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Evaluation of Canal Lining Projects in the Lower Rio Grande Valley of Texas
2011 Ratings and Analysis

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make every drop count

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Rio Grande Basin Initiative
Irrigation Technology Center
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EXECUTIVE SUMMARY

Since 1999, nine (9) irrigation districts in the Hidalgo, Cameron, Willacy and Maverick Counties have installed nine (9) different types of synthetic canal lining materials, totaling approximately 26 miles. In 2005, we began a program to track the long-term effectiveness and durability of these lining projects and to document the damage caused by such factors as weather, animals, intentional and unintentional vandalism, and normal irrigation district operation and maintenance activities. We visually inspected each project and documented any changes using a lining evaluation form which we developed.

For analysis purposes, we grouped all the projects into two general categories: liners with a protective barrier, and liners without a protective barrier. The projects with a protective barrier performed very well. The synthetic liner significantly reduces seepage, while the shotcrete layer protects the liner from damage. This lining system needs little to no maintenance. There were two types of liners used: PVC and polyester. Each performed equally as well.

The performance of synthetic liners without a protective barrier varied dramatically. One important factor was the location of the project. Liners located in high traffic areas (people and animals) showed significantly more damage than those installed in remote areas. Damage caused by mowing and canal cleaning operations was common. Liners carelessly or improperly installed were more susceptible to damage. For example, the smoothness and stability of the material underneath the liner, and the shrinking properties of some liners must be taken into consideration.

The PVC Alloy is the toughest material, is more difficult to cut and less likely to be damaged by unintentional vandalism. Nevertheless, its high shrinking tendency needs to be taken into consideration at installation. The reinforced rubber liners installed in 2009 have performed very well over the past two years.

Additional details are provided in this report, along with considerations when planning a lining project. A summary of the factors that appear to have highest impact on the liner performance is given in Table A-5.

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INTRODUCTION

Since 1999, irrigation districts in Hidalgo, Cameron, Willacy, and Maverick Counties have been experimenting with an assortment of canal lining materials. In 2005, we initiated a program to track the long-term effectiveness and durability of these materials and to document installation and maintenance procedures which will help ensure good performance. Each lining project was periodically inspected to document the effects of such factors as weather, animal traffic, farm machinery traffic, intentional and unintentional vandalism, and normal irrigation district operational and maintenance activities. A summary of the results from the first five (5) years of inspections are presented in this report.

MATERIALS AND METHODS

Lining Materials

The following types of lining materials have been installed in nine (9) irrigation districts in Hidalgo, Cameron, and Willacy and Maverick Counties:

1. Polyester with a shotcrete protection barrier
2. PVC with a shotcrete protection barrier
3. Polypropylene
4. PVC alloy
5. EPDM rubber
6. Polyurethane
7. Green TPO-R
8. Reinforced EPDM
9. Reinforced FPP-R

The liners with a protective barrier were used on unlined canals. The remaining liners were installed in concrete canals. Table 1 provides a generic description of each material. The locations of all of these lining projects except for one district are shown in Figures 1 and 2. Installation date, extent, and other details for each project are given in Table A-1 and A-2. In 1999-2000, Hidalgo County Irrigation District No. 1 installed four (4) types of liners in 18 segments as shown in Figure A-1.

Table 1. Description of each lining material's composition

Material	Description
Polyester with protective barrier	A geocomposite consisting of two layers (top and bottom) of 8 oz/yd2 nonwoven polyester bonded to an olefinic copolymer geomembrane, 20 mil thick. The protective barrier consists of 2-3 inches of shotcrete
PVC with protective barrier	Non-reinforced Poly Vinyl Chloride (PVC). The protective barrier consists of a wire mesh with 2.5 inches of shotcrete
Polypropylene	A reinforced polyester scrim 16 oz/yd2 between polypropylene layers, 24 mil thick
PVC Alloy	A polyvinylchloride blend, reinforced with a polyester scrim, 40 mil thick
EPDM Rubber	A non-reinforced EPDM (ethylene propylene diene monomer), 45 mil thick
Polyurethane	Two layers of 3-oz/yd2, heat-bonded, non-woven geotextile saturated with liquid polyurethane, 40 mil thick
Green TPO-R	A reinforced TPO Geomembrane (flexible thermoplastic polyolefin membrane), 60 mil thick
Reinforced EPDM	A reinforced EPDM (ethylene propylene diene monomer), 45 mil thick
Reinforced FPP-R	A reinforced fPP (polypropylene/rubber-based geomembrane), 45 mil thick

Evaluations and Inspections

Inspections conducted during the winter months have proven to be the most effective as water levels tend to be the lowest during this time of the year. Projects were visually inspected and rated as "*Excellent*" to "*Serious Problems*." The rating criteria is listed in Table 2, along with the types of photographs and other information which were collected. The actual field data sheets used are shown in Figures A-3 and A-4. Separate forms were used for exposed synthetic liners and liners with protective barriers.

Changes to the form used for the 2010-2011 inspections included:

- Number of cuts and tears, including the repaired ones
- Percentage of repair
- Missing sections (length, location)
- Apparent Cause of damage
- Grouping of damage by section
- Condition of seams
- Conditions of structures
- Shrinking of material
- Presence of buckles on shotcrete walls
- Non-ratable sections due to obstructions (e.g. dirt, grass)
- Separate ratings for anchor, free board, and wetted area (Fig. 3)

We divided projects No.1, 2, 5, and 7 into shorter sub-projects due to groupings of observed damage and rating forms were completed for each individual sub-project.

