
RETAINING WALL INVENTORY AND CONDITION ASSESSMENT PROGRAM (WIP) National Park Service Procedures Manual

Publication No. FHWA-CFL/TD-10-003

August 2010



U.S. Department
of Transportation
**Federal Highway
Administration**

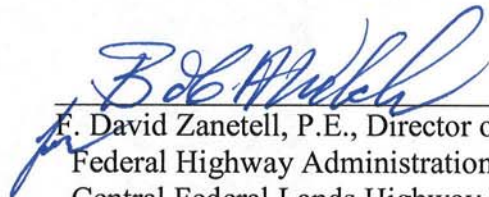


**Central Federal Lands Highway Division
12300 West Dakota Avenue
Lakewood, CO 80228**

FOREWORD

The National Park Service (NPS) is responsible for the management and maintenance of nearly 5,500 miles of paved roads and parkways across more than 250 park properties nationwide. In addition to the primary pavement asset, the NPS is also responsible for appraising and managing deferred maintenance needs of numerous subsidiary roadway features, including bridges, retaining walls, culverts and traffic barriers. Referred to as “equipment” in asset management parlance, these features are major contributors to the safety and accessibility of the NPS roads system and represent substantial roadway infrastructure investments. Given the wide range of geographic settings and public usage comprising the NPS network of roads, defining the backlog of roadway equipment is a major challenge to the park program.

The Federal Lands Highway (FLH) of the Federal Highway Administration (FHWA), in partnership with the National Park Service (NPS), has undertaken the development of a comprehensive retaining wall asset inventory and condition assessment procedure as part of the NPS Retaining Wall Inventory and Condition Assessment Program (WIP). The purpose of this program is to define, quantify, and assess wall assets associated with park roadways in terms of their location, geometry, construction attributes, geotechnical and structural condition, failure consequence, cultural aspects, apparent design criteria, and cost of structure maintenance, repair or replacement. In support of the WIP, this Procedures Manual documents the data collection and management processes, wall attribute and element definitions, and team member responsibilities for conducting retaining wall inventories and condition assessments based on nearly 3,500 wall assessments conducted to date within 32 national parks across the country. Although primarily intended to serve the WIP as it moves forward, this manual should find application within a broader national audience as federal, state and local agencies tackle retaining wall asset issues tied to transportation infrastructure.



E. David Zanetell, P.E., Director of Project Delivery
Federal Highway Administration
Central Federal Lands Highway Division

Notice

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the use of the information contained in this document. This report does not constitute a standard, specification, or regulation.

Quality Assurance Statement

The FHWA provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

Cover Photos: Complex stone masonry earth retaining structures at Glacier National Park (top) and Ranier National Park (bottom).

Technical Report Documentation Page

1. Report No. FHWA-CFL/TD-10-003		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle <i>RETAINING WALL INVENTORY AND ASSESSMENT PROGRAM (WIP) National Park Service Procedures Manual</i>				5. Report Date August 2010	
				6. Performing Organization Code HFTS-16	
7. Author(s) Matthew DeMarco, FHWA-CFLHD; David Keough, NPS-WASO; and Stephen Lewis, FHWA-CFLHD				8. Performing Organization Report No.	
9. Performing Organization Name and Address Federal Highway Administration Central Federal Lands Highway Division 12300 W. Dakota Avenue, Suite 210 Lakewood, CO 80228				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Transportation Management Program National Park Service Department of the Interior 1849 "C" St., N.W. (2420) Washington, D.C. 20240-0001				13. Type of Report and Period Covered Final Report	
				14. Sponsoring Agency Code	
15. Supplementary Notes <i>Program Development Team: Matthew DeMarco, FHWA-CFLHD; David Keough, NPS-WASO; Marilyn Dodson, FHWA-CFLHD; Dan Alzamora, FHWA-RC; Rich Barrows, FHWA-WFLHD; Scott Anderson, FHWA-RC; John Thiel, FHWA-EFLHD; Khalid Mohamed, FHWA-EFLHD; Linden Snyder, FHWA-CFLHD; Stephen Lewis, FHWA-CFLHD</i>					
16. Abstract The Federal Lands Highway (FLH) of the Federal Highway Administration (FHWA), in partnership with the National Park Service (NPS), has undertaken the development of a comprehensive retaining wall asset inventory and condition assessment procedure as part of the NPS Wall Inventory Program (WIP). The purpose of this program is to define, quantify, and assess wall assets associated with park roadways in terms of their location, geometry, construction attributes, geotechnical and structural condition, failure consequence, cultural aspects, apparent design criteria, and cost of structure maintenance, repair or replacement. In support of the WIP, this Procedures Manual documents the data collection and management processes, wall attribute and element definitions, and team member responsibilities for conducting retaining wall inventories and condition assessments based on nearly 3,500 wall assessments conducted to date within 32 national parks across the country. The WIP is supported by several key developments described in this manual, including a comprehensive training program for field inspectors, an MS Access-based database, unique data collection forms, a supporting field guide, and a wall repair/replace cost estimation guide. Although primarily intended to serve the WIP as it moves forward, this manual should find application within a broader national audience as federal, state and local agencies tackle retaining wall asset issues tied to transportation infrastructure.					
17. Key Words WIP, WALL INVENTORY PROGRAM, RETAINING WALLS, ASSET MANAGEMENT			18. Distribution Statement No restriction. This document is available to the public from the sponsoring agency at the website http://www.cflhd.gov .		
19. Security Classification (of this report) Unclassified		20. Security Classification (of this page) Unclassified		21. No. of Pages 188	22. Price NA

