TABLE OF CONTENTS

Page

1.0 INTRODUCTION 1-1

2.0 REPORT FORMAT 2-1

3.0 STUDY PURPOSE AND NEED 3-1

4.0 PRIOR STUDIES, REPORTS AND EXISTING WATER PROJECTS 4-1

4.1 Controlled Notch in Crest of Dam Controlled by Inflatable Bladder 4-1
4.2 Engineered Fishway Around South Abutment of Existing Dam 4-3
4.3 Partial Diversion Dam 4-4
4.4 Island – South Channel Passage 4-6
4.5 Raceway Notch Fish Passage 4-8
4.6 Rock Ramp (Preferred Alternative, February 2009 Study) 4-9
4.6.1 Streambed Reconfiguration (Boulder Weir) 4-9
4.6.2 Streambed Reconfiguration (U-Shaped) 4-11
4.7 Summary of Alternatives Comparison 4-11

5.0 PLANNING PROCESS 5-1

5.1 Introduction 5-1
5.2 Step 1 - Problems and Opportunities 5-1
5.2.1 Problems 5-1
5.2.2 Opportunities 5-1
5.2.3 Planning Objectives 5-2
5.2.4 Constraints 5-2
5.3 Step 2 - Inventory and Forecast 5-2
5.3.1 Introduction 5-2
5.3.2 Inventory of Existing Conditions 5-2
5.3.3 Future without Project Conditions 5-3
5.3.3.1 Water Supply 5-4
5.3.3.2 Conservation and Ecology 5-5
5.3.3.3 Public Safety 5-5
5.3.3.4 Boat Passage 5-5
5.4 Step 3 - Formulation of Alternative Plans 5-5
5.4.1 Introduction 5-5
5.4.2 Pre-Design Site Assessment 5-6
5.4.2.1 Field Survey 5-6
5.4.2.2 Hydrology 5-6
5.4.2.3 Hydraulics 5-6
5.4.2.4 Floodplain 5-11
5.4.3 Design Approach 5-11
5.4.4 Sturgeon Swimming Abilities and Implications for Passage Design 5-18
5.4.4.1 Sturgeon Ecology and Swimming Behavior 5-18
5.4.4.2 Identification of Yellowstone River Slope Anomalies and Potential Rock Ramp Design Analogs 5-25

5.4.5 Hydraulic Conditions at Natural Design Analogs During Known Passage Events ... 5-36
5.4.5.1 Discharge Range ... 5-36
5.4.5.2 Mean Velocity ... 5-39
5.4.5.3 Roughness ... 5-40
5.4.5.4 Variability / Pathways ... 5-41
5.4.5.5 Slope and Slope Length ... 5-44
5.4.6 Fish Passage Design Criteria ... 5-44
5.4.6.1 Mean Velocity ... 5-45
5.4.6.2 Roughness ... 5-45
5.4.6.3 Variability / Pathways ... 5-45
5.4.6.4 Maximum Bed Slope ... 5-45
5.4.6.5 Length of Maximum Slope ... 5-45
5.4.6.6 Design Criteria ... 5-45
5.4.7 Biological Review Team Scoring Criteria ... 5-46
5.4.8 Plans ... 5-50
5.4.8.1 Alternative 1: Rock Ramp ... 5-50
5.4.8.2 Alternative 2: Inflatable Bladder ... 5-68
5.4.8.3 Alternatives Considered But Rejected ... 5-71
5.5 Step 4 - Evaluation of Alternative Plans ... 5-71
5.5.1 Acceptability ... 5-72
5.5.2 Completeness ... 5-72
5.5.3 Effectiveness ... 5-72
5.5.4 Efficiency ... 5-72
5.5.5 Cost Effectiveness and Incremental Cost ... 5-72
5.5.5.1 Potential Solutions ... 5-73
5.5.5.2 Cost Effectiveness ... 5-73
5.5.5.3 Incremental Cost ... 5-73
5.5.5.4 Evaluation Criteria ... 5-73
5.5.6 Significance of Ecosystem Outputs ... 5-74
5.5.6.1 Institutional Recognition ... 5-74
5.5.6.2 Public Recognition ... 5-74
5.5.6.3 Technical Recognition ... 5-75
5.5.7 Risk and Uncertainty ... 5-76
5.6 Step 5 - Plan Comparison ... 5-76
5.7 Step 6 - Selection of Ecosystem Restoration Plan ... 5-77

