Problem Title: HY-8 Culvert Analysis Program – Phase Three of Development Efforts

Research Problem Statement

Background

The FHWA has been producing computerized culvert hydraulic software since the early 1960's (with the HY-1 program).

The HY-8 is a computerized implementation of FHWA culvert hydraulic approaches and protocols. The FHWA publication "Hydraulic Design Series 5: Hydraulic Design of Highway Culverts" (HDS-5) [publication FHWA-NHI-01-020, May 2005 revision] documents the technical methods applied in the HY-8 program and should be considered the primary technical reference for the software.

DOS Versions

The initial HY-8 program was first released in the early 1980's by the Pennsylvania State University, in cooperation with FHWA (versions 1.1, 2.1, and 3.0). Mr. Philip L. Thompson developed later versions of HY-8 (i.e., versions 3.1, 4.1, and 6.0). Mr. Thompson provided these versions to the Federal Highway Administration (FHWA) for distribution. The version 6.0 release added energy dissipation, hydrograph generation, and routing modules. The version 6.1 release corrected some minor fixes and added small enhancement. This remained the official release for many years.

All of these versions were written in the Basic programming language and operated on the DOS operating system. The use of this operating system led to issues and limitations as software, hardware, and operating systems progressed through the years.

Windows Versions

In 2005, the FHWA contracted with Brigham Young University to develop a Windows compatible version of HY-8. This version provided graphical user interface (GUI) for the same hydraulic calculations performed in version 6.1 of HY-8. In the course of the development all program functions have been translated to C++. The software architecture design should allow future versions to run on 32-bit and 64-bit hardware platforms.

Budgetary limitations required FHWA to plan this development effort using a series of planned phases. The first phase resulted in an initial release (version 7.0) that performed basic culvert hydraulics. The second phase (version 7.1) incorporated energy dissipater module; performed hydraulic analyses of embedded culverts; allowed use of modified outlet loss coefficients; incorporates dynamic culvert shape database with new materials; and implemented various improvements, technical updates, and bug corrections.

Current Status

Since the release of version 7.1, the FHWA has budgeted a maintenance effort to correct bugs in the software. Unfortunately, the FHWA does not have sufficient funds to continue to the next phase of HY-8 development (phase three).

Several State DOTs have suggested that the FHWA pursue phase three (and subsequent phases) through the pooled fund project (PFP) process.

Objectives

The objective of this Task Order is to continue the phased development of the 32-bit (non-DOS) non-proprietary software product for the analysis and design of culverts called HY-8 (current version 7.1). The effort would be funded by FHWA and other State DOT contributors (PFP members).

Scope of Work

The scope of work consists of continued development efforts on the HY-8 software (phase three of the on-going development effort).

Tasks

The project will consist of the tasks described below. Where possible, the tasks may be developed concurrently. Some tasks will require technical review and approval by PFP members before any programming efforts.

Task 1 – Project Meetings

Periodically, the contractor should be prepared to engage in brief project meetings with the FHWA technical manager and technical reviewers. The FHWA anticipates these meetings will occur via teleconference which requires no long distance travel.

Task 2 – Enhance Source Code Efficiencies

Update the existing source code to enhance operation and increase efficiencies. Much of these code changes are in preparation for rewriting the profile computation code to account for hydraulic jumps in the analysis. Specifically:

1. Go through the entire HY-8 analysis code and resize arrays to appropriate sizes and modify code so all the arrays are all zero-based instead of 1-based arrays.
2. Modify and simplify some analysis code to make it easier to understand program operation.
3. Remove all unnecessary variables and re-factor much of the user interface code.

Task 3 – Hydrograph Routing

Implement hydrograph routing into the HY-8 program. The routing approach will be consistent with FHWA methods and practices.

The data for determining the inflow hydrograph and stage-storage curves would be supplied by the user. The task will also consider additional approaches to enter this information.

Task 4 – Hydraulic Jump Code Implementation

The phase two HY-8 development efforts developed a theoretical framework and "pseudo-code" for computing hydraulic jumps.[1] The FHWA reviewed the resulting product to ascertain whether they corresponded to FHWA guidance and practices.

This task will implement algorithms for analyzing hydraulic jumps in all currently available HY-8 V 7.1 shapes. This task requires that HY-8 profile computation code be cleaned and modified to include the computations (Task 2).

The task will borrow logic from the BCAP program for hydraulic jumps to facilitate the necessary calculations, but will enhance the approach by computing a backwater curve upstream from the culvert outlet.[2]

Task 5 – Broken Back Culvert Code Implementation

Implement algorithms for analyzing broken-back culverts for all currently available HY-8 V 7.1 shapes.

The FHWA recognizes that incorporating a broken-back shape into HY-8 represents a major change in coding structure and logic because the hydraulic control for headwater calculations may occur at the culvert inlet, break in slope, or outlet.

Before beginning any programming, the consultant will provide the PFP members, for review and approval, a written description of proposed the technical approaches. This ensures these correspond to FHWA (or AASHTO) guidance and practices.

Task 6 – Allow Modification of the Individual Analysis Discharge Values

In the past, users have only been allowed to enter a minimum, design, and maximum value for discharge. HY-8 computes 11 discharge values based on these three values, and there is no way to edit the individual values that HY-8 computes.