Table 2. General performance ratings for canal liners

Rating	Performance
Excellent	No damage
Good	Minor damage appeared on the anchor and the free board. The damage may affect the rest of the liner
Fair	Minor damage appeared on the wet wall of the canal. The damage may affect the rest of the liner if not repaired in a timely manner
Poor	Major damage appeared on the anchor area and the free board section. Most of the section is damaged
Serious Problems	Major damage appeared in the wet area. Liner has been removed in some sections

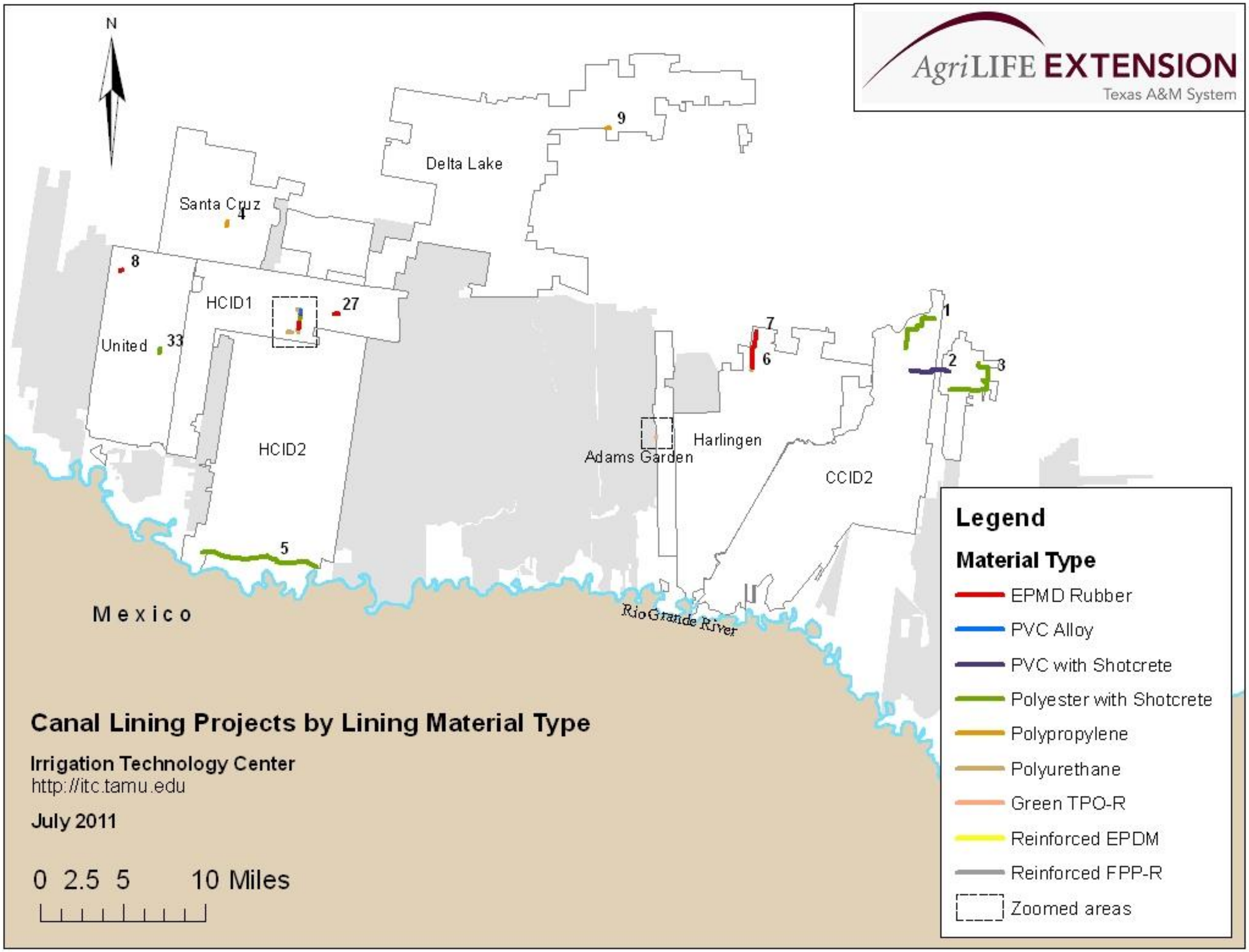

Figure 1. Lining Projects by Material Type in the Hidalgo, Cameron, and Willacy Counties: Location Map 1