6.0 AFFECTED ENVIRONMENT ... 6-1
6.1 Introduction ... 6-1
6.2 Ecological Resources ... 6-1
6.2.1 Introduction ... 6-1
6.2.2 Hydrology ... 6-1
6.2.2.1 Introduction ... 6-1
6.2.2.2 Method ... 6-2
6.2.2.3 Existing Conditions ... 6-2
6.2.3 Geomorphology ... 6-2
6.2.3.1 Method ... 6-2
6.2.3.2 Existing Conditions ... 6-2
6.2.3.3 Sediment Sourcing From Upstream Cutoffs ... 6-3
6.2.4 Federally-Listed Species and State Species of Special Concern ... 6-11
6.2.4.1 Introduction ... 6-11
6.2.4.2 Method ... 6-11

6.2.4.3 Existing Conditions 6-11
6.2.5 Lands and Vegetation 6-25
6.2.5.1 Introduction 6-25
6.2.5.2 Method 6-25
6.2.5.3 Existing Conditions 6-25
6.2.6 Aquatic Assemblages 6-28
6.2.6.1 Introduction 6-28
6.2.6.2 Methods 6-28
6.2.6.3 Existing Conditions 6-28
6.2.7 Recreation 6-31
6.2.7.1 Introduction 6-31
6.2.7.2 Methods 6-31
6.2.7.3 Existing Conditions 6-31
6.3 Cultural Resources 6-32
6.3.1 Introduction 6-32
6.3.2 Method 6-32
6.3.3 Existing Conditions 6-32
6.4 Aesthetic Resources 6-33
6.4.1 Introduction 6-33
6.4.2 Method 6-33
6.4.3 Existing Conditions 6-33
6.5 Water Quality 6-33
6.5.1 Introduction 6-33
6.5.2 Method 6-33
6.5.3 Existing Conditions 6-33
6.5.3.1 Suspended Sediment 6-34
6.5.3.2 Dissolved Solids 6-36
6.5.3.3 Pesticides 6-37
6.5.3.4 Nitrates 6-37
6.6 Air Quality 6-38
6.6.1 Introduction 6-38
6.6.2 Method 6-38
6.6.3 Existing Conditions 6-38

7.0 ENVIRONMENTAL CONSEQUENCES 7-1
7.1 Introduction 7-1
7.2 Adaptive Management 7-1
7.3 Ecological Resources 7-1
7.3.1 Hydrology 7-1
7.3.1.1 Introduction 7-1
7.3.1.2 Methods 7-1
7.3.1.3 Results 7-1
7.3.1.4 Cumulative Effects 7-1
7.3.1.5 Environmental Mitigation 7-1
7.3.1.6 Summary 7-2
7.3.2 Geomorphology 7-2
7.3.2.1 Introduction 7-2
7.3.2.2 Methods 7-2
7.3.2.3 Results 7-2
7.3.2.4 Cumulative Effects 7-4
7.3.2.5 Environmental Mitigation 7-4