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in ²	square inches	645.2	square millimeters	mm ²
ft ²	square feet	0.093	square meters	m ²
yd ²	square yard	0.836	square meters	m ²
ac	acres	0.405	hectares	ha
mi ²	square miles	2.59	square kilometers	km ²
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft ³	cubic feet	0.028	cubic meters	m ³
yd ³	cubic yards	0.765	cubic meters	m ³
NOTE: volumes greater than 1000 L shall be shown in m ³				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m ²	cd/m ²
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in ²	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm ²	square millimeters	0.0016	square inches	in ²
m ²	square meters	10.764	square feet	ft ²
m ²	square meters	1.195	square yards	yd ²
ha	hectares	2.47	acres	ac
km ²	square kilometers	0.386	square miles	mi ²
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m ³	cubic meters	35.314	cubic feet	ft ³
m ³	cubic meters	1.307	cubic yards	yd ³
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m ²	candela/m ²	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in ²

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

TABLE OF CONTENTS

CHAPTER 1 – INTRODUCTION1

 1.1 PURPOSE AND NEED FOR A WALL INVENTORY PROGRAM2

 1.2 BACKGROUND OF PROGRAM DEVELOPMENT3

 1.3 A PROGRAM PERSPECTIVE ON DEFERRED MAINTENANCE4

 1.4 RECOMMENDED INVENTORY AND ASSESSMENT CYCLE.....6

 1.5 TRAINING REQUIREMENTS7

 1.6 PROCEDURES MANUAL ORGANIZATION.....9

CHAPTER 2 - DATA COLLECTION PROCESS AND PROCEDURES.....11

 2.1 GENERAL INVENTORY AND ASSESSMENT PROCESS11

 2.2 PRE-FIELD ACTIVITIES AND PROCEDURES12

 2.2.1 Inventory Planning Request.....12

 2.2.2 Visidata Acquisition.....13

 2.2.3 Initial Park Contact14

 2.2.4 Park Wall Inventory Packet15

 2.2.5 Preliminary RIP and Visidata Review16

 2.2.6 Field Inventory Prep17

 2.2.7 Park WIP Database Upload19

 2.3 FIELD ACTIVITIES AND PROCEDURES.....19

 2.3.1 Kick-Off Meeting.....20

 2.3.2 Wall Reconnaissance22

 2.3.3 Wall Inventory and Assessment.....23

 2.3.4 Close-Out Meeting.....25

 2.4 POST-FIELD ACTIVITIES AND PROCEDURES26

 2.4.1 Field Data Upload to Park WIP Database.....26

 2.4.2 Central WIP Database Update28

 2.4.3 Inventory Findings Memorandum28

 2.4.4 FMSS and RIP Data Transmittals.....29

 2.5 DATA MANAGEMENT ACTIVITIES.....29

CHAPTER 3 – WALL ACCEPTANCE CRITERIA AND GUIDELINES31

 3.1 WALL ACCEPTANCE CRITERIA31

 3.2 APPLYING WALL ACCEPTANCE CRITERIA.....32

 3.2.1 Qualifying Roads32

 3.2.2 Relationship to the Roadway Asset33

 3.2.3 Wall Function.....33

 3.2.4 Wall Height.....33

 3.2.5 Wall Embedment34

 3.2.6 Wall Face Angle35

 3.2.7 Qualifying Wall Examples.....35

CHAPTER 4 – WALL DATA COLLECTION GUIDELINES	39
4.1 WALL LOCATION DATA	41
4.1.1 Park Name.....	41
4.1.2 Inspected By.....	41
4.1.3 Route/Parking No.....	41
4.1.4 Route/Parking Name.....	42
4.1.5 Side of Centerline	42
4.1.6 Visidata Event Milepoint	42
4.1.7 Wall Start/End Milepoint.....	42
4.1.8 Wall Start Latitude/Longitude	43
4.1.9 WIP Wall ID	43
4.1.10 Wall Location Examples.....	43
4.2 WALL DESCRIPTION DATA.....	45
4.2.1 Wall Function.....	45
4.2.2 Primary Wall Type.....	53
4.2.3 Secondary Wall Type(s)	69
