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RESEARCH PROBLEM STATEMENTS IN HYDROLOGY, HYDRAULICS AND WATER QUALITY

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INTRODUCTION

This circular contains thirty-six research problem statements developed by the Committee on Hydrology, Hydraulics and Water Quality. The statements were screened by subcommittees and the ordering of statements by subject represents the best concensus of priority research needs in that subject.

RESEARCH PROBLEM STATEMENTS

PRIORITY STATEMENTS BY SUBJECT

HYDROLOGY

HYDRAULICS

WATER QUALITY

HYDROLOGY

PROBLEM NO. 1

I. NAME OF PROBLEM - ESTIMATION OF EFFECTS OF IN-CHANNEL STORAGE ON FLOOD HYDROGRAPHS AND URBAN DRAINAGES

II. THE PROBLEM - Knowledge of the magnitude and frequency of storm runoff from urban streams is required for safe and economic design of highway drainage structures. Urban drainage systems are so complex that flood routing is often needed to generate the necessary flood hydrographs (peaks, volumes and duration of flooding) for design purposes. However, considerable resources such as manpower, time, expertise and computers are required to route flows and account for storage conditions that usually exist in urban watersheds. An expedient method of generating flood hydrographs is needed which can account for the temporary in-channel storage resulting from highway embankments and detention structures. Previous research by Harley and the U.S. Geological Survey (in the "Interim Analysis of Urban Flood Data") has developed methods of estimating flood peaks, flood volumes, flood hydrographs and basin lagtime for urban watersheds which do not exhibit significant temporary in-channel storage. This research needs to be extended to watersheds with significant storage and simplified methods of quantifying this temporary in-channel storage need to be developed.

III. OBJECTIVES - Provide a simplified and widely applicable technique for reliable estimation of flood hydrographs, flood peaks and flood volumes for urban streams which have significant temporary in-channel storage. The "Interim Analysis of Urban Flood Data" conducted by the Federal Highway Administration (FHWA) and the U.S. Geological Survey (USGS) identified approximately 70 watersheds with significant temporary in-channel storage and these data could form the basis for a more comprehensive data base for defining the estimation technique. Develop equations relating hydrograph parameters (e.g., lagtime, time to peak, peak discharge) to watershed, climatic and urban drainage characteristics. These equations will be used in conjunction with a dimensionless unit hydrograph to estimate flood hydrographs for ungaged urban watersheds with significant temporary in-channel storage. Develop a simplified technique for estimating the duration of flooding above a specified discharge.

IV. CURRENT ACTIVITIES

A. Related research activities: A recently completed project of FHWA and USGS demonstrated that a dimensionless unit hydrograph can be used to estimate flood hydrographs for ungaged urban watersheds. This approach used the Clark Method of linear storage routing and regression equations for estimating peak discharge and basin lagtime. These regression equations were only applicable to urban watersheds without significant in-channel storage. The FHWA Office of Engineering has developed some ideas for modifying the Soil Conservation Service unit hydrograph concept for urban highway drainage applications.

FHWA sponsored a study at Utah State University in 1976 on urban storm runoff inlet hydrographs for typical highway right-of-way sections. That study resulted in a relatively complex computer model to compute hydrographs, but it was not pursued to the next step of using the model to generate simplified design parameters. That study, however, was limited to runoff from the highway right-of-way.

B. Suggested key words for this problem: design floods, urban watersheds, frequency analysis, flood hydrographs, flood volumes, detention storage, storm drainage.

V. URGENCY - Designs of culverts, bridges and other drainage facilities will be improved significantly through more realistic and more easily coordinated design criteria. Significant economic benefits will accrue to both highway and non-highway users.

PROBLEM NO. 2

I. NAME OF PROBLEM - MIXED POPULATION FLOOD-FREQUENCY ANALYSIS

II. THE PROBLEM - Knowledge of the magnitude and frequency of floods is required for safe and economic design of highway drainage structures. General guidelines for estimating magnitude and frequency of future flooding from gaging records have been provided by the Water Resources Council. Existing guidelines only weakly cover the analyses applicable for sites where flooding results from two or more distinct causes such as snowmelt, thunderstorms, hurricanes and cyclonic storms. Highway drainage designers need additional guidance and/or better techniques for estimating magnitude and frequency of floods in areas where multiple flood causes are experienced.

III. OBJECTIVES - Develop more detailed and/or alternate guidelines for estimating magnitude and frequency of flooding in mixed population areas. Develop procedures for discrimination of regions significantly impacted by mixed population phenomena.

IV. CURRENT ACTIVITIES

A. Related research activities: In a pilot study the U.S. Geological Survey has identified gaging stations in Colorado, Montana and Idaho where mixed population flooding occurs. Recent regional flood-frequency reports in Montana and Idaho were based on gaging station data for combined rainfall-snowmelt frequency curves. The U.S. Corps of Engineers has used the concept of mixed population frequency curves in the North Atlantic States and the Pacific Northwest.

Some aspects of problems 6 and 8 may pertain to this problem as well.

B. Suggested key words for this problem: floods, design floods, frequency analysis.

V. URGENCY - More reliable estimates of design floods should provide more effective and safe designs of bridges and culverts with substantial economic benefits to non-highway as well as highway users.

PROBLEM NO. 3

I. NAME OF PROBLEM - THE ECONOMICS OF FLOOD DATA COLLECTION AND CULVERT DESIGN

II. THE PROBLEM - Most culverts must be located on streams where flood data are nonexistent. The design flood must be estimated on the basis of data from other gaged streams in the vicinity by using best available hydrologic models as the information transfer mechanism. If the procedure used for the hydrologic design is economically valid, as more data are collected in the area, the new or replaced culverts in that area will be better designed. However, the procedure for specifying an optimum program of flood data for the design of culverts does not currently exist.

III. OBJECTIVES - Develop techniques for estimating the regional requirements for flood data to be used in designing highway culverts.

IV. CURRENT ACTIVITIES

A. Related research activities: Several studies have addressed this problem in the past, but useful conclusions have yet to be reached.

B. Suggested key words for this problem: culvert design, flood-frequency analysis, data collection networks.

V. URGENCY - The collection of flood data requires time, and this study is a prerequisite to the initiation of optimum data programs. Thus, delays in initiating this study perpetuate the current paucity of understanding concerning the sizing of highway culverts.

PROBLEM NO. 4

I. NAME OF PROBLEM - IMPROVING FLOOD-FREQUENCY ESTIMATES WITH PALEOFLOOD ("ANCIENT FLOOD") TECHNOLOGY

II. THE PROBLEM - Considerable resources have been focused on developing accurate methods to estimate flood-frequency relationships from stream gage records. The small watershed studies undertaken by most states in cooperation with the U.S. Geological Survey are one of the major sources of data and information. The accuracy of flood-frequency predicting methods based on stream gage data is largely a function of the record length. Stream gage data of short duration can be influenced by climate and physiographic factors, some, as yet, unknown or little understood. Whereas, there are some continuous stream gage data for periods in excess of 50 years; most are relatively short term, 25 years and often much less. Simple and cost-effective methods appear to be available for extending in time the length of existing stream gage records; applied research is needed to verify or improve these methods.

Although not entirely new, paleoflood technology is emerging as a previously untapped resource for extending stream gage records in time. Paleoflood technology can include, either separately or in combination, analyses such as channel and flood plain morphology, measurement and interpretation of historic channel changes, carbon dating of flood remnants and alluvial stratigraphy, analysis of lichen growth and tree rings and other similar botanical changes. In application paleoflood technology moderates the influence of those high outiers that distort the higher recurrence interval range of the station record.

III. OBJECTIVES

A. To extend the existing stream gage records in time by establishing the approximate time and magnitude of paleofloods located in gaged watersheds.

B. To estimate the magnitude and recurrence interval of catastrophic floods.

C. To shed some light on the historical climate and physiographic changes that influence stream gage records, annual peak floods in particular.

IV. CURRENT ACTIVITIES

A. Related research activities: Research is currently being conducted by the U.S. Geological Survey (USGS) in the use of botanical analysis to quantify early flood evidence. Also, geomorphic evidence is being used by the USGS and others to extend knowledge of flood frequency.

Some aspects of problems 2 and 6 may pertain to this problem as well.

B. Suggested key words for this problem: paleoflood, botanical evidence, flood-frequency analysis.

V. URGENCY - An accurate flood-frequency relationship is the basic element in most transportation drainage design. Much of the basic research to implement paleoflood technology apparently has been completed. In addition, unlike many hydrology studies, paleoflood hydrology is not dependent upon the future occurrence of events but rather upon past events. Because the data already exist they can be collected and analyzed for a particular state in a year or two for relatively little cost. This technology provides an excellent potential to improve the accuracy of existing flood-frequency estimating methods that are derived from stream gage records by moderating the costly impact of high outliers on station records. With the rapidly escalating cost of construction paleoflood technology promises to provide an immediate return by significantly moderating rising construction costs.

