RIVER ENGINEERING RESEARCH NEEDS IN THE ARMY CORPS OF ENGINEERS

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Abstract River engineering is one of the core competencies of the Army Corps of Engineers. As a cross-cutting topic, river engineering research falls under many separate topic areas: sediment transport modeling; ecosystem restoration; dam and levee safety; infrastructure; fluvial geomorphology; design of riverine structures; and others. The Corps expert Committee on Channel Stabilization has reviewed multiple submitted topics and has identified research topics that would advance the discipline of river engineering. Since the field of river engineering is so broad, and many topics cut across traditional program funding lines, it is easy for key needs to lose visibility. This presentation will discuss the priorities identified by the expert Committee.

INTRODUCTION

The importance of river engineering in USACE was described in an earlier paper (Remus and Jonas, 2010). Research was identified as a critical component, with a recommended first step of reviewing the research needs submitted by Corps field personnel. The collected statements form a valuable record of research needs.

In May 2014, the Corps expert Committee on Channel Stabilization reviewed a collated list of river engineering research needs and ranked them as high, medium or low. Ten needs received high rankings from a strong majority of committee members. These ten are listed below. The order does not reflect any priority.

The research needs were drawn from the Flood Risk Management (FRM) Gateway. Any Corps employee can submit an R&D Statement of Need (SON) for consideration for research funding. Submission guidelines and all previously submitted SONs are included at the FRM Gateway: **http://operations.usace.army.mil/flood.cfm**. Corps employees are strongly encouraged to submit SONs.

The Committee did not attempt to identify research needs not included in the list of SONs. Therefore, the rankings below are a preliminary effort to prioritize river engineering needs, based on the needs that were submitted. Additional work will be required to develop a comprehensive, prioritized list.

RIVER ENGINEERING RESEARCH NEEDS – HIGH PRIORITY

The needs below were all ranked high as the consensus of the Committee. The order does not reflect any relative priority. The descriptions are taken from the FRM Gateway website.

1. **Effects of Training Structures on River Stages**.
    a. **Tracking Number** 2008-F-46
    b. **Need that Drives Requirement**. For many years, various river training structures have been constructed on America's rivers to reduce bank caving and to develop and maintain adequate channel dimensions that support commercial navigation. These training structures include various types of bank stabilization techniques as well as various dikes schemes. These structures provide a more efficient channel by eliminating channel migration through the prevention of bank erosion, realigning a river reach, constricting a channel to increase depth, cutting off side channels and chutes, and concentrating braided rivers into single channels. During the recent floods on the Upper Mississippi River, some have purported that the presence of river training structures actually resulted in higher stages. Previous studies/investigations addressing the impacts of river training works on flood stages will serve to reevaluate and update those findings.
    c. **Extent of Need Across USACE**. Training structures are frequently used throughout the United States to develop rivers for storm damage reduction, navigation, water supply, environmental restoration, recreation, and hydropower. In many parts of the country, floods cause extensive damage even with current flood damage reduction projects in place. If training structures result in increased river levels, then the current level of protection provided by storm damage reduction measures (especially levees) is reduced during floods.
    d. **Requirement**. R&D requirement is to develop a methodology and guidance for evaluating river training structures, especially their impact on overall river stages. This effort will include the evaluation of available tools (including models) and the identification of the ones that are most applicable. An often complex combination of various factors influence channel morphology and thus, river stages. A critical step in determining impacts on river stages is to conduct a detailed geomorphic assessment that identifies these factors for a given river system and determines how these factors are integrated to produce channel morphology.
    e. **Consequences if Requirement Not Met**. The consequences of not meeting the requirement include the potential loss of current levels of protection for flood damage reduction measures on rivers that have been developed with channel training structures. A loss in the level of protection prevents the flood damage reduction measures from providing the benefits that the projects were designed to provide resulting in an increased risk of damage.
    f. **Product Recommendation.** A methodology and guidance for the evaluation of river training structures on river stages will be developed. The Upper and Middle Mississippi River will be used as a test case. Applicable data will be collected and the training works evaluated as to their impact on river stages.

