
Prof. Ruff	Principal Investigator	11.4	4	1	1	4	1	10	1	10	316	348	23.92	8,325
---	Research Assistant	63.2	348	174	87	87	-	435	174	261	174	1740	5.27	8,667
---	Lab. Aid	25.4	-	57	57	115	144	-	57	115	29	574	4.00	2,297
Totals			352	232	145	206	145	445	232	386	519	2662		19,289

one man-month = 174 man-hours.

8.0 Qualifications of Research Team

8.1 The principal investigator has been associated with the academic and design aspects of water engineering phenomena and facilities for over twenty years. In the area of the proposed research.

a. Academic experience. Course and laboratory work, and research under the direction of H.A. Einstein, University of California at Berkeley. Taught course and laboratory classes at several universities. See Appendix.

b. Field Experience. Hydraulic Engineer, Tennessee Valley Authority. Expert witness in numerous river engineering litigation cases in the state and federal courts. Several studies have been made for Arizona State University of the Salt River at Tempe, Arizona. See Appendix.

9.0 Facilities Available

9.1 The most recent update of HEC-6 and the Simons & Li programs are on file in the Arizona State University Computer Center. Also on file in the Center is the "Sediment Transport Computer Package" developed by Simons, Li & Associates, Inc. that contians the following sediment discharge functions: Einstein's Bed Load Function, Yang, Modified Einstein Procedure, Colby, Shen and Hung, Tofaletti, and Meyer-Peter Muller. Other functions that may be considered in this study are: Schoklitsch, Duboys, Shields, Meyer-Peter, and Laursen.

9.2 Topographic maps are available for 1964 and 1979 of the Aqua Fria River from Bell Rd. to Jomax Rd; and for the Salt River, 35th Ave to 57th Ave, maps are available for 1965 and 1979. Numerous topographic maps are also available of the Salt River in the vicinity of the Phoenix International Airport.

