VE #201301
Headwalls Standards Process Improvement

Value Engineering Study Report

STANDARD
DRAWINGS

KENTUCKY

DEPARTMENT OF HIGHWAYS
HEADWALL SUPPLEMENT
RDH SERIES

Study Dates: March 11-13, 2013

Kentucky Transportation Cabinet
Division of Highway Design
200 Mero Street
Frankfort, KY 40622

Contact: **Renee L. Hoekstra, CVS**
(623) 266-3943

March 2013

RHA

"Partnering, Public Information & Value Specialists"

June 3rd, 2013

Mr. Brent Sweger
Kentucky Transportation Cabinet
Division of Professional Services
200 Mero Street
Frankfort, KY 40622

Re: Headwalls Standards Process Improvement
Final Value Engineering Study Report

Dear Brent:

Transmitted herewith is the pdf copy of the Final Value Engineering Study Report for the above referenced project. Two (2) hard copies will be delivered to your office.

RHA appreciates your assistance and cooperation. Should you have any questions please telephone me at (623) 266-3943.

Sincerely,

RH & ASSOCIATES, INC.

Renee L. Hoekstra, CVS
President

2255 N 44th Street, Suite 170, Phoenix, AZ 85008
(623) 266-3943 (800) 480-1401 (602) 275-2972 Fax
www.rhpartnering.com

Table of Contents

Introduction

Executive Summary

Process Description

VE Recommendations

Appendices

INTRODUCTION

Introduction

The value methodology (Synonyms: value analysis, value engineering and value management) is a function-oriented, systematic, team approach to add customer value to a program, facility, system, or service. Improvements like performance, quality, initial and life cycle cost are paramount in the value methodology. The value engineering workshop was conducted in accordance with the methodology as established by SAVE International, the value society, and was structured using the Job Plan as outlined below:

Value Methodology

- **Pre-Study**
    - Identify team members
    - Define workshop location
    - Review project documentation
    - Prepare for the study (workshop)
- **Value Study (Workshop) Job Plan**
    - *Information Phase*
        - Gather, organize and analyze data,
        - Define costs and cost models,
        - Define the problem/purpose of the study,
        - Define study scope, define project goals and workshop goals
        - Complete a gap analysis
    - *Function Analysis Phase*
        - Define and evaluate functions
        - Define needs versus wants
    - *Creative Phase*
        - What else will perform the functions?
        - Is this function required?
    - *Evaluation Phase*
        - Rank and rate the ideas to select
        - Refine the best ideas for further development
    - *Development Phase*
        - Develop the best ideas into VE Alternatives with support and justification
    - *Presentation/Implementation*
        - VE team presents results
        - Prepare and issue the report
        - Report implementation ideas
- **Post Study**
    - Implement approved alternatives
    - Monitor status

Report Content

The report provides the outcomes associated with this VE workshop. The report includes the following sections:

Introduction – This section outlines the VE process and explains the content of the report.

Executive Summary – An overview which includes the VE process, the VE punch list which is to be used during the implementation meeting, a list of the VE study team members and the certification is included.

Process Description – This section describes the process in more detail for the reader to gain a better understanding of the study.

VE Recommendations – Each completed alternative has a separate workbook. Each workbook contains the following information:

- Original Concept
- Alternative Concept
- Advantages and Disadvantages of the Proposed Alternative
- Implementation Requirements
- Performance Ratings
- Discussion
- Supporting Material; Drawings and/or Sketches, Details or Specifications, as possible

Appendices

A – Study Participants
B – Function Analysis
C - Creative List and Evaluation
D – Supporting Data
    i. Gap Analysis
    ii. List of Standard KYTC VE Report Abbreviations

EXECUTIVE SUMMARY

Executive Summary

Background

A Value Engineering (VE) study was conducted during March 11-13, 2013 for the Kentucky Transportation Cabinet (KYTC) for the Headwalls Standards Process Improvement. The VE team identified the project goals as improving the current standards for headwalls.

The VE team identified the workshop objectives at the start of the workshop;

- Ensure that the standards include current/today's materials and practices
- Need to consider that the design should match function
- Verify the accuracy of current standards
- Ensure that the standards are adaptable to changing needs, designs and requirements
- Ensure the standards are flexible in nature
- Avoid proprietary approaches
- Simplify the standards
- Ensure approaches are cost effective
- Standards should accommodate necessary aesthetics

Process Constraints

The VE team identified the project constraints for the VE team at the start of the VE study as:

- There are existing attitudes within the cabinet related to "It's just the way it is", which may make change difficult
- There may be some issues with the impact to the precast industry
- The standards shouldn't add significant costs
- There may be liability concerns related to providing detailed designs versus performance specifications

Process Descriptions

The Headwall Supplement Book was first printed as an independent book in 1983. Previously Roadway Drainage Headwall (RDH) drawings were a part of the Standard Drawing Book and reprinted each time the book was updated, which currently is every four years. The Standard Drawing Book was last revised and reprinted in January 2012. The next printing is scheduled for January of 2016 with the revision process starting in the early part of 2015.

The current Headwall Supplement Book was last revised in 2000. Since that time there has been no updates or revisions made to charts or drawings in it, and in fact, many of the drawings and standards predate 2000. A copy of the Headwall Supplement Book in its current state is issued each time the Standard Drawing Book is reprinted and released.

For this reason it was determined that a Value Engineering Study would be a useful tool to evaluate the current Headwall Supplement Book. Given this is not a project specific study as most VE studies are, the scope of this study is twofold:

1. To look for more efficient ways to design and construct headwalls using current industry materials and construction practices, and

2. Look for ways to realize immediate and long-term cost savings to Kentucky both in the manufacturing of and in the installation of these structures.

Summary of Results

The VE team brainstormed a total of 56 ideas. The ideas were then categorized, as possible. Of the 56 ideas, thirteen (13) ideas were identified for further development into VE proposals, including performance impacts. The description and further discussion of these are included in the VE workbooks section of this report. The following table represents the alternatives developed.

SUMMARY OF RESULTS

No.	Description
1	Use performance specifications and eliminate the standards
2	Use precast concrete headwalls and wingwalls
3	Provide alternate materials for walls
4	Provide alternative approaches for slope protection
5	Provide alternative approaches for end treatments
6	Redesign to the current design criteria
7	Design and detail headwalls and wingwalls separately
8	Standardization of smaller pipe headwall and eliminate most details
9	Eliminate skew quantity sheets
10	All headwall designs should be together within the Standard Specification Book
11	Eliminate standard headwall
12	Use an interactive worksheet for calculations for steel and concrete to eliminate quantities within the standards
13	Integrate into the Standard Drawings and eliminate the Supplement

Gap Analysis

A formal gap analysis was completed to identify the performance of the current standards and the expected performance of the standards. This list was used to help identify the various categories for brainstorming. The gap analysis was completed and is included in Appendix E, the support data section of this report.

Function Analysis

Function definition and analysis is the heart of Value Engineering. It is the primary activity that separates VE from all other “improvement” programs. The objective of this phase is to ensure the entire team agrees upon the purposes for the project elements. Furthermore, this phase assists with development of the most beneficial areas for continuing the study. The data supporting the function analysis can be found in Appendix C.

The VE team identified the functions using active verbs and measurable nouns. This process allowed the team to truly understand all of the functions associated with a headwall. The basic functions were defined as *Retain Earth and Convey Flow*. A Function Analysis Systems Technique (FAST) diagram was completed and is included in Appendix C.

Value Engineering Study
Kentucky Transportation Cabinet
Headwalls Standards Process Improvement

VE Study Team

Renee Hoekstra, CVS, RH & Associates, Inc. – VE Team Leader
Brent Sweger, P.E., AVS, Kentucky Transportation Cabinet – VE Coordinator
Jeff Lail, Kentucky Transportation Cabinet – Standard Drawings Coordinator
Dale Carpenter, P.E., AEI – Structures Specialist
Steve Arnold, Qk4 – Hydraulics Specialist
Kenneth Ott, AEI – Structural Specialist
Phil George, P.E., Stimpel – Construction Specialist
Nick Bingham, Bingham & Bingham – Precast Specialist

Certification

This is to verify that the Value Engineering Study was conducted in accordance with standard value engineering principles and practices.

Renee L. Hoekstra

Renee L. Hoekstra, CVS
RH & Associates, Inc.

VALUE ENGINEERING PUNCH LIST

ITEM NO. N/A PROJECT COUNTY: **N/A** DATE OF STUDY: **3/4-3/8/2013** **VE # 201215**

VE Alternative Number	**VE Team Top Pick**	**Description**	**Activity** (Y,N,UC-Date)	**Implemented** Life Cycle Cost Savings	**Original Cost**	**Alternative Cost**	**Initial Cost Saving**	**Life Cycle Cost Savings** (Total Present Worth)	**FHWA Categories**	**Remarks**
Item #x										
Process: Headwall Standards										
1		Use performance specifications and eliminate the standards								
2		Use precast concrete headwalls and wingwalls								
3		Provide alternate materials for walls								
4		Provide alternative approaches for slope protection								
5		Provide alternative approaches for end treatments								
6		Redesign to the current design criteria								
7		Design and detail headwalls and wingwalls separately								
8		Eliminate most of the details of the smaller pipe headwalls and standardize								
9		Eliminate skew quantity sheets								
10		Combine all headwall standard drawings into the Standard Drawings								
11		Eliminate standard headwall								
12		Use an interactive worksheet for calculations for steel and concrete to eliminate quantities within the standards								
13		Integrate into the Standard Drawings and eliminate the Supplement								

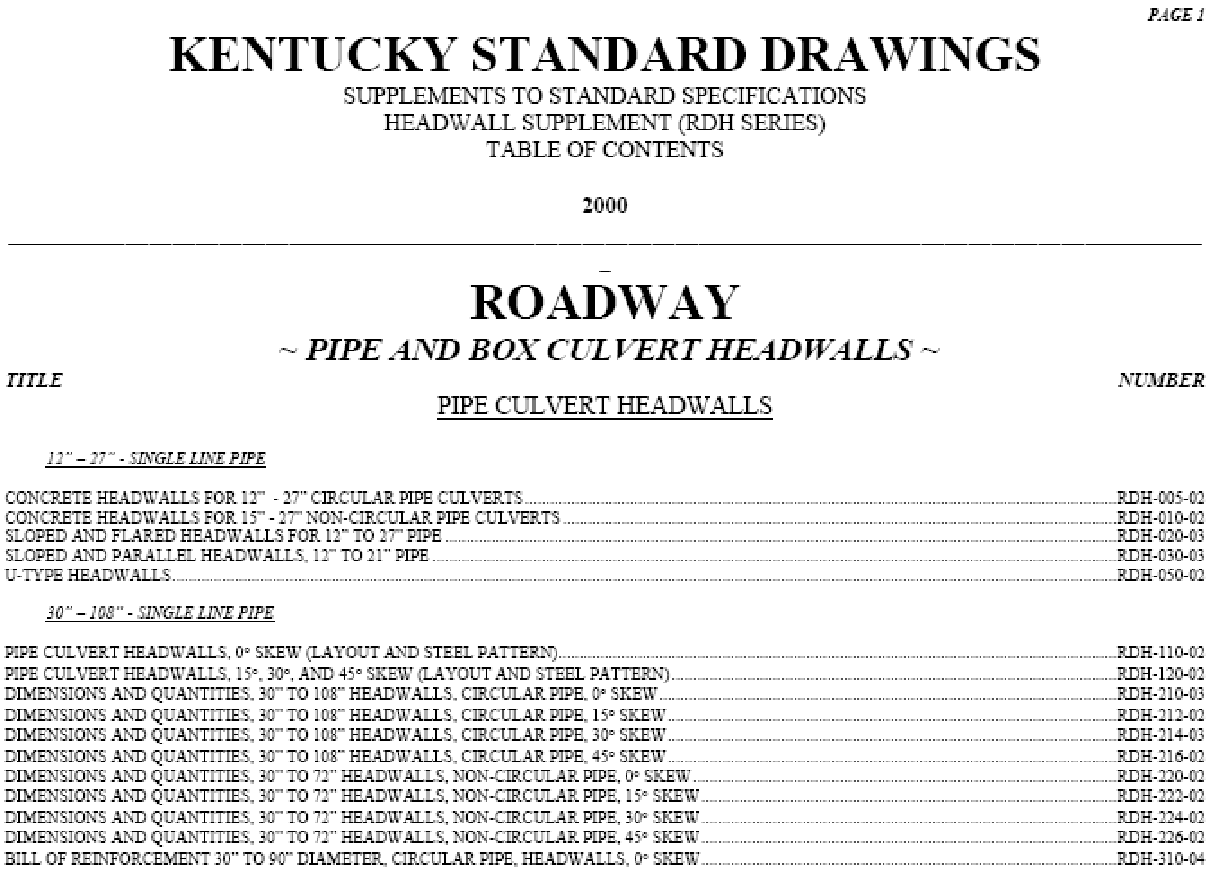
PROJECT DESCRIPTION

Introduction

The Headwall Supplement Book was first printed as an independent book in 1983. Previously RDH drawings were a part of the Standard Drawing Book and reprinted each time the book was updated, which currently is every four years. The Standard Drawing Book was last revised and reprinted in January 2012. The next printing is scheduled for January of 2016 with the revision process starting in the early part of 2015. The current supplemental standards book includes over 100 pages and includes design details for headwalls for various pipe dimensions, various box culvert sizes, dimensions and quantities.

The current Headwall Supplement Book was last revised in 2000. Since that time, there has been no updates or revisions made to charts or drawings in it. However, many of the designs have not been revised and some are not being used, and have not been eliminated. A copy of the Headwall Supplement Book in its current state is issued each time the Standard Drawing Book is reprinted and released.

The Headwall Supplement (RDH Series) to the Standard Specifications includes data for both the pipe and box culvert headwalls, see the table of contents below:



PAGE 1

KENTUCKY STANDARD DRAWINGS

SUPPLEMENTS TO STANDARD SPECIFICATIONS
HEADWALL SUPPLEMENT (RDH SERIES)
TABLE OF CONTENTS

2000

ROADWAY

~ PIPE AND BOX CULVERT HEADWALLS ~

TITLE *NUMBER*

PIPE CULVERT HEADWALLS

12" – 27" - SINGLE LINE PIPE

30" – 108" - SINGLE LINE PIPE

2000 | ***PAGE 2***

PIPE CULVERT HEADWALLS (CONTINUED)

30" – 108" SINGLE LINE PIPE (CONTINUED)

TITLE	*NUMBER*
BILL OF REINFORCEMENT 96" TO 108" DIAMETER, CIRCULAR PIPE, HEADWALLS, 0° SKEW	RDH-312-04
BILL OF REINFORCEMENT 30" TO 72" DIAMETER, CIRCULAR PIPE, HEADWALLS, 15° SKEW	RDH-320-04
BILL OF REINFORCEMENT 78" TO 108" DIAMETER, CIRCULAR PIPE, HEADWALLS, 15° SKEW	RDH-322-04
BILL OF REINFORCEMENT 30" TO 66" DIAMETER, CIRCULAR PIPE, HEADWALLS, 30° SKEW	RDH-330-04
BILL OF REINFORCEMENT 72" TO 96" DIAMETER, CIRCULAR PIPE, HEADWALLS, 30° SKEW	RDH-332-03
BILL OF REINFORCEMENT 102" TO 108" DIAMETER, CIRCULAR PIPE, HEADWALLS, 30° SKEW	RDH-334-04
BILL OF REINFORCEMENT 30" TO 66" DIAMETER, CIRCULAR PIPE, HEADWALLS, 45° SKEW	RDH-340-05
BILL OF REINFORCEMENT 72" TO 96" DIAMETER, CIRCULAR PIPE, HEADWALLS, 45° SKEW	RDH-342-04
BILL OF REINFORCEMENT 102" TO 108" DIAMETER, CIRCULAR PIPE, HEADWALLS, 45° SKEW	RDH-344-04
BILL OF REINFORCEMENT 30" TO 72" DIAMETER, NON-CIRCULAR PIPE, 0° SKEW	RDH-350-03
BILL OF REINFORCEMENT 30" TO 72" DIAMETER, NON-CIRCULAR PIPE, 15° SKEW	RDH-360-04
BILL OF REINFORCEMENT 30" TO 60" DIAMETER, NON-CIRCULAR PIPE, 30° SKEW	RDH-370-05
BILL OF REINFORCEMENT 66" TO 72" DIAMETER, NON-CIRCULAR PIPE, 30° SKEW	RDH-372-04
BILL OF REINFORCEMENT 30" TO 60" DIAMETER, NON-CIRCULAR PIPE, 45° SKEW	RDH-380-04
BILL OF REINFORCEMENT 66" TO 72" DIAMETER, NON-CIRCULAR PIPE, 45° SKEW	RDH-382-04

7'-0"X 5'-1" – 15'-4" X 9'-3" SINGLE LINE PIPE

STEEL PIPE ARCH HEADWALLS - 0° SKEW (PIPE RISE LESS THAN 6'- 0") (LAYOUT AND STEEL PATTERN)	RDH-400-02
STEEL PIPE ARCH HEADWALLS - 0° SKEW (PIPE RISE 6'- 0" OR GREATER) (LAYOUT AND STEEL PATTERN)	RDH-405-02
STEEL PIPE ARCH HEADWALLS - 15° - 30° - 45° SKEW (PIPE RISE LESS THAN 6'- 0") (LAYOUT AND STEEL PATTERN)	RDH-410-02
STEEL PIPE ARCH HEADWALLS - 15° - 30° - 45° SKEW (PIPE RISE 6'- 0" OR GREATER) (LAYOUT AND STEEL PATTERN)	RDH-415-02
DIMENSIONS STEEL PIPE ARCHES - 0° SKEW AND 15° SKEW	RDH-420-02
DIMENSIONS STEEL PIPE ARCHES - 30° SKEW AND 45° SKEW	RDH-425-02
QUANTITIES FOR STEEL PIPE ARCHES - 0° - 15° - 30° AND 45° SKEW	RDH-430-02
BILL OF REINFORCEMENT 7'- 0" X 5'-1" – 15'- 4" X 9'-3" STEEL PIPE ARCHES - 0° SKEW	RDH-435-04
BILL OF REINFORCEMENT 7'- 0" X 5'- 1" – 12'- 10" X 8'- 4" STEEL PIPE ARCHES - 15° SKEW	RDH-440-03
BILL OF REINFORCEMENT 15'- 4" X 9'- 3" STEEL PIPE ARCHES - 15° SKEW	RDH-445-03
BILL OF REINFORCEMENT 7'- 0" X 5'- 1" – 12'- 10" X 8'- 4" STEEL PIPE ARCHES - 30° SKEW	RDH-450-03
BILL OF REINFORCEMENT 15'- 4" X 9'-3" STEEL PIPE ARCHES - 30° SKEW	RDH-455-03
BILL OF REINFORCEMENT 7'- 0" X 5'- 1" – 11'- 5" X 7'- 3" STEEL PIPE ARCHES - 45° SKEW	RDH-460-03
BILL OF REINFORCEMENT 12'- 10" X 8'- 4" – 15'- 4" X 9'- 3" STEEL PIPE ARCHES - 45° SKEW	RDH-465-03

2000 | ***PAGE 3***

PIPE CULVERT HEADWALLS (CONTINUED)

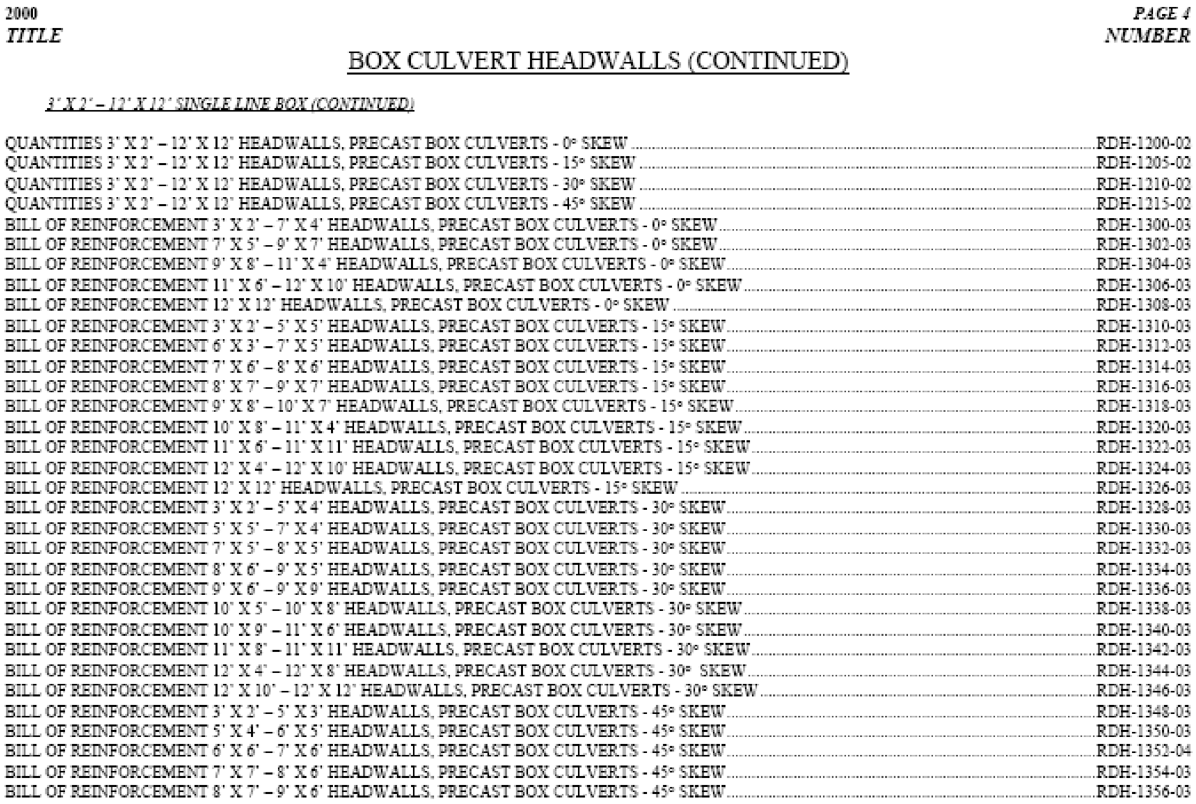
18" – 48" MULTIPLE LINE PIPE

TITLE	*NUMBER*
18" – 24" DOUBLE AND TRIPLE PIPE CULVERT HEADWALLS AT 0° SKEW	RDH-500-03
DOUBLE PIPE CULVERT HEADWALLS, 0° SKEW	RDH-510-04
TRIPLE PIPE CULVERT HEADWALLS, 0° SKEW	RDH-520-05
DIMENSIONS AND QUANTITIES 30" – 48" DOUBLE AND TRIPLE HEADWALLS, CIRCULAR PIPE, 0° SKEW	RDH-522-02
BILL OF REINFORCEMENT 30" – 48" DOUBLE AND TRIPLE HEADWALLS, CIRCULAR PIPE, 0° SKEW	RDH-524-03
DOUBLE PIPE CULVERT HEADWALLS, 15° - 30° AND 45° SKEW	RDH-530-04
DIMENSIONS AND QUANTITIES 30" – 48" DOUBLE HEADWALLS, CIRCULAR PIPE, 15° - 30° - 45° SKEW	RDH-532-04
BILL OF REINFORCEMENT 30" – 48" DOUBLE HEADWALLS, CIRCULAR PIPE, 15° - 30° SKEW	RDH-534-03
BILL OF REINFORCEMENT 30" – 48" DOUBLE HEADWALLS, CIRCULAR PIPE, 45° SKEW	RDH-536-03

BOX CULVERT HEADWALLS

3' X 2' – 12' X 12' SINGLE LINE BOX

PRECAST BOX CULVERT HEADWALLS - 0° SKEW (BOX RISE LESS THAN 6'- 0") (LAYOUT AND STEEL PATTERN)	RDH-1000-02
PRECAST BOX CULVERT HEADWALLS - 0° SKEW (BOX RISE 6'- 0" OR GREATER) (LAYOUT AND STEEL PATTERN)	RDH-1005-02
PRECAST BOX CULVERT HEADWALLS - 15° - 30° AND 45° SKEW (BOX RISE LESS THAN 6'-0") (LAYOUT AND STEEL PATTERN)	RDH-1010-02
PRECAST BOX CULVERT HEADWALLS - 15° - 30° AND 45° SKEW (BOX RISE 6'- 0" OR GREATER) (LAYOUT AND STEEL PATTERN)	RDH-1015-02
DIMENSIONS 3' X 2' – 6' X 6' HEADWALLS, PRECAST BOX CULVERT - 0° SKEW	RDH-1100-02
DIMENSIONS 7' X 4' – 9' X 9' HEADWALLS, PRECAST BOX CULVERT - 0° SKEW	RDH-1105-02
DIMENSIONS 10' X 5' – 11' X 11' HEADWALLS, PRECAST BOX CULVERT - 0° SKEW	RDH-1110-02
DIMENSIONS 12' X 4' – 12' X 12' HEADWALLS, PRECAST BOX CULVERT - 0° SKEW	RDH-1115-02
DIMENSIONS 3' X 2' – 6' X 6' HEADWALLS, PRECAST BOX CULVERT - 15° SKEW	RDH-1120-02
DIMENSIONS 7' X 4' – 9' X 9' HEADWALLS, PRECAST BOX CULVERT - 15° SKEW	RDH-1125-02
DIMENSIONS 10' X 5' – 11' X 11' HEADWALLS, PRECAST BOX CULVERT - 15° SKEW	RDH-1130-02
DIMENSIONS 12' X 4' – 12' X 12' HEADWALLS, PRECAST BOX CULVERT - 15° SKEW	RDH-1135-02
DIMENSIONS 3' X 2' – 6' X 6' HEADWALLS, PRECAST BOX CULVERT - 30° SKEW	RDH-1140-02
DIMENSIONS 7' X 4' – 9' X 9' HEADWALLS, PRECAST BOX CULVERT - 30° SKEW	RDH-1145-02
DIMENSIONS 10' X 5' – 11' X 11' HEADWALLS, PRECAST BOX CULVERT - 30° SKEW	RDH-1150-02
DIMENSIONS 12' X 4' – 12' X 12' HEADWALLS, PRECAST BOX CULVERT - 30° SKEW	RDH-1155-02
DIMENSIONS 3' X 2' – 6' X 6' HEADWALLS, PRECAST BOX CULVERT - 45° SKEW	RDH-1160-02
DIMENSIONS 7' X 4' – 9' X 9' HEADWALLS, PRECAST BOX CULVERT - 45° SKEW	RDH-1165-02
DIMENSIONS 10' X 5' – 11' X 11' HEADWALLS, PRECAST BOX CULVERT - 45° SKEW	RDH-1170-02
DIMENSIONS 12' X 4' – 12' X 12' HEADWALLS, PRECAST BOX CULVERT - 45° SKEW	RDH-1175-02



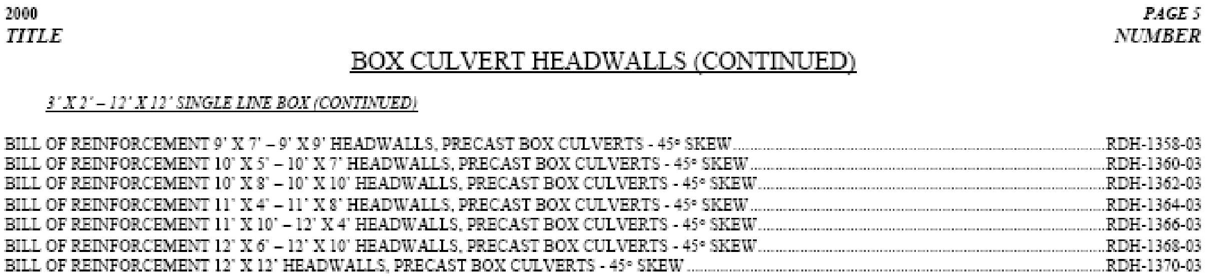
2000 *PAGE 4*

TITLE	*NUMBER*

BOX CULVERT HEADWALLS (CONTINUED)

3' X 2' – 12' X 12' SINGLE LINE BOX (CONTINUED)

QUANTITIES 3' X 2' – 12' X 12' HEADWALLS, PRECAST BOX CULVERTS - 0° SKEW	RDH-1200-02
QUANTITIES 3' X 2' – 12' X 12' HEADWALLS, PRECAST BOX CULVERTS - 15° SKEW	RDH-1205-02
QUANTITIES 3' X 2' – 12' X 12' HEADWALLS, PRECAST BOX CULVERTS - 30° SKEW	RDH-1210-02
QUANTITIES 3' X 2' – 12' X 12' HEADWALLS, PRECAST BOX CULVERTS - 45° SKEW	RDH-1215-02
BILL OF REINFORCEMENT 3' X 2' – 7' X 4' HEADWALLS, PRECAST BOX CULVERTS - 0° SKEW	RDH-1300-03
BILL OF REINFORCEMENT 7' X 5' – 9' X 7' HEADWALLS, PRECAST BOX CULVERTS - 0° SKEW	RDH-1302-03
BILL OF REINFORCEMENT 9' X 8' – 11' X 4' HEADWALLS, PRECAST BOX CULVERTS - 0° SKEW	RDH-1304-03
BILL OF REINFORCEMENT 11' X 6' – 12' X 10' HEADWALLS, PRECAST BOX CULVERTS - 0° SKEW	RDH-1306-03
BILL OF REINFORCEMENT 12' X 12' HEADWALLS, PRECAST BOX CULVERTS - 0° SKEW	RDH-1308-03
BILL OF REINFORCEMENT 3' X 2' – 5' X 5' HEADWALLS, PRECAST BOX CULVERTS - 15° SKEW	RDH-1310-03
BILL OF REINFORCEMENT 6' X 3' – 7' X 5' HEADWALLS, PRECAST BOX CULVERTS - 15° SKEW	RDH-1312-03
BILL OF REINFORCEMENT 7' X 6' – 8' X 6' HEADWALLS, PRECAST BOX CULVERTS - 15° SKEW	RDH-1314-03
BILL OF REINFORCEMENT 8' X 7' – 9' X 7' HEADWALLS, PRECAST BOX CULVERTS - 15° SKEW	RDH-1316-03
BILL OF REINFORCEMENT 9' X 8' – 10' X 7' HEADWALLS, PRECAST BOX CULVERTS - 15° SKEW	RDH-1318-03
BILL OF REINFORCEMENT 10' X 8' – 11' X 4' HEADWALLS, PRECAST BOX CULVERTS - 15° SKEW	RDH-1320-03
BILL OF REINFORCEMENT 11' X 6' – 11' X 11' HEADWALLS, PRECAST BOX CULVERTS - 15° SKEW	RDH-1322-03
BILL OF REINFORCEMENT 12' X 4' – 12' X 10' HEADWALLS, PRECAST BOX CULVERTS - 15° SKEW	RDH-1324-03
BILL OF REINFORCEMENT 12' X 12' HEADWALLS, PRECAST BOX CULVERTS - 15° SKEW	RDH-1326-03
BILL OF REINFORCEMENT 3' X 2' – 5' X 4' HEADWALLS, PRECAST BOX CULVERTS - 30° SKEW	RDH-1328-03
BILL OF REINFORCEMENT 5' X 5' – 7' X 4' HEADWALLS, PRECAST BOX CULVERTS - 30° SKEW	RDH-1330-03
BILL OF REINFORCEMENT 7' X 5' – 8' X 5' HEADWALLS, PRECAST BOX CULVERTS - 30° SKEW	RDH-1332-03
BILL OF REINFORCEMENT 8' X 6' – 9' X 5' HEADWALLS, PRECAST BOX CULVERTS - 30° SKEW	RDH-1334-03
BILL OF REINFORCEMENT 9' X 6' – 9' X 9' HEADWALLS, PRECAST BOX CULVERTS - 30° SKEW	RDH-1336-03
BILL OF REINFORCEMENT 10' X 5' – 10' X 8' HEADWALLS, PRECAST BOX CULVERTS - 30° SKEW	RDH-1338-03
BILL OF REINFORCEMENT 10' X 9' – 11' X 6' HEADWALLS, PRECAST BOX CULVERTS - 30° SKEW	RDH-1340-03
BILL OF REINFORCEMENT 11' X 8' – 11' X 11' HEADWALLS, PRECAST BOX CULVERTS - 30° SKEW	RDH-1342-03
BILL OF REINFORCEMENT 12' X 4' – 12' X 8' HEADWALLS, PRECAST BOX CULVERTS - 30° SKEW	RDH-1344-03
BILL OF REINFORCEMENT 12' X 10' – 12' X 12' HEADWALLS, PRECAST BOX CULVERTS - 30° SKEW	RDH-1346-03
BILL OF REINFORCEMENT 3' X 2' – 5' X 3' HEADWALLS, PRECAST BOX CULVERTS - 45° SKEW	RDH-1348-03
BILL OF REINFORCEMENT 5' X 4' – 6' X 5' HEADWALLS, PRECAST BOX CULVERTS - 45° SKEW	RDH-1350-03
BILL OF REINFORCEMENT 6' X 6' – 7' X 6' HEADWALLS, PRECAST BOX CULVERTS - 45° SKEW	RDH-1352-04
BILL OF REINFORCEMENT 7' X 7' – 8' X 6' HEADWALLS, PRECAST BOX CULVERTS - 45° SKEW	RDH-1354-03
BILL OF REINFORCEMENT 8' X 7' – 9' X 6' HEADWALLS, PRECAST BOX CULVERTS - 45° SKEW	RDH-1356-03



2000 *PAGE 5*

TITLE	*NUMBER*

BOX CULVERT HEADWALLS (CONTINUED)

3' X 2' – 12' X 12' SINGLE LINE BOX (CONTINUED)

BILL OF REINFORCEMENT 9' X 7' – 9' X 9' HEADWALLS, PRECAST BOX CULVERTS - 45° SKEW	RDH-1358-03
BILL OF REINFORCEMENT 10' X 5' – 10' X 7' HEADWALLS, PRECAST BOX CULVERTS - 45° SKEW	RDH-1360-03
BILL OF REINFORCEMENT 10' X 8' – 10' X 10' HEADWALLS, PRECAST BOX CULVERTS - 45° SKEW	RDH-1362-03
BILL OF REINFORCEMENT 11' X 4' – 11' X 8' HEADWALLS, PRECAST BOX CULVERTS - 45° SKEW	RDH-1364-03
BILL OF REINFORCEMENT 11' X 10' – 12' X 4' HEADWALLS, PRECAST BOX CULVERTS - 45° SKEW	RDH-1366-03
BILL OF REINFORCEMENT 12' X 6' – 12' X 10' HEADWALLS, PRECAST BOX CULVERTS - 45° SKEW	RDH-1368-03
BILL OF REINFORCEMENT 12' X 12' HEADWALLS, PRECAST BOX CULVERTS - 45° SKEW	RDH-1370-03

VE RECOMMENDATIONS

VE Alternatives

Introduction

The VE study evaluated the 59 ideas that were brainstormed during the Creative Phase. The thirteen (13) completed alternatives are located in this section of the report. The alternatives developed included, as needed, the following information:

- Original Concept
- Alternative Concept
- Advantages and Disadvantages of the Proposed Alternative
- Performance Measures
- Implementation Requirements
- Discussion
- Drawings and/or Sketches for Proposed Alternative

Performance Attributes

The project manager and the VE team defined the key performance attributes to use for evaluation. The performance attributes developed represented the performance of the headwalls, so as the ideas were considered, the headwall performance could not be negatively impacted. The following key attributes were used as consideration for scoring the ideas, however, each alternative addressed the impacts of the performance attributes (see below):

- Structural – meets structural requirements
- Constructability - ease of construction
- Maintainability – ease and cost of maintenance
- Safety – ensures safe operations for travelling public and maintenance
- Hydraulics – meets hydraulic requirements
- Flexibility – able to work with various applications
- Durability – the product lasts, life cycle

The Performance Criteria is listed on each alternative and is represented as follows:

ST = Structural
C = Constructability
M = Maintainability
S = Safety
H = Hydraulics
F = Flexibility
D = Durability

Each alternative addressed the impacts to performance by rating them on a sliding scale from a +2 Value Added to a -2 Value Decrease to the baseline. If there is a “0” shown as the rating, there is no impact from the baseline. The team was also asked to define the specific impacts, if any.

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Use performance specifications and eliminate the standards

IDEA NUMBER 1

PAGE NO. 1 of 2

ORIGINAL CONCEPT:

The Standard Headwall Drawings are used to construct headwalls and wingwalls.

ALTERNATIVE CONCEPT:

Eliminate the Standard Headwall Drawings for walls greater than 5'-11" in height (measured from top of foundation to top of wall) and only provide structural performance specifications and design criteria.

ADVANTAGES:

- Cost savings realized by efficiency of design
- Designs will be current to today's codes
- Liability is transferred to the contractor or consultant

DISADVANTAGES:

- Requires additional design work
- Requires review of design and drawings by KYTC or consultant

IMPLEMENTATION CONSIDERATIONS:

None apparent

Performance Criteria	**ST**	**C**	**M**	**S**	**H**	**F**	**D**
Performance Measure	**+2**	**0**	**0**	**+1**	**0**	**+1**	**0**
Structural	Helps to meet the most current design standards						
Constructability							
Maintainability							
Safety	Meets current structural safety standards						
Hydraulics							
Flexibility	Things are designed each time using performance specifications, changes are easily made						
Durability							

Rating Scale: **Value Add +2 +1 0 -1 -2 Value Decrease**

TITLE: Use performance specifications and eliminate the standards

DISCUSSION:

The current Standard Headwall Drawings have not been changed for some time, to reflect updated design methods and material assumptions. For example, grade 60 rebar is common now yet the Standard drawings probably were designed using grade 40 rebar. A similar case could be made for concrete strength. Current design methods, commonly referred to as "strength design", have mostly replaced the older "working stress" methods. The Standard Headwall Drawings are likely not current with today's codes. For relatively short walls, the relative difference between the current Standard Headwall Drawings and a current design is likely negligible. However, for taller walls, the difference could be significant.

SUPPORTING MATERIALS:

Proposed Specification:

Headwalls and wingwalls in excess of 5'-11" in height, as measured from top of foundation to top of wall, would be designed using methodology in the currently KYTC adopted edition of AASHTO Bridge Design Specifications. Calculations and drawings shall be sealed by a Civil or Structural Engineer licensed in the State of Kentucky and submitted to KYTC for review. At a minimum, the following loads shall be used in design. Soil weight = 120 pcf, lateral pressure due to soil = 45 pcf (equivalent fluid), lateral surcharge from live load = 240 psf. Allowable soil bearing pressure = 2,000 psf. Other loads may be used if justified by a project specific geotechnical investigation.

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Use Precast Concrete Headwalls and Wingwalls

	IDEA NUMBER	PAGE NO.
	2	1 of 3

ORIGINAL CONCEPT:

Current Standard Headwall Drawings do not, in all instances, specifically address precast concrete construction.

ALTERNATIVE CONCEPT:

As an alternative to the Standard Headwall Drawings, provide structural performance specifications and design criteria for precast construction of headwalls and wingwalls.

ADVANTAGES:

- Cost savings realized by efficiency of design
- Time savings
- Quality of product is improved because it is shop built which leads to better control
- Liability is transferred to the contractor

DISADVANTAGES:

- None apparent

IMPLEMENTATION CONSIDERATIONS:

None apparent

Performance Criteria	**ST**	**C**	**M**	**S**	**H**	**F**	**D**
Performance Measure	**+1**	**+1**	**0**	**0**	**0**	**0**	**0**
Structural	Shop controlled quality is more consistent						
Constructability	On site forms not required, can be constructed in the shop concurrent with site work. There are also efficiencies in installation which also can positively affect the cost and schedule.						
Maintainability							
Safety							
Hydraulics							
Flexibility							
Durability							

Rating Scale: **Value Add +2 +1 0 -1 -2 Value Decrease**

TITLE: Use Precast Concrete Headwalls and Wingwalls

DISCUSSION:

It is assumed that currently, a precast concrete manufacturer constructs headwalls and wingwalls in such a way as to match, as closely as possible, the Kentucky Standard Drawings. There are certain aspects of precast concrete construction that can advantageously change the design and detailing of headwalls and wingwalls. Some examples include clearance to reinforcing, tie-in to pipe or culvert, and availability of high-strength concrete mix. By utilizing current design methods and detailing unique to precast, potential material and time savings can be realized. It is envisioned that a design specification for the design of precast concrete headwalls and wingwalls would be provided as an alternate to the Kentucky Standard Drawings. In this manner, a precast concrete manufacturer could prepare his own structural design and drawings for his product, if he felt that his design would result in increased economy compared to what would result by using the Kentucky Standard Drawings.

SUPPORTING MATERIALS:

Suggested Specification:

As an alternative to the Kentucky Standard Drawings, precast concrete headwalls and wingwalls may be designed using methodology in the currently KYTC adopted edition of AASHTO Bridge Design Specifications. Calculations and drawings shall be sealed by a Civil or Structural Engineer licensed in the state of Kentucky and submitted to KYTC for review. At a minimum, the following loads shall be used in design; Soil weight = 120 pcf, lateral pressure due to soil = 45 pcf (equivalent fluid), lateral surcharge from live load = 240 psf. Allowable soil bearing pressure = 2,000 psf. Other loads may be used if justified by a project specific geotechnical investigation. Structural details shall be provided to depict tie-in to cast in place or precast pipe or culvert.

Sample Pre-cast Headwall Installation

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Provide alternate materials for walls

IDEA NUMBER	PAGE NO.
3	1 of 39

ORIGINAL CONCEPT:

The current standards only allow for reinforced concrete walls as detailed in the Headwall Supplement.

ALTERNATIVE CONCEPT:

Allow designers and contractors to construct alternate walls to include MSE walls, wire walls, gabion baskets, modular block walls, bin walls, soil-nail walls, tie-back walls, and unreinforced gravity walls.

ADVANTAGES:

- Opportunities to reduce cost
- Some alternates are more aesthetically pleasing
- Some alternates are more green
- Provides designers more choices if some alternates are more suitable for a particular project and location

DISADVANTAGES:

- Higher maintenance costs may be a possibility
- Some alternates are less aesthetically pleasing

IMPLEMENTATION CONSIDERATIONS:

Alternates will need to go through a stringent review process through the affected groups within KYTC including design, maintenance, structures, etc. and will require a thorough QA/QC plan. There may be a need to develop generic details for each alternate with performance specifications to ensure that alternates are equivalent as to structural, hydraulic, and scour resistance as well as life expectancy. These alternates are generally proprietary and are designed by the manufacturer/supplier.

<table>
<tr><th>Performance Criteria</th><th>ST</th><th>C</th><th>M</th><th>S</th><th>H</th><th>F</th><th>D</th></tr>
<tr><td>Performance Measure</td><td>0</td><td>+1</td><td>0</td><td>0</td><td>0</td><td>+1</td><td>+1</td></tr>
<tr><td>Structural</td><td colspan="7">All wall types will be designed for the same earth pressure and superimposed live load as the current reinforced concrete walls (which need to be designed to current codes)</td></tr>
<tr><td>Constructability</td><td colspan="7">Since these are options, the designer or contractor could choose to use a particular wall if it is generally more constructible than the reinforced concrete wall. Different options will be better suited/more constructible in specific locations</td></tr>
<tr><td>Maintainability</td><td colspan="7">Each of the 8 alternate wall types will each have their own pluses and minuses and will be addressed in the discussion</td></tr>
<tr><td>Safety</td><td colspan="7">Typically these will be used in a situation where they are protected by guardrail so safety is not a concern. These alternates are not being proposed as alternates to the safety headwalls with grate protection. Generally, these alternate walls are not suited for safety grate installation</td></tr>
<tr><td>Hydraulics</td><td colspan="7">All 8 of these alternates are expected to be placed with the same wingwall configuration as the CIP headwall and should have similar hydraulic characteristics</td></tr>
<tr><td>Flexibility</td><td colspan="7">All 8 alternates are more flexible in terms of fitting them with the existing field conditions as compared to CIP reinforced concrete walls</td></tr>
<tr><td>Durability</td><td colspan="7">All 8 alternates are more forgiving regarding differential settlement (except for the concrete gravity wall) and may tend to be more durable over time than the CIP reinforced concrete walls</td></tr>
</table>

Rating Scale: **Value Add +2 +1 0 -1 -2 Value Decrease**

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Provide alternate materials for walls

DISCUSSION:

The standard CIP reinforced concrete culvert headwalls are retaining walls with a pipe projecting through the middle. The purpose is to shorten the length of pipe required, while also channeling the stream flow into the culvert, to improve the hydraulic capacity of the pipe. The same function can be achieved with nearly any type of retaining wall. There are 8 different types of retaining walls presented, though more could be added if approved by the Cabinet. Each of these wall types can be placed in the same configurations as the standard CIP reinforced headwalls with wings turned and flared to the channel flow. Provided that these wall alternatives are designed with the same structural capacity and can resist scour forces, the contractor has 8 more options to choose from and can choose the one that is most economical to build based on the specific site conditions. For each of these wall types, the portion of the channel between the wingwalls should be protected with the appropriate KYTC channel lining as required to resist the calculated shear forces. Many of these wall types are more forgiving relative to differential settlement with no compromise in structural integrity or slight cracking that can open up with the standard concrete headwalls.

Some of these wall types have already been studied in-depth by KYTC and approved for use as indicated in the attached 1994 study with specifications that were a part of KYTC’s Standard Specifications for Road and Bridge Construction. Some of these specifications are still in the current KYTC specifications and some have been removed. For reference, attached are some CALTRAN drawings that show exactly what is being proposing for several wall types.

SUPPORTING MATERIALS:

- 2010 CALTRANS Plan Sheets related to culvert headwalls (Sheets D-84, D85, D86, D89 & D90) – pages 21-25
- Keystone Headwall Details – page 26
- Modular Gabion Headwall Details – 27
- Washington DOT Design Manual Chapter 8 Excerpt for Walls & Buried Structures – Pages 28-45
- Washington DOT Bridge Design Manual: SEW Wall Drawings – Pages 46-47
- Washington DOT Bridge Design Manual: Soldier Pile/Tieback Wall Drawings – Pages 48-53
- Washington DOT Bridge Design Manual: SEW Soil Wall Drawings – Pages 54-56
- Redi Rock Photo of Headwall Application – Page 57

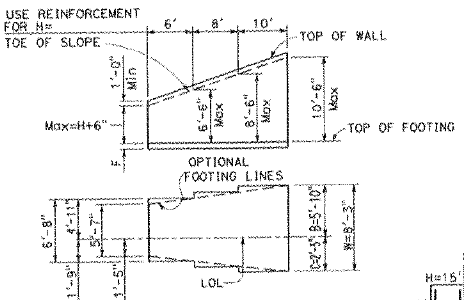
DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS

Dallas J. Forester
REGISTERED CIVIL ENGINEER

May 20, 2011
PLANS APPROVAL DATE

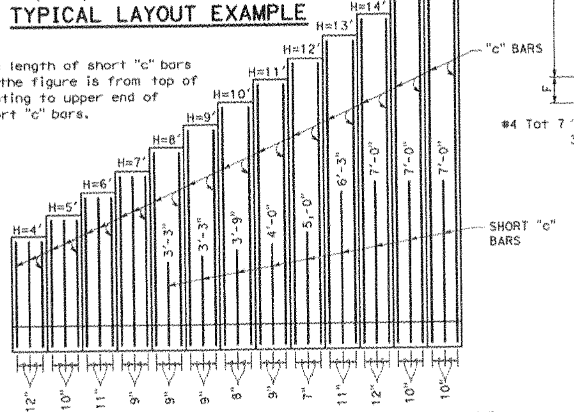
THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

REGISTERED PROFESSIONAL ENGINEER
Dallas Forester
No. C37765
Exp. 12-31-12
CIVIL
STATE OF CALIFORNIA



TYPICAL LAYOUT EXAMPLE

The length of short "c" bars in the figure is from top of footing to upper end of short "c" bars.



REINFORCED CONCRETE WINGWALLS

"H"	4'	5'	6'	7'	8'	9'	10'	11'	12'	13'	14'	15'	16'
W	5'-7"	6'-2"	6'-8"	7'-1"	7'-6"	7'-10"	8'-3"	8'-8"	9'-2"	9'-7"	10'-2"	10'-6"	11'-1"
C	1'-5"	1'-7"	1'-9"	1'-11"	2'-1"	2'-3"	2'-5"	2'-8"	2'-10"	3'-1"	3'-4"	3'-6"	3'-8"
B	4'-2"	4'-7"	4'-11"	5'-2"	5'-5"	5'-7"	5'-10"	6'-0"	6'-4"	6'-6"	6'-10"	7'-0"	7'-5"
F	1'-2"	1'-2"	1'-2"	1'-2"	1'-2"	1'-2"	1'-2"	1'-3"	1'-5"	1'-5"	1'-6"	1'-6"	1'-8"
BATTER	None									½:12			
S	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-6½"	1'-7"	1'-7½"	1'-8"
"c" BARS	#4@12	#4@10	#5@11	#5@9	#6@9	#7@9	#7@8	#8@9	#7@7	#8@11	#9@12	#10@10	#10@10
"d" BARS	#5@12	#5@10	#6@11	#6@9	#6@9	#6@9	#6@8	#7@9	#6@7	#7@11	#8@12	#8@10	#9@10
* Conc CY/LF	0.46	0.52	0.58	0.64	0.69	0.74	0.80	0.88	1.00	1.25	1.37	1.45	1.61
* Reinf LB/LF	26	32	41	50	59	70	81	95	102	99	120	156	171
** CASE I qu (ksf), B' (ft)	3.75,2.24	3.66,2.69	3.59,3.11	3.56,3.49	3.52,3.89	3.52,4.21	3.69,4.46	3.77,4.77	3.89,5.17	3.92,5.61	3.92,6.18	4.04,6.40	4.13,6.95
** CASE II qu (ksf), B' (ft)	1.16,5.58	1.33,6.13	1.51,6.55	1.69,6.86	1.88,7.16	2.08,7.33	2.29,7.60	2.50,7.86	2.77,8.14	2.97,8.47	3.18,8.93	3.41,9.05	3.70,9.43
** CASE III qu (ksf), B' (ft)	1.26,5.46	1.36,5.97	1.49,6.37	1.64,6.66	1.79,6.93	1.95,7.08	2.11,7.33	2.28,7.55	2.50,7.84	2.66,8.12	2.81,8.59	3.00,8.69	3.22,9.10

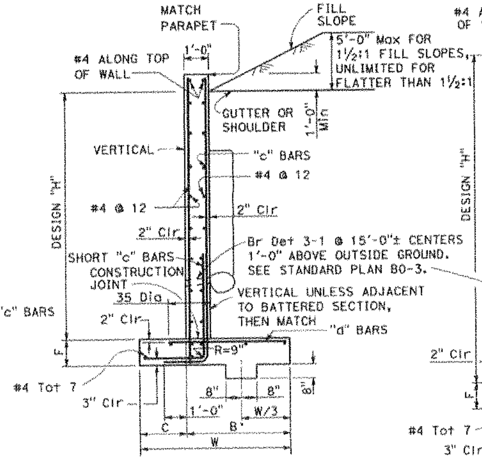
B'=B-(2) eccentricity, B' is the effective footing width.

* Quantities include 1'-0" extension above the design "H" limit.

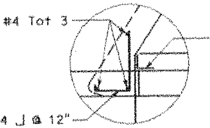
** Soil bearing pressure shown in the table is the equivalent uniform pressure per AASHTO LRFD - 11.6.3.2

NOTES:

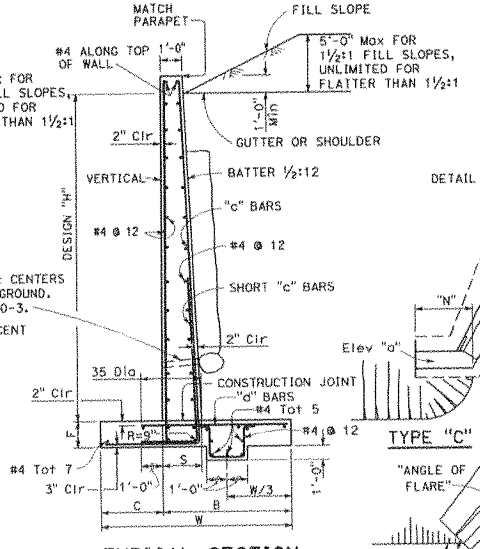
Unit Stresses: f'c=3,600 psi, fy=60,000 psi
Earth density: 120 pcf
Equivalent fluid pressure: 36 pcf
Elevations, length and angle of flare of wings may be varied by the Engineer to suit conditions encountered in the field.
Dimensions "H","L","M","N", Elevation "a" and "Angle of flare" (as apply) are shown on the plans.
Wall height may be exceeded by 6" before going to next greater "H".
Eliminate cutoff wall if adjacent channel is paved and skew is 20° maximum.
For wall offset values, see Standard Plan B3-5.



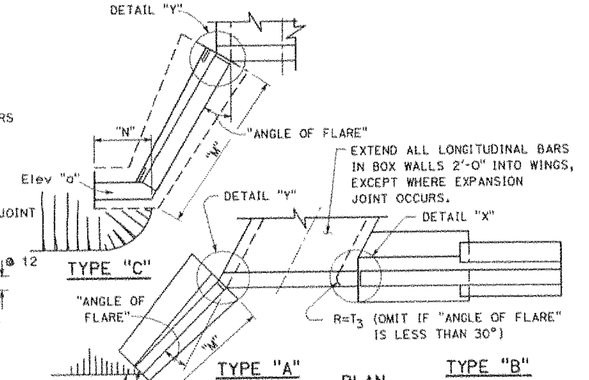
TYPICAL SECTION
H=4' THRU 12'



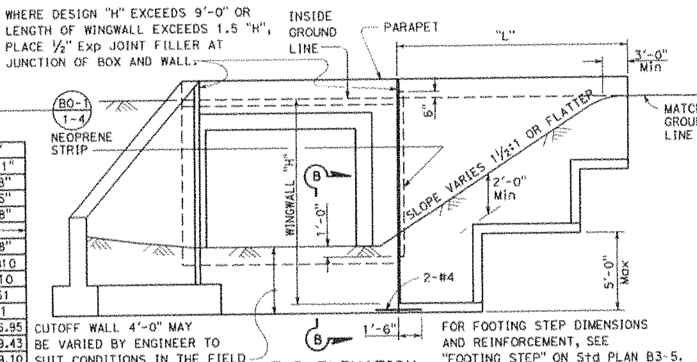
DETAIL "X"



TYPICAL SECTION
H=13' THRU 16'



PLAN

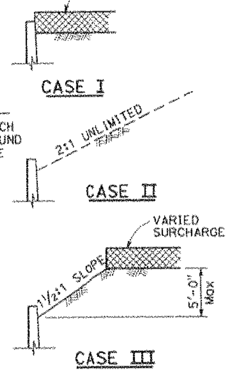


TYPE "A"

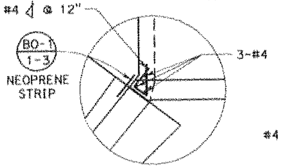
END ELEVATION

TYPE "B"

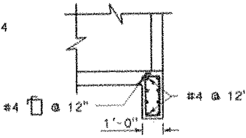
STRAIGHT WINGWALLS



DETAIL OF DESIGN LOADING CASES



DETAIL "Y"



SECTION B-B

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

BOX CULVERT WINGWALLS
TYPES A, B AND C

NO SCALE

D84

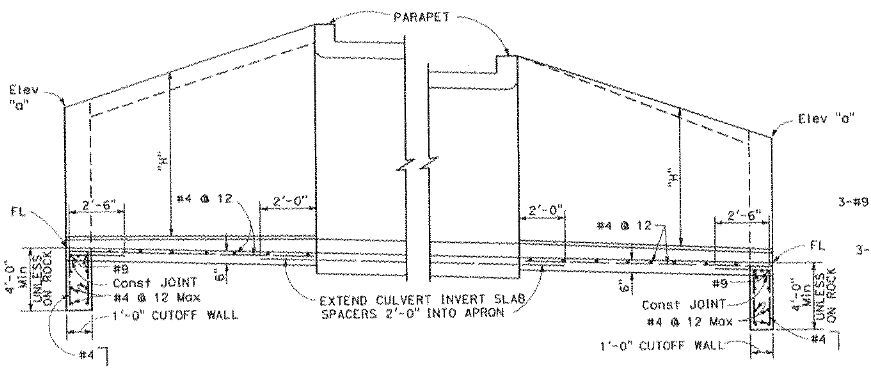
Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

REGISTERED CIVIL ENGINEER

May 20, 2011
PLANS APPROVAL DATE

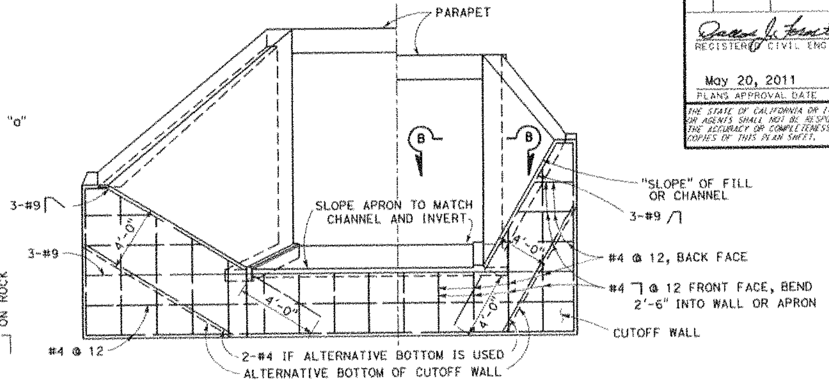
THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

Dallas Forester
No. C37765
Exp. 12-31-12
CIVIL

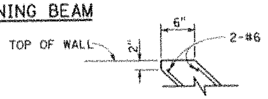


TYPICAL WITH STIFFENING BEAM TYPICAL WITHOUT STIFFENING BEAM

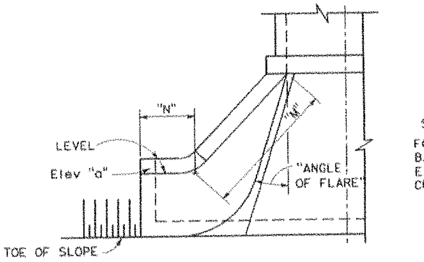
PART LONGITUDAL SECTION



END ELEVATION

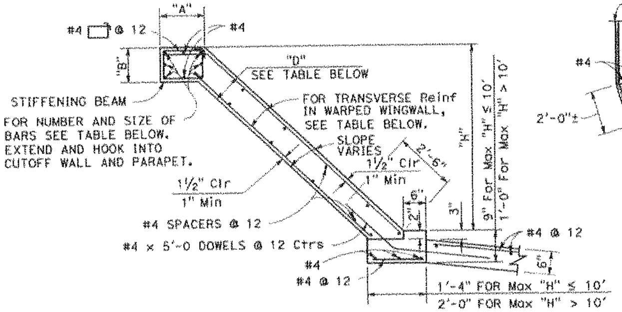


WITHOUT STIFFENING BEAM

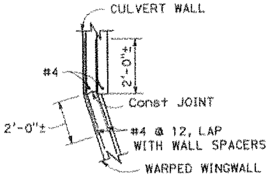


ALTERNATIVE WARPED WINGWALL

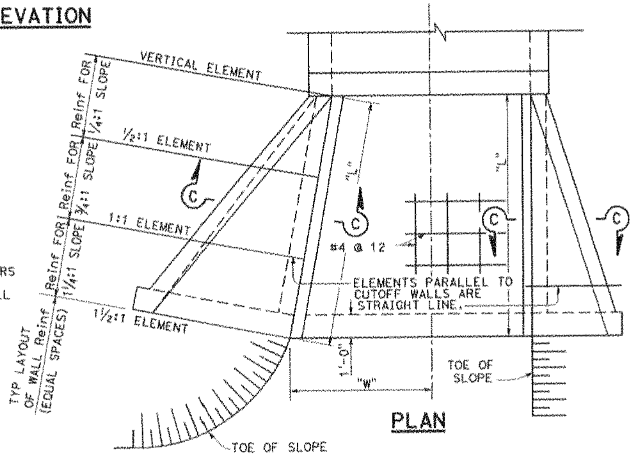
Use where additional protection to toe of embankment is required.