PROBLEM NO. 5

I. NAME OF PROBLEM - CRITERIA FOR THE ANALYSIS OF UNUSUAL EVENTS IN ANNUAL FLOOD PEAK SERIES

II. THE PROBLEM - Highway bridges and culverts are designed to pass a flood event of a magnitude that is expected to be exceeded about once in a specified number of years. Statistical probability analysis of annual flood observations commonly is used to establish a relation between flood magnitude and frequency for gaged sites. Techniques have been developed for estimating flood magnitude-frequency relations at ungaged sites where bridge and culvert design criteria are needed, but these estimating techniques usually are based upon transfer of frequency relations defined for gaged sites. Flood-frequency relations for gaged sites therefore are basic elements of highway drainage structure design.

The reliability of any flood magnitude-frequency relation, whether defined by a log-Pearson Type III probability analysis as recommended by the Water Resources Council or by some other probability analysis, is dependent upon the observed flood record being a representative sample of the floods that can be expected to occur over a very long time period. Records of observed floods are generally of a short duration, yet some contain an observation of one or more very unusual floods. These unusual floods, sometimes called "outliers," may seriously influence the definition of a flood-frequency relation.

III. OBJECTIVES

A. To develop procedures for recognizing those unusual events in a flood record that adversely affect the definition of a flood magnitude-frequency relation.

B. To propose guidelines for defining a flood-frequency relation from a gaging record that contains one or more unusual event.

IV. CURRENT ACTIVITIES

A. Related research activities: Research sponsored by the Water Resources Council Hydrology Committee at the Center for Research in Water Resources, University of Texas at Austin. Some aspects of problems 2 and 8 may pertain to this problem as well.

B. Suggested key words for this problem: outliers, unusual floods, flood-frequency analysis.

V. URGENCY - Flood-frequency relations are a basic element of highway drainage structure design. The success of a design is dependent upon accurate frequency information. The proposed study would lead to improved accuracy of frequency definition and more uniform practices in the hydrologic analysis for design sites.

PROBLEM NO. 6

I. NAME OF PROBLEM - FLOOD-FREQUENCY CHARACTERISTICS FROM CHANNEL PROPERTIES

II. THE PROBLEM - The hydraulic design of highway stream crossings requires estimates of the flood-frequency characteristics of the streams. Traditional methods of making these estimates include use of rainfall records and basin characteristics. These traditional methods produce estimates inadequate for economical crossing design in arid and semi-arid regions and in regions where precipitation and watershed properties are highly variable in space. A different method is needed, one that will produce better estimates in problem regions and independent estimates in others, including urban streams.

III. OBJECTIVES

A. Develop a set of relations for estimating flood-frequency characteristics from channel geometry measurements that will provide consistent results over broad geographic areas of the United States. Estimate the reliability of the results.

B. Improve the understanding of channel morphology and its relation to flow regime in order to develop better estimating relations.

IV. CURRENT ACTIVITIES

A. Related research activities: The U.S. Geological Survey (USGS) has investigated the relationships of flood characteristics to channel width for all or parts of several western states, for Kansas and for part of the Missouri River basin. In the east, a study has been completed in Ohio. The USGS has also published research reports on channel morphology. Some relations of flood characteristics to channel width have been published by Canadians.

B. Suggested key words for this problem: hydrology, hydrography, channel geometry, flood frequency.

V. URGENCY - More reliable estimates of flood-frequency characteristics at highway crossings would result in more efficient design of culverts and bridges. The savings to the nation should be substantial. These improved estimates cannot be made until the analyses and data collection described in this statement are made.

PROBLEM NO. 7

I. NAME OF PROBLEM - HYDROLOGY OF VERY FLAT TERRAIN

II. THE PROBLEM - Some parts of the United States, especially southern Florida and southern Louisiana, have extremely flat topography that complicates hydrologic predictions and presents unique problems with hydraulic design of bridges and culverts. This terrain is characterized by indefinite watershed divides and watershed areas that vary with distribution and intensity of rainfall. Often there is extensive pumping and cross channel flow from one watershed to another. Discharge and sometimes even the direction of flow are unknown at highway crossings.

Hydraulic design of bridge approach roads is more often dictated by elevation

above the water table to avoid subbase saturation than hydrologic considerations. Hydraulic design of culverts and bridge openings and channels and ditches is technically very uncertain.

III. OBJECTIVES - Determine what studies have been conducted and what information is available. Identify alternate methods of estimating discharge, e.g., the applicability of channel geometry techniques. Determine the researchability of the problem and identify reasonable goals of a gaging program. Determine the flood regulation patterns used to operate pump stations in these areas.

IV. CURRENT ACTIVITIES

A. Related research activities: No research is known to be underway on this specific topic although Louisiana is attempting to set up a special gaging program.

B. Suggested key words for this problem: hydrology, flat terrain hydrology, culvert design, bridge design, flood control.

V. URGENCY - Results of this study could lead to a more economical design of bridges and culverts.

PROBLEM NO. 8

I. NAME OF PROBLEM - TEST OF FLOOD-FREQUENCY PREDICTIONS FOR BRIDGE AND CULVERT DESIGN

II. THE PROBLEM - Highway drainage structures are designed for runoff events calculated to recur on the average of once in a certain number of years. As a basis for design, recurrence intervals of 10, 25 and 50 or more years are assigned depending upon the relative importance of the highway and the degree of risk that can be accepted. In order to determine the design capacity needed for a structure for a given recurrence interval, the engineer must usually resort to some information transfer mechanism since observed flood data are usually nonexistent for the site of interest.

Information transfer techniques consist of regional regression equations relating peak discharge to climatic and/or watershed characteristics, rainfall runoff models based on design or historical rainfall values, or simply the transfer of a flood-frequency curve from a nearby gaging station to the ungaged site. These various information transfer techniques can give quite different design discharges. With the exception of the rainfall runoff model based on a design rainfall event these techniques are based on flood-frequency analysis of observed peak discharges at gaging stations. Flood-frequency analysis is a mathematical procedure for estimating the probability of future floods on the basis of past flood events. The solution is obtained by fitting the observed peak discharges to a theoretical probability distribution.

The Water Resources Council (WRC) Hydrology Committee recently completed a pilot test comparing the performance of 10 frequently used transfer techniques for estimating peak discharges for ungaged watersheds. This test indicated that the regression based transfer techniques tended to be more unbiased, more reproducible and easier to apply. The test further indicated that the variability among the various transfer techniques was much greater than the variability resulting from the use of different theoretical probability distributions for the gaging station data. The various transfer techniques were tested at 70 gaging stations in the northwest and midwest regions of the United States. These results cannot be easily generalized to other parts of the country. A nationwide test comparing the selected transfer techniques is needed, particularly as applied to small watersheds (less than 100 square miles) where most of the flood-frequency predictions for bridge and culvert design are needed. The error introduced into the information transfer technique because of the assumed probability distribution for the gaging station data should also be investigated.

In the aggregate the states in cooperation with the U.S. Geological Survey have spent about $25 million accumulating flood information on about 2,000 small watersheds. These data will form the basis for comparison of the selected transfer techniques. The WRC pilot test will provide the basis for the experimental design for objectively comparing the various transfer techniques. This nationwide test will indicate which portions of all states are best served by a particular flood-frequency technique.

III. OBJECTIVES

A. To select for comparison those techniques commonly accepted by professional hydrologists and any new promising techniques.

B. To use the maximum of gaged watersheds smaller than 100 square miles for a national comparison of analysis techniques.

C. To recommend the preferred technique region by region, giving consideration to watershed size, physiographic provinces, climatic differences and other factors controlling hydrologic homogeneity.

D. To prepare regional maps of any statistical parameters needed to apply a preferred technique.

E. To utilize the experimental design and criteria for comparison developed in the WRC pilot test for evaluating the selected transfer techniques.

IV. CURRENT ACTIVITIES

A. Related research activities: FHWA Contract Research Studies at Utah State University; WRC Committee on Hydrology sponsored research at the Center for Research in Water Resources, University of Texas; WRC pilot test of comparison of transfer techniques documented in a recent (1981) WRC report.

B. Suggested key words for this problem: flood-frequency analysis, recurrence interval.

V. URGENCY - Flood-frequency predictions are basic elements in the design of highway drainage structures. The success or failure of a

design is often dependent on the accuracy of such predictions. Engineers have frequently been misled into underdesign or applied factors of safety resulting in overdesign. The consequences have been expensive in either case. For the past 10 to 15 years the U.S. Geological Survey in cooperation with many state highway departments has collected runoff data from a large number of small rural watersheds. These data provide a real opportunity for a study and comparison of flood-frequency techniques. The results of such a study would reduce the risk element in the hydraulic design of bridges and culverts and lead to more uniform practice in the prediction of design discharges for such structures.

HYDRAULICS

PROBLEM NO. 1

I. NAME OF PROBLEM - DRAINAGE SURVEY ACCURACY REQUIREMENTS

II. THE PROBLEM - It has been found that considerable savings in cost can be realized in obtaining drainage surveys using photogrammetric practices as opposed to conventional field surveys. There is also a growing need to obtain survey data on floods in progress, often under adverse weather conditions. Field control is a major cost factor in obtaining drainage surveys using aerial photography as is the accuracy required for the survey. Depending on the required accuracy it may be possible to eliminate or limit the amount of ground control using remote sensing practices. Remote sensing practices are also evolving to where satellites may provide valuable drainage survey data in the near future. With satellite sensing the accuracy required for drainage survey data becomes of paramount importance.

