Assessment of the Uretek Process on Continuously Reinforced Concrete Pavement, Jointed Concrete Pavement, and Bridge Approach Slabs

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by

Kevin Gaspard, P.E. and Mark Morvant, P.E.

Louisiana Transportation Research Center
4101 Gourrier Ave.
Baton Rouge, LA 70808

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ABSTRACT

This study evaluates the rehabilitation method utilizing the injection of Uretek (polyurethane) into the pavement structures on continuously reinforced concrete pavement (CRCP), jointed concrete pavement (JCP), and bridge approach slabs. The polyurethane injection was used to fill voids and level the CRCP and bridge approach slabs. On JCP, it was used to reduce faulting, fill voids, and underseal.

Testing results indicated that injecting polyurethane into the pavement structure is an effective method of leveling CRCP and bridge approach slabs. On the CRCP and bridge approach slabs, IRI values were reduced from 33 to 68 percent, while as much as 2 inches of depression was removed from the slabs.

The polyurethane injection process filled pavement voids as demonstrated by trenching in the JCP and core samples in the CRCP and bridge approach slabs. In the CRCP and bridge approach slabs, the polyurethane was dense. However, varying layers of stiffness ranging from soft to dense were found in samples taken from the JCP. This variation could be problematic, and the causes warrant further investigation through additional research.

Forensic investigation of both the trenched slab and patched areas on the JCP proved to be insightful. Both the trenched and patched slabs were visually inspected. The adjacent slabs in the left lane, which had been previously injected with polyurethane in April 2002, were observed under traffic loading. The joints in the left lane were seen significantly deflecting under traffic and water was seen flowing through the joint and slab, indicating that the polyurethane did fill the voids but did not appear to provide much support to the joints. It should be noted that the star lug load transfer devices were not functioning.

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IMPLEMENTATION STATEMENT

The purpose of this project was to evaluate the polyurethane injection process and establish guidelines for its usage on CRCP, JCP, and bridge approach slabs. Specific guidelines have been developed for each pavement listed above and are available for implementation into DOTD projects.

It is recommended that polyurethane injection be included as an alternative to other rehabilitation methods such as patching and asphaltic concrete overlay for leveling CRCP and bridge approach slabs. Factors such as cost and traffic disruptions should be reviewed when determining which rehabilitation would be most feasible. As a result of this research, DOTD and FHWA have endorsed this process for CRCP and bridge approach slabs. Further research should be conducted to refine the quantity estimation models.

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INTRODUCTION

Louisiana has used the Uretek method since 1994. The Louisiana Department of Transportation and Development (DOTD) has used over 400,000 pounds of polyurethane on 36 projects. The Uretek process has been used to level depressions on bridge approach slabs, continuously reinforced concrete pavement (CRCP), drainage structures, and parking lots. It has also been used on jointed concrete pavements (JCP) to reduce longitudinal and transverse faulting, level depressions, slab undersealing, and filling voids.

The Uretek method is a patented process that uses high density polyurethane foam (HDPF) to lift, realign, underseal, and fill voids under concrete slabs. The HDPF is injected through predrilled 5/8 inch-diameter holes in the slab. Uretek USA has developed specific drilling patterns to address the various types of distress in the slabs. Uretek may be injected between the slab and base course, beneath the base course, and in deep foundation.

On JCP, the Districts have reported success on roadways that were treated with Uretek to reduce faulting and underseal the slabs. No additional faulting was observed on any slabs after four years of service, including the ones in which the star lug load transfer devices were saw-cut to allow the faulting to be corrected in accordance with specifications.

This study evaluated the rehabilitation method utilizing the injection of Uretek (polyurethane) into the pavement structure on CRCP, JCP, and bridge approach slabs. The polyurethane injection was used to fill voids and level the CRCP and bridge approach slabs. On JCP, it was used to reduce faulting, fill voids, and underseal.

OBJECTIVE

Continuously Reinforced Concrete Pavement Leveling

- Improve the ride quality by leveling the depression with Uretek.
- Assess the pavement structure, profile, and rideability before and after the polyurethane process.
- Determine a method(s) to accurately establish the horizontal and vertical dimensions of the CRCP pavement depression.
- Develop a method(s) to estimate polyurethane quantities for Design Engineers.
- Develop guidelines for using the polyurethane method.