SECTION C-C



SECTION B-B



PLAN

WARPED WINGWALLS

WALL DIMENSIONS AND REINFORCING

ELEMENT SLOPE	"H"	8' OR LESS	10'	12'	14'	16'	18'	20'
¼:1	FRONT FACE Reinf REAR FACE Reinf	#4 @ 12 #4 @ 12	#4 @ 7 #4 @ 12	#5 @ 7 #4 @ 12	#5 @ 5 #4 @ 12	#6 @ 6 #4 @ 12	#7 @ 7 #4 @ 12	#7 @ 6 #4 @ 12
¾:1	Front face Reinf Rear face Reinf	#4 @ 12 #4 @ 12	#4 @ 12 #4 @ 12	#4 @ 8 #4 @ 12	#4 @ 8 #4 @ 10	#4 @ 8 #4 @ 7	#4 @ 6 #4 @ 6	#4 @ 6 #5 @ 8
1¼:1	FRONT FACE Reinf REAR FACE Reinf	#4 @ 12 #4 @ 8	#4 @ 12 #4 @ 8	#4 @ 12 #4 @ 5	#4 @ 12 #5 @ 6	#4 @ 12 #6 @ 7	#4 @ 12 #6 @ 6	#4 @ 12 #7 @ 6
"D" AT CUTOFF WALL		6"	6"	6"	7½"	8"	9½"	11"
"D" AT CULVERT		6"	6"	6"	8"	9½"	11"	1'-1"

STIFFENING BEAM DIMENSIONS AND REINFORCING

"H" Max \ "L" Max	12'	14'	16'	18'	20'	25'	30'	35'	40'
6'	NO BEAM. PLACE 2-#6 IN EACH FACE ALONG TOP OF WALL.								
8'				"A"= 1'-0"					
10'			"B"= 9"			"A"= 1'-6"			
12'								"A"= 1'-10"	
14'	TOTAL 6-#6				"B"= 1'-0"		"B"= 1'-3"		"A"= 2'-2"
16'									"B"= 1'-6"
18'				TOTAL 6-#7		TOTAL 8-#8			
20'								TOTAL 8-#9	

NOTES: Walls designed for 2'-0" surcharge; earth density = 120 pcf; equivalent fluid pressure = 36 pcf.
Vary "D" of warped wall uniformly from that at cutoff wall to that at culvert, for maximum "H" > 12'-0".
Where abrasion is anticipated increase apron thickness to 7" minimum to provide 2" minimum reinforcement coverage.
Dimensions "L", "W", "H", "M", "N", Elevation "a", " Angle of flare", and end "Slope" (as apply) are shown on the plans.

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

BOX CULVERT WARPED WINGWALLS

NO SCALE

D86A

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

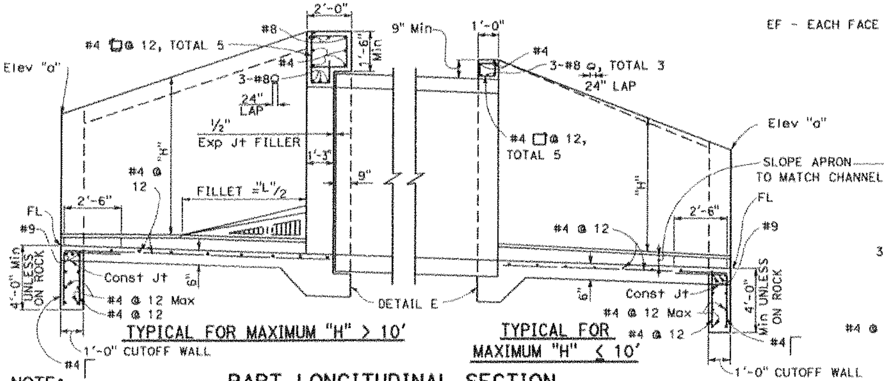
REGISTERED CIVIL ENGINEER

May 20, 2011
PLANS APPROVAL DATE

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

Dallas Forester
No. C37765
Exp. 12-31-12
CIVIL

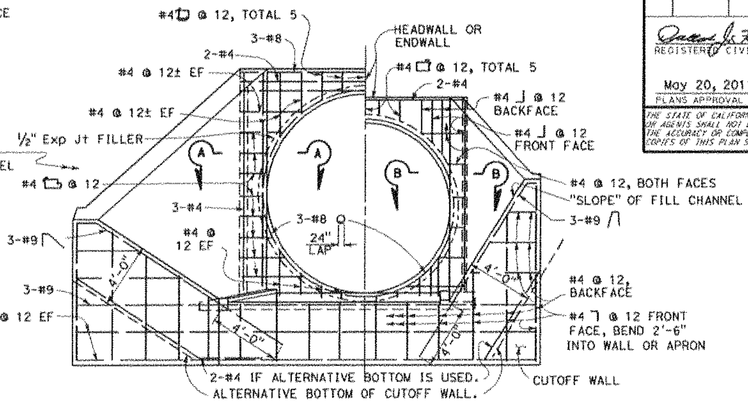
EF - EACH FACE



PART LONGITUDINAL SECTION

NOTE:

RCP shown. Metal pipe similar except eliminate the expansion joint and use hook bolts @ 1'-7" ± spacing. Size and length provided by manufacturer.



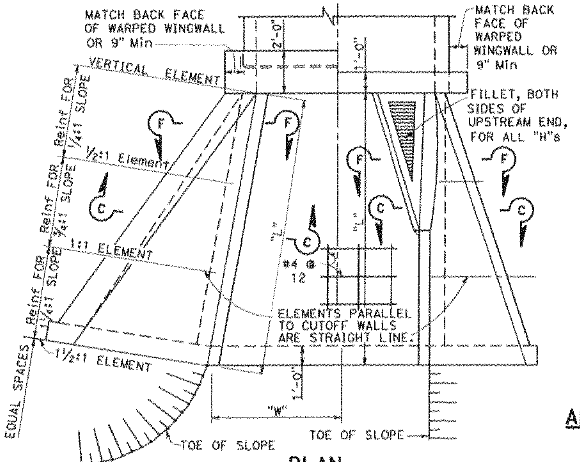
TYPICAL FOR MAXIMUM "H" > 10'

TYPICAL FOR MAXIMUM "H" ≤ 10'

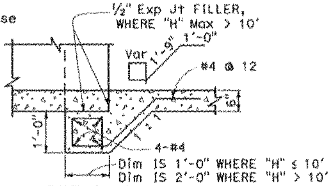
WITHOUT STIFFENING BEAM

END ELEVATION

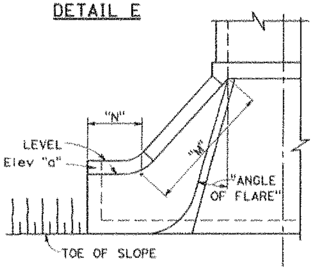
If at upstream end, fillet is not shown.



PLAN

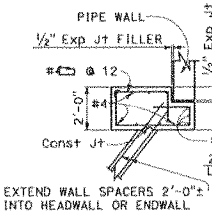


DETAIL E



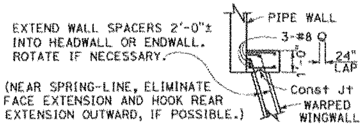
ALTERNATIVE WARPED WINGWALL

Use where additional protection to toe of embankment is required. If at upstream end, fillet is not shown.



EXTEND WALL SPACERS 2'-0"± INTO HEADWALL OR ENDWALL

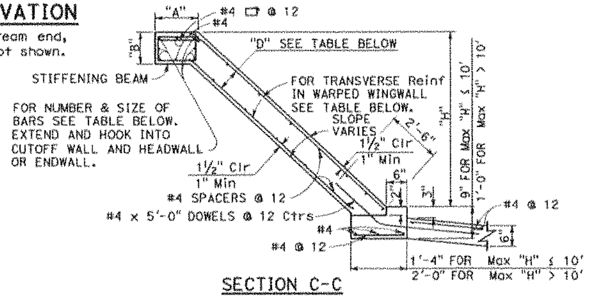
SECTION A-A



EXTEND WALL SPACERS 2'-0"± INTO HEADWALL OR ENDWALL. ROTATE IF NECESSARY.

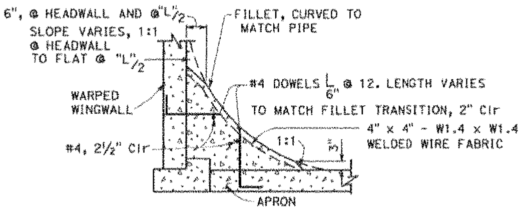
(NEAR SPRING-LINE, ELIMINATE FACE EXTENSION AND HOOK REAR EXTENSION OUTWARD, IF POSSIBLE.)

SECTION B-B



SECTION C-C

Where abrasion is anticipated, increase apron thickness to 7" minimum to provide 2" minimum reinforcement coverage.



SECTION F-F

WARPED WINGWALLS

WALL DIMENSIONS AND REINFORCING

ELEMENT SLOPE	"H"	8' OR LESS	10'	12'	14'	16'	18'	20'
¼:1	FRONT FACE Reinf	#4 @ 12	#4 @ 7	#5 @ 7	#5 @ 5	#6 @ 6	#7 @ 7	#7 @ 6
	REAR FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12
¾:1	FRONT FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 8	#4 @ 8	#4 @ 8	#4 @ 6	#4 @ 6
	REAR FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 10	#4 @ 7	#4 @ 6	#5 @ 8
1¼:1	FRONT FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12
	REAR FACE Reinf	#4 @ 8	#4 @ 8	#4 @ 5	#5 @ 6	#6 @ 7	#6 @ 6	#7 @ 6
"D" AT CUTOFF WALL		6"	6"	6"	7½"	8"	9½"	11"
"D" AT CULVERT		6"	6"	6"	8"	9½"	11"	1'-1"

STIFFENING BEAM DIMENSIONS AND REINFORCING

"H" Max \ "L"	12'	14'	16'	18'	20'	25'	30'	35'	40'
6'	NO BEAM. PLACE 2-#6 IN EACH FACE ALONG TOP OF WALL.								
8'				"A"= 1'-0"					
10'			"B"= 9"			"A"= 1'-6"			
12'								"A"= 1'-10"	
14'	TOTAL 6-#6				"B"= 1'-0"				
16'							"B"= 1'-3"		"A"= 2'-2"
18'			TOTAL 6-#7			TOTAL 8-#8			"B"= 1'-6"
20'								TOTAL 8-#9	

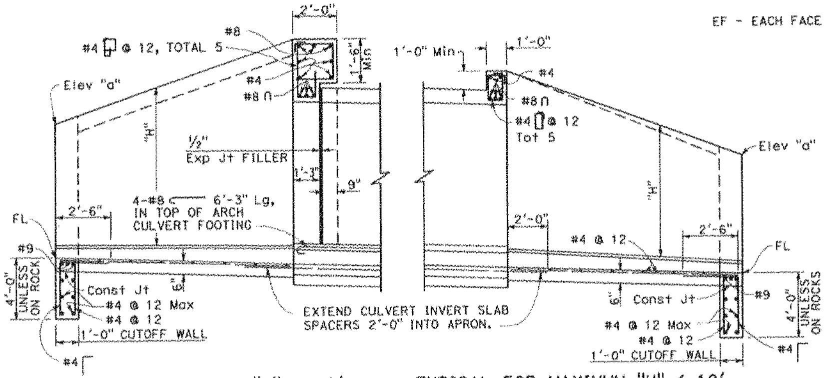
NOTES: Walls designed for 2'-0" surcharge; earth density = 120 pcf; equivalent fluid pressure = 36 pcf.
Vary "D" of warped wall uniformly from that at cutoff wall to that at headwall or endwall, for maximum "H" > 12'-0".
Dimensions "L", "W", "H", "M", "N", Elevation "a"," Angle of flare", and end "Slope" (as apply) are shown on the plans.

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

PIPE CULVERT HEADWALLS, ENDWALLS AND WARPED WINGWALLS

NO SCALE

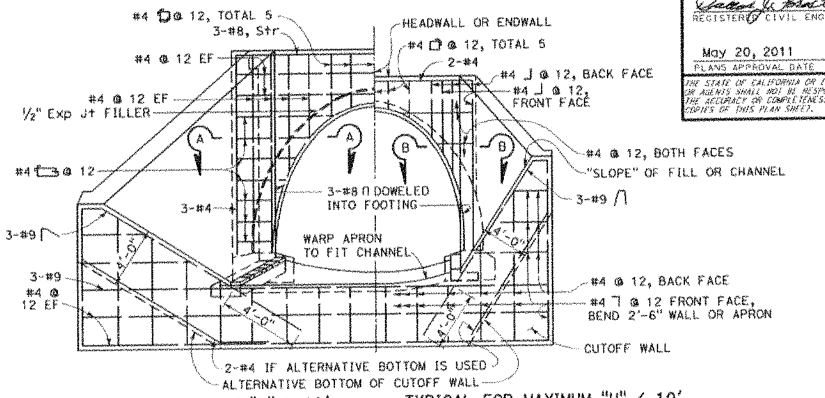
D86B



TYPICAL FOR MAXIMUM "H" > 10'

TYPICAL FOR MAXIMUM "H" ≤ 10'

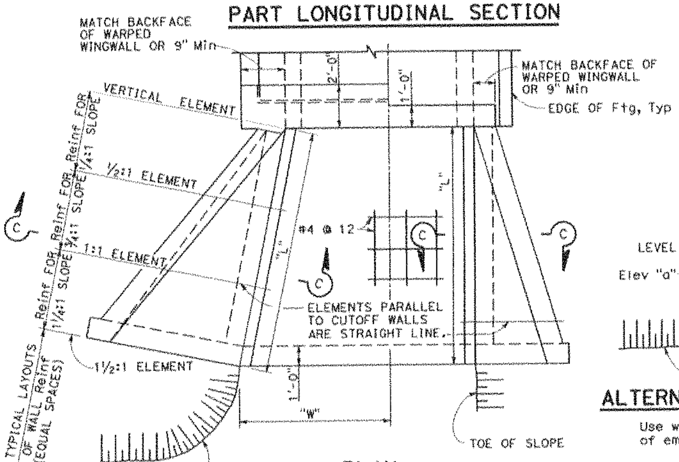
PART LONGITUDINAL SECTION



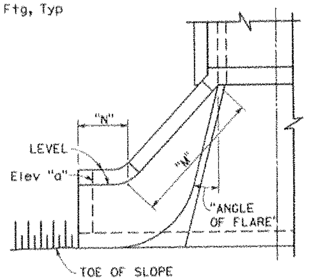
TYPICAL FOR MAXIMUM "H" > 10'

TYPICAL FOR MAXIMUM "H" ≤ 10'

END ELEVATION

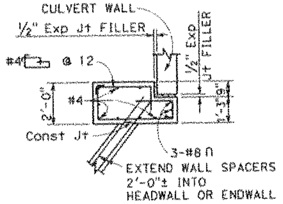


PLAN

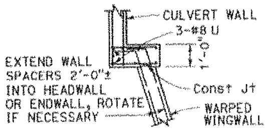


ALTERNATIVE WARPED WINGWALL

Use where additional protection to toe of embankment is required.

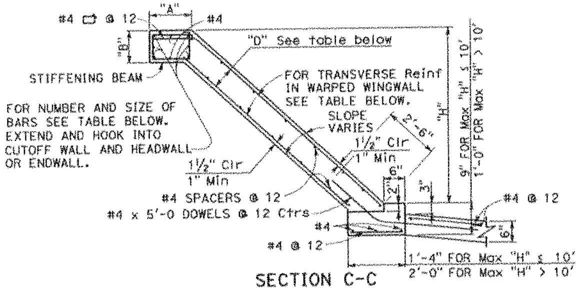


SECTION A-A



SECTION B-B

WITHOUT STIFFENING BEAM



SECTION C-C

Where abrasion is anticipated, increase apron thickness to 7" minimum to provide 2" minimum reinforcement coverage.

WARPED WINGWALLS

WALL DIMENSIONS AND REINFORCING

ELEMENT SLOPE	"H"	8' OR LESS	10'	12'	14'	16'	18'	20'
¼:1	FRONT FACE Reinf	#4 @ 12	#4 @ 7	#5 @ 7	#5 @ 5	#6 @ 6	#7 @ 7	#7 @ 6
	REAR FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12
¾:1	FRONT FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 8	#4 @ 8	#4 @ 8	#4 @ 6	#4 @ 6
	REAR FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 10	#4 @ 7	#4 @ 6	#5 @ 8
1¼:1	FRONT FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12
	REAR FACE Reinf	#4 @ 8	#4 @ 8	#4 @ 5	#5 @ 6	#6 @ 7	#6 @ 6	#7 @ 6
"D" AT CUTOFF WALL		6"	6"	6"	7½"	8"	9½"	11"
"D" AT CULVERT		6"	6"	6"	8"	9½"	11"	1'-1"

STIFFENING BEAM DIMENSIONS AND REINFORCING

"H" Max \ "L"	12'	14'	16'	18'	20'	25'	30'	35'	40'
6'	NO BEAM. PLACE 2-#6 IN EACH FACE ALONG TOP OF WALL.								
8'				"A"= 1'-0"					
10'			"B"= 9"			"A"= 1'-6"			
12'								"A"= 1'-10"	
14'	TOTAL 6-#6				"B"= 1'-0"		"B"= 1'-3"		
16'									"A"= 2'-2"
18'				TOTAL 6-#7		TOTAL 8-#8			"B"= 1'-6"
20'								TOTAL 8-#9	

NOTES:

Walls designed for 2'-0" surcharge; earth density = 120 pcf; equivalent fluid pressure = 36 pcf.
Vary "D" of warped wall uniformly from that at cutoff wall to that at headwall or endwall, for maximum "H" > 12'.
Dimensions "L", "W", "H", "M", "N", Elev "a", "Angle of flare", and "Slope" (as apply) are shown on the plans.

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

Dallas J. Forester
REGISTERED CIVIL ENGINEER

May 20, 2011
PLANS APPROVAL DATE

Dallas Forester
No. C37765
Exp. 12-31-12
CIVIL

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

ARCH CULVERT HEADWALLS, ENDWALLS AND WARPED WINGWALLS

NO SCALE

D86C

2010 STANDARD PLAN D86C

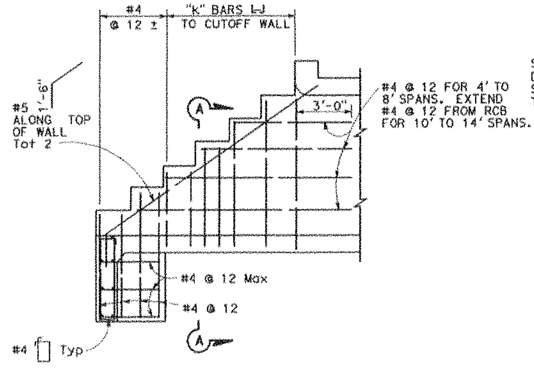
Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

Dallas J. Forester
REGISTERED CIVIL ENGINEER

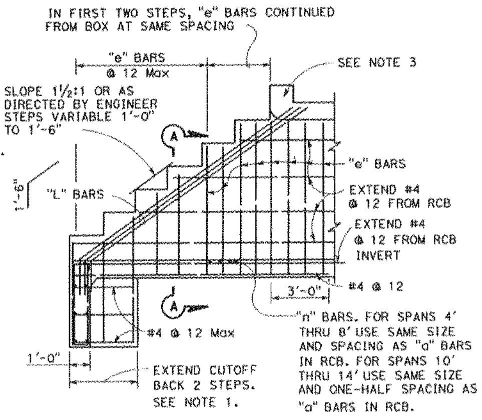
May 20, 2011
PLANS APPROVAL DATE

Dallas Forester
No. C37765
Exp. 12-31-12
CIVIL

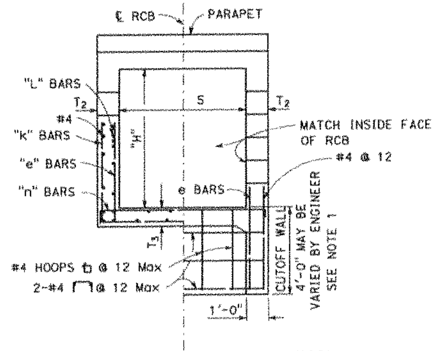
THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.



LONGITUDINAL SECTION
Showing reinforcement in outside face



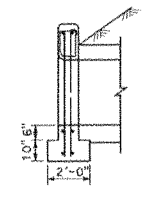
LONGITUDINAL SECTION
Showing reinforcement in inside face



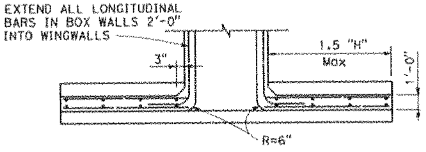
HALF SECTION A-A | END ELEVATION

Dimensions S and T_3 to be same as adjacent RCB.
T_2 = Same as adjacent RCB (8" Min).

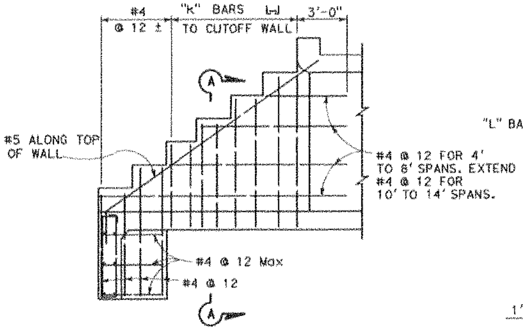
TYPE "E" STEPPED WINGWALL (SINGLE BOX CULVERT)



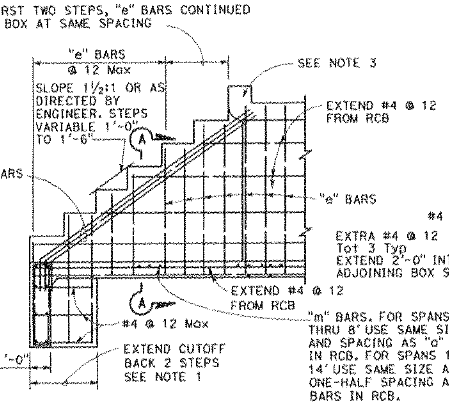
SECTION B-B



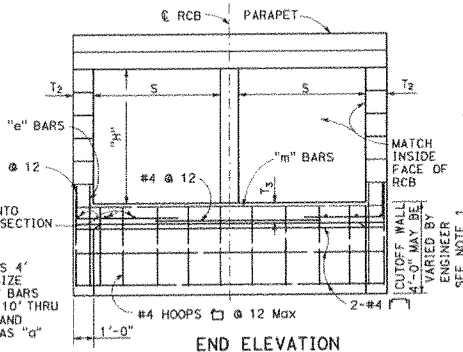
SECTION C-C



LONGITUDINAL SECTION
Showing reinforcement in outside face



LONGITUDINAL SECTION
Showing reinforcement in inside face

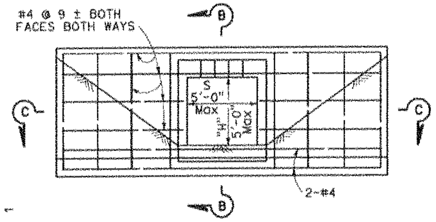


END ELEVATION

Dimensions S and T_3 to be same as adjacent RCB.
T_2 = Same as adjacent RCB (8" Min).

TYPE "E" STEPPED WINGWALL (MULTIPLE BOX CULVERT)

TABLE OF REINFORCEMENT FOR TYPE "E" WINGWALLS										
"H" (SEE NOTE 2)		3'	4'	5'	6'	7'	8'	10'	12'	14'
"K" BARS	BAR No.	#4	#4	#5	#5	#5	#5	#5	#5	#5
	SPACING	@ 12	@ 12	@ 12	@ 10	@ 9	@ 8	@ 7	@ 5	@ 4
"L" BARS	BAR No.	#5	#5	#6	#6	#7	#7	#7	#7	#7
	NUMBER EACH WALL	2	2	3	3	3	3	3	3	3



ELEVATION

TYPE "D" STRAIGHT WINGWALL

Details similar for multiple span boxes.
See Note 3.

DETAIL OF DESIGN LOADING CASES - TYPE "D" STRAIGHT WINGWALL

Case I Level + 240 psf surcharge
Case II 2:1 sloping ground with no surcharge
Case III 1½:1 limited slope (5'-0" Max height)
+ 240 psf surcharge

NOTES:

1. Eliminate cutoff walls if adjacent channel is paved.
2. For "H" not shown use reinforcement for next greater height.
3. For parapet details not shown see Standard Plan D82.

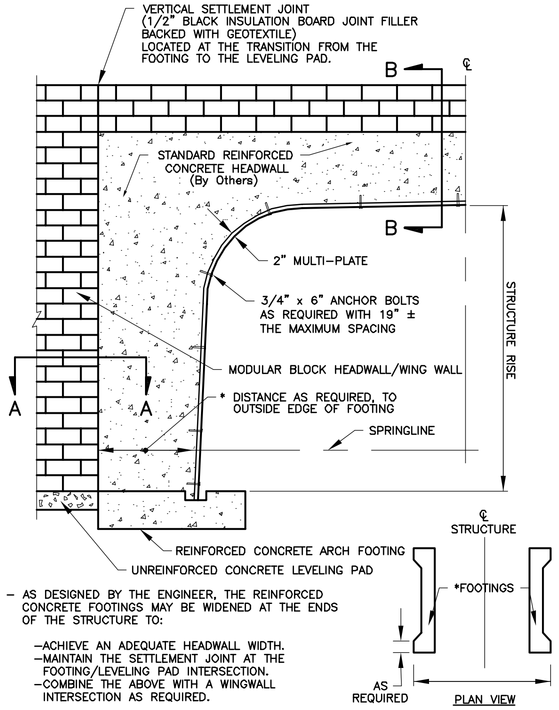
STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

BOX CULVERT WINGWALLS
TYPES D AND E

NO SCALE

D85

CAST IN PLACE HEADWALL DETAILS FOR CULVERTS AT AN ANGLE TO KEYSTONE WALL

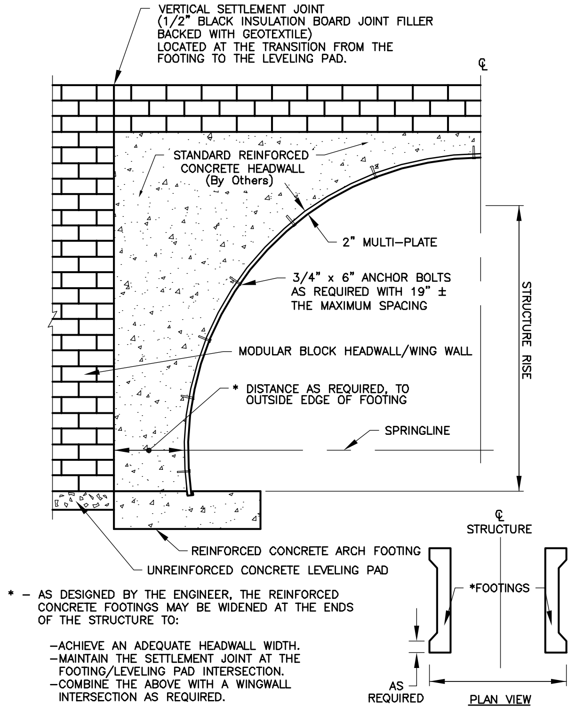


* – AS DESIGNED BY THE ENGINEER, THE REINFORCED CONCRETE FOOTINGS MAY BE WIDENED AT THE ENDS OF THE STRUCTURE TO:

- –ACHIEVE AN ADEQUATE HEADWALL WIDTH.
- –MAINTAIN THE SETTLEMENT JOINT AT THE FOOTING/LEVELING PAD INTERSECTION.
- –COMBINE THE ABOVE WITH A WINGWALL INTERSECTION AS REQUIRED.

NOTE: OUT TO OUT OF FOOTING IS A CRITICAL DIMENSION. SEE PLAN VIEW.

ALUMINUM BOX CULVERT
MODULAR BLOCK/CONC. HEADWALL DETAIL
NO SCALE

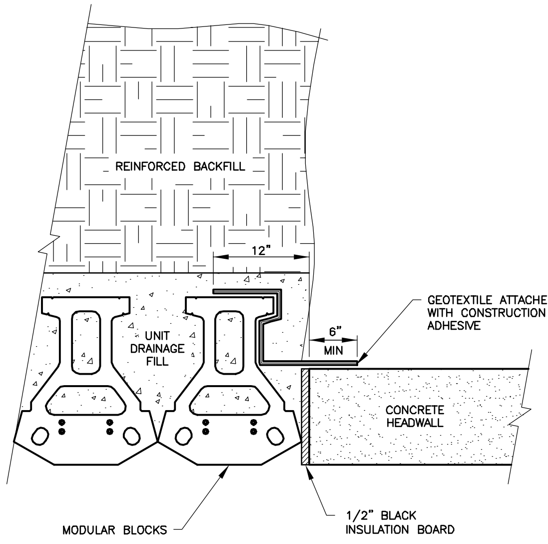


* – AS DESIGNED BY THE ENGINEER, THE REINFORCED CONCRETE FOOTINGS MAY BE WIDENED AT THE ENDS OF THE STRUCTURE TO:

- –ACHIEVE AN ADEQUATE HEADWALL WIDTH.
- –MAINTAIN THE SETTLEMENT JOINT AT THE FOOTING/LEVELING PAD INTERSECTION.
- –COMBINE THE ABOVE WITH A WINGWALL INTERSECTION AS REQUIRED.

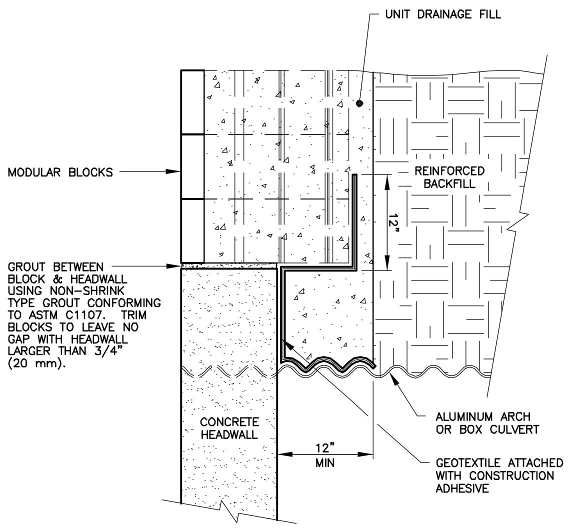
NOTE: OUT TO OUT OF FOOTING IS A CRITICAL DIMENSION. SEE PLAN VIEW.

ALUMINUM STRUCTURAL PLATE
MODULAR BLOCK/CONC. HEADWALL DETAIL
NO SCALE

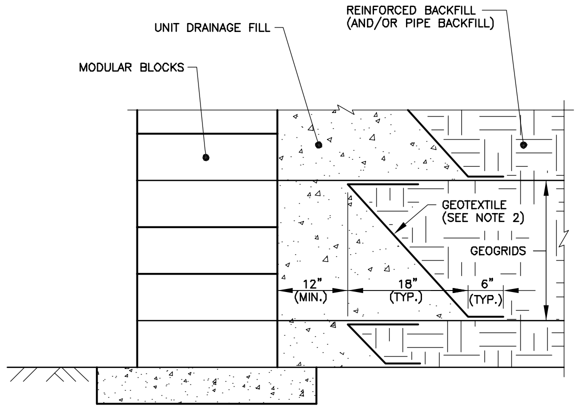


SECTION A–A
MODULAR BLOCK/CONC. HEADWALL
VERTICAL SETTLEMENT JOINT DETAIL
NO SCALE

NOTE: VERTICAL SETTLEMENT JOINTS REQUIRED AT TRANSITION:
A. BETWEEN FOOTINGS
B. BETWEEN WALL TYPES
C. AT ALIGNMENT CHANGES



SECTION B–B
MODULAR BLOCK/CONC. HEADWALL
HORIZONTAL CONNECTION JOINT DETAIL
NO SCALE

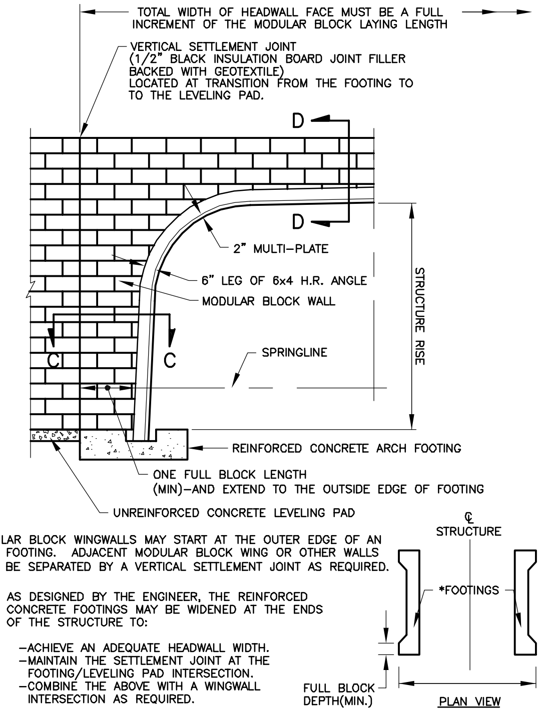


SEPARATION DETAIL IN THE PIPE ZONE

NOTES:
1. DRAINAGE AGGREGATE FILL IN THE PIPE ZONE IS 3/8" TO 3/4" CRUSHED ROCK.
2. GEOTEXTILE MUST BE SELECTED SO IT IS NOT BLINDED BY THE PIPE BACKFILL MATERIAL.

MODULAR BLOCK HEADWALL
PIPE ZONE SEPERATION DETAIL
NO SCALE

KEYSTONE HEADWALL OPTION FOR CULVERTS PERPENDICULAR TO KEYSTONE WALL



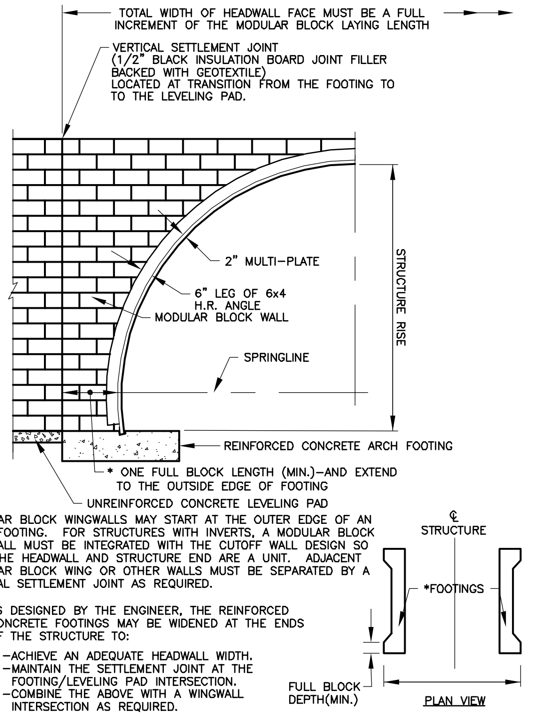
MODULAR BLOCK WINGWALLS MAY START AT THE OUTER EDGE OF AN ARCH FOOTING. ADJACENT MODULAR BLOCK WING OR OTHER WALLS MUST BE SEPARATED BY A VERTICAL SETTLEMENT JOINT AS REQUIRED.

* – AS DESIGNED BY THE ENGINEER, THE REINFORCED CONCRETE FOOTINGS MAY BE WIDENED AT THE ENDS OF THE STRUCTURE TO:

- –ACHIEVE AN ADEQUATE HEADWALL WIDTH.
- –MAINTAIN THE SETTLEMENT JOINT AT THE FOOTING/LEVELING PAD INTERSECTION.
- –COMBINE THE ABOVE WITH A WINGWALL INTERSECTION AS REQUIRED.

NOTE: OUT TO OUT OF FOOTING IS A CRITICAL DIMENSION. SEE PLAN VIEW.

ALUMINUM BOX CULVERT
MODULAR BLOCK HEADWALL DETAIL
NO SCALE



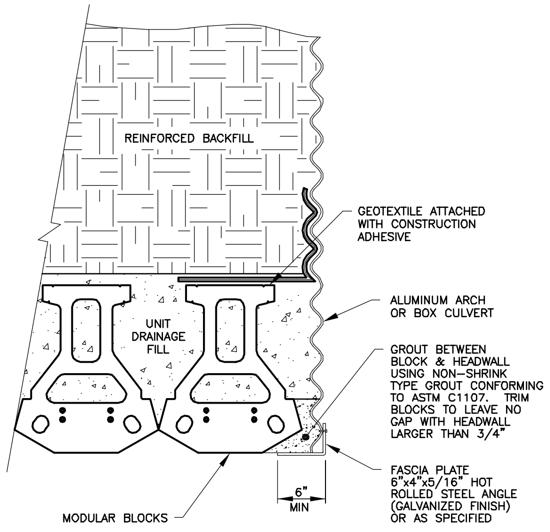
MODULAR BLOCK WINGWALLS MAY START AT THE OUTER EDGE OF AN ARCH FOOTING. FOR STRUCTURES WITH INVERTS, A MODULAR BLOCK HEADWALL MUST BE INTEGRATED WITH THE CUTOFF WALL DESIGN SO THAT THE HEADWALL AND STRUCTURE END ARE A UNIT. ADJACENT MODULAR BLOCK WING OR OTHER WALLS MUST BE SEPARATED BY A VERTICAL SETTLEMENT JOINT AS REQUIRED.

* – AS DESIGNED BY THE ENGINEER, THE REINFORCED CONCRETE FOOTINGS MAY BE WIDENED AT THE ENDS OF THE STRUCTURE TO:

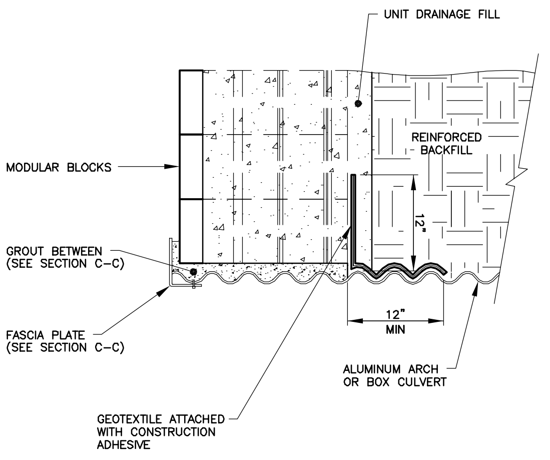
- –ACHIEVE AN ADEQUATE HEADWALL WIDTH.
- –MAINTAIN THE SETTLEMENT JOINT AT THE FOOTING/LEVELING PAD INTERSECTION.
- –COMBINE THE ABOVE WITH A WINGWALL INTERSECTION AS REQUIRED.

NOTE: OUT TO OUT OF FOOTING IS A CRITICAL DIMENSION. SEE PLAN VIEW.

ALUMINUM STRUCTURAL PLATE
MODULAR BLOCK HEADWALL DETAIL
NO SCALE



SECTION C–C
MODULAR BLOCK/ALUMINUM ARCH OR BOX CULVERT
VERTICAL CONNECTION JOINT DETAIL
NO SCALE



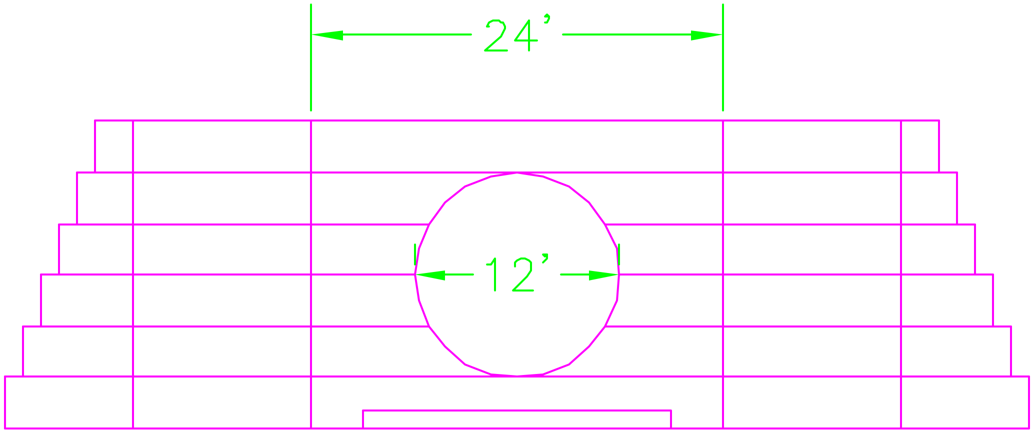
SECTION D–D
MODULAR BLOCK/ALUMINUM ARCH OR BOX CULVERT
HORIZONTAL CONNECTION JOINT DETAIL
NO SCALE

Rick Magnuson, Keystone Retaining Wall Systems 8/25/00 9:33 AM Key-Con6.dwg

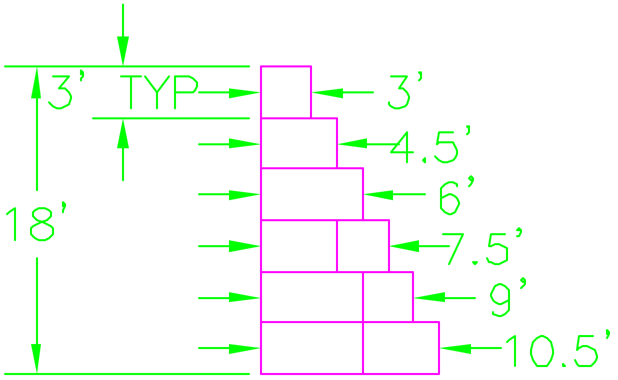
No.	Date	Revision	By

KEYSTONE
RETAINING WALL SYSTEMS
4444 West 78th Street
Minneapolis, MN 55435
(612) 897–1040

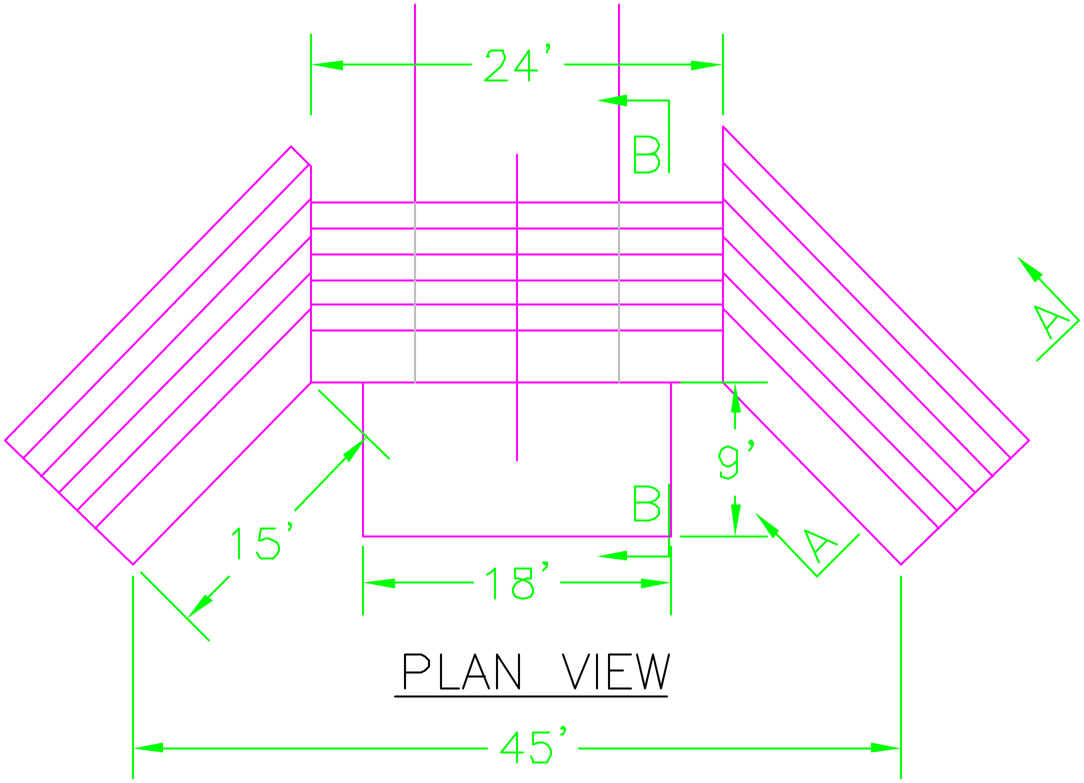
Designed By: RKM
Checked By: CDM
Date: 08/08/00
Client: CONTECH CONSTRUCTION PRODUCTS INC.
Scale: NO SCALE
Title: CULVERT DETAILS
Project No:
Drawing No: 6



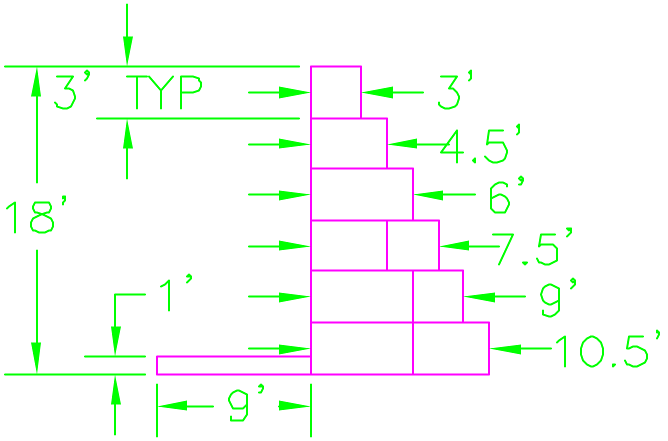
ELEVATION VIEW



SECTION A—A



PLAN VIEW



SECTION B—B

LET | DATE | BY | REV

DIMENSIONS IN INCHES UNLESS NOTED
TOLERANCES UNLESS NOTED:
FRACTIONAL + or − 1/64
DECIMAL .XX .03
+ OR − .XXX .005
.XXXX .0005
ANGULAR +/− 1/2°
FILE GAB

Modular Gabion Systems
2221 CANADA DRY ST. HOUSTON, TEXAS 77023

DWN BY JS
DATE 9/11/02
REV LET
SCALE 1:10
APPR BY
DATA EMBODIED PROPRIETARY INFORMATION WHICH IS CONFIDENTIAL PROPERTY
SHT. 1 OF 2
Proposed Headwall
TITLE
As Noted
MATERIAL
A
091102—1

Chapter 8 Walls and Buried Structures

Contents

8.1 Retaining Walls

8.1.1 General

A retaining wall is a structure built to provide lateral support for a mass of earth or other material where a grade separation is required. Retaining walls depend either on their own weight, their own weight plus the additional weight of laterally supported material, or on a tieback system for their stability. Additional information is provided in Chapter 15 of the WSDOT *Geotechnical Design Manual* M 46-03.

Standard designs for reinforced concrete cantilevered retaining walls, noise barrier walls (precast concrete, cast-in-place concrete, or masonry), and geosynthetic walls are shown in the Standard Plans. The Region Design PE Offices are responsible for preparing the PS&E for retaining walls for which standard designs are available, in accordance with the WSDOT *Design Manual* M 22-01. However, the Bridge and Structures Office may prepare PS&E for such standard type retaining walls if such retaining walls are directly related to other bridge structures being designed by the Bridge and Structures Office.

Structural earth wall (SE) systems meeting established WSDOT design and performance criteria have been listed as “pre-approved” by the Bridge and Structures Office and the Materials Laboratory Geotechnical Branch. The PS&E for “pre-approved” structural earth wall systems shall be coordinated by the Region Design PE Office with the Bridge and Structures Office, and the Materials Laboratory Geotechnical Branch, in accordance with WSDOT *Design Manual* M 22-01.

The PS&E for minor non-structural retaining walls, such as rock walls, gravity block walls, and gabion walls, are prepared by the Region Design PE Offices in accordance with the WSDOT *Design Manual* M 22-01, and any other design input from the Region Materials Offic, Materials Laboratory Geotechnical Branch or Geotechnical Engineer.

All other retaining walls not covered by the Standard Plans such as soil nail walls, soldier pile walls, soldier pile tieback walls and all walls beyond the scope of the designs tabulated in the Standard Plans, are designed by the Bridge and Structures Office according to the design parameters provided by the Geotechnical Engineer.

The Hydraulics Branch of the Design Office should be consulted for walls that subject to floodwater or are located in a flood plain. The State Bridge and Structures Architect should review the architectural features and visual impact of the walls during the Preliminary Design stage. The designer is also directed to the retaining walls chapter in the WSDOT *Design Manual* M 22-01 and Chapter 15 of the WSDOT *Geotechnical Design Manual* M 46-03, which provide valuable information on the design of retaining walls.

8.1.2 Common Types of Walls

The majority of walls used by WSDOT are one of the following six types:

1. Proprietary Structural Earth (SE) Walls - *Standard Specification* Section 6-13.
2. Geosynthetic Walls (Temporary and Permanent) - *Standard Plan* D-3 and *Standard Specification* Section 6-14.
3. Standard Reinforced Concrete Cantilever Retaining Walls- *Standard Plans* D-10.10 through D-10.45 and *Standard Specification* Section 6-11.
4. Soldier Pile Walls and Soldier Pile Tieback Walls - *Standard Specification* Sections 6-16 and 6-17.
5. Soil Nail Walls - *Standard Specification* Section 6-15.
6. Noise Barrier Walls - *Standard Plan* D-2.04 through D-2.68 and *Standard Specification* Section 6-12.

Other wall systems, such as secant pile or cylinder pile walls, may be used based on the recommendation of the Geotechnical Engineer. These walls shall be designed in accordance with the current AASHTO LRFD.

A. **Pre-approved Proprietary Walls –** A wall specified to be supplied from a single source (patented, trademark, or copyright) is a proprietary wall. Walls are generally pre-approved for heights up to 33 ft. The Materials Laboratory Geotechnical Division will make the determination as to which pre-approved proprietary wall system is appropriate on a case-by-case basis. The following is a description of the most common types of proprietary walls:

   1. **Structural Earth Walls (SE) –** A structural earth wall is a flexible system consisting of concrete face panels or modular blocks that are held rigidly into place with reinforcing steel strips, steel mesh, welded wire, or geogrid extending into a select backfill mass. These walls will allow for some settlement and are best used for fill sections. The walls have two principal elements:

      - Backfill or wall mass: a granular soil with good internal friction (i.e. gravel borrow).
      - Facing: precast concrete panels, precast concrete blocks, or welded wire (with or without vegetation).

      Design heights in excess of 33 feet shall be approved by the Materials Laboratory Geotechnical Division. If approval is granted, the designer shall contact the individual structural earth wall manufacturers for design of these walls before the project is bid so details can be included in the Plans. See Appendix 8.1-A2 for details that need to be provided in the Plans for manufacturer designed walls.

      A list of current pre-approved proprietary wall systems is provided in Appendix 15-D of the WSDOT *Geotechnical Design Manual* M 46-03. For additional information see the retaining walls chapter in the WSDOT *Design Manual* M 22-01 and Chapter 15 of the WSDOT *Geotechnical Design Manual* M 46-03. For the SEW shop drawing review procedure see Chapter 15 of the WSDOT *Geotechnical Design Manual*.

   2. **Other Proprietary Walls –** Other proprietary wall systems such as crib walls, bin walls, or precast cantilever walls, can offer cost reductions, reduce construction time, and provide special aesthetic features under certain project specific conditions.

      A list of current pre-approved proprietary wall systems and their height limitations is provided in Appendix 15-D of the WSDOT *Geotechnical Design Manual* M 46-03. The Region shall refer to the retaining walls chapter in the WSDOT *Design Manual* M 22-01 for guidelines on the selection of wall types. The Materials Laboratory Geotechnical Division and the Bridge and Structures Office Preliminary Plans Unit must approve the concept prior to development of the PS&E.

B. **Geosynthetic Wrapped Face Walls –** Geosynthetic walls use geosynthetics for the soil reinforcement and part of the wall facing. Use of geosynthetic walls as permanent structures requires the placement of a cast-in-place, precast or shotcrete facing. Details for construction are shown in Standard Plan D-3, D-3.10 and D-3.11.

C. **Standard Reinforced Concrete Cantilever Walls –** Reinforced concrete cantilever walls consist of a base slab footing from which a vertical stem wall extends. These walls are suitable for heights up to 35 feet. Details for construction and the maximum bearing pressure in the soil are given in the Standard Plans D-10.10 to D-10.45.

   A major disadvantage of these walls is the low tolerance to post-construction settlement, which may require use of deep foundations (shafts or piling) to provide adequate support.

D. **Soldier Pile Walls and Soldier Pile Tieback Walls –** Soldier Pile Walls utilize wide flange steel members, such as W or HP shapes. The piles are usually spaced 6 to 10 feet apart. The main horizontal members are timber or precast concrete lagging designed to transfer the soil loads to the piles. For additional information see WSDOT *Geotechnical Design Manual* M 46-03 Chapter 15. See Appendix 8.1-A3 for typical soldier pile wall details.

E. **Soil Nail Walls –** The basic concept of soil nailing is to reinforce and strengthen the existing ground by installing steel bars called "nails" into a slope or excavation as construction proceeds from the "top down". Soil nailing is a technique used to stabilize moving earth, such as a landslide, or as temporary shoring. Soil anchors are used along with the strength of the soil to provide stability. The Geotechnical Engineer designs the soil nail system whereas the Bridge and Structures Office designs the wall fascia. Presently, the FHWA Publication FHWA-IF-03-017 "Geotechnical Engineering Circular No. 7 Soil Nail Walls" is being used for structural design of the fascia. See Appendix 8.1-A4 for typical soil nail wall details.

F. **Noise Barrier Walls –** Noise barrier walls are primarily used in urban or residential areas to mitigate noise or to hide views of the roadway. Common types, as shown in the Standard Plans, include cast-in-place concrete panels (with or without traffic barrier), precast concrete panels (with or without traffic barrier), and masonry blocks. The State Bridge and Structures Architect should be consulted for wall type selection. Design criteria for noise barrier walls are based on AASHTO's *Guide Specifications for Structural Design of Sound Barriers*. Details of these walls are available in the Standard Plans D-2.04 to D-2.68. The Noise Barriers chapter of the WSDOT *Design Manual* M 22-01 tabulates the design wind speeds and various exposure conditions used to determine the appropriate wall type.

Placement of noise barrier walls on bridges and retaining walls should be avoided if possible. These structures are hazardous to the traffic below during seismic events or in case of vehicular impact. However, if necessary to place a noise barrier wall on a bridge or a retaining wall, see Section 3.12 for the design requirements of these walls. See Appendix 8.1-A5-1 for typical noise barrier wall on bridge details.

Noise barrier walls on bridges and retaining walls are considered special design and shall be designed on a case by case basis. WSDOT Standard Plans for Noise Barrier Walls may not be used for these applications.

The design requirements for precast wall panel connections to bridge and retaining wall barriers are different than for cast-in-place construction. Changing the noise barrier wall type from cast-in-place to precast requires approval of the Bridge Design Engineer.

8.1.3 Design

A. **General –** All designs shall follow procedures as outlined in AASHTO LRFD Chapter 11, the WSDOT *Geotechnical Design Manual* M 46-03, and this manual. See Appendix 8.1-A1 for a summary of design specification requirements for walls.

All construction shall follow procedures as outlined in the WSDOT *Standard Specifications for Road, Bridge, and Municipal Construction*, latest edition.

The Geotechnical Engineer will provide the earth pressure diagrams and other geotechnical design requirements for special walls to be designed by the Bridge and Structures Office. Pertinent soil data will also be provided for pre-approved proprietary structural earth walls (SEW), non-standard reinforced concrete retaining walls, and geosynthetic walls.

B. **Standard Reinforced Concrete Cantilever Retaining Walls –** The Standard Plan reinforced concrete retaining walls have been designed in accordance with the requirements of the AASHTO LRFD Bridge Design Specifications 4th Edition 2007 and interims through 2008.

