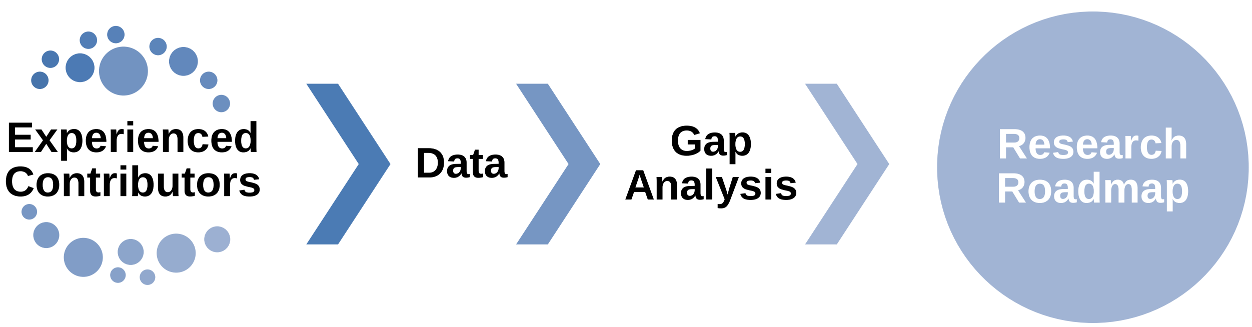
RECLAMATION

Managing Water in the West

Technical Memorandum No. MERL-2014-53

Research Roadmapping Method & Pilot Study



U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Materials Engineering and Research Laboratory
Denver, Colorado

May 2014

MISSION STATEMENTS

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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BUREAU OF RECLAMATION
Technical Service Center, Denver, Colorado
Materials Engineering and Research Laboratory, 86-68180

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Research Roadmapping Method & Pilot Study

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ACKNOWLEDGMENTS

The authors gratefully acknowledge the Bureau of Reclamation Research & Development Office Science & Technology Program for the funding and guidance received throughout this project (Project ID 4022).

ACRONYMS AND ABBREVIATIONS

O&M	Operations & Maintenance

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EXECUTIVE SUMMARY

The original proposal for project ID 4022 was for the evaluation of structural health monitoring (SHM) techniques or technologies to improve Reclamation's infrastructure sustainability. The proposal instead received conditional funding to proceed with a research roadmapping project on the subject of aging infrastructure sustainability. The roadmapping goal is to identify research gaps and determine where future research efforts should focus to provide the greatest benefit.

The first stage in this project was to develop a roadmapping approach. This proceeded under the guidance of the Research & Development Office and by the examples of recent roadmapping efforts:

- *Addressing Climate Change in Long-Term Water Resources Planning and Management* [1]
- *Desalination and Water Purification Technology Roadmap* [2]

The roadmapping effort adopted Reclamation's categorization of its mission critical assets: Dams, Canals, Pipelines, Powerplants, and Pumping Plants. This allowed for detailed evaluations of each type of infrastructure as well as more effective targeting of technical and field personnel for the committee and surveys. The "Powerplants" category will be included in the Hydropower Roadmapping project.

An FY 13 pilot study of "Pipelines" tested the roadmapping method. This pilot study led to several improvements; most notably, the technical and field personnel will be surveyed concurrently during the remaining studies. These survey results, combined with the committee's prioritization of them, become the draft roadmap. This streamlines the roadmapping process significantly. Therefore, the Pipeline survey should be extended to field personnel prior to the development and prioritization of the draft roadmap.

The current schedule places the Dams, Canals, and Pumping Plants draft roadmapping efforts during FY 14. The scheduled project completion is for FY 15, following the compiling of draft roadmaps into a comprehensive research roadmap.

This report concludes the scope of work for the Science & Technology Program Project ID 4022. Future roadmapping products will appear under Project ID 151.

INTRODUCTION

The Bureau of Reclamation (Reclamation), Research and Development Office recently embarked on several research roadmapping endeavors. These roadmaps strategically identify the organization's scientific and engineering needs in order to best direct evolving research activities. Efforts to better understand the impacts of climate change led to the interagency report entitled *Addressing Climate Change in Long-Term Water Resources Planning and Management* [1]. In addition, the *Desalination and Water Purification Technology Roadmap* was prepared to identify opportunities for the growing water supply challenges [2].