The PFP members would decide whether to keep the 11 discharge value or allow the user to specify a different (lesser or user defined) number of values.

The task would then implement a means to allow users to modify the flow values that HY-8 uses to compute the performance table in the Culvert/Crossing input dialog.

Task 7 – Horizontal Culvert Barrels

Implement the ability to analyze horizontally-sloped culvert barrels.

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[1] HEC-14 dated 1983 has a generic approach for analyzing hydraulic jumps in arbitrarily shaped barrels. Previous work has made that approach specific for the currently available barrel shapes in HY-8 V 7.1.

[2] BCAP currently assumes a horizontal water surface between the culvert outlet extending upstream to the location of a hydraulic jump.

Before beginning any programming, the consultant will provide the PFP members, for review and approval, a written description of proposed the technical approaches. This ensures these correspond to FHWA (or AASHTO) guidance and practices.

Task 8 – Adversely Sloped Barrels

Implement the ability to analyze adversely-sloped culvert barrels.

Before beginning any programming, the consultant will provide the PFP members, for review and approval, a written description of proposed the technical approaches. This ensures these correspond to FHWA (or AASHTO) guidance and practices.

Task 9 – Flared End Sections

Inlet loss coefficients (outlet control) and headwater/depth curves (inlet control) have been developed for concrete and metal flared end sections by Dr. Bruce McEnroe at the University of Kansas. The results were published in TRR 1483.

The FHWA understands that while the original reports are available, the raw data are not.

From this work, the contractor will:

1. Produce polynomial curves from the data published in the reports
2. Include the inlet loss coefficients.
3. Apply any associated Manning's 'n' values from the research or if not part of the research, apply HDS-5 associated 'n' values to the respective materials.

This new option would be identified as a "flared end sections" inlet option.

Before beginning any programming, the consultant will provide the PFP members, for review and approval, a written description of proposed the technical approaches. This ensures these correspond to FHWA (or AASHTO) guidance and practices.

Task 10 – Concrete Open-bottom Arches

Concrete open-bottom arch culverts have been tested by Professor Donald Chase at the University of Dayton and reported in 1999. Dr. Chase used small scale models on the order of the same size as those used in the original NBS work upon which HDS-5 is based.

From this work, the contractor will:

1. Determine the values of the empirical coefficients K, M, C, and Y, and convert them into the polynomial equations required by HY-8.
2. Include the inlet loss coefficients.
3. The FHWA understands that no Manning 'n' values are included in the research. Therefore, as these culverts have open bottoms, the contractor will treat them as such and need to allow a bottom 'n' value to be input to HY-8 (as is done now with the aluminum open arch box).

This new option would be identified as a "concrete open arch culvert".

Before beginning any programming, the consultant will provide the PFP members, for review and approval, a written description of proposed the technical approaches. This ensures these correspond to FHWA (or AASHTO) guidance and practices.

Task 11 – South Dakota's Prefabricated Reinforced Concrete Box Culverts

The FHWA completed an exhaustive set of tests on the "South Dakota prefabricated reinforced concrete box culvert." Separate inlet control polynomial equations and inlet loss coefficients were developed for about 50 different combinations of barrel dimensions, fillets, and inlets.

The PFP members will decide whether to include all 50 or a smaller set of culvert combinations for inclusion into HY-8.

From this set of options, the contractor will:

1. Convert the values of the empirical coefficients K, M, C, and Y into the polynomial equations required by HY-8.
2. Include the inlet loss coefficients.
3. Apply associated Manning's 'n' values from the research or if not part of the research, apply HDS-5 associated 'n' values.

This new option would be identified as a "SD Prefabricated RCB culvert" or as appropriate.

Before beginning any programming, the consultant will provide the PFP members, for review and approval, a written description of proposed the technical approaches. This ensures these correspond to FHWA (or AASHTO) guidance and practices.

Subtask K – Generic: Adding Other Culvert Shape & Materials

The PFP members may desire to add additional culvert shapes and materials to the HY-8 shapes database. This Subtask is intended to allow the contractor to perform this activity for some "generic" baseline shape or material.

Inlet control affiliated information may consist of empirical coefficients (e.g., K, M, C, and Y) or other sources (e.g., raw data, curves in reports, etc).

From this data, the contractor will:

1. As technically appropriate, the contractor shall produce polynomial curves required by HY-8.
2. The contractor will include the inlet loss coefficients.
3. The contractor will include Manning 'n' values.

Before beginning any programming, the consultant will provide the PFP members, for review and approval, a written description of proposed the technical approaches. This ensures these correspond to FHWA (or AASHTO) guidance and practices.

Estimate of Problem Funding and Research Period

Recommended Funding:	$100,000
Suggested contribution:	$10,000/year
Research Period:	36 months

Comments

The Federal Highway Administration will serve as the coordinator for this pooled-fund project. State DOT's will be solicited for their interest and participation in this study. FHWA will issue a task order contract under the NHI IDIQ contract conduct the study. Periodic reviews will be arranged to keep participating states and agencies up-to-date on current developments. These reviews may include meetings in Washington D. C. during the annual TRB Session, e-mail submittals and conference calls.

Persons Developing the Problem Statement

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