Economics of Corrosion Protection

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Cost of Corrosion

- NACE IMPACT Study 2016
  - Estimated global cost of corrosion using available studies
  - $2.5 trillion per year
    - 3.4% of global GDP
  - 15%-35% cost savings possible using available corrosion control practices
- Recommend adoption of corrosion management system

http://impact.nace.org/economic-impact.aspx

Coatings Maintenance and Cost

- Maintenance options:
  - Spot repairs
  - Full recoat or reline (lifecycle end)
  - Add cathodic protection as a secondary protection mechanism
  - Effort (and cost) increase for each maintenance step after initial coating

- Cost is increasing
  - Structures inaccessible
  - Need to stay in service
  - Regulations

Cost of Not Maintaining Coatings

- Corrosion and metal loss
  - May lead to weld repairs or section replacements
  - May require significant design work
  - Time intensive in field
  - Quickly exceeds many $100k's

- Structures are critical resources
- Replacement may be "cost prohibitive"

Research Efforts

- **Goal is to keep costs low by improving timing of coatings maintenance**
  - **Maximize coating lifecycle (service life)**
  - **Maintain before metal loss**

- **Studies to discuss:**
  - **Cathodic protection payback period**
  - **Econometric analysis to better understand corrosion cost trends and predict future costs**

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Cathodic Protection (CP) Break-Even Analysis

- CP extends coating service life; may delay recoating until ~20% deterioration[2, 3]

- Research: break-even analysis to estimate payback period
  Inputs: install costs, maintenance, etc.
  Output: *when* added life pays for CP

- Results: CP system cost-effective after 15–30% extended life
  - Impressed current (ICCP) has economies of scale, i.e., payback period decreases as surface area increases
 - Galvanic anode (GACP) economical for smaller surface areas

[2]D. Kroon and J. Rog, Opflow 37, 11 (2011): p. 16
[63]W. von Baeckmann, et. al., Handbook of Cathodic Corrosion Protection, 1997

Econometric Analysis

- **Reclamation has 188 steel penstocks with 6.6 million sqft interior surface area**

- **Total replacement is nearly $0.5 Billion at $50 per sqft (typical)**

- **As of 2021, about 120 penstock had yet to be relined and had avg lining age of about 63 years (near replacement age)**