This research roadmapping project will provide insight to three key questions in regards to Reclamation's infrastructure sustainability:

1) What are the common reasons for reduced service life, extraordinary maintenance, or failure for Reclamation's infrastructure components?
2) What mitigation practices are currently used by Reclamation to address these failures or extend the working life of the infrastructure components?
3) What additional tools, measures, and technology, or improvements in existing technology might allow us to extend the service life for all reserved and constructed Reclamation infrastructure components?

Reclamation infrastructure was subdivided into several categories in order to focus on each infrastructure type separately. Reclamation uses this same categorization to describe its mission critical assets. Table 1 provides these categories as well as a first approximation of the major components for each category to serve as a starting point. The "powerplants" and "other" categories are evaluated under a separate, parallel project under project manager Erin Foraker (Renewable Energy Research Coordinator, Reclamation).

Table 1.—Reclamation mission critical assets

Category	Components
Dams	dams, spillways, outlet works, gates (for dam operation)
Canals	canals, laterals, reservoirs, gates, crane/lifts, trash rack structure, siphons, diversion dams, flow meters
Pipelines	pipeline, surge tank, associated components (with pipeline)
Powerplants	gates, penstock, turbine, excitation, generator, step-up transformer, auxiliaries, instrumentation and controls, unit breaker/switchgear, draft tube
Pumping plants	intake unit, tanks, pump casing, motor, auxiliaries, instrumentation and control, discharge pipe
Other	SCADA systems, communication systems, etc.—outside scope of this work

This report contains existing research information for pipeline infrastructure based on Reclamation databases, reports, publications, and the experiences of pipeline technical and policy specialists. It also includes preliminary results of the questionnaire—Denver Office only—as well as the lessons learned during the pilot study.

RESEARCH METHOD

The research roadmapping project will proceed in several phases. Table 2 provides the estimated timeline for this research roadmapping project. It shows the categories investigated by this project—Pipelines, Pumping Plants, Canals, and Dams—by fiscal year and quarter. The final step will combine these categories into a comprehensive infrastructure roadmap. The interim reports will be the main references for this final project stage.

Table 2.—Roadmapping schedule

Category	FY13 (Qtr.)		FY14 (Qtr.)				FY15 (Qtr.)			
	3	4	1	2	3	4	1	2	3	4
Pipelines	Committee						Comprehensive Research Roadmapping			
		Field survey								
Pumping Plants				Survey & Committee Draft Roadmap						
Canals				Survey & Committee Draft Roadmap						
Dams				Survey & Committee Draft Roadmap						

The Figure 1 schematic summarizes the roadmapping method. The goal is to create a research roadmap that is relevant for at least 5-10 years of Reclamation maintenance and research planning. Details for the research contributors, project data, and gap analysis of Reclamation's research needs are described further below.

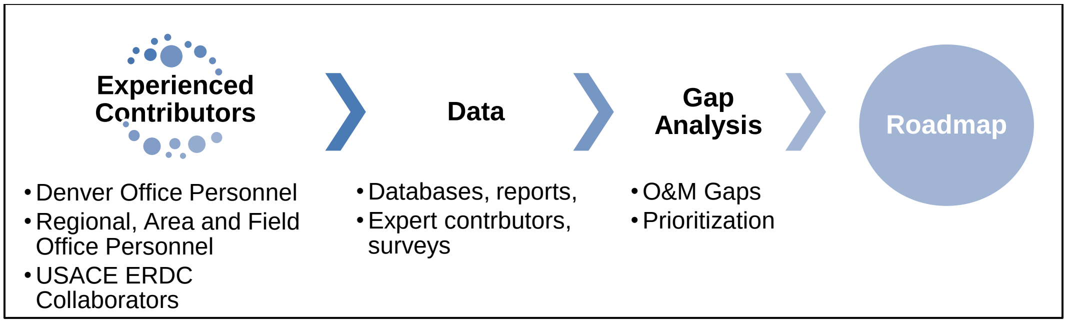


Figure 1.—Process for pipeline infrastructure sustainability roadmap.

Contributors

The success of this roadmap requires the collaborative efforts of many individuals. Planning and execution coincided with regular meetings between researchers, the Reclamation Research and Development Office, and the U.S. Army Corps of Engineers (USACE) Engineering Research and Development Center (ERDC). These meetings provided much needed feedback and direction throughout the roadmapping process.

