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DoD Corrosion Prevention and Control Program

Demonstration of a Liquid-Applied Liner System for Corrosion Protection and Rehabilitation of Wastewater System Structures

Final Report on Project F11-AR24

Clint Wilson, Susan A. Drozdz, Jaclyn Mathis, Larry Clark, and Christopher Olaes

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Final report

Prepared for Office of the Secretary of Defense (OUSD(AT&L))
3090 Defense Pentagon
Washington, DC 20301-3090

Under Project F11-AR24, "Liquid Applied Stress Skin Liner System for Corrosion Protection and Rehabilitation of Wastewater Treatment Systems"

Abstract

Concrete and masonry structures in Department of Defense (DoD) wastewater collection and treatment systems severely corrode over time. Causes include biologically generated sulfuric acid, and are often related to microbially induced concrete corrosion (MICC). This report describes the demonstration of an emerging technology that uses a silicone-modified polyurea compound and closed-cell foam to line deteriorating structures, creating a barrier that is highly resistant to corrosive effluents. At the demonstration site, Fort Bragg, NC, the patented "stress-skin liner" system was applied to one wastewater lift station and eleven manholes.

The technology was applied by licensed contractors without problem, and visual inspection by a third-party contractor confirmed that the quality and condition of the coatings was good. Because no destructive coating-adhesion testing was permitted inside the structures, concrete and masonry coupons were coated with polyurea and tested twice: once at time zero and once after 12 months. Initial coating adhesion was good, but adhesion after exposure was significantly reduced where coating edges were near to uncoated substrate that was continually wetted by sewage. Coating quality after 12 months was confirmed by visual inspection.

The project return on investment (ROI) is 1.00; an alternate ROI calculated without research first costs is 5.5.

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Executive Summary

Corrosion of concrete and masonry in wastewater collection and treatment system structures creates major infrastructure costs for installations operated by the Department of Defense (DoD). The environment inside these structures can become extremely corrosive due to the composition of the waste stream, such as in the presence of biogenic sulfuric acid or other types of microbially induced concrete corrosion (MICC). These conditions are difficult to control, and access to manholes and lift stations for maintenance purposes is hazardous and largely impractical.

This report describes the demonstration of a protective barrier system consisting of liquid-applied silicone-modified polyurea and spray-on closed-cell foam. These materials are combined in a patented, layered application designed to protect steel and masonry wastewater structures from severely corrosive conditions. The objective of the project was to evaluate the performance characteristics of this system and to determine whether it can be applied in an effective manner to existing structures in order to control corrosion and extend expected infrastructure service life.

This demonstration site was Fort Bragg, NC, where the technology was applied to one sanitary sewage lift station and eleven manholes in the wastewater collection system. After application by licensed contractors and an initial visual quality inspection, the structures were inspected at the end of the 12-month performance period to evaluate coating condition. A set of polyurea-coated coupons that were adhesion tested at time zero were lowered into the lift station and exposed for 12 months, after which they were retrieved and subjected to a second adhesion test. These tests, conducted according to ASTM D7234, indicated that initial coating adhesion was good, but could be significantly weakened where edges are located near bare substrate that is continually wetted by sewage.

Extended applicability and modes of implementing this technology DoD-wide are currently being investigated in a follow-on study by ERDC-CERL. The topics include market maturity, technology transfer, safety requirements, and other issues that could not be fully evaluated at the time of the demonstration. The project return on investment (ROI) was 1.00; an alternate ROI projection for real-world applications, not including research first costs, is 5.5.

Preface

This demonstration was performed for the Office of the Secretary of Defense (OSD) under Department of Defense (DoD) Corrosion Control and Prevention Project F11-AR24, "Liquid Applied Stress Skin Liner System for Corrosion Protection and Rehabilitation of Wastewater Treatment Systems." The proponent was the U.S. Army Office of the Assistant Chief of Staff for Installation Management (ACSIM), and the stakeholder was the U.S. Army Installation Management Command (IMCOM). The technical monitors were Daniel J. Dunmire (OUSD(AT&L)), Bernie Rodriguez (IMPW-FM), and Valerie D. Hines (DAIM-ODF)

The work was performed by the Materials Branch of the Facilities Division (CEERD-CFM), U. S. Army Engineer and Structures Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), Champaign, IL. The ERDC-CERL project managers were Clint A. Wilson and Susan A. Drozdz. Significant portions of this work were performed by Mandaree Enterprise Corporation (MEC), Warner Robins, GA. At the time this report was prepared, the Vicki L. Van Blaricum was Chief, CEERD-CFM, Donald K. Hicks was Chief, CEERD-CF, and the Kurt Kinnevan, CEERD-CZT, was Technical Director for Adaptable and Resilient Installations. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Ilker Adiguzel.