Data Statistics
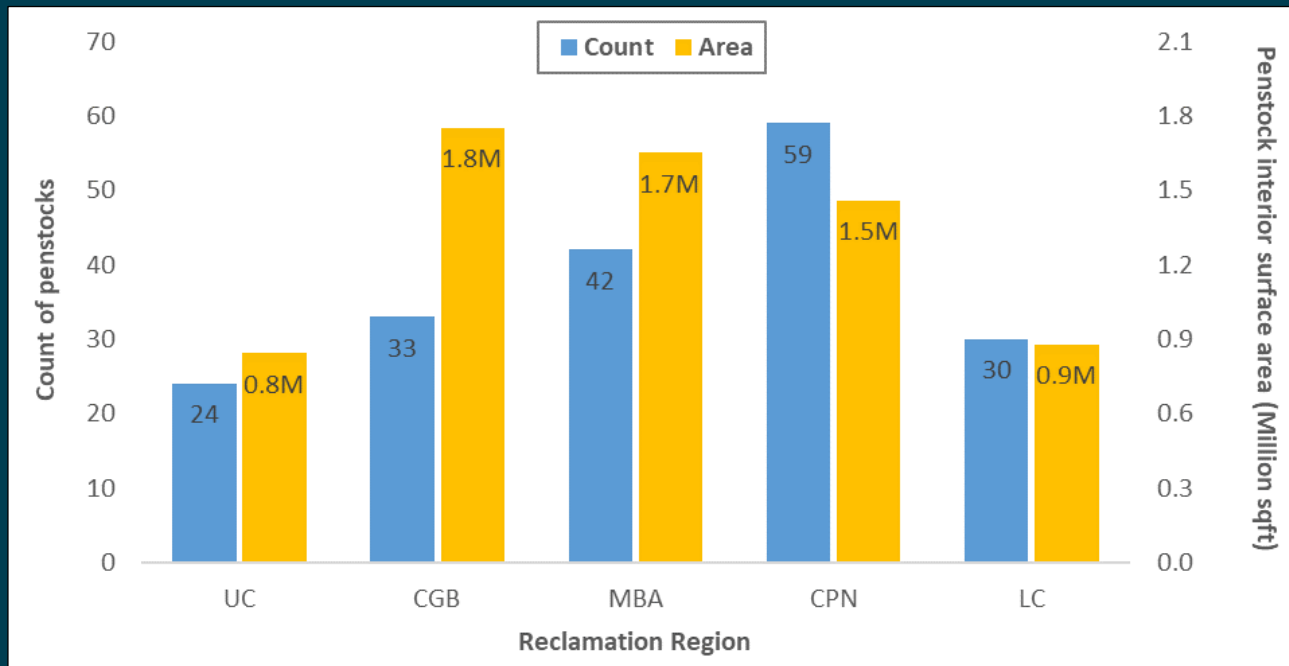
| Variable	Average	Min	Max
Total cost ($1,000's)	1,245	44	8,765
Average cost ($ per sqft)	85	19	382
Quantity (sqft)	26,019	114	471,804
Existing Lining Type*			
Coal Tar Enamel	0.88	0	1
Cement Mortar	0.04	0	1
Polyurethane	0.03	0	1
Vinyl	0.04	0	1
Epoxy	0.04	0	1
New Lining Type*			
Polyurethane	0.08	0	1
Vinyl	0.03	0	1
Epoxy	0.90	0	1
Pipe Diameter (ft)	14.8	4	39.3
Pipe Slope (degrees)	17.9	0	41.9
Pipe Length (ft)	1,207	85	12,515
Robotic	0.51	0	1
Time (year)	2017	1999	2020
Reclamation Region			
Upper Colorado Basin	0.04	0	1
Lower Colorado Basin	0.19	0	1
Columbia-Pacific Northwest	0.62	0	1
California Great Basin	0.03	0	1
Missouri Basin/Arkansas-Rio Grande-Texas Gulf	0.12	0	1
Reclamation	0.88	0	1

- Evaluated 73 relining jobs with pipe diameters larger than 42" (3.5 ft)
- All costs indexed to 2020$
- Contract award costs only; does not include:
  - Modifications
  - Non-contract costs

Final Model

- Modeled for cost per sqft (shown) and total relining cost
- Cost per sqft decreases as area relined increases (economies of scale)
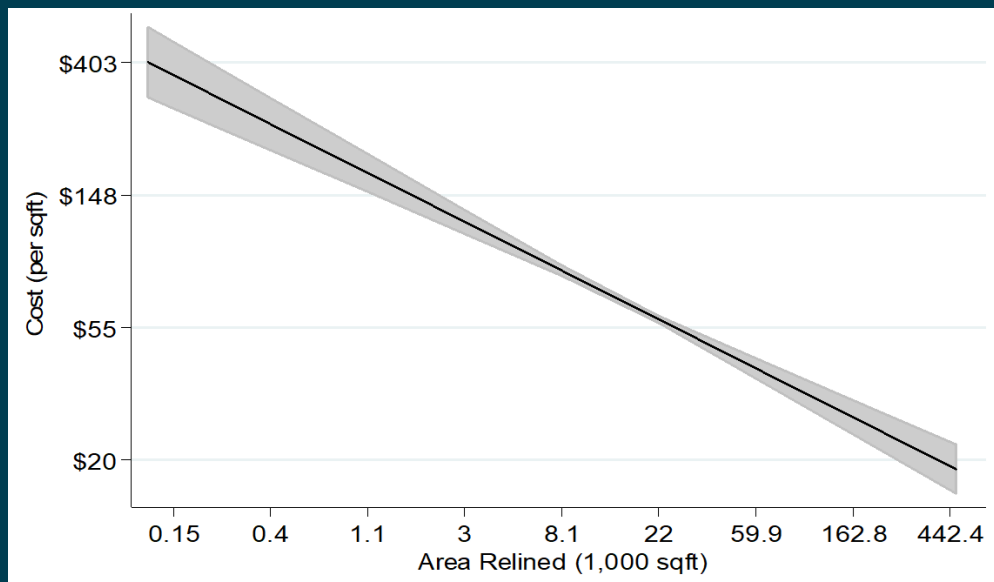
Independent Variable	Final Model
ln(Area Relined)	-0.369*** (0.025)
Reclamation Ownership	0.553*** (0.083)
AW Diameter	-0.010** (0.004)
AW Slope	0.022*** (0.008)
Robotic Application * AW Diameter	0.030*** (0.008)
Robotic Application * AW Slope	-0.011* (0.006)
Region	
California Great Basin	-0.420*** (0.125)
Columbia Pacific-Northwest	-0.915*** (0.088)
Missouri Basin/Arkansas-Rio Grande-Texas Gulf	-0.624*** (0.081)
Upper Colorado	-0.571*** (0.076)
R-squared	0.9199