1. Western Washington Walls (Types 1 through 4)
    a. The seismic design of these walls has been completed using and effective Peak Ground Acceleration of 0.51g.
    b. Active Earth pressure distribution was linearly distributed per Section 7.7.4. The corresponding Ka values used for design were 0.24 for wall Types 1 and 2, and 0.36 for Types 3 and 4.
    c. Seismic Earth pressure distribution was uniformly distributed per WSDOT *Geotechnical Design Manual* M 46-03, Nov. 2008, Section 15.4.2.9, and was supplemented by AASHTO LRFD Bridge Design Specifications (Fig. 11.10.7.1-1). The corresponding Kae values used for design were 0.43 for Types 1 and 2, and 0.94 for Types 3 and 4.
    d. Passive Earth pressure distribution was linearly distributed. The corresponding Kp value used for design was 1.5 for all walls. For Types 1 and 2, passive earth pressure was taken over the depth of the footing. For Types 3 and 4, passive earth pressure was taken over the depth of the footing and the height of the shear key.
    e. The retained fill was assumed to have an angle of internal friction of 36 degrees and a unit weight of 130 pounds per cubic foot. The friction angle for sliding stability was assumed to be 32 degrees.
    f. Load factors and load combinations used per AASHTO LRFD Bridge Design Specifications 3.4.1-1 and 2. Stability analysis performed per AASHTO LRFD Bridge Design Specifications Section 11.6.3 and C11.5.5-1&2.
    g. Wall Types 1 and 2 were designed for traffic barrier collision forces, as specified in AASHTO LRFD Bridge Design Specifications section A13.2 for TL-4. These walls have been designed with this force distributed over the distance between wall section expansion joints (48 feet).
2. Eastern Washington Walls (Types 5 through 8)
    a. The seismic design of these walls has been completed using and effective Peak Ground Acceleration of 0.2g.
    b. Active Earth pressure distribution was linearly distributed per Section 7.7.4 of this manual. The corresponding Ka values used for design were 0.36 for wall Types 5 and 6, and 0.24 for Types 7 and 8.
    c. Seismic Earth pressure distribution was uniformly distributed per WSDOT *Geotechnical Design Manual* M 46-03, Nov. 2008, Section 15.4.2.9, and was supplemented by AASHTO LRFD Bridge Design Specifications (Fig. 11.10.7.1-1). The corresponding Kae values used for design were 0.55 for Types 5 and 6, and 0.30 for Types 7 and 8.
    d. Passive Earth pressure distribution was linearly distributed, and was taken over the depth of the footing and the height of the shear key. The corresponding Kp value used for design was 1.5 for all walls.
    e. The retained fill was assumed to have an angle of internal friction of 36 degrees and a unit weight of 130 pounds per cubic foot. The friction angle for sliding stability was assumed to be 32 degrees.
    f. Load factors and load combinations used per AASHTO LRFD Bridge Design Specifications 3.4.1-1&2. Stability analysis performed per AASHTO LRFD Bridge Design Specifications section 11.6.3 and C11.5.5-1&2.

g. Wall Types 7 and 8 were designed for traffic barrier collision forces, as specified in AASHTO LRFD Bridge Design Specifications section A13.2 for TL-4. These walls have been designed with this force distributed over the distance between wall section expansion joints (48 feet).

C. **Non-Standard Reinforced Concrete Retaining Walls –** For retaining walls where a traffic barrier is to be attached to the top of the wall, the AASHTO LRFD Extreme Event loading for vehicular collision must be analyzed. These loads are tabulated in LRFD Table A13.2-1. Although the current yield line analysis assumptions for this loading are not applicable to retaining walls, the transverse collision load (F_t) may be distributed over the longitudinal length (L_t) at the top of barrier. At this point, the load is distributed at a 45 degree angle into the wall. Future updates to the LRFD code will address this issue.

For sliding, the passive resistance in the front of the footing may be considered if the earth is more than 2 feet deep on the top of the footing and does not slope downward away from the wall. The design soil pressure at the toe of the footing shall not exceed the allowable soil bearing capacity supplied by the Geotechnical Engineer. For retaining walls supported by deep foundations (shafts or piles), refer to Sections 7.7.5, 7.8 and 7.9 of this manual.

D. **Soldier Pile and Soldier Pile Tieback Walls**

1. **Permanent Ground Anchors (Tiebacks) –** See AASHTO LRFD Section 11.9 "Anchored Walls". The Geotechnical Engineer will determine whether anchors can feasibly be used at a particular site based on the ability to install the anchors and develop anchor capacity. The presence of utilities or other underground facilities, and the ability to attain underground easement rights may also determine whether anchors can be installed.

The anchor may consist of bars, wires, or strands. The choice of appropriate type is usually left to the Contractor but may be specified by the designer if special site conditions exist that preclude the use of certain anchor types. In general, strands and wires have advantages with respect to tensile strength, limited work areas, ease of transportation, and storage. However, bars are more easily protected against corrosion, and are easier to develop stress and transfer load.

The geotechnical report will provide a reliable estimate of the feasible factored design load of the anchor, recommended anchor installation angles (typically 10° to 45°), no-load zone dimensions, and any other special requirements for wall stability for each project.

Both the "tributary area method" and the "hinge method" as outlined in AASHTO LRFD Section C11.9.5.1 are considered acceptable design procedures to determine the horizontal anchor design force. The capacity of each anchor shall be verified by testing. Testing shall be done during the anchor installation (See *Standard Specification Section* 6-17.3(8) and WSDOT *Geotechnical Design Manual* M 46-03).

a. The horizontal anchor spacing typically follows the pile spacing of 6 to 10 feet. The vertical anchor spacing is typically 8 to 12 feet. A minimum spacing of 4 feet in both directions is not recommended because it can cause a loss of effectiveness due to disturbance of the anchors during installation.

b. For permanent ground anchors, the anchor DESIGN LOAD, T, shall be according to AASHTO LRFD. For temporary ground anchors, the anchor DESIGN LOAD, T, may ignore extreme event load cases.

c. The lock-off load is 60 percent of the controlling factored design load for temporary and permanent walls (see WSDOT *Geotechnical Design Manual* M 46-03 Chapter 15).

2. **Permanent Ground Anchor Corrosion Protection –** The Geotechnical Engineer will specify the appropriate protection system; the two primary types are:
   a. Simple Protection: The use of simple protection relies on Portland cement grout to protect the tendon, bar, or strand in the bond zone. The unbonded lengths are sheaths filled with anti-corrosion grease, heat shrink sleeves, and secondary grouting after stressing. Except for secondary grouting, the protection is usually in place prior to insertion of the anchor in the hole.

   b. Double Protection: a corrugated PVC, high-density polyethylene, or steel tube accomplishes complete encapsulation of the anchor tendon. The same provisions of protecting the unbonded length for simple protection are applied to those for double protection.

3. **Design of Soldier Pile –** The soldier piles shall be designed for shear, bending, and axial stresses according to the latest AASHTO LRFD and WSDOT *Geotechnical Design Manual* M 46-03 design criteria. The bending moment shall be based on the elastic section modulus “S” for the entire length of the pile for all Load combinations

   a. Lateral Loads

      (1) Lateral loads are assumed to act over one pile spacing above the base of excavation in front of the wall. These lateral loads result from horizontal earth pressure, live load surcharge, seismic earth pressure, or any other applicable load.

      (2) Lateral loads are assumed to act over the shaft diameter below the base of excavation in front of the wall. These lateral loads result from horizontal earth pressure, seismic earth pressure or any other applicable load.

      (3) Passive earth pressure usually acts over three times the shaft diameter or pile spacing, whichever is smaller.

   b. Depth of Embedment

      The depth of embedment of soldier piles shall be the maximum embedment as determined from the following;

      (1) 10 feet

      (2) As recommended by the Geotechnical Engineer of Record

      (3) As required for skin friction resistance and end bearing resistance.

      (4) As required to satisfy horizontal force equilibrium and moment equilibrium about the bottom of the soldier pile for cantilever soldier piles without permanent ground anchors.

      (5) As required to satisfy moment equilibrium of lateral force about the bottom of the soldier pile for soldier piles with permanent ground anchors.

4. **Design of Lagging –** Lagging for soldier pile walls, with and without permanent ground anchors, may be comprised of timber, precast concrete, or steel. The expected service life of timber lagging is 20 years which is less than the 75 year service life of structures designed in accordance with AASHTO LRFD.

   The Geotechnical Engineer will specify when lagging shall be designed for an additional 250 psf surcharge due to temporary construction load or traffic surcharge. The lateral pressure transferred from a moment slab shall be considered in the design of soldier pile walls and laggings.

Temporary Timber Lagging – Temporary lagging is based on a maximum 36 month service life before a permanent fascia is applied over the lagging. The wall Design Engineer shall review the Geotechnical Recommendations or consult with the Geotechnical Engineer regarding whether the lagging may be considered as temporary as defined in Section 6-16.3(6) of the *Standard Specifications*. Temporary timber lagging shall be designed by the contractor in accordance with Section 6-16.3(6)B of the *Standard Specifications.*

Permanent Lagging – Permanent lagging shall be designed for 100% of the lateral load that could occur during the life of the wall in accordance with AASHTO LRFD Sections 11.8.5.2 and 11.8.6 for simple spans without soil arching. A reduction factor to account for soil arching effects may be used if permitted by the Geotechnical Engineer.

Timber lagging shall be designed in accordance with AASHTO LRFD Section 8.6. The size effect factor (CF_b) should be considered 1.0, unless a specific size is shown in the wall plans. The wet service factor (CM_b) should be considered 0.85 for a saturated condition at some point during the life of the lagging. The load applied to lagging should be applied at the critical depth. The design should include the option for the contractor to step the size of lagging over the height of tall walls, defined as walls over 15 feet in exposed face height.

Timber lagging designed as a permanent structural element shall consist of treated Douglas Fir-Larch, grade No. 2 or better. Hem-fir wood species, due to the inadequate durability in wet condition, shall not be used for permanent timber lagging. Permanent lagging is intended to last the design life cycle (75 years) of the wall. Timber lagging does not have this life cycle capacity but can be used when both of the following are applicable:

(1) The wall will be replaced within a 20 year period or a permanent fascia will be added to contain the lateral loads within that time period.

And,

(2) The lagging is visible for inspections during this life cycle.

5. **Design of Fascia Panels –** Cast-in-place concrete fascia panels shall be designed as a permanent load carrying member in accordance with AASHTO LRFD Section 11.8.5.2. For walls without permanent ground anchors the minimum structural thickness of the fascia panels shall be 9 inches. For walls with permanent ground anchors the minimum structural thickness of the fascia panels shall be 14 inches. Architectural treatment of concrete fascia panels shall be indicated in the plans.

   Concrete strength shall not be less than 4,000 psi at 28 days. The wall is to extend 2 feet minimum below the finish ground line adjacent to the wall.

   When concrete fascia panels are placed on soldier piles, a generalized detail of lagging with strongback (see Appendix 8.1-A3-5) shall be shown in the plans. This information will assist the contractor in designing formwork that does not overstress the piles while concrete is being placed.

   Precast concrete fascia panels shall be designed to carry 100% of the load that could occur during the life of the wall. When timber lagging (including pressure treated lumber) is designed to be placed behind a precast element, conventional design practice is to assume that lagging will eventually fail and the load will be transferred to the precast panel. If another type of permanent lagging is used behind the precast fascia panel, then the design of the fascia panel will be controlled by internal and external forces other than lateral pressures from the soil (weight, temperature, Seismic, Wind, etc.). The connections for precast panels to soldier piles shall be designed for all applicable loads and the designer should consider rigidity, longevity (to resist cyclic loading, corrosion, etc.), and load transfer.

   See Section 5.1.1 of this manual for use of shotcrete in lieu of cast-in-place conventional concrete for soldier pile fascia panels.

8.1.4 Miscellaneous Items

A. **Drainage –** Drainage features shall be detailed in the Plans.

Permanent drainage systems shall be provided to prevent hydrostatic pressures developing behind the wall. A cut that slopes toward the proposed wall will invariably encounter natural subsurface drainage. Vertical chimney drains or prefabricated drainage mats can be used for normal situations to collect and transport drainage to a weep hole or pipe located at the base of the wall. Installing horizontal drains to intercept the flow at a distance well behind the wall may control concentrated areas of subsurface drainage (see WSDOT *Geotechnical Design Manual* M 46-03 Chapter 15).

All reinforced concrete retaining walls shall have 3-inch diameter weepholes located 6 inches above final ground line and spaced about 12 feet apart. In case the vertical distance between the top of the footing and final ground line is greater than 10 feet, additional weepholes shall be provided 6 inches above the top of the footing. No weepholes are necessary in cantilever wingwalls.

Weepholes can get clogged up or freeze up, and the water pressure behind the wall may start to increase. In order to keep the water pressure from building, it is important to have well draining gravel backfill and underdrains. Appropriate details must be shown in the Plans.

No underdrain pipe or gravel backfill for drains is necessary behind cantilever wingwalls. A 3 foot minimum thickness of gravel backfill shall be shown in the Plans behind the cantilever wingwalls. Backfill material shall be included with the civil quantities (not the bridge quantities). If it is necessary to excavate existing material for the backfill, then this excavation shall be a part of the bridge quantities for “Structure Excavation Class A Incl. Haul”.

B. **Scour –** The foundation for all walls constructed along rivers and streams shall be evaluated during design by the Hydraulics Engineer for scour in accordance with AASHTO LRFD Sec. 2.6.4.4.2. The wall foundation shall be located at least 2 feet below the scour depth in accordance with the WSDOT *Geotechnical Design Manual* M 46-03 Section15.4.5.

C. **Joints –** For cantilevered and gravity walls constructed without a traffic barrier attached to the top, joint spacing should be a maximum of 24 feet on centers. For cantilevered and gravity walls constructed with a traffic barrier attached to the top, joint spacing should be a maximum of 48 feet on centers or that determined for adequate distribution of the traffic collision loading. For counterfort walls, joint spacing should be a maximum of 32 feet on centers. For soldier pile and soldier pile tieback walls with concrete fascia panels, joint spacing should be 24 to 32 feet on centers. For precast units, the length of the unit depends on the height and weight of each unit. Odd panels for all types of walls shall normally be made up at the ends of the walls. Every joint in the wall shall provide for expansion. For cast-in-place construction, a minimum of ½ inch premolded filler should be specified in the joints. A compressible back-up strip of closed-cell foam polyethylene or butyl rubber with a sealant on the front face is used for precast concrete walls.

No joints other than construction joints shall be used in footings except at bridge abutments and where substructure changes such as spread footing to pile footing occur. In these cases, the footing shall be interrupted by a ½ inch premolded expansion joint through both the footing and the wall. The maximum spacing of construction joints in the footing shall be 120 feet. The footing construction joints should have a 6-inch minimum offset from the expansion joints in the wall.

D. **Architectural Treatment –** The type of surface treatment for retaining walls is decided on a project specific basis. Consult the State Bridge and Structures Architect during preliminary plan preparation for approval of all retaining wall finishes, materials and configuration. The wall should blend in with its surroundings and complement other structures in the vicinity.

E. **Shaft Backfill for Soldier Pile Walls –** Specify controlled density fill (CDF, 145 pcf) for soldier pile shafts (full height) when shafts are anticipated to be excavated in the dry

When under water concrete placement is anticipated for the soldier pile shafts, specify pumpable lean concrete.

F. **Detailing of Standard Reinforced Concrete Retaining Walls**

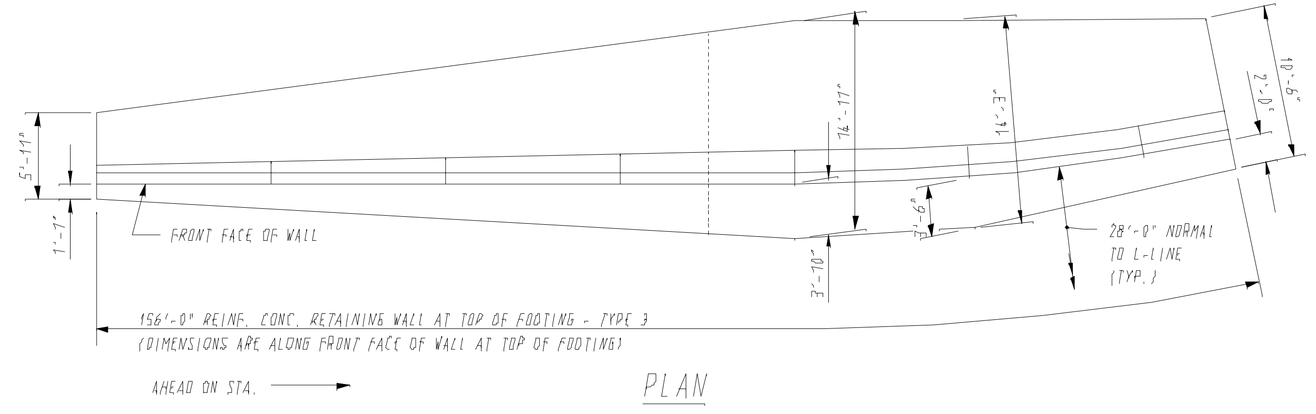
1. In general, the “H” dimension shown in the retaining wall Plans should be in foot increments. Use the actual design “H” reduced to the next lower even foot for dimensions up to 3 inches higher than the even foot.

   Examples: Actual height = 15′-3”↑, show “H” = 15’ on design plans
   Actual height > 15′-3”↑, show “H” = 16’ on design plans

   For walls that are not of a uniform height, “H” should be shown for each segment of the wall between expansion joints or at some other convenient location. On walls with a steep slope or vertical curve, it may be desirable to show 2 or 3 different “H” dimensions within a particular segment. The horizontal distance should be shown between changes in the “H” dimensions.

   The value for “H” shall be shown in a block in the center of the panel or segment. See Example, Figure 9.4.4-1.

2. Follow the example format shown in Figure 8.1.4-1.
3. Calculate approximate quantities using the Standard Plans.
4. Wall dimensions shall be determined by the designer using the Standard Plans.
5. Do not show any details given in the Standard Plans.
6. Specify in the Plans all deviations from the Standard Plans.
7. Do not detail reinforcing steel, unless it deviates from the Standard Plans.
8. For pile footings, use the example format with revised footing sizes, detail any additional steel, and show pile locations. Similar plan details are required for footings supported by shafts.



1. SEE ST'D. PLAN D-2f FOR TYPE 3 RET. WALL.
2. SEE "ALTERNATE DETAIL" ON ST'D. PLAN D-4 FOR DRAINAGE DETAILS. GRAVEL BACKFILL FOR DRAINS, GRAVEL BACKFILL FOR WALLS & UNDERDRAIN PIPE ARE NOT INCLUDED IN BRIDGE QUANTITIES.

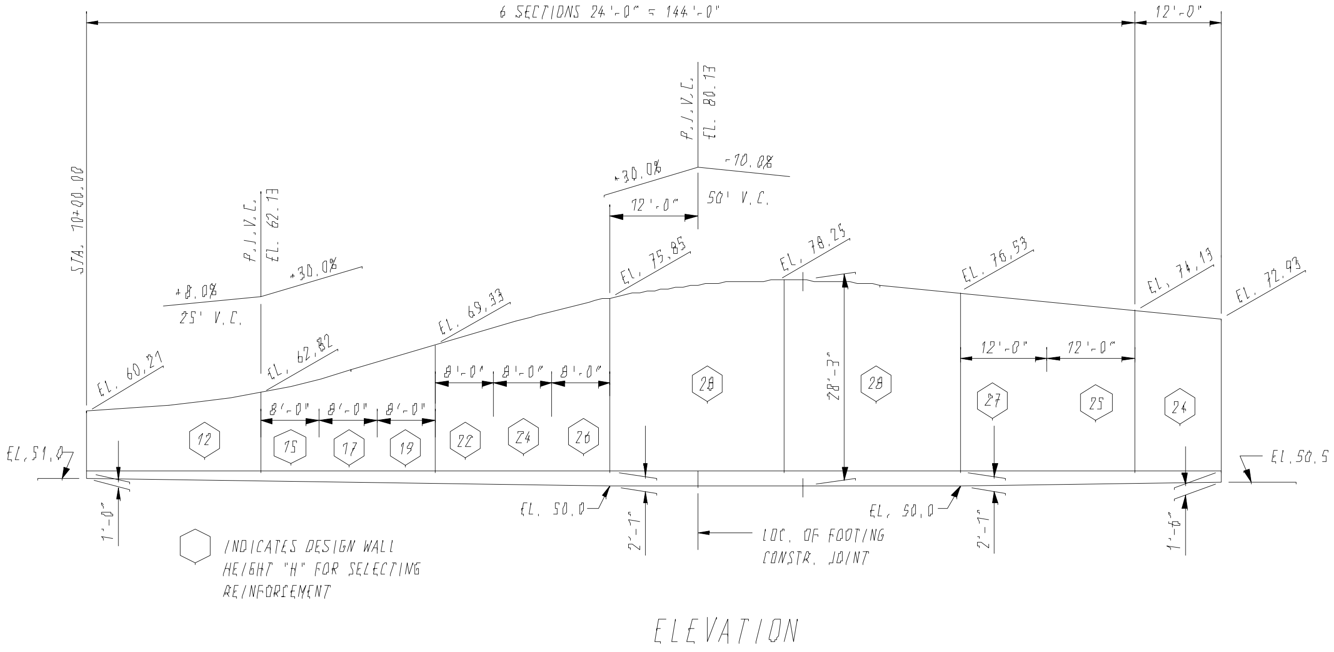


Figure 8.1.4-1

8.2 Miscellaneous Underground Structures

8.2.1 General

Miscellaneous underground structures consist of box culverts, precast reinforced concrete three-sided structures, detention vaults, and metal pipe arches.

Where miscellaneous underground structures pass under or support roadways and other structures, they shall be designed for seismic effects as follows:

- Seismic effects need not be considered for structures with span lengths of 20 feet or less.
- Seismic effects shall be considered for structures with span lengths more than 20 feet. The potential effects of unstable ground conditions (e.g., liquefaction, liquefaction induced settlement, landslides, ground motion attenuation with depth, and fault displacements) on the function of the underground structures shall be considered. The *AASHTO LRFD Bridge Design Specifications* Section 12.6.1 exemption from seismic loading shall not apply.

As with any structure, a geotechnical soils report with loading or pressure diagrams, settlement criteria, and ground water levels will be needed from the Materials Laboratory Geotechnical Office in order to complete the design. The requirement of BDM Section 3.5 for inclusion of live load in Extreme Event-I load combination is applicable.

In addition to the *AASHTO LRFD Bridge Design Specifications*, the FHWA Publication No. FHWA-NHI-09-010 dated November 2008, *Technical Manual for Design and Construction of Road Tunnels Civil Elements*, may also be used as a design specification reference for the seismic design requirement.

8.2.2 Design

A. **Box Culverts** – Box culverts are four-sided rigid frame structures and are either made from cast-in-place (CIP) reinforced concrete or precast concrete. In the past, standardized box culvert plan details were shown in the WSDOT *Standard Plans*, under the responsibility of the Hydraulics Branch. These former Standard Plans have been deleted and are no longer available. Now box culvert design is standardized under applicable AASHTO material specifications, and design plans are not required in the PS&E. Box culverts shall be in accordance with ASTM C1433.

B. **Precast Reinforced Concrete Three-Sided Structures** – Precast reinforced concrete three-sided structures are patented or trademarked rigid frame structures made from precast concrete. Some fabricators of these systems are: Utility Vault Company, Central Pre-Mix Prestress Company, and Bridge Tek, LLC. These systems require a CIP concrete or precast footing that must provide sufficient resistance to the horizontal reaction or thrust at the base of the vertical legs.

The precast concrete fabricators are responsible for the structural design and the preparation of shop plans. Precast reinforced concrete three sided structures, constructed in accordance with the current WSDOT General Special Provisions (GSP's) for these structures, shall be designed under AASHTO LRFD Bridge Specifications. The fabricators of systems which have received WSDOT pre-approval are specified in the GSP's. The bridge designer reviewing the project will be responsible for reviewing the fabricator's design calculations and details with consultation from the Construction Support Unit. Under the current GSP, precast reinforced concrete three sided structures are limited to spans of 26 feet or less. However, in special cases it may be necessary to allow longer spans, with the specific approval of the Bridge and Structures Office. Several manufacturers advertise spans over 40 feet.

C. **Detention Vaults** – Detention vaults are used for stormwater storage and are to be watertight. These structures can be open at the top like a swimming pool, or completely enclosed and buried below ground. Detention vaults shall be designed by the AASHTO LRFD Bridge Design Specification and the following: Seismic design effects shall satisfy the requirements of ACI 350.3-06 "Seismic Design of Liquid-Containing Concrete Structures." Requirements for Joints and jointing shall satisfy the requirements of ACI 350-06. Two references for tank design are the PCA publications *Rectangular Concrete Tanks*, Revised 5th Edition (1998) and *Design of Liquid-Containing Structures for Earthquake Forces* (2002).

The geotechnical field investigations and recommendations shall comply with the requirements given in 8.16 of the WSDOT *Geotechnical Design Manual* M 46-03. In addition to earth pressures, water tables, seismic design, and uplift, special consideration should be given to ensure differential settlement either does not occur or is included in the calculations for forces, crack control and water stops.

Buoyant forces from high ground water conditions should be investigated for permanent as well as construction load cases so the vault does not float. Controlling loading conditions may include: backfilling an empty vault, filling the vault with stormwater before it is backfilled, or seasonal maintenance that requires draining the vault when there is a high water table. In all Limit States, the buoyancy force (*WA*) load factor shall be taken as $\gamma_{WA} = 1.25$ in AASHTO LRFD Table 3.4.1-1. In the Strength Limit State, the load factors that resist buoyancy (γ_{DC}, γ_{DW}, γ_{ES}, Etc.) shall be their minimum values, per AASHTO LRFD Table 3.4.1-2 and the entire vault shall be considered empty. During the vault construction, the water table shall be taken as the seal vent elevation or the top of the vault, if open at the top. In this case the load factors that resist buoyancy shall be their minimum values, except where specified as a construction load, per AASHTO LRFD Section 3.4.2. In certain situations tie-downs may be required to resist buoyancy forces. The resisting force (R_n) and resistance factors (ø) for tie-downs shall be provided by the Geotechnical Engineers. The buoyancy check shall be as follows:

For Buoyancy without tie-downs:

$$(R_{RES} / R_{UPLIFT}) \geq 1.0$$

For Buoyancy with tie-downs:

$$(R_{\mathrm{RES}} / [R_{UPLIFT} + øR_n]) \geq 1.0$$

Where:

$$R_{RES} = \left| \gamma_{DC}\, DC + \gamma_{DW}\, DW + \gamma_{ES}\, ES + \gamma_{\mathrm{i}}\, Q_{\mathrm{i}} \right|$$

$$R_{UPLIFT} = \left| \gamma_{\mathrm{WA}}\, WA \right|$$

ACI 350-06 has stricter criteria for cover and spacing of joints than the AASHTO LRFD Specifications. Cover is not to be less than 2 inches (ACI 7.7.1), no metal or other material is to be within 1½ inches from the formed surface, and the maximum bar spacing shall not exceed 12 inches (ACI 7.6.5). Crack control criteria is per AASHTO LRFD 5.7.3.4 with $\gamma_e = 0.5$ (in order to maintain a crack width of 0.0085 inches, per the commentary of 5.7.3.4).

Joints in the vault's top slab, bottom slab and walls shall allow dissipation of temperature and shrinkage stresses, thereby reducing cracking. The amount of temperature and shrinkage reinforcement is a function of reinforcing steel grade "and length between joints (ACI Table 7.12.2-1). All joints shall have a shear key and a continuous and integral PVC waterstop with a 4-inch minimum width. The purpose of the waterstop is to prevent water infiltration and exfiltration. Joints having welded shear connectors with grouted keyways shall use details from WSDOT Precast Prestressed Slab Details or approved equivalent, with weld ties spaced at 4′-0″ on center. Modifications to the above joints shall be justified with calculations. Calculations shall be provided for all grouted shear connections. The width of precast panels shall be increased to minimize the number of joints between precast units.

For cast-in-place walls in contact with liquid that are over 10′ in height, the minimum wall thickness is 12″. This minimum thickness is generally good practice for all external walls, regardless of height, to allow for 2 inches of cover as well as space for concrete placement and vibration.

After the forms are placed, the void left from the form ties shall be coned shaped, at least 1 inch in diameter and 1½ inches deep, to allow proper patching.

Detention vaults that need to be located within the prism supporting the roadway are required to meet the following maintenance criteria. A by-pass piping system is required. Each cell in the vault shall hold no more than 6,000 gallons of water to facilitate maintenance and cleanout operations. Baffles shall be water tight. Access hatches shall be spaced no more than 50 feet apart. There shall be an access near both the inlet and the outfall. These two accesses shall allow for visual inspection of the inlet and outfall elements, in such a manner that a person standing on the ladder, out of any standing water, will be in reach of any grab handles, grates or screens. All other access hatches shall be over sump areas. All access hatches shall be a minimum 30 inch in diameter, have ladders that extend to the vault floor, and shall be designed to resist HS-20 wheel loads with applicable impact factors as described below.

Detention vaults that need to be located in the roadway shall be oriented so that the access hatches are located outside the traveled lanes. Lane closures are usually required next to each access hatch for maintenance and inspection, even when the hatches are in 12′-0″ wide shoulders.

A 16 kip wheel load having the dynamic load allowance for deck joints, in AASHTO LRFD Table 3.6.2.1-1, shall be applied at the top of access hatches and risers. The load path of this impact force shall be shown in the calculations.

Minimum vault dimensions shall be 4′-0″ wide and 7′-0″ tall; inside dimensions.

Original signed plans of all closed top detention vaults with access shall be forwarded to the Bridge Plans Engineer in the Bridge Project Unit (see Section 12.4.10.B of this manual). This ensures that the Bridge Preservation Office will have the necessary inventory information for inspection requirements. A set of plans must be submitted to both the WSDOT Hydraulics Office and the Regional WSDOT Maintenance Office for plans approval.

D. **Metal Pipe Arches –** Soil ph should be investigated prior to selecting this type of structure. Metal Pipe arches are not generally recommended under high volume highways or under large fills.

Pipe arch systems are similar to precast reinforced concrete three sided structures in that these are generally proprietary systems provided by several manufacturers, and that their design includes interaction with the surrounding soil. Pipe arch systems shall be designed in accordance with the *AASHTO Standard Specifications for Highway Bridges*, and applicable ACI design and ASTM material specifications.

E. **Tunnels –** Tunnels are unique structures in that the surrounding ground material is the structural material that carries most of the ground load. Therefore, geology has even more importance in tunnel construction than with above ground bridge structures. In short, geotechnical site investigation is the most important process in planning, design and construction of a tunnel. These structures are designed in accordance with the *AASHTO LRFD Bridge Design Specifications*.

Tunnels are not a conventional structure, and estimation of costs is more variable as size and length increase. Ventilation, safety access, fire suppression facilities, warning signs, lighting, emergency egress, drainage, operation and maintenance are extremely critical issues associated with the design of tunnels and will require the expertise of geologists, tunnel experts and mechanical engineers.

For motor vehicle fire protection, a standard has been produced by the National Fire Protection Association. This document, *NFPA 502 – Standard for Road Tunnels, Bridges, and Other Limited Access Highways*, uses tunnel length to dictate minimum fire protection requirements:

300 feet or less: no fire protection requirements
300 to 800 feet: minor fire protection requirements
800 feet or more: major fire protection requirements

Some recent WSDOT tunnel projects are:

I-90 Mt. Baker Ridge Tunnel Bore Contract: 3105 Bridge No: 90/24N

This 1500 foot long tunnel is part of the major improvement of Interstate 90. Work was started in 1983 and completed in 1988. The net interior diameter of the bored portion, which is sized for vehicular traffic on two levels with a bike/pedestrian corridor on the third level, is 63.5 feet. The project is the world's largest diameter tunnel in soft ground, which is predominantly stiff clay. Construction by a stacked-drift method resulted in minimal distortion of the liner and insignificant disturbance at the ground surface above.

Jct I-5 SR 526 E-N Tunnel Ramp Contract: 4372 Bridge No: 526/22E-N

This 465 foot long tunnel, an example of the cut and cover method, was constructed in 1995. The interior dimensions were sized for a 25 foot wide one lane ramp roadway with a vertical height of 18 feet. The tunnel was constructed in three stages. 3 and 4 foot diameter shafts for the walls were placed first, a 2 foot thick cast-in-place top slab was placed second and then the tunnel was excavated, lined and finished.

I-5 Sleater-Kinney Bike/Ped. Tunnel Contract: 6031 Bridge No: 5/335P

This 122 foot long bike and pedestrian tunnel was constructed in 2002 to link an existing path along I-5 under busy Sleater-Kinney Road. The project consisted of precast prestressed slab units and soldier pile walls. Construction was staged to minimize traffic disruptions.

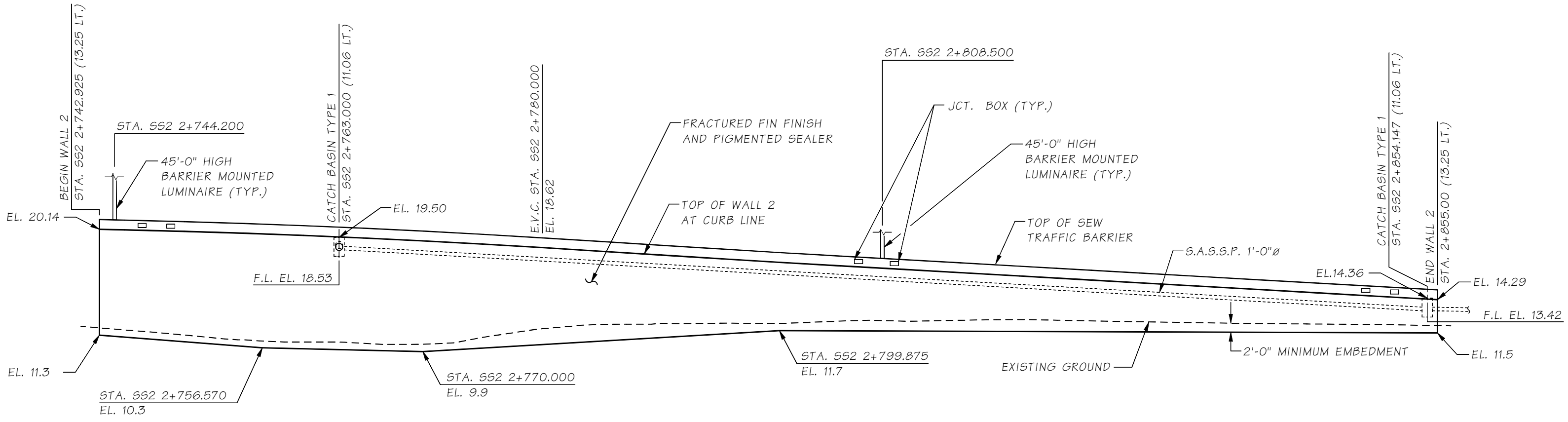
8.2.3 References

1. *AASHTO LRFD Bridge Design Specifications*, 5th Edition, American Association of State Highway and Transportation Officials, Washington, D.C.
2. AASHTO *Standard Specifications for Highway Bridges*, 17th Ed., 2002
3. WSDOT *Standard Specifications for Highway Bridges and Municipal Construction*, Olympia, Washington 98501.
4. ACI 350/350R-06 Code Requirements for Environmental Engineering Concrete Structures, ACI, 2006.
5. Munshi, Javeed A. *Rectangular Concrete Tanks*, Rev. 5th Ed., PCA, 1998.
6. Miller, C. A. and Constantino, C. J. "Seismic Induced Earth Pressure in Buried Vaults", PVP-Vol.271, *Natural Hazard Phenomena and Mitigation*, ASME, 1994, pp. 3-11.
7. Munshi, J. A. *Design of Liquid-Containing Concrete Structures for Earthquake Forces*, PCA, 2002.
8. NFPA 502, *Standard for Road Tunnels, Bridges, and Other Limited Access Highways*.

Appendix 8.1-A1 Summary of Design Specification Requirements for Walls

Wall Types	Design Specifications	
Pre-Approved Proprietary Structural Earth Walls	General	Design shall be based on current editions, including current interims, of the following documents; AASHTO Standard Specifications for Highway Bridges - 17th Edition for projects initiated prior to October 1, 2010. AASHTO LRFD Bridge Design Specifications for projects initiated after October 1, 2010, WSDOT Geotechnical Design Manual (GDM) and WSDOT Bridge Design Manual (BDM).
	Seismic	AASHTO LRFD Bridge Design Specifications 1000 year map design acceleration.
	Traffic Barrier	Moment slab barrier shall be designed in accordance with the WSDOT BDM and the AASHTO LRFD Bridge Design Specifications section A13.3 for Concrete Railings considering a minimum TL-4 impact load, unless otherwise specified in the Contract Plans or Contract Special Provisions.
Non-Preapproved Proprietary Structural Earth Walls	General	Design shall be based on current editions, including current interims, of the following documents; AASHTO LRFD Bridge Design Specifications, WSDOT GDM and WSDOT BDM.
	Seismic	AASHTO LRFD Bridge Design Specifications 1000 year map design acceleration.
	Traffic Barrier	Moment slab barrier shall be designed in accordance with the WSDOT BDM and the AASHTO LRFD Bridge Design Specifications section A13.3 for Concrete Railings considering a minimum TL-4 impact load, unless otherwise specified in the Contract Plans or Contract Special Provisions.
Standard Plan and Non-Standard Geosynthetic Walls	General	Design shall be based on current editions, including current interims, of the following documents; AASHTO LRFD Bridge Design Specifications, WSDOT GDM and WSDOT BDM.
	Seismic	AASHTO LRFD Bridge Design Specifications 1000 year Seismic Acceleration map.
	Traffic Barrier	For Standard Plan Geosynthetic walls use Standard Plan D-3b (D-3.15) or D-3c (D-3.16) barriers. Special design barriers to be constructed on Standard Plan or Non-Standard Geosynthetic Walls shall be designed in accordance with the WSDOT Bridge Design Manual and the AASHTO LRFD Bridge Design Specifications section A13.3 for Concrete Railings considering a minimum TL-4 impact load.
Standard Plan and Non-Standard Reinforced Concrete Cantilever Walls	General	Current Standard Plan walls are designed in accordance with AASHTO LRFD Bridge Design Specifications 4th Edition 2007 and interims through 2008 and the WSDOT Geotechnical Design Manual Nov. 2008. Non-standard reinforced concrete cantilever walls shall be designed in accordance with the current editions, including current interims, of the following documents; AASHTO LRFD Bridge Design Specifications, WSDOT Geotechnical Design Manual and WSDOT Bridge Design Manual.
	Seismic	AASHTO LRFD Bridge Design specifications 1000 year map design acceleration.
	Traffic Barrier	WSDOT Bridge Design Manual and the AASHTO LRFD Bridge Design Specifications section A13.3 for Concrete Railings considering a minimum TL-4 impact load. F_t is distributed over L_t at the top of barrier. Load from top of barrier is distributed at a 45 degree angle into the wall. Current Standard Plan walls are designed for TL-4 impact loading distributed over 48 ft at the base of wall

Wall Types	**Design Specifications**	
Soldier Pile Walls With & Without Tie-Backs	General	Design shall be based on current editions, including current interims, of the following documents; AASHTO LRFD Bridge Design Specifications, WSDOT GDM and WSDOT BDM.
	Seismic	AASHTO LRFD Bridge Design Specifications 1000 year map design acceleration.
	Traffic Barrier	AASHTO LRFD Bridge Design Specifications section A13.3 for Concrete Railings considering a minimum TL-4 impact load. F_t is distributed over L_t at the top of barrier. Load from top of barrier is distributed downward into the wall spreading at a 45 degree angle.
Standard Plan Noise Barrier Walls	General	AASHTO Guide Specifications for Structural Design of Sound Barriers – 1989 & Interims.
	Seismic	AASHTO Guide Specifications for Structural Design of Sound Barriers – 1989 & Interims.
	Traffic Barrier	AASHTO Guide Specifications for Structural Design of Sound Barriers – 1989 & Interims.
Non-Standard Noise Barrier Walls	General	Design shall be based on current editions, including current interims, of the following documents; AASHTO LRFD Bridge Design Specifications, WSDOT GDM and WSDOT BDM.
	Seismic	AASHTO LRFD Bridge Design specifications 1000 year map design acceleration.
	Traffic Barrier	WSDOT Bridge Design Manual and the AASHTO LRFD Bridge Design Specifications section A13.3 for Concrete Railings considering a minimum TL-4 impact load.
Soil Nail Walls	General	All soil nail walls and their components shall be designed using the publication “Geotechnical Engineering Circular No. 7” FHWA-IF-03-017. The Geotechnical Engineer completes the internal design of the soil nail wall and provides recommendations for nail layout. The structural designer will layout the nail pattern. The geotechnical engineer will review the nail layout to insure compliance with the Geotechnical recommendations. The structural designer shall design the temporary shotcrete facing as well as the permanent structural facing, including the bearing plates, and shear studs. The upper cantilever of the facing that is located above the top row of nails shall be designed in accordance with current editions, including current interims, of the following documents; AASHTO LRFD Bridge Design Specifications, WSDOT GDM and WSDOT BDM.
	Seismic	AASHTO LRFD Bridge Design Specifications 1000 year map design acceleration.
	Traffic Barrier	Moment slab barrier shall be designed in accordance with the WSDOT Bridge Design Manual and the AASHTO LRFD Bridge Design Specifications section A13.3 for Concrete Railings considering a minimum TL-4 impact load
Non Standard Non Proprietary Walls Gravity Blocks, Gabion Walls	General	Design shall be based on current editions, including current interims, of the following documents; AASHTO LRFD Bridge Design Specifications, WSDOT GDM and WSDOT BDM.
	Seismic	AASHTO LRFD Bridge Design specifications 1000 year map design acceleration.
	Traffic Barrier	WSDOT Bridge Design Manual and the AASHTO LRFD Bridge Design Specifications section A13.3 for Concrete Railings considering a minimum TL-4 impact load.



DEVELOPED ELEVATION

Bridge Design Engr.
Supervisor
Designed By
Checked By
Detailed By
Bridge Projects Engr.
Prelim. Plan By
Architect/Specialist

M:\STANDARDS\Walls\MSE ELEV.MAN

DATE REVISION BY APP'D

REGION NO.	STATE	FED. AID PROJ. NO.	SHEET NO.	TOTAL SHEETS
10	WASH.			
JOB NUMBER				

BRIDGE
AND
STRUCTURES
OFFICE

Washington State
Department of Transportation

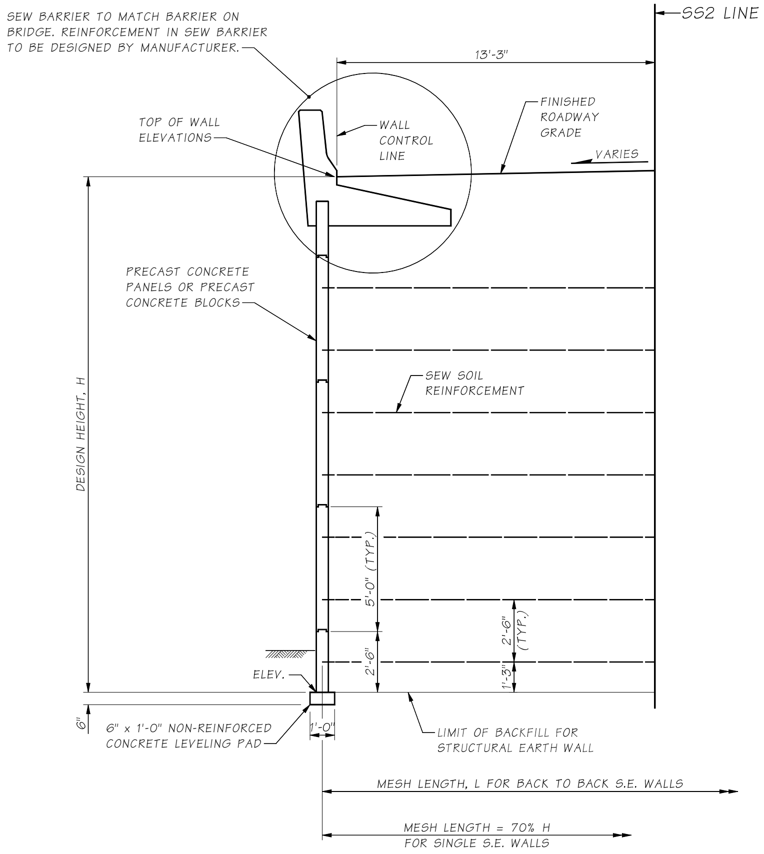
SEW WALL ELEVATION

BRIDGE SHEET NO.

SHEET
OF
SHEETS

JOB NO. SHEET
SR

Fri Sep 03 11:29:50 2010



TYPICAL CROSS SECTION

SR ___ JOB NO. ___ SHEET ___

8.1-A2-2

Bridge Design Engr.	M:\STANDARDS\Walls\MSE SECTION.MAN				
Supervisor					
Designed By					
Checked By					
Detailed By					
Bridge Projects Engr.					
Prelim. Plan By					
Architect/Specialist	DATE	REVISION	BY	APP'D	

REGION NO.	STATE	FED. AID PROJ. NO.	SHEET NO.	TOTAL SHEETS
10	WASH.			
JOB NUMBER				

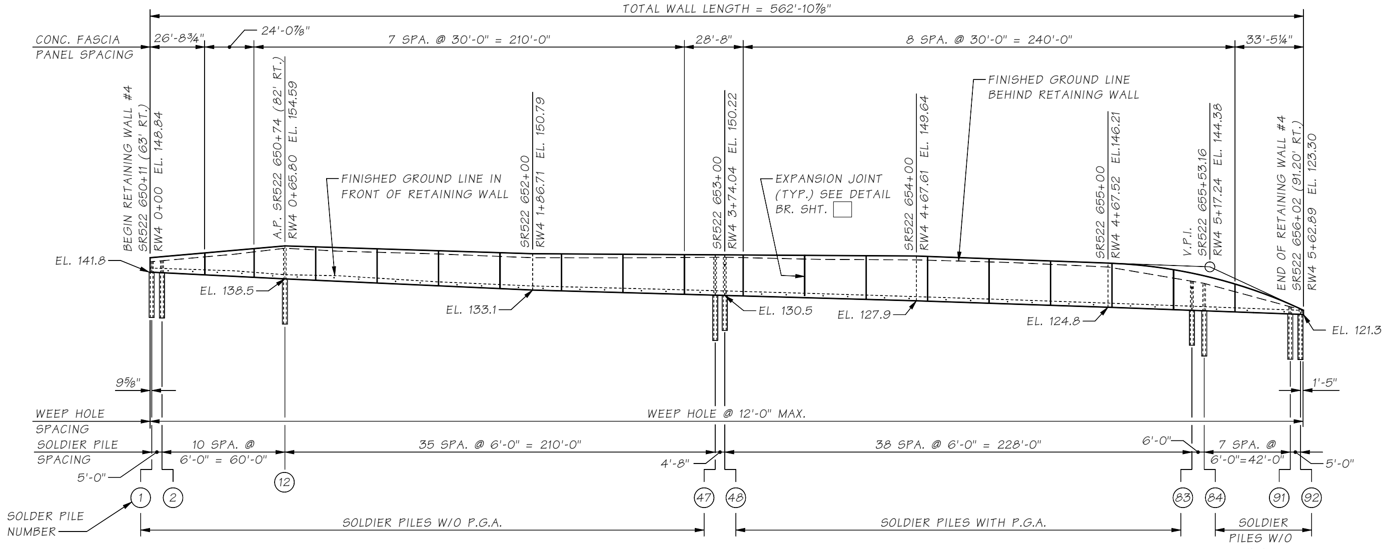
BRIDGE
AND
STRUCTURES
OFFICE

Washington State Department of Transportation

SEW WALL SECTION

BRIDGE SHEET NO.
SHEET
OF
SHEETS

Fri Sep 03 11:29:52 2010



REFLECTED DEVELOPED ELEVATION

A.P. = ANGLE POINT

GENERAL NOTES

(FOR SOLDIER PILES WITH P.G.A.)

1. ALL MATERIAL AND WORKMANSHIP SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF THE WASHINGTON STATE DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS FOR ROAD, BRIDGE AND MUNICIPAL CONSTRUCTION-ENGLISH, DATED 2010, AND AMENDMENTS.
2. THIS STRUCTURE HAS BEEN DESIGNED IN ACCORDANCE WITH THE REQUIREMENTS OF THE AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS - 4TH EDITION - 2007 WITH INTERIMS THRU 2009.
3. W SECTION STEEL SOLDIER PILES SHALL CONFORM TO ASTM A992. HP SECTION STEEL SOLDIER PILES SHALL CONFORM TO ASTM A572. SOLDIER PILES SHALL BE PAINTED TO THE LIMITS SHOWN IN THE PLANS IN ACCORDANCE WITH SECTION 6-16.3(4).
4. PLATES FOR THE SOLDIER PILE ASSEMBLY STIFFENER SHALL CONFORM TO ASSTM A572 GR. 50. THE 8"ø EXTRA STRONG PIPE SHALL CONFORM TO THE REQUIREMENTS OF ASTM A53 GR. B.
5. ALL WELDING SHALL BE DONE TO MINIMIZE DISTORTION. THE WELDING SEQUENCES AND PROCEDURES TO BE USED SHALL BE SUBMITTED TO THE ENGINEER FOR APPROVAL PRIOR TO THE START OF WELDING.
6. UNLESS OTHERWISE SHOWN IN THE PLANS, THE CONCRETE COVER MEASURED FROM THE FACE OF THE CONCRETE TO THE FACE OF ANY REINFORCING STEEL SHALL BE 1½".
7. ALL DIMENSIONS ARE HORIZONTAL AND VERTICAL UNLESS OTHERWISE SHOWN.
8. EXISTING GROUND LINE IS APPROXIMATE AND SHALL BE VERIFIED BY THE CONTRACTOR IN THE FIELD.
9. PERMANENT GROUND ANCHOR LOCK OFF LOAD = 60 PERCENT OF FACTORED DESIGN LOAD.

GENERAL NOTES

(FOR SOLDIER PILES WITHOUT P.G.A.)

1. ALL MATERIAL AND WORKMANSHIP SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF THE WASHINGTON STATE DEPARTMENT OF TRANSPORTATION STANDARD SPECIFICATIONS FOR ROAD, BRIDGE AND MUNICIPAL CONSTRUCTION-ENGLISH, DATED 2010, AND AMENDMENTS.
2. THIS STRUCTURE HAS BEEN DESIGNED IN ACCORDANCE WITH THE REQUIREMENTS OF THE AASHTO LRFD BRIDGE DESIGN SPECIFICATIONS - 4TH EDITION - 2007 WITH INTERIMS THRU 2009.
3. W SECTION STEEL SOLDIER PILES SHALL CONFORM TO ASTM A992. HP SECTION STEEL SOLDIER PILES SHALL CONFORM TO ASTM A572. SOLDIER PILES SHALL BE PAINTED TO THE LIMITS SHOWN IN THE PLANS IN ACCORDANCE WITH SECTION 6-16.3(4).
4. UNLESS OTHERWISE SHOWN IN THE PLANS, THE CONCRETE COVER MEASURED FROM THE FACE OF THE CONCRETE TO THE FACE OF ANY REINFORCING STEEL SHALL BE 1½".
5. ALL DIMENSIONS ARE HORIZONTAL AND VERTICAL UNLESS OTHERWISE SHOWN.
6. EXISTING GROUND LINE IS APPROXIMATE AND SHALL BE VERIFIED BY THE CONTRACTOR IN THE FIELD.

SOLDIER PILE/TIEBACK WALL

SR ____ JOB NO. ____ SHEET ____

Bridge Design Engr.	M:\STANDARDS\Walls\SOLDIER TIEBACK ELEV.MAN								
Supervisor					REGION NO.	STATE	FED. AID PROJ. NO.	SHEET NO.	TOTAL SHEETS
Designed By					10	WASH.			
Checked By									
Detailed By					JOB NUMBER				
Bridge Projects Engr.									
Prelim. Plan By									
Architect/Specialist	DATE	REVISION	BY	APP'D					

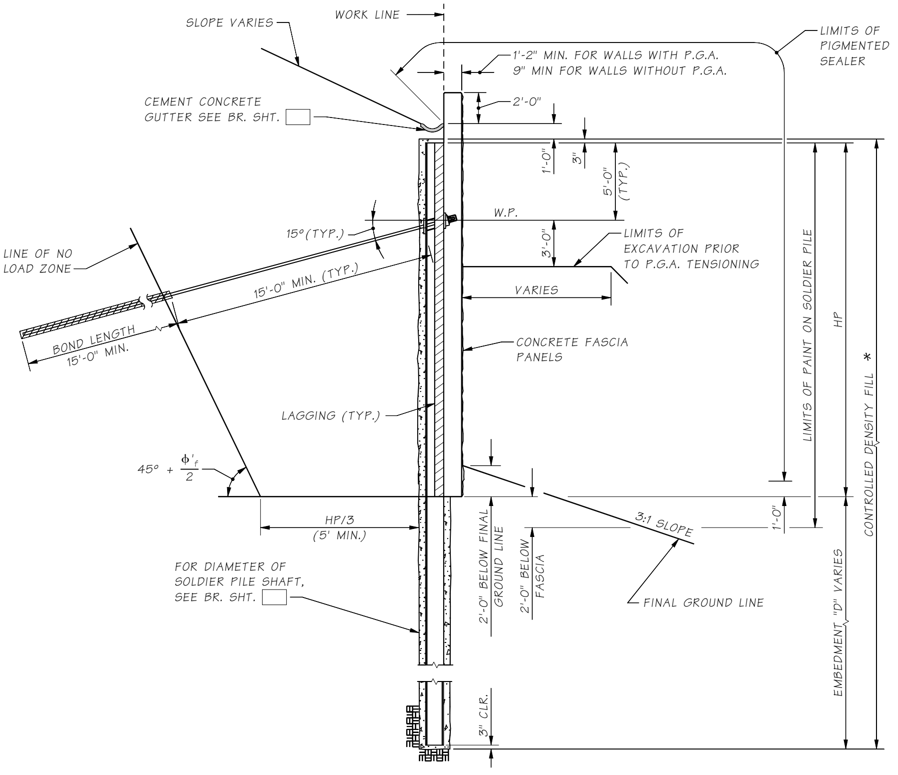
BRIDGE
AND
STRUCTURES
OFFICE

Washington State
Department of Transportation

SOLDIER PILE/TIEBACK WALL
ELEVATION

BRIDGE SHEET NO.
SHEET
OF
SHEETS

Fri Sep 03 11:29:53 2010



TYPICAL SECTION

SHOWN FOR SOLDIER PILE WITH P.G.A.
SIMILAR FOR SOLDIER PILE WITHOUT P.G.A.

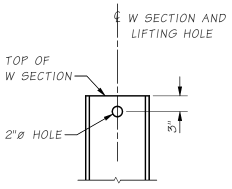
P.G.A.= PERMANENT GROUND ANCHOR

LAGGING SYSTEM SHALL BE DESIGNED BY THE CONTRACTOR AND SUBMITTED TO THE ENGINEER FOR APPROVAL IN ACCORDANCE WITH THE STANDARD SPECIFICATION SECTION 6-16.3(6).

* USE CONTROLLED DENSITY FILL WHEN PLACED IN THE DRY. USE PUMPABLE LEAN CONCRETE WHEN PLACED IN THE WET.

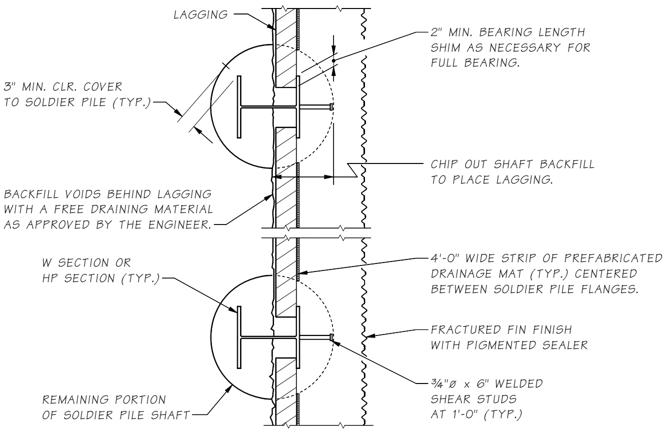
Note to Designer:

For walls with P.G.A. use a section size with a flange width bigger than or equal to HP12x53 or W12x65

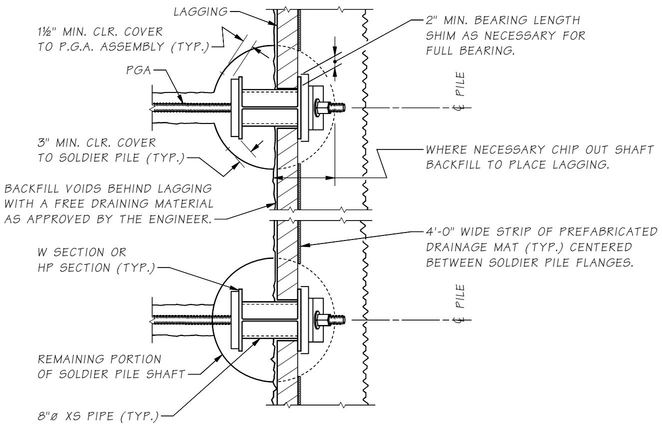


SOLDIER PILE LIFTING HOLE

LIFTING HOLE TO BE DRILLED IN THE SHOP PRIOR TO PAINTING THE PILE.



PLAN SOLDIER PILE WALL WITHOUT P. G. A.



PLAN SOLDIER PILE WALL WITH P. G. A.

LAGGING IN SERVICE
LESS THAN 36 MONTHS

Bridge Design Engr.
Supervisor
Designed By
Checked By
Detailed By
Bridge Projects Engr.
Prelim. Plan By
Architect/Specialist

DATE | REVISION | BY | APP'D

M:\STANDARDS\Walls\SOLDIER TIEBACK DETAILS A.MAN

REGION NO.	STATE	FED. AID PROJ. NO.	SHEET NO.	TOTAL SHEETS
10	WASH.			

JOB NUMBER

BRIDGE
AND
STRUCTURES
OFFICE

Washington State
Department of Transportation

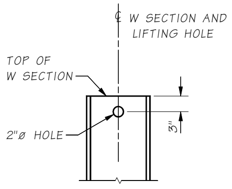
SOLDIER PILE/TIEBACK WALL
DETAILS 1 OF 2

BRIDGE SHEET NO.
SHEET
OF
SHEETS

Fri Sep 03 11:29:55 2010

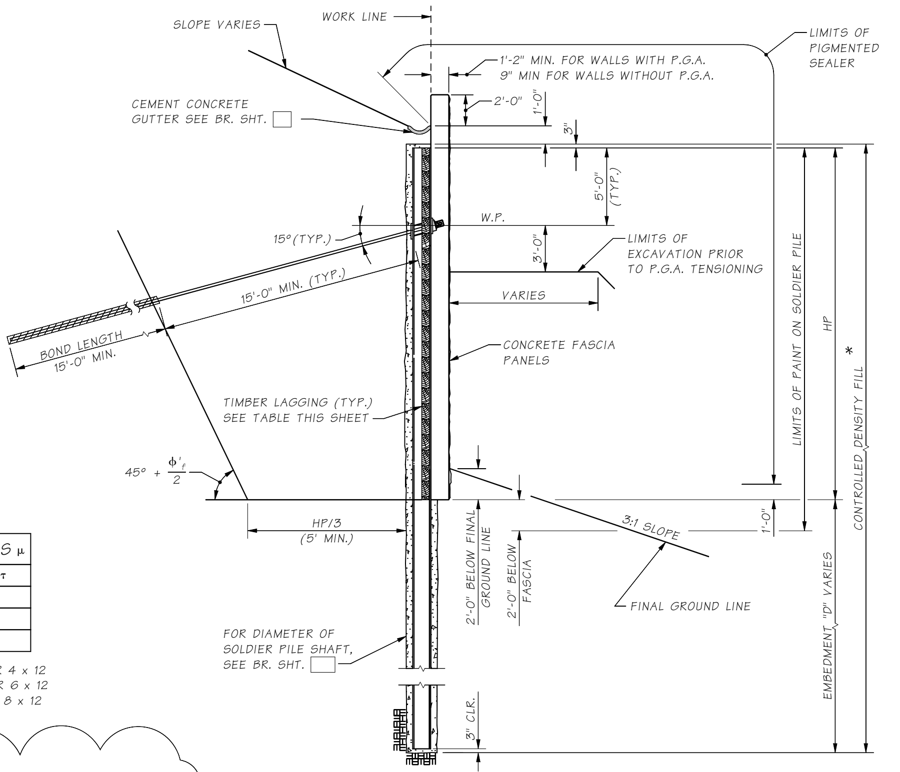
SR
JOB NO.
SHEET

8.1-A3-2



SOLDIER PILE LIFTING HOLE

LIFTING HOLE TO BE DRILLED IN THE SHOP PRIOR TO PAINTING THE PILE.