The following Fort Bragg personnel are gratefully acknowledged for their support and assistance in this project: Russell Castillo, Water and Wastewater UP, IMBG-PWB-U, Fort Bragg Department of Public Works; Brannon Richards, Engineer, Old North Utility Systems; and James Meyers, Electrician, Old North Utility Systems.

The Commander of ERDC was COL Bryan S. Green and the Director was Dr. Jeffery P. Holland.

Unit Conversion Factors

Multiply	By	To Obtain
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
inches	0.0254	meters
mils	0.0254	millimeters
pounds (force) per inch	175.1268	newtons per meter
square feet	0.09290304	square meters

1 Introduction

1.1 Problem statement

This project addresses a costly corrosion problem found in Department of Defense (DoD) wastewater collection and treatment systems. These systems are constructed mostly of reinforced concrete or masonry, which is vulnerable to numerous corrosive substances and deteriorating stresses that reduce expected system service life. The corrosion of reinforced concrete in wastewater systems ranks among the top 25 most costly for DoD, according to the LMI report SKT50T2, Revision 1, *The Annual Cost of Corrosion for the Department of Defense Facilities and Infrastructure* (Herzberg, O'Meara, and Stroh 2014).

One proposed technology application for mitigating corrosion to these systems is a liquid-applied polymer that cures into a durable, nonporous coating. Such a coating works by toughening the concrete surface and isolating the concrete and reinforcement steel from the highly corrosive conditions inside wastewater systems. The principal purpose of this technology is to extend the service life of partially deteriorated structures that have been in service for a considerable time. However, it also could be used to protect new construction where corrosive conditions are expected. The U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) executed a field demonstration/validation of a liquid-applied stress skin liner for the DoD Corrosion Prevention and Control Program (CPC).

The product selected for this demonstration was the SpectraShield Liner System,* which consists of an epoxy concrete primer, a rapid-cure silicone-modified polyurea barrier coating, and a spray-applied closed-cell foam material. This system cures into a three-layer lining that the manufacturer calls a "stress skin." It is waterproof and claimed to provide its own quasi-structural support, for liner durability. The manufacturer claims that the

* Spectra Tech LLC, Noblesville, IN 46061.

product does not deteriorate upon prolonged exposure to corrosive effluents in wastewater streams, including biogenic sulfuric acid that is one identified cause of microbially induced concrete corrosion (MICC).

1.2 Objective

The objective of this demonstration was to evaluate the performance characteristics of the selected polyurea liner system for the protection of masonry, concrete, and steel components of wastewater treatment systems.

1.3 Approach

Fort Bragg, NC, was selected as the demonstration site. The project team and personnel from the Department of Public Works (DPW) identified sanitary wastewater infrastructure damaged by corrosive effluents. One lift station and eleven manholes were selected for application of the polyurea lining system.

The lining process was accomplished from 4 – 13 December 2013. The work involved pressure-washing the manholes and lift station, and removing all deteriorated materials, including all the steel steps in the manholes. All leaks were repaired to stop water intrusion, after which the liner coatings were applied. A feature of the coating-application process to be noted is that the installation company used a specialized truck with equipment designed to facilitate application of the liquid polyurea material in remote areas.

In addition to periodic visual inspection of the demonstration structures, metrics included concrete test coupons coated with the polyurea material. Adhesion tests were performed to assess the liner system's capability to remain adhered to the concrete or masonry substrates.

2 Technical Investigation

2.1 Technology overview

Corrosion damage typical for wastewater treatment system components is shown in Figure 1 and Figure 2. These pictures are consistent with the effects of MICC, including exposure and corrosion of concrete reinforcement steel. The chemical structure of polyurea in the demonstrated product cures to form a barrier coating that resists corrosion. The foam layer provides a substrate for an additional coat of liquid polyurea, which provides additional standoff between coated concrete and effluent.

Figure 1. Example of MICC-deteriorated concrete in Fort Bragg system.