2. **The WES Stream Investigation and Streambank Stabilization Handbook**
    a. **Tracking Number** 2014-F-24
    b. **Need that Drives Requirement**. The WES Stream Investigation and Streambank Stabilization Handbook was last updated in 1997. The handbook is widely used

by USACE field offices, other Federal agencies and the public to provide and outline templates for proper investigative, stabilization and restoration techniques.

c. **Extent of Need Across USACE**. The stream investigation, stabilization and restoration community of practice has greatly progressed in the past 15 plus years and practitioners need to have the most current information to address natural resource issues.

d. **Requirement**. Combine the current handbook with updated ERDC Tech Notes and Reports, Bulletins, EM updates, Hydraulic Design Criteria and additional pertinent information.

e. **Consequences if Requirement Not Met**. If the current WES Stream Investigation and Streambank Stabilization Handbook (1997) is not updated the USACE field offices, other Federal Resource Agencies and the public will not have the most current and up to date stream stabilization and restoration methods.

f. **Product Recommendation.** A methodology and guidance for the evaluation of river training structures on river stages will be developed. The Upper and Middle Mississippi River will be used as a test case. Applicable data will be collected and the training works evaluated as to their impact.

3. **Streambank Stabilization and Grade Control Techniques Suitable for Stream and Watershed Restoration Projects (Update of Section 32 Program)**

a. **Tracking Number** 2008-F-43

b. **Need that Drives Requirement**. Engineering design criteria for low-cost, environmentally relevant streambank protection and grade stabilization techniques suitable for stream and watershed restoration projects. The Corps has excellent design guidance for measures such as full bank riprap revetment, but no guidance for innovative and alternative measures increasingly requested by local stakeholders. Methods such as rootwads, Newbury rock riffles, stone barbs, J-hooks, W-weirs and many more are described in the gray literature, without reliable design criteria. Many have only limited design criteria or are emerging techniques. Reviewing the performance of completed projects is complicated by the lack of as-built plans, design computations, or monitoring, and by the use of unique designs, among other considerations. The Corps capability to include innovative stream stabilization measures in the engineering toolbox is critical to our success in stream and watershed restoration, as well as in regional sediment management.

c. **Extent of Need Across USACE**. This need exists through all Corps districts. It applies in particular to smaller watershed and stream restoration projects. It would also be useful in projects where watershed sediment reduction is a goal.

d. **Requirement**. The following R&D efforts would be effective in meeting this need: a. A major step would be an update of the Section 32 program to address stream stabilization measures (bed and bank) suitable for restoration projects. (The original Section 32 demonstration program constructed low-cost innovative streambank stabilization measures, and monitored their performance over time.) Like the original Section 32 program, an updated program should combine district expertise and ERDC and NRCS research capability. b. R&D to evaluate the performance of a wide range of ecologically relevant stabilization measures in

constructed projects, along with available design criteria. The goal would be to come up with relevant design recommendations. (R&D work has been done along these lines for bendway weirs and for stone toe protection, which are only two of numerous techniques in use. This work has been leveraged against work done by the US Bureau of Reclamation.) This work should be coordinated with the efforts of other agencies, such as the US Bureau of Reclamation. c. R&D to compile a comprehensive national list of methods used, with engineering and ecological limitations and benefits. This would be a joint effort with the USBR. It would take a USBR hydraulic engineering report for the Middle Rio Grande, and give it national application by addressing other methods and constraints. (Listings of methods and techniques have been performed in several references, but lack discussion of the engineering design criteria.) This national list of methods is probably the logical first step of the three listed here. It should be performed by ERDC-CHL in conjunction with IWR, ERDC-EL, district personnel, USBR, and NRCS.

e. **Consequences if Requirement Not Met**. The consequences of not meeting this need are: a. A lack of design guidance for streambank stabilization and grade control measures suitable for stream and watershed restoration projects. b. A lack of leadership in an arena where the Corps has traditionally provided guidance to both Corps districts and the wider community of practice c. A lack of a systems approach to restoration projects. The incorporation of sound engineering criteria for ecologically-friendly techniques is essential to project success.

f. **Product Recommendation.** This effort would build on several ongoing efforts by ERDC-CHL, USBR, NRCS, USDA, and the Desert Research Institute. The results should be incorporated into Corps guidance.