Lower Colorado shown: Region coefficient below. Standard errors shown in parenthesis. Statistical Significance: ***1% Level, **5% Level, *10% Level. Area Weighted (AW).

Final Model

- Graphs show robotics cost effect for diameter and slope

- Illustrates interaction variable, e.g., "Robotic Application * AW Slope"

- Future costs may reduce as savings are passed on to Govt.

- Non-contract savings not accounted for (e.g., reduced outage, safety)
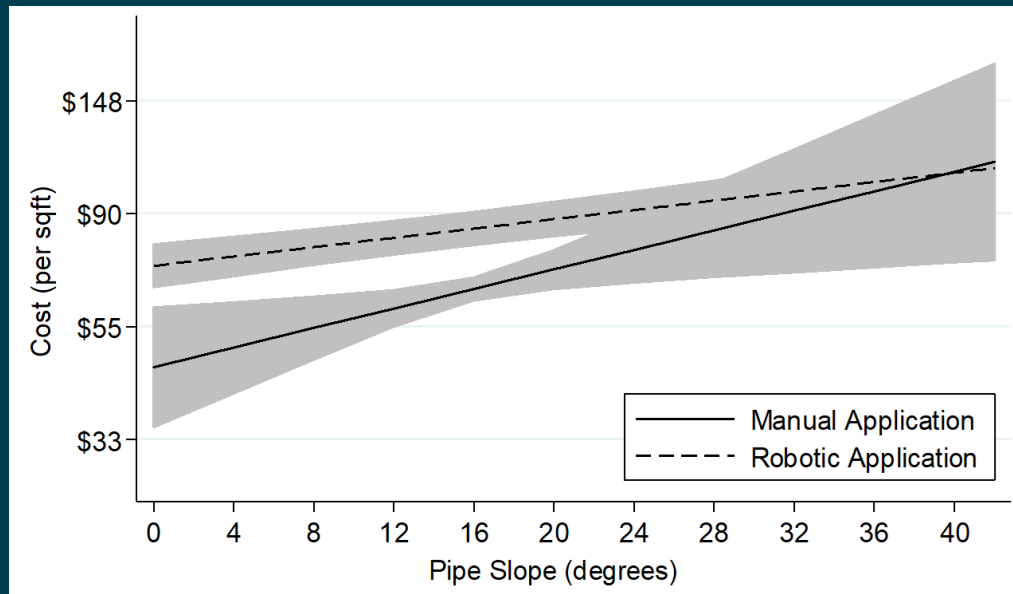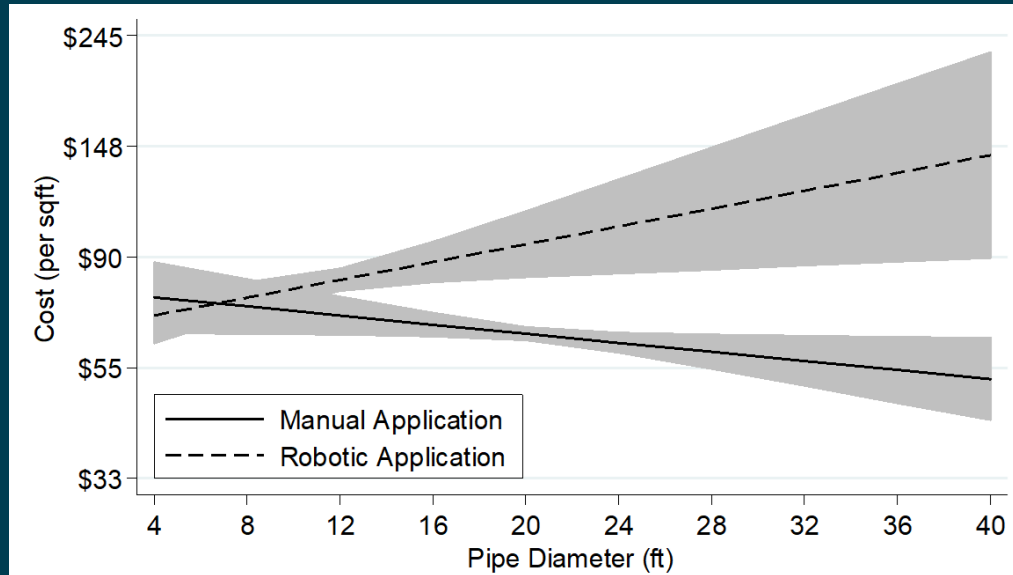
Future Spending Prediction

