Hydraulics of Buried Invert Culverts With Natural Stream Bottoms

Presented at the

2003 Western Hydraulics Engineers Conference

Stevenson, WA

April 15-17, 2003

Blake Tullis

William Grenney

Utah State University

NCHRP Project 15-24
Hydraulic Loss Coefficients For Culverts

- Utah Water Research Lab Capabilities
- Project Objectives

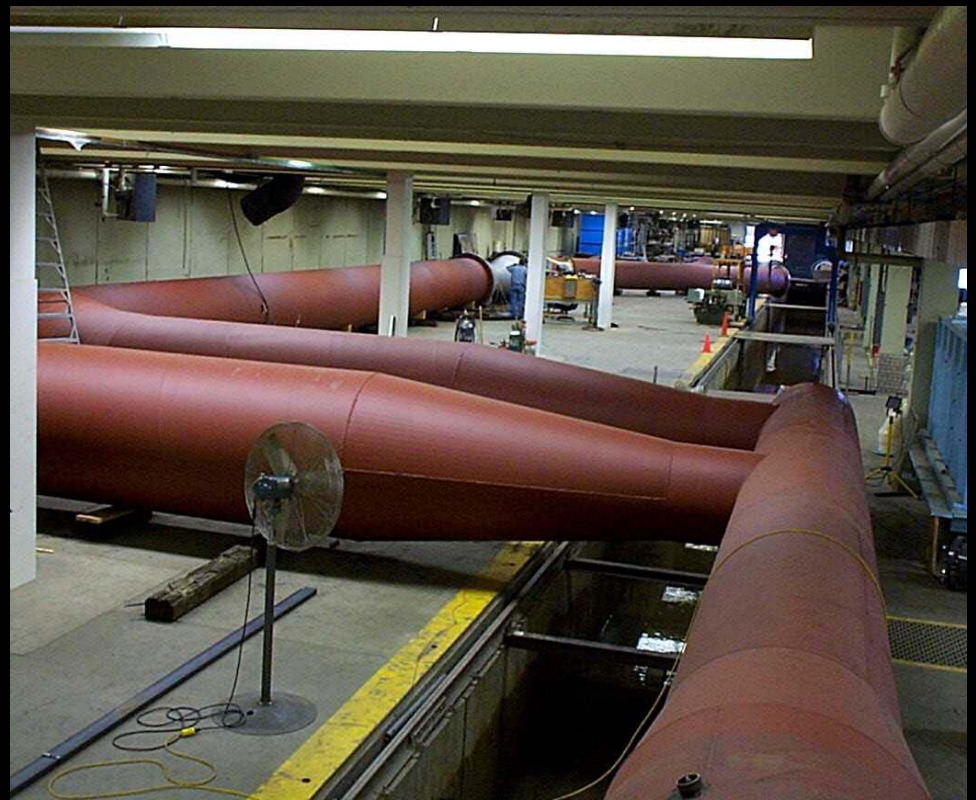
Utah Water Research Laboratory

- 102,000 sf Facility
- 50,000 sf Hydraulics Section
- Gravity flow rates up to 200 cfs
- Large flume (8'x6'x600')
- High velocity flume (4'x2'x80')
- 300,000 pound weight tank
- Rainfall simulator/erosion bed (20'x20')
- Simulated rainfall up to 31 in/hr
- 11,000 sf Environmental Quality Lab
- Extensive computer facilities
- Faculty, staff and student offices

72-inch venturi flow meter calibration

Southern Nevada Water Authority
180 Inch venturi flow meter serving Las Vegas

10-, 20-, & 60-inch models of 180-inch field piping/flow meter



Erosion Control

8’ High Velocity Flume

Durability and failure point for erosion control blankets.

Erosion Control

Rainfall Simulator

Scale River Models

(Guadalupe River, CA)