Transportation hydraulic engineers have become accustomed to an existing level of survey accuracy. This accuracy has derived largely from the accuracy used in the roadway embankment design. Because of sensitivity of remote sensing and photogrammetry costs to accuracy, there is a need to determine what survey data accuracy or accuracies are required for drainage design.

III. OBJECTIVES - The objectives are:

A. Review drainage design practices to determine what design accuracies are being obtained.

B. Review published rules, regulations, laws, ordinances, policies and similar regulatory requirements to determine what design accuracies are expected.

C. Conduct research to determine what survey accuracies are required in light of the findings in III A and B.

IV. CURRENT ACTIVITIES - No other research in this field of interest has been identified.

V. URGENCY - The photogrammetric and remote sensing potential is expanding at a rapid rate. To influence the photogrammetric and remote sensing development, it is imperative that required drainage survey accuracy be defined immediately.

PROBLEM NO. 2

I. NAME OF PROBLEM - HYDRAULICS OF BRIDGE WATERWAYS

II. THE PROBLEM - Where highways cross waterways water is conveyed through bridges and culverts and, for larger floods, may flow over the embankment. Present procedures for sizing the structures involve estimating the flow for each structure as an isolated unit. The resulting discharges are summed and adjusted to make sure that the total is equal to the assumed design flow. Scour caused by a constriction is computed when the estimated flow is known. Sustained high flows will result in an enlarged section and a possible change in the flow distribution. In all of these computations one-dimensional or empirical approximations are used. In reality flow may be through any or all of several bridges and culverts or over the road simultaneously while the channel may be degrading or aggrading, and often the flow may be more nearly two- or three-dimensional.

Significant lateral velocities and significant lateral variations in stage are observed in wide flood plains characterized by rapid expansions or contractions, highly variable roughness or variable topography. Two-dimensional models can provide information about transverse, as well as longitudinal, water surface profiles; local velocities near bridge approach embankments; and the lateral flow distribution at a proposed bridge site. Application of existing two-dimensional finite-element models which were developed as research, not operational tools, to such bridge crossings (for example, the application of the model RMA-2 developed by Resource Management Associates to the Congaree River) have revealed numerous deficiencies in these models.

III. OBJECTIVES - The objective is to develop improved one- and two-dimensional computational procedures to describe this dynamic interactive process. Field or laboratory research could provide insight into the physics of this problem and data to calibrate and verify models. Computerized models using modern graphics would help to standardize and streamline the design process. Guidelines should be developed for selecting the most appropriate (one- or two-dimensional) design method.

The following components of two-dimensional finite-element models need to be tested in a variety of hypothetical and field situations and compared on the basis of stability, accuracy and economy:

(1) automatic grid renumbering techniques;
(2) element types;
(3) methods of numerical integration;
(4) methods for solving large, sparse, banded matrix equations;
(5) boundary conditions;
(6) roughness coefficients and eddy viscosities.

These components of finite-element models

need to be tested in situations that incorporate the particular difficulties arising in flood plain modeling such as large ground-surface gradients and discontinuities in roughness.

IV. CURRENT ACTIVITIES

A. Related research activities: An FHWA study being conducted by USGS (Shearman and Schneider) includes a task for computerizing multiple opening analysis along with other features of bridge waterways hydraulics. The study will also include updated procedures for handling wide wooded flood plains, road overtopping and constriction scour. An NCHRP study being conducted by Dames and Moore is using existing models like the Corps of Engineers HEC-2 to generate data for regression equations that should suffice for planning needs. The NCHRP study does not consider multiple openings or road overtopping, but it does include constriction scour relations. Additional work that may be needed to meet the above problem statement objectives will be converting programs to an interactive mode and developing graphics enhancements.

B. A current study is underway to develop a two-dimensional finite-element model well suited to the particular problems of modeling river flood plain systems. The study is being conducted for FHWA by the USGS.

C. Suggested key words for this problem: bridge and culvert hydraulics, bridge waterways, scour, finite-element model, bridge site, flood plain model.

V. URGENCY - The results of this study will assist in reducing the size and cost of hydraulic structures by improving the designer's capability to study the alternative drainage schemes. Since attention would be focused on the composite model research needs would be easily identified as the weak lines in the model. Approximately $3 billion is spent nationwide on bridges each year for replacement, rehabilitation or new construction; consequently there is a potential for significant savings in public funds through use of improved design procedures since the majority of the nation's bridges are waterway bridges.

Several current bridge site studies of wide complex flood plains using the two-dimensional model RMA-2 indicated the need for a two-dimensional model that can be applied by the design engineer to analyze proposed crossings. These studies have also revealed deficiencies in currently available models. The proposed research will develop a tool better suited for such modeling efforts.

PROBLEM NO. 3

I. NAME OF PROBLEM - SCOUR AT BRIDGES

II. THE PROBLEM - Considerable effort in manpower and money has been spent on the problem of scour at bridges. The problems have been studied using fluid flow theory, laboratory model studies, field data collection programs, empirical correlation of laboratory and field data and field observations resulting in rules of thumb. Scour and the effects of scour can still not be quantified with any degree of certainty. This uncertainty is costly not only in bridges lost to scour but in those needlessly (but unknowingly) over-designed. The location and design of river training works and countermeasures to protect bridge piers and abutments is an empirical process. Furthermore, laboratory model studies have been conducted using sand bed channels only. As a result knowledge of scour in other soils or in mixed bed materials is lacking.

This research has been beneficial however for much has been learned about scour. For example, local scour depth increases as pier size increases for a given flow; local scour increases with velocity up to a point; and contraction scour depth increases as the width of the constriction decreases. There are four types of scour: local, contraction, lateral channel migration and general scour. These scour types interact even though they have most often been isolated for study. Their net effect is often considered to be additive.

Recent research has focused on the collection of field data to validate the available formulas. However these effects have met with major logistical problems, costly instrumentation packages and difficult data interpretation problems. Much has been learned from these efforts about collecting field scour data but little usable data have been obtained.

Most researchers have recognized the scour mechanisms, that is, the vortex system at piers and abutments and the contracted streamlines in constrictions. Both mechanisms result in shear stresses at the bed sufficient to erode the bed material. The mechanisms have been studied separately (for example, Liu, Bradley and Plate, 1957; Shen, et al., 1969; Schneider, 1968) to simplify the problem, but this previous work is not conclusive. Since flow in the vicinity of the bridge is three-dimensional further investigations making one- or two-dimensional approximations may not be productive.

III. OBJECTIVES

A. Reduce risk and cost in designing new bridges by making available more knowledge about scour.

B. Provide for more efficient countermeasures.

C. Evaluate current design practices to reduce backwater and increase capacity.

The specific objective is to quantify the mechanics of scour in order to learn how the four types of scour interact and how to extrapolate laboratory data to field. This research could be conducted in two ways. Measurements of velocity distribution, bed shear stress, strengths and transport capabilities of the vortex systems and other data as required should be related to constriction ratio, abutment and pier geometries. The measured stresses can then be related to the erodibility of soil other than sand. The shedding characteristics of the vortex systems may be related to the design of riprap as a

countermeasure. Shen and Schneider (1970) found that the horseshoe vortex system at a pier could be contained harmlessly at the pier by attaching a trough-like structure to the pier.

In addition, a mathematical model which considers the three-dimensional nature of the flow through the constriction should be developed. The laboratory data would be valuable in this effort. Because of the complexity of the problem and the potential computer storage requirements, certain cross sections or locations of maximum shear may have to be identified in lieu of a model of the complete flow field.

IV. CURRENT ACTIVITIES

A. References:

1. Liu, H. K., Bradley, J. N., and Plate, E. J., "Backwater Effects of Piers and Abutments," Colorado State University, Civil Engineering Section, Report No CER57HKL10, p. 364, 1957.

2. Schneider, V. R., "Mechanics of Local Scour," Ph.D Dissertation, Colorado State University, Fort Collins, Colorado, 1968.

3. Shen, H. W., Schneider, V. R., and Karaki, S., "Local Scour Around Bridge Piers," American Society Civil Engineers Proc., Journal of Hydraulics Division, V. 95, No. HY6, pp. 1919-1940, 1969.

4. Shen, H. W. and Schneider, V. R., "Effect of Bridge Pier Shape on Local Scour," Preprint Paper No. 1238, Presented to the ASCE National Meeting on Transportation Engineers, Boston, Massachusetts, July 15-17, 1970, p. 10, 1970.

5. Hopkins, G. R., Vance, R. W., and Kasraie, B., "Scour Around Bridge Piers," FHWA Report RD-79-103, February 1980.

6. Chang, F. F. M., "Scour at Bridge Piers - Field Data from Louisiana Files," FHWA Report RD-79-105, January 1970.

7. Jain, S. C. and Fischer, E. E., "Scour Around Circular Bridge Piers at High Froude Numbers," FHWA Report RD-79-104, April 1979.

V. URGENCY - This study of scour would result in quantifying the mechanisms of scour. The resulting mathematical model could be used not only to develop design criteria to predict scour but to devise rational methods to reduce and prevent scour and to increase bridge capacity.