Jointed Concrete Pavement Faulting

- Assess the pavement profile, structure, faulting, and joint load transfer efficiency before and after the polyurethane process.
- Assess the pavement profile, structure, faulting, and joint load transfer efficiency of concrete slabs that were previously treated with polyurethane in 2002.
- Assess the effects of different polyurethane injection patterns and depths.
- Develop a method(s) to estimate polyurethane quantities for Design Engineers.
- Develop guidelines for using the polyurethane method.
- Evaluate slabs that were injected with polyurethane in April 2002.

Bridge Approach Slab Leveling

- ❖ Improve the ride quality by leveling the bridge approach slab with polyurethane.
- ❖ Assess the pavement structure, profile, and rideability before and after the polyurethane process.
- ❖ Develop a method(s) to estimate polyurethane quantities required to level the approach slab for Design Engineers.
- ❖ Develop guidelines for using the polyurethane method on concrete approach slabs.

SCOPE

Continuously Reinforced Concrete Pavement

The Uretek process was evaluated on a pavement depression located at Mile Post 193.4, I-10, West Bound, St. James Parish, S.P. Number 450-12-0028. The test section length was 90 feet long and included both travel lanes.

Jointed Concrete Pavement

The Uretek process was evaluated on Evangeline Thruway, S.P. 424-02-0083, U.S. 167 & U.S. 90, Lafayette Parish. Evangeline Thruway is a six-lane curb and gutter highway. Three areas were tested between stations 3+76 and 7+20. Area 1 included 15 concrete slabs. Some of the slabs in the center lane had 1-inch fault heights at the transverse joints. Area 2 included 18 concrete slabs. Most of the slabs in this area had been injected with polyurethane in April 2002. Area 3 included 12 concrete slabs. One of the slabs was treated with polyurethane and then trenched to determine if the polyurethane undersealed the slab and filled voids at the transverse and longitudinal joints.

Bridge Approach Slabs

Two bridge approach slabs were evaluated on S.P. 455-02-0065, I-49, St. Landry Parish near Nuba, Louisiana.

- ❖ US 167 Extension, Departure slab, North bound lanes, Bridge Number 4550214731, CSLM 14.73
- ❖ Bayou Duplente, Approach slab, South bound lanes, Bridge Number 4550212802, CSLM 12.8

METHODOLOGY

Testing Locations

CRCP Leveling

The CRCP evaluated was located at mile post 193.4, I-10, West bound in St. James parish. The embankment for this section of I-10 was constructed over an area with poor subgrade conditions using hydraulic sand fill. The pavement is approximately 35 years old, and its structure consists of 8 inches of CRCP, 5 inches of asphaltic concrete base course, and 12 inches of sand-shell base course. Pavement depressions have been observed over the years on this section of I-10, many of which are located at cross drain pipes. Embankment settlement and poor compaction around the cross drain pipes are believed to cause these depressions.

Several methods of repair, such as CRCP patching and using asphaltic concrete to fill in the depression, have been used. DOTD elected to evaluate the polyurethane injection method, as an alternative to the previously mentioned repair methods.

The location selected for this study had a measured pavement depression of 2.3 inches at the pavement edge and did not show signs of failure. Polyurethane injection area boundaries were located by holding a string line along the edge of the pavement. The locations where the pavement was visibly vertically departing from the string line were marked, as shown figure 1. Testing began approximately 10 feet before and after the depression. For details of all baselines, equipment testing, concrete coring, and Uretek injection locations, see figure 2.

In order to establish guidelines for the polyurethane injection process, a partnership was established between Uretek USA and LTRC with the following conditions.

- Uretek USA donated the labor and materials for the polyurethane injection process and elected to have their consultant (ERES) conduct testing on the research test sections.
- LTRC conducted field testing on the research test section and published a technical assistance report.