The pilot study utilized the experience and knowledge of the Denver Office's technical and policy personnel. Furthermore, Reclamation's Regional, Area, and Field Office personnel input is needed to provide a comprehensive data-set for Reclamation pipeline infrastructure's research and engineering needs.

Data

Several approaches were made to collect existing data for this roadmapping project. Reclamation databases, reports, and publications were evaluated in search of quantitative information. Qualitative information was collected by means of an electronic SurveyMonkey® questionnaire. The questionnaire directly queried the three key project questions listed in this report's introduction for each infrastructure component.

Gap Analysis

A process of research gap identification completes the draft roadmapping method. These gaps identify Reclamation research needs, which may be addressed with operations & maintenance (O&M), research, new or existing technologies, etc. Important considerations for the prioritization include Reclamation need and benefit.

PILOT STUDY

Pipeline Reports, Publications, and Databases

Attempts were made to identify and obtain useful existing data for this project. Reclamation's literature and maintenance databases were evaluated initially. Table 3 lists Reclamation O&M databases containing information that is potentially relevant to pipeline infrastructure condition, repair, or maintenance. O&M database analyses were led by Erin Foraker. Several challenges arose, including inconsistency in the hierarchical classification of Reclamation features as well as in the reporting methods. Therefore, the database information proved to be less suited for critical evaluation than first hoped, and the efforts to retrieve data from these sources was suspended.

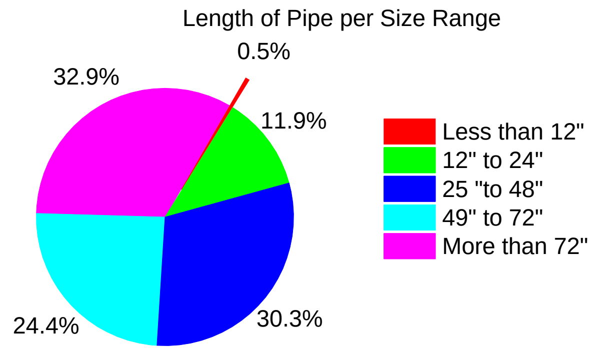
Table 3.—Reclamation O&M databases

Acronym	System Name	Description
CARMA	Capital Asset and Resource Management Application	Database used for maintenance scheduling, primarily on power facilities
POMTS	Power Operations Maintenance Tracking System	Records all outages, forced and scheduled
RAX	Replacements, Additions, and Extraordinary Maintenance	Database of upcoming, high-dollar projects as determined by facility managers
MR&R	Major Rehabilitation & Replacement	Extraordinary maintenance (outside of regular O&M) to be invested in within 5 years

The investigation of previous Reclamation literature produced several promising sources of information. Table 4 summarizes these references. However, much of this data here is nearly twenty years old and must be considered carefully. Ref [6-7] provide two additional non-Reclamation sources that may be useful.

Table 4.—Reclamation documents of in-service pipelines

Report Title (year)	Key Information
Statistical Compilation of Reclamation Engineering Features on Bureau of Reclamation Projects (1992) [3]	• Reclamation constructed 1,161 miles of pipelines • Statistics included for additional 264 miles of pipeline constructed by others, under construction, or constructed under loan program. • Data is limited to transmission pipelines—distribution lines not included.



Pipe Database (1994) [4]

- Compiled by Richard Fuerst from Reclamation Technical Service Center.
- Reclamation constructed more than 4,000 miles of pipeline—including transmission and distribution lines

Pipe Type	Mile
Asbestos cement	2236
Ductile iron	28
Embedded cylinder prestressed concrete	79
Lined cylinder prestressed concrete	37
Monolithic cast-in place	6
Non-cylinder prestressed concrete	60
Polyvinyl chloride	210
Pretensioned concrete cylinder	294
Reinforced concrete cylinder	36
Reinforced concrete pressure	984
Reinforced plastic mortar	83
Steel	322

Historical Performance of Buried Water Pipe Lines (1994) [5]

- In collaboration with the American Water Works Association (AWWA)
- Survey of pipe type and pipe managers satisfaction of field performance each size range
- Survey of pipe performance with follow-up phone interviews to calculate pipe failures per mile-year—where “failure” is defined as “some type of action after installation to correct a pipe deficiency.”

$$\text{Failure Rate} = \frac{\sum(\text{Number of Failures})}{\sum(\text{Years in Service} \times \text{Pipe Length})}$$

- Report does not provide or evaluate the cause and location of each failure. Further evaluation of pipe age versus pipe failure rate possible, but this may overlook key variables such as soil resistivity, construction workmanship, etc.