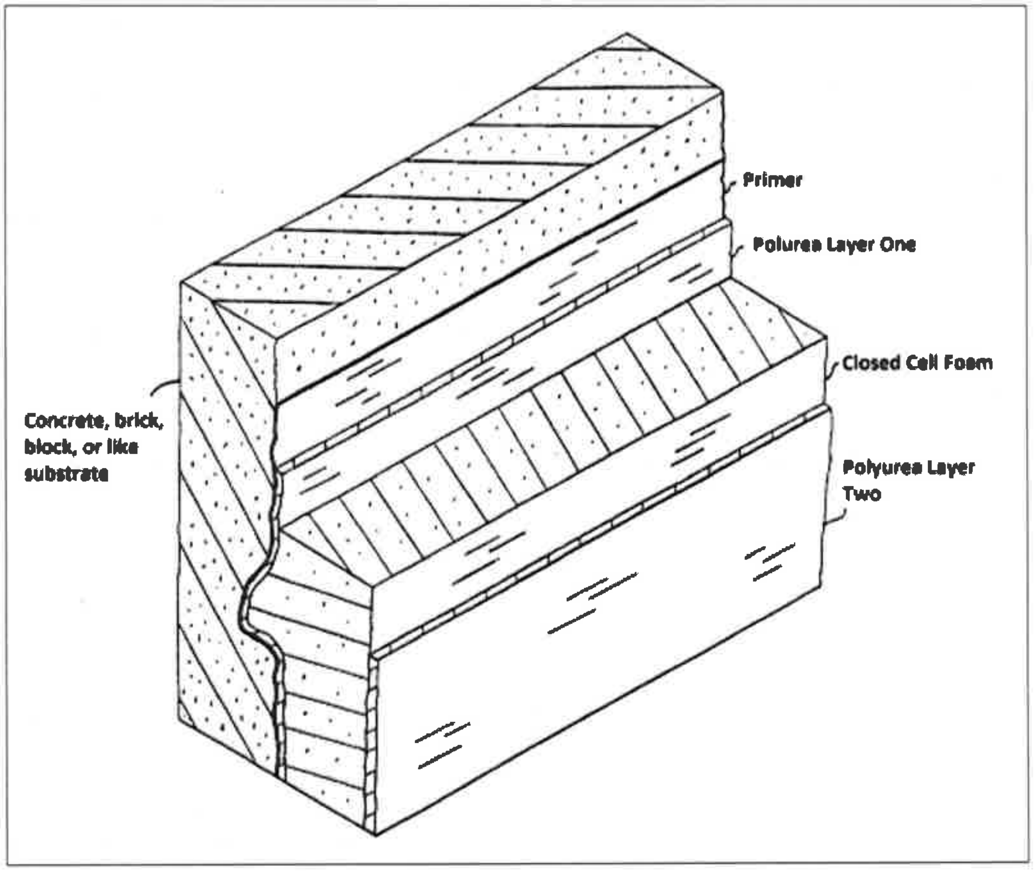
Figure 2. MICC deteriorated concrete and exposed rebar.

To prepare for application of the SpectraShield system, the interior surfaces of the target structures must be hydroblasted or pressure washed, depending on the surface and conditions. Preparation also includes repair of all breaches in the structure to prevent system leakage or infiltration of ground water. Leaks are eliminated with a proprietary SpectraShield polymeric foam grout and/or a cementitious material formulated to form a plug against water intrusion.

The components of SpectraShield include a two-component epoxy primer for the bare, cleaned substrate. The first coat of the liquid polyurea barrier coating is applied over the primer, followed by installation of the closed-cell foam lining material and a final application of polyurea coating to the remaining foam surfaces. The system is illustrated in Figure 3. The lining system has sufficient flexibility to accommodate some shifting of the underlying structure while resisting cracking. The system may be considered for use in new construction as well as structural rehabilitation.

The Material Safety Data Sheets (MSDS) and technical data sheets for the liner system materials are presented in Appendix A.

Figure 3. Illustration of components in liner system.