Dam Modernization & Rehabilitation

Lake Turner,

Wesley Seale, and

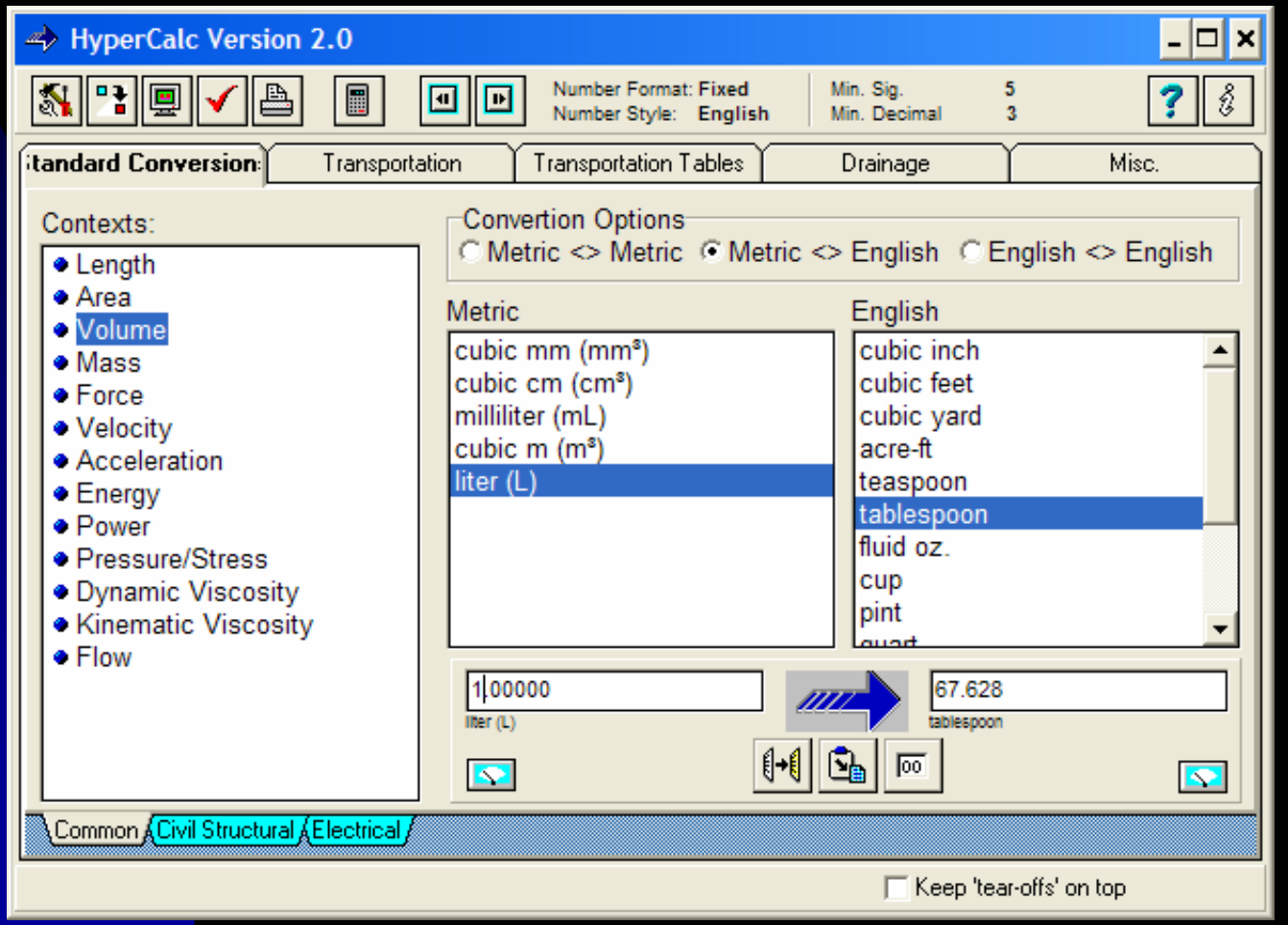
Wirtz , Texas