4.2.4 Approximate Year Built.....	69
4.2.5 Architectural Facings.....	70
4.2.6 Surface Treatments	76
4.2.7 Wall General Description Notes	80
4.2.8 Wall Length	80
4.2.9 Maximum Wall Height	80
4.2.10 Wall Face Area	81
4.2.11 Vertical Offset.....	81
4.2.12 Wall Start/End Offset.....	82
4.2.13 Face Angle	82
4.2.14 Photo Description/No.....	82
4.2.15 Park Designated Wall ID	83
4.3 WALL CONDITION ASSESSMENT	83
4.3.1 Wall Element and Overall Performance Definitions	84
4.3.2 Minimum Element Rating Requirements	95
4.3.3 Element Condition Narrative Guidance.....	96
4.3.4 Element Condition Rating Definitions	99
4.3.5 Weighting Factors.....	101
4.3.6 Data Reliability Factors	102
4.4 WALL ACTION ASSESSMENT	102
4.4.1 Final Wall Condition Rating.....	104
4.4.2 Investigation Requirements	104
4.4.3 Design Criteria.....	104
4.4.4 Cultural Concerns	105
4.4.5 Failure Consequence.....	105

4.4.6 Recommended Action.....	106
4.5 WORK ORDER DEVELOPMENT	110
4.5.1 Brief Work Order Description	111
4.5.2 Repair/Replace Recommendations/Cost.....	111
CHAPTER 5 – FUTURE WIP DEVELOPMENT	113
APPENDIX A – PRE-FIELD DOCUMENTS AND FORMS	117
Pre-Inventory Phone Interview Checklist	
Park Notification Letter	
Kick-Off Meeting Agenda	
Retaining Wall Questionnaire	
RIP Route Identification Report – Example	
Visidata Preliminary Wall Location Form	
Documents and Equipment Checklist	
APPENDIX B – FIELD DOCUMENTS AND FORMS	129
Retaining Wall Reconnaissance Form	
Field Inspection Form	
WIP Field Guide	
WIP Cost Guide	
Visidata Quick Start Guide	
APPENDIX C – POST-FIELD DOCUMENTS AND FORMS	149
Park Summary Letter	
FMSS Specification Data Template	
FMSS Data Input Procedures and Test Guide	
APPENDIX D – DATABASE DOCUMENTS	161
WIP Database Users Manual	

LIST OF FIGURES

Figure 1. Photo. Two-man inventory team at Mount Rainier National Park..... 1

Figure 2. Photo. Culturally significant culvert headwall at Acadia National Park.....3

Figure 3. Photo. Rope training for safely accessing walls.....8

Figure 4. Graphic. Four basic WIP activities categories 10

Figure 5. Graphic. Visidata screen shot 12

Figure 6. Photo. Multi-tiered soil nail wall with decorative modular block facing..... 15

Figure 7. Graphic. Example of a RIP Route Inventory Report..... 17

Figure 8. Photo. Vehicle safety during field inventories 20

Figure 9. Photo. Inventory team members working together to define wall attributes/elements .. 23

Figure 10. Graphic. The WIP database 3-page architecture 26

Figure 11. Photo. Example of borderline wall acceptance case 30

Figure 12. Photo. A qualifying culvert headwall..... 33

Figure 13. Photo. Slope protection wall at Haleakala National Park..... 34

Figure 14. Photo. A mid-slope wire-faced MSE wall that just meets the height criterion 36

Figure 15. Photo. Fill wall at Colorado National Monument 38

Figure 16. Photo. An example of parking area walls at Capulin Volcano National Monument ... 43

Figure 17. Photo. A gabion gravity fill wall under construction below roadway grade..... 44

Figure 18. Photo. A mortared stone masonry cut wall at Rocky Mountain National Park 45

Figure 19. Photo. Example of a stone masonry wall supporting the bridge approach 46