TYPICAL SECTION

SHOWN FOR SOLDIER PILE WITH P.G.A.
SIMILAR FOR SOLDIER PILE WITHOUT P.G.A.

P.G.A.= PERMANENT GROUND ANCHOR

* USE CONTROL DENSITY FILL WHEN PLACED IN THE DRY. USE PUMPABLE LEAN CONCRETE WHEN PLACED IN THE WET.

TIMBER LAGGING SIZES μ	
DEPTH (FT) τ	SIZE τ
0 - 9	4 x
9 - 18	6 x
18 - 30	8 x

4 x - OPTIONAL 4 x 8, 4 x 10 OR 4 x 12
6 x - OPTIONAL 6 x 8, 6 x 10 OR 6 x 12
8 x - OPTIONAL 8 x 8, 8 x 10 OR 8 x 12

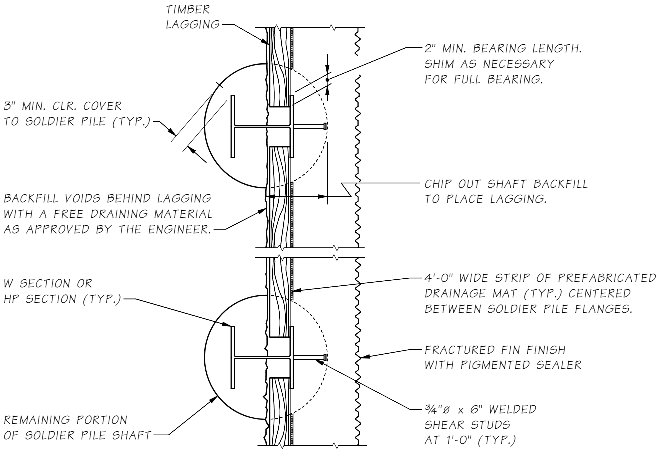
Notes to Designer:

τ Depths and sizes shown are for example only. Fill in the table according to the earth pressure diagram and recommendations from the Geotechnical Services Branch, based on LRFD timber design for permanent lagging.

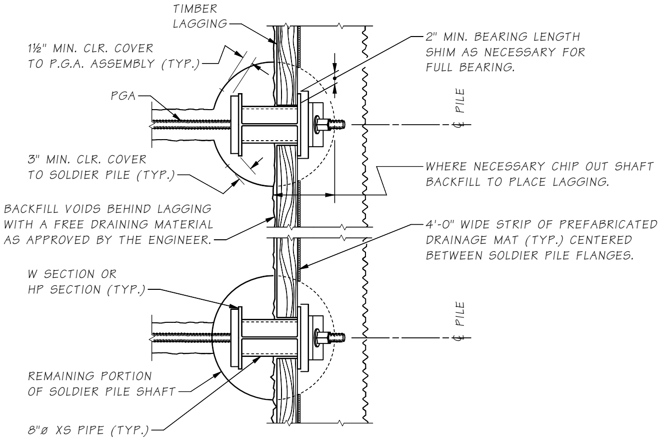
μ Determine, if possible, the length of time that the wall lagging will be used as the primary structural member in the transverse direction before a permanent wall fascia is applied.

For walls with P.G.A. use a section size with a flange width bigger than or equal to HP12x53 or W12x65.

For walls without concrete fascia panels:
1. Hem-fir timber lagging shall not be used.
2. Douglas fir-larch, grade no. 2 or better, treated in accordance with section 9-09.3(1), shall be used and shall be specified in the plan sheets and Special Provisions.



PLAN
SOLDIER PILE WALL WITHOUT P. G. A.



PLAN
SOLDIER PILE WALL WITH P. G. A.

LAGGING IN SERVICE
36 MONTHS OR LONGER

Bridge Design Engr. M:\STANDARDS\Walls\SOLDIER TIEBACK DETAILS B.MAN
Supervisor
Designed By
Checked By
Detailed By
Bridge Projects Engr.
Prelim. Plan By
Architect/Specialist
DATE REVISION BY APP'D

REGION NO.	STATE	FED. AID PROJ. NO.	SHEET NO.	TOTAL SHEETS
10	WASH.			
JOB NUMBER				

BRIDGE
AND
STRUCTURES
OFFICE

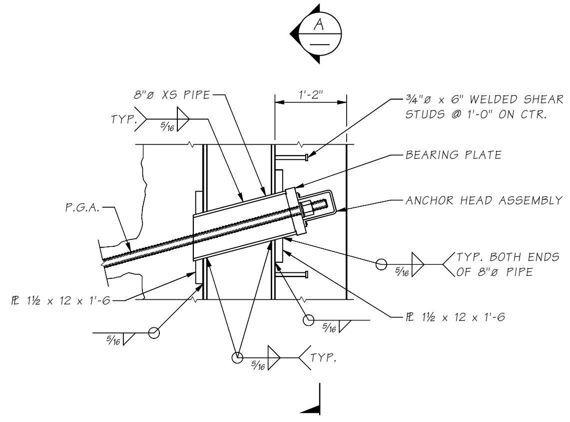
Washington State
Department of Transportation

SOLDIER PILE/TIEBACK WALL
DETAILS 1 OF 2

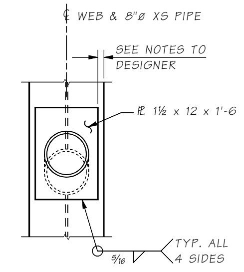
BRIDGE SHEET NO.
SHEET
OF
SHEETS

JOB NO.
SR
SHEET

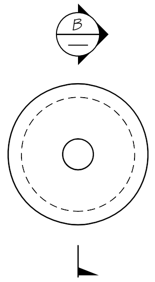
Fri Sep 03 11:29:57 2010



ELEVATION - SOLDIER PILE
WITH P.G.A. THRU WEB

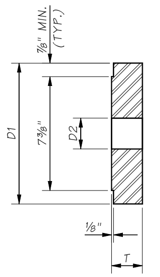


VIEW A



BEARING PLATE

BEARING PLATE SHALL BE DESIGNED BY THE CONTRACTOR AND SUBMITTED TO THE ENGINEER FOR APPROVAL IN ACCORDANCE WITH THE STANDARD SPECIFICATION SECTION 6-17.3(5).



SECTION B

Notes to Designer:

1. Plates must be checked for size and welds. Plates are used to replace flange steel removed for pipe installation.
2. Weld must be checked along web to pipe and plate to flange. welds must be capable of tranferring PGA loads and flexural loads.
3. For walls with P.G.A. use a section size with a flange width bigger than or equal to HP12x53 or W12x65.

Bridge Design Engr.
Supervisor
Designed By
Checked By
Detailed By
Bridge Projects Engr.
Prelim. Plan By
Architect/Specialist

M:\STANDARDS\Walls\SOLDIER TIEBACK DETAILS 2.MAN

DATE	REVISION	BY	APP'D

REGION NO.	STATE	FED. AID PROJ. NO.	SHEET NO.	TOTAL SHEETS
10	WASH.			

JOB NUMBER

BRIDGE
AND
STRUCTURES
OFFICE

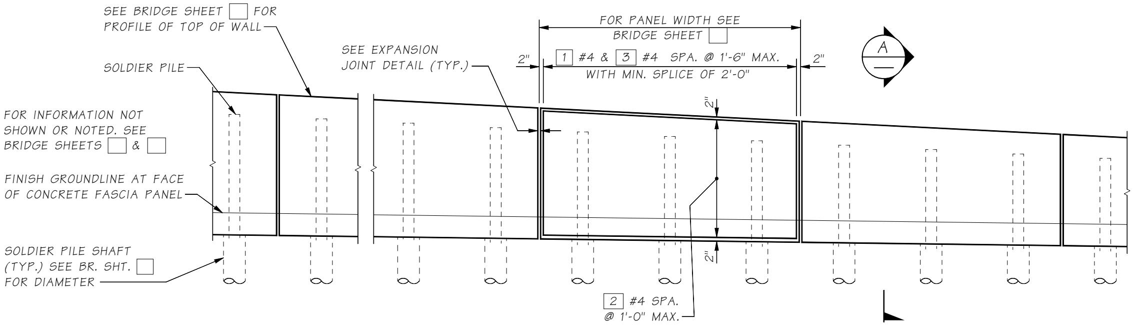
Washington State Department of Transportation

SOLDIER PILE/TIEBACK WALL
DETAILS 2 OF 2

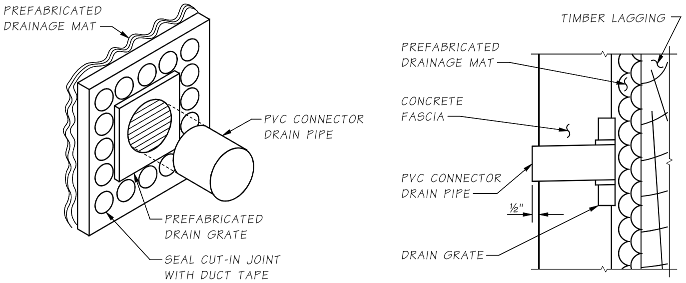
BRIDGE SHEET NO.
SHEET
OF
SHEETS

SR
JOB NO.
SHEET

Fri Sep 03 11:30:00 2010

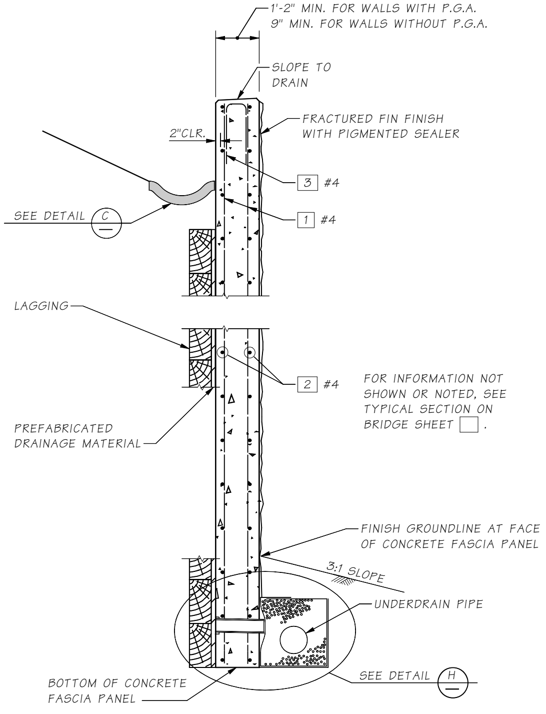


PARTIAL WALL ELEVATION

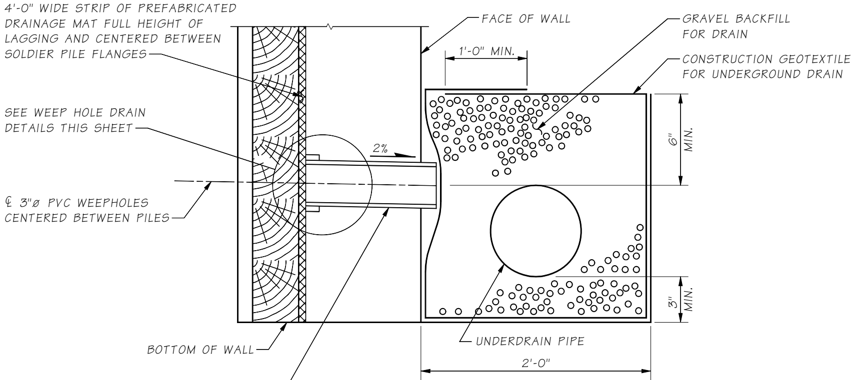


WEEP HOLE DRAIN DETAILS

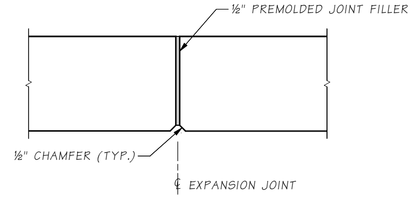
DRAIN GRATE INSTALLATION SHALL NOT DISRUPT PREFABRICATED DRAINAGE MAT



SECTION A

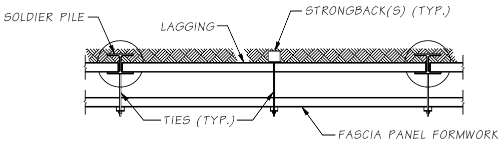


DETAIL H



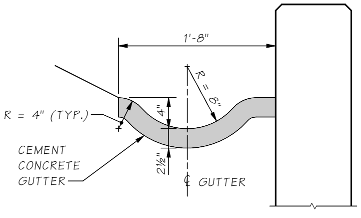
EXPANSION JOINT DETAIL

NOTE:
EXPANSION JOINTS SHALL BE LOCATED AS SHOWN ON BRIDGE SHEET ☐.



TYPICAL FASCIA PANEL FORMWORK

- SEE SECTION 6-16.3(2) FOR FASCIA PANEL FORMING REQUIREMENTS.
- STRONGBACK(S) AND TIES SPACED AS REQUIRED FOR FORMING.



DETAIL C

Bridge Design Engr.	M:\STANDARDS\Walls\SOLDIER TIEBACK FASCIA.MAN								
Supervisor					REGION NO.	STATE	FED. AID PROJ. NO.	SHEET NO.	TOTAL SHEETS
Designed By					10	WASH.			
Checked By									
Detailed By					JOB NUMBER				
Bridge Projects Engr.									
Prelim. Plan By									
Architect/Specialist	DATE	REVISION	BY	APP'D					

BRIDGE
AND
STRUCTURES
OFFICE

Washington State
Department of Transportation

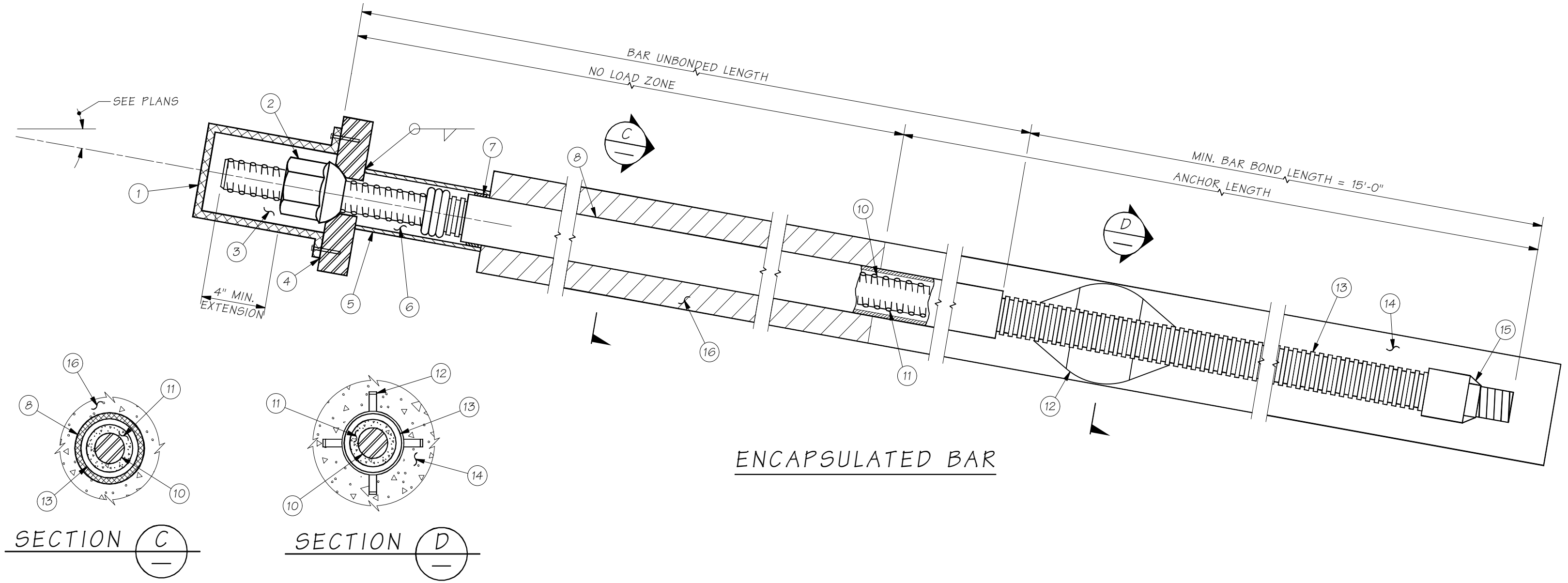
SOLDIER PILE/TIEBACK WALL
FASCIA PANEL DETAILS

BRIDGE SHEET NO.

SHEET
OF
SHEETS

Fri Sep 03 11:30:02 2010

SR
JOB NO.
SHEET

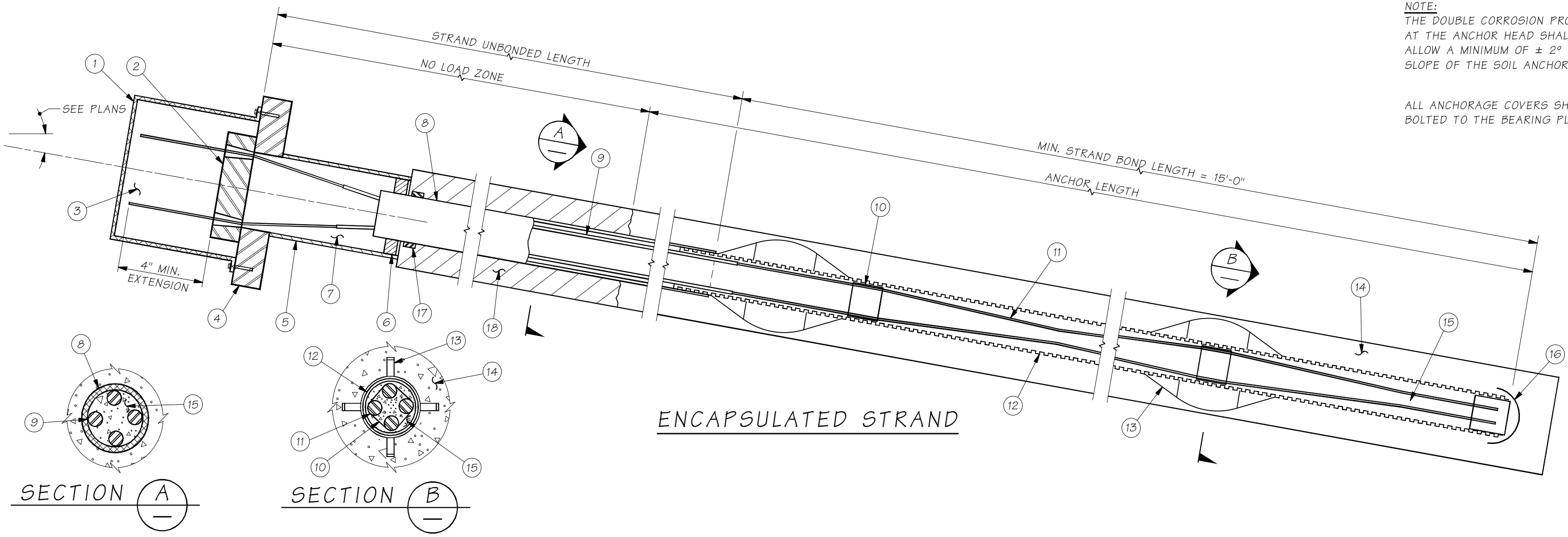


ENCAPSULATED BAR

1. ANCHORAGE COVER
2. NUT
3. ANTICORROSION GREASE
4. BEARING PLATE
5. TRUMPET
6. ANTICORROSION GREASE
7. SEAL
8. SMOOTH PVC BOND BREAKER
9. PROTECTED BAR COUPLER
10. BAR TENDON
11. ENCAPSULATION GROUT
12. CENTRALIZERS
13. CORRUGATED PVC
14. ANCHOR GROUT
15. END CAP
16. NONSTRUCTURAL FILLER

NOTE:
THE DOUBLE CORROSION PROTECTION SYSTEM AT THE ANCHOR HEAD SHALL BE DETAILED TO ALLOW A MINIMUM OF ± 2° VARIATION IN THE SLOPE OF THE SOIL ANCHOR FOR PLACEMENT TOLERANCE.

ALL ANCHORAGE COVERS SHALL BE BOLTED TO THE BEARING PLATES.



ENCAPSULATED STRAND

1. ANCHORAGE COVER
2. ANCHOR HEAD AND WEDGES
3. ANTICORROSION GREASE
4. BEARING PLATE
5. TRUMPET
6. SEAL
7. ANTICORROSION GREASE
8. PVC OR POLYETHYLENE TUBE
9. INDIVIDUALLY GREASED AND SHEATHED STRAND.
10. SPACER
11. STRAND TENDON
12. CORRUGATED PVC
13. CENTRALIZER
14. ANCHOR GROUT
15. ENCAPSULATION GROUT
16. END CAP
17. TENSION RING TO RESIST SPITTING FORCE OF DEFLECTED STRANDS.
18. NON-STRUCTURAL FILLER

Bridge Design Engr.	M:\STANDARDS\Walls\PERMANENT GROUND ANCHOR.MAN				
Supervisor					
Designed By					
Checked By					
Detailed By					
Bridge Projects Engr.					
Prelim. Plan By					
Architect/Specialist	DATE	REVISION	BY	APP'D	

REGION NO.	STATE	FED. AID PROJ. NO.	SHEET NO.	TOTAL SHEETS
10	WASH.			
JOB NUMBER				

BRIDGE
AND
STRUCTURES
OFFICE

Washington State Department of Transportation

SOLDIER PILE/TIEBACK WALL
PERMANENT GROUND ANCHOR DETAILS

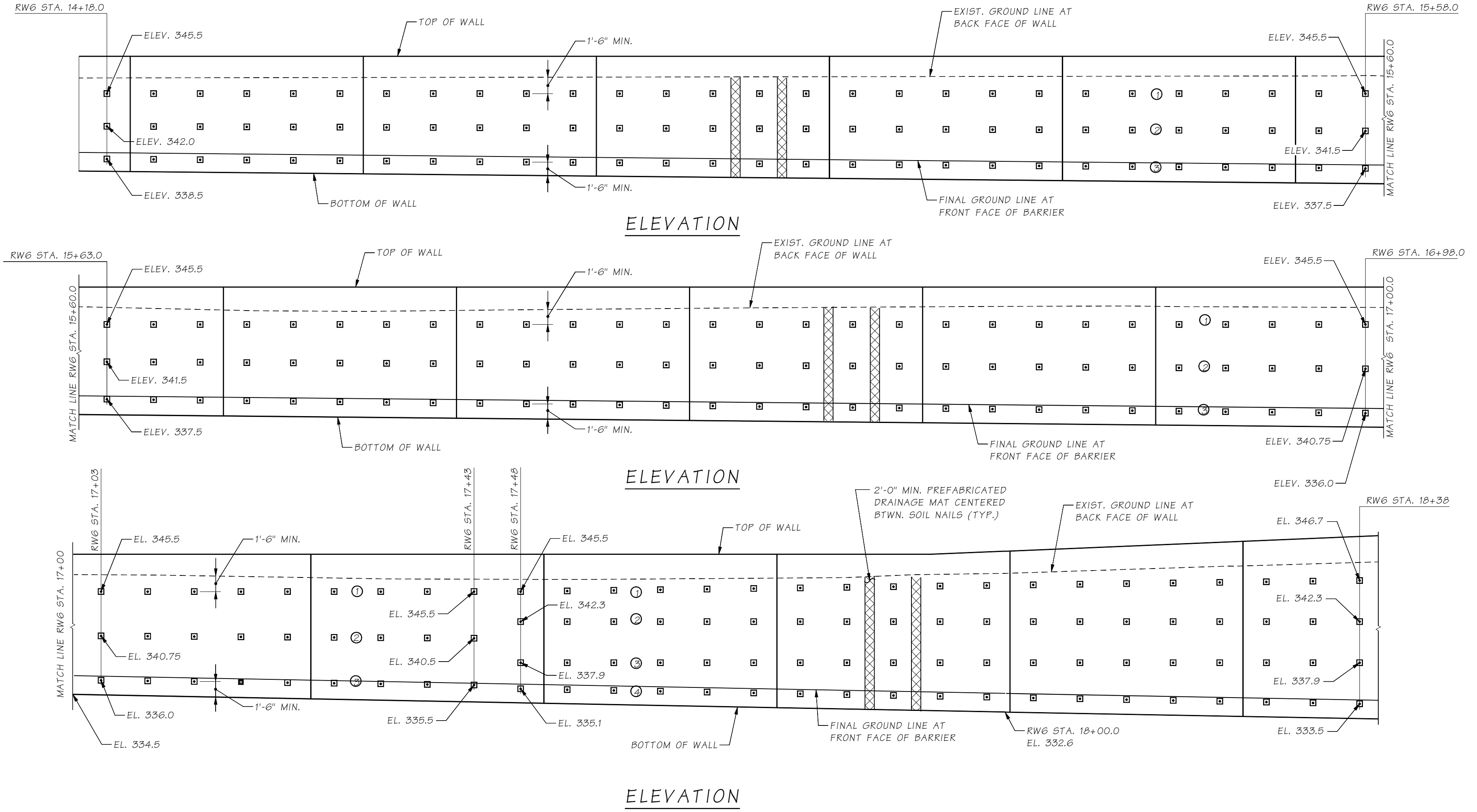
BRIDGE SHEET NO.

SHEET
OF
SHEETS

SR
JOB NO.
SHEET

8.1-A3-6

Fri Sep 10 13:34:11 2010



Bridge Design Engr.	M:\STANDARDS\Walls\SOIL NAIL ELEVATION.MAN			
Supervisor				
Designed By				
Checked By				
Detailed By				
Bridge Projects Engr.				
Prelim. Plan By				
Architect/Specialist	DATE	REVISION	BY	APP'D

REGION NO.	STATE	FED. AID PROJ. NO.	SHEET NO.	TOTAL SHEETS
10	WASH.			
JOB NUMBER				

BRIDGE
AND
STRUCTURES
OFFICE

Washington State Department of Transportation

SOIL NAIL LAYOUT

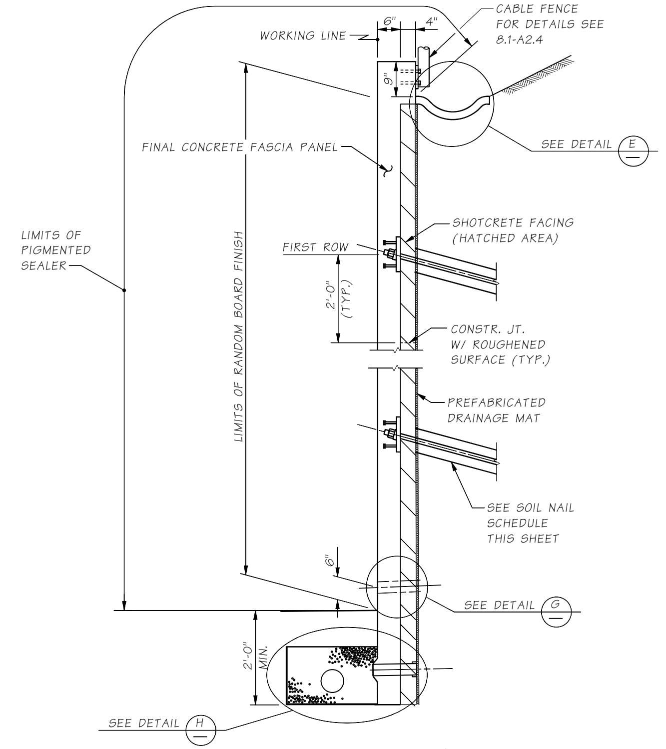
BRIDGE SHEET NO.

SHEET OF SHEETS

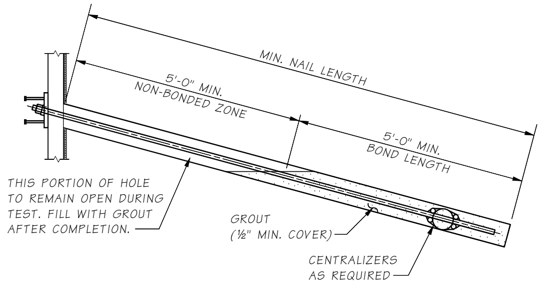
Fri Sep 03 11:30:04 2010

SR JOB NO. SHEET

8.1-A4-1

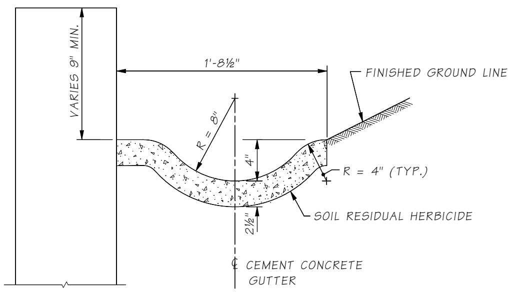


TYPICAL SECTION
SOIL NAIL WALL



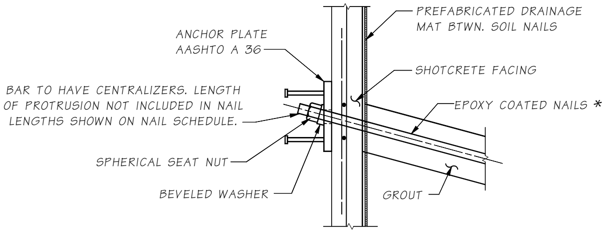
TL = TEST LOAD = (BOND LENGTH) X (DESIGN LOAD TRANSFER)

TEST NAIL DETAIL



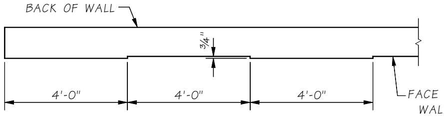
DETAIL E

CEMENT CONCRETE GUTTER

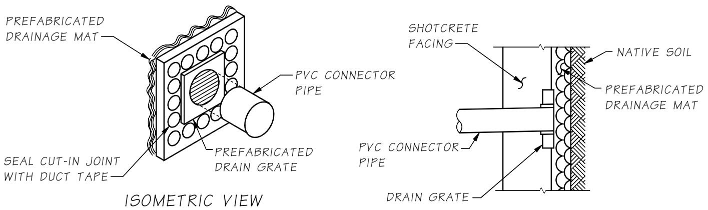


NAIL HEAD DETAIL

* DOUBLE CORROSION PROTECTION REQUIRED FOR SOIL NAILS AT LOCATIONS SHOWN. SEE SOIL NAIL LAYOUTS FOR DETAILS



PLAN
WALL FACE FINISH

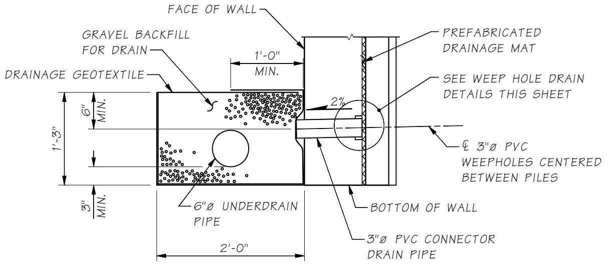


ISOMETRIC VIEW

SECTIONAL VIEW

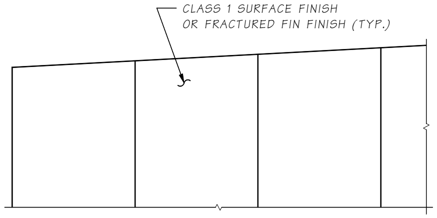
DETAIL G

DRAIN GRATE INSTALLATION SHALL NOT DISRUPT PREFABRICATED DRAINAGE MAT



DETAIL H

TYPICAL FABRIC DRAIN CONNECTION TO UNDERDRAIN PIPE



ELEVATION
WALL FACE FINISH

Bridge Design Engr.	M:\STANDARDS\Walls\SOIL NAIL TYP SECT.MAN				
Supervisor					
Designed By					
Checked By					
Detailed By					
Bridge Projects Engr.					
Prelim. Plan By					
Architect/Specialist	DATE	REVISION	BY	APP'D	

REGION NO.	STATE	FED. AID PROJ. NO.	SHEET NO.	TOTAL SHEETS
10	WASH.			
JOB NUMBER				

BRIDGE
AND
STRUCTURES
OFFICE

Washington State
Department of Transportation

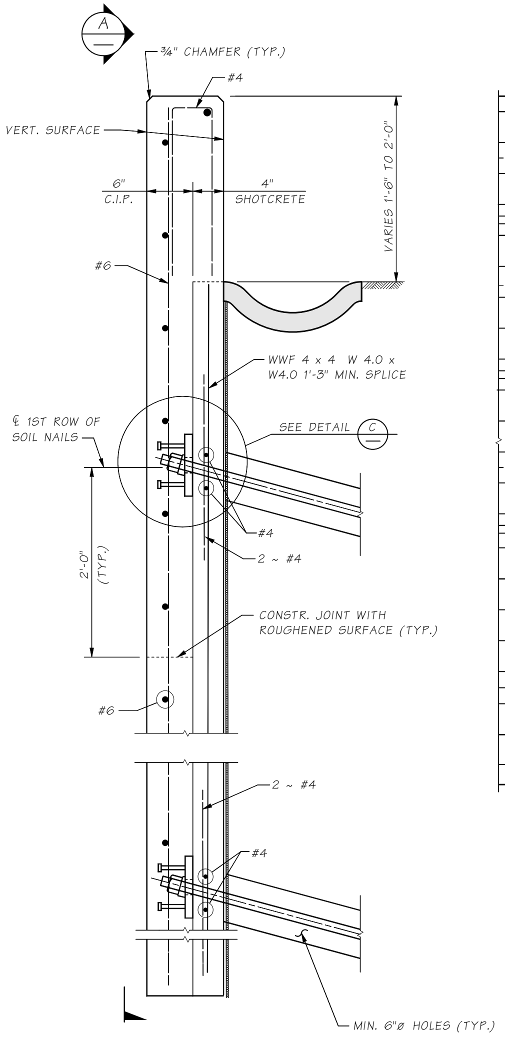
SOIL NAIL WALL SECTION

BRIDGE SHEET NO.
SHEET
OF
SHEETS

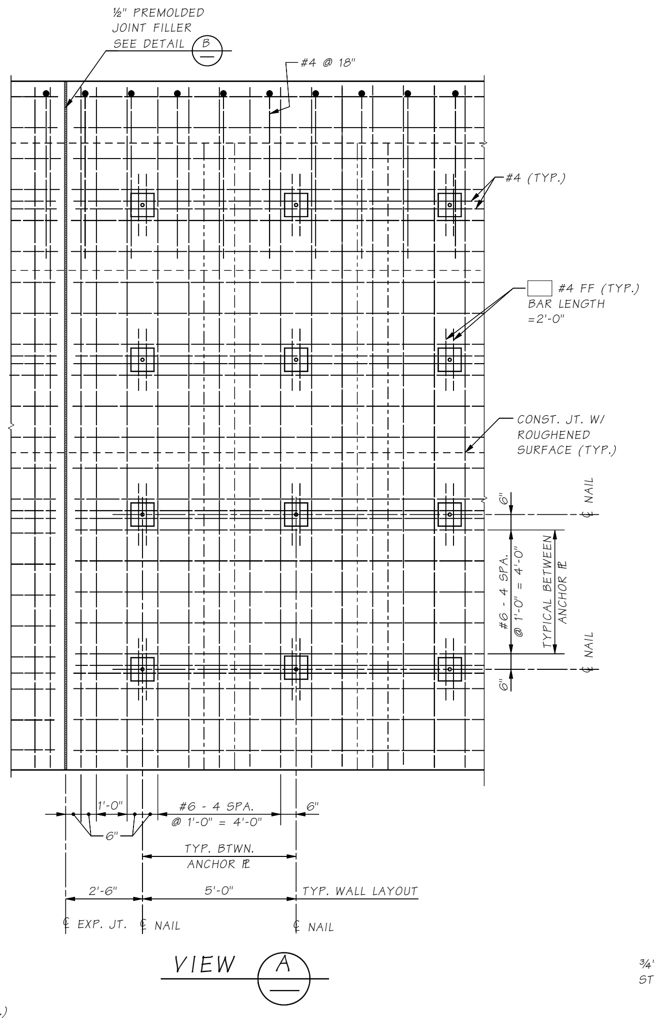
Fri Sep 03 11:30:06 2010

8.1-A4-2

SR JOB NO. SHEET

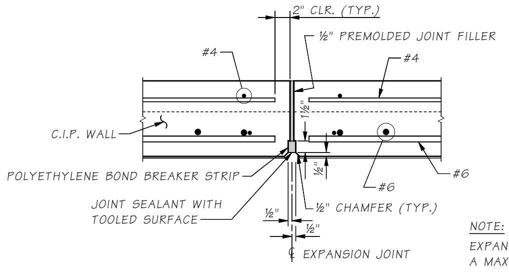


TYPICAL SECTION



FASCIA WALL REINFORCEMENT

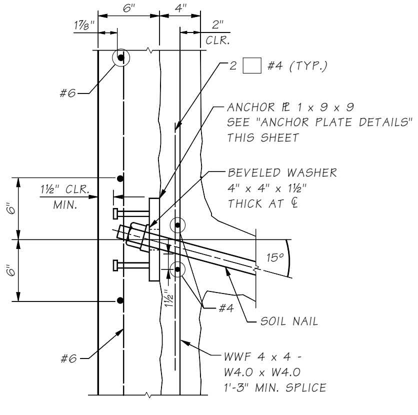
WWF NOT SHOWN FOR CLARITY



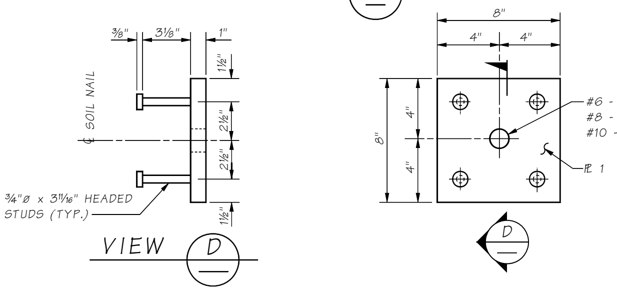
DETAIL B

NOTE:

EXPANSION JOINTS TO BE LOCATED AT A MAXIMUM SPACING OF 24'-0" C. TO C., CENTERED BETWEEN NAILS, EXCEPT IF THE JOINT IS WITHIN 1'-6" OF A STEP AT THE TOP OF WALL, THE JOINT IS TO BE LOCATED AT THAT STEP.



DETAIL C



ANCHOR PLATE DETAILS

AASHTO A 36

8.1-A4-3

SHEET
JOB NO.
SR

Bridge Design Engr.
Supervisor
Designed By
Checked By
Detailed By
Bridge Projects Engr.
Prelim. Plan By
Architect/Specialist

M:\STANDARDS\Walls\SOIL NAIL FASCIA.MAN

DATE | REVISION | BY | APP'D

REGION NO.	STATE	FED. AID PROJ. NO.	SHEET NO.	TOTAL SHEETS
10	WASH.			

JOB NUMBER

BRIDGE
AND
STRUCTURES
OFFICE

Washington State Department of Transportation

SOIL NAIL WALL
FASCIA PANEL DETAILS

BRIDGE SHEET NO.
SHEET
OF
SHEETS

Fri Sep 03 11:30:08 2010

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Provide alternative approaches for slope protection

IDEA NUMBER	PAGE NO.
4	1 of 5

ORIGINAL CONCEPT:

The current standards provide for concrete headwalls only, scour is addressed only with a paved invert, and there are no provisions for scour protection beyond the structure limits other than as a channel design.

ALTERNATIVE CONCEPT:

Use different approaches for slope protection in-lieu-of concrete headwalls at culvert termini, inlet, outlet or both. Approaches to be included:

- Gunite/Shotcrete
- Rip-Rap (Rock Slope Protection (RSP)
- Geotextile Fabric Wall
- Vegetative Cover, including soil bags
- Soil Cement

ADVANTAGES:

- Accelerated performance
- Lower costs
- Lower labor skills required
- Installation can occur with the culvert, not after
- Less obtrusive
- No special treatments required for traffic safety <36”
- Minimizes long term maintenance
- Selection of locally available materials
- Lowers CO_2 emissions (N/A for Shotcrete)
- Minimizes dewatering (N/A for Shotcrete)

DISADVANTAGES:

- Extends the pipe
- May increase r-o-w costs/needs

IMPLEMENTATION CONSIDERATIONS:

Prepare/institutional details of each application.

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Provide alternative approaches for slope protection

Performance Criteria	**ST**	**C**	**M**	**S**	**H**	**F**	**D**
Performance Measure	**0**	**2**	**2**	**2**	**-1**	**2**	**0**
Structural	Deletes the structure						
Constructability	Local materials, common labor skills, installation with the culvert						
Maintainability	RSP added when needed, shotcrete has no maintenance						
Safety	Avoids impact obstacles and vertical hazards <36” in pipe size						
Hydraulics	Negative effects at the inlet unless the culvert is beveled, no effects at the outlet						
Flexibility	Conforms to actual conditions on-site as encountered						
Durability	Enables vegetation to grow through RSP, or prevent vegetation by underlain fabric. Prevents erosion.						

DISCUSSION:

Extending the culvert beyond what is required for a vertical headwall, but RSP, shotcrete soil cement, stacked concrete bags et al, enables steepening of the slope from embankment slope (2:1 or flatter) to as steep as 1:1.

Alternatives would shorten the time to construct by avoiding structure excavation, multi-stage form, rebar, poured footings, form, rebar, pour, strip, finish walls and hand backfill, which interferes with continued placement of embankment. RSP or other slope protection is placed concurrently with the culvert. Excavation is reduced, dewatering is not necessary or less likely since footing excavation and turndown footing below grade is not required, and materials are placed.

Supporting Materials Include:

1) State of Tennessee Department of Transportation Sample Details
2) Sample Rock End Treatment Picture

Rating Scale: Value Add +2 +1 0 -1 -2 Value Decrease

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

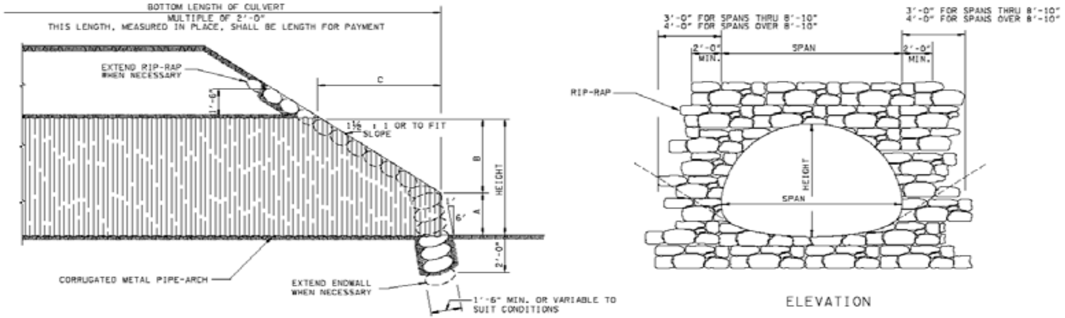
TITLE: Provide alternative approaches for slope protection

SUPPORTING MATERIALS:

REV. 7-1-72: CHANGED DEPARTMENT NAME.

■ REV. 1-1-76: CHANGED DWG. NO. FROM CM-1-5(68) TO D-PE-8.

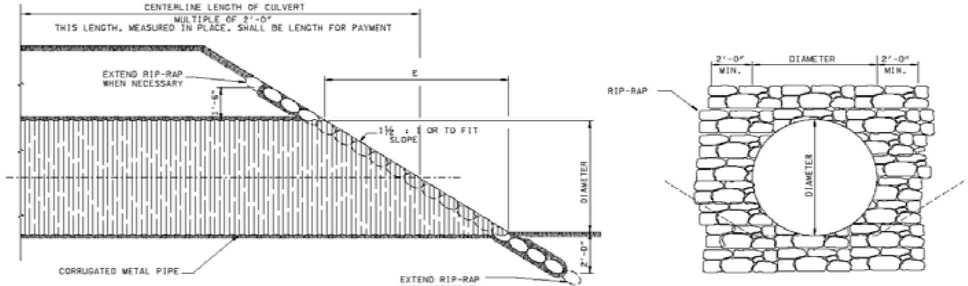
REV. 1-15-97: REDREW. REORGANIZED AND REDESIGNED SHEET ON CADD.



SECTION ON CENTERLINE

ELEVATION

BEVELED END PIPE-ARCH



SECTION ON CENTERLINE

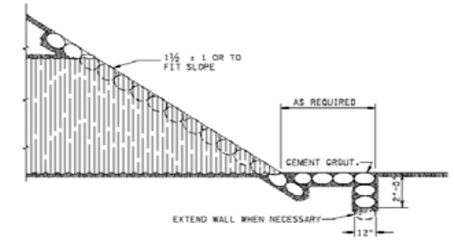
ELEVATION

BEVELED END PIPE

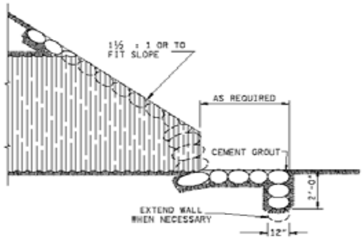
PIPE - ARCH CULVERTS						
SPAN	HEIGHT	RIP-RAP C.Y. (ONE END)		A	B	C
		ONE LINE	TWO LINES			
58"	36"	2.7	4.2	1'-0"	2'-0"	3'-0"
65"	40"	2.9	4.4	1'-0"	2'-4"	3'-6"
72'	44"	3.1	5.0	1'-0"	2'-8"	4'-0"
6'-1"	4'-7"	3.1	5.0	2'-3"	2'-4"	3'-6"
6'-4"	4'-9"	3.3	5.4	2'-1"	2'-8"	4'-0"
6'-9"	4'-11"	3.4	5.6	2'-5"	2'-6"	3'-9"
7'-0"	5'-1"	3.5	5.8	2'-3"	2'-10"	4'-3"
7'-3"	5'-3"	3.6	6.0	2'-1"	3'-2"	4'-9"
7'-8"	5'-5"	3.7	6.3	2'-4"	3'-1"	4'-7½"
7'-11"	5'-7"	3.9	6.7	2'-2"	3'-5"	5'-1½"
8'-2"	5'-9"	4.0	6.9	2'-0"	3'-9"	5'-7½"
8'-7"	5'-11"	4.1	7.1	2'-4"	3'-7"	5'-4½"
8'-10"	6'-1"	4.3	7.5	2'-2"	3'-11"	5'-10½"
9'-4"	6'-3"	4.9	8.3	2'-5"	3'-10"	5'-9"
9'-6"	6'-5"	5.0	8.5	2'-4"	4'-1"	6'-1½"
9'-9"	6'-7"	5.2	8.9	2'-2"	4'-5"	6'-7½"
10'-3"	6'-9"	5.3	9.2	2'-5"	4'-4"	6'-6"
10'-8"	6'-11"	5.4	9.4	2'-9"	4'-2"	6'-3"
10'-11"	7'-1"	5.6	9.9	2'-7"	4'-6"	6'-9"
11'-5"	7'-3"	5.7	10.1	2'-10"	4'-5"	6'-7½"
11'-7"	7'-5"	5.9	10.5	2'-8"	4'-9"	7'-1½"
11'-10"	7'-7"	6.1	11.0	2'-6"	5'-1"	7'-7½"
12'-4"	7'-9"	6.2	11.2	2'-10"	4'-11"	7'-4½"
12'-6"	7'-11"	6.3	11.4	2'-8"	5'-3"	7'-10½"
12'-8"	8'-1"	6.5	11.7	2'-6"	5'-7"	8'-4½"
12'-10"	8'-4"	6.7	12.1	2'-4"	6'-0"	9'-0"
13'-5"	8'-5"	6.9	12.5	2'-7"	5'-10"	8'-9"
13'-11"	8'-7"	7.0	12.7	2'-11"	5'-8"	8'-6"
14'-1"	8'-9"	7.1	12.8	2'-9"	6'-0"	9'-0"
14'-3"	8'-11"	7.3	13.2	2'-7"	6'-4"	9'-6"
14'-10"	9'-1"	7.5	13.6	2'-11"	6'-2"	9'-3"
15'-4"	9'-3"	7.6	13.8	3'-2"	6'-1"	9'-1½"
15'-6"	9'-5"	7.8	14.2	3'-0"	6'-5"	9'-7½"
15'-8"	9'-7"	7.9	14.3	2'-10"	6'-9"	10'-1½"
15'-10"	9'-10"	8.2	14.9	2'-8"	7'-2"	10'-9"
16'-5"	9'-11"	8.3	15.1	3'-0"	6'-11"	10'-4½"
16'-7"	10'-1"	8.5	15.5	2'-10"	7'-3"	10'-10½"

RIP-RAP QUANTITIES NOTE

QUANTITIES SHOWN ARE FOR ONE END AND ARE FOR ESTIMATING PURPOSES ONLY. PAYMENT TO BE MADE FOR QUANTITIES ACTUALLY PLACED AND COMPUTED FOR EACH INSTALLATION.



DETAIL OF APRON FOR OUTLET END OF PIPE
USE ONLY WHEN NECESSARY



DETAIL OF APRON FOR OUTLET END OF PIPE-ARCH
USE ONLY WHEN NECESSARY

ROUND PIPE CULVERTS			
PIPE SIZE	RIP-RAP(ONE END)C.Y.		E
	ONE LINE	TWO LINES	
42"	2.9	4.7	5'-3"
48"	3.2	5.4	6'-0"
54"	3.5	6.1	6'-9"
60"	3.8	6.7	7'-6"
66"	4.1	7.4	8'-3"
72"	4.5	8.4	9'-0"
78"	4.8	9.1	9'-9"
84"	5.1	9.8	10'-6"
90"	5.2	10.2	11'-3"
96"	5.5	11.0	12'-0"
102"	6.2	12.4	12'-8"
108"	6.6	13.2	13'-6"
114"	7.0	14.0	14'-3"
120"	7.4	14.8	15'-0"
126"	7.8	15.6	15'-9"
132"	8.2	16.4	16'-6"
138"	8.6	17.2	17'-3"
144"	9.0	18.0	18'-0"
150"	9.4	18.8	18'-9"
156"	9.9	19.8	19'-6"
162"	10.3	20.6	20'-3"
168"	10.8	21.6	21'-0"
174"	11.2	22.4	21'-9"
180"	11.7	23.4	22'-6"

■ MINOR REVISION -- FHWA APPROVAL NOT REQUIRED.

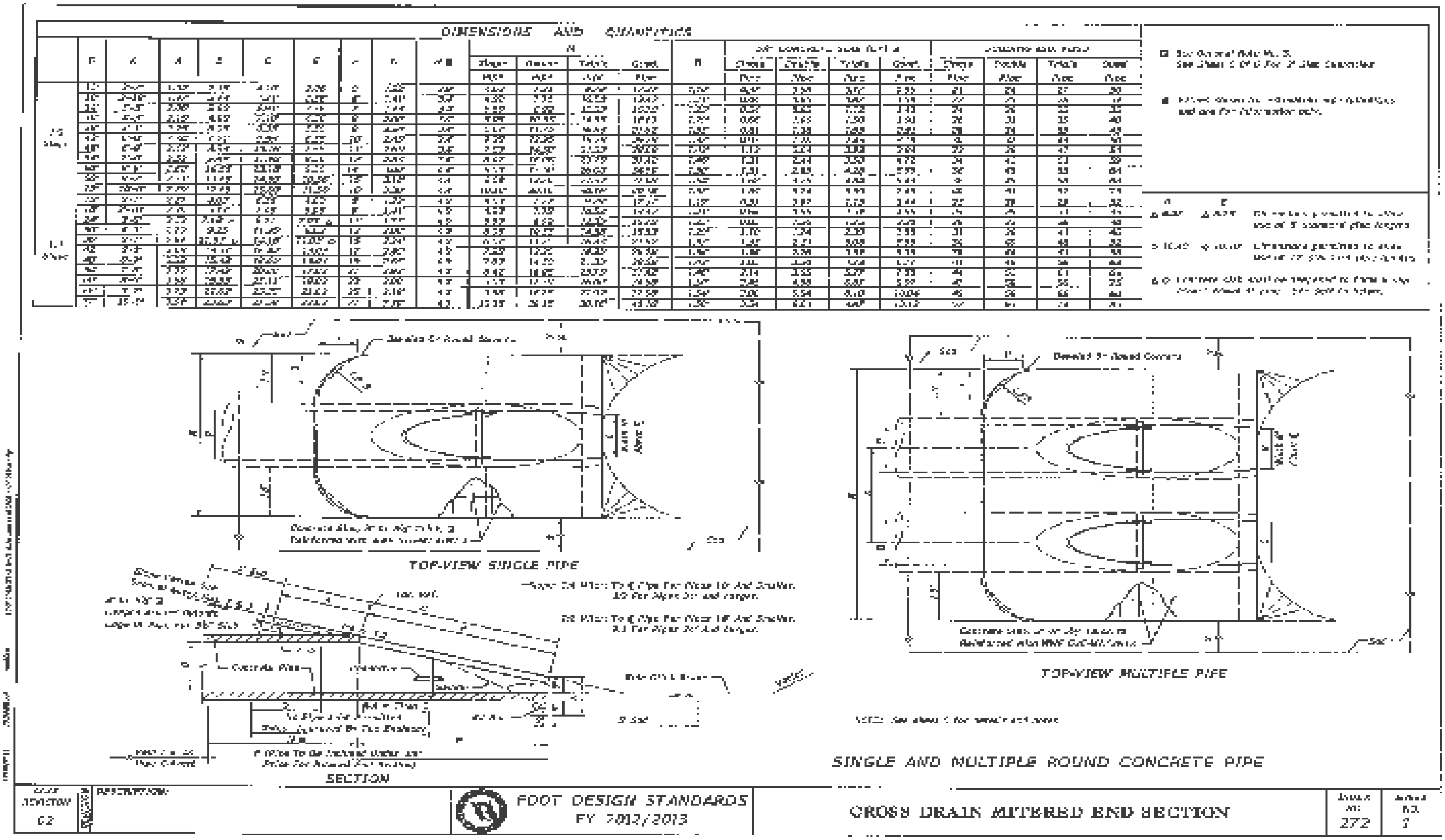
STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

DETAIL OF
STANDARD PIPE
AND PIPE-ARCH
CULVERT WITH BEVELED
ENDS AND RIP-RAP

D-PE-8

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Provide alternative approaches for slope protection



Ratir

TITLE: Provide alternative approaches for slope protection

Sample of a rock end treatment

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE:
Provide alternate approaches for end treatments

	IDEA NUMBER	PAGE NO.
	5	1 of 28

ORIGINAL CONCEPT:

The existing Standard Drawings and Headwall Supplement limit the options for safety headwalls to pipes 36” and smaller. There are also limited options for pipe end treatments in lieu of headwalls.

ALTERNATIVE CONCEPT:

Provide alternates and design criteria to the existing Standard Drawings for grates for safety headwalls for larger culverts and box culverts.

ADVANTAGES:

- Provides safety headwalls for greater than 36” pipe thus allowing for the elimination of guardrail at those locations
- Provides for more end treatment options than those shown in the existing Standard Drawings or Headwall Supplement
- Potential cost savings by allowing for more alternates, differing materials and installation
- End treatment options using rip-rap in-lieu of concrete and steel
- Alternate end treatments for small entrance pipes
- May be easier to maintain end treatments

DISADVANTAGES:

- Some alternates may be more costly
- Some alternates may create maintenance issues

IMPLEMENTATION CONSIDERATIONS:

KYTC Central Office administration will have to approve any revisions to the Standard Drawings and Headwall Supplement.

Performance Criteria	**ST**	**C**	**M**	**S**	**H**	**F**	**D**
Performance Measure	**0**	**0**	**-1**	**+2**	**+1**	**+2**	**0**
Structural							
Constructability	Some may be easier to construct, which may mean a savings in cost and schedule						
Maintainability	Potential maintenance issue with grates						
Safety	Provides additional safety headwall options for pipes > 36”						
Hydraulics	May provide enhanced hydraulics for entrance pipes over those not using an end treatment						
Flexibility	Provides more options than in the current Standard Drawings and Headwall Supplement						
Durability							

DISCUSSION:

The current standards limit the end treatments that can be used. Examples of additional types of end treatments include safety headwalls for pipes > 36”, alternate safety headwalls for culverts parallel to traffic, mitered end sections, “half-height” headwalls, metal flared sections for culverts and entrance pipes, rip-rap ends, and concrete end treatment for entrance pipes. Design for safe grates for box culverts and larger pipes are also included. It is the recommendation of the team that a simple detail be provided for each of the end treatments using a single sheet for each.

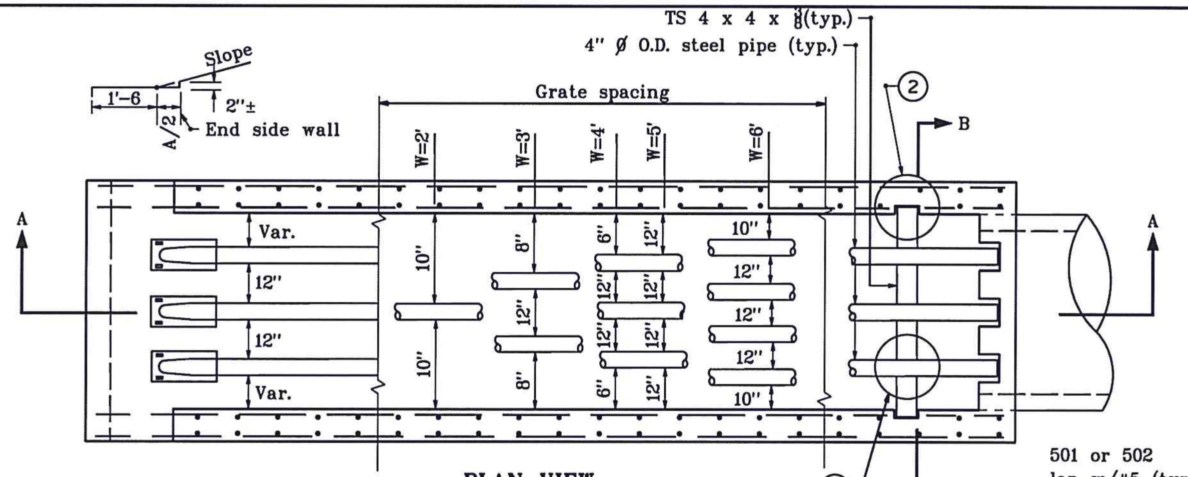
SUPPORTING MATERIALS:

See attached end treatment and headwall examples from various state departments of transportation and other agencies.