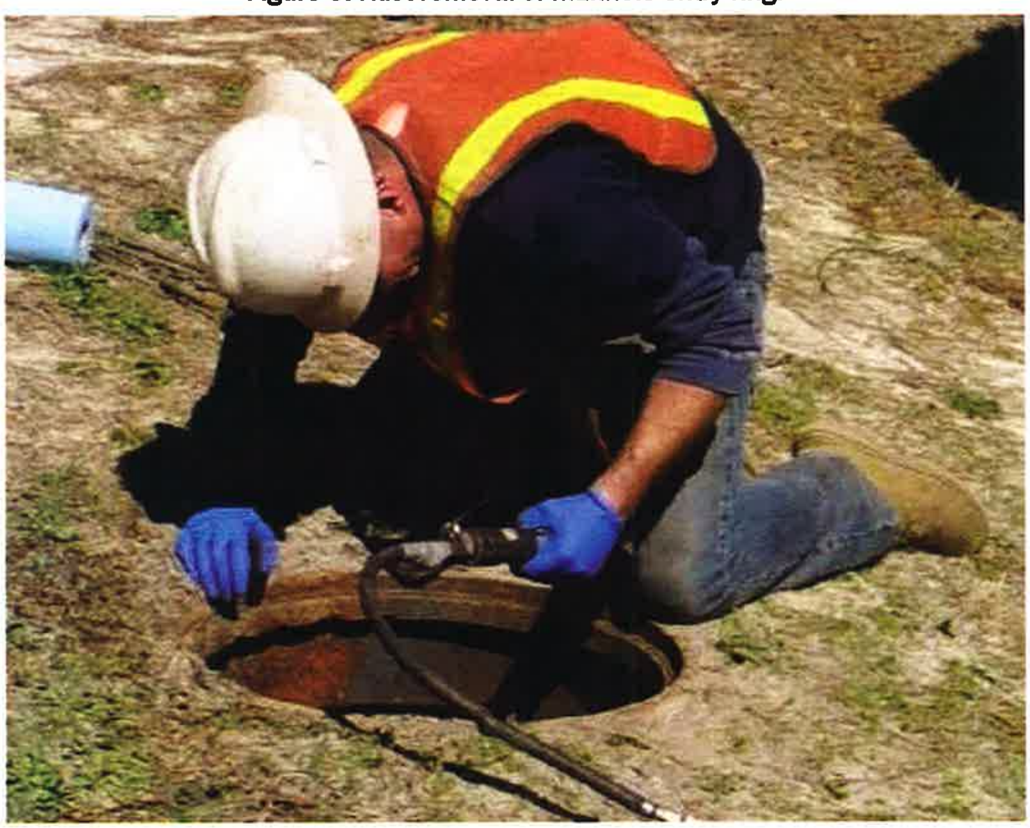
2.2 Field work

The Fort Bragg DPW coordinated the initial preparation of the manholes and lift station. A Fort Bragg DPW support contractor was hired to plug the sewer lines leading to the lift station and to provide temporary pumps and lines to bypass the lift station. Once the bypass was complete, the contractor pumped out the lift station and performed an initial pressure washing at the standard pressure of 3,000 pounds per square inch (psi).

After initial washing, all surfaces in the lift station were hydroblasted at up to 40,000 psi (Figure 4). Note that the concrete deterioration visible in the figure was caused by MICC, not the force of the hydroblasting procedure. This high-pressure washing ensures thorough cleaning of all surfaces, including removal of loose mortar and debris as required by the SpectraShield application instructions. Manholes were pressure washed, but not hydroblasted. Additionally, the steel collars of the manhole entries were cleaned and descaled (Figure 5).

Figure 4. Hydro-blasting a lift station.

Figure 5. Rust removal of manhole entry ring.



Many of the manholes were equipped with steel ladder rungs (Figure 6) that were originally installed for access purposes but are no longer needed. During surface preparation, these rungs were removed with permission to improve the lining results. Generally, rungs should be removed when they are unsafe or not required by applicable codes or local policies. However, when appropriate, permanent access ladder rungs may be left in place before application of the SpectraShield system.

Figure 6. Ladder rungs to be removed.

All damage and leaks found after hydroblasting were repaired using Spectra-Grout or MS-Plug. Spectra-Grout is a proprietary hydrophilic polyurethane product for repairing cracks and leaks. MS-Plug is one brand of hydraulic cement that expands and rapidly cures to provide a more structural-type barrier to leaks. Other commercially available water-plugging treatments may also perform equally well, but they must cure rapidly and stop leaks immediately to ensure full performance of SpectraShield.

Once all repairs were complete, the primer and polyurea barrier material were applied. The initial coating—SpectraShield Wet/Dry Primer—was a two-component epoxy primer designed for wet concrete applications. The primer was followed by the initial layer of polyurea, which is blended from two solid material components. In this project, these materials were heated up to 150 °F using Graco-Guzmer H-20/35 Pro–Dual Plural Component Proportioning Unit spray equipment housed in a purpose-modified truck for onsite portability (Figure 7). In addition to the coating application equipment, the truck is equipped with air compressors for supplied breathing air, and blowers to ventilate the confined spaces that are to be coated.

Figure 7. Specially equipped application-support vehicle.