Figure 20. Photo. Example of bridge approach walls to be included in the WIP inventory..... 47

Figure 21. Photo. Example of bridge approach walls to be included in the WIP inventory..... 47

Figure 22. Photo. Example of secondary bridge walls to be included in the WIP inventory. 48

Figure 23. Photo. A mortared stone masonry fill wall with a large arched culvert 49

Figure 24. Photo. Switchback wall at Sequoia National Park 49

Figure 25. Photo. Seawall at Sandy Hook unit, Gateway National Recreation Area 50

Figure 26. Photo. Slope protection system at Rocky Mountain National Park 51

Figure 27. Photo. Timber-lagged soldier pile tieback wall at Mesa Verde National Park 53

Figure 28. Photo. Micropile tieback wall prior to shotcrete facing finish 53

Figure 29. Photo. Steel sheet piling with bar ground anchors placed through steel walers..... 54

Figure 30. Photo. Precast hollow concrete “bin” blocks with a formlined architectural facing..... 55

Figure 31. Photo. Heavily corroded metal bin wall at Golden Gate National Recreation Area..... 55

Figure 32. Photo. Cast-in-place concrete cantilever walls serving as wingwall structures 56

Figure 33. Photo. Timber-lagged, soldier pile fill wall at Olympic National Park..... 56

Figure 34. Photo. Cantilever steel sheet pile cut wall with “deadman” anchors 57

Figure 35. Photo. Concrete crib wall at Sequoia National Park 58

Figure 36. Photo. Metal crib wall at Mesa Verde National Park..... 58

Figure 37. Photo. Timber crib wall at Yellowstone National Park..... 59

Figure 38. Photo. Tall painted brick wall at Golden Gate National Recreation Area 59

Figure 39. Photo. Painted concrete gravity wall at Golden Gate National Recreation Area.....60

Figure 40. Photo. Dry-laid stone masonry wall at Yellowstone National Park.....61

Figure 41. Photo. Well-constructed, angular rock fill gabion wall at the Blue Ridge Parkway....61

Figure 42. Photo. Mortared stone masonry head wall along the Blue Ridge Parkway62

Figure 43. Photo. Multi-tiered, plantable, geosynthetic wrapped MSE wall.....63

Figure 44. Photo. Precast panel MSE wall at Great Smoky Mountains National Park63

Figure 45. Photo. Segmental block wall at Bryce Canyon National Park64

Figure 46. Photo. Wire-faced MSE wall at Colorado National Monument.....64

Figure 47. Photo. Soil nail wall at Yellowstone National Park65

Figure 48. Photo. Tangent pile cut wall constructed of drilled shafts66

Figure 49. Photo. Geosynthetic reinforced earth wall with planted geocell facing.....66

Figure 50. Photo. Segmental concrete “T” wall at Zion National Park67

Figure 51. Photo. “Fractured Fin” formliner architectural facing69

Figure 52. Photo. Rough wood formliner at Golden Gate National Recreation Area69

Figure 53. Photo. Well-vegetated wire-faced MSE wall in Siskiyou National Forest71

Figure 54. Photo. Dramatic example of sculpted shotcrete facing71

Figure 55. Photo. Single-course, mortared stone facing in front of an MSE wall structure.....72

Figure 56. Photo. Simulated stone, deep-inset formliner and individually stained rock units73

Figure 57. Photo. Timber-faced soil nail wall73

Figure 58. Photo. Concrete blocks textured with a bush hammer prior to placement.....75

Figure 59. Photo. Float-finished, colored shotcrete applied over an MSE wall facing75

Figure 60. Photo. Severe weathering distress on painted steel sheet piling76

Figure 61. Photo. Sculpted shotcrete stained to match the surrounding landscape77

Figure 62. Photo. Weathering steel, sold under the “CORTEN” trademark77

Figure 63. Graphic. Required field measurements79

Figure 64. Photo. Galvanized MSE wall facing system83

Figure 65. Photo. Severely weathered reinforced concrete headwall.....84

Figure 66. Photo. Examples of mortar applications.....84

Figure 67. Photo. A mortared stone masonry headwall along the Blue Ridge Parkway85

Figure 68. Photo. Examples of deteriorating wall foundation conditions86

Figure 69. Photo. Plugged “weep hole” drain at bottom of mortared stone masonry wall87

Figure 70. Photo. Parapet damage at Glacier National Park.....88

Figure 71. Photo. Timber crib wall fill settlement and bearing failure.....88

Figure 72. Photo. Example of “Upslope” secondary element90

Figure 73. Photo. MSE wall at Glacier National Park awaiting final facing.....90

Figure 74. Photo. Tree damage to retaining walls91

Figure 75. Photo. Overturning stone masonry wall at Great Smoky Mountains National Park....92