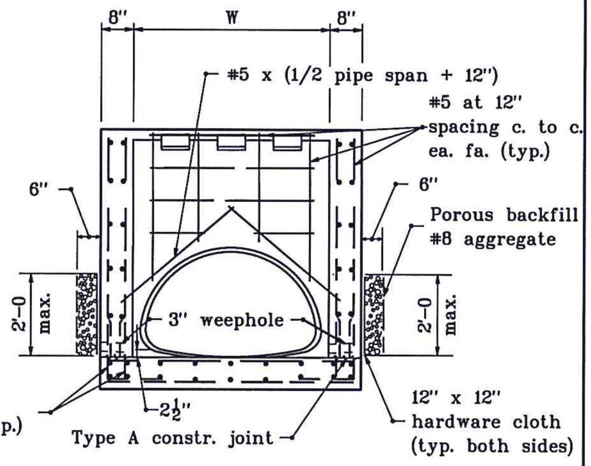
1) Indiana DOT Grated Box Type I – Page 65
2) Indiana DOT Grated Box Type II – Page 66-69
3) Indiana DOT Pre-Cast Concrete End Section – Page 70
4) Tennessee DOT Concrete Wingwalls – Page 71
5) Tennessee DOT Half-Height Headwalls – Pages 72-75
6) Louisville & Jefferson County MWD Flared End Section – Pages 76-77
7) Indiana DOT Metal Pipe End Section – Pages 78-80
8) Florida DOT Cross Drain Mitered End Section – Pages 81-83
9) Tennessee DOT Standard Pipe & Pipe Arch – Page 84
10) Louisville & Jefferson County MWD Driveway Pipe – Page 85
11) Iowa DOT Safety Grates – Pages 86-89
12) Scour basin & Pipe Inlet Drawing – Page 90

Rating Scale: **Value Add** **+2 +1 0 -1 -2** **Value Decrease**

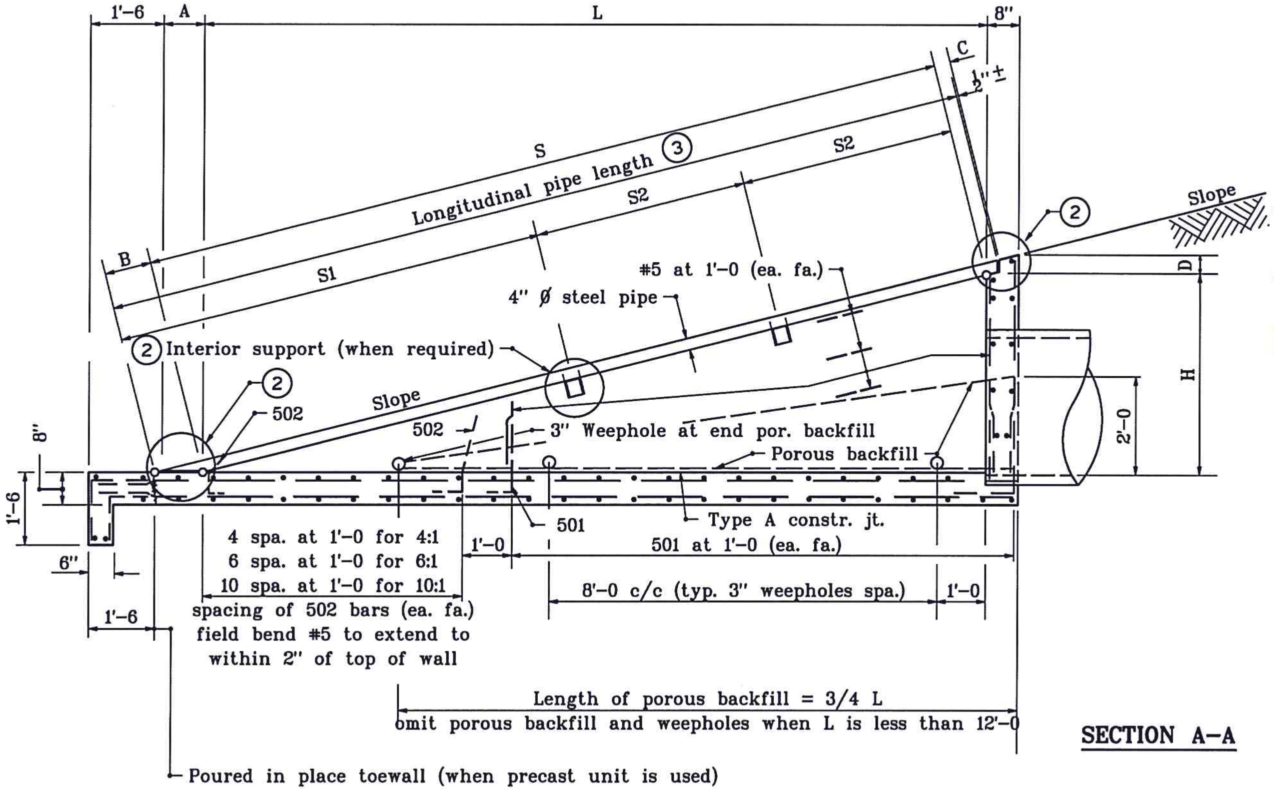
EXAMPLE #1



PLAN VIEW



GRATE REMOVED
SECTION B-B



SECTION A-A

GENERAL NOTES

1. The invert grade of the grated box end section shall be the same as that of the pipe.
② See Standard Drawing E 715-GBTO-04 for Details A, B, C, and D.
③ See Standard Drawings E 715-GBTO-05 through -08 for tables.
4. Type I grated box end sections shall be used for mainline cross-culverts' outlet pipes within the clear zone.
5. See Standard Drawing E 715-GBTO-02 for bending diagrams.

INDIANA DEPARTMENT OF TRANSPORTATION
GRATED BOX END SECTION
TYPE I
JANUARY 1999

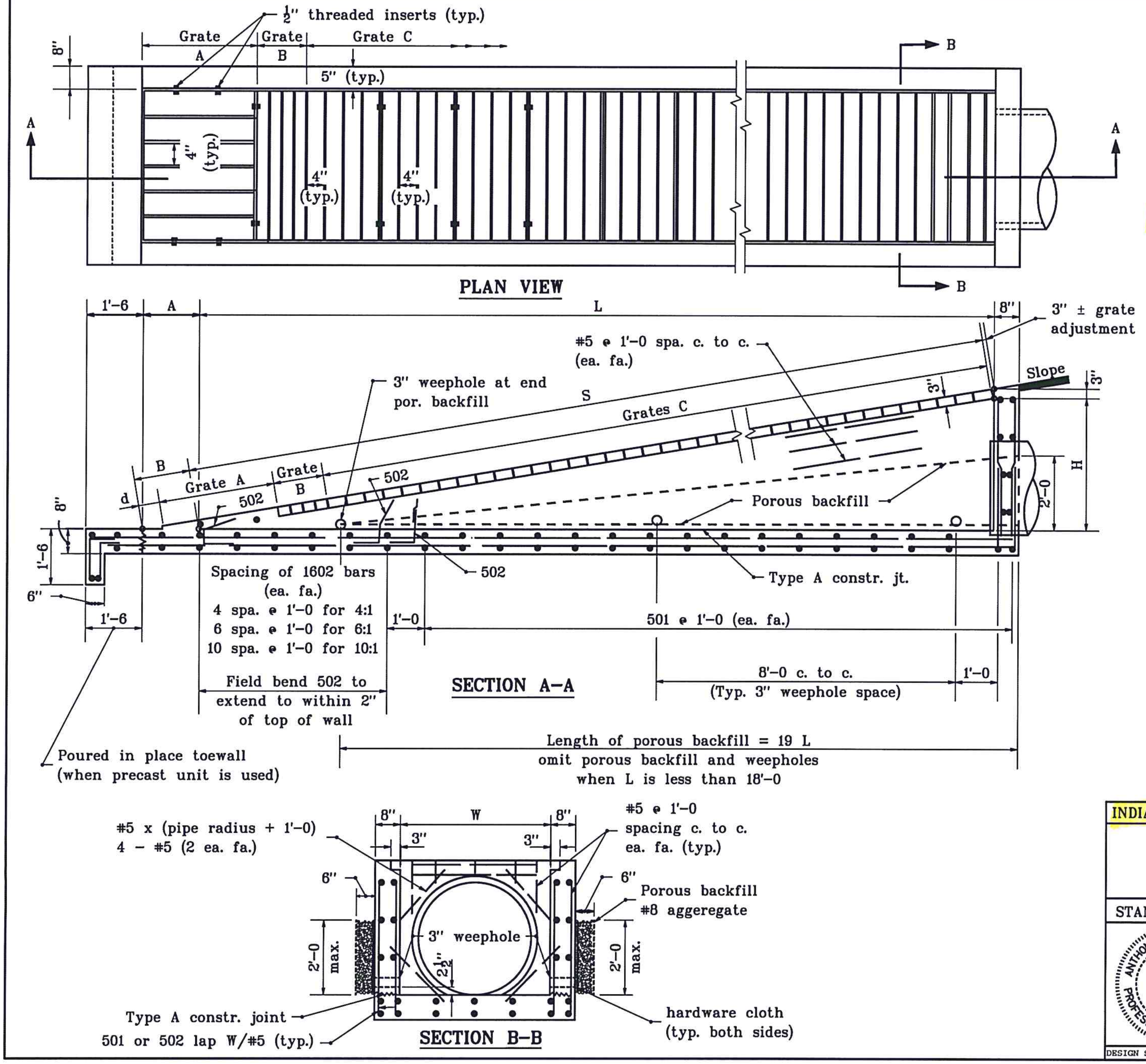
STANDARD DRAWING NO. E 715-GBTO-03

ANTHONY L. UREMOVICH No. 18095

DESIGN STANDARDS ENGINEER

DETAILS PLACED IN THIS FORMAT	11-15-99
/s/ Anthony L. Uremovich DESIGN STANDARDS ENGINEER	11-15-99 DATE
/s/ Firooz Zandi CHIEF HIGHWAY ENGINEER	11-15-99 DATE
ORIGINALLY APPROVED	1-04-99

EXAMPLE #2



GENERAL NOTES

1. The invert grade of the grated box end section shall be the same as that of the pipe.
2. See Standard Drawings E 715-GBTT-05 and -06 for dimensions tables.
3. Type II grated box end sections shall be used for culverts parallel to the mainline within the clear zone.
4. See Standard Drawing E 715-GBTT-02 for bending diagrams.

INDIANA DEPARTMENT OF TRANSPORTATION

GRATED BOX END
SECTION TYPE II

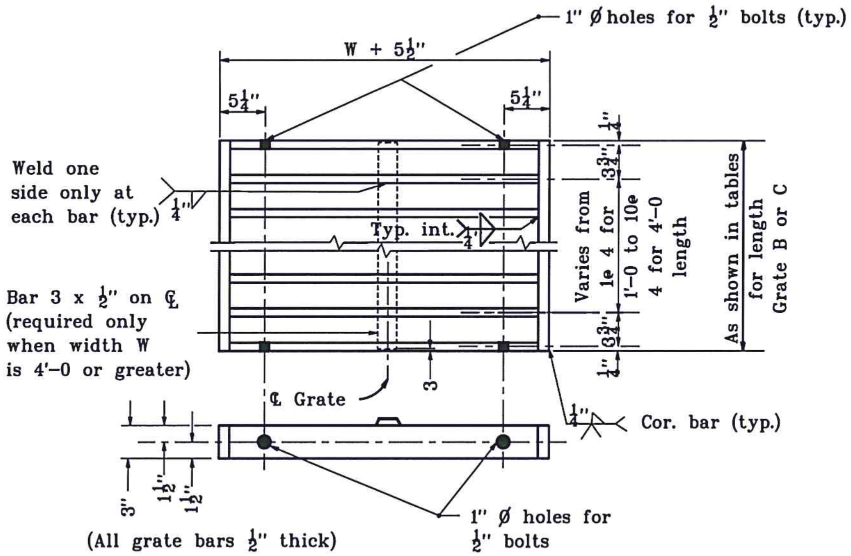
JANUARY 1999

STANDARD DRAWING NO. E 715-GBTT-01

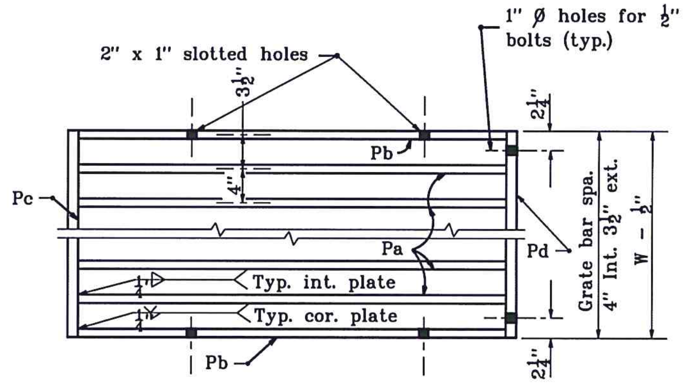
ANTHONY L. UREMOVICH
REGISTERED
No. 18095
STATE OF INDIANA
PROFESSIONAL ENGINEER

DESIGN STANDARDS ENGINEER

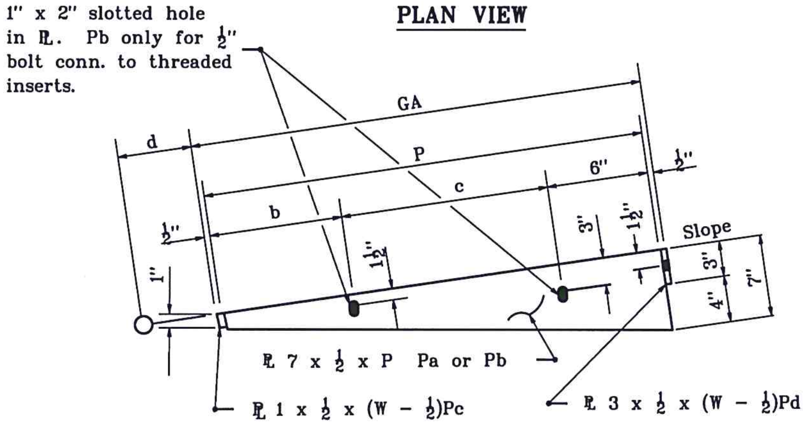
DETAILS PLACED IN THIS FORMAT	11-15-99
/s/ Anthony L. Uremovich DESIGN STANDARDS ENGINEER	11-15-99 DATE
/s/ Firooz Zandi CHIEF HIGHWAY ENGINEER	11-15-99 DATE
APPROVED	1-04-99



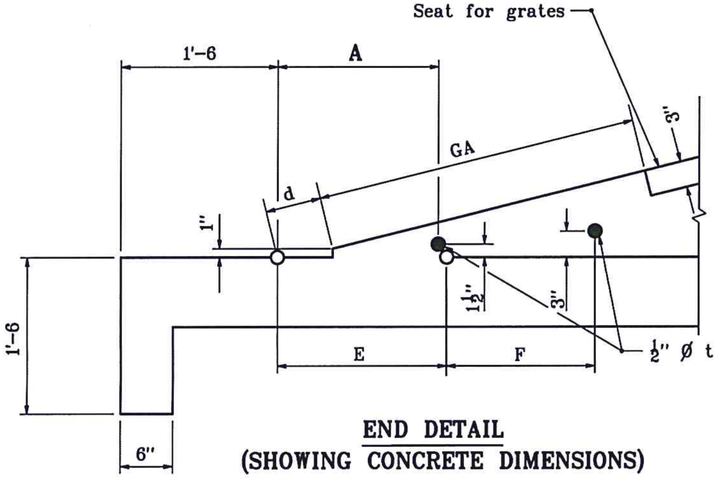
GRATE B & C



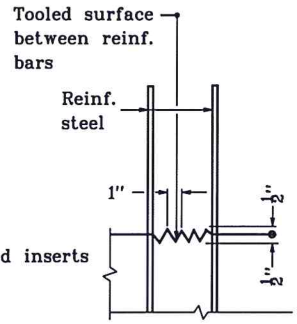
PLAN VIEW



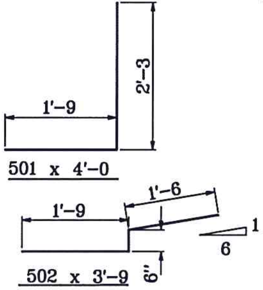
ELEVATION GRATE A



END DETAIL (SHOWING CONCRETE DIMENSIONS)



TYPE A CONSTR. JOINT



INDIANA DEPARTMENT OF TRANSPORTATION

GRATED BOX END SECTION TYPE II

JANUARY 1999

STANDARD DRAWING NO. E 715-GBTT-02

DETAILS PLACED IN THIS FORMAT 11-15-99

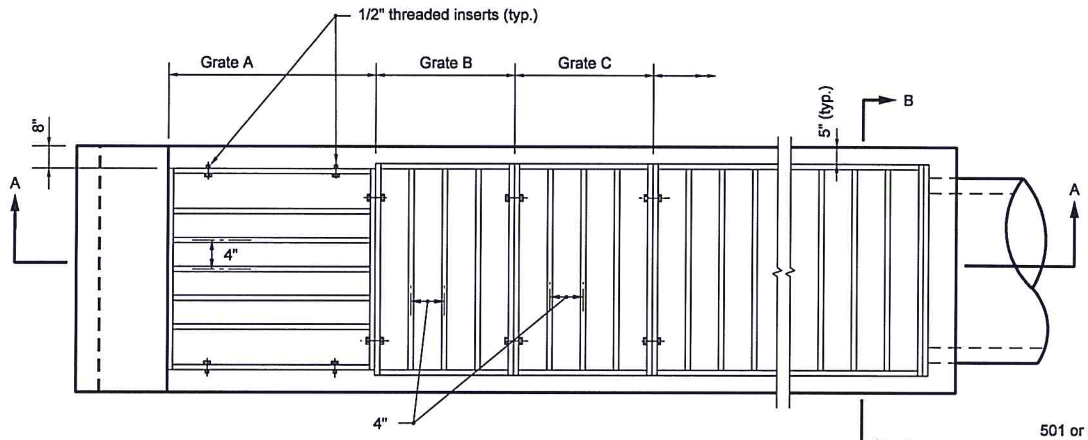
No. 18095

/s/ Anthony L. Uremovich 11-15-99
DESIGN STANDARDS ENGINEER DATE

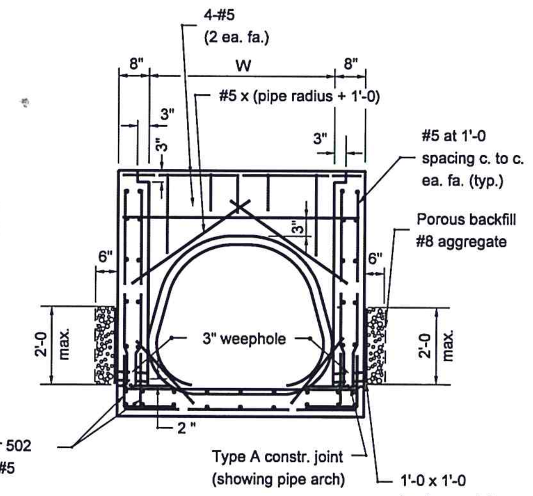
/s/ Firooz Zandi 11-15-99
CHIEF HIGHWAY ENGINEER DATE

DESIGN STANDARDS ENGINEER

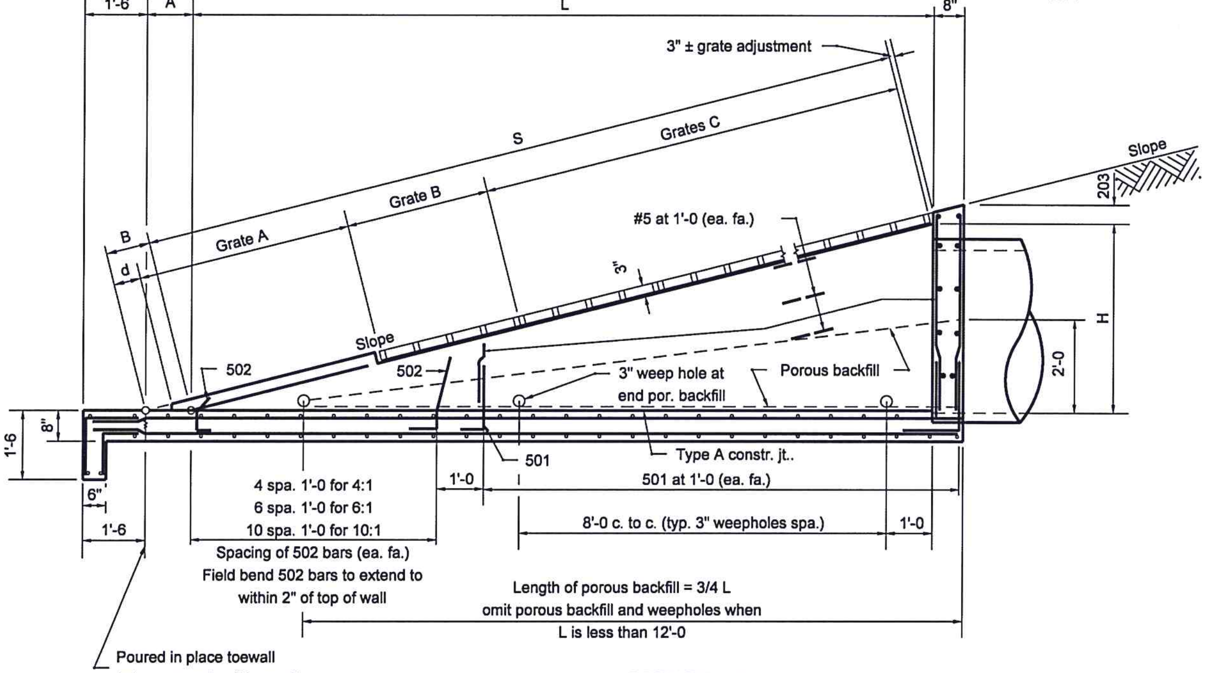
ORIGINALLY APPROVED 1-04-99



PLAN VIEW



GRATE REMOVED
SECTION B-B



SECTION A-A

GENERAL NOTES

1. The invert grade of the grated box end section shall be the same as that of the pipe.
2. See Standard Drawings E 715-GBTT-05 and -06 for dimensions tables.
3. See Standard Drawing E 715-GBTT-02 for bending diagrams.
4. Type II grated box end sections shall be used for culverts parallel to the mainline within the clear zone.

INDIANA DEPARTMENT OF TRANSPORTATION

GRATED BOX END
SECTION TYPE II

MARCH 2006

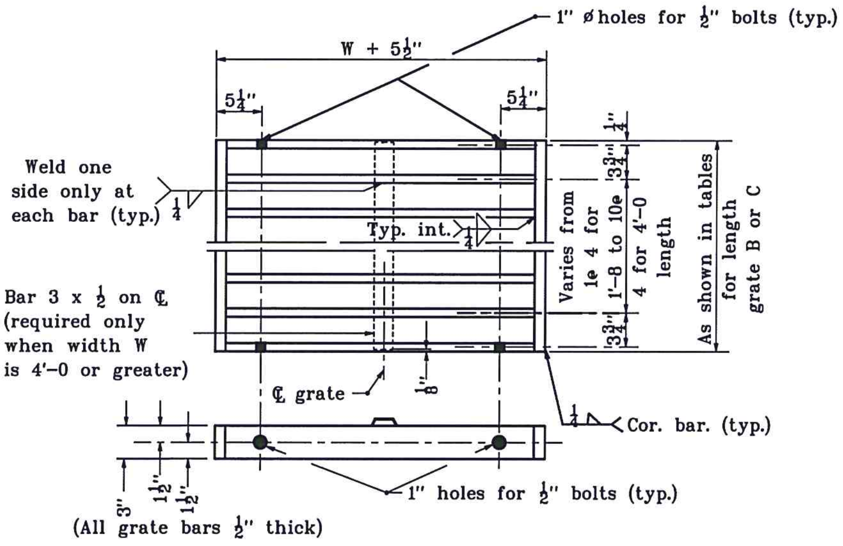
STANDARD DRAWING NO. E 715-GBTT-03

No. 9750

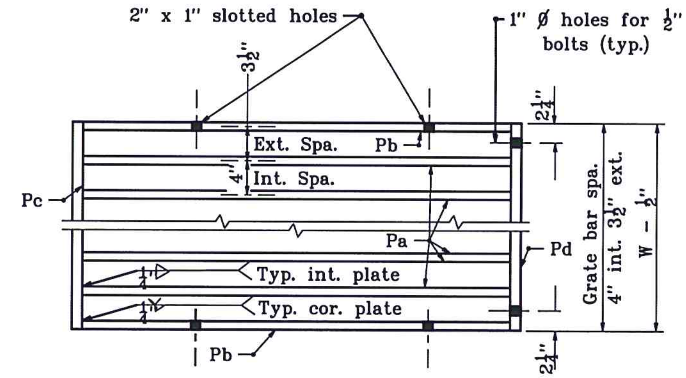
DESIGN STANDARDS ENGINEER

/s/ Richard L. VanCleave 3-01-06
DESIGN STANDARDS ENGINEER DATE

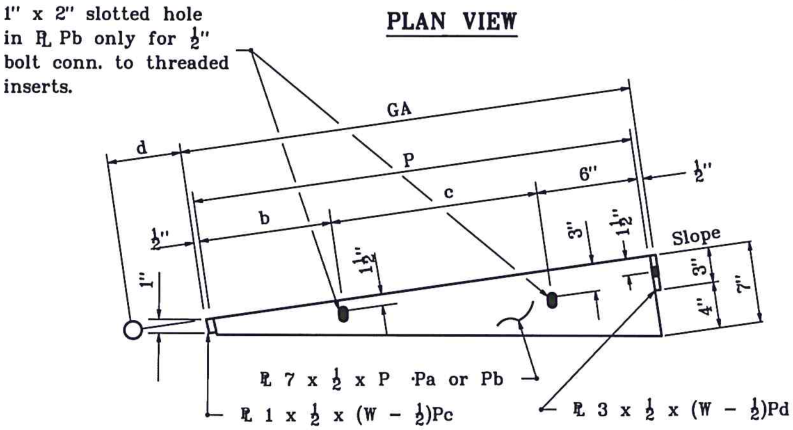
/s/ Richard K. Smutzer 3-01-06
CHIEF HIGHWAY ENGINEER DATE



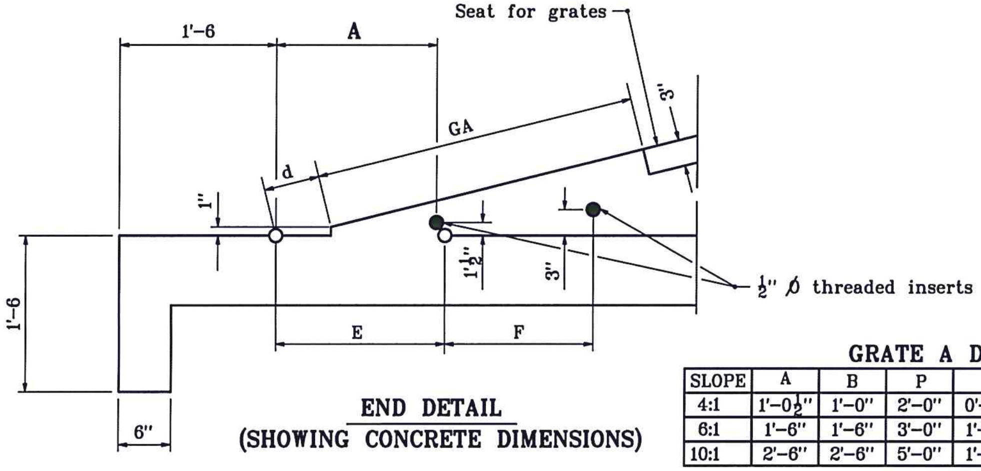
GRATE B & C



PLAN VIEW



ELEVATION GRATE A



END DETAIL (SHOWING CONCRETE DIMENSIONS)

GRATE A DIMENSIONS TABLE

SLOPE	A	B	P	b	c	d	E	F	G
4:1	1'–0½"	1'–0"	2'–0"	0'–8"	0'–10'	4"	1'–0½"	0'–10"	2'–1"
6:1	1'–6"	1'–6"	3'–0"	1'–0"	1'–6"	6"	1'–6½"	1'–6"	3'–1"
10:1	2'–6"	2'–6"	5'–0"	1'–8"	2'–10"	10"	2'–6½"	2'–10"	5'–1"

INDIANA DEPARTMENT OF TRANSPORTATION

GRATED BOX END SECTION
TYPE II

JANUARY 1999

STANDARD DRAWING NO. **E 715-GBTT-04**

ANTHONY L. UREMOVICH No. 18095

DESIGN STANDARDS ENGINEER

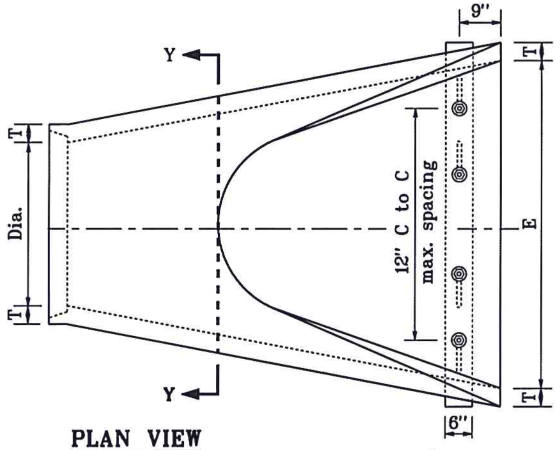
DETAILS PLACED IN THIS FORMAT 11-15-99

/s/ Anthony L. Uremovich 11-15-99
DESIGN STANDARDS ENGINEER DATE

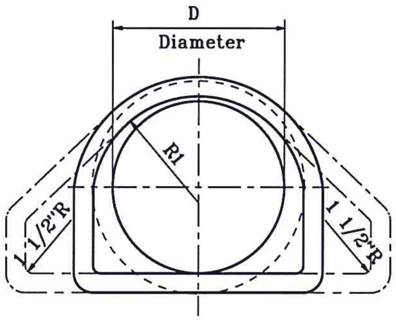
/s/ Firooz Zandi 11-15-99
CHIEF HIGHWAY ENGINEER DATE

ORIGINALLY APPROVED 1-04-99

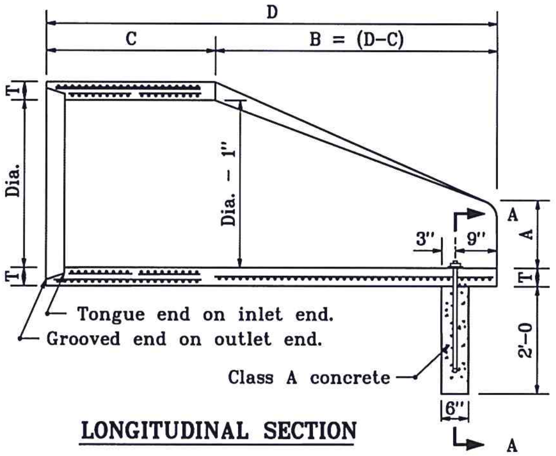
EXAMPLE #3



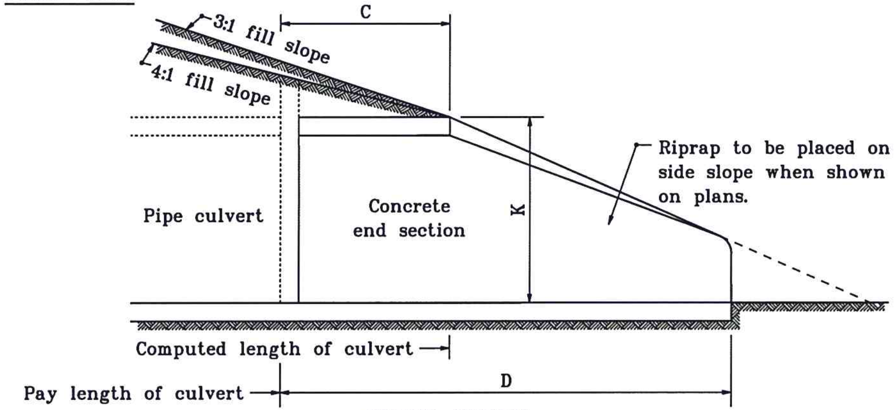
PLAN VIEW



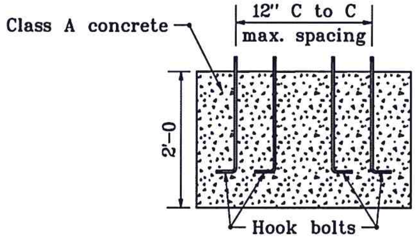
SECTION Y-Y



LONGITUDINAL SECTION



SLOPE DETAIL



SECTION A-A

Concrete Pipe Toe Anchor

TABLE OF DIMENSIONS

DIA.	T (min.)	A (±1")	C (±1")	D (±1")	E (±1")	K	R1	R2	APPROX. WEIGHT, lb.
12"	2"	5"	4'-3	6'-2	2'-0	1.3	$10\frac{1}{8}''$	9"	800
15"	$2\frac{1}{4}''$	7"	4'-0	6'-3	2'-6	1.5	$12\frac{1}{2}''$	11"	1100
18"	$2\frac{1}{2}''$	11"	4'-1	6'-2	3'-0	1.8	$15\frac{1}{2}''$	12"	1300
21"	$2\frac{3}{4}''$	11"	3'-6	6'-3	3'-6	2.1	$16\frac{1}{8}''$	13"	1500
24"	3"	1'-0	2'-8	6'-3	4'-0	2.3	$16\frac{3}{16}''$	14"	1800
27"	$3\frac{1}{4}''$	1'-1	2'-5	6'-3	4'-6	2.6	$18\frac{9}{16}''$	$14\frac{1}{2}''$	2100
30"	$3\frac{1}{2}''$	1'-2	1'-10	6'-3	5'-0	2.9	$18\frac{1}{2}''$	15"	2400
33"	$3\frac{3}{4}''$	1'-3	3'-6	8'-3	5'-6	3.1	$23\frac{3}{4}''$	$17\frac{1}{2}''$	4100
36"	4"	1'-5	3'-1	8'-3	6'-0	3.4	$24\frac{5}{16}''$	20"	4200

INDIANA DEPARTMENT OF TRANSPORTATION

PRECAST CONCRETE END SECTION

MAY 1998

STANDARD DRAWING NO. E 715-PCES-01

ANTHONY L. UREMOVICH
No. 18095

DESIGN STANDARDS ENGINEER

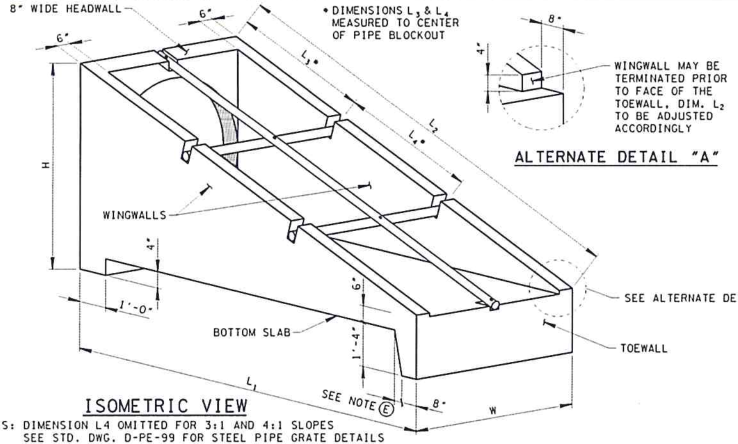
DETAILS PLACED IN THIS FORMAT 11-15-99

/s/ Anthony L. Uremovich 11-15-99
DESIGN STANDARDS ENGINEER DATE

/s/ Firooz Zandi 11-15-99
CHIEF HIGHWAY ENGINEER DATE

ORIGINALLY APPROVED 5-01-98

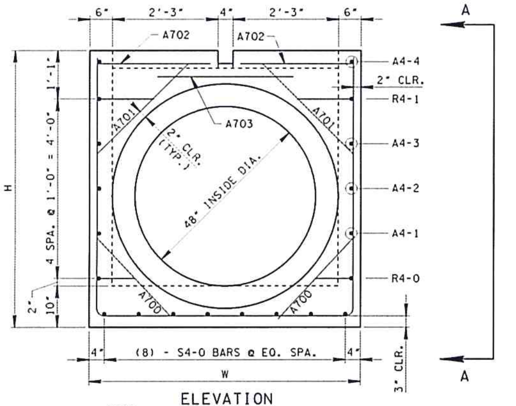
EXAMPLE #4



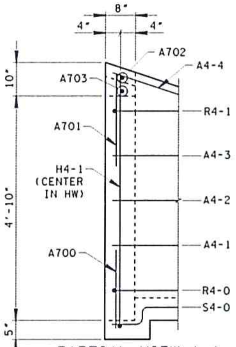
ISOMETRIC VIEW

NOTES: DIMENSION L4 OMITTED FOR 3:1 AND 4:1 SLOPES
SEE STD. DWG. D-PE-99 FOR STEEL PIPE GRATE DETAILS
¾" CHAMFER REQUIRED ON ALL EXPOSED EDGES

ALTERNATE DETAIL "A"



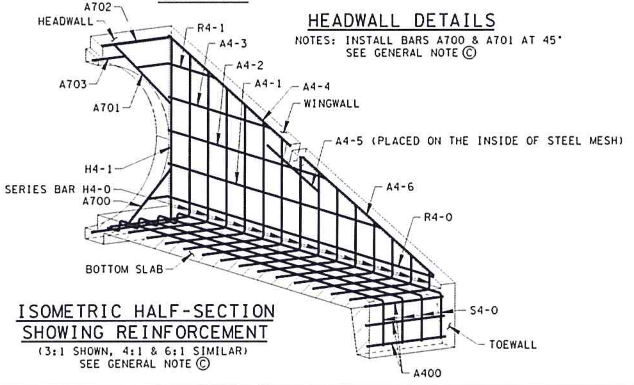
ELEVATION



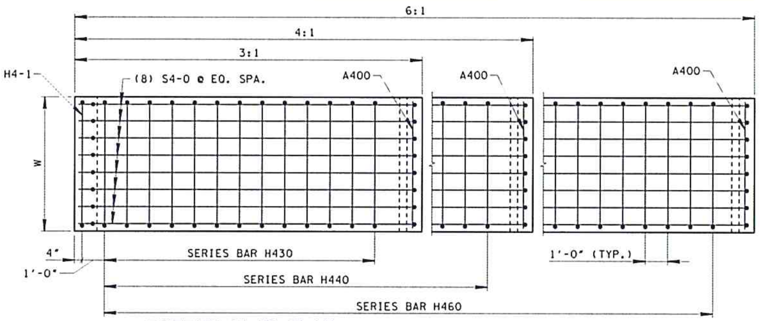
PARTIAL VIEW A-A

HEADWALL DETAILS

NOTES: INSTALL BARS A700 & A701 AT 45°
SEE GENERAL NOTE Ⓒ

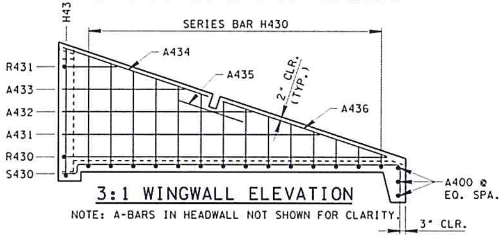


ISOMETRIC HALF-SECTION SHOWING REINFORCEMENT
(3:1 SHOWN, 4:1 & 6:1 SIMILAR)
SEE GENERAL NOTE Ⓒ



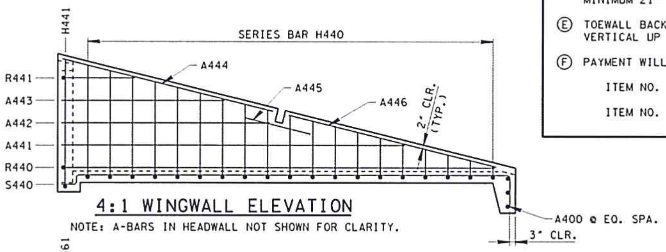
BOTTOM SLAB PLAN

NOTE: A-BARS IN HEADWALL NOT SHOWN FOR CLARITY.



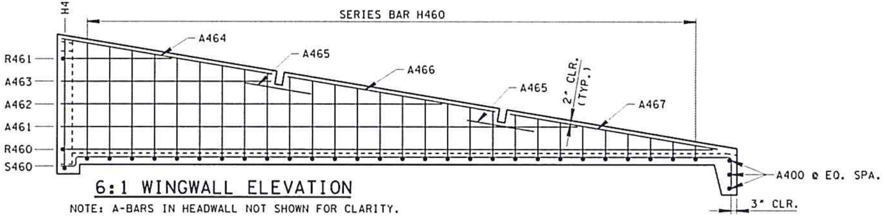
3:1 WINGWALL ELEVATION

NOTE: A-BARS IN HEADWALL NOT SHOWN FOR CLARITY.



4:1 WINGWALL ELEVATION

NOTE: A-BARS IN HEADWALL NOT SHOWN FOR CLARITY.



6:1 WINGWALL ELEVATION

NOTE: A-BARS IN HEADWALL NOT SHOWN FOR CLARITY.

GENERAL NOTES

Ⓐ DRAWING TO BE USED FOR ALL CAST-IN-PLACE AND ALL PRECAST 48" CONCRETE ENDWALLS (TYPE "U") FOR CROSS DRAINS ONLY. "U" ENDWALL TO BE PLACED AT 90° SKEW TO CENTERLINE. SEE STD. DWG. D-PE-99 FOR SKEWED CONNECTION DETAIL WHEN CROSS DRAIN IS NOT PERPENDICULAR TO CENTERLINE. CAST-IN-PLACE CONCRETE ENDWALL SHALL BE CONSTRUCTED IN ACCORDANCE WITH STANDARD SPECIFICATIONS, SECTION 611 AND/OR SPECIAL PROVISIONS.

Ⓑ SEE STD. DWG. D-PE-48B FOR BILL OF STEEL & PRECAST NOTES.

Ⓒ "-" IN BAR DESIGNATION REPRESENTS 3, 4 OR 6 FOR 3:1, 4:1 OR 6:1 SLOPES, RESPECTIVELY.

Ⓓ SPLICING OF REINFORCEMENT IS ACCEPTABLE PROVIDED THAT A MINIMUM 21" SPLICE LENGTH IS USED.

Ⓔ TOEWALL BACK SLOPE MAY BE CONSTRUCTED VARIABLE FROM VERTICAL UP TO 15°.

Ⓕ PAYMENT WILL BE MADE UNDER:

ITEM NO. 611-07.01, CLASS "A" CONCRETE (PIPE ENDWALLS)----CU. YD.
ITEM NO. 611-07.02, STEEL BAR REINFORCING (PIPE ENDWALLS)----LB.

DIMENSIONS AND QUANTITIES FOR ONE ENDWALL 48" PIPE

SLOPE	CONCRETE ENDWALL DIMENSIONS						STRUCTURAL STEEL PIPE DIMENSIONS		ESTIMATED QUANTITIES		
	H	L_1	L_2	L_3	L_4	W	LG	WG	CLASS "A" CONC. CU. YD.	STEEL BAR REINF. LB.	STRUCTURAL STEEL LB.
3:1	6'-1"	15'-5"	16'-3"	7'-4⅞"	-	5'-10"	16'-1⅞"	1 @ 5'-10"	3.79	333	167
4:1		20'-4"	20'-11½"	10'-3¼"	-		20'-10⅝"	1 @ 5'-10"	4.83	420	203
6:1		30'-2"	30'-7"	10'-0¾"	10'-0⅛"		30'-6⅜"	2 @ 5'-10"	6.92	597	320

NOTE: SEE STD. DWG. D-PE-99 FOR STRUCTURAL STEEL PIPE DIMENSIONS LG & WG.

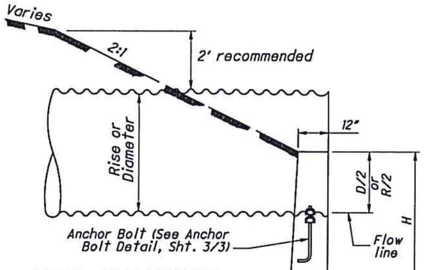
NOT TO SCALE

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

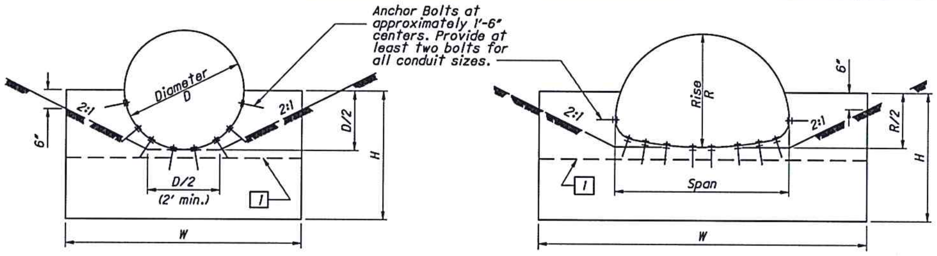
48" CONCRETE ENDWALL
CROSS DRAIN WITH
STEEL PIPE GRATE
(FOR 3:1, 4:1 & 6:1 SLOPES)

3-01-12
D-PE-48A

EXAMPLE #5



METAL PIPE PROFILE
W/ ANCHOR BOLT OPTION



CIRCULAR

PIPE-ARCH

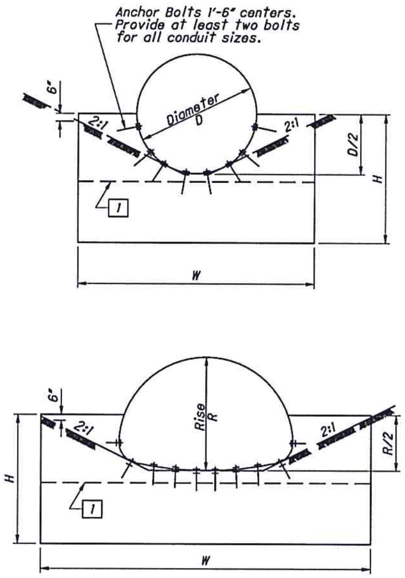
METAL PIPE END TREATMENT "A" W/ ANCHOR BOLT OPTION

CAST-IN-PLACE HW FOR CORRUGATED METAL PIPE & PLASTIC PIPE (English)

CIRCULAR					PIPE ARCH						PIPE ARCH					
D	W	H	T	CONC. cu. yds.	SPAN	RISE	W	H	T	CONC. cu. yds.	SPAN	RISE	W	H	T	CONC. cu. yds.
12"	2'-0"	3'-0"	12"	0.21	2.67"x½" Corrugations						*81"	59"	12'-4"	5'-5"	15"	2.14
15"	2'-6"	3'-2"	12"	0.27	17"	13"	3'-0"	3'-0"	12"	0.31	87"	63"	13'-0"	5'-7"	17"	2.50
18"	3'-0"	3'-3"	12"	0.33	21"	15"	3'-6"	3'-0"	12"	0.35	95"	67"	14'-0"	5'-9"	20"	3.14
21"	3'-6"	3'-4"	12"	0.39	24"	18"	4'-0"	3'-2"	12"	0.43	103"	71"	15'-0"	5'-11"	22"	3.54
24"	4'-0"	3'-6"	12"	0.46	28"	20"	4'-6"	3'-3"	12"	0.48	112"	75"	16'-0"	6'-1"	24"	3.96
27"	4'-6"	3'-8"	12"	0.53	35"	24"	5'-6"	3'-5"	12"	0.61	117"	79"	17'-9"	6'-3"	25"	4.89
30"	5'-0"	3'-9"	12"	0.60	42"	29"	6'-6"	3'-7"	12"	0.73	128"	83"	18'-0"	6'-5"	26"	5.01
33"	5'-6"	3'-10"	12"	0.68	49"	33"	7'-8"	3'-9"	12"	0.90	137"	87"	19'-0"	6'-7"	27"	5.45
36"	6'-0"	4'-0"	12"	0.76	57"	38"	9'-0"	4'-0"	12"	1.10	142"	91"	20'-9"	6'-9"	27"	6.31
39"	6'-6"	4'-2"	12"	0.84	64"	43"	10'-0"	4'-4"	12"	1.31	6"x2" Corrugations					
42"	7'-0"	4'-3"	12"	0.92	71"	47"	11'-0"	4'-8"	12"	1.54	(18" Corner Radius)					
48"	8'-0"	4'-6"	12"	1.10	*77"	52"	11'-8"	5'-3"	12"	1.84	*6'-1"	4'-7"	11'-8"	5'-7"	12"	1.89
54"	9'-3"	4'-9"	12"	1.33	*83"	57"	12'-4"	5'-5"	15"	2.46	*6'-4"	4'-9"	12'-0"	5'-8"	14"	2.12
60"	10'-6"	5'-6"	12"	1.78	6"x2" Corrugations						*6'-9"	4'-11"	12'-4"	5'-9"	15"	2.42
66"	11'-9"	5'-9"	12"	2.06	(31" Corner Radius)						*7'-0"	5'-1"	12'-8"	5'-10"	16"	2.44
72"	13'-0"	6'-0"	12"	2.37	13'-3"	9'-4"	23'-11"	7'-11"	32"	9.63	7'-3"	5'-3"	12'-11"	5'-11"	17"	2.69
78"	14'-3"	6'-3"	14"	2.94	13'-6"	9'-6"	24'-9"	8'-0"	32"	10.12	7'-8"	5'-5"	13'-2"	6'-0"	18"	2.77
84"	15'-6"	6'-6"	14"	3.30	14'-0"	9'-8"	24'-10"	8'-1"	33"	10.33	7'-11"	5'-7"	14'-0"	6'-1"	20"	3.15
90"	16'-9"	6'-9"	16"	4.00	14'-2"	9'-10"	25'-9"	8'-2"	33"	10.87	8'-2"	5'-9"	14'-8"	6'-2"	21"	3.45
96"	18'-0"	7'-0"	16"	4.40	14'-5"	10'-0"	26'-7"	8'-3"	33"	11.39	8'-7"	5'-11"	15'-0"	6'-3"	22"	3.75
102"	19'-3"	7'-3"	18"	5.28	14'-11"	10'-2"	26'-9"	8'-4"	34"	11.68	8'-10"	6'-1"	15'-10"	6'-4"	23"	4.15
108"	20'-6"	7'-6"	20"	6.21	15'-4"	10'-4"	26'-11"	8'-5"	34"	11.96	9'-4"	6'-3"	16'-0"	6'-5"	24"	4.65
114"	21'-9"	7'-9"	22"	7.25	15'-7"	10'-6"	27'-9"	8'-6"	34"	12.51	9'-6"	6'-5"	16'-10"	6'-6"	26"	4.93
120"	23'-0"	8'-0"	24"	8.38	15'-10"	10'-8"	28'-7"	8'-7"	35"	13.06	9'-9"	6'-7"	17'-9"	6'-7"	27"	5.41
*126"	23'-0"	8'-3"	26"	8.64	16'-3"	10'-10"	28'-8"	8'-8"	35"	13.34	10'-3"	6'-9"	17'-10"	6'-8"	27"	5.45
132"	23'-0"	8'-6"	28"	9.23	16'-6"	11'-0"	29'-7"	8'-9"	35"	13.94	10'-8"	6'-11"	17'-11"	6'-9"	27"	5.59
138"	24'-1"	8'-9"	30"	10.50	17'-0"	11'-2"	29'-8"	8'-10"	36"	14.24	10'-11"	7'-1"	18'-10"	6'-10"	28"	5.97
144"	25'-2"	9'-0"	32"	11.89	17'-2"	11'-4"	30'-7"	8'-11"	36"	14.84	11'-5"	7'-3"	18'-11"	6'-11"	28"	6.12
150"	26'-4"	9'-3"	34"	13.38	17'-5"	11'-6"	31'-5"	9'-0"	36"	15.42	11'-7"	7'-5"	19'-9"	7'-0"	28"	6.52
156"	27'-5"	9'-6"	36"	15.01	17'-11"	11'-8"	31'-7"	9'-1"	37"	15.83	11'-10"	7'-7"	20'-9"	7'-1"	29"	6.94
162"	28'-7"	9'-9"	38"	16.75	18'-1"	11'-10"	32'-5"	9'-2"	37"	16.43	12'-4"	7'-9"	20'-10"	7'-2"	29"	7.12
168"	29'-8"	10'-0"	40"	18.61	18'-7"	12'-0"	32'-6"	9'-3"	37"	16.78	12'-6"	7'-11"	21'-8"	7'-3"	29"	7.53
174"	30'-9"	10'-3"	42"	20.28	18'-9"	12'-2"	33'-4"	9'-4"	38"	17.43	12'-8"	8'-1"	22'-7"	7'-4"	30"	7.95
180"	31'-11"	10'-6"	43"	21.87	19'-3"	12'-4"	33'-5"	9'-5"	38"	17.78	12'-10"	8'-4"	23'-7"	7'-5"	30"	8.48
186"	33'-0"	10'-9"	44"	23.54	19'-6"	12'-6"	34'-5"	9'-6"	38"	18.49	13'-5"	8'-5"	23'-7"	7'-6"	30"	8.63
192"	34'-2"	11'-0"	45"	25.30	19'-8"	12'-8"	35'-3"	9'-7"	39"	19.19	13'-11"	8'-7"	23'-7"	7'-7"	31"	8.81
198"	35'-3"	11'-3"	46"	27.12	19'-11"	12'-10"	36'-3"	9'-8"	39"	19.95	14'-1"	8'-9"	25'-1"	7'-8"	31"	9.29
204"	36'-4"	11'-6"	47"	29.15	20'-5"	13'-0"	36'-3"	9'-9"	39"	20.30	14'-3"	8'-11"	25'-6"	7'-9"	31"	9.78
210"	37'-6"	11'-9"	48"	31.03	20'-7"	13'-2"	37'-2"	9'-10"	40"	21.05	14'-10"	9'-1"	25'-6"	7'-10"	32"	10.25
216"	38'-7"	12'-0"	49"	33.43	3"x1" Corrugations						15'-4"	9'-3"	25'-6"	7'-11"	32"	10.25
222"	39'-9"	12'-3"	50"	36.26	40"	31"	6'-6"	3'-7"	12"	0.70	15'-6"	9'-5"	26'-5"	8'-0"	32"	10.74
228"	40'-10"	12'-6"	51"	37.52	46"	36"	7'-8"	3'-9"	12"	0.85	15'-8"	9'-7"	27'-5"	8'-1"	33"	11.28
234"	42'-0"	12'-9"	52"	39.86	53"	41"	9'-0"	4'-0"	12"	1.06	15'-10"	9'-10"	28'-5"	8'-2"	33"	12.00
240"	43'-1"	13'-0"	53"	42.28	60"	46"	10'-0"	4'-4"	12"	1.27	16'-5"	9'-11"	28'-5"	8'-3"	33"	12.09
246"	44'-2"	13'-3"	54"	44.83	66"	51"	11'-0"	4'-8"	12"	1.54	16'-7"	10'-1"	29'-4"	8'-4"	34"	12.64
252"	45'-4"	13'-6"	55"	47.44	*73"	55"	11'-8"	5'-3"	12"	1.81	--	--	--	--	--	--

* Determine channel configuration for pipe sizes between end treatment "A" and end treatment "B" by 2:1 slopes passing through a point 6" below the top and at each side of the headwall. For end treatment "B", 2:1 slopes are tangent to pipe.

1	Top surface of 6" inlet headwall extension



METAL PIPE END TREATMENT "B"
W/ ANCHOR BOLT OPTION

STATE OF OHIO DEPARTMENT OF TRANSPORTATION

STATE HYDRAULIC ENGINEER

REVISIONS
7/30/07
7/20/12

ROADWAY HYDRAULIC ENGINEER
Matt Cozzoli

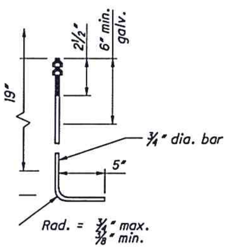
OFFICE OF HYDRAULIC ENGINEERING

STANDARD HYDRAULIC CONSTRUCTION DRAWING
HALF-HEIGHT HEADWALLS FOR CORRUGATED METAL PIPE AND PLASTIC PIPE

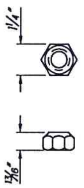
SCD NUMBER
HW-2.1

1/3

I:\hy\Proposed File Structure\Standard Drawings\Current\HW\hw21_07-20-12.dgn 02-AUG-2012 8:22AM hyaryanh

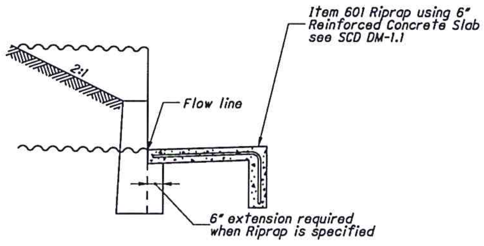


ANCHOR BOLT

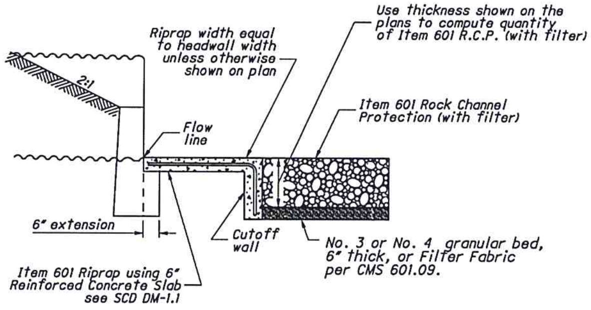


NUT

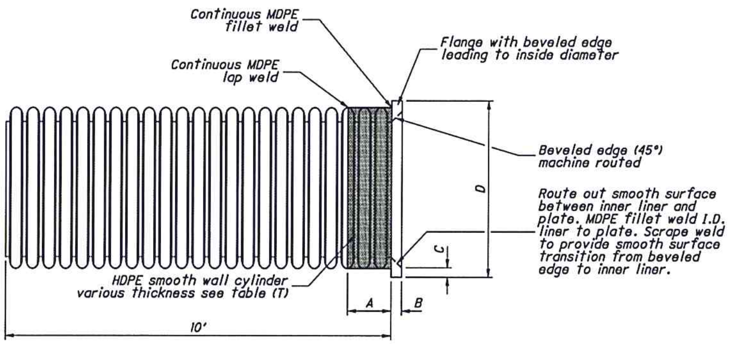
(ASTM A 325 and A 153)



INLET CHANNEL PROTECTION DETAIL



OUTLET CHANNEL PROTECTION DETAIL



HDPE IMPROVED INLET - TYPE A CONDUITS

PIPE SIZE	A	B	C	D	T
12 in.	6.00 in.	0.50 in.	1.00 in.	15.15 in.	0.13 in.
15 in.	6.00 in.	0.63 in.	1.26 in.	18.73 in.	0.19 in.
18 in.	6.00 in.	0.75 in.	1.50 in.	22.57 in.	0.25 in.
24 in.	8.00 in.	1.00 in.	2.00 in.	30.08 in.	0.25 in.
30 in.	8.00 in.	1.25 in.	2.50 in.	37.50 in.	0.38 in.
36 in.	10.00 in.	1.50 in.	3.00 in.	45.00 in.	0.38 in.
42 in.	10.00 in.	1.75 in.	3.50 in.	51.90 in.	0.38 in.
48 in.	10.00 in.	2.00 in.	4.00 in.	59.60 in.	0.38 in.
60 in.	12.00 in.	2.50 in.	5.00 in.	74.50 in.	0.38 in.