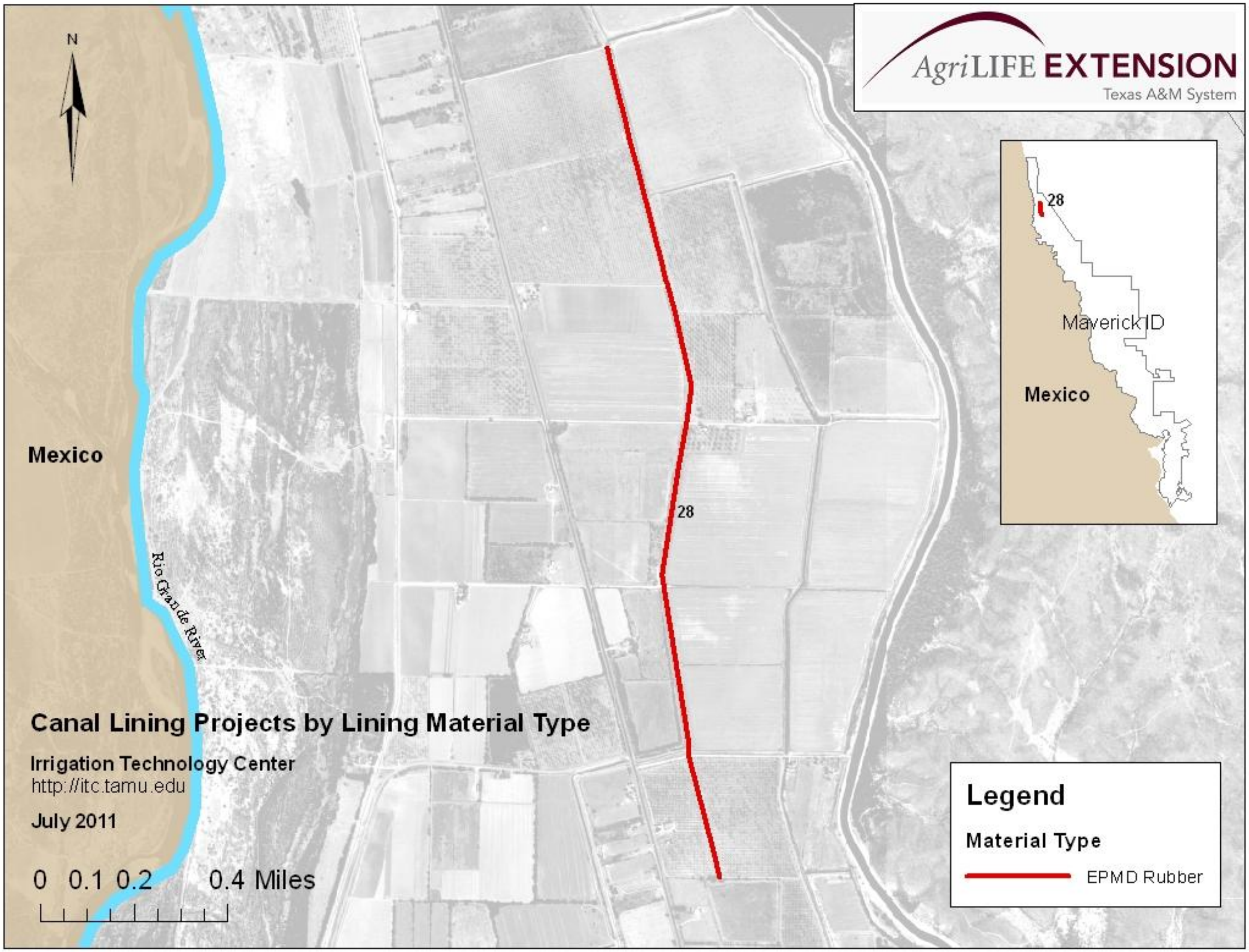

Figure 2. Lining Project in the Maverick County: Location Map 2

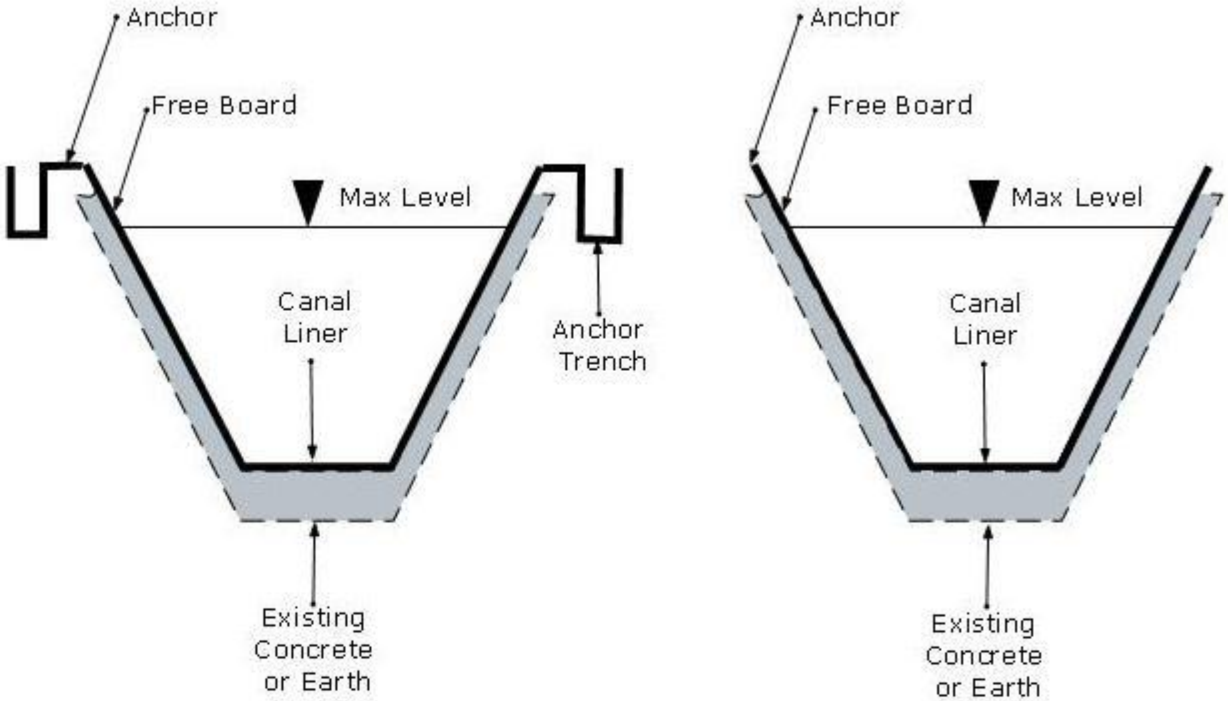

Figure 3. Ratings were completed separately for the anchor (i), free board (ii), and wetted area (iii).
A: Liner with anchor trench. B: Liner without anchor trench

RESULTS AND DISCUSSION

Table 3 lists the average ratings for each type of liner. The changes in ratings over the past five years are shown in Figure 4. We grouped all the projects into two categories: liners with a protective barrier, and liners without a protective barrier. Liners with a protective barrier performed very well and have required no maintenance, while the performance of the liners without a protective barrier has varied dramatically.

The ratings on an individual project and sub-projects basis are provided in Tables A-3 and A-4. A summary of the factors that seems to have higher impact on the material performances is given in Table A-5.

Table 3. Range of the performance rating results by lining material for the year 2011

Material	No. of Projects	Total Miles	Rating (2011)	Age (years)
With a protective barrier				
Polyester with shotcrete	5	15.95	Good	4-7
PVC with shotcrete	1	2.64	Good	5
Without a protective barrier				
Polypropylene	2	0.60	Excellent to Serious Problems	5-6
PVC Alloy	3	0.02	Good to Serious Problems	12
EPDM Rubber	9	5.61	Good to Serious Problems	6-11
Polyurethane	9	1.36	Fair to Serious Problems	7-12
Green TPO-R, Reinforced EPDM, Reinforced FPP-R	3	0.12	Excellent	2

Liners with a Protective Barrier

All six (6) projects are still in *Good* condition after 4 to 7 years and have required no maintenance. No difference in performance was observed between the two types of synthetic liners used under the shotcrete. While hairline cracks have developed in the shotcrete, no related problems have been observed. The overall rating declined from *Excellent* to *Good* this year due to the appearance of vertical pencil size cracks, horizontal hairline cracks, and buckles.

An example of buckling is shown in Figure 5. Most buckles were found in the eastern section of Project No.5. These buckles appear to have been caused by water seeping through the levee due to improper installation of the liner (i.e., not properly anchored). However, this buckling appears to have had no impact on the condition and performance of the synthetic liner. Insufficient free-board in some sections also caused some erosion of soil under the synthetic liner (Fig. 6).