Pipe/Culvert Testing

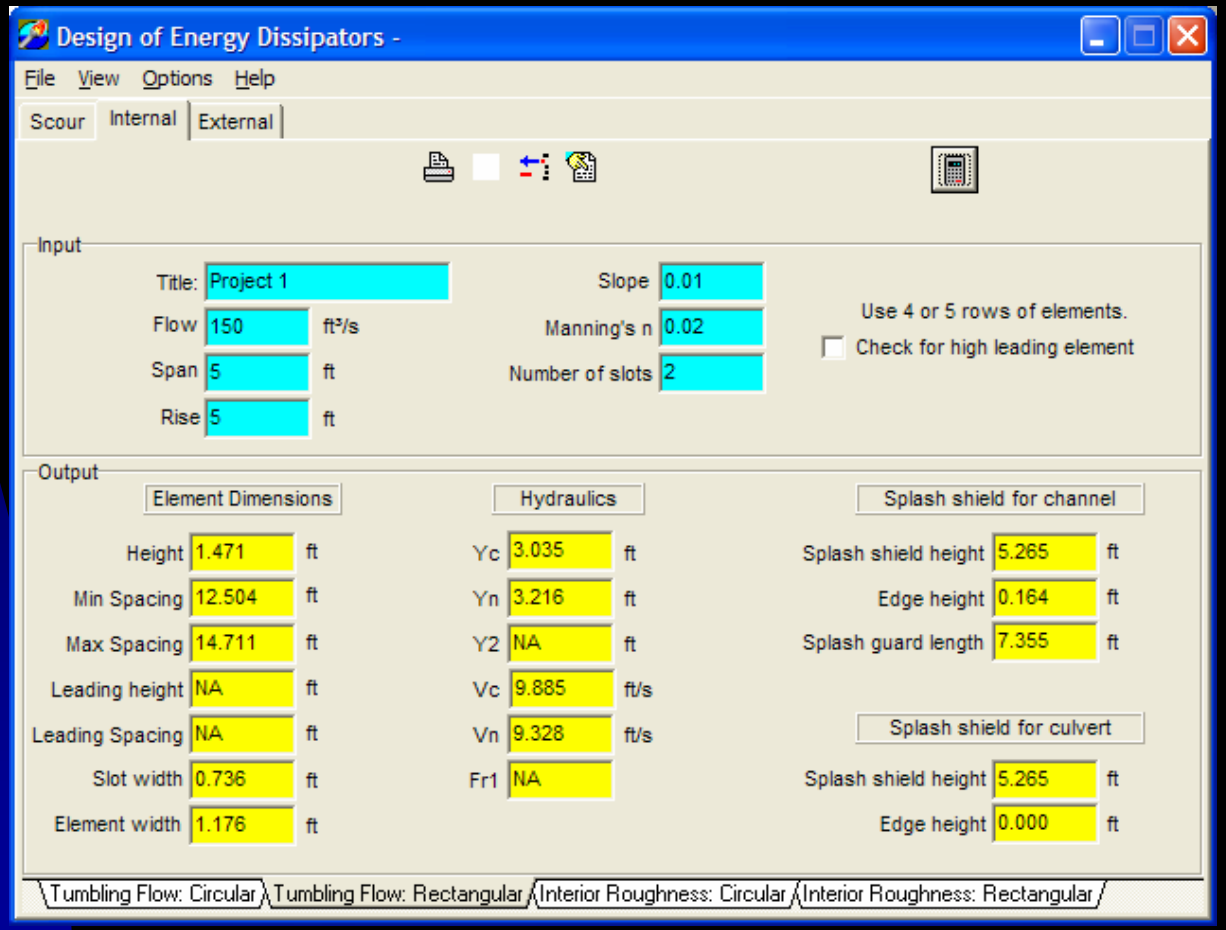
Stability of retaining wall blocks under high velocity (31 cfs) and shear stress.