7.3.2.6 Summary 7-4
7.3.3 Federally-Listed Species and State Species of Special Concern 7-4
7.3.3.1 Introduction 7-4
7.3.3.2 Methods 7-5
7.3.3.3 Results 7-5
7.3.3.4 Cumulative Effects 7-8
7.3.3.5 Environmental Mitigation 7-8
7.3.3.6 Summary 7-9
7.3.4 Lands and Vegetation 7-9
7.3.4.1 Introduction 7-9
7.3.4.2 Methods 7-9
7.3.4.3 Results 7-9
7.3.4.4 Cumulative Effects 7-10
7.3.4.5 Environmental Mitigation 7-10
7.3.4.6 Summary 7-10
7.3.5 Aquatic Assemblages 7-11
7.3.5.1 Introduction 7-11
7.3.5.2 Methods 7-11
7.3.5.3 Results 7-11
7.3.5.4 Cumulative Effects 7-15
7.3.5.5 Summary 7-15
7.3.6 Recreation 7-15
7.3.6.1 Introduction 7-15
7.3.6.2 Methods 7-15
7.3.6.3 Results 7-15
7.3.6.4 Cumulative Effects 7-16
7.3.6.5 Environmental Mitigation 7-16
7.3.6.6 Summary 7-18
7.4 Cultural Resources 7-18
7.4.1 Introduction 7-18
7.4.2 Methods 7-18
7.4.3 Results 7-19
7.4.3.1 No Action 7-19
7.4.3.2 Rock Ramp Alternative 7-19
7.4.4 Cumulative Effects 7-19
7.4.5 Environmental Mitigation 7-19
7.4.6 Summary 7-19
7.5 Aesthetic Resources 7-19
7.5.1 Introduction 7-19
7.5.2 Methods 7-19
7.5.3 Results 7-20
7.5.3.1 No Action 7-20
7.5.3.2 Rock Ramp Alternative 7-20
7.5.4 Cumulative Effects 7-20
7.5.5 Environmental Mitigation 7-20
7.5.6 Summary 7-20
7.6 Surface Water Quality 7-20
7.6.1 Introduction 7-20
7.6.2 Methods 7-20
7.6.3 Results 7-21
7.6.3.1 Suspended Sediment 7-21
7.6.3.2 Dissolved Solids, Pesticides, and Nutrients 7-21

7.6.4 Cumulative Effects 7-22
7.6.5 Environmental Mitigation 7-22
7.6.6 Summary 7-22
7.7 Air Quality 7-22
7.7.1 Introduction 7-22
7.7.2 Methods 7-22
7.7.3 Results 7-22
7.7.3.1 No Action 7-22
7.7.3.2 Rock Ramp Alternative 7-23
7.7.4 Cumulative Effects 7-23
7.7.5 Environmental Mitigation 7-23
7.7.6 Summary 7-23

8.0 DESCRIPTIONS OF SELECTED PLAN 8-1
8.1 Plan Components; including mitigation 8-1
8.2 Design and Construction Considerations 8-1
8.2.1 Design 8-1
8.2.2 Construction 8-1
8.3 LERRD Considerations 8-2
8.4 Operation and Maintenance Considerations 8-2
8.5 Plan Accomplishments 8-2
8.6 Summary of Economic, Environmental and Other Social Effects 8-2

9.0 PLAN IMPLEMENTATION 9-1
9.1 Institutional Requirements 9-1
9.2 Division of Plan Responsibilities, Cost Sharing and Other Non-Federal Responsibilities 9-1
9.3 Views of Non-Federal Sponsor(s) and Any Other Agencies 9-1

10.0 CONSULTATION AND COORDINATION 10-1
10.1 Public Involvement Program 10-1
10.2 Cooperating Agency Team 10-1
10.3 Meetings 10-1
10.4 Endangered Species Act Consultation 10-1
10.5 Coordination and Compliance with Other Applicable Laws, Regulations, and Policies 10-1
10.5.1 Clean Water Act of 1977 10-2
10.5.2 Farmland Protection Policy Act of 1995 10-2
10.5.3 Fish and Wildlife Coordination Act of 1958 10-2
10.5.4 Migratory Bird Treaty Act and Executive Order 13186 10-3
10.5.5 National Historic Preservation Act of 1966 10-3
10.5.6 Rivers and Harbors Appropriation Act of 1899 10-4
10.5.7 Executive Order 13112 for Invasive Species 10-4
10.5.8 Other Executive Orders 10-4
10.5.9 State Water Rights 10-4
10.5.10 Montana Environmental Policy Act 10-5
10.5.11 Stream Protection Act 10-5
10.5.12 Short-Term Water Quality Standards for Turbidity (318) 10-5
10.5.13 Montana Land-Use License of Easement on Navigable Waters 10-6
10.5.14 Stormwater Discharge General Permits 10-6

10.5.15 401 Water Quality Certification for Other Federal Permits and Licenses 10-6
10.6 List of Preparers 10-7
10.7 Distribution List 10-7