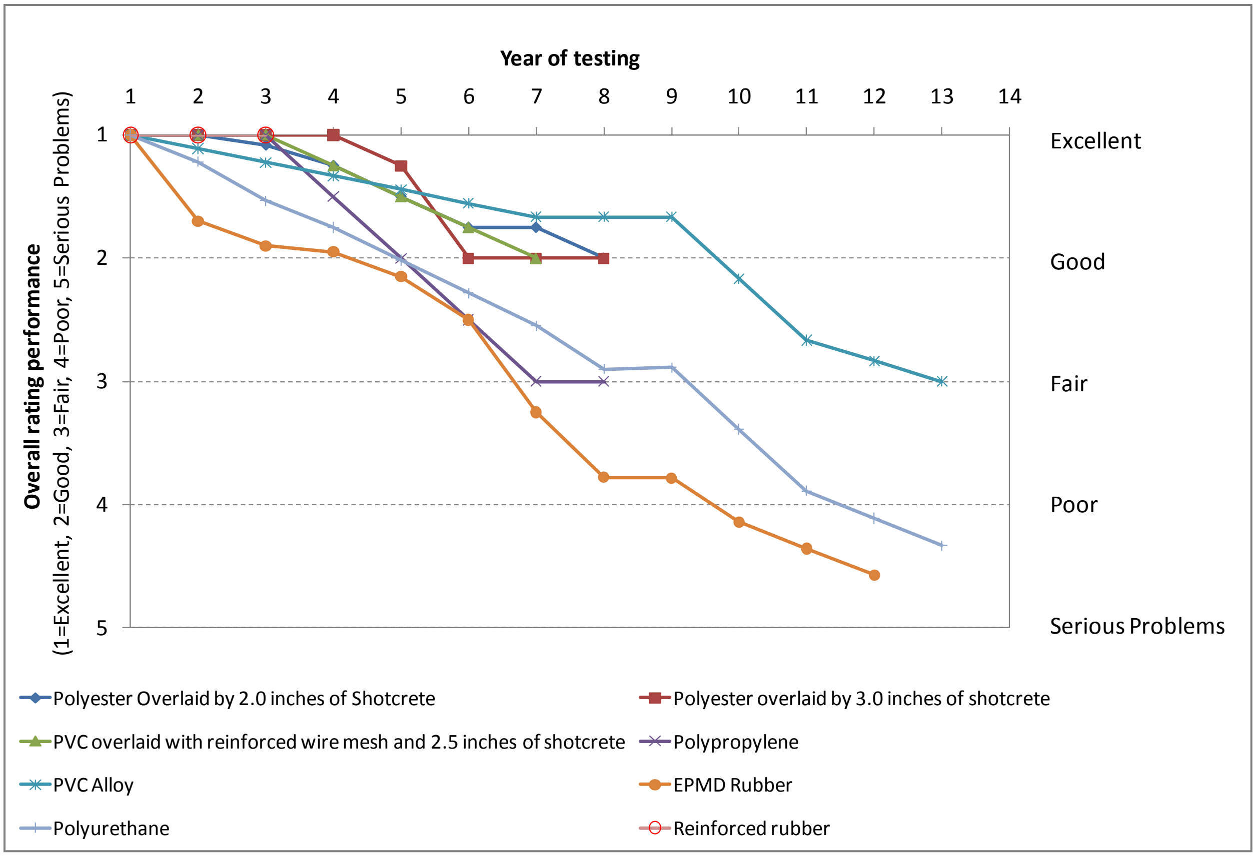

Figure 4. Average performance rating results by lining material for the year 2011.

Figure 5. A buckle on the shotcrete protective barrier

Figure 6. Erosion underneath the synthetic liner

Liners without a Protective Barrier

The performance of the liners without a protective barrier has varied significantly. The reinforced rubber projects were rated as *Excellent* but have only been installed for two (2) years. Of the other four types of materials, the polypropylene and PVC alloy liners had the least amount of damage. The performance of EPDM rubber and polyurethane varied significantly. While some projects are still in *Good* or *Fair* condition, others have *Serious Problems* or have failed completely.

Exposed liners are obviously more susceptible to damage caused by weather, animals, farm machinery traffic, and vandalism (even if unintentional such as fishing in the canal). As a result, liners in remote areas have performed much better than those in urban or high traffic areas. Damage was also common due to the districts' mowers and maintenance activities and the cleaning out of aquatic vegetation and sedimentation (Fig. 7). The installation procedures used and maintenance of the liners also appears to explain some of the variation in performance as discussed below.

Figure 7. Damage on the anchor likely caused by mowers.

Polypropylene

The two polypropylene projects are rated as *Excellent* and *Serious Problems*. Project No.4 is in *Excellent* condition after six (6) years, with no visual problems, except for the last few feet where damaged was caused by the collapse of the concrete canal section.

Project No.9 (5-years old) was rated as *Serious Problems* due to extensive damage caused by the collapsing and very sharp-edged canal concrete sections (Fig. 8A). Also in project No.9, concrete sections approximately 1-foot wide were poured on top of the liner at a spacing of 500 feet (Fig. 8B). The purpose of the concrete sections is reported to have been to keep the liner in place and provide access points for sediment removal. Our conclusion is that long-term evaluation is needed to determine if such sections are useful for these purposes.

Figure 8. A: Collapsing and very sharp-edged canal concrete sections. B: Concrete sections poured on top of a polypropylene liner to hold the material in place

PVC Alloy

Of the three (3) PVC projects, two (2) were rated *Good* after 12 years (No.16 and 22), and one as *Serious Problems* (No.24). In two projects, this material has performed well, requiring little maintenance with no major damage observed. The cuts and tears that have occurred have not developed into larger problems. However, in Project No.24, significant amount of damage was caused by the combination of shrinking and hollow areas under the liner which resulted in tears, and road workers who used a portable pump to supply water for road construction (Fig. 9).

Figure 9. PVC Alloy liner damage.

EPDM Rubber

Of the nine (9) EPDM projects, one (1) is still in *Good* conditions after 11 years (No.19), while the ratings of the others range from *Fair* to *Serious Problems*. Two projects (No.14 and 26) and several sections from other projects have been removed. Subsections E and F of project No.7 are still in *Good* conditions.