Denver Steering Committee

This project collected the knowledge and expertise of Reclamation's professionals in the Denver Office (Steering Committee) through a questionnaire. This Steering Committee received the pipeline questionnaire in June 2013 (Attachment A). Five completed questionnaires were analyzed. Two additional questionnaire sources were included in the analysis for Section 1, only.

The steering committee met for a workshop in July 2013. The meeting purpose was to introduce the project goals and present the questionnaire results. Steering committee members were able to voice their concerns and provide insight to the scope and strategy for this project. Key challenges that were unveiled include:

- Should all pipe types be studied, or should it be limited to those currently specified? What about future or experimental pipe types?
- How can the infrastructure best be classified in such a way to obtain information on all the structural components?
- How would personnel turnover affect field survey results? New personnel that are completing the survey may have limited or non-validated information.
- Should policies and politics be included in any part of the analyses?

Questionnaire Results and Analysis

Attachment B provides the raw data for the questionnaires. Table 5 shows a summary of the Section 1 data—most common reasons for failure, reduced service life, or replacement for pipeline systems. No computations were performed; however, the categories are listed by approximate frequency in descending order.

Table 5.—Reasons for pipeline failure, reduced service life, or replacement

Category	Subcategories
Corrosion Damage	All types
	Stray current
	Concentration cell at concrete
Geotechnical Issues	Landslides
	Poor drainage
	Poor foundation, construction, installation
	Overload, burying too deep
	Soil heaving
	Undercutting of toe of slope
Pipe Joint Failure	Installation damage
	Gasket deterioration
	Coupling failures between structure and pipeline
Operational Issues	Mis-operation (general)
	Inadequate venting
	Inadequate pressure
	Hydraulic transients
Design Issues	
Cavitation	
Spalling Damage	
Damage from Future Construction Activities	
Tank Failure (surge, regulating, storage, etc.)	Corrosion damage
	Hydraulic transient
	Poor design
	Geotechnical issues
	Coating damage
	Air compressor maintenance
Appurtenance Failure (valves, etc)	Corrosion damage
	Maintenance/exercising on air/vacuum valves
	Maintenance/exercising on pressure regulators
	Expansion joints (lack of), packing failure
	Geotechnical issues
	Pump issue due to installation / manufacturing tolerances

The Section 1 raw data was subsequently coded according to the cause of failure: mechanical, geotechnical, corrosion, coatings, design, O&M, and installation. Figure 2 provides the coded top two responses from each questionnaire by frequency. Some responses have compounding factors; for example, “pipe joint failures due to installation” is coded as both installation and mechanical because an improvement in one or both areas has the potential to alleviate the failure.

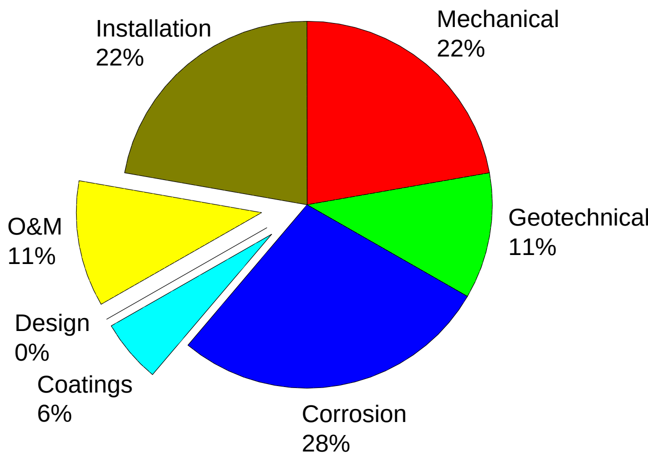


Figure 2.—Section 1 coded results (top two)

Section 2 and Section 3 of the questionnaire addressed the mitigation methods that are used by Reclamation today as well as those that are needed, respectively. The responses to these two sections were coded to aid in the qualitative analysis. Four survey responses were utilized in this analysis. Altogether, each response appeared to qualify for one of six coded areas. Table 6 defines these codes.