- Applies model to the 121 assumed to need relining soon

- Assumes one relining per year per region
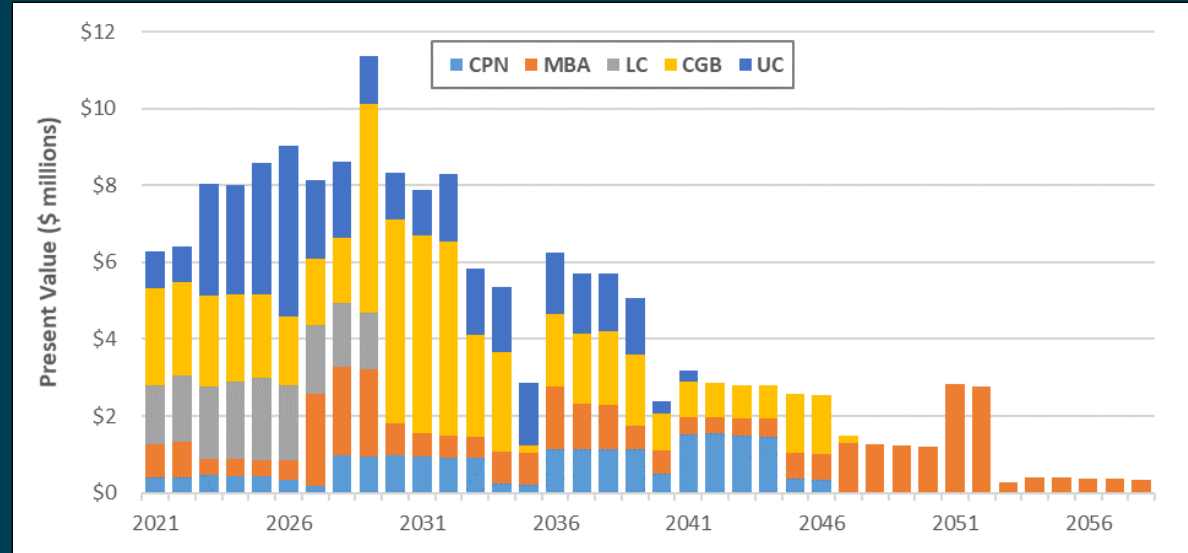
Region	Number of Penstocks	Final Program Year	Avg. area relined per year (sqft)	Present value ($ millions)	Annualized cost ($ millions)
California Great Basin	27	2047	64,908	$58.64	$3.01
Columbia Pacific-Northwest	26	2046	28,696	$20.61	$1.09
Upper Colorado	21	2041	39,101	$36.67	$2.27
Lower Colorado	9	2029	15,850	$16.16	$2.03
Missouri Basin/ Arkansas-Rio Grande-Texas Gulf	38	2058	36,359	$35.78	$1.47
Reclamation, All	121			$167.86	$6.89

Cost Forecasting Tool

Screenshot of app tool user interface (above), weblink: https://apps.gov.powerapps.us/play/b693bfe3-6ec7-47ed-b5d7-eff742f97b53?tenantId=0693b5ba-4b18-4d7b-9341-f32f400a5494
Excel tool available to non-DOI users: https://data.usbr.gov/catalog/4614/item/11466

Questions? Comments?

BUREAU OF — RECLAMATION