NOTES

GENERAL: Provide a riprap reinforced concrete slab according to SCD DM-1.1 if the pipe is depressed or it is specified in the plan. Payment for the slab is made per square yard of **Item 601 Riprap Using 6" Reinforced Concrete Slab** and includes the cost of the cutoff wall.

This drawing is for cast-in-place half-height concrete headwalls. When furnishing precast half-height headwalls, conform to pre-approved designs on file with the Office of Materials Management. Precast half-height headwalls are only approved for round conduits with a maximum conduit diameter of 78". When precast headwalls are furnished, provide openings for the anchor cable as shown and fill with grout after placement of the anchor cable. If anchor bolts are to be used with a precast headwall, fill the anchor cable openings with grout.

CONCRETE: Use Class C concrete for headwall. Concrete quantities are based on headwalls without the 6" extension under the channel protection.

ANCHOR BOLTS: Furnish bolts (see detail sheet 2/3) that meet ASTM A 307 for anchoring both ends of metal pipe. The top 6" min. of the bolt must be galvanized according to ASTM A 153. Cost of anchors is included in the price bid per foot of Item 603.

Headwall dimensions are based on end treatment "A" for pipe sizes up to and including 120", 71"x47", and 66"x51", and on end treatment "B" for sizes over and including 132", 13'-3"x9'-4", and 7'-3"x5'-3".

PLASTIC PIPE: Plastic pipe may not be available in all the sizes specified on this drawing.

ANCHOR CABLE: Furnish anchor cable (see detail sheet 2/3) that meets ASTM A 603 for anchoring both ends of plastic pipe. Wire rope clip must be galvanized according to ASTM A 153. Cost of anchor cable and wire rope clip is included in the unit price bid per foot of Item 603.

IMPROVED INLET FOR HDPE PIPE: Furnish improved inlet at upstream end of culverts and open-ended storm sewers using plastic pipe.

Use HDPE smooth cap and flange materials according to ASTM D 3350 345464C.

STATE OF OHIO DEPARTMENT OF TRANSPORTATION
STATE HYDRAULIC ENGINEER

REVISIONS
7/30/07
7/20/12

ROADWAY HYDRAULIC ENGINEER
Matt Cozzoli

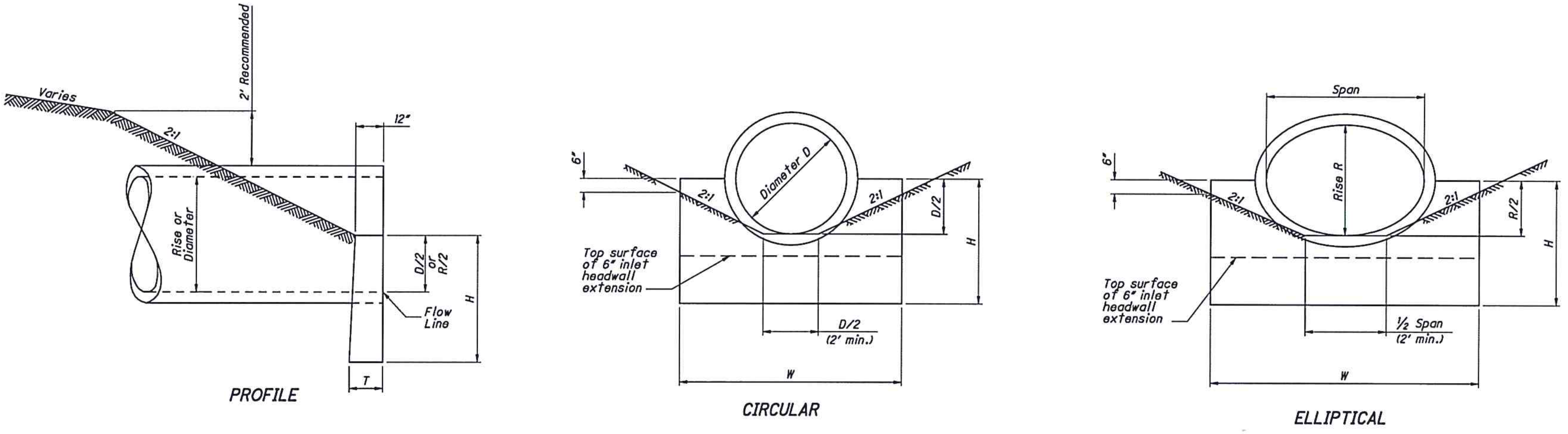
OFFICE OF
HYDRAULIC
ENGINEERING

STANDARD HYDRAULIC CONSTRUCTION DRAWING
HALF-HEIGHT HEADWALLS FOR
CORRUGATED METAL PIPE AND
PLASTIC PIPE

SCD NUMBER
HW-2.1

3/3

I:\hy\Proposed File Structure\Standard Drawings\Current\HW\hw21_07-20-12.dgn 02-AUG-2012 8:22AM hyaryanh



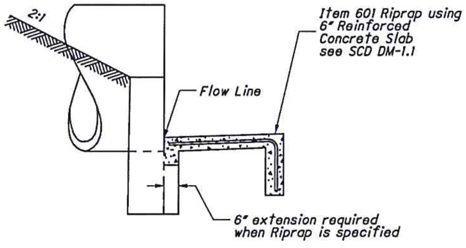
PROFILE

CIRCULAR

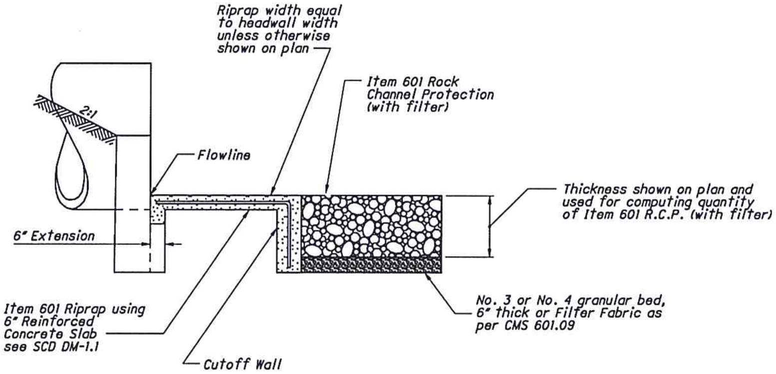
ELLIPTICAL

CONCRETE PIPE

See Sheet 2 of 2 for Pipe Tables and NOTES.



INLET CHANNEL PROTECTION DETAIL



OUTLET CHANNEL PROTECTION DETAIL

STATE OF OHIO DEPARTMENT OF TRANSPORTATION
STATE HYDRAULIC ENGINEER

REVISIONS
7/30/07
7/20/12

ROADWAY HYDRAULIC ENGINEER
Matt Cozzoli

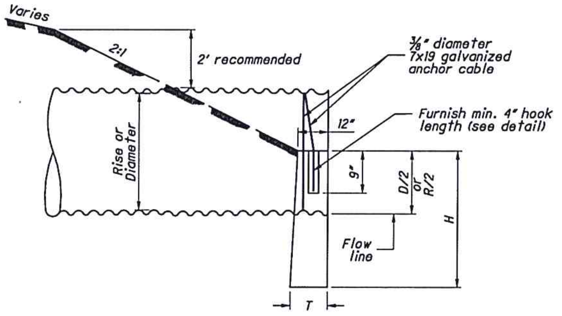
OFFICE OF HYDRAULIC ENGINEERING

STANDARD HYDRAULIC CONSTRUCTION DRAWING
HALF-HEIGHT HEADWALLS FOR CONCRETE PIPE

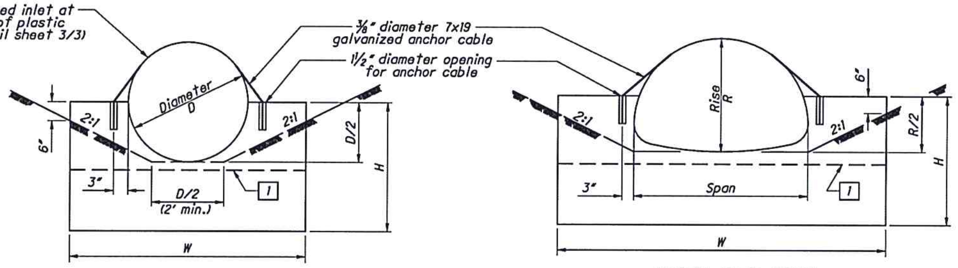
SCD NUMBER
HW-2.2

1/2

I:\hy\Proposed File Structure\Standard Drawings\Current\HW\hw22_07-20-12.dgn 02-AUG-2012 8:22AM hyaryanh



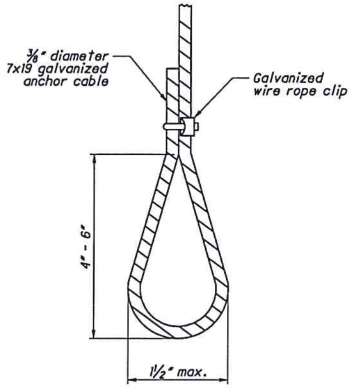
PLASTIC & METAL PIPE PROFILE W/ ANCHOR CABLE OPTION



CIRCULAR

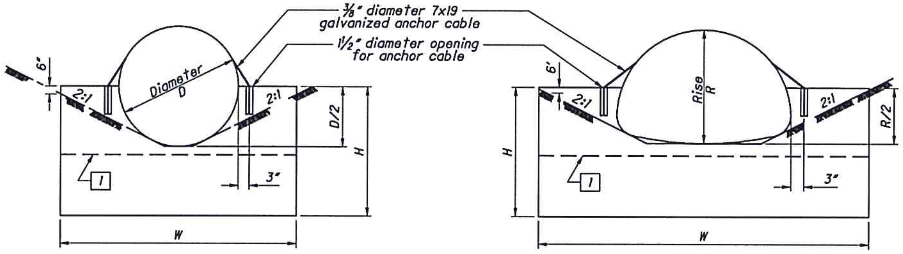
METAL PIPE-ARCH

PLASTIC & METAL PIPE END TREATMENT "A" W/ ANCHOR CABLE OPTION



ANCHOR CABLE DETAIL

1	Top surface of 6" inlet headwall extension



METAL PIPE END TREATMENT "B" W/ ANCHOR CABLE OPTION

NOTES

Wrap galvanized anchor cable one time completely around the circumference of the conduit. Furnish hook at least 4" long at the ends of the anchor cable as shown above.

Cut galvanized anchor cable to length required.

Form or drill 1½" diameter openings for anchor cable at locations shown. Alternatively, place anchor cable in wet concrete at the dimensions shown above to secure conduit to headwall.

Fill any openings made for anchor cables with grout after anchor cables are placed to a taut fit.

STATE OF OHIO DEPARTMENT OF TRANSPORTATION

STATE HYDRAULIC ENGINEER

REVISIONS
7/30/07
7/20/12

ROADWAY HYDRAULIC ENGINEER
Matt Cozzoli

OFFICE OF HYDRAULIC ENGINEERING

STANDARD HYDRAULIC CONSTRUCTION DRAWING

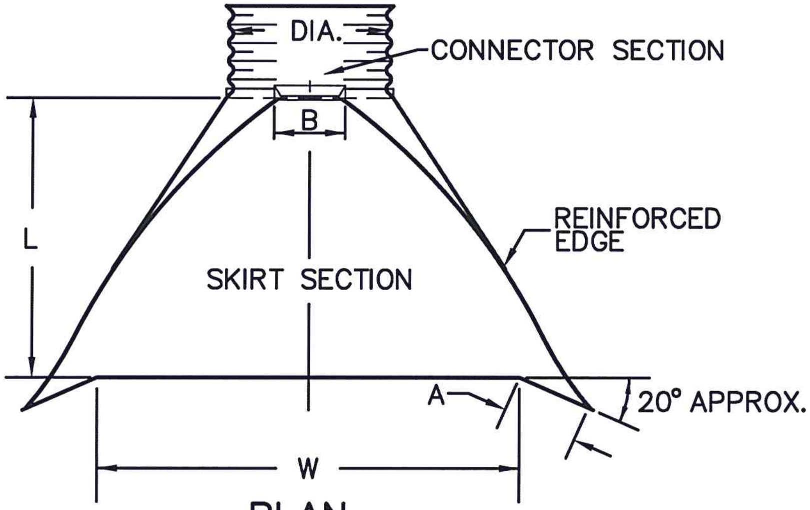
HALF-HEIGHT HEADWALLS FOR CORRUGATED METAL PIPE AND PLASTIC PIPE

SCD NUMBER
HW-2.1

2/3

I:\hy\Proposed File Structure\Standard Drawings\Current\HW\hw21_07-20-12.dgn 02-AUG-2012 8:22AM hyaryanh

EXAMPLE #6

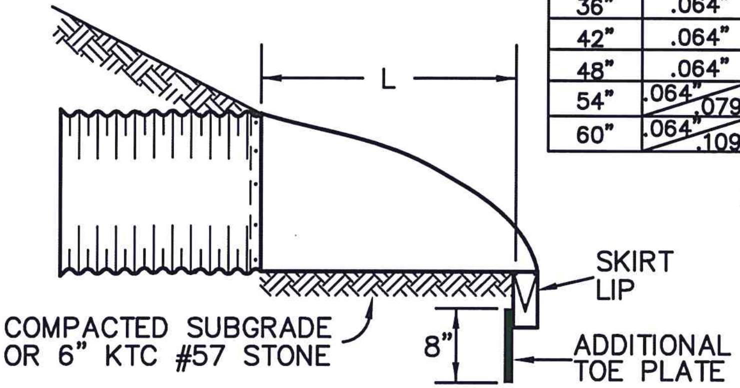


PLAN

NOTES:

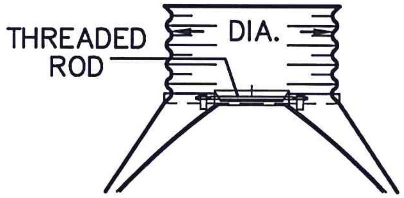
1. TOE PLATE TO BE PUNCHED TO MATCH HOLES IN SKIRT LIP. 3/8" GALV. BOLTS TO BE FURNISHED. LENGTH OF TOE PLATE IS W+10" FOR 12" TO 30" DIA. PIPE AND W+22" FOR 36" TO 60" DIA. PIPE.
2. SKIRT SECTION FOR 12" TO 30" DIA. PIPE TO BE MADE IN ONE PIECE.
3. SKIRT SECTION FOR 36" TO 54" DIA. PIPE MAY BE MADE FROM TWO SHEETS JOINED BY REVITING OR BOLTING ON CENTERLINE, 60" MAY BE CONSTRUCTED IN THREE PIECES.
4. CONNECTOR SECTION, CORNER PLATE AND TOE PLATE TO BE SAME SHEET THICKNESS AS SKIRT
5. END-SECTIONS AND FITTINGS ARE TO BE ALUMINUM ALLOY.

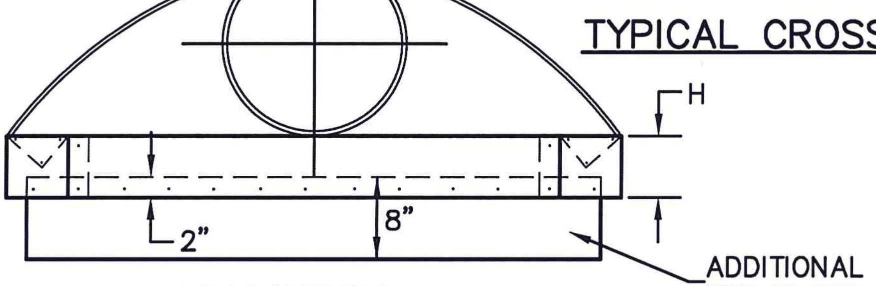
PIPE DIA.	SHEET THICK-NESS	DIMENSIONS				
		A 1"TOL.	B MAX.	H 1"TOL.	L 1 1/2"TOL	W 2"TOL.
12"	.064"	6"	6"	6"	21"	24"
15"	.064"	7"	8"	6"	26"	30"
18"	.064"	8"	10"	6"	31"	36"
24"	.064"	10"	13"	6"	41"	48"
30"	.064"	12"	16"	8"	51"	60"
36"	.064"	14"	19"	9"	60"	72"
42"	.064"	16"	22"	11"	69"	84"
48"	.064"	18"	27"	12"	78"	90"
54"	.064" .079"	18"	30"	12"	84"	102"
60"	.064" .109"	18"	33"	12"	87"	114"



TYPICAL CROSS-SECTION

ALTERNATE CONNECTION





ELEVATION

MSD

Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky 40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

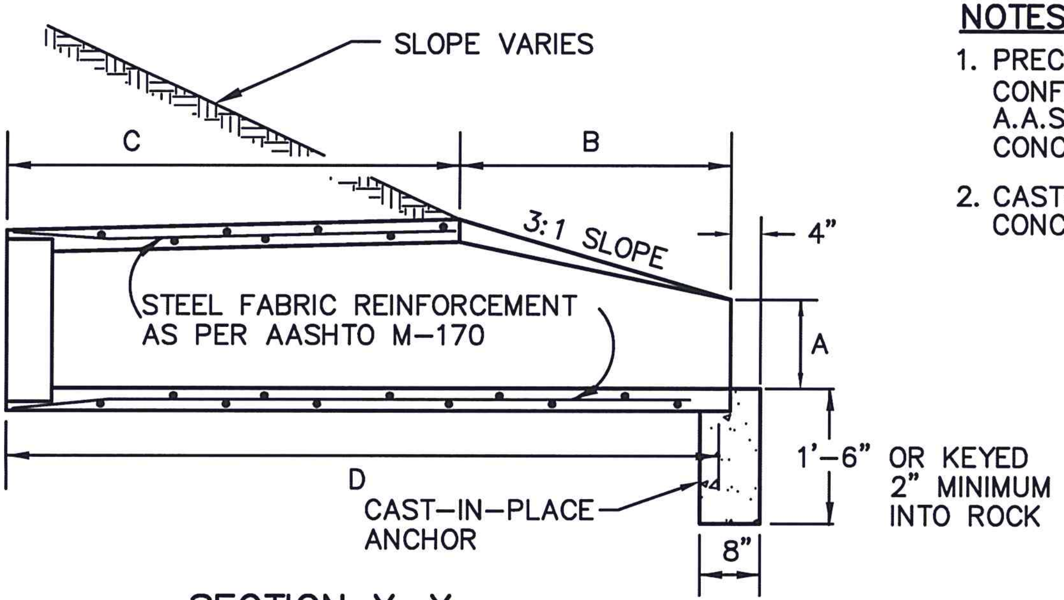
FLARED END SECTION FOR CORRUGATED METAL PIPE

STANDARD DRAWING NO. DE-02-01

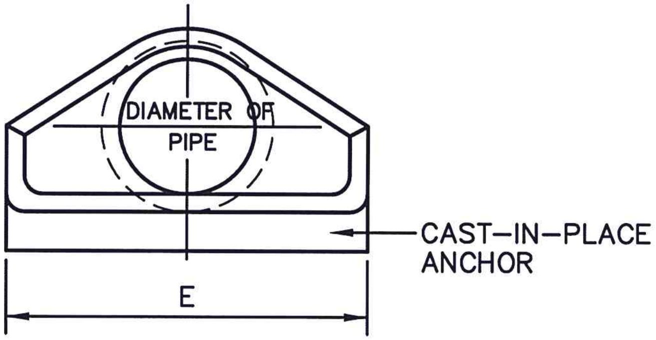
APPROVED BY: DIRECTOR OF ENGINEERING 9/30/2009 DATE

NOTES

1. PRECAST CONCRETE FLARED END SECTION SHALL CONFORM TO THE APPLICABLE REQUIREMENTS OF A.A.S.H.T.O. M-170 CLASS III, WALL B REINFORCED CONCRETE PIPE.
2. CAST-IN-PLACE ANCHOR SHALL BE OF CLASS "A" CONCRETE FOR FULL WIDTH OF FLARED END SECTION.

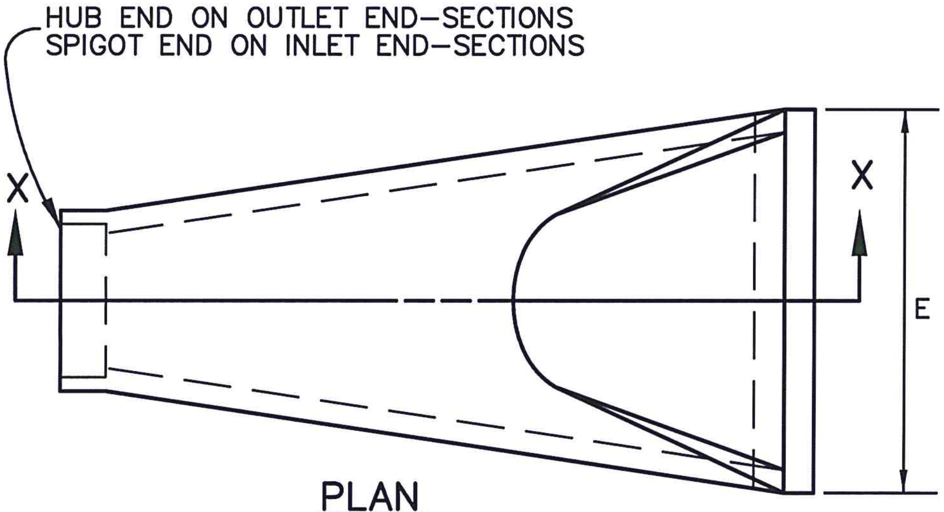


SECTION X-X



END VIEW

END SECTION DIMENSIONS					
DIA.	A	B	C	D	E
12"	4"	2'-0"	4'-1"	6'-1"	2'-0"
15"	6"	2'-3"	3'-10"	6'-1"	2'-6"
18"	9"	2'-3"	3'-10"	6'-1"	3'-0"
24"	10"	3'-7"	2'-8"	6'-3"	4'-0"
30"	1'-0"	4'-6"	1'-7 3/4"	6'-1 3/4"	5'-0"
36"	1'-3"	5'-3"	2'-10 3/4"	8'-1 3/4"	6'-0"
42"	1'-9"	5'-3"	2'-11"	8'-2"	6'-6"
48"	2'-0"	6'-0"	2'-2"	8'-2"	7'-0"



PLAN

MSD

Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky 40203-1913
502-587-0603 – WWW.MSDLOUKY.ORG

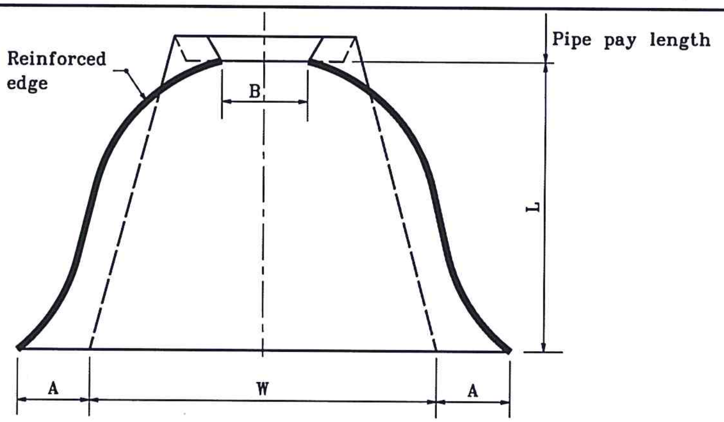
FLARED END SECTION
FOR R.C.P.

STANDARD DRAWING NO. DE-01-01

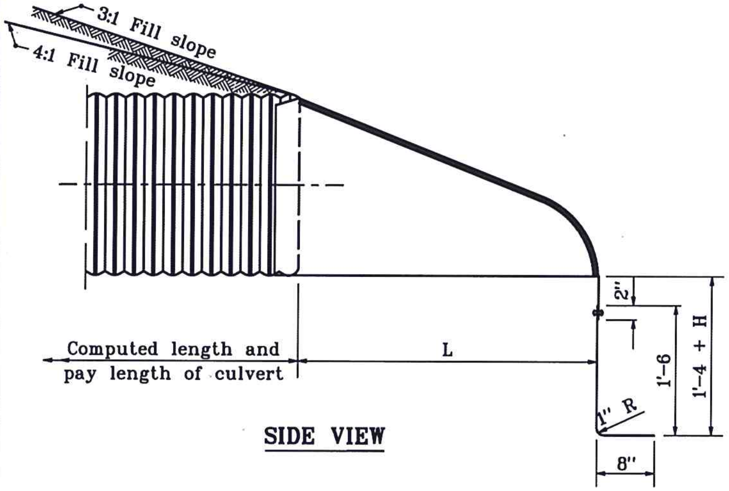
APPROVED BY: ____ DIRECTOR OF ENGINEERING

9/30/2009
DATE

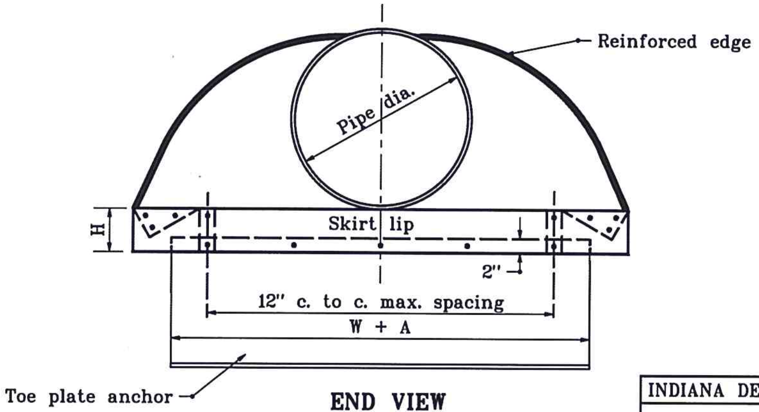
PIPE DIA.	END SECTION THICK. (in.)	DIMENSIONS					APPROX. SLOPE	BODY
		A (±1")	B (Max.)	H (±1")	L (±1½")	W (±2")		
12	.064	6	6	6	21	24	2½:1	1 Pc.
15	.064	7	8	6	26	30	2½:1	1 Pc.
18	.064	8	10	6	31	36	2½:1	1 Pc.
21	.064	9	12	6	36	42	2½:1	1 Pc.
24	.064	10	13	6	41	48	2½:1	1 Pc.
30	.079	12	16	8	51	60	2½:1	1 Pc.
36	.079	14	19	9	60	72	2½:1	2 Pc.



PLAN VIEW



SIDE VIEW



END VIEW

INDIANA DEPARTMENT OF TRANSPORTATION

METAL PIPE END SECTION

JANUARY 1998

STANDARD DRAWING NO. E 715-MPES-01

DETAILS PLACED IN THIS FORMAT 11-15-99

ANTHONY L. UREMOVICH
No. 18095

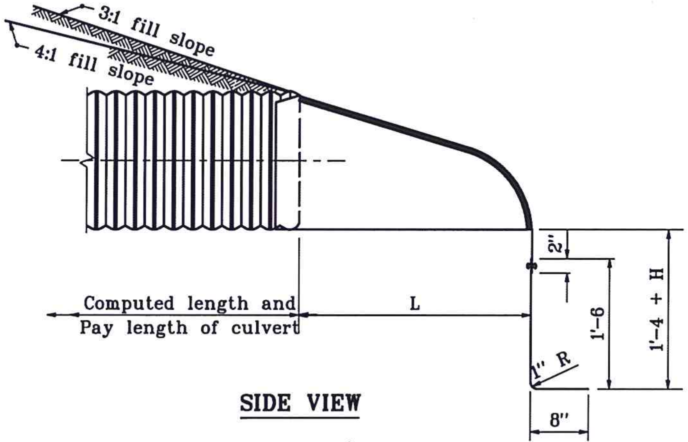
/s/ Anthony L. Uremovich 11-15-99
DESIGN STANDARDS ENGINEER DATE

/s/ Firooz Zandi 11-15-99
CHIEF HIGHWAY ENGINEER DATE

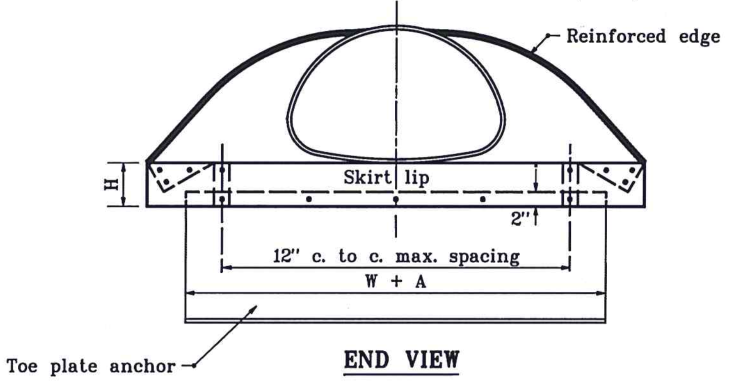
DESIGN STANDARDS ENGINEER

ORIGINALLY APPROVED 1-02-98

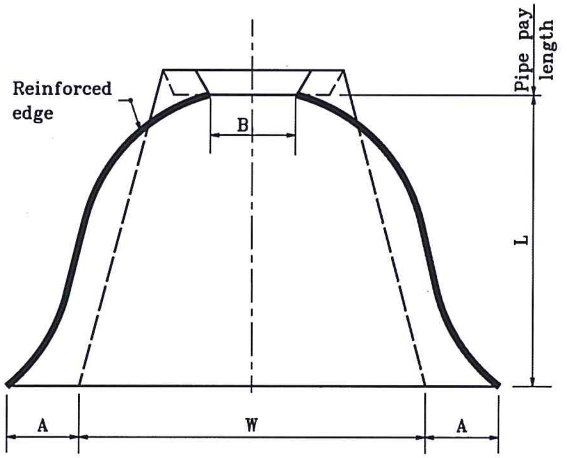
PIPE-ARCH DIMENSIONS		END SECTION THICK. (in.)	DIMENSIONS					APPROX. SLOPE	BODY
SPAN	RISE		A (±1")	B (Max.)	H (± 1")	L (±1½")	W (±2")		
17	13	.064	7	9	6	19	30	2½:1	1 Pc.
21	15	.064	7	10	6	23	36	2½:1	1 Pc.
24	18	.064	8	12	6	28	42	2½:1	1 Pc.
28	20	.064	9	14	6	32	48	2½:1	1 Pc.
35	24	.079	10	16	8	39	60	2½:1	1 Pc.
42	29	.079	12	18	9	46	75	2½:1	1 Pc.



SIDE VIEW



END VIEW



PLAN VIEW

INDIANA DEPARTMENT OF TRANSPORTATION

METAL PIPE ARCH
END SECTION

JANUARY 1998

STANDARD DRAWING NO. E 715-MPES-02

ANTHONY L. UREMOVICH
No. 18095

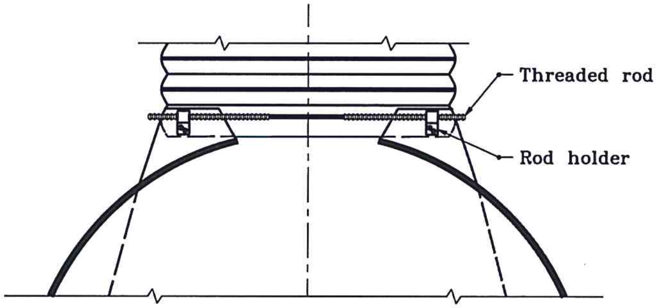
DESIGN STANDARDS ENGINEER

DETAILS PLACED IN THIS FORMAT 11-15-99

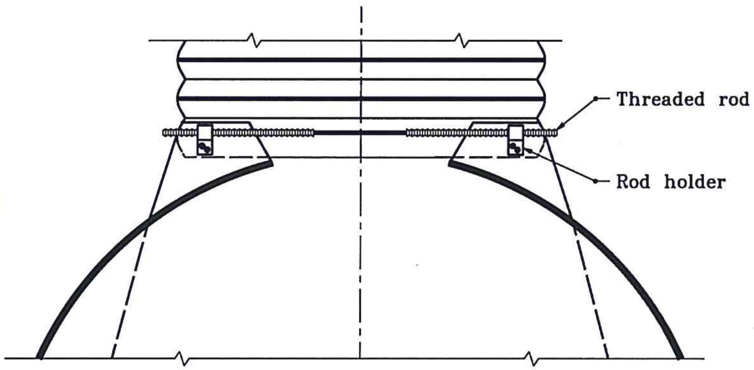
/s/ Anthony L. Uremovich 11-15-99
DESIGN STANDARDS ENGINEER DATE

/s/ Firooz Zandi 11-15-99
CHIEF HIGHWAY ENGINEER DATE

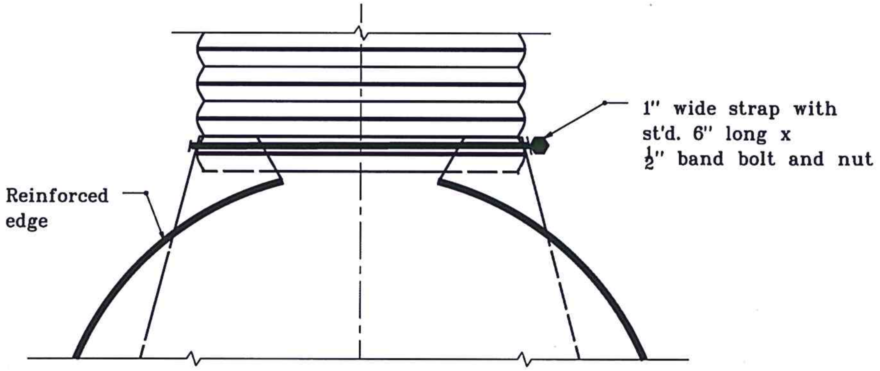
ORIGINALLY APPROVED 1-02-98



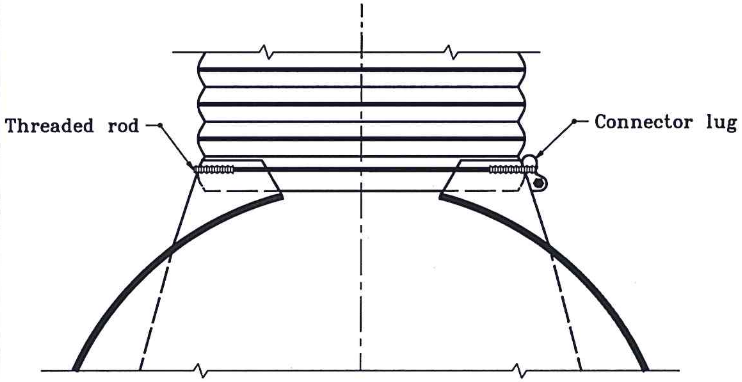
TYPE 1
FOR 17" x 13" THROUGH 42" x 29" ONLY



TYPE 4
FOR 30" THROUGH 36" ONLY



ALTERNATE TYPE 3
FOR 12" THROUGH 24" ONLY



TYPE 3
FOR 12" THROUGH 24" ONLY

INDIANA DEPARTMENT OF TRANSPORTATION

METAL PIPE
END SECTION CONNECTIONS
JANUARY 1998

STANDARD DRAWING NO. E 715-MPES-03

ANTHONY L. UREMOVICH
No. 18095

DESIGN STANDARDS ENGINEER

DETAILS PLACED IN THIS FORMAT 7-27-99

/s/ Anthony L. Uremovich 7-27-99
DESIGN STANDARDS ENGINEER DATE

/s/ Firooz Zandi 7-27-99
CHIEF HIGHWAY ENGINEER DATE

ORIGINALLY APPROVED 1-02-98

COUNTY OF	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
DAVIESS		~~39a~~	142

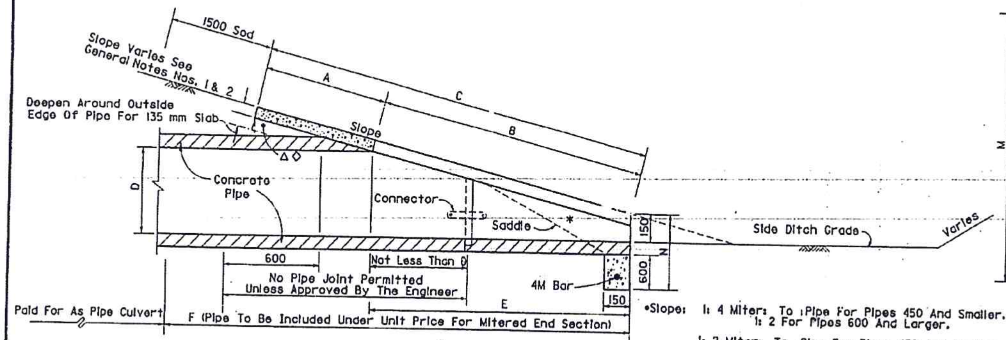
2-306.00 90

DIMENSIONS AND QUANTITIES

	D	A	B	C	E	F	G	M	N	135 CONCRETE SLAB (m_3)	SODDING (m^2)
1: 2 Slope	375	0.59	0.66	1.25	0.63	1.52	0.37	1.41	0.82	0.39	11
	450	0.60	0.84	1.44	0.78	1.83	0.43	1.56	0.82	0.44	12
	600	0.63	1.17	1.80	1.09	2.13	0.53	1.68	0.83	0.52	13
	750	0.66	1.51	2.16	1.39	2.44	0.61	1.85	0.85	0.62	15
	900	0.69	1.85	2.54	1.70	2.74	0.68	2.03	0.86	0.76	16
	1050	0.71	2.20	2.91	2.00	3.05	0.75	2.21	0.87	0.89	17
	1200	0.74	2.94	3.28	2.30	3.35	0.81	2.30	0.89	1.02	18
1: 3 Slope	375	0.64	0.94	1.58	0.91	2.12	0.37	1.41	0.82	0.47	12
	450	0.66	1.17	1.83	1.14	2.35	0.43	1.50	0.82	0.52	13
	600	0.70	1.65	2.35	1.59	2.80	0.53	1.68	0.83	0.64	15
	750	0.74	2.12	2.86	2.04	3.25	0.61	1.85	0.85	0.79	17
	900	0.79	2.60	3.39	2.49	3.70	0.68	2.03	0.86	0.95	19
	1050	0.82	3.07	3.89	2.94	4.15	0.75	2.21	0.87	1.13	20
	1200	0.86	3.54	4.40	3.39	4.60	0.81	2.30	0.89	1.57	22
1: 4 Slope	375	0.69	1.25	1.94	1.23	2.44	0.37	1.41	0.82	0.54	13
	450	0.72	1.56	2.28	1.53	2.74	0.43	1.50	0.82	0.60	14
	600	0.77	2.18 △	2.96	2.14 △	3.35	0.53	1.68	0.83	0.76	17
	750	0.82	2.82	3.64	2.75	3.96	0.61	1.85	0.85	0.96	19
	900	0.88	3.45◇	4.32	3.36◇	4.57	0.68	2.03	0.86	1.14	21
	1050	0.93	4.08	5.01	3.97	5.18	0.75	2.21	0.87	1.36	24
	1200	0.98	4.70	5.68	4.58	5.79	0.81	2.30	0.89	1.57	26

B	E	
△1.95	△ 1.90	Dimensions permitted to allow use of 2.44 standard pipe lengths.
◇3.17	◇ 3.10	Dimensions permitted to allow use of 3.66 standard pipe lengths.

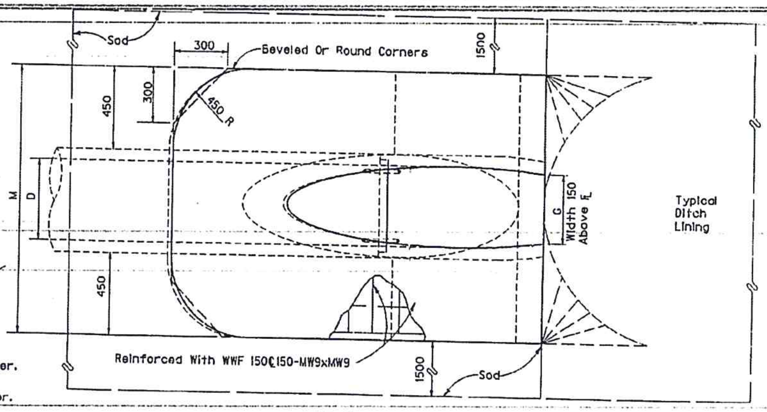
△◇ Concrete slab shall be deepened to form bridge across crown of pipe. See section below.



•Slope: 1: 4 Miter: To 1 Pipe For Pipes 450 And Smaller.
1: 2 For Pipes 600 And Larger.

1: 2 Miter: To 1 Pipe For Pipes 450 And Smaller.
1: 1 For Pipes 600 And Larger.

SECTION



TOP VIEW-SINGLE PIPE

NOTE: See sheet 3 for details and notes.

KENTUCKY
DEPARTMENT OF HIGHWAYS

CROSS DRAIN
MITERED END SECTION *
SINGLE CONCRETE PIPE

	Name	Date
Designed By	MDJ	05/90
Drawn By		
Checked By	ETC	05/98
F.H.W.A. Approved:		

Approved By
State Drainage Engineer

Revision No.	Sheet No.	Index No.
98	1 of 3	

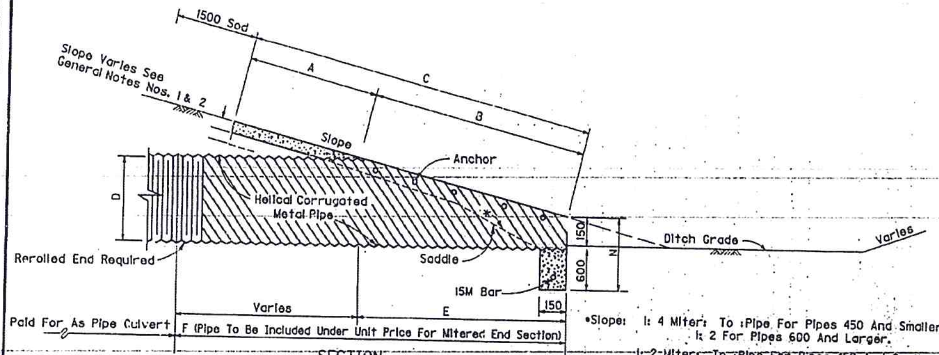
* BASED ON FLORIDA
DOT STANDARDS

COUNTY OF	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
DAVIESS		~~386~~	142

2-306.00 91

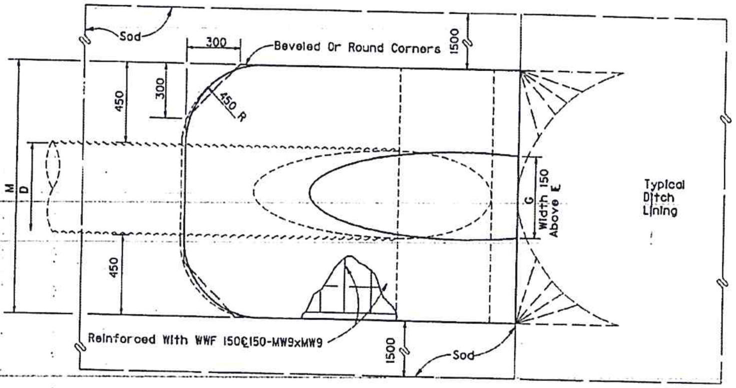
DIMENSIONS AND QUANTITIES

	D	A	B	C	E	F	G	M	N	135 CONCRETE SLAB (m₃)	SODDING (m²)
1: 2 Slope	375	0.75	0.51	1.27	0.45	1.52	0.37	1.31	0.76	0.36	11
	450	0.76	0.68	1.44	0.61	1.83	0.43	1.39	0.76	0.38	12
	600	0.76	1.02	1.78	0.91	2.13	0.52	1.55	0.76	0.46	13
	750	0.76	1.36	2.12	1.22	2.44	0.61	1.70	0.76	0.55	14
	900	0.76	1.70	2.46	1.52	2.74	0.68	1.85	0.76	0.63	16
	1050	0.76	2.04	2.81	1.83	3.05	0.74	2.00	0.76	0.74	17
	1200	0.76	2.38	3.15	2.13	3.35	0.81	2.15	0.76	0.83	18
1: 3 Slope	375	0.76	0.71	1.47	0.68	1.90	0.37	1.32	0.76	0.40	12
	450	0.76	0.95	1.71	0.90	2.12	0.43	1.39	0.76	0.42	13
	600	0.76	1.42	2.18	1.35	2.57	0.52	1.55	0.76	0.53	14
	750	0.76	1.90	2.66	1.80	3.02	0.61	1.70	0.76	0.64	16
	900	0.76	2.37	3.13	2.25	3.47	0.68	1.85	0.76	0.75	18
	1050	0.76	2.86	3.62	2.70	3.92	0.74	2.00	0.76	0.87	19
	1200	0.76	3.32	4.08	3.15	4.37	0.81	2.[illegible]	0.76	0.99	21
1: 4 Slope	375	0.76	0.94	1.70	0.91	2.13	0.37	1.32	0.76	0.43	12
	450	0.76	1.25	2.02	1.22	2.44	0.43	1.39	0.76	0.46	14
	600	0.76	1.88	2.64	1.83	3.05	0.52	1.55	0.76	0.60	16
	750	0.76	2.51	3.27	2.44	3.66	0.61	1.70	0.76	0.73	18
	900	0.76	3.14	3.90	3.05	4.26	0.68	1.85	0.76	0.86	20
	1050	0.76	3.77	4.53	3.66	4.87	0.74	2.00	0.76	1.00	22
	1200	0.76	4.[illegible]0	5.16	4.26	5.48	0.81	2.15	0.76	1.14	24



SECTION

*Slope: 1: 4 Miter: To :Pipe For Pipes 450 And Smaller.
1: 2 For Pipes 600 And Larger.
1: 2 Miter: To :Pipe For Pipes 450 And Smaller.
1: 1 For Pipes 600 And Larger.



TOP VIEW-SINGLE PIPE

NOTE: See Sheet 3 For Details And Notes.

KENTUCKY
DEPARTMENT OF HIGHWAYS

CROSS DRAIN
MITERED END SECTION
SINGLE CORRUGATED METAL PIPE

	Names	Dates
Designed By	MDJ	05/98
Drawn By		
Checked By	ETG	05/98
F.H.W.A. Approved		

Approved By

State Drainage Engineer

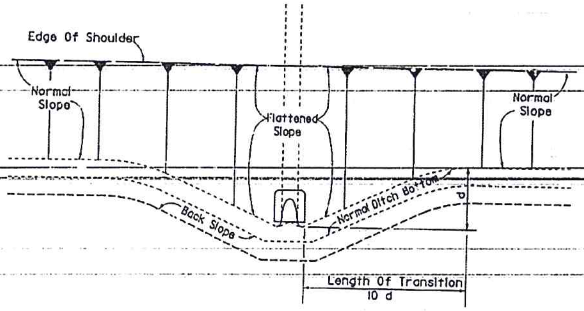
Revision No.	Sheet No.	Index No.
98	2 of 3	

COUNTY OF	FISCAL YEAR	SHEET NO.	TOTAL SHEETS
DAVIESS		~~39c~~ 92	142

2-306.00

GENERAL NOTES

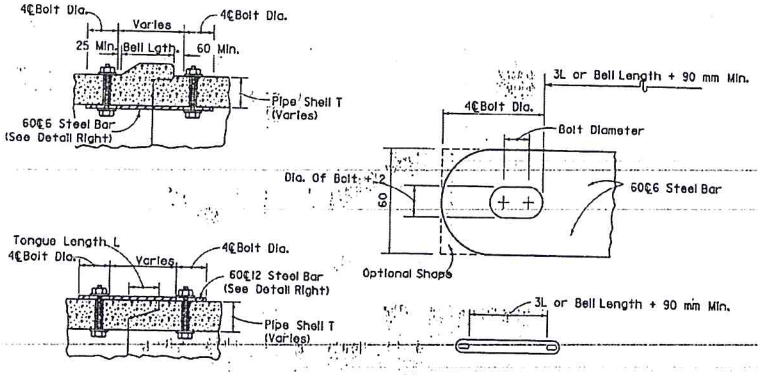
1. Mitered end sections for pipe sizes 375mm, 450mm and 600mm round or equivalent pipe arch or elliptical pipe are permitted within the clear zone. When the slope intersection permits, the mitered end section may be located with the culvert opening as close as 2.5 m beyond the outside edge of the shoulder.
2. Slope and ditch transitions shall be used when the normal roadway slope must be flattened to place end section outside clear zone. See detail left.
3. The reinforced concrete slab shall be constructed for all sizes of cross drain pipe and cast in place with Class ~ concrete. Slabs shall be 135 mm thick unless 75 mm thickness called for in plans.
4. Concrete pipe used in the assembly of mitered end sections shall be selective lengths to avoid excessive connuctions.
5. Corrugated metal pipe galvanizing that is damaged during beveling and perforating for mitered end section shall be repaired.
6. That portion of corrugated metal pipe in direct contact with the concrete slab shall be bituminous coated prior to placing of the concrete.
7. Unless otherwise designated in the plans, concrete pipe mitered end sections may be used with any type of cross drain pipe; corrugated steel pipe mitered end sections may be used with any type of cross drain pipe except aluminum pipe; and, corrugated aluminum mitered end sections mcy be used with any type of cross drain pipe except steel pipe. When bituminous coated metal pipe is specified for cross drain pipe, mitered end sections shall be constructed with like pipe or concrete pipe.
8. When the mitered end section pipe is dissimilar to the cross drain pipe, a concrete jacket shall be constructed in accordance with Standard Index 280.
9. When existing multiple cross drain pipes are spaced other than the dimensions shown in this detail, or have non-parallel axes, or have non-uniform sections, the mitered end sections will be constructed either separately as single pipe mitered end sections or collectively as multiple pipe or sections as directed by the Engineer; however, mitered end sections will be paid for each based on each independent pipe end.
10. The cost of all pipe(s), fastners, reinforcing, connectors, anchors, concrete, sealants, jackets, and coupling bands shall be included in the cost for the mitered end section. Sodding shall be paid for separately under the contract unit price of Sodding, M2.
11. Mitered end sections shall be paid for under the contract unit price for Mitered End Section (CD), EA, based on each independent pipe end. Mitered end sections used for detention/retention basin outlets are to be paid for under the contract unit price for Mitered End Section (BO), EA.



PLAN

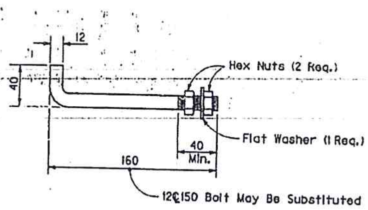
NOTE: See General Note 2

SLOPE AND DITCH TRANSITIONS



All bars, bolts, nuts and washers are to be galvanized steel.
Bolt diameters shall be 10 mm for 375 mm to 900 mm pipe and 15 mm for 1050 mm to 1800 mm pipe.
Three connectors required per joint, located 60° right and left of bottom center of pipe.
Bolt holes in pipe shell are to be drilled.

CONCRETE PIPE CONNECTOR



Anchors required for CMP only.

Anchor, washer and nuts to be galvanized steel.

Bend anchor where required to center in concrete slab. Damaged surfaces to be repaired after bending. Anchors are to be spaced a distance equal to four (4) corrugations. Place the anchors in the outside crest of corrugation.

Flat washers to be placed on inside wall of pipe.

Holes in the mitered end pipe are to be drilled or punched; burning not permitted.

ANCHOR DETAIL

KENTUCKY
DEPARTMENT OF HIGHWAYS

CROSS DRAIN MITERED END SECTION

SPECIAL DETAILS AND NOTES

	Name	Dates
Designed By	MDJ	05/98
Drawn By		
Checked By	ETG	05/98
F.H.W.A. Approved		

Approved By
State Drainage Engineer

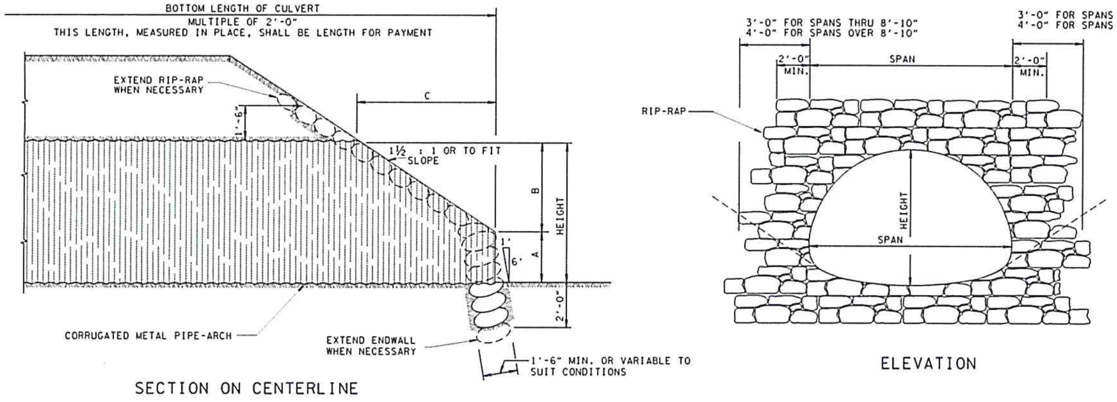
Revision No.	Sheet No.	Index No.
98	3 of 3	

EXAMPLE #7

REV. 7-1-72: CHANGED DEPARTMENT NAME.

☐ REV. 1-1-76: CHANGED DWG. NO. FROM CM-1-5(68) TO D-PE-8.

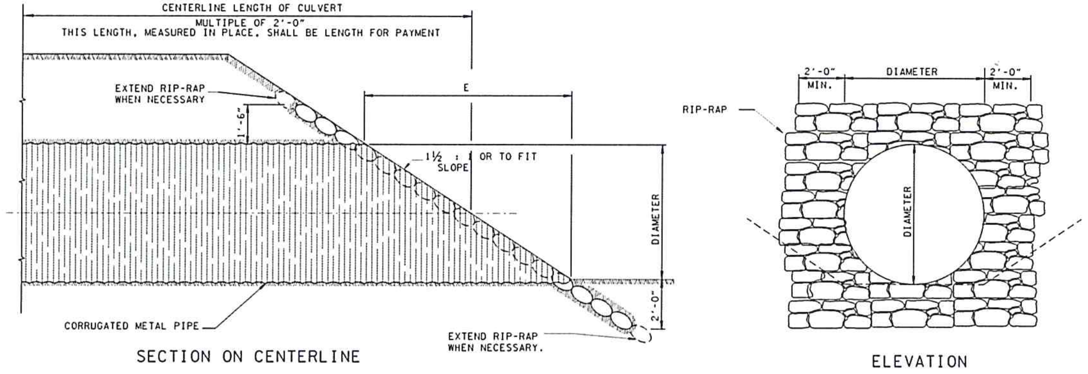
REV. 1-19-97: REDREW. REORGANIZED AND REDESIGNED SHEET ON CADD.