Discharge velocity = 31 fps

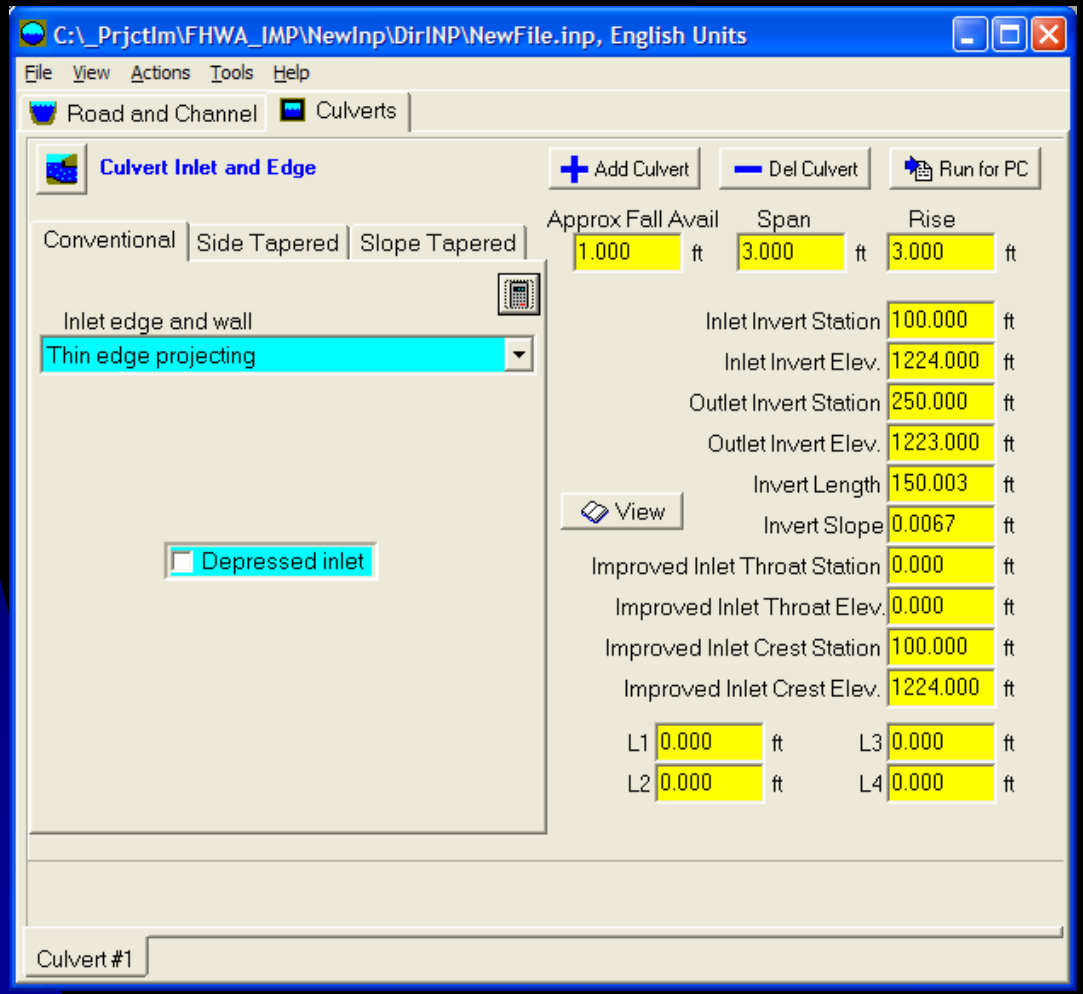
Hyper Calc


HyperCalc Version 2.0
Number Format: Fixed
Number Style: English
Min. Sig. 5
Min. Decimal 3
tandard Conversion
Transportation
Transportation Tables
Drainage
Misc.
Contexts:
Length
Area
Volume
Mass
Force
Velocity
Acceleration
Energy
Power
Pressure/Stress
Dynamic Viscosity
Kinematic Viscosity
Flow
Convertion Options
Metric <> Metric
Metric <> English
English <> English
Metric
cubic mm (mm³)
cubic cm (cm³)
milliliter (mL)
cubic m (m³)
liter (L)
English
cubic inch
cubic feet
cubic yard
acre-ft
teaspoon
tablespoon
fluid oz.
cup
pint
1.00000
liter (L)
67.628
tablespoon
Common
Civil Structural
Electrical
Keep 'tear-offs' on top