11.0 RECOMMENDATIONS 11-1

12.0 LITERATURE CITED 12-1

LIST OF TABLES

Table 5-1 Potential Reference Reaches 5-26
Table 5-2 Statistical Summary of Matthews Rapid Boulder Measurements 5-30
Table 5-3 Hydraulic Analysis Results for Matthews Rapid 5-39
Table 5-4 Hydraulic Analysis Results for Wolf Rapid 5-39
Table 5-5 Maximum Roughness Values for Similar Discharges at Matthews Rapid and Wolf Rapid 5-41
Table 5-6 Water Velocities and Depths for Potential Fish Passage Pathways at Wolf Rapid 5-42
Table 5-7 Water Velocities and Depths for Potential Fish Passage Pathways at Matthews Rapid 5-43
Table 5-8 Rock Ramp Design Criteria 5-46
Table 5-9 Average Depths and Percentage of All Depths Exceeding 1 m for Cross-Sections Surveyed at Matthews and Wolf Rapids on the Yellowstone River in September 2009 5-49
Table 5-10 Rock Ramp Division of Flows 5-53
Table 5-11 Rock Ramp Estimated Costs 5-68
Table 5-12 Inflatable Bladder Estimated Cost 5-71
Table 6-1 Measured Extent of Two Primary Mid-Channel Bars Downstream of Cartersville Dam Through Time 6-10
Table 6-2 Species of Special Concern in the Vicinity of Cartersville Dam (Montana Natural Heritage Program) 6-12
Table 6-3 Soil Characteristics and Descriptions 6-27
Table 7-1 Bank Protection Inventory, Reach C10 7-3

LIST OF FIGURES

Figure 1-1 Location and Vicinity Map 1-2
Figure 1-2 Cartersville Irrigation Dam from South Bank 1-3
Figure 1-3 State Park, Boat Ramp, Fishing Access, Island Downstream of Dam 1-3
Figure 1-4 Cartersville Irrigation District Headgate, North Bank 1-4
Figure 1-5 State Park on South Bank 1-4
Figure 4-1 Inflatable Dam, February 2009 4-2
Figure 4-2 Location of Proposed Fishway 4-4
Figure 4-3 Muggli Fishway on the Tongue River (similar to proposed) 4-4
Figure 4-4 Partial Diversion Dam 4-5
Figure 4-5 Island – South Channel Passage 4-6
Figure 4-6 Raceway Notch Fish Passage 4-8
Figure 4-7 U-Shaped Rock Ramp 4-10
Figure 4-8 Boulder Weir 4-10