4. Full Integration of Hydraulic Engineering with Ecological Components of Project Planning and Design

a. **Tracking Number** 2008-F-49

b. **Need that Drives Requirement**. Since the Corps has added the mission of aquatic ecosystem restoration, an increasing percentage of projects include restoration goals. Although the restoration objectives are formulated by ecologists, their successful attainment relies on the support of hydraulic engineers (for hydrologic, hydraulic, and sedimentation aspects of design). There is a need for improvements in the planning and design process that would fully integrate Corps engineering and ecological components from the beginning of projects. The need is to ensure that hydrology, hydraulics, and most importantly, sedimentation, are not tacked on at the end of the planning process. The goal is a systems approach that would include all disciplines from start to finish, with a common vision of project goals and processes. The benefits include an improved capability to deliver viable and sustainable projects that meet goals and functions.

c. **Extent of Need Across USACE**. This need exists through all Corps districts, and covers a majority of projects.

d. **Requirement**. Extension and coordination of Planning and Engineering guidance and processes to address the gap that currently exists between ecologists and engineers. This should be based on R&D into a) the best engineering methods to

support ecosystem restoration projects, and b) the best metrics for ecologists to furnish to engineers to assure project success. This would focus on integrating design with habitat form, function, and maintenance, since these are physical processes that can be defined. A further step of tying species response to physical changes should not be included in this work unit, since the temporal and spatial variance is too great. This work unit should focus on fully integrating what is currently known in the engineering and ecological disciplines into a coherent approach.

e. **Consequences if Requirement Not Met**. The current consequences of not meeting this requirement include the following: a. Projects which cannot achieve goals in a sustainable manner b. Delays (or in some cases cancellation) of projects due to lack of coordination among disciplines. c. Increased projects costs due to delays, and to lost opportunities in shared data collection and information gathering. d. Decreased customer satisfaction.

f. **Product Recommendation.** This R&D should be conducted jointly by the Institute of Water Resources (IWR), Coastal & Hydraulics Laboratory, and Environmental Laboratory. The hydraulic engineering component should be overseen by a Project Development Team (PDT) using the expert Committee on Channel Stabilization as a nucleus. The results should be included in applicable guidance that is coordinated through both Planning and Engineering functions.

5. **Natural Channel Design Manual**

a. **Tracking Number** 2008-F-79

b. **Need that Drives Requirement**. The Corps is presently involved in river restoration projects throughout the country in which the goal is to restore habitat, improve fisheries and stabilize fluvial sediments. While the NRCS National Engineering Handbook does a thorough job of documenting Rosgen's methods for natural channel design, there is presently little Corps guidance for design and construction of river restoration projects using channel design methods that fully utilize our hydraulic engineering modeling capability in sediment transport, hydraulics, and hydrology. The Corps has designed and constructed many stream restoration projects using non-Rosgen methods, but has not documented the methodology in a comprehensive manner. Hydraulic and design engineers need this guidance to improve the likelihood of a stable and functional stream restoration project. (Note: the term "natural channel design" is normally associated with the methodology published by Dave Rosgen. It's used here to describe the design of a channel that has the appearance and function of a natural channel to the maximum extent possible.)

c. **Extent of Need Across USACE**. This need exists through all Corps districts.

d. **Requirement**. Perform literature review and critical evaluation of restoration channel design methodologies. Document experiences of field engineers with significant experience in successful natural channel designs. Document lessons learned from constructed stream restoration projects. The final product should be a design manual that has incorporates the results of these investigations into a step-by-step procedure for natural channel design that meets the highest hydraulic engineering standards of the Corps.

e. **Consequences if Requirement Not Met**. Not meeting this need will result in poorly designed and non-functioning river restoration projects. In many cases failure of the project will result in loss of habitat and the production of sediment that will ultimately have to be removed from federal navigation or flood control channels.
f. **Product Recommendation.** This R&D should result in a manual that hydraulic and design engineers can use to guide them though a river restoration project. The Corps expert Committee on Channel Stabilization should be involved in work unit oversight. Division technical experts in sedimentation should be included in the field review.