PROBLEM NO. 4

I. NAME OF PROBLEM - IMPLEMENTATION OF IMPROVED TECHNOLOGY FOR HIGHWAY DRAINAGE DESIGN

II. THE PROBLEM - In spite of considerable efforts to identify, disseminate and provide training there has been limited success in implementing new technology in the design of highway drainage structures. It is believed this reluctance is based in part on a natural resistance to change and in part on conceived consequences which may or may not result from the implementation of new technology.

III. OBJECTIVES - The objectives are to fully identify the reasons for delays in implementing completed research and identify corrective measures to overcome the deficiencies in implementation. In general this is anticipated to consist of:

A. Conducting a national in-depth inventory of problems encountered in implementing completed highway drainage research and determine reasons why implementation was not attempted. Identify and evaluate existing systems for implementation.

B. Developing effective methods for improving the implementation of improved highway drainage technology.

IV. CURRENT ACTIVITIES

A. No other research in this field of interest has been identified.

B. Suggested key words for this problem: technology transfer, hydraulics, drainage design, standard, systems, computer.

V. URGENCY - The potential benefits of full utilization of the extensive research completed to date continue to be unrealized. This research effort could be accomplished quickly and at a relatively modest cost, thereby placing it in the immediate need category.

PROBLEM NO. 5

I. NAME OF PROBLEM - EFFECTS OF INSTREAM MINING ON CHANNEL STABILITY

II. THE PROBLEM - Instream mining activities frequently cause unstable channel conditions and related damage to highway embankments and bridges. The analysis of hydraulic, geologic and water quality factors associated with instream mining and resultant channel instability are lacking as related to specific channels. Problems associated with instream mining are considered continuous in time as the channel has little opportunity to reach stable conditions.

Conversely, there is some evidence that a controlled level of instream mining in the immediate vicinity of some bridges or culverts may produce a beneficial effect by preventing aggradation that might otherwise reduce the hydraulic capacity of such structures.

III. OBJECTIVES - The objective is to document a variety of streams affected by instream mining as a means of determining the significant hydraulic and geologic factors associated with unstable channel conditions. Specific objectives include a survey to determine the extent of the problem, evaluation of factors associated with channel instability and

recommended methods to prevent or control channel instability.

IV. CURRENT ACTIVITIES

A. Related research activities: Completed research on degradation and aggradation (FHWA/RD-80/159) documents the results of numerous instream mining operations. In addition this report provides much of the information posed in the objectives section of the subject problem statement. An evaluation of countermeasures for hydraulic problems at bridges (FHWA/RD-78/162 & 163) provides documentation of 12 case histories specifically on instream mining (reference report 162, p. 108).

B. Suggested key words for this problem: instream mining, channel stability.

V. URGENCY - Many stream channels are excellent and renewable sources of aggregate. As other sources of aggregate diminish instream mining has increased often with a resultant increase in damage to highway crossings. Methods are urgently needed to identify when such damage can be expected, when there will be a beneficial effect from instream mining and if appropriate how to reduce or avoid the damage to highway structures from this activity. The result would be a considerable savings and increased safety to the traveling public. Since instream mining is legal in many states the total impact of this activity needs to be recognized to determine if legislative controls on such activities are warranted.

PROBLEM NO. 6

I. NAME OF PROBLEM - CONTROL OF STREAM INSTABILITY AT BRIDGE CROSSINGS

II. THE PROBLEM - Stream instability must be considered in design to provide for the most cost-effective crossing. For existing crossings it has been demonstrated that application of appropriate countermeasures for stream hazards substantially extends design life. Numerous references on stream instability at highway crossings and the use of countermeasures are available from the FHWA and from other sources; however, much of this information is not readily available and is scattered throughout many publications. There is a need for a synthesis of existing research information and development of a document especially aimed at moderately sized streams (10 to 100 meters wide). The synthesis should include aspects of vertical control of streambeds (degradation) and horizontal control of stream banks (banks erosion and meander migration).

III. OBJECTIVES - The objectives are:

A. Review existing technology to determine the most effective stream instability control methods.

B. Provide a synthesis report useful to bridge and hydraulic engineers.

IV. CURRENT ACTIVITIES - A synthesis of this type has not been done, although numerous publications are available to serve as source material. The FHWA is currently developing a Hydraulic Engineering Circular on this subject.

V. URGENCY - Bridge replacement is falling far behind the rate of bridges needing replacement. Proper consideration of stream instability is only one concern for bridge engineers; but by decreasing the number of bridges lost to hydraulic hazards the total number needing replacement for any reason is lessened. Guidance on practical cost-effective measures to control scour and erosion problems is needed in the design as well as maintenance of stream crossings. A synthesis of the valuable information would greatly facilitate implementation of proven methods to reduce potential bridge losses due to channel instability.

PROBLEM NO. 7

I. NAME OF PROBLEM - RIVER TRAINING WORKS AS RELATED TO HIGHWAYS

II. THE PROBLEM - The highway engineer is often confronted with the problem of stabilizing channels at highway stream crossings. The task may involve training works associated with either a channel relocation or control of channel shifting and bank erosion. Most river training installations are expensive and many have failed to accomplish desired results. A need exists for information on this subject compiled for ready use by highway engineers. Case histories, design methods and details, costs and materials relating to prediction and control of river meanders and undesirable channel shifting should be studied and presented in a form useful to the highway designer.

III. OBJECTIVES - To prepare a state of the art report on river training works with specific applications to the highway river crossing problem. The study should employ state of the art knowledge of river mechanics and the behavior of alluvial streams.

IV. CURRENT ACTIVITIES

A. Related research activities: FHWA has completed research in the following areas:

1. Channel Changes
2. Flow Control Measures
3. Riprap

B. Suggested key words for this problem: river training, channel stabilization, river meanders, alluvial streams.

V. URGENCY - The Federal Highway Administration has conservatively estimated annual costs of flood damage to highways to be on the order of $140 million per year. Improved procedures for protecting highway embankments and drainage structures utilizing river training works can be used by the state highway agencies to reduce such costs to a significant degree.

PROBLEM NO. 8

I. NAME OF PROBLEM - EFFECT OF VERY LARGE SEDIMENT CONCENTRATIONS ON FLOW CHARACTERISTICS

II. THE PROBLEM - Intense storms in arid regions can cause floods in watersheds that are normally dry. Many of these watersheds have soil deposits composed of silt, sand and rocks that are readily transported by the flowing water. This creates large concentrations of sediments in the water course. Calculations of velocity, discharge, sediment transport, scour, Froude number, etc., may not be valid when the fluid properties (density and viscosity) and the flow characteristics (turbulence) are modified by large concentrations of fine sediments.

III. OBJECTIVES - The objectives of this research study are to first predict the amount of sediment that will be carried by a stream for a given discharge and then to determine the effect of heavy sediment concentrations on flow characteristics. Estimates of scour potential, slope protection needs, channel capacity, conveyance and hydraulic jump potential are all common hydraulic design problems that are complicated when the fluid no longer acts as clear water.

IV. CURRENT ACTIVITIES

A. No other research in this field of interest has been identified.

B. Suggested key words for this problem: sedimentation, flash floods, arid region hydraulics.

V. URGENCY - The problem of insufficient knowledge of how to design for water that may have significantly different characteristics has been known for some time. Development of more knowledge in this area is needed to achieve improved cost-effective designs for transportation facilities located in flood plains which carry large sediment loads.

PROBLEM NO. 9

I. NAME OF PROBLEM - A COST-EFFECTIVE APPROACH TO HYDRAULIC DESIGN OF HIGHWAY DRAINAGE STRUCTURES

II. THE PROBLEM - Conventional practice in the hydraulic design of highway drainage is to provide for conveyance of the peak discharge for a flood with a preselected recurrence interval. Usually consideration is only given to initial capital costs, and the probability or chance of property damage and traffic delays due to other (larger and smaller) flood events are seldom quantified in economic terms. A cost-effective approach is needed to define the optimum design hydraulic load considering not only capital costs but also potential economic losses due to the flood hazards represented by a range of flood events.

III. OBJECTIVES - To develop criteria and procedures for incremental cost analysis for use by decision makers in the selection of designs for highway drainage facilities. The procedure would recognize the probability that various floods will be exceeded during the life of the highway; include techniques for arriving at an optimum design considering capital costs and potential economic losses; and provide guidance for decision making in view of limiting constraints, initial capital investment and potential damage costs.

The scope of the effort should include design procedures considering individual as well as drainage facilities on a route or route segment. Included should be consideration of the availability of alternative routes, the importance of the route or route segment to commerce and national defense, traffic volumes and desired level of traffic service and the need for the route for emergency supply or evacuation in case of a natural disaster and other factors.

The procedures for the design of each drainage feature would include an economic analysis of the hazards to life and property, including both the risk of damage to the highway and other property affected by the presence of the highway; total cost of the highway encroachment, including capital costs for construction and costs for maintenance, repair and reconstruction and for liability due to damage caused by the highway, costs of traffic interruption and other factors. It should also provide guidance for decision making in recognition of budgetary constraints for capital investment and potential damage costs and consideration of a preferred level of traffic service. Inherent in this are methods for evaluating the present worth of probable future costs and techniques to minimize or mitigate damages.

The procedure would include consideration of flow duration as well as flood peaks in assessing flood losses.