The first polyurea coating is applied (Figure 8) to a minimum recommended thickness of 75 mils. The material cures in a few seconds and can immediately be coated with the foam. The foam is a two-component polyurethane closed-cell foam formulation (isocyanate and polymeric resin) that is applied at a 1:1 ratio with the plural-component proportioning unit. The equipment must be heated to a minimum temperature of 125 °F at the gun. Like the polyurea, the foam is also a 100% solid, zero-VOC formulation. The foam is applied at a recommended thickness of 350 mils to provide adequate cushion protection from impact damage and to add structural support to the combined liner system. Figure 9 shows the applicator applying the foam over the initial barrier coat in a manhole. The foam application is followed by the final application of the barrier coating to a recommended 75 mils thickness. Once the final coating is applied, it is date stamped (Figure 10) for reference purposes during inspection and maintenance. Figure 11 shows a completed manhole. No difficulties were encountered during preparation or application. Cleanup was completed according to the manufacturer's recommendations.

Figure 8. Applying initial barrier coat.

Figure 9. Applying foam over initial barrier coat.

Figure 10. Coating date stamp.

Figure 11. Finished manhole.

2.3 Inspection and monitoring

To evaluate the performance of the SpectraShield lining system, the demonstration site was monitored by the prime contractor for the demonstration, Mandaree Enterprise Corporation, to ensure that preparation and application were executed according to the manufacturer's specifications. At the time of the application, material coupons were prepared for use in adhesion testing of the polyurea coating. An initial adhesion test was performed on coupons just after liner installation, and those coupons were then suspended in the lift station for one year of exposure. The demonstration structures were also left to normal exposure for one year, after which they were visually inspected to assess performance.

3 Discussion

3.1 Metrics

At the time of this demonstration, there was no industry-wide standard to use as a performance benchmark. For this project, the application quality was evaluated for conformance to the manufacturer's instructions .

The performance goals for the polyurea liner system were to

- effectively adhere to the substrate materials in wastewater system structures;
- prevent damage to concrete, masonry, and steel reinforcement from MICC or corrosive materials transported by wastewater lines; and
- provide a positive return on investment over a 30-year life cycle.

To assess the adhesion of the polyurea coating, brick and concrete coupons were prepared for adhesion testing performed according to ASTM D7234.

The condition of the liners applied to the eleven manholes and lift station were visually examined after 12 months of service to determine their condition under normal exposure for damage, wear, or deterioration. The manufacturer warranty for this product is 10 years (Appendix B).

3.2 Results

3.2.1 Evaluation of application process

The stress liner application in the 11 manholes and the lift station were monitored closely to ensure that workmanlike procedures and processes were followed. The hydroblaster appeared to do an excellent job of removing loose materials to prepare the surfaces. The coating equipment maintained the correct temperatures throughout all applications and was well tended, assuring smooth operation of all spray equipment. All coatings were applied to cover 100% of the surface and met the minimum thickness requirements. No holidays or other coating defects observed after application.

3.2.2 Coating adhesion tests

Five coupons were used in the coating adhesion tests:

- one square concrete slab roughly the size of a brick (C-1)
- two red bricks formed of dense red clay (RB-1 and RB-2)
- two red bricks formed of less-dense red clay blended with sand (B-1 and B-2)

Brick specimens were tested alongside concrete. The Fort Bragg structures are concrete, but adhesion tests on brick are important because many installations still operate wastewater systems with brick structures.

The coupons were prepared when the liner system was applied. Each was drilled with a hole so the specimens could hang from a cable during the 12-month exposure tests. The concrete coupon and one coupon of each type of brick were coated with the demonstrated epoxy primer, then coated with one layer of the polyurea compound. The two remaining brick coupons (one of each type) were coated with polyurea only.

The coating-adhesion tests were performed by Mandaree in accordance with ASTM D7234. The first adhesion tests were executed at the conclusion of the liner application work using an Elcometer 106/6 concrete adhesion tester. The results of Test 1 are shown in Table 1. Two post-test coupons are shown in Figure 12 and Figure 13. The contractor test report is included in Appendix C.

Table 1. Test 1–Initial test (time zero) results.

Coupon	Coating	Failure force (PSI)	Failure mode	Failure area (% of test surface)
C-1, concrete	Primed	410	Substrate Failure	90
RB-1, red brick	Primed	530	Glue Failure	90
B-1, sandy red brick	Unprimed	550	Substrate Failure	98
RB-2, red brick	Unprimed	260	Substrate Failure	99
B-2, sandy red brick	Primed	450	Substrate Failure	98

Figure 12. Concrete specimen C-1 after time-zero test.

Figure 13. Brick specimen RB-1 after time-zero test.

After the time-zero test, the coupons had sufficient surface area for performing a second test after 12 months. To provide exposure for the second test, the coupons were hung on cables inside the lift station. After about 10 months, however, the coupons fell into full sewage immersion at the bottom of the lift station. The DPW contractor shut down the lift station and pumped it out so the coupons could be retrieved. Only the brick coupons were recovered; the concrete coupon was lost. Table 2 shows the results of the second round of tests.