6. **Watershed Sediment Management: R&D to support engineering assessments**
   a. **Tracking Number** 2008-F-42
   b. **Need that Drives Requirement**. Corps districts need relevant and up-to-date methods for evaluating the technical effectiveness of sediment reduction measures. While these measures are proposed in an increasing number of watershed studies, their benefits (in decreased sediment yield) are not adequately estimated without overall guidance. The accurate technical estimation of the benefit (or impact) of various alternatives on sediment volumes and channel stability is critical to an appropriate plan formulation process. Existing guidance has not been updated to incorporate advances in the understanding and analysis of sedimentation, to address innovative practices, or to discuss current automation tools (such as GIS).
   c. **Extent of Need Across USACE**. This need exists through all Corps districts. An increasing number of studies include sediment reduction as a goal.
   d. **Requirement**. R&D to answer technical questions in several areas, with eventual incorporation in guidance. These areas include an evaluation of current sediment management techniques, recommended software and analysis methods , data collection, quantifying uncertainty in the data used - model selection and results, how to deal with data gaps and unknowns, impacts of region and land use on results, incorporation of current methods such as GIS, and others.
   e. **Consequences if Requirement Not Met**. The consequences of not meeting this need include: a. Delays in approval or requests for reformulation b. Watershed projects that do not deliver the intended benefits due to inaccurate technical estimates of sediment reduction. c. Increased study costs due to data and modeling unknowns.
   f. **Product Recommendation.** The final product should be cost-effective and available for use. It should take advantage of completed and ongoing R&D to the maximum extent possible. This would involve significant coordination with other federal agencies (USGS, NRCS, EPA, etc.), as well as state, local, and non-governmental organizations. The methods developed should be coordinated with field personnel, and should also be demonstrated to ensure utility. Three to five district studies should be selected as demonstration sites; the methods developed should be coordinated with the district personnel implementing these studies. The final products should be incorporated into Corps guidance. The R&D efforts

should be undertaken by ERDC-CHL (and coordinated with IWR through the Regional Sediment Management Program).

7. Evalutaion of Sediment Flushing and Other Means of Sediment Bypass for Reservoirs

a. **Tracking Number** 2008-F-40

b. **Need that Drives Requirement**. Sediment deposition reduces the useful life of reservoirs and often severely impacts authorized project purposes. Many USACE reservoirs are nearing the end or have exceeded their project lives and others are experiencing decreased project benefits due to sediment deposition. Flushing and other means of sediment bypass through reservoirs offer potential solutions for reducing the deposition of sediment thereby extending their useful lives. While flushing can be effective in reducing sediment deposition, the effects of sediment that is flushed must also be considered as it relates to water quality and downstream channel morphology. Also, the loss of coastal wetlands and freshwater marshes, particularly along the gulf coast region of the United States, is an ecological problem with far-reaching consequences and may be related to the reduction in available fine grain sediment load of the river system which feeds the wetlands. Fine grain sediment is required for the restoration of degraded wetland areas as well as the long term maintenance of healthy marsh. Reservoirs located along the main stem and tributaries of the upper river system may trap much of the fine grain sediment, preventing the material from ever reaching the coastal boundary. The re-entrainment of fine grain material deposited in reservoir pools through flushing operations, and the bypass of sediment through the reservoir by means of tunnels or conduits are potential solutions for addressing the deposition of fine grain sediment in the reservoirs. The feasibility of these methods to prevent deposition of material in the reservoirs and to supply the material to the river system for potential delivery to the coastal zone needs to be addressed.

c. **Extent of Need Across USACE**. The USACE maintains and operates more than 380 dams and reservoirs within the United States. Continued sediment deposition within these reservoirs results in the loss of storage allocated for project uses such as flood control, water supply, hydropower, recreation, and environmental purposes. With rising costs, as well as adverse environmental impacts of constructing new dams, the need for extending the useful life of existing reservoirs is becoming increasingly important. Research offers the benefit of developing more universal methods of increasing the useful life of reservoirs by reducing the amount of sediment that is being trapped in our reservoirs and possibly removing portions of the material already deposited, thus preventing additional depletion of storage or recovering storage lost due to sediment deposition. Also, USACE districts, as well as other federal agencies such as the U.S. Bureau of Reclamation, that own/operate reservoirs need effective ways to prevent the retention of fine grain sediment that could potentially be used for wetland restoration and maintenance farther downstream.