Table 6.—Questionnaire codes for Section 2 and 3

Code	Description
Condition Monitoring	Any monitoring to a completed pipeline systems, including inspection by personnel, real-time monitoring, regular equipment exercising, and maintenance
New Materials	calls for new or different materials to satisfy an engineering need, including procedures for the evaluation of these materials
Reporting	information logging for pipeline systems, including the documentation of failures and localized point-of-contacts to oversee maintenance or construction activities
Standards	improvement, updating, or implementation of operating procedures
Training	relative to duties, including design, installation, and maintenance
Design Data	information critical to the successful design of a project, including geotechnical and materials selection

Section 3 provides a direct gap analysis of Reclamation research needs. Therefore, Figure 3 shows the gap between the current mitigation tools (Section 2) and the potential improvements or needs (Section 3). These initial results indicate a significant gap or need for more condition monitoring at Reclamation. There is also a need for new materials, training, and reporting. Guidelines for Reporting Corroded Pipe [8] provides an example of recent efforts to improve failure reporting methods.

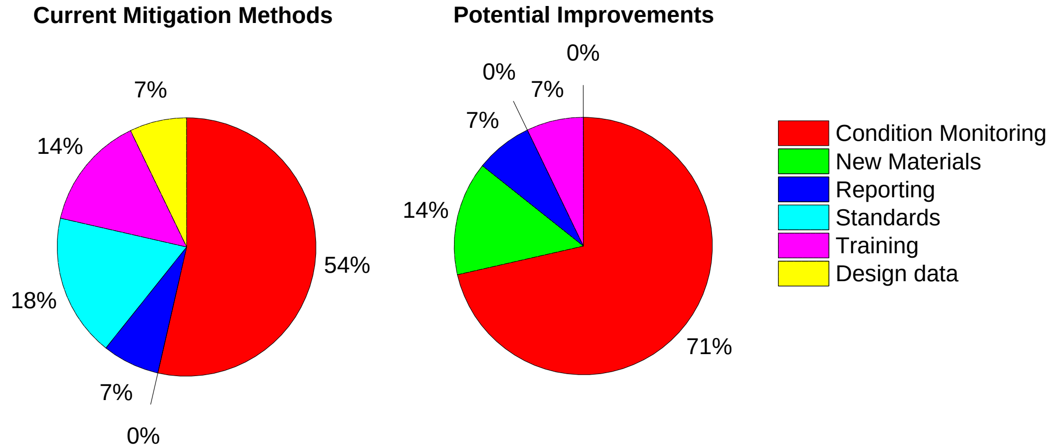


Figure 3.—Section 2 and Section 3 coded results

The analysis did not always provide a clear distinction between the "current methods of mitigation" and the "additional tools, measures, technology, or improvements in existing technology" that are needed. Therefore, "here's what we do; we need to do more of it and better," may be an appropriate interpretation. Frequently this was the case for the implementation of additional or new monitoring technologies such as "real-time monitoring" or "video crawlers."

Field Survey Development

An electronic pdf-fillable survey was developed using input from the questionnaire results as well as steering committee feedback. The electronic survey appears in Attachment C. The intended survey recipients are Reclamation Regional, Area, and Field Offices. This input is vital to understand the research and maintenance needs of the water system personnel and managers.

The study of pipelines and pipeline failures was deemed sensitive at the time of this work and a decision was made to postpone the field survey to a later date.

LESSONS LEARNED

This roadmapping method was carefully constructed; however, major limitations and challenges became apparent through the pilot study process and analysis. These items and the anticipated improvements are highlighted here:

- Historical documents and maintenance databases lacked the information needed to develop a comprehensive research roadmap. The historical documents provide minimum input because their scope is different. The maintenance databases lack the consistency required to provide an accurate. Furthermore, it also only paints part of the picture compared to a straightforward questionnaire.