Table 2. Test 2 results after 12 months exposure.

Coupon #	Coating	Failure Force (PSI)	Failure mode	Failure area (% of test surface)
C-1, concrete	Primed	Coupon lost in bottom of lift station		
RB-1, red brick	Primed	450	Adhesive failure A/B	75
B-1, sandy red brick	Unprimed	200	Adhesive failure A/B	75
RB-2, red brick	Unprimed	200	Adhesive failure A/B	35
B-2, sandy red brick	Primed	100	Adhesive failure A/B	50

The test results show a significant change between the first and second tests. In the initial test the bricks and concrete coupons were new and the coatings displayed maximum bond strength; in each test, the substrate material failed without loss of adhesion between the substrate and the coatings. Coupon RB-1 failed at the glue/barrier coat interface only after the tester approached its maximum force. In the second test, much less force was required to reach adhesion failure. In these cases, the failure mode changed from substrate failure to coating/substrate adhesion failure.

As noted, two sites on each coupon were used for adhesion testing—one at time zero and the other at 12 months. In all cases where the substrate failed in the first adhesion test, the coating was damaged in such a way that moisture and sewage could permeate the exposed, porous masonry substrate. Therefore, the second test more closely represents adhesion performance in a case where the barrier coating has been damaged and the substrate exposed to wet sewage. During the 12 month exposure, the coupons were supposed to hang directly over the sewage, but for the last two months they were fully immersed in sewage before being retrieved. Note that coupon RB-1 (Figure 13) passed through Test 1 with only minor coating damage and little direct exposure of substrate; its adhesion result in Test 2 was relatively undiminished, and even remained greater than or comparable to most of the other specimens during Test 1. Nevertheless, the RB-1 failure mode changed to adhesion (versus substrate), indicating that immersion had a negative effect on coating adhesion. The result supports the idea that such a large loss of coating adhesion in the second test was greatly affected by wetting of the coupon substrate.

3.2.3 Twelve-month site assessment

All eleven manholes and the lift station were examined during the closeout assessment visit. No damage was observed to any coatings. The SpectraShield Barrier Coat stress liner appeared intact and performing well after 12 months of service. Photo documentation of the manholes and lift station are in Appendix D.

3.3 Lessons learned

There were no problems with the preparation or application of the SpectraShield lining system. The application crew for this project was experienced and competent.

3.3.1 Performance metrics

There are no industry-accepted performance standards for evaluating this proprietary technology other than manufacturer's technical data sheets. In situ adhesion testing of the applied coating was not possible in this demonstration as it would have been destructive, and repair of the tested areas would be costly. Also, it would be impractical and costly for public works organizations at DoD installations to acquire, operate, and maintain all of specialized equipment required to repair this liner system. Furthermore, the SpectraShield system is protected by a process patent (Hume and Danielle 1997), so it may not be possible to repair liner damage except by retaining the services of a licensed contractor (see Appendix E). Based on the authors' engineering judgment, however, the exposed polyurea layer appears to be tough, flexible, and highly resistant to damage under normal wastewater system operating conditions. Anecdotal evidence offered by users at similar locations indicates that the material provides good performance in excess of 10 years.

3.3.2 Coupon test results

During the performance period, it was observed that test coupons coated with the polyurea component did not all perform well, with adhesion having been compromised near coating edges adjacent to bare substrate surfaces (see section 3.2.2 and Appendix C). This result indicates that repairs should be made soon after any liner damage occurs in order to prevent further loss of coating adhesion. Also, care must be taken during installation to avoid terminating the polyurea application anywhere immersion or exposure to heavy moisture is expected. Even this precaution may not be sufficient in some cases because the more corrosive conditions within a wastewater-collection system often occur in the head space above the water surface. More testing of the specific causes of adhesion degradation would be needed to understand the mechanisms involved. However, such testing may not be needed if other evidence were to show acceptable coating adhesion over time in real-world applications. Finally, as with any other coating system, proper surface preparation is critical to assure good bond strength.

3.3.3 Acquisition issues for DPW applications

As noted above, the demonstrated coating system process is protected by a U.S. Patent (see Appendix E). The terms of the ten-year coating warranty require that technology application and repairs be made only by licensed applicators, not third parties or DPW personnel (see Appendix B). Prospective DPW users should be aware, then, that it is not feasible for installations to use in-house equipment and personnel to repair damage to the liner outside of the warranty period. Furthermore, federal acquisition of the demonstrated system for use on a military installation would require a sole-source approach. Some market competitors offer products with performance claims similar to those made about the SpectraShield system, so it may be possible to develop specifications to support competitive bidding for this type of technology.