d. **Requirement**. R&D requirement is to develop methodology and necessary models for evaluating the potential for flushing and re-entraining sediment

through reservoir operational techniques/manipulation, and to develop models, physical and numerical, to determine hydraulic functionality and structure configuration of potential sediment bypass systems. Furthermore, analysis needs to be conducted to evaluate the intermediate impacts of bypassed sediment on the geomorphology of the river system between the reservoir and the ultimate destination of the sediment to ensure that no adverse impacts are created.

e. **Consequences if Requirement Not Met**. The consequences of not meeting the requirement include the continued reduction in the useful lives of existing reservoirs and the loss of project benefits due to storage volume depletion. Additional consequences include a lost potential opportunity to increase the available sediment concentrations which could be beneficial to slowing or halting the continued loss of coastal wetlands and marshes.

f. **Product Recommendation.** Methodology and guidance for analysis and design of sediment flushing procedures and sediment bypass systems. Increased understanding and modeling capabilities for assessment of both temporal and spatially varied morphological changes within the entire system.

8. Sediment Modeling Tools

a. **Tracking Number** 2008-F-57

b. **Need that Drives Requirement**. Watershed erosion and sediment transport modeling are crucial to the Corps' navigation mission and are finding increased application as the Corps takes on environmental rehabilitation work. Dredging of inland waterways, channel restoration, dam removal, bank stabilization, reservoir operation, Total Maximum Daily Load (TMDL) computations and water quality best management practices(BMPs) planning all require significant sediment analysis. Additionally, the Corps is beginning to consider the impact of bed change on levee risk (which can be the result of either erosion or deposition) and certification. Analyses of this type are notoriously complex yet nearly all of the technology available in Corps models is decades old and targeted to historical applications (e.g. dredging). There have been notable advancements in the last 20 years that should be incorporated in the Corps' sediment models. Additionally, there are and other problems require original, innovative R&D solutions. Finally, because of the significant uncertainty associated with sediment data and analysis, it is also imperative that Corps sediment models begin to incorporate stochastic principles in their simulations, allowing users to articulate results in terms of outcome uncertainty.

c. **Extent of Need Across USACE**. Any Corps of Engineers District with dredging, levee certification, channel modification, river restoration, reservoir management, dam removal or watershed management missions needs to perform sediment transport analyses. Increasingly the Corps of Engineers is asked to perform detailed sediment studies to justify these efforts, select strategies or predict outcomes.

d. **Requirement**. R&D products (main stream H&H models) that are heavily used in Corps planning studies need to be able to model the detailed aspects of water movement in urban areas. Most Corps of Engineers software products for H&H analyses have only recently added rudimentary sediment capabilities and still

require serious research and development before they are robust enough to answer the kinds of questions district engineers and biologists are likely to pose in the next decade.

e. **Consequences if Requirement Not Met**. The consequences for not meeting this requirement include the inability to perform detailed sediment analysis for Corps planning studies. Consequences of poorly planned sediment management include bank failure, levee risk (from toe scour and aggredation), unplanned or unnecessary dredging costs and habitat degradation.

f. **Product Recommendation.** Specific products to provide this capability should draw on methods and technology available from peer reviewed literature and other research institutions. Design and development of techniques and computer algorithms should be consistent with published standards for sediment transport modeling. However, wherever possible short-comings of existing techniques should be identified, and improved methodologies should be researched and developed wherever possible.

9. Web-based Storage and Retrieval System for Channel Cross-Section Data

a. **Tracking Number** 2014-F-4

b. **Need that Drives Requirement**. USGS gage data is readily accessible via the internet, and accordingly, academic and other research literature extensively utilizes gage data to draw broad conclusions about degradation or aggradation trends. The COE has invested hundreds of millions of dollars in regular bathymetric surveys which, if they were more easily accessible, could likewise be used by academic, Corps of Engineers, and other researchers to develop good science to improve management of our flood control channels. Unfortunately, the hassle involved in requesting data from the Corps of Engineers, plus the time it takes to meet such requests, severely limits the use of the data. The need for better management of large amounts of cross-section data has been so pressing in the Kansas City District that we contracted the development of a tool for querying, displaying, exporting, and generating useful geomorphic information.