EPDM rubber is very susceptible to vandalism and punctures caused by animals, including ants (Fig. 10). Children were reported to cutoff portions of the liner for use as rubber bands. It also appears that many cuts and tears initially occurred on the exposed areas which experience the most human and animal traffic. Unless repaired in a timely manner, these tears quickly enlarge (Fig. 11). In some cases, steel and concrete anchors were added to try to keep the liner from shrinking and floating (Fig. 12).

Figure 10. Ant colony in the EPDM rubber liner

Figure 11. Cuts/tears caused by vandalism or traffic, and quickly enlarging due to shrinkage


Figure 12. Steel anchors added to try to keep the liner from shrinking and floating

Polyurethane

Of the nine (9) polyurethane projects, one (1) is rated as *Fair* after 12 years (No.17), and the others range from *Fair* to *Serious Problems*. Project No. 11 failed and has been removed, as has a section of No.18. This section was replaced and is listed here as Subproject No.18b.

Unlike other types of liners, the polyurethane was manufactured on-site by specialized machinery, and requires that the chemicals used to be properly handled. Several problems occurred during its manufacture and installation, including inconsistency in product thickness, which caused large variation in performance. Little to no maintenance has occurred since installation.

Observed problems include the liner falling off the canal walls which was likely caused by a combination of weather damage, vandalism, traffic, mowing, and sharp concrete edges (Fig. 13 and 14). In some segments, the top layer of the material has peeled off, but this had a minor effect on performance (Fig. 15). Figure 16 shows one lining project where the polyurethane project is rated as *Fair* in spite of serious problems in the anchor area.

Figure 13. Damage caused by the sharp edge of the concrete underneath

Figure 14. Polyurethane liner hanging off the canal side

Figure 15. Top layer of the material peeling off


Figure 16. One polyurethane-lined segment in Fair condition after 12 years of use

Reinforced rubber (collaboration with Firestone)

In our 2009 ratings, the rubber liners performed the worst. Since then, the manufacturer, Firestone, Inc., has modified the product. In 2010, Firestone donated three new formulations of this material (Green TPO-R, Reinforced EPDM, and Reinforced FPP-R) for evaluation purposes which were installed in the Adams Garden irrigation district (Figure A-2). All three projects were rated as *Excellent* (Figs. 17-19).

Figure 17. Green TPO-R


Figure 18. Reinforced FPP-R


Figure 19. Reinforced EPDM

SUMMARY

The six (6) projects using a protective barrier were rated from *Excellent* to *Good* after 5 years. The use of a protective barrier can extend the life of the lining project by preventing inadvertent damage and discouraging vandalism. Our only concern is the potential negative impacts of buckles on the liner's integrity.

The performance of the synthetic liners without a protective barrier varied dramatically, ranging from *Excellent* to *Serious Problems*. Some were found to be more susceptible to such factors as installation problems, unintentional damage and vandalism. Among the installation issues the most important seemed to be the smoothness and stability of the material underneath the liner, and the shrinking properties.

Most of the damage to the synthetic liners occurred around the exposed areas of the liner near the top anchor area. If the damage is not repaired in a timely manner, small tears can grow into larger ones. In general, exposed synthetic liners need more frequent inspections and regular maintenance. Mowing along the edge of canal causes significant damage on the liners without a protective barrier.

Key observations for each type of liner are as follow:

- <u>Liners with a Protective Barrier</u> (6 projects, 19 miles total)
    - Water seeping behind the liner where not properly anchored resulting in buckles
    - Horizontal and pencil size cracks in the shotcrete on the side walls of the canal
    - No differences in performance was observed due to different synthetic liner or shotcrete thicknesses
    - No maintenance has been required to-date

- <u>Polypropylene</u>
    - Sharp edges in the canal concrete primarily on the anchor causing cuts and serious damage
    - One project was rated as *Excellent* after six (6) years, while the other had *Serious Problems* after five (5) years (vandalism and wall structural problems)

- <u>PVC Alloy</u>
    - Shrinkage caused significant damage in areas
    - Two (2) were rated as *Good* after 12 years, and one has *Serious Problems* due to tears likely resulting from unintentional damage and shrinkage of the product..

- EPDM Rubber
  - Is easy to cut due to softness of the material
  - Shrinking causes quick enlargement of cuts.
  - Requires constant maintenance
  - Is more susceptible to vandalism (intentional and unintentional)
  - More damage was observed in sections that have structures such gates, farm turnouts, and bridges
  - The material should not be applied to canal sections with broken concrete sides and anchors
  - One (1) project was rated as *Good* after 11 years, the others range from *Fair* to *Serious Problems*. Two (2) projects and several sections from other projects failed and have been removed

- Polyurethane
  - Since the material is produced and installed on the site, its long term performance depends on the proper handling and mixing of the chemical components
  - The material has two (2) layers glued together. While the top layer has had serious damage (pealing and degradation), the second layer is still holding, resulting in satisfactory performance
  - The material can be cut when installed on broken concrete canal sections
  - We inspected nine (9) projects, of which one (1) is still in *Good* conditions after 12 years, and the others range from *Fair* to *Serious Problems*. One (1) project has been removed and one (1) section from another project has been removed

- Reinforced Rubber (collaboration with Firestone)
  - We inspected three (3) short projects, and they are all in *Excellent* condition after 2 years

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Martin Barroso Jr., former GIS Specialist.

Eric Leigh, former Extension Associate.

The districts involved in this project provided assistance through their canal riders and personnel supervisors, which resulted particularly useful for the identification of the causes of damage.

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APPENDIX A: Tables, Detailed Location Map, and 2011 Field Rating Form

Table A- 1. Location, Type, and Extent of Lining Project in Eight (8) Districts*

Irrigation District	Project	Canal	Material	Total Length		Date of Installation
				Feet	Miles	
CCID No.2	1	Canal C	Polyester overlaid by 2.0 inches of shotcrete	18,430	3.49	Jan-Nov 2004
	2	Canal 39	PVC overlaid with reinforced wire mesh and 2.5 inches of shotcrete	13,932	2.64	Jan 2005
	3	Canal 13	Polyester overlaid by 2.0 inches of shotcrete	25,744	4.88	Sept-Jan 2006-2007
Santa Cruz	4	Main Canal	Polypropylene	1,847	0.35	Nov 2004
HCID No.2	5	Lateral A	Polyester overlaid by 3.0 inches of shotcrete	38,505	7.29	Sept 2004
Harlingen	6	Wyrick Canal	Polyurethane	965	0.18	Nov 2004
	7	Wyrick Canal	EPDM Rubber	12,057	2.28	Nov 2004
United	8	Mission Main	EPDM Rubber	670	0.13	Feb 2005
Delta Lake	9	Raymondville Canal	Polypropylene	1,342	0.25	Jan 2006
Maverick	28	Lateral 2a	EPMD Rubber	12,735	2.40	2004
Adams Garden	30	AG 15	Reinforced EPDM	92	0.02	2009
Adams Garden	31	AG 15	Reinforced FPP-R	209	0.04	2009
Adams Garden	32	AG 15	Green TPO-R	306	0.06	2009
United	33	Bryan Canal	Polyester Overlaid by 2.0 inches of Shotcrete	1,404	0.27	2009