- Overall, research roadmapping is not a common or well-understood concept to many of the persons receiving these questionnaires. This made it very important to describe the project clearly and to construct the questionnaire carefully.
- The three-section questionnaire seems to be of appropriate construction to obtain all information necessary to complete this roadmapping project.
- The pdf-fillable survey is designed to collect quantitative information for analysis. While this would be useful information to have, the three-section questionnaire will be the sole dataset to maintain consistency and simplicity.
- The analysis method posed a great challenge. For example, Figures 2 and 3 fail to provide suitable detail. Likewise, Table 5 lacks a defendable analysis method. Subsequent work will adopt the table structure but will give a thorough portrayal of the adverse outcome, causal analysis, frequency, gap analysis, research need and benefit through additional columns.
- The infrastructure was divided into three basic components for the pilot study: Pipelines, Surge tanks, and Associated pipe components. The data analysis indicated that the following categorization/description would produce better data: Pipe body, Pipe joint, Tank (regulating, elevated, etc.), Appurtenance (valves, meters, etc.), Siphon, and Tunnel. This categorization was adopted into the pdf-fillable survey. Additional distribution of the questionnaire should follow this as well.

FUTURE WORK

It is recommended that the pipelines study be extended to collect information from the field offices. The three-section questionnaire is preferred to the pdf-fillable electronic survey to proceed with a simplified method. The key reason for this is to be able to incorporate the field results directly with the Denver professionals' responses.

The field survey results should represent a diverse population, several regions and types of pipe systems. A minimum of 10-15 complete questionnaires are desired to be confident that the results are representative of Reclamation's infrastructure as a whole.

CONCLUSIONS

The first year of funding provided a number of advancements in the way of method development. The pilot study proceeded using the best knowledge available at the time. The initial results were provided here. Following this study, the method was adjusted to increase the level of detail in the results and maintain simplicity in the method.

The remaining project schedule will proceed using a singular data collection phase. The three-section, open-ended questionnaire will be completed by Reclamation professionals in the Denver Office as well as the field offices. This information will be analyzed to produce a detailed table that can be prioritized and ranked to show Reclamation's research need and benefit. The prioritization of this information is still undergoing refinement.

The documentation and improvement of this research method will continue for the benefit of future roadmappers.

This concludes the scope of work for Project ID 4022. Future results will be reported under Project ID 151.

REFERENCES

[1] Brekke, L.D., "Addressing Climate Change in Long-Term Water Resources Planning and Management, User Needs for Improving Tools and Information," Bureau of Reclamation, Science and Technology Program, Technical Report, January 2011.

[2] "Desalination and Water Purification Technology Roadmap – A Report of the Executive Committee," Bureau of Reclamation, Desalination & Water Purification Research & Development Program, Report #95, January 2003.

[3] "Statistical Compilation of Engineering Features on Bureau of Reclamation Projects," Bureau of Reclamation, 1992.

[4] Fuerst, R.P., "Pipe Database," Bureau of Reclamation, Technical Service Center, 1992.

[5] von Fay, K.F, Peabody, M.T., "Historical Performance of Buried Water Pipe Lines," Bureau of Reclamation, Report Number R-94-12, September 1994.

[6] Folkman, S., Rice, J., Sorenson, A., Braithwaite, N., "Survey of Water Main Failures in the United States and Canada," *Journal of the American Water Works Association*, 104:10, 2012.

[7] Romer, A.E., Ellison, D., Bell, G.E.C., Clerk, B., "Failure of prestressed concrete cylinder pipe," Awwa Research Foundation, 2008.

[8] Turcotte, R.C., "Guidelines for Reporting Corroded Pipe," Bureau of Reclamation, Technical Memorandum No. MERL-2011-36.

ATTACHMENT A

Pipeline Questionnaire

Questionnaire for steering committee members

List the most common reasons for failure, reduced service life, or replacement for Reclamation components in descending order of importance.

Component	#1	#2	#3	#4	#5
Pipeline					
Surge tank					
Associated pipeline components					

Additional comments

What mitigation measures can Reclamation use today to address these failures or extend the component's service life?

Component	#1	#2	#3	#4	#5
Pipeline					
Surge tank					
Associated pipeline components					

Additional comments

What are additional tools, measures, technology, or improvements in existing technology are needed to address reduced service life or failure?

Component	#1	#2	#3	#4	#5
Pipeline					
Surge tank					
Associated pipeline components					

Additional comments

Figure A1.—Questionnaire supplied to Denver Pipeline Steering Committee.