Figure 4-9 Summary of Alternatives, February 2009 4-12
Figure 4-10 Summary of Participant Rankings, February 2009 4-13
Figure 5-1 Cartersville Dam Viewed From the Right (South) Bank During Low Discharge. 5-3
Figure 5-2 Movement of Shovelnose Sturgeon 5-4
Figure 5-3 Plan and Profile of Existing Channel Condition 5-7
Figure 5-4 USGS Gage Yellowstone R. at Forsyth (Scientific Investigations Rpt 2004-5266) 5-8
Figure 5-5 Surveyed River Cross Sections 5-9
Figure 5-6 HEC RAS Calibrated Profile, North Channel 5-10
Figure 5-7 HEC-RAS Calibrated Profile, South Channel 5-10
Figure 5-8 Existing Velocity (ft/s) Q = 6500 cfs 5-12
Figure 5-9 Cartersville Dam North Channel Model Calibration 5-13
Figure 5-10 Cartersville Dam South Channel Model Calibration 5-14
Figure 5-11 Floodplain Map for the City of Forsyth 5-15
Figure 5-12 Floodplain Map for Rosebud County 5-16
Figure 5-13 Solutions for Fish Passage 5-17
Figure 5-14 Stream Simulation (geomorphic approach) Process Flowchart 5-17
Figure 5-15 2007 Aerial Photograph of Matthews Rapid 5-27
Figure 5-16 LiDAR-Derived Water Surface Profile, Matthews Rapid 5-27
Figure 5-17 Water Surface Slope Calculated at 100-ft Increments, Matthews Rapid 5-28
Figure 5-18 Matthews Rapid Looking North From the Right (southern) Bank 5-28
Figure 5-19 View From Right (southern) Bank Showing Steep Section of Matthews Rapid with Course Boulder Field in Foreground. 5-29
Figure 5-20 Box and Whisker Plot Showing Distribution of Boulder Measurements at Matthews Rapid; Minimum, Mean, and Max Values for Each Axis are Labeled 5-30
Figure 5-21 Histogram Showing Frequency of Number of Occurrences for Boulder Axis Measurements, Matthews Rapid 5-30
Figure 5-22 2007 Aerial Photograph of Wolf Rapid, RM 146 5-31
Figure 5-23 LiDAR-Derived Water Surface Profile, Wolf Rapid 5-32
Figure 5-24 Water Surface Slope Calculated at 100-ft Increments, Wolf Rapid 5-32
Figure 5-25 Wolf Rapid Looking Northwest From the Right (southeast) River Bank 5-33
Figure 5-26 Cross-Sections (green lines) and Profiles (blue lines) Surveyed at Matthews Rapid and Wolf Rapid 5-34
Figure 5-27 Surveyed Stream Bed Profile, Matthews Rapid, Broken Into Two Slope Segments 5-35
Figure 5-28 Surveyed Stream Bed Profile, Wolf Rapid, Broken Into Three Slope Segments 5-36
Figure 5-29 Matthews Rapid Calibration Profile 5-37
Figure 5-30 Matthews Rapid Velocity Profile (ft/s), Q = 7490 ft/s 5-38
Figure 5-31 Movements of Shovelnose Sturgeon 5-38
Figure 5-32 ADCP velocity measurement points (light green points) and potential fish passage pathways (brown lines) through Matthews Rapid and Wolf Rapids. 5-44
Figure 5-33 Rock Ramp, Slope 0.5% / 0.2% /0.5%, Option 1 5-52
Figure 5-34 Mean Column Velocities (ft/s), Q = 2700 cfs, Option 1 5-54
Figure 5-35 Mean Column Velocities (ft/s), Q = 6500 cfs, Option 1 5-54
Figure 5-36 Mean Column Velocities (ft/s), Q = 48,800 cfs, Option 1 5-55
Figure 5-37 Water Depth (ft), Q = 2700 cfs, Option 1 5-55
Figure 5-38 Water Depth (ft), Q = 6500 cfs, Option 1 5-56
Figure 5-39 Water Depth (ft), Q = 48,800 cfs, Option 1 5-56
Figure 5-40 North Channel Proposed Design, Option 1 5-57
Figure 5-41 North and South Channel Cross Section, Option 1 5-58
Figure 5-42 Rock Ramp, Slope 0.5%, Option 2 5-59
Figure 5-43 Mean Column Velocities (ft/s), Q=2700 cfs, Option 2 5-60
Figure 5-44 Mean Column Velocities (ft/s), Q=6500 cfs, Option 2 5-60
Figure 5-45 Mean Column Velocities (ft/s), Q=48,800 cfs, Option 2 5-61