* Installation of project No.29 is estimated to be completed in 2011 (3 inches of shotcrete, Main Canal in HCID No.6)

Table A- 2. Location, Type, and Extent of Lining Projects for HCID No.1

Project	Canal	Material	Total Length		Date of Installation
			Feet	Miles	
10	East Main Canal	Polyurethane	1,823	0.35	1999
11	East Main Canal	Polyurethane	1,364	0.26	1999
12	East Main Canal	EPMD Rubber	1,000	0.19	2000
13	East Main Canal	EPMD Rubber	1,291	0.24	2000
14	East Main Canal	EPMD Rubber	191	0.04	2000
15	East Main Canal	Polyester overlaid by 3.0 inches of shotcrete	110	0.02	2007
16	East Main Canal	PVC Alloy	23	0.00	1999
17	East Main Canal	Polyurethane	604	0.11	1999
18	East Main Canal	Polyurethane	307	0.06	1999
19	East Main Canal	EPMD Rubber	162	0.03	2000
20	East Main Canal	Polyurethane	224	0.04	1999
21	East Main Canal	Polyurethane	46	0.01	1999
22	East Main Canal	PVC Alloy	46	0.01	1999
23	East Main Canal	Polyurethane	558	0.11	1999
24	East Main Canal	PVC Alloy	17	0.00	1999
25	East Main Canal	Polyurethane	1,280	0.24	1999
26	Lateral 19	EPMD Rubber	200	0.04	2000
27	Lateral 19	EPMD Rubber	1,347	0.26	2000

Table A- 3. Yearly Performance Rating by Project in 2011

Project No.	Canal	Material Type	Date of Installation	2005	2006	2007	2009	2011
7+	Wyrick Canal	EPMD Rubber	2004	Fair	Poor	Fair	Poor	Serious Problems
8	Mission Main		2005	Excellent	Poor	Fair	Good	Poor
12	East Main Canal		2000	Good	Fair	Fair	Poor	Serious Problems
13*	East Main Canal		2000	Good	Fair	Good	Fair	Serious Problems
14	East Main Canal		2000	Good	Fair	Removed	Removed	
19	East Main Canal		2000	Excellent	Excellent	Excellent	Good	Good
26	Lateral 19		2000	Good	Fair	Serious Problems	Removed	
27	Lateral 19		2000	Good	Fair	Serious Problems	Serious Problems	Serious Problems
28	Lateral 2a		2004				Serious Problems	Serious Problems
32	AG 15	Green TPO-R	2009				Excellent	Excellent
1+	Canal C	Polyester overlaid by 2.0 inches of shotcrete	2004	Excellent	Excellent	Excellent		Good
3	Canal 13		2006			Excellent		Good
33	Bryan Canal		2009				Excellent	Excellent
5#+	Lateral A	Polyester overlaid by 3.0 inches of shotcrete	2004	Excellent	Excellent	Excellent	Good	Good
15	East Main Canal		2007			Excellent	Excellent	Excellent

* Only 13a; 13b was removed and replaced
# Some sections were rated Fair and one was rated Poor
+ Project that was split in sub-projects

(Table A-3 continue)

Project No.	Canal	Material Type	Date of Installation	2005	2006	2007	2009	2011
4	Main Canal	Polypropylene	2004	Excellent	Excellent	Excellent	Excellent	Excellent
9	Raymoundville Canal		2006	Excellent	Excellent	Excellent		Serious Problems
6	Wyrick Canal	Polyurethane	2004	Excellent	Good	Good	Fair	Poor
10	East Main Canal		1999	Good	Fair	Fair	Poor	Serious Problems
11	East Main Canal		1999	Poor	Serious Problems	Removed	Removed	
17	East Main Canal		1999	Excellent	Excellent	Excellent	Fair	Fair
18**	East Main Canal		1999	Excellent	Excellent	Excellent	Poor	Serious Problems
20	East Main Canal		1999	Serious Problems	Serious Problems	Serious Problems	Serious Problems	Serious Problems
21	East Main Canal		1999	Excellent	Excellent	Excellent	Good	Poor
23	East Main Canal		1999	Good	Good	Good	Fair	Poor
25	East Main Canal		1999	Excellent	Good	Good	Serious Problems	Serious Problems
16	East Main Canal	PVC Alloy	1999	Excellent	Excellent	Excellent	Excellent	Good
22	East Main Canal		1999	Good	Good	Good	Fair	Good
24	East Main Canal		1999	Good	Good	Good	Poor	Serious Problems
2+	Canal 39	PVC overlaid with reinforced wire mesh and 2.5 inches of shotcrete	2005	Excellent	Excellent	Excellent		Good
30	AG 15	Reinforced EPDM	2009				Excellent	Excellent
31	AG 15	Reinforced FPP-R	2009				Excellent	Excellent