IV. CURRENT ACTIVITIES

A. Related research activities: FHWA Contract Research with Water Resources Engineers, Flood Risk Factor in the Design of Box Culverts and Bridges.

B. Suggested key words for this problem: design flood, flood plain encroachments, risk, capital cost, deferred costs, hydraulic designs.

V. URGENCY - The Federal Highway Administration's annual budget for emergency repair and reconstruction of damage to highways on the Federal-aid system from natural disasters is on the order of $100 million. The states and local jurisdictions undoubtedly spend a like amount for the repair and reconstruction of roads damaged by events which are not widespread enough to be declared an emergency. An additional $40 million is expended annually by the Federal Emergency Management Agency (FEMA) for repair and reconstruction of off-system (non-Federal-aid) roads and streets. Much of the costs incurred by local governments for emergency repairs are disallowed by FEMA, so the actual costs are much higher than $40 million annually. In addition to these costs courts have held highway agencies liable for flood damages and these costs are not accounted for in the above recital. The bulk of the FHWA $100 million ER funds is expended for flood damage repair.

In view of an annual expenditure nationally on the order of $200 million+ for flood damage repairs, it is appropriate to reassess present design criteria and procedures and to develop and utilize, where appropriate,

techniques for optimizing the design of drainage structures on the basis of total costs, initial capital cost and potential economic losses assigned to the structures.

PROBLEM NO. 10

I. NAME OF PROBLEM - ESTIMATING EMBANKMENT DAMAGE DUE TO FLOOD OVERTOPPING

II. THE PROBLEM - Highway stream crossings are frequently built so that the embankments are overtopped under some flood conditions. An economic analysis model has been developed to determine the design alternative with the optimum crossing conditions. One of the weak links in the model, however, is in estimating embankment damage that results from scour when overtopping of the roadway by flood waters occurs.

III. OBJECTIVES

A. Document field experience after floods to record amount of pavement and embankment damage for various depths and duration of overtopping floods. Records should reflect embankment soil types, vegetation cover, embankment heights, estimate of water surface drop over the roadway and estimated flow velocity over the downstream shoulder.

B. Establish prediction methods for estimating embankment damage based on field experience and controlled experimental data.

C. Establish guidelines for use of protection such as riprap, filter cloth, nylon matting and fiberglass roving on embankments.

IV. CURRENT ACTIVITIES

A. Related research activities:

1. A recent research study of flood risk analysis for design of bridge waterways included a thorough literature review of embankment erosion, but the literature review did not reveal satisfactory methods for predicting highway embankment erosion during overtopping.

2. There are a number of existing embankment erosion studies, but they have very limited applicability to this problem because they deal with sheet erosion. This problem is more analogous to the erosion that might take place during the overflow of a dam.

3. An effort to assemble field observations from maintenance records for recent flood events is underway. This information will be very useful in providing direction to the research effort. The FHWA is developing an administrative research effort to study the effects of overtopping under controlled conditions.

B. Suggested key words for this problem: embankment erosion, embankment protection, scour, spillway protection, spillway design, flooding, flood risk analysis, flood hazard analysis.

V. URGENCY - During the period 1953 to 1973 an average of more than 1000 bridges were built over water per year on the Federal-aid system alone. During approximately the same period 43 percent of the bridge failures were characterized by washed out approach embankments according to a very limited analysis of FHWA emergency relief files. The large number of bridges that have been built (many of which will be replaced under the bridge replacement program) and the frequency of embankment failure represent evidence in support of the urgency for research to better define optimum stream crossing design.

PROBLEM NO. 11

I. NAME OF PROBLEM - COST-EFFECTIVE ROADWAY DRAINAGE STORM DRAIN DESIGN USING ECONOMIC (RISK) ANALYSIS TECHNIQUES

II. THE PROBLEM - Cost-effective roadway drainage and storm drain design is based on a difficult trade-off of highway safety, hydraulics and storm frequency factors. There are a number of goals that are at cross purposes. For example, since design storms are relatively infrequent economics dictates that drainage costs be kept low; however, traffic safety considerations require that pavement flooding be kept within tolerable limits.

The flow of stormwater on a pavement is quite sensitive to any change in design parameters, particularly cross slope, storm frequency and longitudinal slope. Changes in these parameters could adversely affect the width of spread and conflict with traffic safety considerations. With the cost of automotive energy rising each year traffic delays caused by minor storms are matters of serious concern. Energy cost and time lost may be important factors that should be considered in the economic balance.

The principles established in the economic (risk) analysis approach for designing encroachments on flood plains are excellent tools for evaluating the roadway drainage problem. Development of an economic analysis approach for roadway drainage and storm drain design may provide for cost-effective improvements in existing highway drainage design procedures.

III. OBJECTIVES - To develop economic (risk) analysis procedures for roadway drainage and storm drain design considering traffic safety, hydraulics, storm frequency, energy and time losses, damage and economics.

IV. CURRENT ACTIVITIES

A. Related research activities: FHWA sponsored research on highway drainage computer programs.

B. Reference: FHWA's HEC No. 17, The Design of Encroachments of Flood Plains Using Risk Analysis.

C. Suggested key words for this problem: risk analysis highway drainage computer program, pavement drainage.

V. URGENCY - Highway drainage engineers are in urgent need of an economic (risk) analysis approach for selecting cost-effective drainage design parameters since drainage costs on urban highways are a significant portion of overall project costs.

PROBLEM NO 12

I. NAME OF PROBLEM - BEHAVIOR OF SUPERCRITICAL SEDIMENT-TRANSPORTING FLOW

II. THE PROBLEM - Streams in which the flow is supercritical can become extremely unstable and can behave entirely different from the more common subcritical rivers. Culverts can become completely clogged and deposition can occur at bridges.

III. OBJECTIVES - The objectives are to acheive a better understanding of the mechanisms of sediment transport under conditions of supercritical flow and to develop design procedures which take into consideration the sediment load and the hydraulic forces under these conditions. Preliminary analysis of the problem indicates that little or no obstruction to the flow can be tolerated, and that a different kind of design may be necessary for highway crossings of such streams.

IV. CURRENT ACTIVITIES

A. While the problem has been recognized there have been no formal studies undertaken to establish a design approach for such conditions.

B. Suggested key words for this problem: drainage structures, river behavior, supercritical flow, deposition and scour.

V. URGENCY - It is likely that supercritical flow occurs at highway stream crossings more often than is generally realized. This type of flow condition may contribute to flood damage because it is not recognized and taken into consideration during the design of the highway stream crossing. A design approach which includes a means of identifying when a problem is likely to occur has the potential for significant improvements in the design of highway drainage structures along with a corresponding savings of public funds.

PROBLEM NO. 13

I. NAME OF PROBLEM - LONG SPAN CULVERT HYDRAULICS

II. THE PROBLEM - National emphasis of highway safety, bridge replacement, environmental protection and economics has generated an increasing interest in the use of long span structural plate corrugated metal and precast concrete arch structures for highway drainage at stream crossings. Industry has responded to these needs and is actively promoting the use of a wide range of sizes and shapes of "long span" structures which are often an alternative to special designs and standard bridges.

The size, shape, end treatment and corrugation configurations available from various suppliers offer the designer an array of alternatives; however, only a limited effort has been expended to develop hydraulic analysis and design techniques similar to that available for conventional culvert and bridge design. Adequate procedures are not available for estimating the extent of scour which will occur in long span culverts with natural bottoms.

III. OBJECTIVES - To expand and/or develop criteria and procedures with design aids to be used for the hydraulic analysis and design of long span structures. This development will include appropriate entrance losses and inlet control characteristics of the various structures. Confirmation of friction losses within the barrel where arch structures are utilized with the natural stream bottom should be included in the development process.

The use of step backwater computations appears to be the best approach for establishing the tailwater-headwater relationship for structures of this type; however, present methods of evaluating the various entrance, friction and exit losses are not readily adaptable to the water-surface profile computational process.

IV. CURRENT ACTIVITIES

A. Related research activities: In January 1974 the Federal Highway Administration's Office of Engineering, Bridge Division, Hydraulics Branch developed a preliminary draft of a publication titled "Hydraulic Design of Large Structural Plate Corrugated Metal Culverts." The FHWA has issued a design manual (Calculator Design Series No. 4) which included procedures for hydraulic design and analysis of some long span culverts. The information utilized to develop this manual is largely empirical and based on knowledge and experience gained from research for conventional culvert design.

B. Suggested key words for this problem: long span culverts, hydraulic design, culvert hydraulics.

V. URGENCY - Present emphasis on bridge replacement, economics and hydraulic efficiency relative to flood plain management and flood risk require a thorough investigation and documentation of the design for stream crossings.

The analysis and design techniques being utilized should be confirmed and/or improved as necessary in order to assure that the long span culvert will function hydraulically as designed.