SECTION ON CENTERLINE

ELEVATION

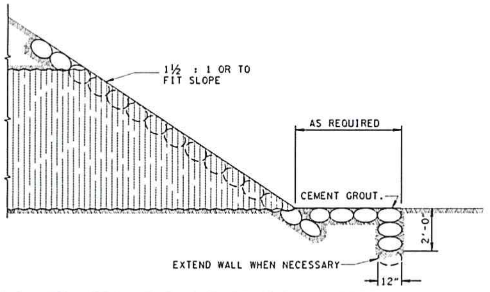
BEVELED END PIPE-ARCH



SECTION ON CENTERLINE

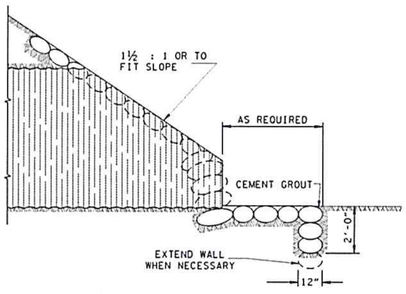
ELEVATION

BEVELED END PIPE



DETAIL OF APRON FOR OUTLET END OF PIPE

USE ONLY WHEN NECESSARY



DETAIL OF APRON FOR OUTLET END OF PIPE-ARCH

USE ONLY WHEN NECESSARY

PIPE - ARCH CULVERTS

SPAN	HEIGHT	RIP-RAP C.Y. (ONE END)		A	B	C
		ONE LINE	TWO LINES			
58"	36"	2.7	4.2	1'-0"	2'-0"	3'-0"
65"	40"	2.9	4.4	1'-0"	2'-4"	3'-6"
72'	44"	3.1	5.0	1'-0"	2'-8"	4'-0"
6'-1"	4'-7"	3.1	5.0	2'-3"	2'-4"	3'-6"
6'-4"	4'-9"	3.3	5.4	2'-1"	2'-8"	4'-0"
6'-9"	4'-11"	3.4	5.6	2'-5"	2'-6"	3'-9"
7'-0"	5'-1"	3.5	5.8	2'-3"	2'-10"	4'-3"
7'-3"	5'-3"	3.6	6.0	2'-1"	3'-2"	4'-9"
7'-8"	5'-5"	3.7	6.3	2'-4"	3'-1"	4'-7½"
7'-11"	5'-7"	3.9	6.7	2'-2"	3'-5"	5'-1½"
8'-2"	5'-9"	4.0	6.9	2'-0"	3'-9"	5'-7½"
8'-7"	5'-11"	4.1	7.1	2'-4"	3'-7"	5'-4½"
8'-10"	6'-1"	4.3	7.5	2'-2"	3'-11"	5'-10½"
9'-4"	6'-3"	4.9	8.3	2'-5"	3'-10"	5'-9"
9'-6"	6'-5"	5.0	8.5	2'-4"	4'-1"	6'-1½"
9'-9"	6'-7"	5.2	8.9	2'-2"	4'-5"	6'-7½"
10'-3"	6'-9"	5.3	9.2	2'-5"	4'-4"	6'-6"
10'-8"	6'-11"	5.4	9.4	2'-9"	4'-2"	6'-3"
10'-11"	7'-1"	5.6	9.9	2'-7"	4'-6"	6'-9"
11'-5"	7'-3"	5.7	10.1	2'-10"	4'-5"	6'-7½"
11'-7"	7'-5"	5.9	10.5	2'-8"	4'-9"	7'-1½"
11'-10"	7'-7"	6.1	11.0	2'-6"	5'-1"	7'-7½"
12'-4"	7'-9"	6.2	11.2	2'-10"	4'-11"	7'-4½"
12'-6"	7'-11"	6.3	11.4	2'-8"	5'-3"	7'-10½"
12'-8"	8'-1"	6.5	11.7	2'-6"	5'-7"	8'-4½"
12'-10"	8'-4"	6.7	12.1	2'-4"	6'-0"	9'-0"
13'-5"	8'-5"	6.9	12.5	2'-7"	5'-10"	8'-9"
13'-11"	8'-7"	7.0	12.7	2'-11"	5'-8"	8'-6"
14'-1"	8'-9"	7.1	12.8	2'-9"	6'-0"	9'-0"
14'-3"	8'-11"	7.3	13.2	2'-7"	6'-4"	9'-6"
14'-10"	9'-1"	7.5	13.6	2'-11"	6'-2"	9'-3"
15'-4"	9'-3"	7.6	13.8	3'-2"	6'-1"	9'-1½"
15'-6"	9'-5"	7.8	14.2	3'-0"	6'-5"	9'-7½"
15'-8"	9'-7"	7.9	14.3	2'-10"	6'-9"	10'-1½"
15'-10"	9'-10"	8.2	14.9	2'-8"	7'-2"	10'-9"
16'-5"	9'-11"	8.3	15.1	3'-0"	6'-11"	10'-4½"
16'-7"	10'-1"	8.5	15.5	2'-10"	7'-3"	10'-10½"

RIP-RAP QUANTITIES NOTE

QUANTITIES SHOWN ARE FOR ONE END AND ARE FOR ESTIMATING PURPOSES ONLY. PAYMENT TO BE MADE FOR QUANTITIES ACTUALLY PLACED AND COMPUTED FOR EACH INSTALLATION.

ROUND PIPE CULVERTS

PIPE SIZE	RIP-RAP(ONE END)C.Y.		E
	ONE LINE	TWO LINES	
42"	2.9	4.7	5'-3"
48"	3.2	5.4	6'-0"
54"	3.5	6.1	6'-9"
60"	3.8	6.7	7'-6"
66"	4.1	7.4	8'-3"
72"	4.5	8.4	9'-0"
78"	4.8	9.1	9'-9"
84"	5.1	9.8	10'-6"
90"	5.2	10.2	11'-3"
96"	5.5	11.0	12'-0"
102"	6.2	12.4	12'-8"
108"	6.6	13.2	13'-6"
114"	7.0	14.0	14'-3"
120"	7.4	14.8	15'-0"
126"	7.8	15.6	15'-9"
132"	8.2	16.4	16'-6"
138"	8.6	17.2	17'-3"
144"	9.0	18.0	18'-0"
150"	9.4	18.8	18'-9"
156"	9.9	19.8	19'-6"
162"	10.3	20.6	20'-3"
168"	10.8	21.6	21'-0"
174"	11.2	22.4	21'-9"
180"	11.7	23.4	22'-6"

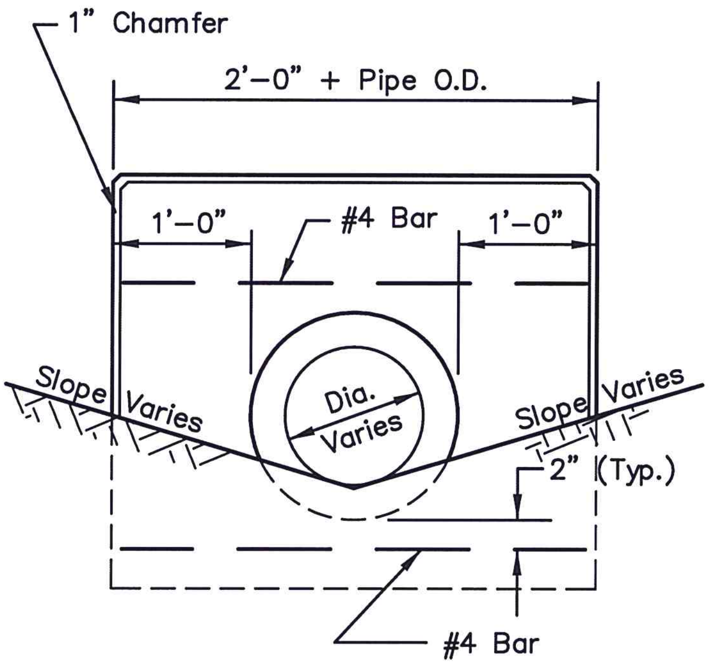
☐ MINOR REVISION -- FHWA APPROVAL NOT REQUIRED.

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

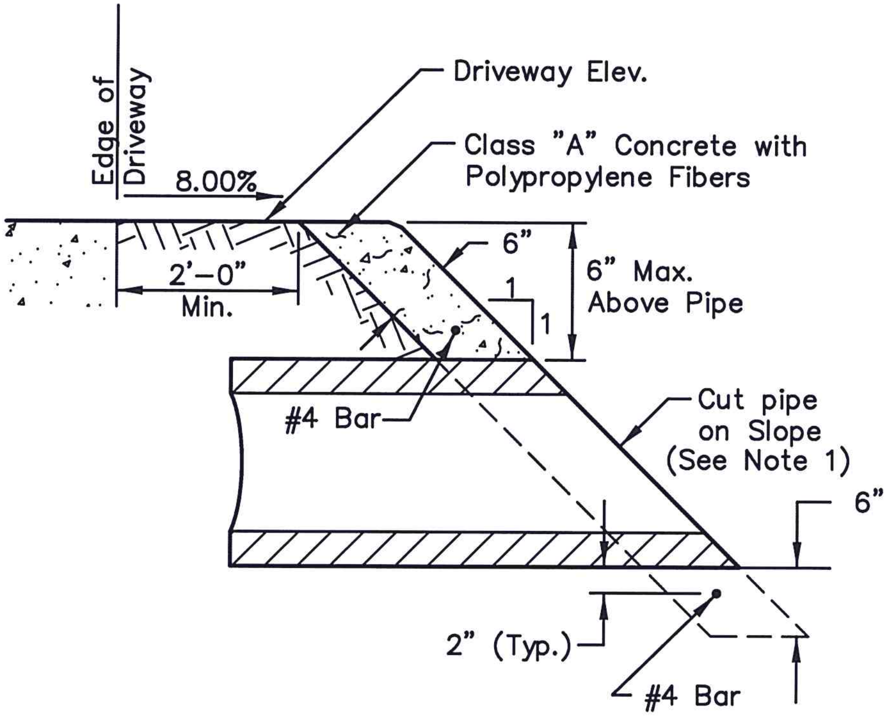
DETAIL OF
STANDARD PIPE
AND PIPE-ARCH
CULVERT WITH BEVELED
ENDS AND RIP-RAP

D-PE-8

EXAMPLE #8



ELEVATION



SECTION

NOTES:

1. Pipe shall be Trimmed Flush with End Treatment.
2. Concrete shall receive a light broom finish w/all exposed edges haveing a 1" Chamfer.
3. Do not elevate top of end treatment above edge of driveway.

MSD

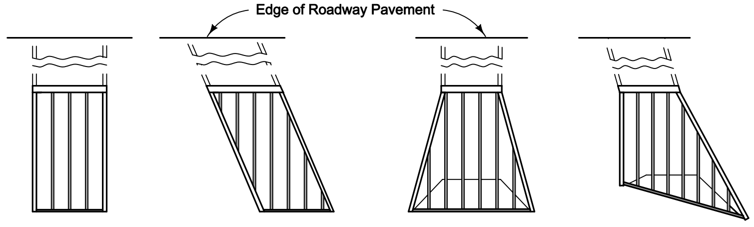
Louisville and Jefferson County
Metropolitan Sewer District
700 W. Liberty Street
Louisville, Kentucky 40203-1913
502–587–0603 – WWW.MSDLOUKY.ORG

END TREATMENT FOR
DRIVEWAY PIPE

STANDARD DRAWING NO. DE–03–01

APPROVED BY: DIRECTOR OF ENGINEERING 9/30/2009 DATE

DESIGNER INFO



Straight
Type 1 Culvert

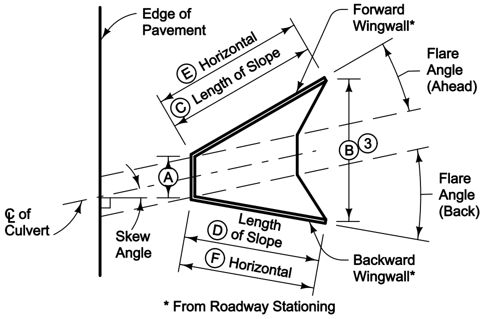
Skewed
Type 2 Culvert

Flared
Type 3 Culvert

Flared-Skewed
Type 4 Culvert

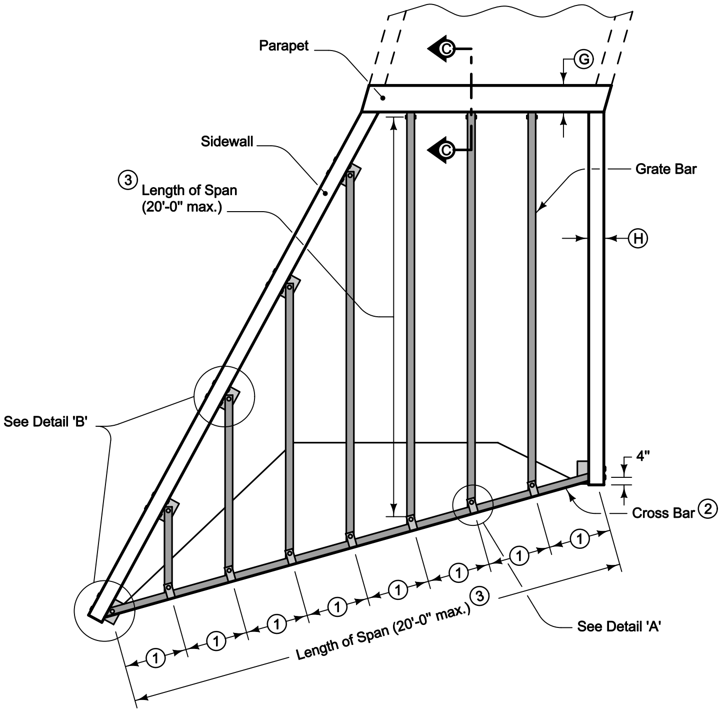
INSTALLATION TYPES

Grate bars to be perpendicular to direction of traffic flow.

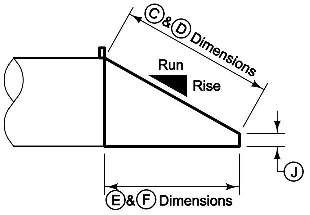


* From Roadway Stationing

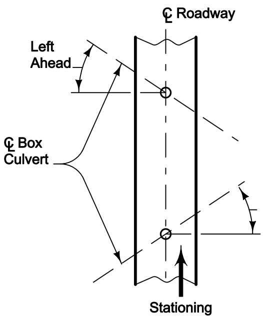
TOP VIEW



INSTALLATION PLAN



SIDE VIEW
DETAILS OF DIMENSIONS



SKEW ANGLE DETERMINATION

GRATE & CROSS BAR SIZE REQUIREMENTS		
Length of Span	Nominal Pipe Size ②	O.D. Size
less than 12'	3.0"	3.5"
12'-16'	3.5"	4.0"
greater than 16'	4.0"	4.5"

The dimensions shown in the "Tabulation of Safety Grate Treatment" are from the original construction plans. Verify these dimensions at the site before fabrication of the components. Shop drawings are required. The Contractor is responsible for using the correct pipe diameters, correct dimensions and proper fit of the safety grate into the headwall opening.

Install bolts and lock nuts complying with Article 4153.06 at all locations as shown. Use brackets that comply with ASTM A36 and are galvanized per ASTM A123.

Use steel washers meeting the dimensional requirements of Materials I.M. 453.07.

The Contractor may encounter reinforcing steel when drilling holes though the exising structure wall.

Furnish Schedule 40 Pipe meeting the requirements of Article 4153.05.

Galvanize all pipes, fittings and hardware after all cutting, welding, drilling and fabrication.

Gas Metal-Arc and Flux-Cored Arc welding may be used for welding incidental items as indicated on this sheet, provided that the fabricator furnishes certifications for the gas, uses approved filler metal and qualified welders approved by the Iowa DOT.

Price Bid for "Safety Grate, (Type 1,2,3, or 4), Culvert" is considered full compensation for furnishing all materials and work necessary to fabricate and install the grate system as required for each headwall opening.

① Equal spaces 24 inches minimum, 30 inches maximum, edge of sidewall to center of bracket or center to center of bracket.

② Cross Bar diameter equal to or greater than Grate Bar diameter.

③ If more than 20 feet, midspan support is required. Refer to sheets 3 and 4.

Iowa Department
of Transportation

REVISION	
New	04-20-10

STANDARD ROAD PLAN

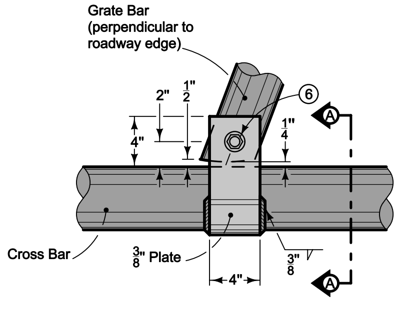
RF-29

SHEET 1 of 4

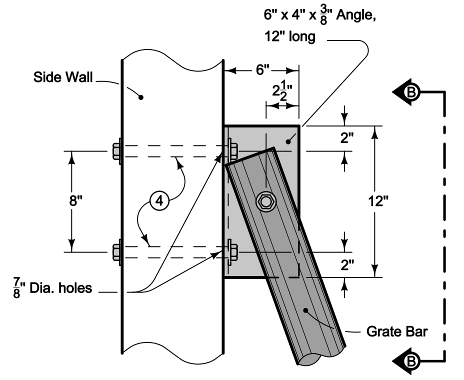
REVISIONS: New. Replaces 540-4A,B,C,D.

Deanna Maifield
APPROVED BY DESIGN METHODS ENGINEER

SAFETY GRATES
FOR BOX CULVERTS



DETAIL 'A'
TOP VIEW



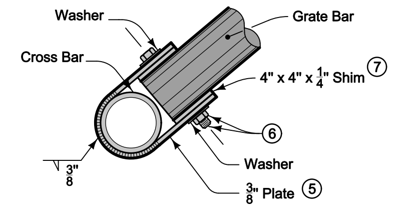
DETAIL 'B'
TOP VIEW

④ Holes are to be $\frac{7}{8}$ inch diameter made with equipment designed to cut through concrete and reinforcing steel.

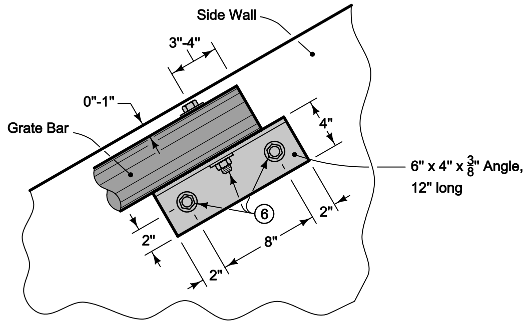
⑤ Bend plates or strips without cracking material.

⑥ $\frac{3}{4}$ inch bolt, lock nut and washers. All holes are to be $\frac{7}{8}$ inch diameter.

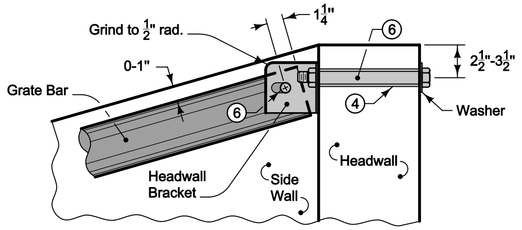
⑦ Shim thickness equal to difference in diameters of Grate Bar and Cross Bar.



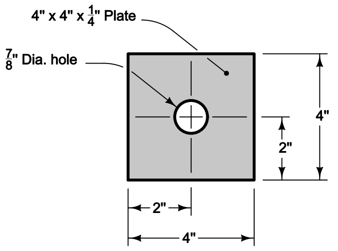
SECTION A-A



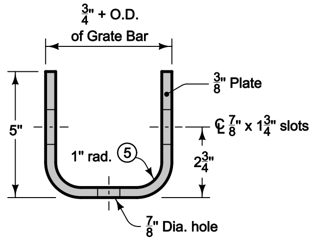
SECTION B-B



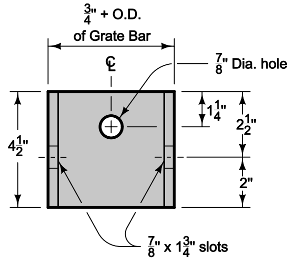
SECTION C-C



SHIM DETAIL



HEADWALL BRACKET
TOP VIEW



HEADWALL BRACKET
FRONT VIEW

Iowa Department
of Transportation

REVISION
New 04-20-10

STANDARD ROAD PLAN

RF-29

SHEET 2 of 4

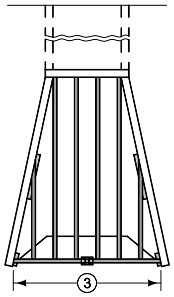
REVISIONS: New. Replaces 540-4A,B,C,D.

Deanna Maifeld
APPROVED BY DESIGN METHODS ENGINEER

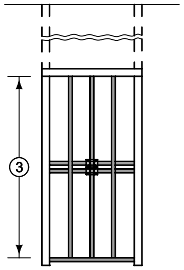
SAFETY GRATES
FOR BOX CULVERTS

③ If more than 20 feet, midspan support is required. Refer to sheets 3 and 4.

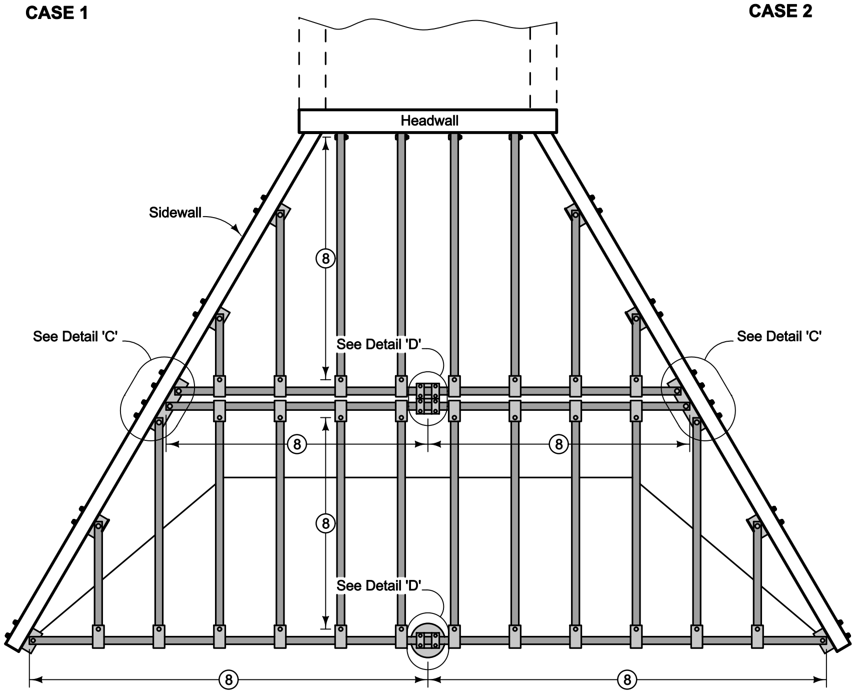
⑧ Length of span (20 feet maximum).



CASE 1



CASE 2



INSTALLATION PLAN WITH MIDSPAN SUPPORT

Iowa Department of Transportation

STANDARD ROAD PLAN

REVISION	
New	04-20-10

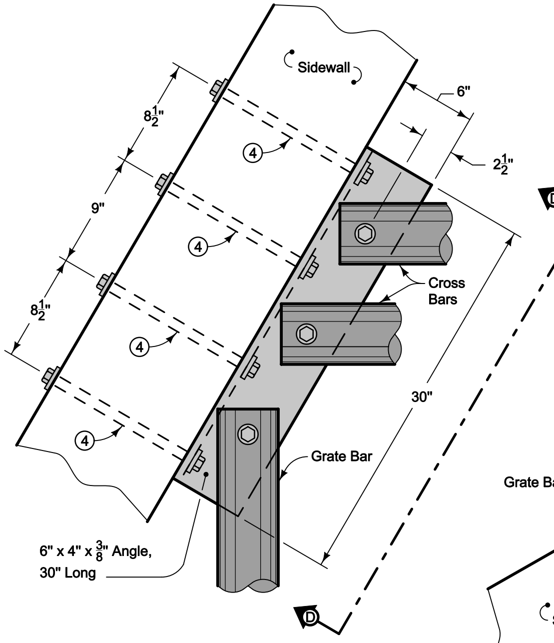
RF-29

SHEET 3 of 4

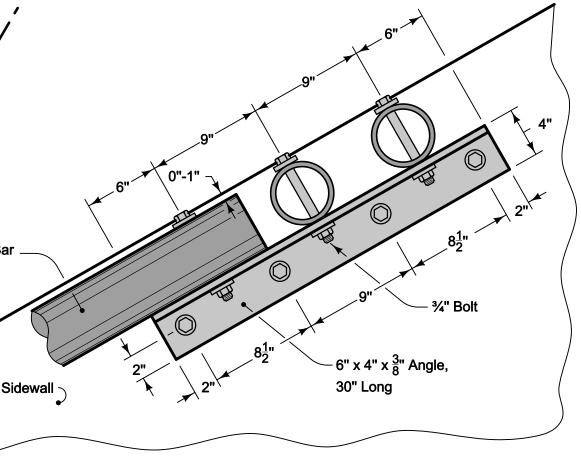
REVISIONS: New. Replaces 540-4A,B,C,D.

Deanna Maifield
APPROVED BY DESIGN METHODS ENGINEER

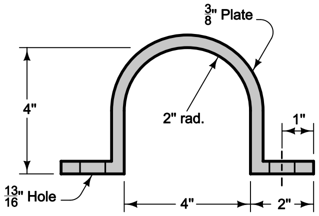
SAFETY GRATES
FOR BOX CULVERTS



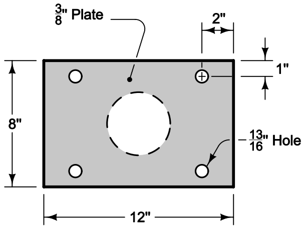
DETAIL 'C'



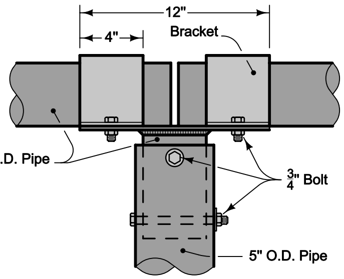
SECTION D-D



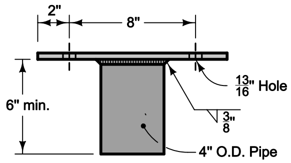
BRACKET END VIEW



TOP VIEW

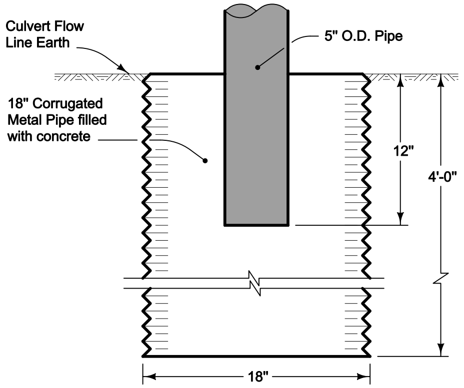


CROSS BAR SUPPORT ASSEMBLY SIDE VIEW

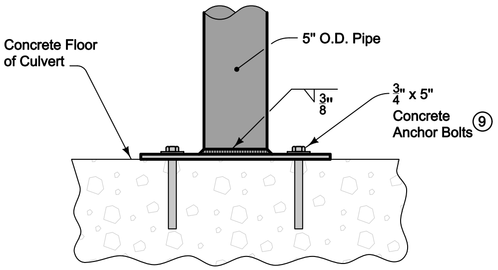


SIDE VIEW SUPPORT PLATE

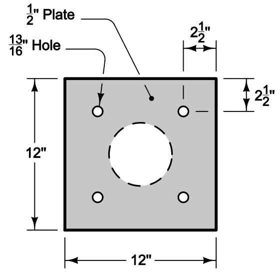
DETAIL 'D'



BOTTOM SUPPORT ON EARTH



BOTTOM SUPPORT ON CULVERT FLOOR



BOTTOM SUPPORT PLATE TOP VIEW

④ Holes are to be ⅞ inch diameter made with equipment designed to cut through concrete and reinforcing steel.

⑨ Set approved anchor bolts using epoxy grout as described in the Materials I.M. 453.08 for anchor bolts.

Iowa Department of Transportation

REVISION	
New	04-20-10

STANDARD ROAD PLAN

RF-29

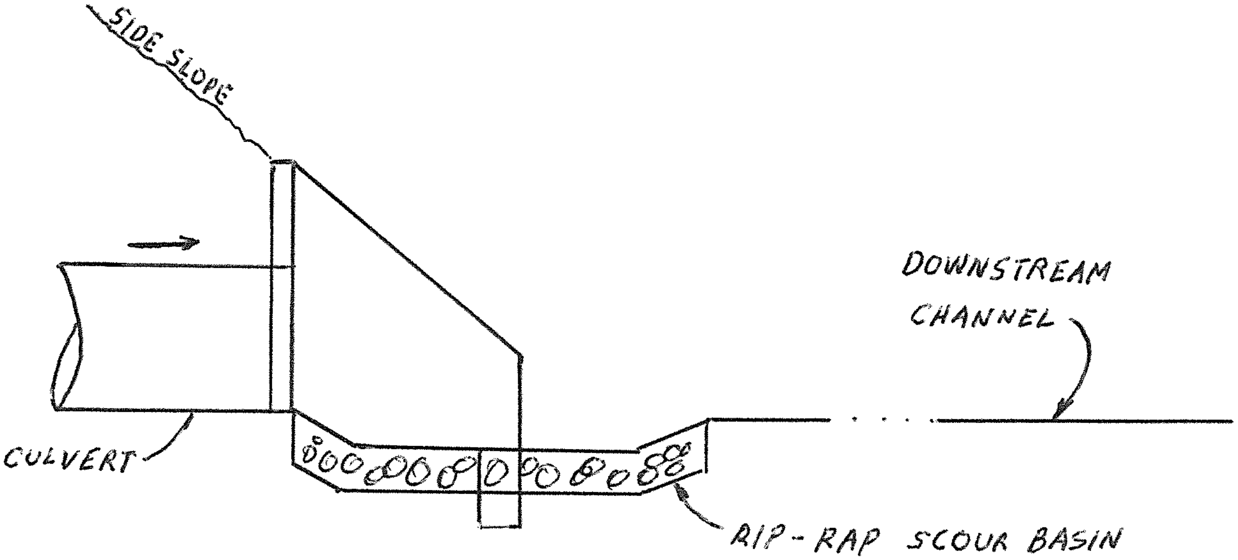
SHEET 4 of 4

REVISIONS: New. Replaces 540-4A,B,C,D.

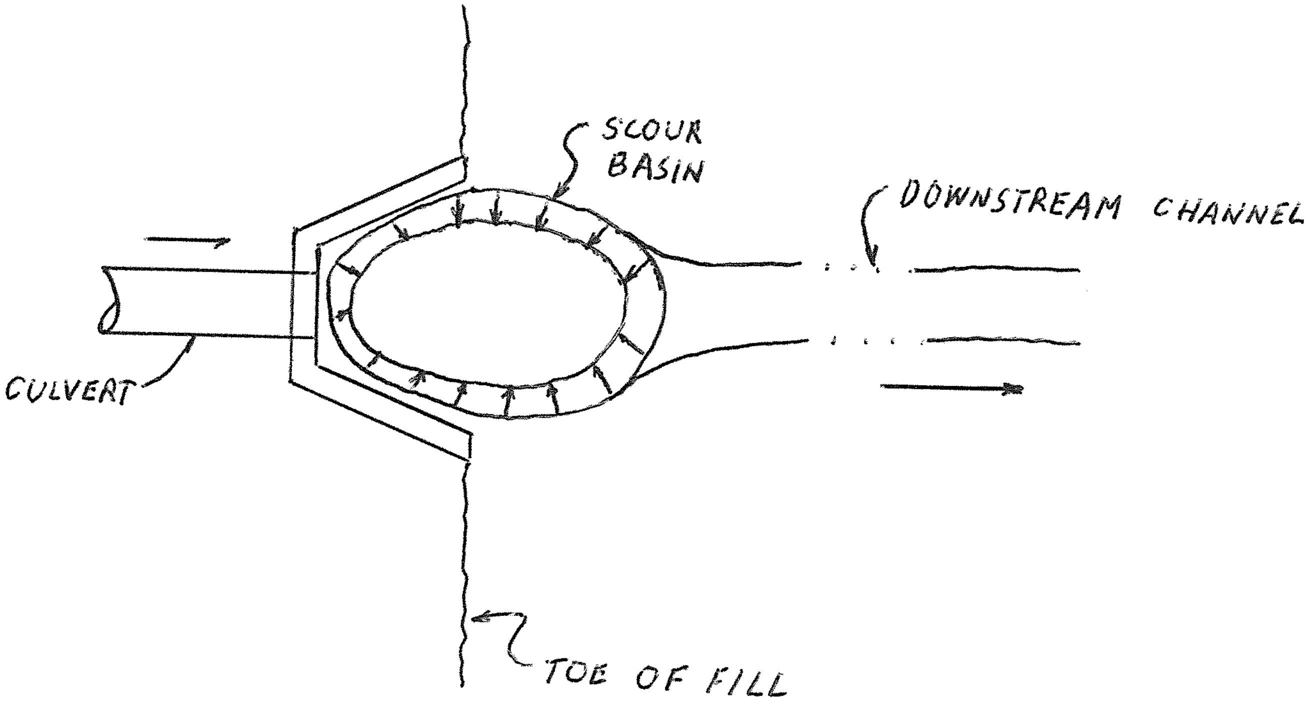
Deanna Maifield
APPROVED BY DESIGN METHODS ENGINEER

SAFETY GRATES FOR BOX CULVERTS

SCOUR BASIN @ PIPE OUTLET (NO PAVED INVERT)



PROFILE VIEW



PLAN VIEW

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Redesign to the current design criteria

	IDEA NUMBER	PAGE NO.
	6	1 of 2

ORIGINAL CONCEPT:

The existing headwall supplement does not refer to design criteria, materials strength, foundation requirements, or backfill constraints. The information available in the supplement, while sparse, appears to refer to technology and materials 40+ years old and is not consistent with current practice.

ALTERNATIVE CONCEPT:

Redesign the headwalls and wing walls to current AASHTO design criteria considering the availability of higher strength concrete and steel reinforcement. Include reasonable assumptions for soil strength, foundation limitations and backfill loading on the drawings.

ADVANTAGES:

- Optimizes structural components
- Provides structural component reliability
- Provides a basis for alternate structures
- Allows for integration with performance specifications
- Brings structural components up to date per current design code
- Saves material costs compared to the existing supplement

DISADVANTAGES:

- Implementation effort

IMPLEMENTATION CONSIDERATIONS:

Redesign will be based on design criteria prescribed from the KYTC. Recommend using AASHTO LRFD Bridge Design Specifications current edition since KYTC uses this for all other transportation structures. Utilize 3500 psi concrete or greater and 60 grade reinforcing steel in the design. Assume 2,000 lbs/sf allowable soil pressure, 2’ live load surcharge, and 45 lbs/cf backfill load (current KYTC practice).

Performance Criteria	**ST**	**C**	**M**	**S**	**H**	**F**	**D**
Performance Measure	**+1**	**+1**	**+1**	**+1**	**0**	**+1**	**0**
Structural	The current wingwalls may be under designed and prone to separation from the headwall						
Constructability	Existing detailed counterfort can be removed from the details in the supplement						
Maintainability	Elements can be included that consider debris mitigation						
Safety	Wingwall and headwalls can be designed to accommodate safety grates						
Hydraulics							
Flexibility	A new design can separate the headwall from the wing wall details						
Durability							

DISCUSSION:

Design Criteria
The design criteria used for a redesign will be the baseline criteria for other products and design performance specifications. All design assumptions, methodology and design specifications need to be recorded in the proposed standards/supplement in general note format. This should be a lead in statement which describes what is in the preceding sheets to aid the reader in understanding where the information came from and the assumptions made in the designs and details.

Reinforcing Steel
The current supplement and KYTC construction specifications refer to 40 and 50 grade reinforcing steel to be used in the construction of the headwalls. 60 grade reinforcement is the available material today and the 40 and 50 grade steel is either unavailable or an extra cost to obtain.

Concrete Design
The concrete identified in the KYTC construction specifications for headwalls is 3,500 psi Class “A” Concrete. The supplement is unclear as to the concrete strength assumed for the original design of the standard drawings. Without stated design criteria in the supplement the user cannot make comparisons between viable alternatives such as precast units or components.

Rebar Clearances
The redesign also allows for consistency in detailing practices such as rebar clearance for casting against soil for the bottom of the footing verses the vertical walls. Allowances can also be made for precast concrete rebar clearances. Some of the current supplement sheets are vague as to the required rebar clearances.

Backfill Pressure
It has been identified that some of the wingwalls on larger structures have pulled away and even tipped over, which means that the backfill pressures have not correctly been designed and need to be added to the design criteria.

Design Example
A sample calculation for the wingwall for an 84” pipe headwall (RDH-120-02 thru RDH-382-04) assuming 3,500psi concrete strength and 60ksi steel strength, an equivalent soil fluid pressure of 45#/cf and a 2’ live load surcharge demonstrated that the wall thickness could be reduced from 10” to 8” with no change in rebar size or spacing. Current AASHTO LFRD design criteria were used for the calculations.

Rating Scale: Value Add +2 +1 0 -1 -2 Value Decrease

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Design and detail headwalls and wingwalls separately

	IDEA NUMBER	PAGE NO.
	7	1 of 7

ORIGINAL CONCEPT:

The current Headwall Supplement details both the headwall and wingwall for a given pipe as a single unit.

ALTERNATIVE CONCEPT:

Design and detail a headwall for a particular application with the necessary call out information to match separately designed/detailed wingwalls.

ADVANTAGES:

- Reduces the number of detail sheets in the supplement or standard drawings
- Enhances options for wingwall styles and material
- Reduces future effort to change headwall standards since the wingwalls are on a separate detail sheet
- Allows for varied pipe headwall applications such as multiple pipes or types of pipe without impacting the wing details

DISADVANTAGES:

- Implementation effort
- Transition training for new methodology

IMPLEMENTATION CONSIDERATIONS:

The effort to re-detail the supplement may be a challenge.

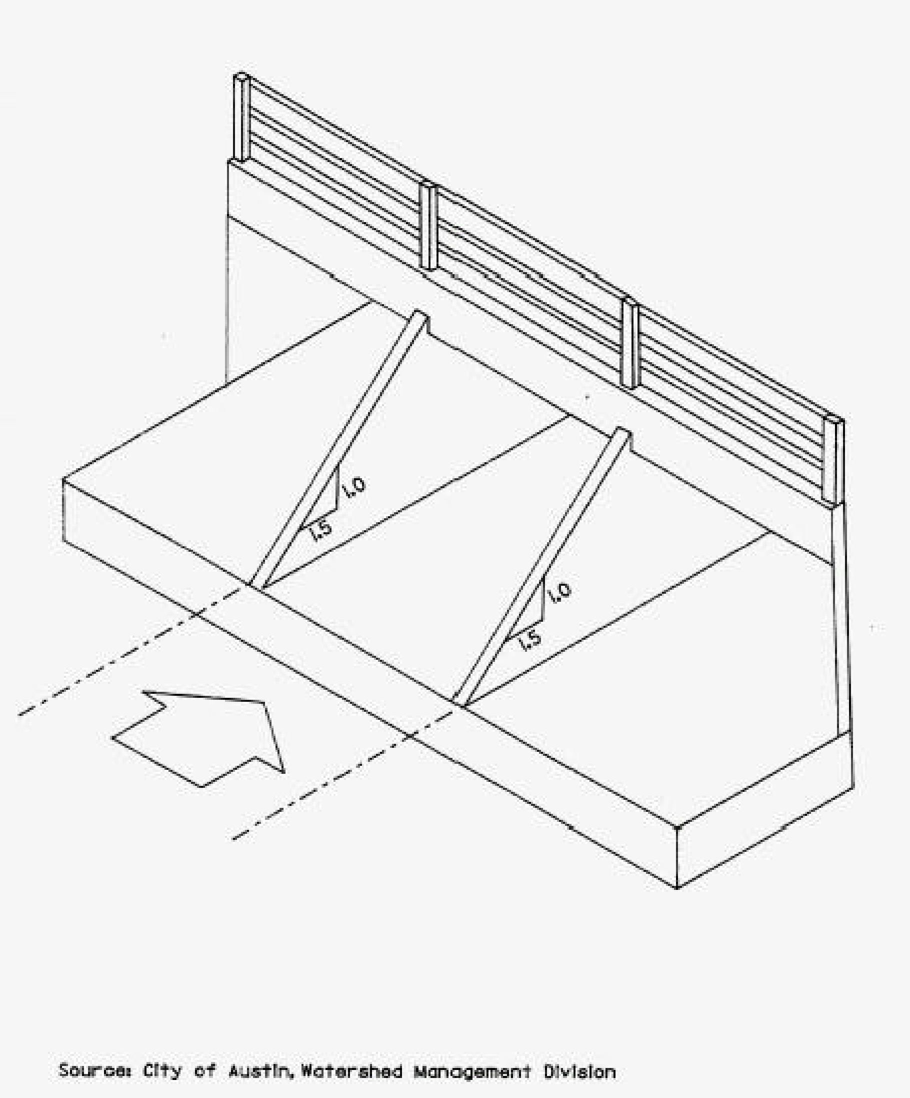
Performance Criteria	**ST**	**C**	**M**	**S**	**H**	**F**	**D**
Performance Measure	**+1**	**+1**	**0**	**0**	**0**	**+1**	**0**
Structural	Enhances design to match field conditions by using appropriate walls						
Constructability	Poor wall details in the current supplement such as counterforts can be removed						
Maintainability							
Safety							
Hydraulics							
Flexibility	Separate wall details and options provides a natural bidding transition for various prefabrication options along with CIP						
Durability							

Rating Scale: Value Add +2 +1 0 -1 -2 Value Decrease

TITLE: Design and detail headwalls and wingwalls separately

DISCUSSION:

The current KYTC Headwall Supplement details wingwalls with various skews for each pipe application. Utilizing a separate detail sheet for the wingwall from the headwalls will allow the design engineer options in the plan preparation for drainage projects. A headwall can be designed and detailed for the necessary pipe applications such as multiple, elliptical, circular, or box culvert style then choose the appropriate wingwall details for the given height. The proposed supplement/standard drawing will have a set of wingwalls detailed separately and independently from the headwall details. Along with reducing the number of detail sheets in the supplement, various options for wingwalls can be specified such as precast, modular, tie-back or MSE. The headwall details can easily be designed to include safety features such as grates and debris mitigation features such as "nosing". "Nosing" is the use of sloping walls between multiple pipes to prevent debris from lodging at the pipe entrance.



Source: City of Austin, Watershed Management Division

Debris Mitigation "nosing" detail to be used with multiple pipe headwall

Additional Supporting Documentation Includes:

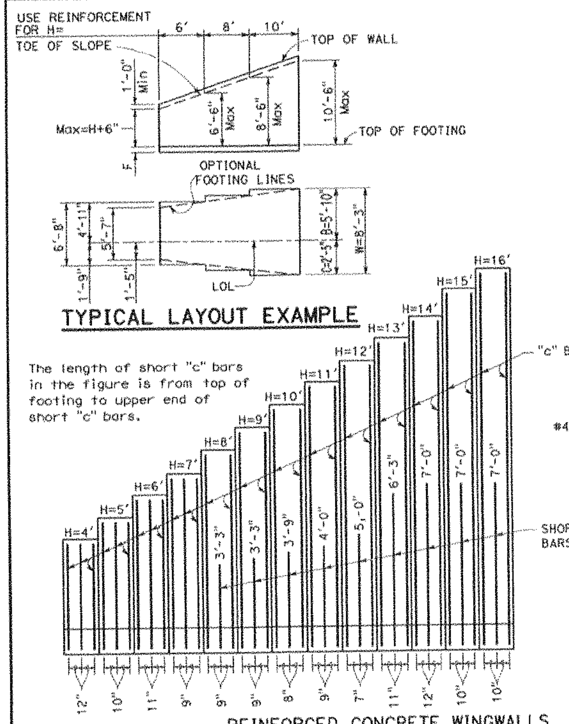
1) Caltrans Sample Detail Standards

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS

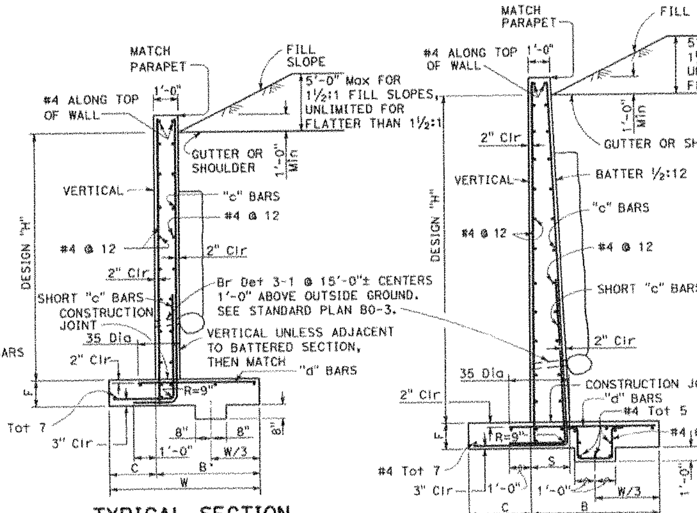
Dallas J. Forester
REGISTERED CIVIL ENGINEER

May 20, 2011
PLANS APPROVAL DATE

Dallas Forester
No. C37765
Exp. 12-31-12
CIVIL

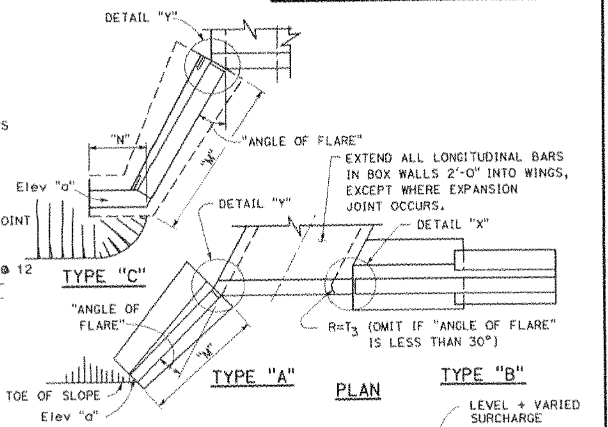


REINFORCED CONCRETE WINGWALLS

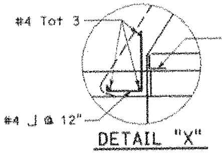


TYPICAL SECTION
H=4' THRU 12'

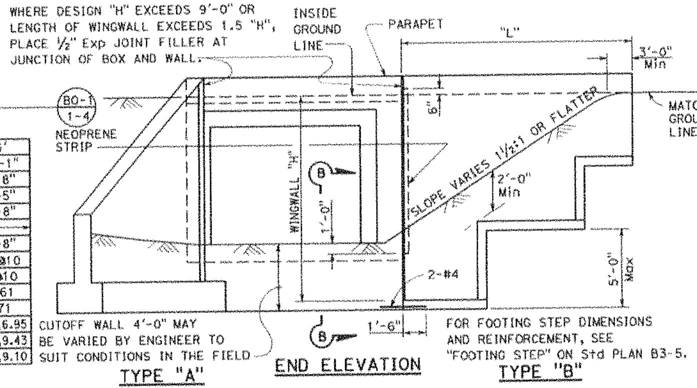
TYPICAL SECTION
H=13' THRU 16'



PLAN



DETAIL "X"

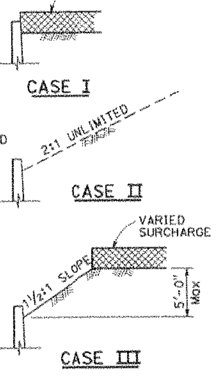


TYPE "A"

END ELEVATION

TYPE "B"

STRAIGHT WINGWALLS



CASE I

CASE II

CASE III

DETAIL OF DESIGN
LOADING CASES

"H"	4'	5'	6'	7'	8'	9'	10'	11'	12'	13'	14'	15'	16'
W	5'-7"	6'-2"	6'-8"	7'-1"	7'-6"	7'-10"	8'-3"	8'-8"	9'-2"	9'-7"	10'-2"	10'-6"	11'-1"
C	1'-5"	1'-7"	1'-9"	1'-11"	2'-1"	2'-3"	2'-5"	2'-8"	2'-10"	3'-1"	3'-4"	3'-6"	3'-8"
B	4'-2"	4'-7"	4'-11"	5'-2"	5'-5"	5'-7"	5'-10"	6'-0"	6'-4"	6'-6"	6'-10"	7'-0"	7'-5"
F	1'-2"	1'-2"	1'-2"	1'-2"	1'-2"	1'-2"	1'-2"	1'-3"	1'-5"	1'-5"	1'-6"	1'-6"	1'-8"
BATTER	None									½:12			
S	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-6½"	1'-7"	1'-7½"	1'-8"
"c" BARS	#4@12	#4@10	#5@11	#5@9	#6@9	#7@9	#7@8	#8@9	#7@7	#8@11	#9@12	#10@10	#10@10
"d" BARS	#5@12	#5@10	#6@11	#6@9	#6@9	#6@9	#6@8	#7@9	#6@7	#7@11	#8@12	#8@10	#9@10
* Conc CY/LF	0.46	0.52	0.58	0.64	0.69	0.74	0.80	0.88	1.00	1.25	1.37	1.45	1.61
* Reinf LB/LF	26	32	41	50	59	70	81	95	102	99	120	156	171
** CASE I qu (ksf), B' (ft)	3.75,2.24	3.66,2.69	3.59,3.11	3.56,3.49	3.52,3.89	3.52,4.21	3.69,4.46	3.77,4.77	3.89,5.17	3.92,5.61	3.92,6.18	4.04,6.40	4.13,6.95
** CASE II qu (ksf), B' (ft)	1.16,5.58	1.33,6.13	1.51,6.55	1.69,6.86	1.88,7.16	2.08,7.33	2.29,7.60	2.50,7.86	2.77,8.14	2.97,8.47	3.18,8.93	3.41,9.05	3.70,9.43
** CASE III qu (ksf), B' (ft)	1.26,5.46	1.36,5.97	1.49,6.37	1.64,6.66	1.79,6.93	1.95,7.08	2.11,7.33	2.28,7.55	2.50,7.84	2.66,8.12	2.81,8.59	3.00,8.69	3.22,9.10

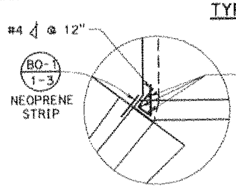
B'=B-(2) eccentricity, B' is the effective footing width.

* Quantities include 1'-0" extension above the design "H" limit.

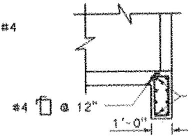
** Soil bearing pressure shown in the table is the equivalent uniform pressure per AASHTO LRFD - 11.6.3.2

NOTES:

Unit Stresses: f'c=3,600 psi, fy=60,000 psi
Earth density: 120 pcf
Equivalent fluid pressure: 36 pcf
Elevations, length and angle of flare of wings may be varied by the Engineer to suit conditions encountered in the field.
Dimensions "H","L","M","N", Elevation "a" and "Angle of flare" (as apply) are shown on the plans.
Wall height may be exceeded by 6" before going to next greater "H".
Eliminate cutoff wall if adjacent channel is paved and skew is 20° maximum.
For wall offset values, see Standard Plan B3-5.



DETAIL "Y"



SECTION B-B

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

BOX CULVERT WINGWALLS
TYPES A, B AND C

NO SCALE

D84

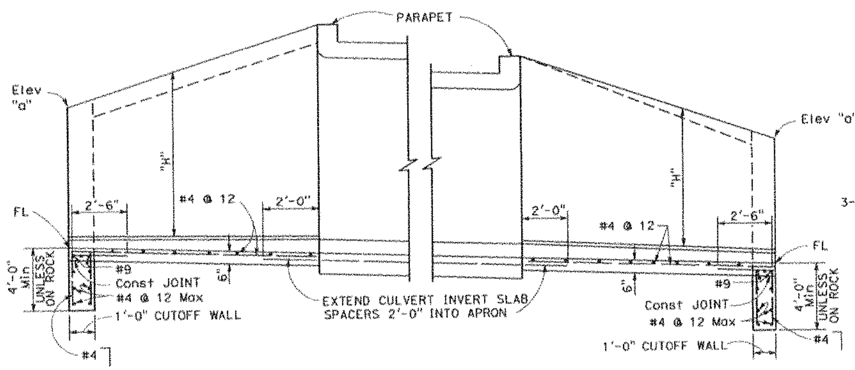
Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS

Dallas J. Forester
REGISTERED CIVIL ENGINEER

May 20, 2011
PLANS APPROVAL DATE

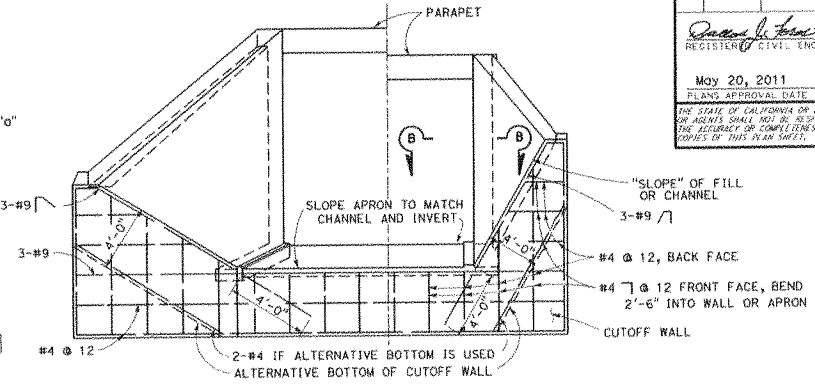
Dallas Forester
No. C37765
Exp. 12-31-12
CIVIL

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

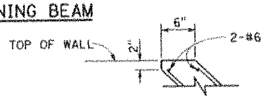


TYPICAL WITH STIFFENING BEAM TYPICAL WITHOUT STIFFENING BEAM

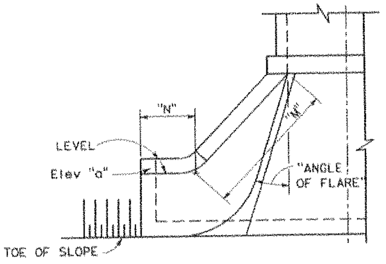
PART LONGITUDAL SECTION



END ELEVATION

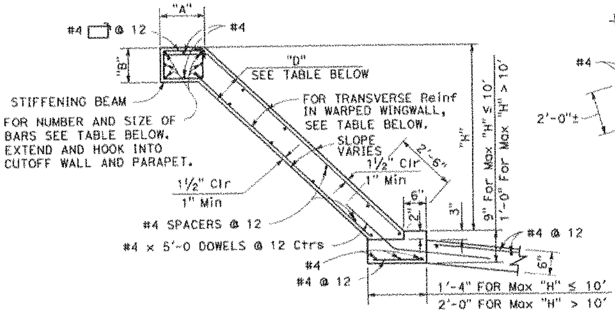


WITHOUT STIFFENING BEAM

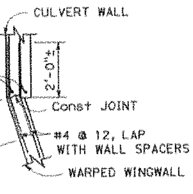


ALTERNATIVE WARPED WINGWALL

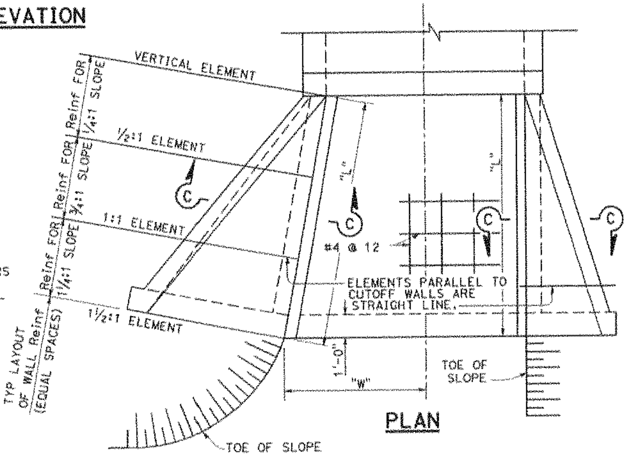
Use where additional protection to toe of embankment is required.



SECTION C-C



SECTION B-B



PLAN

WARPED WINGWALLS

WALL DIMENSIONS AND REINFORCING

ELEMENT SLOPE	"H"	8' OR LESS	10'	12'	14'	16'	18'	20'
¼:1	FRONT FACE Reinf	#4 @ 12	#4 @ 7	#5 @ 7	#5 @ 5	#6 @ 6	#7 @ 7	#7 @ 6
	REAR FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12
¾:1	Front face Reinf	#4 @ 12	#4 @ 12	#4 @ 8	#4 @ 8	#4 @ 8	#4 @ 6	#4 @ 6
	Rear face Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 10	#4 @ 7	#4 @ 6	#5 @ 8
1¼:1	FRONT FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12
	REAR FACE Reinf	#4 @ 8	#4 @ 8	#4 @ 5	#5 @ 6	#6 @ 7	#6 @ 6	#7 @ 6
"D" AT CUTOFF WALL		6"	6"	6"	7½"	8"	9½"	11"
"D" AT CULVERT		6"	6"	6"	8"	9½"	11"	1'-1"

STIFFENING BEAM DIMENSIONS AND REINFORCING

"H" Max \ "L" Max	12'	14'	16'	18'	20'	25'	30'	35'	40'
6'	NO BEAM, PLACE 2-#6 IN EACH FACE ALONG TOP OF WALL.								
8'				"A"= 1'-0"					
10'			"B"= 9"			"A"= 1'-6"			
12'								"A"= 1'-10"	
14'	TOTAL 6-#6				"B"= 1'-0"		"B"= 1'-3"		"A"= 2'-2"
16'									"B"= 1'-6"
18'			TOTAL 6-#7			TOTAL 8-#8			
20'								TOTAL 8-#9	

NOTES: Walls designed for 2'-0" surcharge; earth density = 120 pcf; equivalent fluid pressure = 36 pcf.
Vary "D" of warped wall uniformly from that at cutoff wall to that at culvert, for maximum "H" > 12'-0".
Where abrasion is anticipated increase apron thickness to 7" minimum to provide 2" minimum reinforcement coverage.
Dimensions "L", "W", "H", "M", "N", Elevation "a", " Angle of flare", and end "Slope" (as apply) are shown on the plans.

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

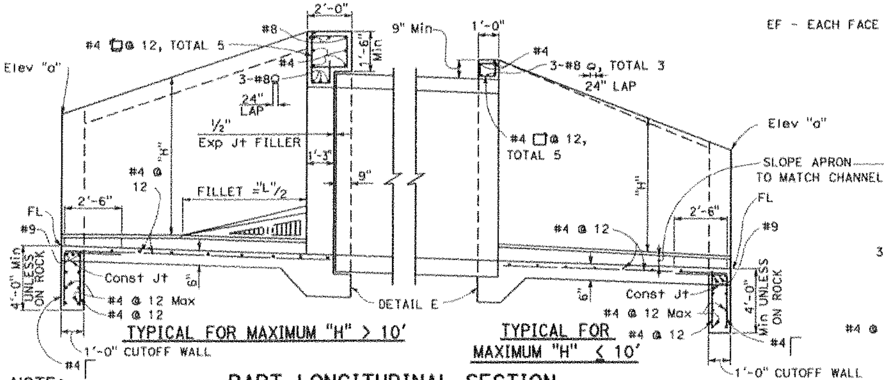
BOX CULVERT
WARPED WINGWALLS

NO SCALE

D86A

8-15-10

EF - EACH FACE



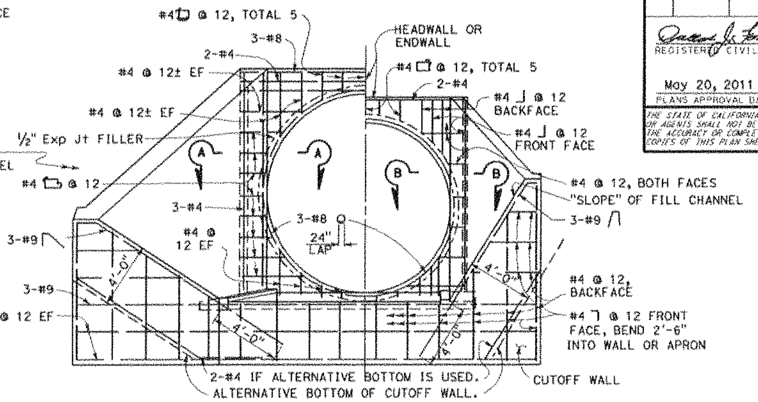
TYPICAL FOR MAXIMUM "H" > 10'

TYPICAL FOR MAXIMUM "H" ≤ 10'

PART LONGITUDINAL SECTION

NOTE:

RCP shown. Metal pipe similar except eliminate the expansion joint and use hook bolts @ 1'-7" ± spacing. Size and length provided by manufacturer.