** Only 18a; 18b was removed and replaced in 2008

+ Project that was split in sub-projects

Table A- 4. Rating by Sub-Project in 2011

Project No.	Material Type	Feet	Miles	Date of Installation	2011
7A	EPMD Rubber	1,075	0.20	2004	Serious Problems
7B		3,483	0.66	2004	Serious Problems
7C		1,972	0.37	2004	Serious Problems
7D		2,826	0.54	2004	Poor
7E		1,343	0.25	2004	Good
7F		1,358	0.26	2004	Good
13A	EPMD Rubber	250	0.05	2000	Serious Problems
13B*		1,041	0.20	Unknown*	Fair
1A	Polyester overlaid by 2.0 inches of shotcrete	2,629	0.50	2004	Good
1B		9,240	1.75	2004	Good
1C		3,943	0.75	2004	Good
1D		1,311	0.25	2004	Excellent
1E		1,308	0.25	2004	Good
5A	Polyester overlaid by 3.0 inches of shotcrete	2,694	0.51	2004	Excellent
5B		3,167	0.60	2004	Excellent
5C		2,988	0.57	2004	Good
5D		3,851	0.73	2004	Excellent
5E		5,575	1.06	2004	Fair
5F		3,119	0.59	2004	Fair
5G		3,169	0.60	2004	Fair
5H		1,537	0.29	2004	Excellent
5I		10,048	1.90	2004	Poor
5L		2,359	0.45	2004	Fair
18A	Polyurethane	205	0.04	1999	Serious Problems
18B*		102	0.02	2008*	Good
2A	PVC overlaid with reinforced wire mesh and 2.5 inches of shotcrete	8,061	1.53	2005	Good
2B		5,871	1.11	2005	Good

* The original liner has been removed and replaced

Table A- 5. Summary of factors that have higher impact on the material performances

Type of Liner	Liners with a protective barrier	Polypropylene	PVC Alloy	EPDM Rubber	Polyurethane
Pressure of water infiltrating from the levee	X				
Wall structural problems	X	X			
Sharp edge of canal wall		X		X	X
Shrinking			X	X	
Irregular material underneath				X	
Vandalism (intentional and unintentional)				X	
Animal punctures (animal hoofs, vultures, ants, etc)				X	
Human and maintenance traffic				X	X
Lack of maintenance				X	
Inconsistency in product thickness					X
Weather damage					X

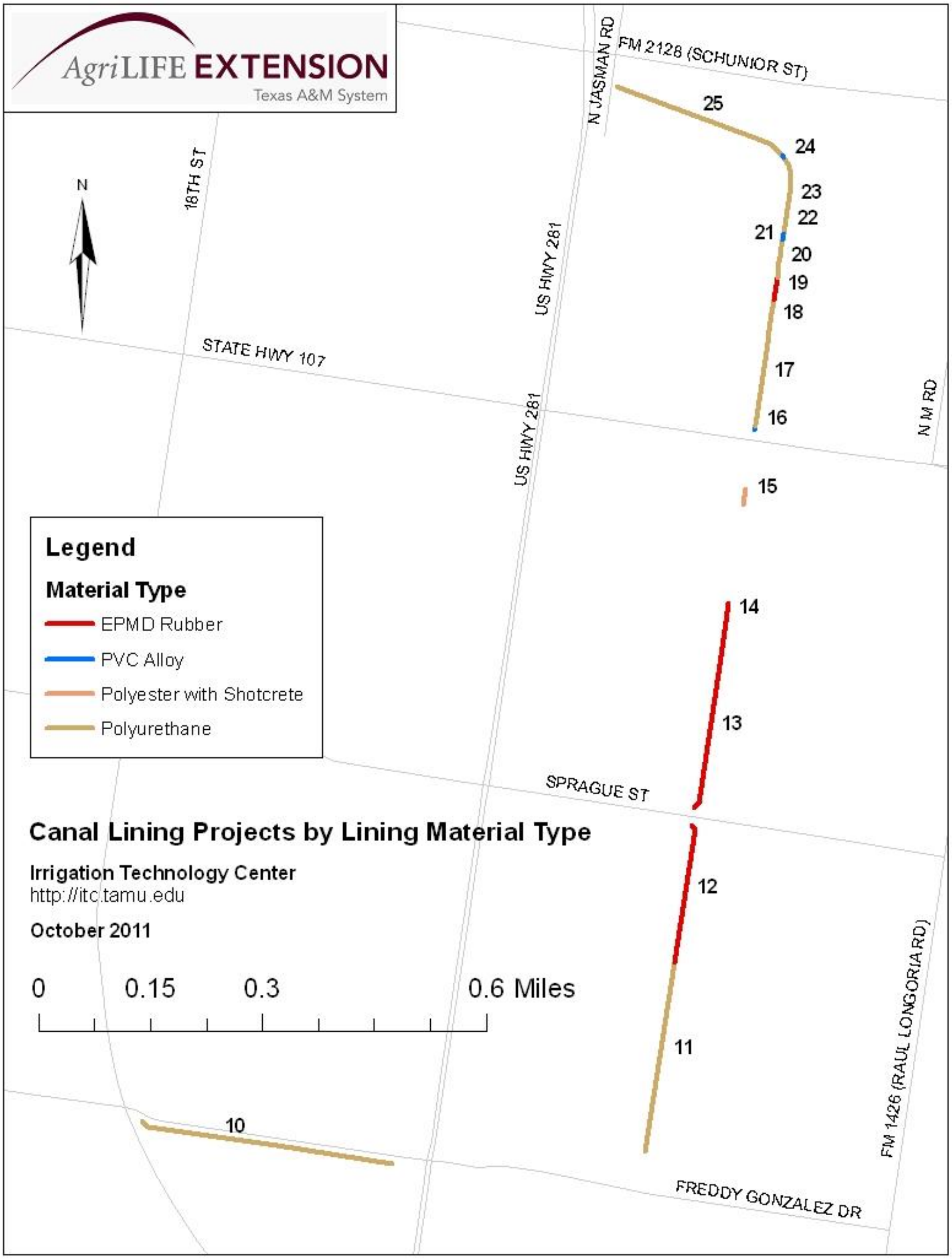

Figure A- 1. Lining Projects by Material Type: Location Map 2, HCID1 Zoomed Area

Figure A- 2. Lining Projects by Material Type: Location Map 2, Adams Garden Zoomed Area

Synthetic Lining – Field Questions (page 1 while walking, page 2 at end) - From upstream to downstream

PAGE 1

Id project:	Date: / /20___	Begin Time: AM/PM	End Time: AM/PM

Evaluators: ______________________________________ **Average Water Depth**: ________ft/in

Number of Cut/Tears/Holes (include repaired, assume repairs = damage, (*) half for holes diameter):

	In (*)	Anchor	Free board	Wet Wall	Bottom
Small	< 6				
Medium	< 15				
Large	< 45				
BIG	> 45				