PROBLEM NO. 14

I. NAME OF PROBLEM - TEST AND EVALUATION OF MAJOR STORMWATER DRAINAGE SYSTEMS

II. THE PROBLEM - A number of major expressways and urban arterials have experienced highway pavement flooding during relatively minor storms. Traffic delays during the flooding have produced a level of service that is undesirable. A new generation of computer drainage models has provided the highway drainage engineer with sophisticated tools

for investigating the problem and for devising cost-effective solutions to existing problems. Various cities, such as Chicago, Denver, Los Angeles, El Paso, etc., have constructed storm drainage systems based on locally developed design procedures and techniques. At the time these expressways were designed such design procedures were considered to be the best methods available; however, new methods, such as the EPA SWMM computer program and the FHWA highway drainage computer program, are now coming into existence to provide highway engineers with improved computer models to aid drainage design. An evaluation should be made of the new design models by comparing computed runoff values with field measured values.

III. OBJECTIVES

A. To measure the performance of the surface drainage system in urban areas on selected portions of expressways and/or arterials under actual storm conditions. Measurements should include (1) continuous recording of rainfall over the entire drainage area and (2) continuous recording of runoff from subunits of storm drain systems for which rates of flow had been computed in the design process.

B. To compare runoff based on measured rainfall in accordance with the various design procedures.

C. To analyze the computed vs. observed runoff from the test areas.

D. To evaluate the validity of the various design procedures.

E. To identify design procedures that produce the closest results to the measured runoff.

F. To make recommendations for improving design procedures.

IV. CURRENT ACTIVITIES

A. Related research activities: FHWA sponsored research on inlet hydrographs at Utah State University and local storm research at the University of Illinois. Information on areal rainfall and runoff in the storm drain system is available for selected urban highway projects.

B. Suggested key words for this problem: inlet hydrographs, Chicago Method, roadway drainage, SWMM, FHWA highway drainage computer program.

V. URGENCY - Engineers working with urban drainage problems are in urgent need of an accurate means of designing roadway drainage and storm sewers. Evaluation and verification of design procedures that accurately model field conditions would be a major advance in roadway drainage design.

PROBLEM NO. 15

I. NAME OF PROBLEM - HEAD LOSS IN STORM DRAIN MANHOLES AND JUNCTION CHAMBERS

II. THE PROBLEM - Extensive highway storm drainage systems have a multitude of manholes and junction chambers which are significant components of the system. An important element of storm drain design is computing the head loss at these structures. Adequate structure drop must be provided at manholes to offset energy loss; however, since total fall available in the storm drain system is usually limited it is important that head losses be kept to a minimum to produce cost-effective designs.

Some municipalities have investigated the problem and developed design procedures. The City of Los Angeles has developed a procedure and tested it in the city's research facility. This method along with others could be studied and incorporated into a general design procedure.

III. OBJECTIVES - The objective is to develop computational procedures to estimate head loss at storm drain manholes and junction chambers. Field and laboratory research may be necessary to verify the design procedures. Geometric layout of manholes and junction chambers must be studied to identify cost-effective designs.

IV. CURRENT ACTIVITIES

A. Related research activities: City of Los Angeles research.

B. Suggested key words for this problem: head loss in manholes and junctions.

V. URGENCY - Much of the future highway work will be upgrading urban freeway systems which will contain large expensive storm drain systems. It is imperative that accurate design procedures be used to estimate the manhole and junction chamber losses so that cost-effective designs will be produced.

PROBLEM NO. 16

I. NAME OF PROBLEM - METHODS FOR ACCOMMODATING FLOATING DEBRIS AT BRIDGES

II. THE PROBLEM - Lodging of debris at bridges is one of the primary causes of bridge failure or the need for high maintenance efforts. The types of floating debris causing bridge damage are drift, such as brush, logs, etc., and ice.

Presence of floating debris at a bridge may cause a flow constriction with increased potential for high flow velocities and subsequent scour, impact damage and lateral displacement of the structure.

Present methods for controlling floating debris include the design of streamlined pier shapes, increased bridge clearance, physical removal of debris and drift arrestors placed in the stream near the bridge.

III. OBJECTIVES - The objective is to determine the best methods for preventing bridge damage caused by floating debris. The various methods may be categorized as debris prevention, passage improvement and physical removal of debris at the bridge site. Specific objectives include:

A. The classification of streams or areas to determine the problem severity and probable type of floating debris.

B. Survey of methods presently used to prevent damage by debris.

C. Effectiveness of methods now in use.

D. Recommendations for new techniques to prevent drift problems.

IV. CURRENT ACTIVITIES

A. Related research activities: National Research Council of Canada and Corps of Engineers (CRREL) Research on Ice Loads on Bridges.

B. Suggested key words for this problem: floating debris, bridges, damage prevention, ice.

PROBLEM NO. 17

I. NAME OF PROBLEM - ENERGY DISSIPATION AT CULVERT OUTLETS AND STORM DRAIN OUTLETS

II. THE PROBLEM - There is an urgent need to develop criteria for the design and use of simple, practical, economical stilling devices for dissipating the energy of the flow from culverts and storm drain outlets up to 144-inch diameter or equivalent size. Damaging erosion of drainage channels often results from discharge of high velocity flow from the outlets of culverts and storm drains. Energy dissipators can be effective in reducing the velocity of flow from culverts to a degree that damage to the channel and channel bank will not undermine the culvert or endanger the highway embankment.

III. OBJECTIVES

A. To develop criteria which will provide the designer with a basis for selecting the type of energy dissipator most suited to the conditions.

B. There are several complex types of energy dissipators suitable for the more costly applications such as for reclamation, flood control or the larger highway drainage structures. For most highway drainage systems consisting of commercial culverts or storm drains simpler, more effective and economical devices including prefabricated modular types are urgently needed.

C. Designs should be applicable to pipe or box culverts of all shapes operating over a wide range of discharge rates and relations of velocity head to depth of flow at the outlet.

IV. CURRENT ACTIVITIES

A. Related research activities: No known ongoing research in this area. The FHWA has published HEC No. 14, Hydraulic Design of Energy Dissipators for Culverts and Channels.

B. Suggested key words for this problem: energy dissipators, stilling basins.

V. URGENCY - Inadequate outlet designs result in added maintenance or need for subsequent drainage and erosion control facility replacements and improvements. There is also recurring loss due to overdesigns where the design principles are not clearly established for erosion control structures. Erosion at culvert and storm design outlets is a perennial problem; better guidance and design will help to reduce construction and maintenance costs and enhance safety and aesthetics in accord with good engineering practice.

PROBLEM NO. 18

I. NAME OF PROBLEM - EROSION RESISTANCE OF GRASSES USED IN HIGHWAY DRAINAGE CHANNELS

II. THE PROBLEM - The U.S. Department of Agriculture has performed tests on various grass covers to determine their hydraulic retardance and resistance to erosion and has published the results, mainly during the 1950's.

Since that time various types of vegetation such as Crown Vetch and Bahia have come into general use as ground covers and erosion control measures. Hydraulic and erosion control data are needed on these types of vegetative covers.

III. OBJECTIVES

A. To determine the hydraulic retardance and erosion resistance of grasses and vegetal cover being used along the highway right-of-way. Perform tests similar to those used by the Agriculture Research Station at Stillwater, Oklahoma using both permissible velocity and tractive force theory. Quality of cover as influenced by climatic and agronomic considerations should be an important variable in this study.

B. To determine design criteria for various commercial materials and mats that provide a permanent, nondeteriorating and noneroding cover on bare earth for supporting vegetal growth.

IV. CURRENT ACTIVITIES

A. Related research activities: SCS publication, "Handbook of Channel Design for Soil and Water Conservation," Mississippi State University tests on sodded channels.

B. Suggested key words for this problem: vegetation, retardance, erosion, resistance.

V. URGENCY - Channel design methods presently in use utilize vegetation as one type of lining. In many instances vegetation is the best lining choice since it retards flow, is self healing and allows infiltration; however, design information is not available for many of the grasses being widely used on highways. Proper design and construction of such grass lined channels has the potential of saving maintenance dollars, and serious safety hazards and aesthetic problems may be avoided.

PROBLEM NO. 19

I. NAME OF PROBLEM - SPUR DIKES AT BRIDGE ABUTMENTS

II. THE PROBLEM - Many highway crossings of major streams have long approach fills on the flood plain to reduce structure costs. These fills block the passage of overbank flow and divert flood plain flow to a bridge opening. Eddies, formed when lateral flow from the flood plain mixes with main channel flow, cause scour at bridge abutments and at adjacent piers and reduce the effectiveness of part of the bridge opening. Spur dikes projecting upstream from bridge abutments have been effective in preventing serious problems at these locations, but research data are needed to develop criteria for the design of the spur dikes. Downstream dikes or trailing dikes are sometimes needed to prevent scour by redistribution of flow in the flood plains.

Although existing research data and field observations of existing dikes have been very helpful in the design of spur dikes, additional research information is needed to improve designs and to give engineers more confidence in their performance. Needed research on these structures consists of two parts which can be programmed concurrently. Part one includes extensive laboratory testing of various types and shapes of dikes in both fixed and movable bed models. Part two consists of field observations and measurements of flood conditions at existing dikes.

III. OBJECTIVES

A. To expand present data so that adequate criteria can be developed for the design of spur dikes taking into account various types, shapes and orientation, flow distribution, bridge opening and vegetal cover.