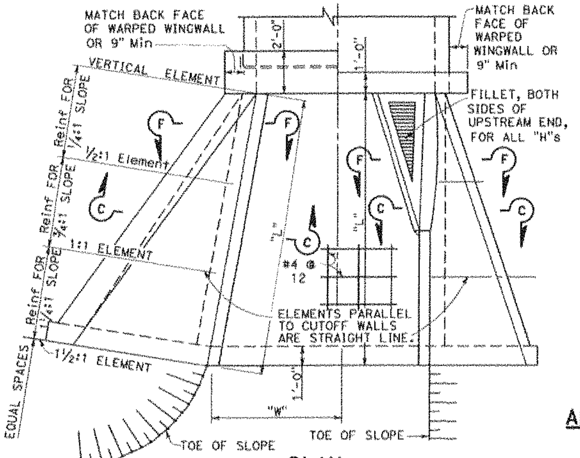
TYPICAL FOR MAXIMUM "H" > 10'

TYPICAL FOR MAXIMUM "H" ≤ 10'

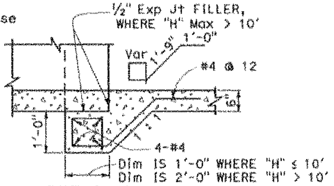
WITHOUT STIFFENING BEAM

END ELEVATION

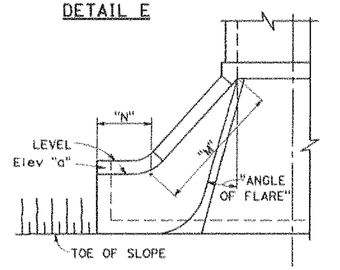
If at upstream end, fillet is not shown.



PLAN

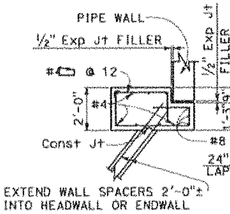


DETAIL E

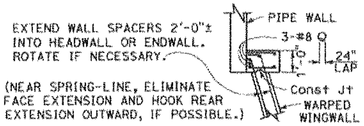


ALTERNATIVE WARPED WINGWALL

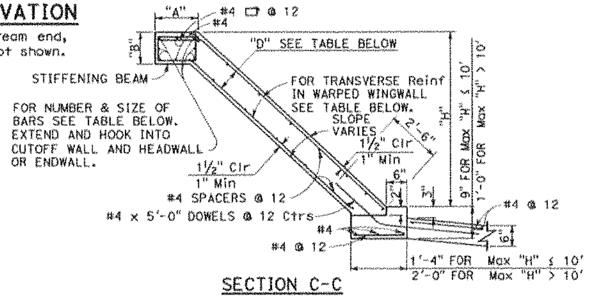
Use where additional protection to toe of embankment is required. If at upstream end, fillet is not shown.



SECTION A-A

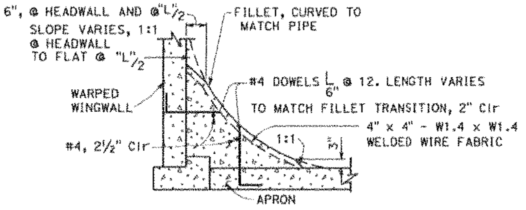


SECTION B-B



SECTION C-C

Where abrasion is anticipated, increase apron thickness to 7" minimum to provide 2" minimum reinforcement coverage.



SECTION F-F

WARPED WINGWALLS

WALL DIMENSIONS AND REINFORCING

ELEMENT SLOPE	"H"	8' OR LESS	10'	12'	14'	16'	18'	20'
¼:1	FRONT FACE Reinf	#4 @ 12	#4 @ 7	#5 @ 7	#5 @ 5	#6 @ 6	#7 @ 7	#7 @ 6
	REAR FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12
¾:1	FRONT FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 8	#4 @ 8	#4 @ 8	#4 @ 6	#4 @ 6
	REAR FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 10	#4 @ 7	#4 @ 6	#5 @ 8
1¼:1	FRONT FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12
	REAR FACE Reinf	#4 @ 8	#4 @ 8	#4 @ 5	#5 @ 6	#6 @ 7	#6 @ 6	#7 @ 6
"D" AT CUTOFF WALL		6"	6"	6"	7½"	8"	9½"	11"
"D" AT CULVERT		6"	6"	6"	8"	9½"	11"	1'-1"

STIFFENING BEAM DIMENSIONS AND REINFORCING

"H" Max \ "L"	12'	14'	16'	18'	20'	25'	30'	35'	40'
6'	NO BEAM. PLACE 2-#6 IN EACH FACE ALONG TOP OF WALL.								
8'				"A"= 1'-0"					
10'			"B"= 9"			"A"= 1'-6"			
12'								"A"= 1'-10"	
14'	TOTAL 6-#6			"B"= 1'-0"			"B"= 1'-3"		
16'									"A"= 2'-2"
18'			TOTAL 6-#7			TOTAL 8-#8			"B"= 1'-6"
20'								TOTAL 8-#9	

NOTES: Walls designed for 2'-0" surcharge; earth density = 120 pcf; equivalent fluid pressure = 36 pcf.
Vary "D" of warped wall uniformly from that at cutoff wall to that at headwall or endwall, for maximum "H" > 12'-0".
Dimensions "L", "W", "H", "M", "N", Elevation "a"," Angle of flare", and end "Slope" (as apply) are shown on the plans.

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

REGISTERED CIVIL ENGINEER

May 20, 2011
PLANS APPROVAL DATE

Dallas Forester
No. C37765
Exp. 12-31-12
CIVIL

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

2010 STANDARD PLAN D86B

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

PIPE CULVERT
HEADWALLS, ENDWALLS AND WARPED WINGWALLS

NO SCALE

D86B

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

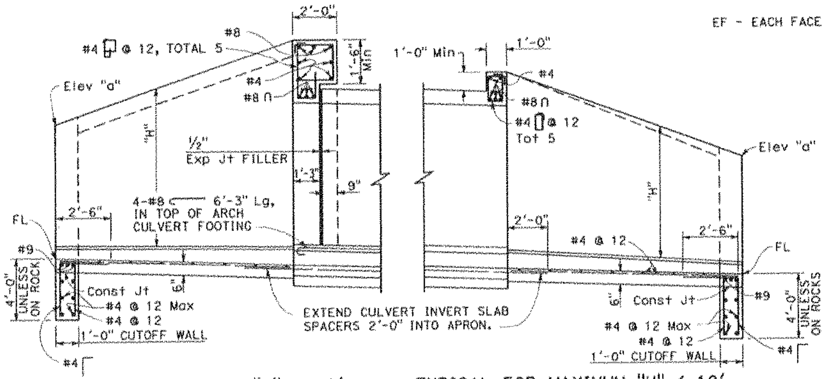
REGISTERED CIVIL ENGINEER

May 20, 2011
PLANS APPROVAL DATE

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

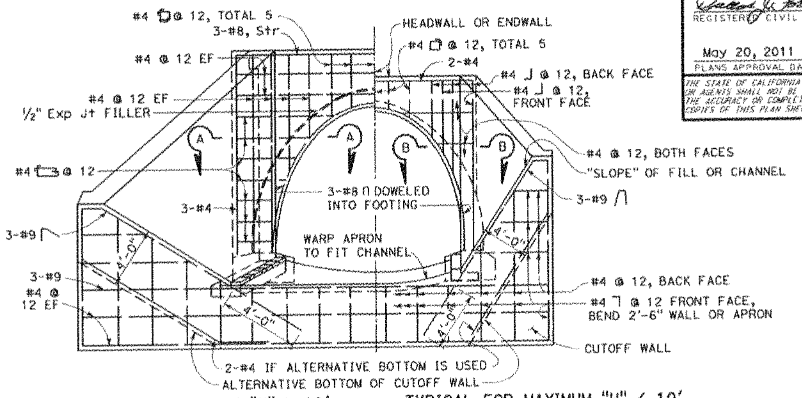
Dallas Forester
No. C37765
Exp. 12-31-12
CIVIL

EF - EACH FACE



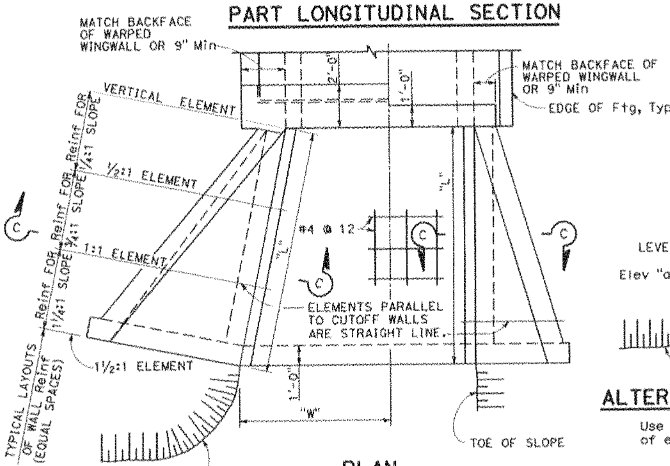
TYPICAL FOR MAXIMUM "H" > 10'   TYPICAL FOR MAXIMUM "H" ≤ 10'

PART LONGITUDINAL SECTION

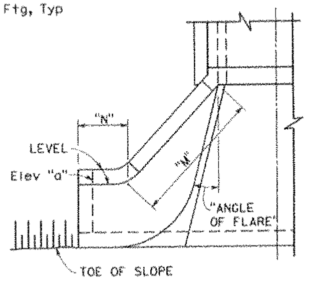


TYPICAL FOR MAXIMUM "H" > 10'   TYPICAL FOR MAXIMUM "H" ≤ 10'

END ELEVATION

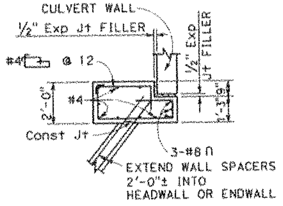


PLAN

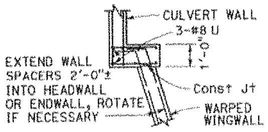


ALTERNATIVE WARPED WINGWALL

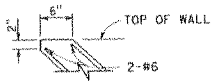
Use where additional protection to toe of embankment is required.



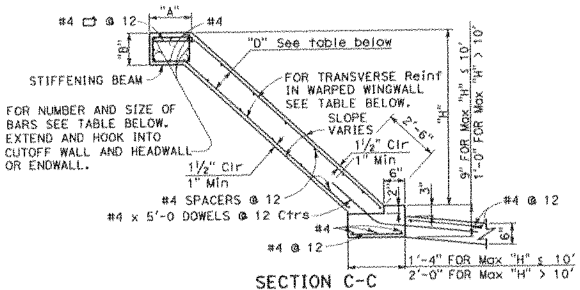
SECTION A-A



SECTION B-B



WITHOUT STIFFENING BEAM



SECTION C-C

Where abrasion is anticipated, increase apron thickness to 7" minimum to provide 2" minimum reinforcement coverage.

WARPED WINGWALLS

WALL DIMENSIONS AND REINFORCING

ELEMENT SLOPE	"H"	8' OR LESS	10'	12'	14'	16'	18'	20'
¼:1	FRONT FACE Reinf	#4 @ 12	#4 @ 7	#5 @ 7	#5 @ 5	#6 @ 6	#7 @ 7	#7 @ 6
	REAR FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12
¾:1	FRONT FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 8	#4 @ 8	#4 @ 8	#4 @ 6	#4 @ 6
	REAR FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 10	#4 @ 7	#4 @ 6	#5 @ 8
1¼:1	FRONT FACE Reinf	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12	#4 @ 12
	REAR FACE Reinf	#4 @ 8	#4 @ 8	#4 @ 5	#5 @ 6	#6 @ 7	#6 @ 6	#7 @ 6
"D" AT CUTOFF WALL		6"	6"	6"	7½"	8"	9½"	11"
"D" AT CULVERT		6"	6"	6"	8"	9½"	11"	1'-1"

STIFFENING BEAM DIMENSIONS AND REINFORCING

"H" Max \ "L"	12'	14'	16'	18'	20'	25'	30'	35'	40'
6'	NO BEAM, PLACE 2-#6 IN EACH FACE ALONG TOP OF WALL.								
8'				"A"= 1'-0"					
10'			"B"= 9"			"A"= 1'-6"			
12'								"A"= 1'-10"	
14'	TOTAL 6-#6			"B"= 1'-0"			"B"= 1'-3"		
16'									"A"= 2'-2"
18'			TOTAL 6-#7			TOTAL 8-#8			"B"= 1'-6"
20'								TOTAL 8-#9	

NOTES:

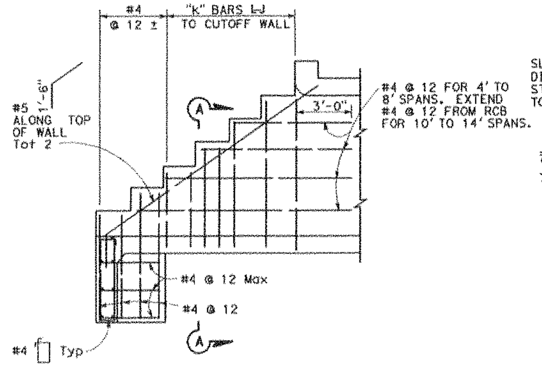
Walls designed for 2'-0" surcharge; earth density = 120 pcf; equivalent fluid pressure = 36 pcf.
Vary "D" of warped wall uniformly from that at cutoff wall to that at headwall or endwall, for maximum "H" > 12'.
Dimensions "L", "W", "H", "M", "N", Elev "a", "Angle of flare", and "Slope" (as apply) are shown on the plans.

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

ARCH CULVERT HEADWALLS, ENDWALLS AND WARPED WINGWALLS

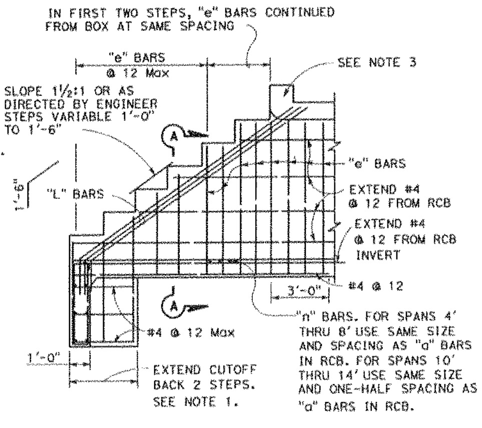
NO SCALE

D86C



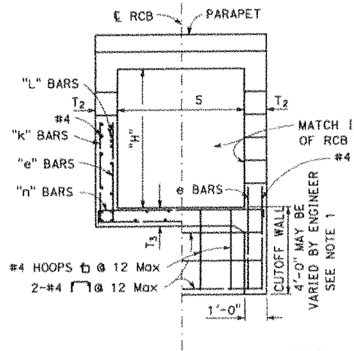
LONGITUDINAL SECTION

Showing reinforcement in outside face



LONGITUDINAL SECTION

Showing reinforcement in inside face

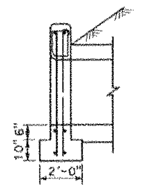


HALF SECTION A-A | END ELEVATION

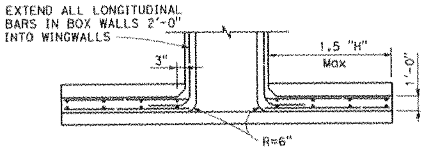
Dimensions S and T_3 to be same as adjacent RCB.

T_2 = Same as adjacent RCB (8" Min).

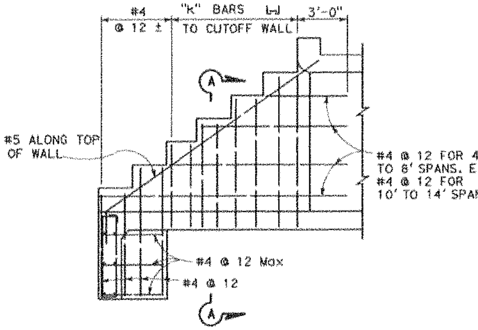
TYPE "E" STEPPED WINGWALL (SINGLE BOX CULVERT)



SECTION B-B

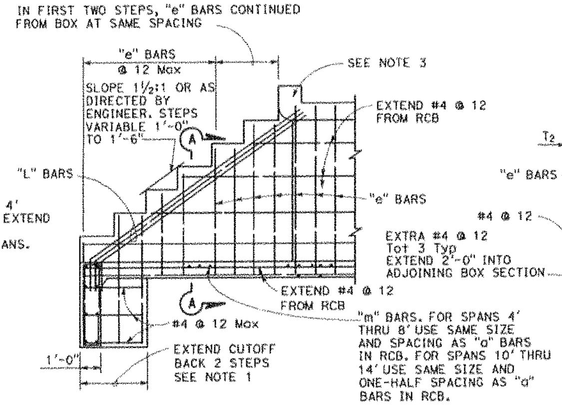


SECTION C-C



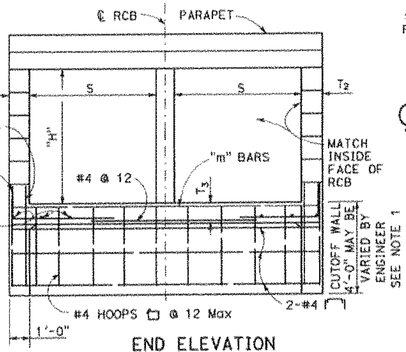
LONGITUDINAL SECTION

Showing reinforcement in outside face



LONGITUDINAL SECTION

Showing reinforcement in inside face

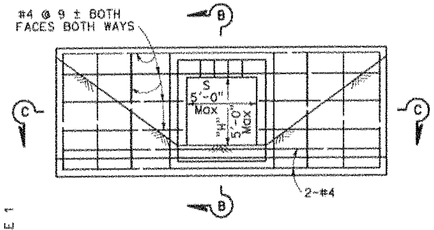


END ELEVATION

Dimensions S and T_3 to be same as adjacent RCB.

T_2 = Same as adjacent RCB (8" Min).

TYPE "E" STEPPED WINGWALL (MULTIPLE BOX CULVERT)



ELEVATION

TYPE "D" STRAIGHT WINGWALL

Details similar for multiple span boxes.
See Note 3.

DETAIL OF DESIGN LOADING CASES - TYPE "D" STRAIGHT WINGWALL

Case I Level + 240 psf surcharge
Case II 2:1 sloping ground with no surcharge
Case III 1½:1 limited slope (5'-0" Max height) + 240 psf surcharge

TABLE OF REINFORCEMENT FOR TYPE "E" WINGWALLS

"H" (SEE NOTE 2)		3'	4'	5'	6'	7'	8'	10'	12'	14'
"K" BARS	BAR No.	#4	#4	#5	#5	#5	#5	#5	#5	#5
	SPACING	@ 12	@ 12	@ 12	@ 10	@ 9	@ 8	@ 7	@ 5	@ 4
"L" BARS	BAR No.	#5	#5	#6	#6	#7	#7	#7	#7	#7
	NUMBER EACH WALL	2	2	3	3	3	3	3	3	3

NOTES:

1. Eliminate cutoff walls if adjacent channel is paved.
2. For "H" not shown use reinforcement for next greater height.
3. For parapet details not shown see Standard Plan D82.

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS

Dallas J. Forester
REGISTERED CIVIL ENGINEER

May 20, 2011
PLANS APPROVAL DATE

Dallas Forester
No. C37765
Exp. 12-31-12
CIVIL

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

BOX CULVERT WINGWALLS
TYPES D AND E

NO SCALE

D85

9-21-10

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Eliminate most details for smaller pipe headwall and standardize

IDEA NUMBER	**PAGE NO.**
8	1 of 2

ORIGINAL CONCEPT:

The Supplemental Standard Drawings detail pipe headwalls as small as 12” with straight walls and flared walls.

ALTERNATIVE CONCEPT:

Detail a standard drawing with general details and criteria for pipes up to 60” in height with minimum performance specification.

ADVANTAGES:

- Reduces detail sheets in the supplement
- Encourages alternative designs or applications
- Transfers some liability to the contractor

DISADVANTAGES:

- Places more responsibility on the contractor to construct the headwalls and wing walls with minimum plan details

IMPLEMENTATION CONSIDERATIONS:

Implement contract bidding and construction oversight practices that rely on industry standards more than finitely detailed plans.

Performance Criteria	**ST**	**C**	**M**	**S**	**H**	**F**	**D**
Performance Measure	**0**	**+1**	**0**	**0**	**0**	**+1**	**0**
Structural							
Constructability	Contractor will have more control of the actual detail (concrete forming/rebar)						
Maintainability							
Safety							
Hydraulics							
Flexibility	Contractor will have the opportunity to introduce options without untimely construction change submittals						
Durability							

Rating Scale: **Value Add +2 +1 0 -1 -2 Value Decrease**

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE:	Standardization of smaller pipe headwall and eliminate most details

DISCUSSION:

Changing the existing supplemental/standard drawings by reducing the detail information will encourage contractor innovation and reduce the effort to update future standard drawing revisions as well as transfer some of the liability now currently borne by KYTC. The amount of detail in the existing supplement/standard drawing restricts the options available to the contractor along with obligating the Cabinet to maintain numerous detail sheets. The basic design for short reinforced concrete wingwalls is controlled by minimum temperature and shrinkage reinforcement instead of imposed loads. Reducing the details associated with the current supplement can also be integrated with a performance specification style bidding process.

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Eliminate skew quantity sheets

	IDEA NUMBER	PAGE NO.
	9	1 of 3

ORIGINAL CONCEPT:

The current Headwall Supplement provides quantity sheets for concrete and rebar based upon specific skew angles.

ALTERNATIVE CONCEPT:

Use a more general detail to include skewed applications with quantities on a per lineal foot basis of each component required to accommodate skew for various height walls, which would also include bar sizes based upon wall heights.

ADVANTAGES:

- Enables more site specific designs, "plug-and-play" use may not have provided the best structure
- Reduces pages and complexity in the supplement
- Reduces potential confusion of users "drowning" in paper
- Quantity accuracy should improve
- Quantities required should more closely match quantities needed to satisfy field conditions

DISADVANTAGES:

- Reduces the customary use of "plug-and-play" application
- Quantity determinations require more thought
- Regaining confidence of the users resultant information as reliable

IMPLEMENTATION CONSIDERATIONS:

Learning to use more typical design features as they may apply to accommodate specific field conditions.

Performance Criteria	**ST**	**C**	**M**	**S**	**H**	**F**	**D**
Performance Measure	**+1**	**+2**	**0**	**0**	**0**	**+2**	**0**
Structural	Simplifies application of skew to design for any angle, improves realization to fit actual field conditions						
Constructability	Quantities are applicable regardless of angle on a per foot basis rather than unit basis						
Maintainability							
Safety							
Hydraulics							
Flexibility	Provides for any angle skew as needed, enables component or mix and match concept approach to design						
Durability							

Rating Scale: **Value Add +2 +1 0 -1 -2 Value Decrease**

TITLE: Eliminate skew quantity sheets

DISCUSSION:

The sheer volume of the “nomograph” type approach to headwall designs tends to disengage the engineer and/or contractor from the simple processes of features affected by skew. Determination of quantities is a simple task which should be determined in each specific case to avoid oversights of other conditions inherent in the design/use of the product. Included is an example of a headwall sheet used by Caltrans in its Standard Drawings of 2010 similar in approach to that used also by the state of Tennessee, Department of Transportation.

Additional Supporting Documentation Includes:

1) Caltrans Sample Details

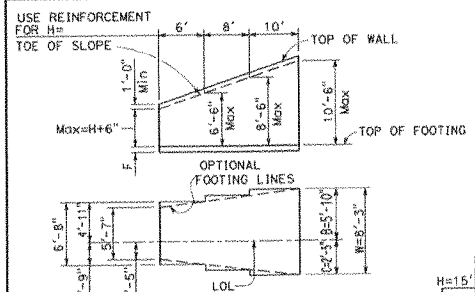
Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS

REGISTERED CIVIL ENGINEER

May 20, 2011
PLANS APPROVAL DATE

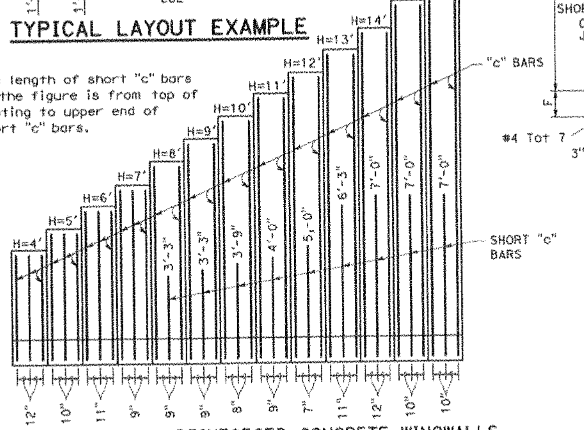
THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

REGISTERED PROFESSIONAL ENGINEER
Dallas Forester
No. C37765
Exp. 12-31-12
CIVIL
STATE OF CALIFORNIA



TYPICAL LAYOUT EXAMPLE

The length of short "c" bars in the figure is from top of footing to upper end of short "c" bars.



REINFORCED CONCRETE WINGWALLS

"H"	4'	5'	6'	7'	8'	9'	10'	11'	12'	13'	14'	15'	16'
W	5'-7"	6'-2"	6'-8"	7'-1"	7'-6"	7'-10"	8'-3"	8'-8"	9'-2"	9'-7"	10'-2"	10'-6"	11'-1"
C	1'-5"	1'-7"	1'-9"	1'-11"	2'-1"	2'-3"	2'-5"	2'-8"	2'-10"	3'-1"	3'-4"	3'-6"	3'-8"
B	4'-2"	4'-7"	4'-11"	5'-2"	5'-5"	5'-7"	5'-10"	6'-0"	6'-4"	6'-6"	6'-10"	7'-0"	7'-5"
F	1'-2"	1'-2"	1'-2"	1'-2"	1'-2"	1'-2"	1'-2"	1'-3"	1'-5"	1'-5"	1'-6"	1'-6"	1'-8"
BATTER	None									½:12			
S	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-0"	1'-6½"	1'-7"	1'-7½"	1'-8"
"c" BARS	#4@12	#4@10	#5@11	#5@9	#6@9	#7@9	#7@8	#8@9	#7@7	#8@11	#9@12	#10@10	#10@10
"d" BARS	#5@12	#5@10	#6@11	#6@9	#6@9	#6@9	#6@8	#7@9	#6@7	#7@11	#8@12	#8@10	#9@10
* Conc CY/LF	0.46	0.52	0.58	0.64	0.69	0.74	0.80	0.88	1.00	1.25	1.37	1.45	1.61
* Reinf LB/LF	26	32	41	50	59	70	81	95	102	99	120	156	171
** CASE I qu (ksf), B' (ft)	3.75,2.24	3.66,2.69	3.59,3.11	3.56,3.49	3.52,3.89	3.52,4.21	3.69,4.46	3.77,4.77	3.89,5.17	3.92,5.61	3.92,6.18	4.04,6.40	4.13,6.95
** CASE II qu (ksf), B' (ft)	1.16,5.58	1.33,6.13	1.51,6.55	1.69,6.86	1.88,7.16	2.08,7.33	2.29,7.60	2.50,7.86	2.77,8.14	2.97,8.47	3.18,8.93	3.41,9.05	3.70,9.43
** CASE III qu (ksf), B' (ft)	1.26,5.46	1.36,5.97	1.49,6.37	1.64,6.66	1.79,6.93	1.95,7.08	2.11,7.33	2.28,7.55	2.50,7.84	2.66,8.12	2.81,8.59	3.00,8.69	3.22,9.10

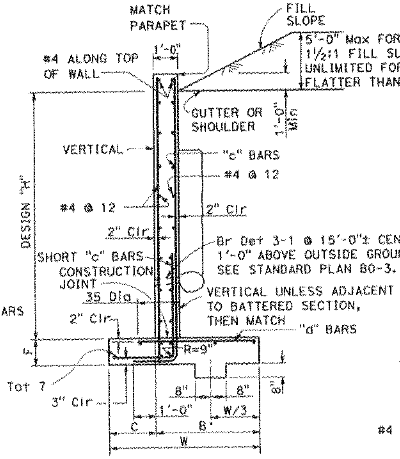
B'=B-(2) eccentricity, B' is the effective footing width.

* Quantities include 1'-0" extension above the design "H" limit.

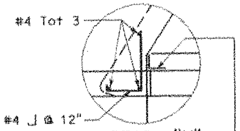
** Soil bearing pressure shown in the table is the equivalent uniform pressure per AASHTO LRFD - 11.6.3.2

NOTES:

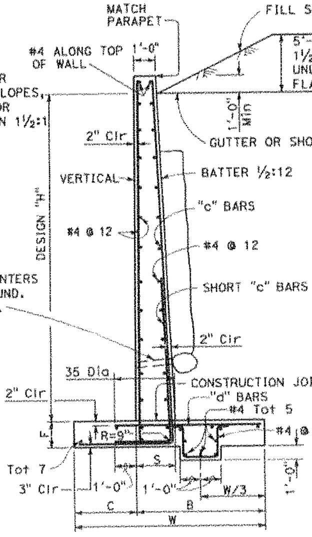
Unit Stresses: f'c=3,600 psi, fy=60,000 psi
Earth density: 120 pcf
Equivalent fluid pressure: 36 pcf
Elevations, length and angle of flare of wings may be varied by the Engineer to suit conditions encountered in the field.
Dimensions "H","L","M","N", Elevation "a" and "Angle of flare" (as apply) are shown on the plans.
Wall height may be exceeded by 6" before going to next greater "H".
Eliminate cutoff wall if adjacent channel is paved and skew is 20° maximum.
For wall offset values, see Standard Plan B3-5.



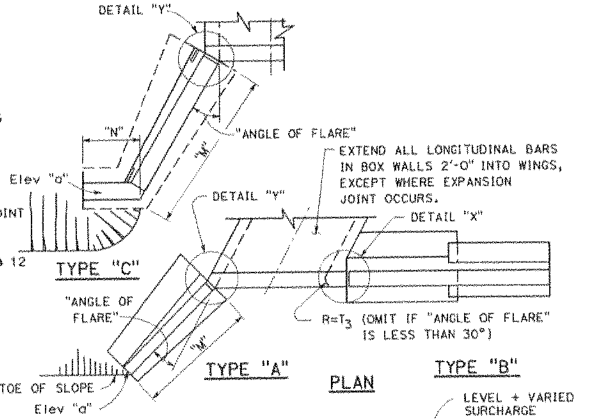
TYPICAL SECTION
H=4' THRU 12'



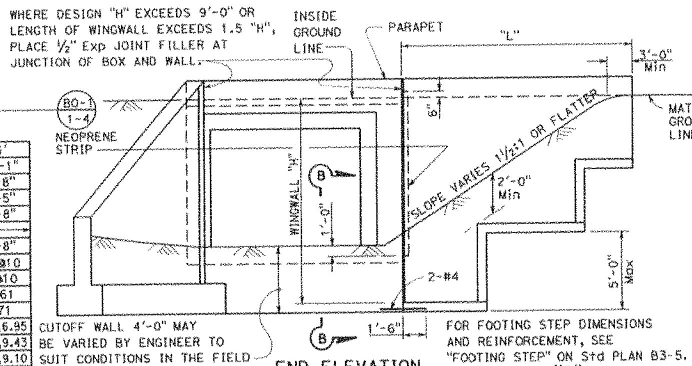
DETAIL "X"



TYPICAL SECTION
H=13' THRU 16'



PLAN

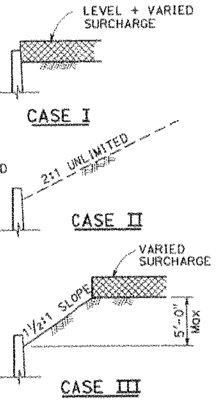


TYPE "A"

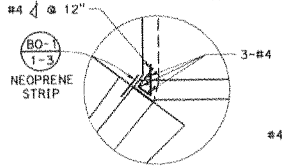
END ELEVATION

TYPE "B"

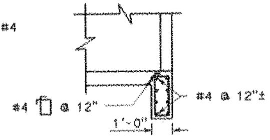
STRAIGHT WINGWALLS



DETAIL OF DESIGN LOADING CASES



DETAIL "Y"



SECTION B-B

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

BOX CULVERT WINGWALLS
TYPES A, B AND C

NO SCALE

D84

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Combine all headwall design standards into the Standard Drawings

	IDEA NUMBER	PAGE NO.
	10	1 of 2

ORIGINAL CONCEPT:

At present, all safety headwall options are found in the Kentucky Standard Drawings (RDB-100 to RDB-160). The non-safety headwall options are shown in a separate document (Headwall Supplement).

ALTERNATIVE CONCEPT:

Update, revise, and simplify the material presented in the Headwall Supplement and add this information into the Kentucky Standard Drawings alongside the safety headwall options.

ADVANTAGES:

- All information regarding headwalls, utilized by the KYTC, is in one document. Provides ease of data retrieval and use by the engineer and contractor
- Savings in printing costs by eliminating the Headwall Supplement document
- Easier to update and maintain the information

DISADVANTAGES:

- Internal acceptance
- Learning curve as to where to find the information

IMPLEMENTATION CONSIDERATIONS:

Must get approval by KYTC Central Office administration. Must revise, update and simplify the material currently in the Headwall Supplement document.

Performance Criteria	**ST**	**C**	**M**	**S**	**H**	**F**	**D**
Performance Measure	**+1**	**0**	**+2**	**+1**	**0**	**0**	**0**
Structural	Having details together promotes addressing structures to provide safety design						
Constructability							
Maintainability	Easier to maintain and update information with all materials in one document						
Safety	See “Structural” comment						
Hydraulics							
Flexibility							
Durability							

Rating Scale: **Value Add** **+2** **+1** **0** **-1** **-2** **Value Decrease**

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: All headwall designs should be together within the Standard Specification Book

DISCUSSION:

Much of the material in the Headwall Supplement needs to be updated to current design standards. The presentation of the material in the supplement can be simplified and depicted on fewer sheets. This revised material can be shown in the Kentucky Standard Drawings alongside the materials for safety headwalls, thus eliminating the need to have a separate document.

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Eliminate standard headwall

IDEA NUMBER 11

PAGE NO. 1 of 2

ORIGINAL CONCEPT:

Two standard drawings (RDH-005-02 and (RDH-010-02) have standard concrete headwalls.

ALTERNATIVE CONCEPT:

Eliminate the two standard drawings with standard headwall designs.

ADVANTAGES:

- Encourages the use of safer, traversable alternative designs
- Removes unnecessary pages from the standard drawings book

DISADVANTAGES:

- There may be some instances where the standard headwall design is desired by the engineer

IMPLEMENTATION CONSIDERATIONS:

Designers will need to be educated about this change through a design memo. Although removed from the standard drawings, it would not prohibit designers from using a standard headwall design, if needed.

Performance Criteria	**ST**	**C**	**M**	**S**	**H**	**F**	**D**
Performance Measure	**0**	**0**	**0**	**+2**	**0**	**0**	**0**
Structural							
Constructability							
Maintainability							
Safety	Using other safety headwall options provides for safer conditions of motorists that may run off the road						
Hydraulics							
Flexibility							
Durability							

Rating Scale: **Value Add** **+2** **+1** **0** **-1** **-2** **Value Decrease**

TITLE: Eliminate standard headwall

DISCUSSION:

There are several alternatives to the standard straight headwall that designers can use that are as economical and/or safe. For example, a mitered culvert end can be built to match the slope along with slope protection. Mitered designs using single pipes (perpendicular to the road) 36 inches or less in diameter, or dual pipes 30 inches or less are considered traversable. The use of the mitered design can be used for larger diameter culverts within the clear zone areas protected by guardrail.

Another option that already exists in the standard drawings is the use of a sloped and flared headwall which also allows for containment and erosion protection as water enters and exits the culvert. In fact, the KYTC Drainage Manual states that the sloped and flared headwall was "designed in 1974 to replace the standard and raised headwall in most instances."

Examples of mitered culvert design

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Use an interactive worksheet for calculations for steel and concrete to eliminate quantities within the standards

	IDEA NUMBER	PAGE NO.
	12	1 of 2

ORIGINAL CONCEPT:

Roughly 100 pages of the Headwall Supplement contain dimensions and bills of reinforcement for the various headwall designs.

ALTERNATIVE CONCEPT:

Develop software in which the designer can input basic information and the output includes the headwall dimensions and quantities of steel and concrete.

ADVANTAGES:

- Adds flexibility to designs to use various skews and pipe diameters
- Reduces the potential for miscalculations/ misreading of tables in estimating
- Reduces the number of pages within the supplement
- Ability to easily modify or expand in the future
- Bid codes can be added to the program

DISADVANTAGES:

- Learning curve for engineers/contractors
- Added task for consultant or KYTC design and details need to be added to design plans if not covered by standard drawings
- May be more susceptible to input errors under the radar because “the computer says so”.

IMPLEMENTATION CONSIDERATIONS:

This application could be developed using an intern, young engineer, or the Kentucky Transportation Center research program.

VALUE ENGINEERING ALTERNATIVE

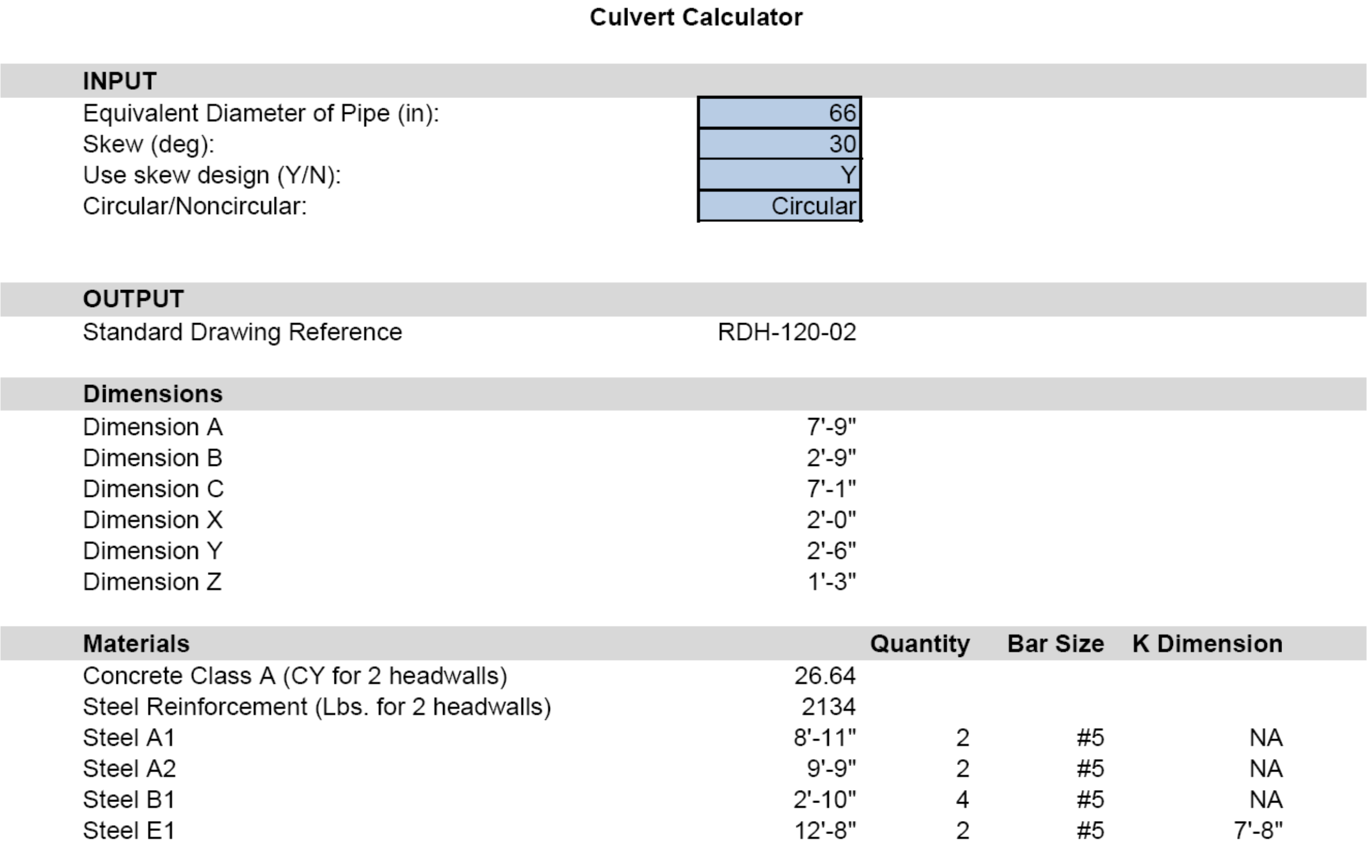
KYTC Headwalls Process Improvement

TITLE: Use an interactive worksheet for calculations for steel and concrete to eliminate quantities within the standards

DISCUSSION:

In an era where computers are standard equipment for design and information can be shared via the internet, it only makes sense to develop design tools that use this capability. It makes sense to migrate away from having information in multiple tables to a flexible calculator that provides the outputs of dimensions and quantities based on limited inputs. There will be time needed to translate the information into usable software.

For sizing, the designer would input the diameter of pipe, skew of pipe, whether the wingwalls will use a skew design, and if the pipe is circular or non-circular. The output would include the wall thickness, height, wingwall length, etc. The output would also include the volume of concrete, weight of steel, and the bill of reinforcement. This would eliminate the possibility of mistakes of leaving out the cross referencing bill of reinforcement sheet on the project layout sheet.



Culvert Calculator

INPUT	
Equivalent Diameter of Pipe (in):	66
Skew (deg):	30
Use skew design (Y/N):	Y
Circular/Noncircular:	Circular

OUTPUT	
Standard Drawing Reference	RDH-120-02

Dimensions	
Dimension A	7'-9"
Dimension B	2'-9"
Dimension C	7'-1"
Dimension X	2'-0"
Dimension Y	2'-6"
Dimension Z	1'-3"

Materials		**Quantity**	**Bar Size**	**K Dimension**
Concrete Class A (CY for 2 headwalls)	26.64			
Steel Reinforcement (Lbs. for 2 headwalls)	2134			
Steel A1	8'-11"	2	#5	NA
Steel A2	9'-9"	2	#5	NA
Steel B1	2'-10"	4	#5	NA
Steel E1	12'-8"	2	#5	7'-8"

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Integrate into Standard Drawings and eliminate Headwall Supplemental

IDEA NUMBER 13

PAGE NO. 1 of 2

ORIGINAL CONCEPT:

Currently the Headwall Supplement Book and the Standard Drawing Book are currently stand alone documents. The supplement contains only pipe and box culvert headwalls.

ALTERNATIVE CONCEPT:

Reduce the number of pages in the current Headwall Supplement through other measures such as drawing elimination, use of performance specifications, and other alternatives. Integrate the remaining pages into the Standard Drawing Book. Integrating the two documents with all of the "standard" design elements ensures that the information will all be together in one book.

ADVANTAGES:

- Puts all of the Standard Drawings in one document. (was one document prior to 1983)
- With integration, the door is open for new and innovative headwall designs
- Will reduce printing costs to the Cabinet

DISADVANTAGES:

- Precast manufacturers would be required to have the whole book of Standard Drawings instead of just the supplement
- We would lose some semblance of autonomy in our headwall designs

IMPLEMENTATION CONSIDERATIONS:

None apparent

Performance Criteria	ST	C	M	S	H	F	D
Performance Measure	0	0	+1	0	0	0	0

Structural	
Constructability	
Maintainability	One less document and fewer drawings that would require maintenance
Safety	
Hydraulics	
Flexibility	
Durability	

Rating Scale: **Value Add +2 +1 0 -1 -2 Value Decrease**

VALUE ENGINEERING ALTERNATIVE
KYTC Headwalls Process Improvement

TITLE: Integrate into Standard Drawings and eliminate Headwall Supplemental

DISCUSSION:

By reducing the number of drawings and charts in the current Headwall Supplement Book, the remaining drawings could be integrated back into the Standard Drawing Book. This would create one single document versus two separate ones and make the document more manageable. It would also reduce printing costs incurred by the Cabinet. Integrating drawings from the existing Headwall Supplement into the Standard Drawing Book would be beneficial as long as some combination of different materials and practices are adopted. Some different methodologies might include the development of an interactive worksheet allowing designers to input specific design criteria, use of performance specifications to design headwalls, designing a standard headwall that can be combined with other types (materials) of wingwalls. Likewise, the use of different materials such as rip rap, geotextile fabric for slope protection, precast units, and others would create new avenues for designing “pipe end treatments” that would achieve the desired outcome in a more efficient and cost effective manner, while maintaining safety.

APPENDICES

APPENDIX A
Study Participants

VE STUDY ATTENDEES
Kentucky Transportation Cabinet
Headwalls Standards Process Improvements

March 2013			NAME	ORGANIZATION	POSITION	TELEPHONE		CELL		E-MAIL
11	12	13								
X	X	X	Renee Hoekstra	RH & Associates, Inc.	VE Team Leader	623	266-3943	623	764-7490	rhpartnering@earthlink.net
		Ph	Boday Borres	KYTC	KYTC - Transportation Engineering Branch Manager	502	889-4448	480	773-8533	boday.borres@ky.gov
X	X	X	Brent Sweger	KYTC	KYTC - VE Coordinator	502	564-3280	502	229-5737	brent.sweger@ky.gov
X	X	X	Kenneth Ott	AEI	Structural Specialist	502	245-3813	502	807-8198	kott@aei.cc
X	X	X	Dale Carpenter	AEI	Structural Specialist	502	245-3813	502	229-3605	dcarpenter@aei.cc
X	X	X	Steve Arnold	Qk4	Drainage Specialist	502	719-7894	502	299-4878	sarnold@qk4.com
X	X	X	Phil George	PE Stimpel	Construction Specialist	530	949-8768			pegeorge@stimpel.net
X	X	X	Nick Bingham	Bingham & Bingham	Precast Specialist	775	857-7017			sub220@yahoo.com
X	X	X	Jeff Lail	KYTC	Team Member	502	564-3280	Ext	3410	jeff.lail@ky.gov
		Ph	Jeff Jasper	KYTC	Director Division of Highway Design					jeff.jasper@ky.gov

VE STUDY ATTENDEES
Kentucky Transportation Cabinet
Headwalls Standards Process Improvements

March 2013			NAME	ORGANIZATION	POSITION	TELEPHONE	CELL
11	12	13				E-MAIL	
		Ph	Doug Gesso	KYTC	Division of Highway Design		
						doug.gesso@ky.gov	

APPENDIX B
Function Analysis

Appendix B – Function Analysis

Function definition and analysis is the heart of Value Engineering. It is the primary activity that separates VE from all other "improvement" programs. The objective of this phase is to ensure the entire team agrees upon the purposes for the project elements. Furthermore, this phase assists with development of the most beneficial areas for continuing study.

The VE team identified the functions of a *headwall* using active verbs and measurable nouns. This process allowed the team to truly understand all of the functions associated with the element.

Function	Classification
Protect Slope & Protect Pipe	***Higher Order***
Retain Earth & Convey Flow	**Basic**
Support Structure	Secondary
Accommodate Pipe	Secondary
Improve Hydraulics	Secondary
Channel Flow	Secondary
Prevent Scour	Secondary
Anchor Pipe	Secondary
Ensure Durability	Secondary
Reduce ROW	Secondary
Accommodate Maintenance	Secondary
Accommodate Aesthetics	Secondary
Ensure Stability	Secondary
Ensure Safety	Secondary
Install Headwall	***Lower Order***

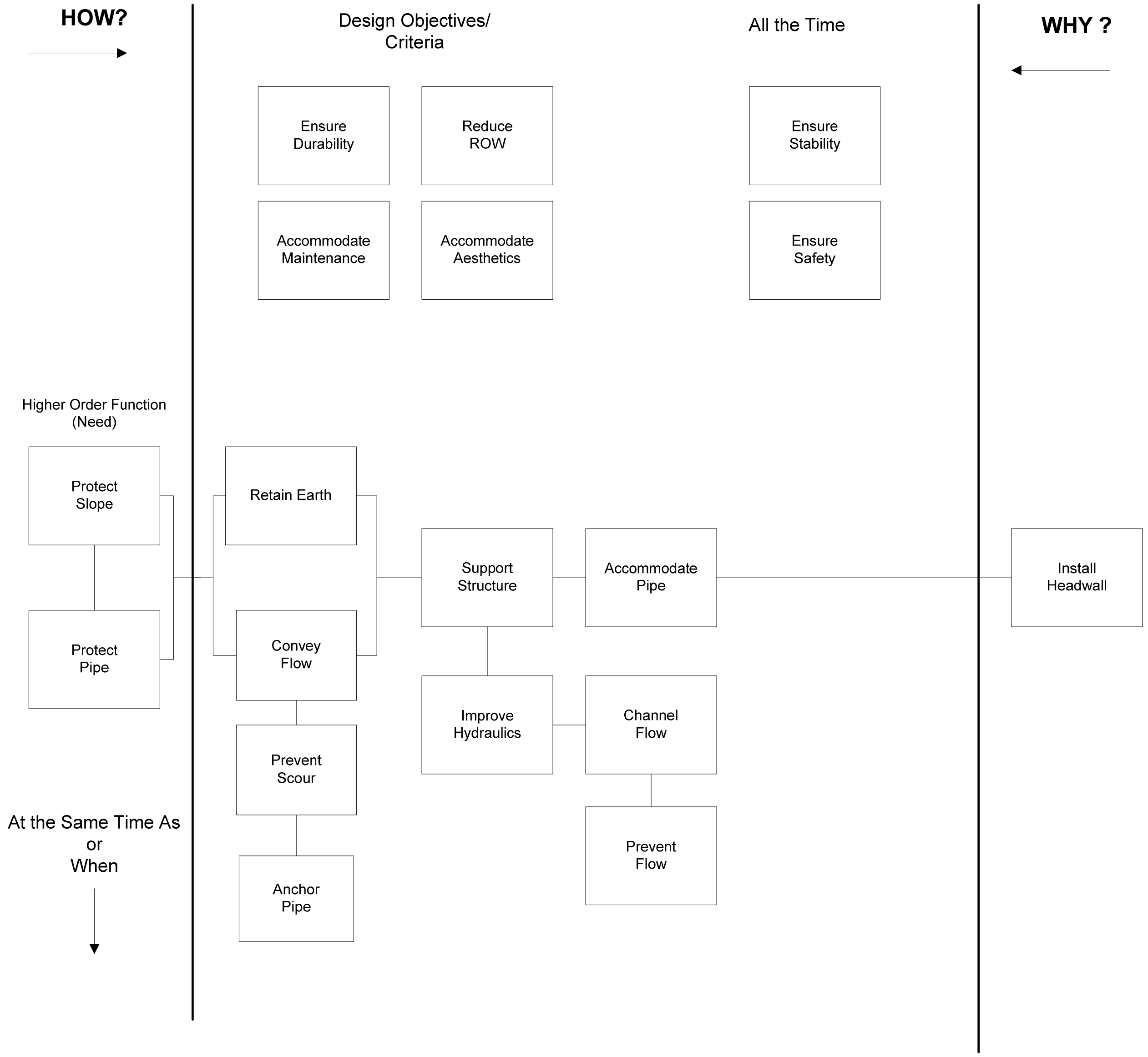
The definitions of the classifications are:

Higher Order Function defines the problem (study) goal and is outside the scope of the study.

Basic Function defines a performance feature that *must* be obtained to satisfy only user's needs not desires. It answers the question, "What must it do?".

Secondary Functions defines required performance features other than those that must be accomplished. These are the user's desires and answers the question, "What else do we want or does it do?".

The following represents the Function Analysis Systems Technique (FAST) Diagram completed for this project.



APPENDIX C
Creative Idea List & Evaluation

Appendix C – Creative List and Evaluation Process

Creative Idea List

The list of ideas and comments that resulted from the study is included in this appendix. Some of the ideas were selected for further development as represented in the previous section.

Evaluation Process

Prior to the team evaluating the ideas, a Fatal Flaw Analysis was completed to eliminate any of the ideas that would not be implementable in Kentucky. Then the team scored the ideas using a nominal group technique keeping in mind the goals, constraints and the performance attributes developed.

Group Nominal Technique Evaluation Results Score

The prioritization for further development and documentation is as follows:

Score =

- 2-7 – Number of votes meeting the criteria (Workbook)
- 0-1 – Number of votes meeting the criteria (No workbook)
- FF – Fatal Flaw
- ABC – Already Been Considered
- OS – Outside Scope

The creative idea list represents all of the ideas and includes scoring for the ideas that were rated using the group nominal technique.

Creative Idea List

No.	Description	Comments	Score
	Materials and Practices		
MP-01	Use Gunite		w/MP-44
MP-02	Use rip rap at the end of the pipe		w/MP-44
MP-03	Use higher strength concrete		w/SS-10
MP-04	Use higher strength steel		w/SS-10
MP-05	Use masonry cinder block		FF
MP-06	Use geotextile fabrix to reinforce the soil around the end of the pipe		w/MP-44
MP-07	Use MSE walls (with facing)		w/MP-43
MP-08	Use wire walls		w/MP-43
MP-09	Use gabion baskets		w/MP-43
MP-10	Use dry stack rocks		FF
MP-11	Use modular block		w/MP-43
MP-12	Use bin walls		w/MP-43
MP-13	Use railroad ties		FF
MP-14	Use ground cover to stabilize slope		w/MP-44
MP-15	Use soil nail walls		w/MP-44
MP-16	Use tie-back walls		w/MP-44
MP-17	Use soldier pile lagging		FF
MP-18	Use sheet piles		FF
MP-19	Use a concrete gravity wall (with reinforcement)		w/MP-43
MP-20	Use precast concrete headwalls and wingwalls		2
MP-21	Provide rebar clearance design criteria		w/SS-10
MP-22	Establish overall design criteria and assumptions		w/SS-10
MP-23	Use a can wall		FF
MP-24	Place railing on top of tall walls		ABD
MP-25	Make all outlets and inlets integral with safety grates		w/MP-45
MP-26	Integrate scour protection with design criteria (aprons, soil cement, cable block, scour stop)		w/MP-45
MP-27	Integrate energy dissipation with design criteris (rip rap, concrete baffles)		w/MP-45
MP-28	Extend pipe to the toe of slope to eliminate headwalls		2
MP-29	Use end anchors at the end of the pipe to improve stability		w/MP-28
MP-30	Use soil cement in liue of wall		w/MP-44
MP-31	Provide a multi-barrel culvert design criteria		0
MP-32	Use pavers for the paved invert		FF
MP-33	Provide larger pipe diameter criteria for safety walls		w/MP-45
MP-34	Eliminate standard headwall		2
MP-35	Modify the standard headwall which can be combined with any other type of wing wall		w/SS-10
MP-36	Eliminate wing walls		1

Creative Idea List

No.	Description	Comments	Score
MP-37	Address nosing design criteria		w/SS-02
MP-38	Establish criteria for entrance pipes (smaller pipe)		1
MP-39	Use metal (flared) end section in lieu of walls		w/MP-45
MP-40	Use reinforced pipe ends		w/MP-45
MP-41	Use mitered pipe ends		w/MP-45
MP-42	Use plastic headwalls		FF
MP-43	Provide alternate materials for walls		5
MP-44	Provide alternative approaches for slope protection		5
MP-45	Provide alternative approaches for end treatments		7
	Simplify Standards		
SS-01	Integrate into standard drawings and eliminate supplementals		4
SS-02	Design and detail headwalls and wingwalls separately		3
SS-03	Eliminate skew quantity sheets		2
SS-04	Use an interactive worksheet for calculations for concrete and steel to eliminate the quantitites within the standards		4
SS-05	Change the name of the document to Pipe Termini in lieu of Headwall Supplement		0
SS-06	Provide design software that can provide simple designs in lieu of the calculations		0
SS-07	Elminiate most details and standardize smaller pipe headwall drawings		1
SS-08	Eliminate counterfort		2
SS-09	Use performance specifications and eliminate the standards		2
SS-10	Redesign to the current design criteria		2
SS-11	Combine all headwall design standards within the Standard Drawings		0

APPENDIX D
Supporting Data

Appendix D – Supporting Data

Gap Analysis

The team identified the performance of the current Supplemental Standards and then identified the expected performance of the Supplemental Standards. A gap analysis was completed to allow the team to understand the potential areas for improvement.

GAP ANALYSIS

Current Standards Performance	Expected Performance
Strength of concrete is too low	Optimize the amount of materials used
Lower strength steel	Optimize the amount of materials used
Only reinforced concrete walls are included	Multiple options for walls
Limited options available for safety headwalls	Need for multiple barrells and for larger diameter
Standards for rebar clearances show only 2"	Update rebar clearances
Assumes reinforced concrete is placed on site, only	Need to include precast options
Precast concrete is not addressed	"
No integration of the standard headwall with different types of walls	Need options if we use other types of walls since other types of walls have not been used
Not sure whether to pave or not to pave inlet and outlet	Still need to understand the need in this document
Trying to address too many situations	Fewer details needed to build a headwall
Addresses precast option for precast culverts only	Need to include precast options
Skew is addressed but no longer used	Eliminate the skew design options
No integration of standards between standard drawings and headwall standards	Needs to have integration
Current name of the document is the Headwall Supplement	Pipe Termini Supplement
Does not address scour impacts	Needs to be addressed
Does not address energy (hydraulic) issues	Needs to be addressed
No indication of the use of precast for headwalls	Need to include precast options
The accuracy is dependent on information that, in some cases, is over 50 years old	Improve accuracy
No multiple barrell details for head walls	Needs to be addressed
No discussion of impacts versus Level of Service	No needed improvements
Soil pressures are not addressed, it only uses one standard approach	Improve accuracy
No criteria or assumptions included with the standards	Add design criteria and assumptions

Standard KYTC VE Report Abbreviations

List of Common Abbreviations

AADT	Average Annual Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADD	Area Development District
ADT	Average Daily Traffic
CRF	Crtical Rate Factor
CSB	Crushed Stone Base
CY	Cubic Yard
DES	Design Executive Summary
DGA	Dense Graded Aggregate
DHV	Design Hour Volume
EA	Each
FHWA	Federal Highway Administration
FT	Foot or Feet
IJS	Interchange Justification Study
KTC	Kentucky Transportation Center
KYTC	Kentucky Transportation Cabinet
LF	Linear Feet
LOS	Level of Service
LS	Lump Sum
MI	Mile
MOU	Memorandum of Understanding
MP	Milepoint
MPO	Metropolitan Planning Organziation
MSE	Mechanically Stabilized Earth
NHS	National Highway System
PD	Project Development
PDP	Project Delivery and Preservation
PL&G	Preliminary Line and Grade
RCBC	Reinforced Concrete Box Culvert
ROW	Right-of-Way
SYP	Six Year Plan
TRB	Transportation Research Board
V/C	Volume to Capacity Ratio
VE	Value Engineering
VPH	Vehicles per Hour