4 Economic Summary

4.1 Costs and assumptions

The demonstrated coating system can be applied either to deteriorated structures or new structures. This economic analysis was developed based on the circumstances for the present demonstration, i.e., application to a deteriorated structure that has been in service for many years. Operation and maintenance costs for wastewater system structures is expected to be similar under both Alternatives 1 and 2, so those costs were excluded from the analysis.

4.1.1 Alternative 1 (current practice)

Alternative 1 is continued use of the structures without corrosion protection. The structures are assumed to be replaced in kind when they fail at the end of their service life. Based on engineering expertise and judgment, service life is assumed to be 25 years for both manholes and lift stations, based on conditions observed at the project site and comparisons with typical performance. The manhole structures evaluated for this project were assumed to have been in service for up to 10 years, so 10 years was subtracted from the 25 year service life, leaving a remaining service life of 15 years. The lift station structure was assumed to have been in service for 15 years, so the assumed remaining service was 10 years.

The cost of replacing one manhole was estimated at $4,500, so the total replacement cost for all eleven manholes is $49,500. The cost of replacing the lift station, estimated to be $1,421,000, was applied at Year 10. Only the construction costs were considered in this analysis, because the service life of pumps and other equipment would not be affected by installation of the liner system. The costs described in this section are reflected in Table 3, column B (baseline costs).

The total cost of the CPC demonstration project, including research and administrative expenses, was $550,000. (Funding included a 100% in-kind match of $275,000 from Fort Bragg.)

4.1.2 Alternative 2 (demonstrated technology)

For this alternative, it is assumed that a newly installed liner will last 10 years (i.e., the period of the manufacturer's warranty) before beginning to fail. This is a conservative assumption because the liner will not fail all at once, but will gradually degrade through local debonding or mechanical stresses. Therefore, the liner will continue to provide some protection even after the 10 year mark. Under these assumptions, the lined structures will age 10 years with no degradation. Then begins a period of slower degradation during which the structures are partially protected from corrosion. Although maintenance could be performed during this period, it is assumed that repairs would be too difficult and costly compared with the resulting benefit. For the 11 manholes, the service life assumed for Alternative 1 was 15 years. For Alternative 2, it is reasonable to expect that the remaining service life of the same manholes, now coated, would exceed 20 years (starting at Year 10) while being partially protected. These assumptions are supported, although not explicitly tested, by other research (Vipulanandan 1996). Therefore, the total service life of the lined manholes should exceed 30 years.

Assumptions for the lift station are similar to those for the manholes. The structure ages 10 years with no degradation while protected by the liner. Then begins a period of slower degradation while partially protected. Maintenance could be performed during this period, and is assumed to take place after 10 years, when the first signs of localized liner failure occur. Lift station maintenance costs during this 20 year period of slow failure are estimated to be $20,000. The assumed remaining service life for the lift station in Alternative 1 was 10 years; in Alternative 2, at Year 10, it is reasonable to expect the service life to be 20 years while partially protected from corrosion. Therefore, the total service life of the lift station would be 30 years, with a replacement cost of $1,421,000. The costs described in this section are reflected in Table 3, column D (new system costs).

All other costs under Alternative 2 are assumed to be accounted for in the project $550K project cost. Any other maintenance would be minor, so no additional maintenance cost was included.

4.2 Projected return on investment (ROI)

The return on investment (ROI) calculation follows the method prescribed in Office of Management and Budget Circular No. A-94 (1994), which includes the research costs related to executing the demonstration. Accounting for total demonstration project costs of $550,000, the ROI ratio was calculated at 1.0.

Table 3. OMB ROI for demonstration of the SpectraShield stress-skin liner system.

Return on Investment Calculation

Investment Required			550,000
Return on Investment Ratio	1.00	Percent	100%
Net Present Value of Costs and Benefits/Savings	191,887	740,233	548,346

A Future Year	B Baseline Costs	C Baseline Benefits/Savings	D New System Costs	E New System Benefits/Savings	F Present Value of Costs	G Present Value of Savings	H Total Present Value
1							
2							
3							
4							
5							
6							
7							
8							
9							
10	1,421,000					722,294	722,294
11							
12							
13							
14							
15	49,500					17,939	17,939
16							
17							
18							
19							
20			20,000		5,168		-5,168
21							
22							
23							
24							
25							
26							
27							
28							
29							
30			1,421,000		186,719		-186,719

4.3 Alternate ROI calculation

Using the same OMB discounting methodology, the ROI ratio was recalculated excluding research and other costs unique to a CPC demonstration project (Table 4). Exclusive of demonstration costs, the same baseline application costs were assumed. Specifically, the cost of installing the polyurea liner was calculated to be about $100,000. Therefore, over a 30 year period the alternate ROI was 5.5.