B. To analyze and evaluate performance of prototype installations in the field during and following flood flow.

C. To define where trailing dikes are needed to inhibit scour at the downstream toe of the abutment fill.

IV. CURRENT ACTIVITIES

A. Related research activities: None known to be ongoing.

B. Suggested key words for this problem: spur dikes, bridge abutments.

V. URGENCY - Good design criteria and additional field observations of existing dikes will encourage a wider and better use of these structures. It is estimated that the use of spur dikes in conjunction with new bridge construction and remedial work on existing bridges could approach savings of $3 million annually.

PROBLEM NO. 20

I. NAME OF PROBLEM - DESIGN OF LARGE DETENTION BASINS AND APPURTENANCES

II. THE PROBLEM - Large detention basins, both permanent and temporary, are increasingly being specified for entrapment of buoyant and seattleable constituents of runoff from highway and non-highway rights-of-way prior to discharge into lakes and streams. There is no rational method available to the designer to estimate efficiency of constituent removal relative to size of basin. In addition information is needed regarding estimating frequency of clean out, design of outlet structures, provisions for maintenance draw down, design of overflow sections, aesthetic and multiple use considerations, methods of predicting quantity and nature of inflow constituents and skimming methods.

III. OBJECTIVES - To develop a design manual on permanent and temporary detention basin design for transportation facilities. The manual would provide comprehensive guidelines, criteria and recommendations regarding all facets of detention basin design, construction and maintenance considerations. A nationwide review of experience with use of basins should be conducted.

IV. CURRENT ACTIVITIES

A. Related research activities: NCHRP study on erosion control features; USGS study in North Carolina; HPR studies, Pennsylvania, Milwaukee, Florida.

B. Suggested key words for this problem: sediment basins, design manual, water quality, detention basins, spillway design, outlet structures, skimming.

V. URGENCY - Federal and state laws, rules and regulations have been promulgated that mandate measures to mitigate environmental damage caused by stormwater runoff. Detention of runoff appears at this time to be the most cost-effective method available. A design manual is urgently needed in order that use of basins proceeds on a rational basis.

WATER QUALITY

PROBLEM NO. 1

I. NAME OF PROBLEM - WATER QUALITY MONITORING PROGRAM OBJECTIVES AND REQUIREMENTS FOR TRANSPORTATION PROJECTS

II. THE PROBLEM - Water quality of highway runoff or of water bodies crossed by roadways may be monitored for any of a number of reasons. These include (1) scientific research on quality levels or quality change mechanisms, (2) problem identification, (3) preliminary design of controls, (4) final design corroboration, (5) regulatory compliance monitoring and (6) operational performance monitoring.

Numbers of samples and laboratory analyses to satisfy each of these example objectives range from less than 100 to over 50,000. Comparable sampling, laboratory and analyses costs range from several thousand dollars to many millions of dollars. These findings have resulted from recent (1981) research on the monitoring of general urban runoff including watershed, street surface,

storm and combined sewage and receiving water flows.

Analysis of the statistical reliability and costs of quality monitoring programs directed specifically at the unique roadway runoff problem has never been made. Still, highway and other road surface runoff is often singled out as being a significant source of water pollution. Monitoring to prove that allegation, to support controls of the pollutants identified and to predict or demonstrate their adverse effects should be reliably planned and implemented.

III. OBJECTIVES - To relate water quality monitoring objectives for studying road surface runoff to the sample and station number requirements and to the costs of sample programs thus indicated. Guidelines will be formulated on development of project study objectives. For example: Why is certain data being collected? How is it to be used?

IV. CURRENT ACTIVITIES

A. Recent Federal Highway Administration research results exist on (1) monitoring of stream and road surface runoff and (2) mathematical modeling of processes of pollutant transport on and near road surfaces. Whether the data base is sufficient for model calibration or verification or for any other purpose remains a question.

B. Sonnen's 1981 research results on monitoring of urban runoff quality, performed for EPA, suggest that monitoring requirements vary tremendously depending on the objective to be satisfied.

C. Most research on sampling sufficiency of any relevance has been on hydrologic parameters, such as rainfall, gage density and the like.

V. URGENCY - New roadway designs and installations and refurbishments of old road surfaces and rights-of-way continue apace. Adequate pollution controls for the runoff from these surfaces are required by state and federal laws. Water quality sampling of runoff to support conclusions about that adequacy is expensive, but sufficient monitoring is required to satisfy reliably any of a number of objectives for such monitoring. Until monitoring guidelines are produced to relate specific objectives to monitoring requirements insufficient or more than sufficient monitoring is highly likely to result. Either result could be catastrophically costly, both economically and intangibly.

PROBLEM NO. 2

I. NAME OF PROBLEM - EFFECTIVENESS OF TEMPORARY EROSION CONTROL METHODS TO REDUCE WATER POLLUTION

II. THE PROBLEM - There has been an increasing emphasis over the past several years on the prevention of water pollution due to highway construction and operation. One of the pollutants of concern is sediment. Probably the greatest emphasis to date has been directed at sediment since the damaging effects of erosion on the highway are readily visible and the concentration of sediment in runoff is higher than that of other pollutants.

The highway system is most vulnerable to erosion damage and sediment runoff during the construction period; thus there have been numerous publications advocating various temporary erosion control measures. In general these measures are to remain in place until vegetation is established or other permanent controls are installed; then they are removed or biodegraded.

While many different temporary erosion control measures have been advocated few have been evaluated. Most are not designed but are improvised based on field experience. It appears that some measures may not work or may create more problems than they solve. Failures of several of the commonly suggested methods are often observed on highway projects.

III. OBJECTIVES - To evaluate the temporary erosion control methods commonly proposed by means of laboratory or field studies in order to determine their efficiency, practicality, ease of construction and durability; and to develop guidelines for the design, construction and maintenance of those measures proven to be effective.

IV. CURRENT ACTIVITIES

A. Related research activities: EPA has developed, under contract, several recent reports dealing with temporary erosion control methods. Most involve gross estimates of efficiency. A new NCHRP research study has just been initiated on the effectiveness of erosion control methods for roadside development.

B. Suggested key words for this problem: water pollution control, erosion, temporary erosion control.

V. URGENCY - There is a pressing need to evaluate the performance of the temporary erosion control methods currently being promulgated. If they do not perform as well as expected their continued use may result in undue sediment pollution of natural waterways and damage to the highway. In fact they may act as placebos curing nothing but providing a false sense of security.

PROBLEM NO. 3

I. NAME OF PROBLEM - NATURAL SYSTEMS TO TREAT HIGHWAY RUNOFF

II. THE PROBLEM - Growing awareness of the potential for environmental damage from the construction and operation of highways and highway drainage systems has resulted in the need to identify and quantify the environmental effects and to develop measures for the protection of the total environment from any adverse effects. Rainfall along highways produces massive amounts of runoff which present significant problems of collection and treatment for contaminant removal by conventional methods. There is a need to develop and evaluate techniques for using the assimilative capacity of natural

biological systems that are complementary to highway construction to abate objectionable constituents of highway runoff before discharge into receiving waters. The abatement methodologies must be capable of handling large and variable volumes of runoff in an economical and environmentally compatible manner. Resulting methodologies must be adaptable for application to a variety of site conditions including different soil types, vegetative covers and topographies.

III. OBJECTIVES - The objective is to determine the feasibility of using natural ecological systems to treat highway runoff so as to minimize contaminant loadings to receiving waters. All available information on the potentially feasible systems will be described. Experimentation will be conducted to fill critical information gaps and to develop criteria for establishing reliable abatement systems.

IV. CURRENT ACTIVITIES

A. Highway research in FHWA FCP Project 3E has been scanned in preparing this statement. Many ongoing projects are monitoring, identifying and quantifying highway runoff constituents. The transport mechanisms of certain contaminants are being determined under Project 3E. The next step will be to develop methods of treating objectionable constituents of highway runoff. Results of related research being conducted by the Corps of Engineers and the Environmental Protection Agency on land treatment of wastewater and the management of leachates and runoff from land disposal of dredged and fill material may have potential application to this problem.

B. Suggested key words for this problem: abatement/treatment, highway runoff, contaminants.

V. URGENCY - This research will develop state of the art knowledge on the feasibility of utilizing natural biological systems to treat massive amounts of highway runoff and therefore is highly urgent. Discussions at the Federal Highway Administration sponsored annual research review of the Federally Coordinated Program of Research and Development in Highway Transportation at Columbus, Ohio on November 8, 1977 indicated that certain states (New Jersey and California) are currently interested in the potential of wetlands and marshes to treat highway runoff.

PROBLEM NO. 4

I. NAME OF PROBLEM - STRUCTURAL METHODS FOR REMOVAL OF CONSTITUENTS FROM HIGHWAY RUNOFF

II. THE PROBLEM - Much research work is being performed on methods of removing sediment from highway runoff. However, it may become necessary, at least at some sites, to remove other constituents from the runoff. Treatment for one type of constituent may release or enhance the concentration of another constituent.

Research is underway on the quality of highway runoff. If this work and other studies on the effects of the materials on plants and animals show that problems exist it may become necessary to remove certain constituents from the runoff.

Preliminary work indicates that some constituents decay, some are absorbed to sediment and some are lost through ion exchange with soils. These characteristics may lead to some conclusions as to possible removal methods. For example, it appears that sediment ponds may be an excellent method of removing contaminants other than sediment while some oil skimmer designs may be completely unworkable.