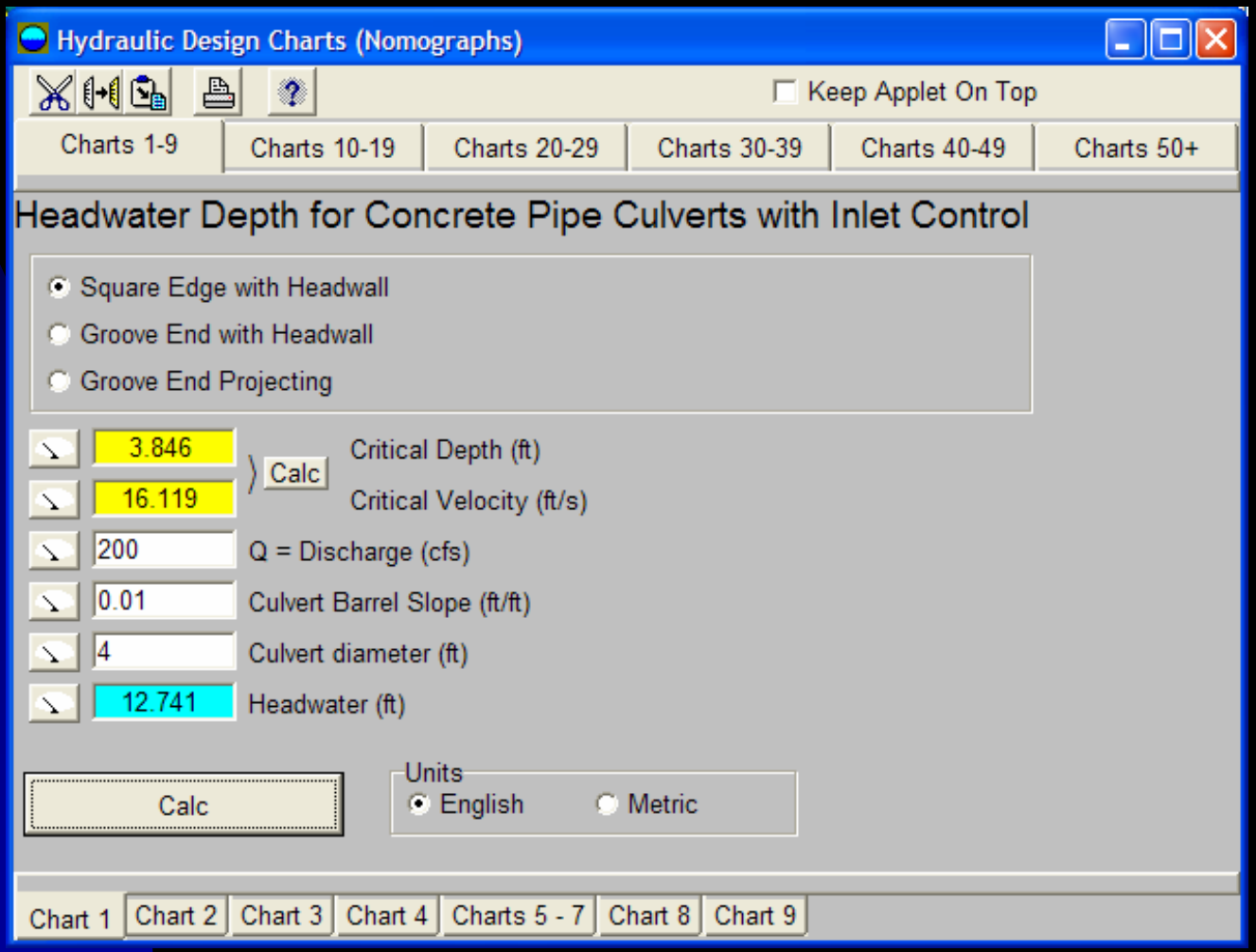
HY8 Energy


Design of Energy Dissipators -
File View Options Help
Scour Internal External
Input
Title: Project 1
Flow 150 ft³/s
Span 5 ft
Rise 5 ft
Slope 0.01
Manning's n 0.02
Number of slots 2
Use 4 or 5 rows of elements.
Check for high leading element
Output
Element Dimensions
Height 1.471 ft
Min Spacing 12.504 ft
Max Spacing 14.711 ft
Leading height NA ft
Leading Spacing NA ft
Slot width 0.736 ft
Element width 1.176 ft
Hydraulics
Yc 3.035 ft
Yn 3.216 ft
Y2 NA ft
Vc 9.885 ft/s
Vn 9.328 ft/s
Fr1 NA
Splash shield for channel
Splash shield height 5.265 ft
Edge height 0.164 ft
Splash guard length 7.355 ft
Splash shield for culvert
Splash shield height 5.265 ft
Edge height 0.000 ft
Tumbling Flow: Circular
Tumbling Flow: Rectangular
Interior Roughness: Circular
Interior Roughness: Rectangular