Figure 1

CRCP Depression

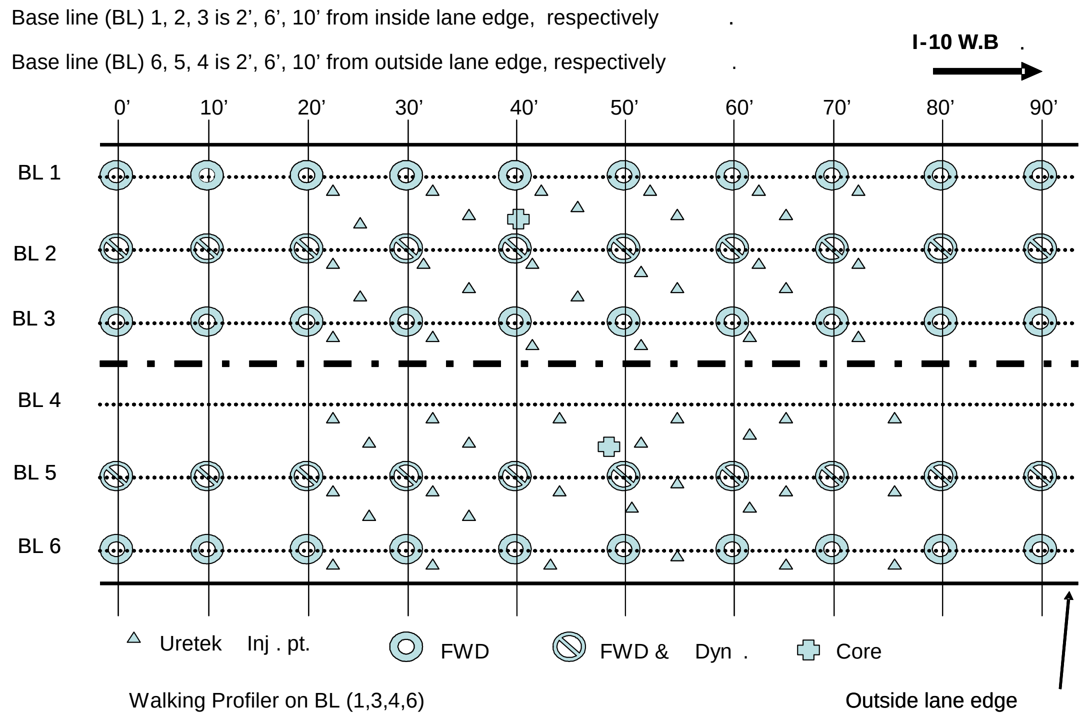

Figure 2

CRCP testing layout

JCP Faulting

The JCP evaluated was located on Evangeline Thruway (US 167 – US 90) in Lafayette, Louisiana, S.P. 424-02-0083. District 03 headquarters asked LTRC to evaluate the Uretek process on this patching and slab leveling project. Additionally, slabs that had been injected with Uretek under a previous patching project in April 2002 were also evaluated.

Evangeline Thruway is a six-lane curb and gutter urban roadway with subsurface drainage. The pavement is approximately 38 years old and its structure consists of 9 inches of Portland cement concrete and 12 inches of soil cement with a silty-clay subgrade. Failures have occurred in the load transfer devices (star lugs), leaving only aggregate interlock to transfer loads across the joints. Severe faulting exists in both the longitudinal and transverse joints, especially in the center lane. Further adding to the deterioration of this pavement are heavy truck loads (>100,000 lbs.) along this sugar cane hauling route. Additionally, many of the slabs were severely cracked and needed to be replaced.

Three areas were selected for evaluation. Area 1 had slabs with faulting heights of approximately 1 inch. Area 2 had slabs that were rehabilitated with polyurethane injection in 2002. Area 3 had slabs that were visibly moving under traffic loading. Appendix 1 presents the slab locations.

Bridge Approach Slab Leveling

Two bridge approach slabs were evaluated on S.P. 455-02-0065, I-49, St. Landry Parish near Nuba, Louisiana.

- US 167 Extension, Departure slab, North bound lanes, Bridge Number 4550214731, CSLM 14.73
- Bayou Duplente, Approach slab, South bound lanes, Bridge Number 4550212802, CSLM 12.8

These approach slabs have experienced settlement that caused pavement depressions. Depressions in concrete approach slabs are common in Louisiana. They have been mitigated by overlaying with asphaltic concrete, mud jacking, reconstruction, and polyurethane injection. District 03 asked LTRC to evaluate the polyurethane injection process and determine its effectiveness. The approach slabs and adjacent pavement are approximately 21 years old. The existing roadway typical section is 10-inch thick concrete pavement, 2-inch thick asphaltic concrete base course, and 6-inch thick treated soil. The existing bridge approach slabs had typical sections that consisted of 10-inch thick concrete pavement, 12-inch thick stone, and 6-inch thick treated soil. Figures 3 and 4 present the testing layout.