III. OBJECTIVES - To derive practial methods of removing problem constituents from highway runoff before such runoff reaches watercourses.

IV. CURRENT ACTIVITIES

A. Related research activities: FHWA and Washington SHD research on quality of highway runoff. NCHRP study on erosion control methods. Various EPA research studies. Corps of Engineers wash rack and other studies.

B. Suggested key words for this problem: highway runoff, pollutants, pollutant removal.

V. URGENCY - If ongoing research defines certain pollutants in highway runoff as being harmful there will be pressure to quickly derive means of treating the runoff. Some preliminary work along this line should be initiated as soon as possible so that rash decisions to utilize unworkable treatment methods will not be made.

PROBLEM NO. 5

I. NAME OF PROBLEM - OPERATIONS AND MAINTENANCE (O&M) OF SANITARY TREATMENT FACILITIES AT ROADSIDE REST AREAS

II. THE PROBLEM - The effluents from many roadside rest area sewage treatment facilities fail to meet state and federal water quality requirements. To some extent these inefficiencies are due to design inadequacies but in many cases the problem results from an underestimate of O&M needs and a misunderstanding of the peculiar needs of rest area systems. The intermittent nature of the waste loadings and the resulting wide fluctuations in waste strength present major operational problems. The periodic maintenance of the treatment works rather than full time operator assisted systems can also lead to diminished treatment efficiencies. States need guidance in upgrading the effluents through operation and maintenance practices rather than further construction funding.

III. OBJECTIVES

A. To define the operation and maintenance problems that commonly exist at rest area sanitary treatment facilities.

B. To develop O&M methodologies to meet the needs of the facilities. Develop

operational guidance for all of the most widely used processes (i.e., lagoons, package plants, oxidation ditches, land treatment systems).

C. To investigate various operational modes and make recommendations based on the manpower and time requirements of each. Delineate equipment and supply limitations for the common treatment trains.

D. To produce a manual or series of manuals that address the above findings.

IV. CURRENT ACTIVITIES

A. Related research activities: The extent of research being conducted by other agencies or organizations is not known. Organizations with similar facilities and needs are:

1. Corps of Engineers Recreational Areas
2. Forest Service Campgrounds
3. State and National Parks Systems
4. Amusement Parks - especially large theme parks in the outskirts of metropolitan areas (Disney World, Busch Gardens, etc.)

B. Suggested key words for this problem: intermittent loads, small treatment works, sewage effluents, roadside sanitary facilities

V. URGENCY - Effluent requirements mandated by federal and state laws will not be relaxed in the coming years. Construction funding will not be available for replacement of processes not currently meeting permit requirements. Therefore, there resides a tremendous need to assess the present technologies and develop methods for existing systems to attain the effluent design standards. Creative O&M activities must be placed into practice to meet the discharge permits while remaining within the funding and manpower limitations of the state governments.

PROBLEM NO. 6

I. NAME OF PROBLEM - RESTORATION OF WETLANDS AS MITIGATION FOR ADVERSE IMPACTS RESULTING FROM THE CONSTRUCTION OF TRANSPORTATION FACILITIES

II. THE PROBLEM - The location and construction of transportation facilities through wetlands areas cannot always be avoided. Certain unavoidable loss of wetlands usually occurs where this situation does exist. Regulatory agencies are requiring replacement or restoration of wetlands as conditions to approval for permits to construct in such areas.

The transportation agency is often required to restore or replace wetlands without having the proper design criteria or technical guidance required to successfully implement restoration programs. Unsuccessful mitigation attempts by various transportation agencies have lent skepticism to the permit review process and have prevented reasonable "trade-offs" from being a legitimate approach to obtaining necessary environmental permits.

III. OBJECTIVES - Synthesis study and development of guidelines and design criteria for the reconstruction of certain typical wetlands such as marshes (both tidal and freshwater), swamps, submerged vegetation meadows, etc., that may be successfully used in wetlands restoration. This would include the gathering of data to understand the physical and chemical requirements of various typical wetlands flora and experimentation in the form of demonstration projects to experimentally produce a variety of wetlands systems.

IV. CURRENT ACTIVITIES

A. Related research activities: U.S. Corps of Engineers restoration experiments with dredge spoil, various university research activities on marsh and seagrass restoration.

B. Suggested key words for this problem: wetlands, fish and wildlife habitat, mitigation, marshes, swamp, restoration.

V. URGENCY - The loss of wetlands in the United States has reached critical proportions due to construction and development. There is an urgent need to develop guidelines and criteria for restoration and creation of wetlands lost through construction of transportation facilities.

PROBLEM NO. 7

I. NAME OF PROBLEM - TOLERABLE TEMPORARY VARIANCES IN WATER QUALITY STANDARDS RELATED TO TOTAL SUSPENDED SOLIDS AND TURBIDITY AS CAUSED BY TRANSPORTATION CONSTRUCTION PROJECTS

II. THE PROBLEM - In the course of constructing transportation facilities it becomes necessary to work in and around streams. This work by necessity will cause a temporary increase in the total sediment discharge and turbidity. Many streams provide a water resource of varying values and susceptibility to damage from such modified sediment regimes. Current water quality standards are based on permanent sediment regime changes in water quality with little flexibility for relatively brief and temporary increases due to construction practices. In order to justify efforts to modify existing water quality standards it becomes necessary to quantify the impact on the water resource of these temporary changes in the sediment regime.

III. OBJECTIVES - The objectives of this research would be national in scope and consist of the following objectives. Quantification identified below should attempt to include such details as sediment concentrations, gradations, particle angularity, sediment nature or origin, duration of change in sediment regime, magnitude of changes in sediment regime and the resulting impact on downstream aquatic biota.

A. A case history of common transportation construction projects completed in the past twenty years should be undertaken to determine if:

1. the sediment discharges have returned to normal, and
2. the temporary increase in sediment discharge occurring during construction resulted in a permanent degradation of the nation's water resource.

B. Quanitfying the tolerance of key aquatic organisms to temporary increases in sediment discharge and turbidity. Research may be necessary to complete the work accomplished to date.

C. Quantifying the acceptable limits of temporary changes in the sediment regime on agricultural, municipal, recreational and industrial uses.

D. Determining seasonal effects of temporary changes in the sediment regime.

E. Well documented case history measurements over time are then needed to verify the research finding (before/during/after construction).

F. Research should include suggested draft revisions to existing federal water quality regulations based on the research findings.

IV. CURRENT ACTIVITIES

A. Related research activities: Some completed research regarding the effects of sediment on fisheries, industry, agriculture, recreation and municipal standards for permanent sediment standards are known. However, the permanent environmental effect of temporary increases in the sediment discharge is not well defined.

B. Suggested key words for this problem: water, quality, sediment, temporary, impacts, construction, variances, turbidity.

V. URGENCY - There are intensive research efforts that are national in scope being directed at preventing or mitigating temporary increases in sediment discharge arising from construction projects. Additional resources are being directed at designing and constructing facilities to control these temporary increases in the sediment discharges. The foregoing continues to occur without knowledge as to whether temporary increases in sediment discharges from construction projects are permanently degrading the receiving waters.

Regulatory agencies continue to be inflexible about not exceeding water quality standards established for permanent quality levels resulting in delays for needed construction. These delays are costly both in money and loss of life due to untimely replacement of needed transportation facilities.

The foregoing places this research into the immediate need category.

PROBLEM NO. 8

I. NAME OF PROBLEM - PREDICTIVE MODELING OF THE FATE OF HIGHWAY RUNOFF POLLUTANTS

II. THE PROBLEM - Research in recent years has indicated that numerous constituents transported by highway and street surface runoff may be a serious source of pollution to receiving surface waters. Considerable pressure is being applied to transportation departments by regulatory agencies to provide treatment of storm runoff waters on the transportation facility prior to any discharge into receiving waters. In most cases the treatment practices are required without benefit of design criteria for pollutant removal or the desired results of such treatment in terms of resulting impacts on downstream surface waters.

Considerable data now exist which would indicate the types and concentrations of pollutants that might normally be expected in highway surface runoff. There are no satisfactory mathematical tools available, however, that can predict the fate of these materials (salts, nutrients, heavy metals, etc.) as they are transported to receiving waters or the ultimate fate and resultant impact of these materials upon receiving waters and associated aquatic biosystems.

III. OBJECTIVES - To develop a practical computerized predictive model to determine the ultimate concentrations of pollutants in highway and surface runoff that would affect receiving waters to be used as a tool to design best treatment practices and determine the effectiveness or need of such practices in project design.

IV. CURRENT ACTIVITIES

A. Related research activities: FHWA and various state research on quality of highway runoff. EPA studies on urban runoff and predictive modeling.

b. Suggested key words for this problem: highway runoff, pollutants, pollutant removal, storm runoff models.

V. URGENCY - Section 208 of PL 92-500 presently requires regional water quality management plans by the various states. Non-point sources of pollution (storm runoff) are included in the scope of 208 planning. Water pollution abatement practices by regulatory agencies now are being required on transportation projects often at alarming costs without benefit of any analysis of the need or effectiveness of such practices. Modeling tools are sorely needed so that a more responsible approach to project design can be realized.