ATTACHMENT B

Questionnaire Data

Table B7.—Pipelines raw data

SECTION 1. Most common reasons for failure, reduced service life, or replacement in descending order of importance:				
#1	#2	#3	#4	#5
Corrosion (all types, inc. stray current)	Poor foundation/construction	Overload/burying too deep	Poor design	Hydraulic transients
Corrosion damage, especially at concrete interfaces	Mis-operation	Joint failure	Cavitation	Soil heaving
Pipe joint failures, during installation & rubber gasket deterioration	Corrosion of metallic pipe materials	Coupling failures between structures and pipelines	Broken pipe during installation (AC mainly-no longer used)	RPM pipe failures (due to poor manufacturing and standard design-no longer used)
Geotechnical issues, landslides, drainage issues	Corrosion damage, erosion/spalling damage	Mis-operation of equipment such as inadequate venting & pressure	-	-
Comments: Pipeline failures due to improper embedment installation techniques. Pipeline failures due to location near landslide or undercutting toe of slope. Damage from future construction activities by others. Note: order of importance could be different after #1 and #2.				
SECTION 2. Mitigation methods that Reclamation can use today:				
Increased monitoring and surveillance	Routine and regular maintenance	Implement proper operating procedures – per designers	-	-
More in-depth exams & measurements	SOP type documents for more complex piping schemes	Training or tabletop exercises for disaster scenarios such as earthquakes	-	-
Follow the most current Reclamation corrosion standards, all of Rec, not just TSC	Provide training to all regions on how the corrosion standard should be used	Provide better training for inspectors and designers on correct procedures for installation of pipe joints	Get better geotechnical information about possible problems	Provide a localized point in Reclamation that is responsible for ensuring corrosion monitoring is performed and if any construction activities are occurring in ROW
Regular scheduled inspections using NDE techniques such as ultrasound	Coatings/linings surveys	-	-	-
Comments: More in-depth measurements such as video inspections, use of pigs, acoustic emissions, etc. that may apply.				
SECTION 3. Additional tools, measures, technology, or improvements in existing technology that are needed:				
Real time monitoring	NDT inspections	-	-	-
More use of video crawlers & smart pigs	Better incidence reporting	Better pipe condition monitoring	Better coatings and coatings applications techniques	-
New pipe types are always being developed that can provide longer service life for a pipeline. Provide a procedure where these promising	-	-	-	-

technologies can be tested. As manufacturers are only interested in short term products.				
Monitoring on a regularly scheduled basis and using data obtained to analyze condition/calculate safety factor	-	-	-	-

Table B8.—Surge tank raw data

SECTION 1. Most common reasons for failure, reduced service life, or replacement in descending order of importance:				
#1	#2	#3	#4	#5
Corrosion	Hydraulic transients	Poor design	-	-
Coating damage	-	-	-	-
No failures that I know of…	-	-	-	-
Geotechnical issues	Corrosion damage	-	-	-
Comments: I suppose this may cover air chambers as well. Don't know of any major problems with them either. Maintenance of air compressors may be an issue				
SECTION 2. Mitigation methods that Reclamation can use today:				
Increased monitoring and surveillance	Routine and regular maintenance	Implement proper operating procedures – per designers	-	-
No comments	-	-	-	-
None	-	-	-	-
Regular scheduled inspection using NDE techniques such as ultrasound	Coatings/linings survey	-	-	-
SECTION 3. Additional tools, measures, technology, or improvements in existing technology that are needed:				
NDT inspections	Real time monitoring	-	-	-
No comments	-	-	-	-
None	-	-	-	-
Monitoring on a regularly scheduled basis and using data obtained to analyze condition/calculate safety factor	-	-	-	-

Table B9.—Associated pipe components raw data

SECTION 1. Most common reasons for failure, reduced service life, or replacement in descending order of importance:				
#1	#2	#3	#4	#5
Corrosion	Cavitation	Poor maintenance – lack of exercising or operation	-	-
Lack of maintenance on air/vac valves	Lack of maintenance on pressure regulators	Packing failure	-	-
Corrosion on metallic pipe between pipe between pipeline and appurtenances	Improper or no maintenance of valves	Pump problems due to installation procedures & manufacturing tolerances	-	-