9.3 All computer facilities required for this study are available in the University Computer Center.

10.0 Work Time Schedule

```
                    1982                                  1983

                 July Aug Sept Oct Nov Dec      Jan Feb Mar Apr May Jun July

                 |----|---|----|---|---|---|    |---|---|---|---|---|---|----|

1. Program
   HEC-6,
   Simons
   & Li
   and Q's      ____________________
   functions
   for ASU
   computers

2. Locate
   x-sections
   & card                  ___________
   punch
   coordinates

3. Card
   punch                   --------
   hydrologic
   data

4. Collect
   field                   --------
   sediment
   samples

5. Analyze
   sediment                   ---------
   samples

6. Problem
   formulation  ____________________________

7. Computer
   runs                                 ____________________________

8. Data
   analysis                                   ____________________

9. Report                                                   ---------------
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11.0 Manpower And Budget Estimate

July 1982 - July 1983

I.	PERSONNEL:		
	A. Salaries and Wages		
	1. Principal Investigator - P.E. Ruff full-time, two months summer	$8,325	
	2. Graduate Research Assistant 1/2 time - 9 months full-time, 2 months summer	8,667	
	3. Laboratory Aids - Students 574 hours @ $4.00	2,297	
	4. Secretarial Assistance	200	
	TOTAL S & W	$19,489	
	B. Fringe Benefits	2,071	
	TOTAL PERSONNEL		$21,560
II.	OPERATIONS:		
	A. Computer Time	2,000	
	B. Purchase of Computer Programs	400	
	C. Supplies & Materials Publications	250	
	TOTAL OPERATIONS		2,650
III.	TRAVEL:		1,493
	Trip to C.S.U. Sedimentation Conference Conference in California on HEC		
IV.	TOTAL DIRECT COSTS		$25,703
V.	INDIRECT COSTS @ 24.5% of TDC		6,297
VI.	TOTAL PROJECT COSTS		$32,000

12.0 Progress Reporting Procedures

12.1 Monthly progress reports will be submitted the first week of each month. The reports will discuss each of the topics listed under item 10.0, Work Time Schedule, and will include an updated bar graph.

12.2 Quarterly reports will specify the research items completed and underway, expected problems and techniques selected to solve them, cost of research program to date. An update of the monthly progress bargraph will be included.

13.0 Appendix

ARIZONA STATE UNIVERSITY

Paul F. Ruff
Professor of Engineering

Degrees:

MS	Case Western Reserve University, 1953
BS	Case Western Reserve University, 1947

Academic Experience:

1974-	Arizona State University, Professor
1964-65	Massachusetts Institute of Technology, NSF Fellow
1959-74	Arizona State University, Associate Professor
1958-59	Arizona State University, Assistant Professor
1956-58	University of California, Associate in Engineering
1953-56	Washington State University, Assistant Professor

Industrial Experience:

1956-58	University of California, Hydraulic Research Engineer
1953-56	Washington State University, Assistant Hydraulic Engineer
1949-53	Havens & Emerson, Assistant Design Engineer
1947-48	Tennessee Valley Authority, Hydraulic Engineer

Consulting Experience:

Hydrology, Hydraulic Engineering, Hydraulic Model Studies, Water Resources Systems, Flood Control.
Water Resources Planning and Management Journal (ASCE), Editor, 1979-80.

Awards, Scholarships and Honor Societies:

Tau Beta Pi
Chi Epsilon
Sigma Xi
National Science Foundation Faculty Fellow

Membership in Scientific and Professional Societies:

American Society of Civil Engineers
American Society for Engineering Education
Registered Professional Civil Engineer
Registered Professional Land Surveyor

Principal Areas of Research or Teaching Interest:

Fluid Mechanics, Hydraulic Engineering, Sediment Transport, Hydrualic Model Studies, Water Resources Systems Planning and Design.

Principal Publications (1955-1976):

"An Investigation of Physical Barriers to Increase Highway Visibility During Dust Storms," Center for Environmental Studies, Arizona State University, Tempe, Arizona, 1976.
"Hydrodynamics Laboratory Manual," Civil Engineering, College of Engineering Sciences, Arizona State University, Tempe, Arizona, 1973.
"Water Resources Systems - A Lecture Series," - (editor), Arizona State University, Tempe, Arizona, 1971.
"A History of the Salt River Channel in the Vicinity of Tempe, Arizona 1868-1969," Arizona State University, Tempe, Arizona, 1971.
"Water Resources Systems," - (editor), Arizona State University, Tempe, Arizona, 1970.
"A Fixed-Bed Hydrualic Model Study of the Salt River - Tempe, Arizona," Arizona State University, Tempe, Arizona, 1970.
"A Model Study of Hydraulic Outlet Structures for Dams," Salt River Project, Phoenix, Arizona, 1969.
"A Preliminary Investigation of the Flows Producing Vibrations in Hydraulic Outlet Structures," Salt River Project, Phoenix, Arizona, 1964.
"An Integrated Program of Investigations of Monomolecular Layers on a Wave-Disturbed Surface," U.S. Bureau of Reclamation, 1964.
"An Investigation to Determine the Effectiveness of a Chemical Additive for Reducing Seepage in an Irrigation Canal--The Indian Bend Pump Lateral," U.S. Bureau of Reclamation, Boulder City, Nevada, 1962.
"An Investigation to Determine the Effectiveness of a Chemical Additive for Reducing Seepage in the South Canal: A Summary," U.S. Bureau of Reclamation, Boulder City, Nevada, 1961.
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"Model Studies of Spillways," Institute of Engineering Research, University of California, 1958.
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U.S. Army Corps of Engineers, Hydrologic Engineering Center," HEC-2 Water Surface Profiles," Users Manual, 1976, Davis, Calif.

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U.S. Army Engineers, Hydrologic Engineering Center, "Sediment Transport," Volume 12, 1977, Davis, Calif.

U.S. Bureau of Reclamation, "Design of Small Dams," 1960, Denver, Colo.

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U.S. Department of Transportation, "Highways In The River Environment, Hydraulic And Environmental Design Consideration," Training and Design Manual, 1975, Wash., D.C.

U.S. Geological Survey, Computation of Fluvial-Sediment Discharge," Book 3, chapter C3, 1972, Wash., D.C.

U.S. Geological Survey, "Laboratory Theory And Methods of Sediment Analysis," Book 5, Chapter 1, 1969, Wash., D.C.

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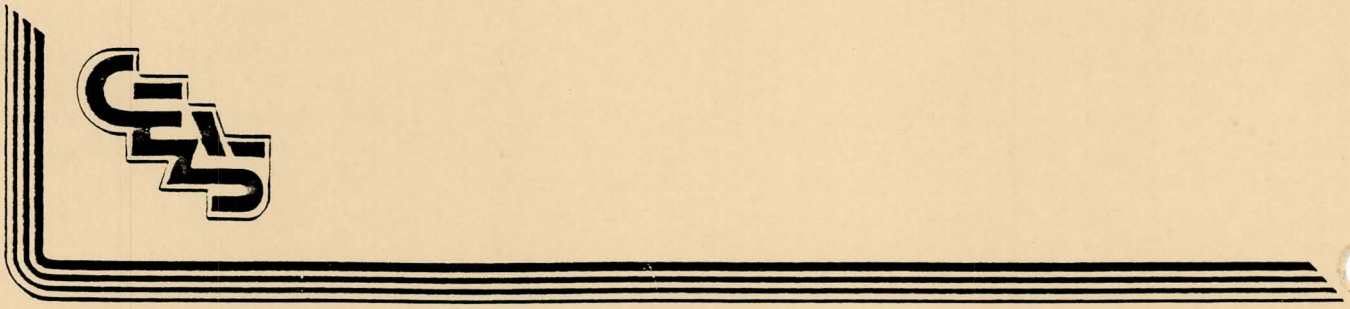
Personal Communication with Thomas, W.A., U.S. Corps of Engineers, Waterways Expt. Station, Vicksburg, Miss.