Table 4. ROI for "real-world" application of the SpectraShield system.

Alternate Return on Investment Calculation

Investment Required			100,000
Return on Investment Ratio	5.48	Percent	548%
Net Present Value of Costs and Benefits/Savings	191,887	740,233	548,346

A Future Year	B Baseline Costs	C Baseline Benefits/Savings	D New System Costs	E New System Benefits/Savings	F Present Value of Costs	G Present Value of Savings	H Total Present Value
1							
2							
3							
4							
5							
6							
7							
8							
9							
10	1,421,000					722,294	722,294
11							
12							
13							
14							
15	49,500					17,939	17,939
16							
17							
18							
19							
20			20,000		5,168		-5,168
21							
22							
23							
24							
25							
26							
27							
28							
29							
30			1,421,000		186,719		-186,719

5 Conclusions and Recommendations

5.1 Conclusions

The stress skin liner—made of a layered polyurea compound and closed-cell foam —is a promising technology to use for protecting wastewater treatment and sanitary sewer collection systems from the effects of corrosion. The polyurea "stress skin" used in the SpectraShield system adheres well to unwetted concrete substrate, isolating it from the corrosive sewer environment. The three-layer system, which includes a quasi-structural closed-cell foam component between inner and outer polyurea coatings, is inherently impermeable to water and therefore should also reduce both sewage leakage and ground water intrusion as long as it remains well adhered and undamaged.

The liner has the potential to provide extended service life to the sewer infrastructure in Army and DoD facilities that are deteriorating due to corrosive conditions. The modified silicone polyurea formulation was found to be durable and to perform well in harsh environments. It adheres well when the proper surface preparation is performed, although it is crucial to repair gaps or cuts in the liner. Anecdotal evidence from industry users suggests that durability extends at least as long as the ten-year manufacturer's warranty). Extending the life of current structures provides a life-cycle cost benefit when compared with alternatives. This specific three-layer liner system is patented and available only through the manufacturer's licensees, so procurement costs or other issues may somewhat limit its potential benefits. However, other polyurea-based liner applications are also used in the industry, but none of these products was examined during this demonstration. A follow-on study being conducted by ERDC as of the time of this writing will provide additional technical information on polyurea-based coatings for use in wastewater-collection systems and structures.

The stress liner system performed well over the twelve-month assessment period. Adhesion testing showed the coating system adheres well immediately upon application and should remain intact in the absence of liner damage that exposes the substrate to wetting or immersion. It seems likely that the polyurea should adhere well beyond the first 12 months. No published documentation on long-term performance is available for this proprietary technology, but the product warranty makes the manufacturer responsible for repairing defects during the first 10 years of service.

5.2 Recommendations

5.2.1 Applicability

The demonstrated polyurea stress-skin liner system is applicable to new construction or rehabilitation of existing wastewater system infrastructure. The technology validated in this demonstration project should be considered where repairs are needed due to MICC or other corrosive factors while full replacement would be cost-prohibitive or disruptive to operations. The application and adhesion test results indicate that this technology, when properly adhered and not damaged, can protect and extend the service life of wastewater collection systems with a positive return on investment by reducing maintenance requirements and costs—particularly those related to corrosion processes and leakage or ground water infiltration. The impermeable barrier materials (when well adhered and undamaged) can isolate wastewater system structures from accelerated corrosion caused by acidic waste streams. Also, because this liner system has quasi-structural properties, it may be beneficial where minor strengthening and sealing characteristics can help to stabilize an aging brick or concrete manhole that is beginning to crumble.

5.2.2 Implementation

Since the conclusion of this demonstration, there has been significant growth in the use of polyurea coatings for protection of wastewater system infrastructure, including some alternative liner systems offered by new market competitors. The development of an established market with a variety of commercial alternatives and experienced applicators will facilitate the development of implementation recommendations within the framework of Unified Facilities Guide Specifications (UFGS) or Unified Facilities Criteria (UFC).

ERDC-CERL is performing follow-on research and studies of polyurea-based applications, and the product of that work will include specific recommendations for additions to applicable sections of the UFGS and UFC to facilitate DoD-wide implementation. The study addresses market maturity, technology transfer, safety requirements, and other issues that could not be fully evaluated at the time of this demonstration.

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