Geotechnical issues affecting anchors, supports, etc.	Expansion joints/lack of	-	Couplings – corrosion damage	-
SECTION 2. Mitigation methods that Reclamation can use today:				
Increased monitoring and surveillance	Routine and regular maintenance	Implement proper operating procedures – per designers	-	-
Mandatory recalibration & testing of PRV's and pressure regulating valves at specified intervals	Mandatory required inspections of smaller pipelines at specified intervals	-	-	-
Make sure in the design process that all corrosion issues between metallic pipe types have been addressed	Provide better training to operators about the importance of maintenance for all pipeline components	A localized point in Reclamation could also oversee maintenance issues that arise by following project after completion…this information could then be better transmitted to future designers to prevent future problems	-	-
Inspect and verify proper equipment/valve operation	Inspect couplings for wall loss due to corrosion using UT	-	-	-
SECTION 3. Additional tools, measures, technology, or improvements in existing technology that are needed:-				
NDT inspections	-	-	-	-
Better cathodic isolation and cathodic isolation training	-	-	-	-
None	-	-	-	-
Monitoring on a regularly scheduled basis and using data obtained to analyze condition/calculate safety factor	-	-	-	-

ATTACHMENT C

Electronic Field Survey

RECLAMATION

Managing Water in the West

Pipelines, Tanks, & Appurtenances

Infrastructure Sustainability Survey

To be completed by Reclamation Regional, Area, and Facility personnel

Name:	
Office/Title:	
Phone:	
Email:	

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Reclamation's Research and Development Office is undergoing roadmapping efforts to strategically identify the organization's scientific and engineering needs. Please complete the survey below to the best of your knowledge. The information will be used to guide the next 5-10 years of maintenance and research planning.

The goal of this survey is to provide insight to three key questions in regards to Reclamation's pipeline infrastructure sustainability:

1) What are the common reasons for reduced service life, extraordinary maintenance, or failure for Reclamation's infrastructure components?
2) What mitigation practices are currently used by Reclamation to address these failures or extend the working life of the infrastructure components?
3) What additional tools, measures, and technology, or improvements in existing technology might allow us to extend the service life for these infrastructure components?

U.S. Department of the Interior
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Figure C10.—Cover page for Pipeline Infrastructure Sustainability Survey

Pipelines, Tanks, & Appurtenances

Infrastructure Sustainability Survey

Summarize structure inventory and failures in the tables by choosing most applicable responses from the drop-down menus. Enter pipe length, service years, and # of failures directly. Use subsequent sheets as needed. Tables can be found on page 5 for pipeline/structures not shown.

Pipeline Information					
Project					
Pipeline/Structure				Pressure	
Pipe Type				Size (in)	
Joint Type				Length (ft)	
Cathodic Protection System		System Type		Service (yrs)	

Performance/History of Failures (two most common)		
Location of Failure		
Failures (#)		
Cause		
Typical Action		
Risk		

Tools, Measures, and Technology Needed for Improvement (in order)	
#1	
#2	
#3	
Comments:	

Figure C11.—Example of pdf-fillable section for Infrastructure Sustainability Survey.

Table C12.—Drop-down menu items for respective sections of survey

Pipeline Information			
Pipe Type	**Joint Type**	**System Type**	**Size (in)**
Asbestos cement	Bell and spigot	Sacrificial anode	Less than 12
Gray cast iron	Mechanical coupling	Impressed current	12 to 24
Prestressed cylinder pipe	Welded	Unknown	25 to 48
Non-cylinder prestressed	Other		49 to 72
Pretensioned		**Pressure**	Over 72
Reinforced plastic mortar	**Cathodic Protection System**	High	
Precast concrete	Yes	Low	
Cast-in-place concrete	No		
Performance/History of Failures			
Location of failure	**Cause**	**Typical action**	**Risk**
Pipe body	Corrosion damage	Repair	High: loss of life (explain below)
Joint	Design issue	Replacement	Medium: immediate repair or replacement
Tank (regulating, elevated, etc.)	External damage by others	None	Low: routine or scheduled
Appurtenance (valves, meters, etc.)	Installation damage	Other	
Siphon	Geotechnical issues		
Tunnel	Operational issue		
	Other		
Tools, Measures, and Technology Needed for Improvement			
Structural Health Monitoring (advanced monitoring, real-time monitoring)			
Corrosion protection (cathodic protection and coatings)			
New materials (testing and repair methods)			
Design data (gathering of critical information including geotechnical and materials selection)			
Standards (improvement, updating, distributing, and implementing of operating procedures)			
Training (design, installation and maintenance)			
New condition assessment methods (non-destructive testing/evaluation (NDT/NDE), etc.)			
Personnel or funding resources to perform regular O&M			
Reporting (distribution of documentation for failures, maintenance, etc.)			