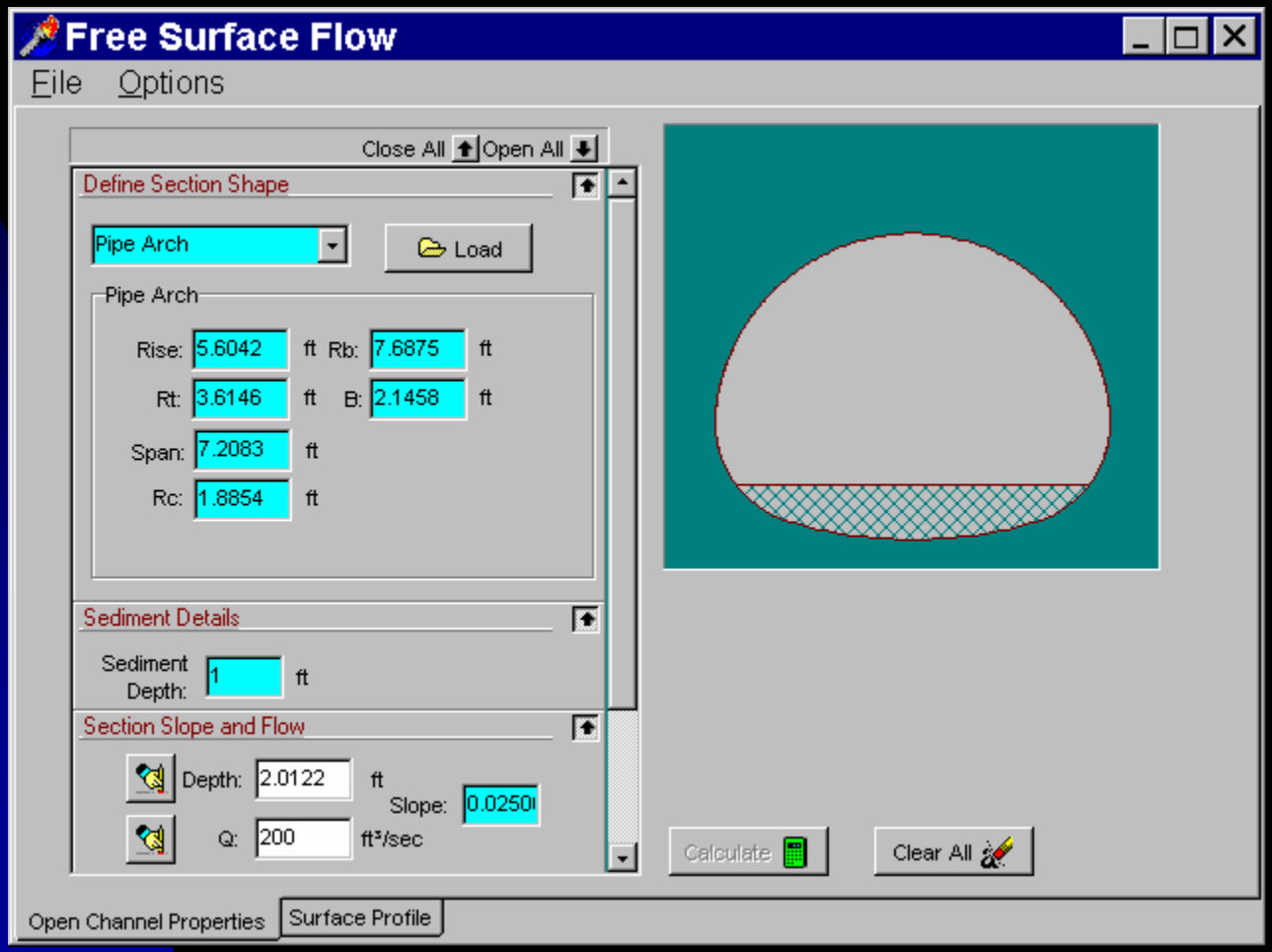
HY8 Inp Generator



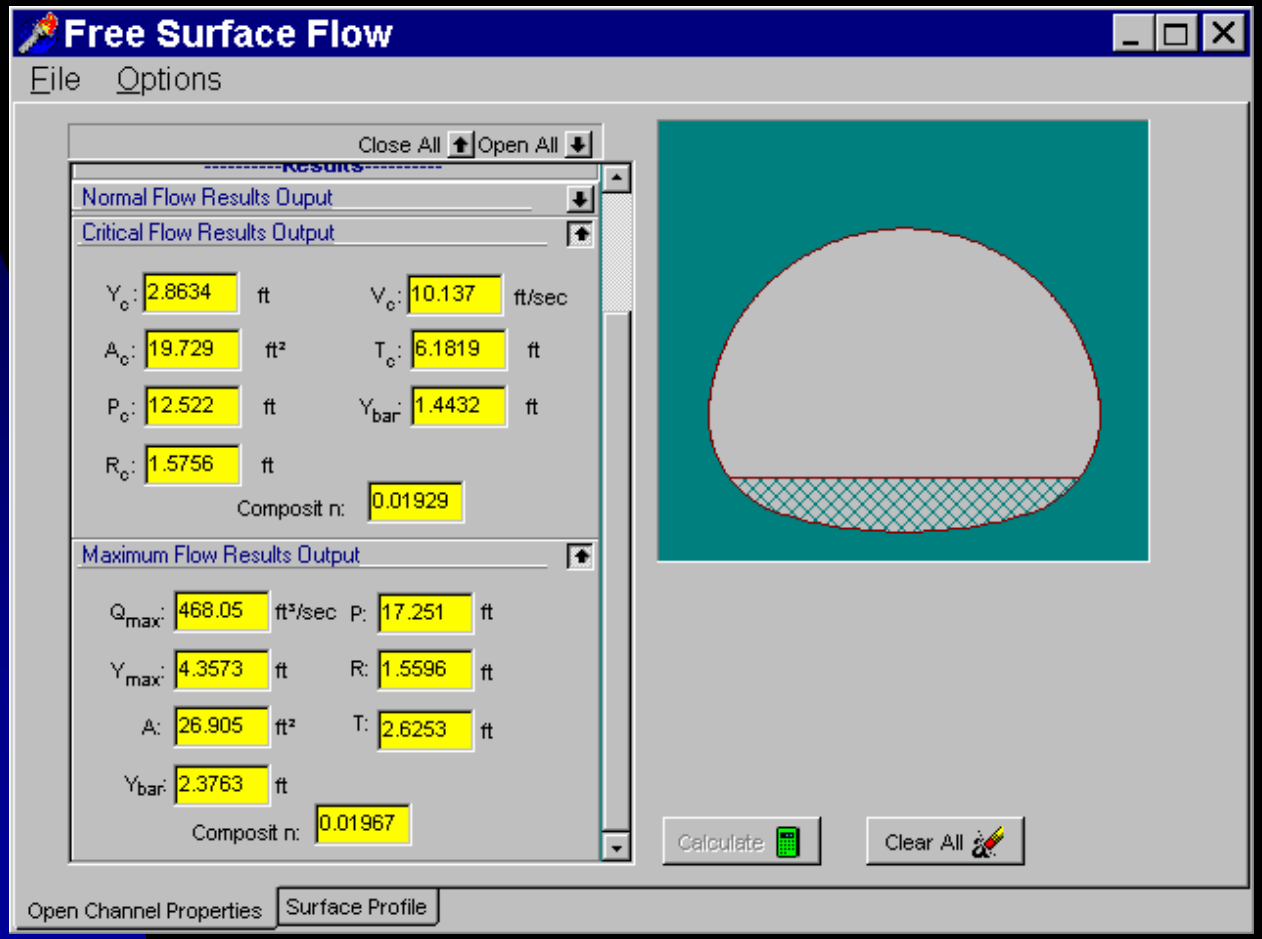
HDS-5 Chart Calculator



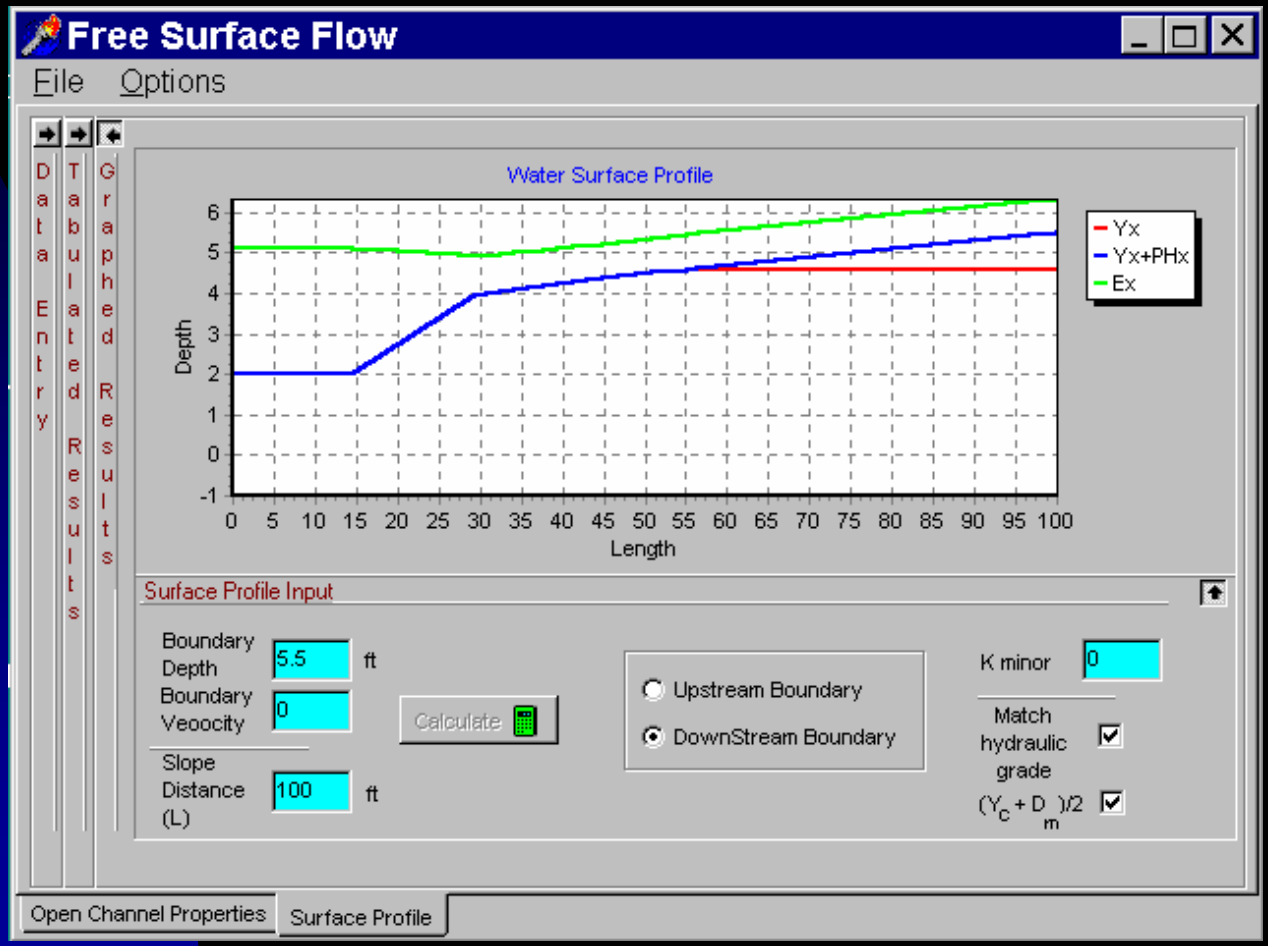
Prototype Hydraulic Model



Prototype Hydraulic Model



Prototype Hydraulic Model



Culvert loss coefficients, what's the big deal?