Figure 5-46 Water Depth (ft), Q=2700 cfs, Option 2 5-61
Figure 5-47 Water Depth (ft), Q=6500 cfs, Option 2 5-62
Figure 5-48 Water Depth (ft), Q=48,800 cfs, Option 2 5-62
Figure 5-49 North Channel Proposed Design, Option 2 5-63
Figure 5-50 North and South Channel Cross Section, Option 2 5-64
Figure 5-51 Rock Ramp, Slope 0.5% / 1.27%, Option 3 5-65
Figure 5-52 Riprap 5-66
Figure 5-53 Location of Riprap Sources 5-67
Figure 5-54 Plan and Profile of Inflatable Bladder Alternative 5-69
Figure 5-55 Obermeyer Gate 5-70
Figure 6-1 Aerial Photograph of Yellowstone River Above Cartersville Dam 6-3
Figure 6-2 Yellowstone River at Cartersville Dam Showing (left to right), 1950, 1976, 2001, and 2007 Conditions 6-4
Figure 6-3 Yellowstone River at Cartersville Dam, 2007 Showing Areas of Bendway Cutoff and Downstream Deposition 6-5
Figure 6-4 Hammond Valley Bendway Cutoff Between 1976 (left) and 2001 (right) 6-6
Figure 6-5 1950-2001 Bank Erosion (red arrows), Showing Island Growth and Bank Retreat Downstream of Cartersville Dam. Blue Lines are 1950 Bankfull Boundaries 6-7
Figure 6-6 Close Up View of 1950-2001 Bank Erosion (red arrows) Immediately Downstream of Cartersville Dam. Blue Lines are 1950 Bankfull Boundaries 6-8
Figure 6-7 Measured Bankline Migration Rates Immediately Downstream of Cartersville Dam 6-9
Figure 6-8 Exposed Area of Mid-Channel Bars Downstream of Cartersville Dam 6-10
Figure 6-9 Cartersville Dam Study Area 6-26
Figure 6-10 Extent of NRCS Mapped Soil Series 6-27
Figure 6-11 Yellowstone River Suspended Sediment Concentration Values Measured at Forsyth, 1978-1981 6-35
Figure 6-12 Yellowstone River Suspended Sediment Discharge Values Measured at Forsyth, 1978-1981 6-35
Figure 6-13 Statistical Summary of Suspended Sediment Concentrations for Yellowstone River Basin Sites, 1999-2001; YF is Yellowstone River at Forsyth (Miller, et al, 2004) 6-36
Figure 6-14 Statistical Summary of Dissolved Solids Concentrations for Yellowstone River Basin Sites, 1999-2001; YF is Yellowstone River at Forsyth (Miller, et al, 2004) 6-37
Figure 6-15 Summary of Pesticide and Nitrate Detections in Yellowstone River Near Forsyth, 1999-2004 (http://agr.mt.gov) 6-38
Figure 7-1 Ownership Map for New Boat Ramp 7-17
Figure 7-2 Location of New Boat Ramp 7-18

LIST OF APPENDICES

Appendix A Sturgeon Movement Data
Appendix B Correspondence

LIST OF ABBREVIATIONS

%	-	percent
‘	-	foot (feet)
<	-	less than
ADCP	-	acoustic Doppler current profiler
BNSF	-	Burlington Northern Santa Fe
BRT	-	biological review team
CES	-	Cumulative Effects Study
cfs	-	cubic feet per second
DEQ	-	Department of Environmental Quality
FWCA	-	Fish and Wildlife Coordination Act
FWP	-	Department of Fish, Wildlife and Parks
EA	-	Environmental Assessment
ESA	-	Endangered Species Act
F	-	Fahrenheit
FL	-	fork length
FOB	-	Freight on Board
ft	-	feet
ft^2	-	feet squared, square feet
ft/s	-	feet per second
FWP	-	Fish, Wildlife and Parks
GIS	-	geographic information system
Jan	-	January
Jul	-	July
km/h	-	kilometers per hour
LERRD	-	Lands, easements, rights-of-way, relocations, and disposal areas
LiDAR	-	Light Detection and Ranging
M	-	meters
Mar	-	March
Max	-	maximum
MEPA	-	Montana Environmental Policy Act
MFISH	-	Montana Fisheries Information System
mg/l	-	Milligrams per liter
MNHP	-	Montana Natural Heritage Program
MRL	-	Montana Rail Link
MT	-	Montana
NEPA	-	National Environmental Policy Act
Nov	-	November
NRCS	-	Natural Resources and Conservation Service
NWI	-	National Wetland Inventory
O&M	-	Operation and Maintenance
OM&R	-	Operation, Maintenance and Replacement
P&G	-	Principals and Guidelines
psf	-	pounds per square foot
RM	-	river mile
SHPO	-	State Historic Preservation Office
sq. mi.	-	square mile
TMDL	-	Total Maximum Daily Load

U.S.	-	United States
USACE	-	United States Army Corp of Engineers
USFWS	-	United States Fish and Wildlife Service
USGS	-	United States Geological Survey
WAPA	-	Western Area Power Administration
WRDA	-	Water Resource Development Act
XS	-	cross section