Figure 76. Photo. Developing wall problems at New River Gorge National River93

Figure 77. Graphic. Required wall assessment and rating elements per WIP wall type94

Figure 78. Photo. Concrete crib wall obscured by heavy vegetation.....101

Figure 79. Photo. New rockery wall along Guanella Pass Road, CO.....103

Figure 80. Photo. Stone masonry-faced MSE wall at Bryce Canyon National Park.....104
Figure 81. Photo. Culvert headwall along the Baltimore-Washington Parkway106
Figure 82. Photo. Cast-in-place gravity wall at Steamtown National Historic Site106
Figure 83. Photo. Dry-laid stone masonry elements in need of replacement107
Figure 84. Photo. Severely corroded metal bin wall.....107

LIST OF TABLES

Table 1. WIP wall functions and associated field inventory codes44

Table 2. WIP wall types and associated field inventory codes.....52

Table 3. WIP architectural facing types and associated field inventory codes.....68

Table 4. WIP surface treatment types and associated field inventory codes74

Table 5. Condition narrative guidance for typical wall element distresses95

Table 6. Primary and secondary wall element numerical condition rating definitions98

Table 7. Wall performance rating definitions99

Table 8. Data reliability definitions100

ACRONYMS

Acronym	Definition	Acronym	Definition
AASHTO	American Association of State Highway Transportation Officials	HALE	Haleakala National Park
ACAD	Acadia National Park	HOSP	Hot Springs National Park
ADT	Average Daily Traffic	IMR	Intermountain Region
AKR	Alaska Region	LCS	List of Classified Structures
BAWA	Baltimore Washington Parkway	MEVE	Mesa Verde National Park
BIP	NPS Bridge Inspection Program	MORA	Mount Rainier National Park
BISO	Big South Fork National River and Recreation Area	MSE	Mechanically Stabilized Earth
BLRI	Blue Ridge Parkway	MWR	Midwest Region
BRCA	Bryce Canyon National Park	NATR	Natchez Trace National Park
CAVO	Capulin Volcano National Monument	NBIS	National Bridge Inventory System
CFLHD	Central Federal Lands Highway Division	NCR	National Capital Region
CMU	Concrete Masonry Unit	NER	North East Region
COLM	Colorado National Monument	NPS	National Park Service
CRLA	Crater Lake National Park	OLYM	Olympic National Park
CRV	Cost-to-Replace Value	PWR	Pacific West Region
DEWA	Delaware Water Gap National Recreation Area	QA	Quality assurance
DOT	Department of Transportation	QC	Quality control
EFLHD	Eastern Federal Lands Highway Division	RIP	NPS Road Inventory Program
ERFO	Emergency Relief for Federally Owned Roads	ROMO	Rocky Mountain National Park
FCI	Facility Condition Index	SEKI	Sequoia and Kings Canyon National Parks
FHWA	Federal Highway Administration	SER	Southeast Region
FLHD	Federal Lands Highway Division	SHEN	Shenandoah National Park
FMSS	Facility Management Software System	UV	Ultraviolet Radiation
FTP	File Transfer Protocol	WASO	Washington Administrative Support Office
FW	Fill Wall	WFLHD	Western Federal Lands Highway Division
GLAC	Glacier National Park	WICA	Wind Cave National Park
GOGA	Golden Gate National Recreation Area	WIP	Wall Inventory Program
GPS	Global Positioning System	YELL	Yellowstone National Park
GRSM	Great Smoky Mountains National Park	YOSE	Yosemite National Park
GWMP	George Washington Memorial Parkway	ZION	Zion National Park

ACKNOWLEDGEMENTS

The NPS Retaining Wall Inventory and Assessment Team would like to thank Mr. Butch Wlaschin, Director, Federal Highway Administration Office of Asset Management, and Mr. Mark Hartsoe, Chief, National Park Service Park Roads and Parkways Program, for their support and guidance throughout the development and implementation of this valuable program. In addition, we would especially like to thank the numerous Park Superintendents, Facility Managers, Resource and Maintenance staff throughout the inventory parks for their enthusiastic participation, support and safe implementation of the WIP. Finally, we would also like to thank the FHWA Resource Center and Federal Lands Highway Division technical and management staffs for their efforts to merge cross-functional skills across division offices for the successful delivery of the first-ever earth retaining structure inventory and condition assessment in our nation's national parks.