NCHRP Project 15-24
Project Objectives

1. *Refine and/or develop loss coefficients for conventional and nontraditional installations in environmentally sensitive applications. Specifically, this includes:*

   - *Determine inlet control design curves and entrance and exit loss coefficients for outlet control for various culvert shapes and end treatments. The order of priority for modeling/testing culvert shapes is* ***circular, rectangular/square, arch, and elliptical****.*

NCHRP Project 15-24
Project Objectives
(continued)

- *Each culvert shape tested will be evaluated for both **submerged** and **unsubmerged** conditions for the following:*
  - ***a.*** *buried and/or bottomless culverts*
  - ***b.*** *multiple circular culverts*
  - ***c.*** *rehabilitated circular culverts*

NCHRP Project 15-24 Project Objectives (continued)

2. *Develop hydraulic roughness coefficients for bottomless (i.e., open footings) or buried invert culverts. Coefficients shall be developed for both full and partially full conditions and shall include various streambed materials for both concrete and metal culverts.*

Phase I

- Literature Review

  a) Identify deficiencies in loss coefficient data base for culvert/end treatment designs for environmentally sensitive culvert installations.

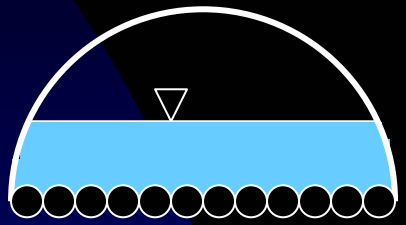
  b) Review published methods for determining flow resistance coefficients for composite channels (i.e., side wall material differs from bed material).

  c) Review published data for multi-barrel culvert installations

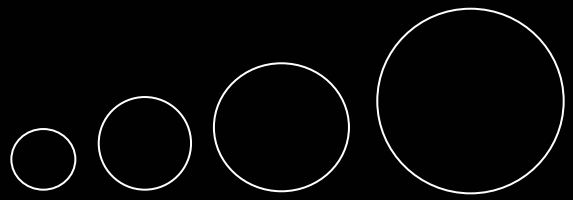
- Finalize work plan based on results of literature review

Phase II Laboratory Testing

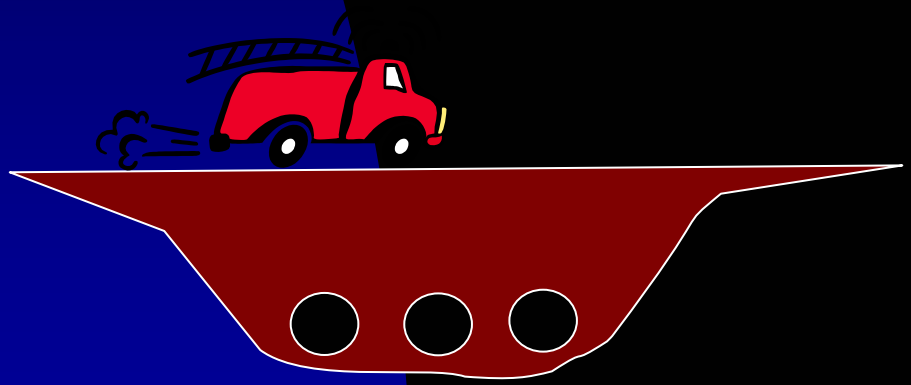
Key Issues



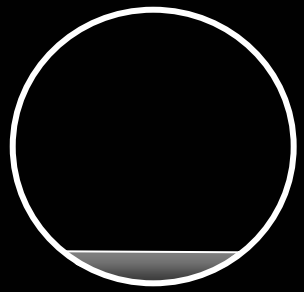
Composite Roughness Coefficients
(Flow vs. Depth relationship)



Size-scale effects by testing both small and large diameter culverts (possibly up to 48-inch diameter).



Loss coefficients for multi-barrel culverts
(size and spacing, approach flow non-uniformity, etc.)



Loss coefficients for rehabilitated culverts

Supplemental Material Sources

Several culvert manufactures have agreed to provide free culvert and end treatment materials for the project

- Advanced Drainage Systems, Inc.
- Construction Products, Inc.
- Mountain States Concrete Pipe Assoc.

Presentation of Results

- A description of the experimental design justifying the scaling techniques and model dimensions.
- A compendium of experimental data on CD ROM
- A set of design charts and graphs similar to those in the Appendix of HDS 5.
- Equations and coefficients that can be used to directly calculate values of the design parameters.