c. **Extent of Need Across USACE**. Virtually all districts with flood control or navigation projects use cross-sections as a method for assessing channel degradation or aggradation over time. I know of no district that has made this data easily available for widespread benefit.

d. **Requirement**. The Kansas City District (NWK) has an especially robust dataset, which we have compiled into a single database with tens of thousands of cross-sections. We recently contracted with North Arrow Research to develop a tool for querying, displaying, exporting, and generating useful geomorphic information from the cross-sections. This tool has been developed as a desktop utility, but could easily be implemented on a web platform to allow easy access by researchers outside of the Corps. The architecture for storage, display, and information generation is already built. The tool would need to be adapted to operate in a web browser, the data stored on ERDC servers, and other districts made aware of how to format and upload their own data.

e. **Consequences if Requirement Not Met**. Business as usual means a continued under-utilization of hundreds of millions of dollars in excellent bathymetric data.

Adapting the NWK Cross-section Viewer/Analysis tool for web-based storage and retrieval will allow that data to be used more broadly and help the Corps to better understand and manage our projects.

f. **Product Recommendation.** An adaptation of the NWK Cross-section Analysis/Viewer tool to allow web-based storage and retrieval of information. Presentation of the tool at the 2015 sediment conference, through webinars, or other appropriate venues for technology transfer to other districts.

10. Sediment Data Collection Techniques and Model Applications

a. **Tracking Number** 2008-F-42

b. **Need that Drives Requirement**. Many Corps of Engineers projects have a component which must consider sedimentation effects. These investigations often involve the use of a suite of sediment models. The current and future generation of these sediment models will utilize 1, 2 and 3D hydrodynamics, and will potentially have the highest degree of uncertainty of any models used in H&H work. Successful, cost effective modeling requires the utilization of the correct balance of sediment and bathymetric data, field investigation, and experience. Sediment and bathymetric data are often scarce and expensive to acquire. Some of the newer techniques, such as particle tracking, are quite expensive and represent a substantial project investment. The purpose of this proposal is to develop guidance to assist Corps personnel in making decisions on the value of different data collection strategies, as well as the optimization of data collection and modeling efforts.

c. **Extent of Need Across USACE**. Most Corps offices require sediment impact assessments and modeling at various degrees of complexity.

d. **Requirement**. The R&D requirement for this need is to develop a coordinated approach for evaluating data requirements, data collection protocols, optimization of data, effective incorporation of data into sediment models, and value of data for a variety of sediment assessment and transport models utilized in large and small scale applications.

e. **Consequences if Requirement Not Met**. The consequences for not meeting the requirement are increased cost and uncertainty of results which impact project life cycle performance.

f. **Product Recommendation.** The products from this work are guidelines and methodologies that will help project managers and engineers make decisions on data collection efforts for a variety of applications, with the intent of optimizing model parameter input. This guidance will help reduce the uncertainty of model input data and therefore reduce the uncertainty of model results. A specific goal of the work should be the development of a PROSPECT course, along with workshops which will describe field data collection techniques, new technologies, and the selection and application of sediment assessment and transport models that are currently available.

OTHER CONSIDERATIONS

Research needs were discussed in both the 2014 conference call held by the Committee and in the 2009 workshop on river engineering capability (Remus and Jonas, 2010). Other considerations related to research are identified below.

- There is a continuing need for river engineering research: not all the work has been done.
- The river engineering community of practice should identify and articulate research needs.
- Training and technology transfer of research products is essential.
- In the past, river engineers at USACE Divisions and Headquarters played a critical role in maintaining the agency's focus on both research and training related to river engineering.

SUMMARY AND CONCLUSIONS

River engineering is one of the essential technical competencies of the Corps of Engineers. Ongoing research is required to answer critical questions and address current topics. This paper discusses submitted SONs in the field of river engineering, and the identification of high priority research needs by the expert committee. A logical next step would be the development of an overall strategic plan for river engineering research needs for the Corps. Ideally, this could be used to coordinate efforts with other federal agencies and entities.

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