Structure (gate, pipe, ...):		1____ N/A	2____ N/A	3____ N/A	4____ N/A	5____ N/A	6____ N/A	7____ N/A	8____ N/A	9____ N/A
Lining detached?		Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
Seams coming apart?		Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
Clogging?		Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
General Condition?	Excellent									
	Good									
	Fair									
	Poor									
	Serious Problems									

Pictures (locate in map) First picture code: ______ Last picture code: ______

1		13	
2		14	
3		15	
4		16	
5		17	
6		18	
7		19	
8		20	
9		21	
10		22	
11		23	
12		24	

Other comments:

Figure A- 3. Field Rating Form Used in 2011 for Exposed Synthetic Liners

Synthetic Lining – Field Questions (page 1 while walking, page 2 at end) - From upstream to downstream

PAGE 2

Is the damage **grouped**? ☐ No ☐ Several groupings ☐ Majority (50-75%) ☐ All grouped

Location of groupings

1st (upstream)	2nd	3rd	4th (downstream)
(copy general sketch) ●--->			

Missing sections (location, starting from a reference point, length): ☐ NO ☐ YES

1st (upstream)	2nd	3rd	4th (downstream)
(copy general sketch) ●--->			

Shrinking Cross-Section? ☐ NO ☐ YES

Sedimentation Thickness (average): ☐ None ☐ Light (0.5-1 In) ☐ Medium (1-3 In) ☐ Heavy (> 3 In)

Percentage classes (write if other):		0	0-5	5-20	20-50	50-100	Notes
Anchor coming out of the entrenchment							
Unevenness of dirt under anchor							
Damaged seams/overlapping							
Repaired damage							
Detachment from wall							
Sedimentation							
Multilayer coming apart							
Abrasion							
Vegetation growing through damage							
Wrinkles?							
Canal walls structural problems							What? ___________
-- Not ratable above water level (e.g. grass, dirt)	Free board						Why:____________
	Wet wall						Why:____________
	Bottom						Why:____________

Evidences on cause of damage_____________ ____

Guess the cause of the damage: vandalism, traffic, animal, maintenance, machinery, weather, abrasion, sharp edge of wall, collapsing wall, uneven under anchor, glue failure, debris, shrinking, other:____

Vegetation in drainage ditch and along the outer embankment of the levee:

- ☐ Normal; rain-fed weeds only
- ☐ Canal fed grass or small weeds only
- ☐ Moderate; bushes & some small to no trees with no water near levee or drain
- ☐ Dense; more bushes & larger trees, little or no standing water, little or no aquatic vegetation
- ☐ Dense and lush; bushes, trees, lots of aquatic vegetation with standing water

Evidence of seepage? ____

Rating method From: ☐ left ☐ right By: ☐ driving ☐ walking

Overall material performance: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ Serious Problems

(Figure A-3 continued)

Shotcrete/Concrete – Field Questions (page 1 while walking, page 2 at end) - From up to downstream

PAGE 1

Id project:	Date: / /20___	Begin Time: AM/PM	End Time: AM/PM

Evaluators: ___________________________________ **Average Water Depth**: _______ft/in

Count number of locations where (use percentage in case of large areas):

--Lining detached from canal wall:

- Erosion between the lining and earth canal bank: R _______________ L _______________
- Buckles: R _______________ L _______________

--Shotcrete detached from synthetic under-liner: R _______________ L _______________

--Horizontal cracks: Dry: Hairline _________ Pencil ___________ Large ___________

Wet: Hairline _________ Pencil ___________ Large ___________

Frequency of cracks (average distance (ft) between them, include repaired, assume repairs = damage):

	None	Sparse (#)	> 10 ft	10-5 ft	5-3 ft	< 3 ft	Notes
Hairline Cracks							
Pencil-size Cracks							
Large Cracks							

Structures (gate, pipe, …):		1____	2____	3____	4____	5____	6____	7____	8____	9____
Cracks?		Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
Clogging?		Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N	Y / N
General Condition?	Excellent									
	Good									
	Fair									
	Poor									
	Serious Problems									

Pictures (locate in map) First picture code: ______ Last picture code: ______

1		11	
2		12	
3		13	
4		14	
5		15	
6		16	
7		17	
8		18	
9		19	
10		20	

Other comments:

Figure A- 4. Field Rating Form Used in 2011 for Synthetic Liners with Protective Barrier

Shotcrete/Concrete – Field Questions (page 1 while walking, page 2 at end) - From up to downstream

PAGE 2

Is the damage **grouped**? ☐ No ☐ Several groupings ☐ Majority (50-75%) ☐ All grouped

--- Location of groupings:

1st (upstream)	2nd	3rd	4th (downstream)
(copy general sketch)			

Missing sections (location, starting from a reference point, length): ☐ NO ☐ YES

1st (upstream)	2nd	3rd	4th (downstream)
(copy general sketch)			

Thickness consistency of shotcrete/concrete layer:

☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ Serious Problems ☐ Not noticeable

Sedimentation Thickness (average): ☐ None ☐ Light (0.5-1 In) ☐ Medium (1-3 In) ☐ Heavy (> 3 In)

Percentage classes (write if other):		0	0-5	5-20	20-50	50-100	Notes
Repaired damage							
Sedimentation							
Vegetation growing through damage							
Liner anchor coming out of the entrenchment							N/A
Not ratable above water level (e.g. grass, dirt)	Free board						Why:________
	Wet wall						Why:________
	Bottom						Why:________

Conditions synthetic anchor: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ Serious Problems ☐ N/A

Evidences on cause of damage____

____

Guess the cause of the damage: vandalism, traffic, animal, maintenance, machinery, weather, buckles, collapsing wall, natural movements, other: ____

Canal walls structural problems? ☐ NO ☐ YES What: __________________________________

Vegetation in drainage ditch and along the outer embankment of the levee:

- ☐ Normal; rain-fed weeds only
- ☐ Canal fed grass or small weeds only
- ☐ Moderate; bushes & some small to no trees with no water near levee or drain
- ☐ Dense; more bushes & larger trees, little or no standing water, little or no aquatic vegetation
- ☐ Dense and lush; bushes, trees, lots of aquatic vegetation with standing water

Evidence of seepage? ____

Rating method From: ☐ left ☐ right By: ☐ driving ☐ walking

Overall material performance: ☐ Excellent ☐ Good ☐ Fair ☐ Poor ☐ Serious Problems

(Figure A-4 continued)