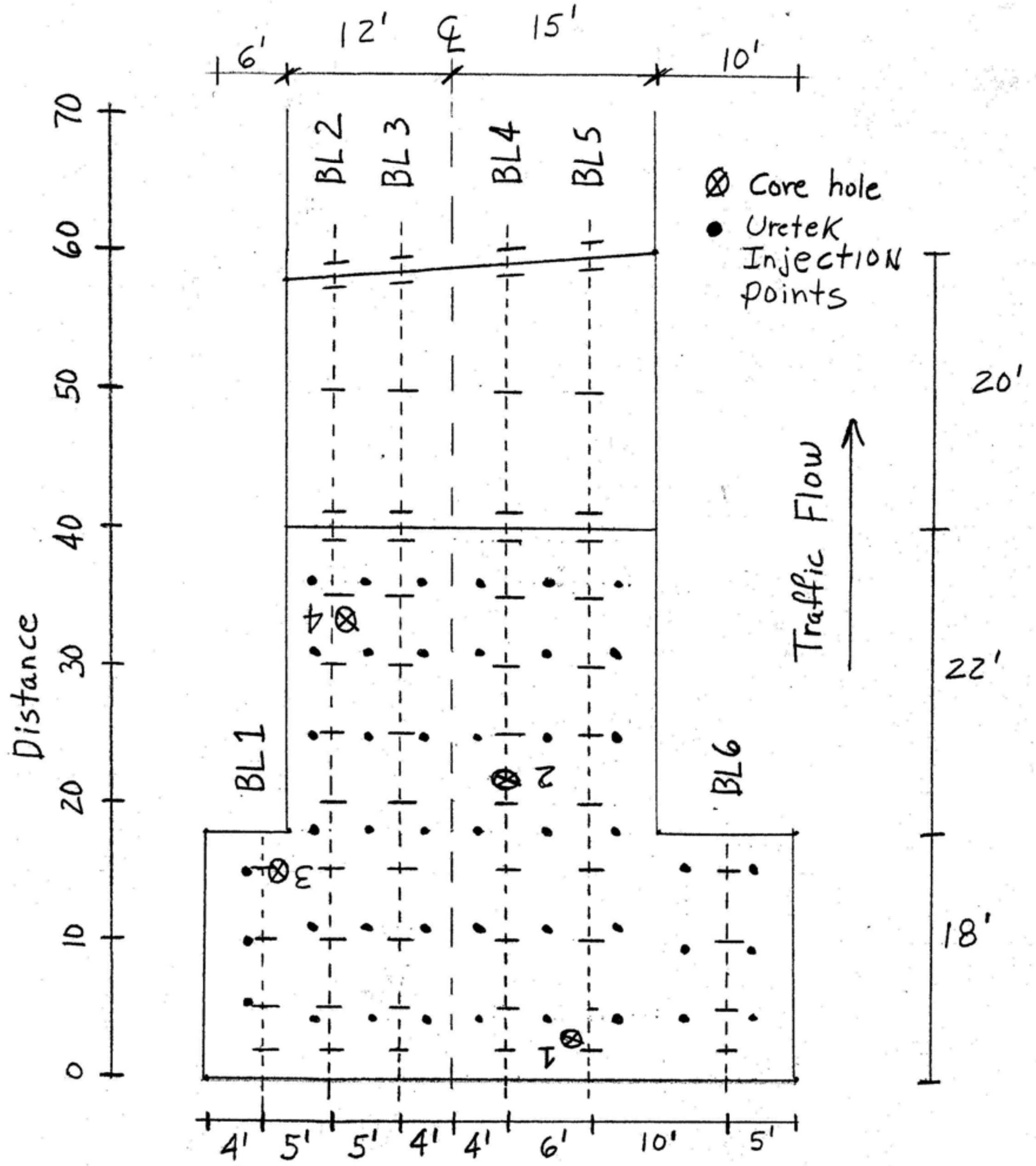

Figure 3
Testing layout for US 167 NB approach slab

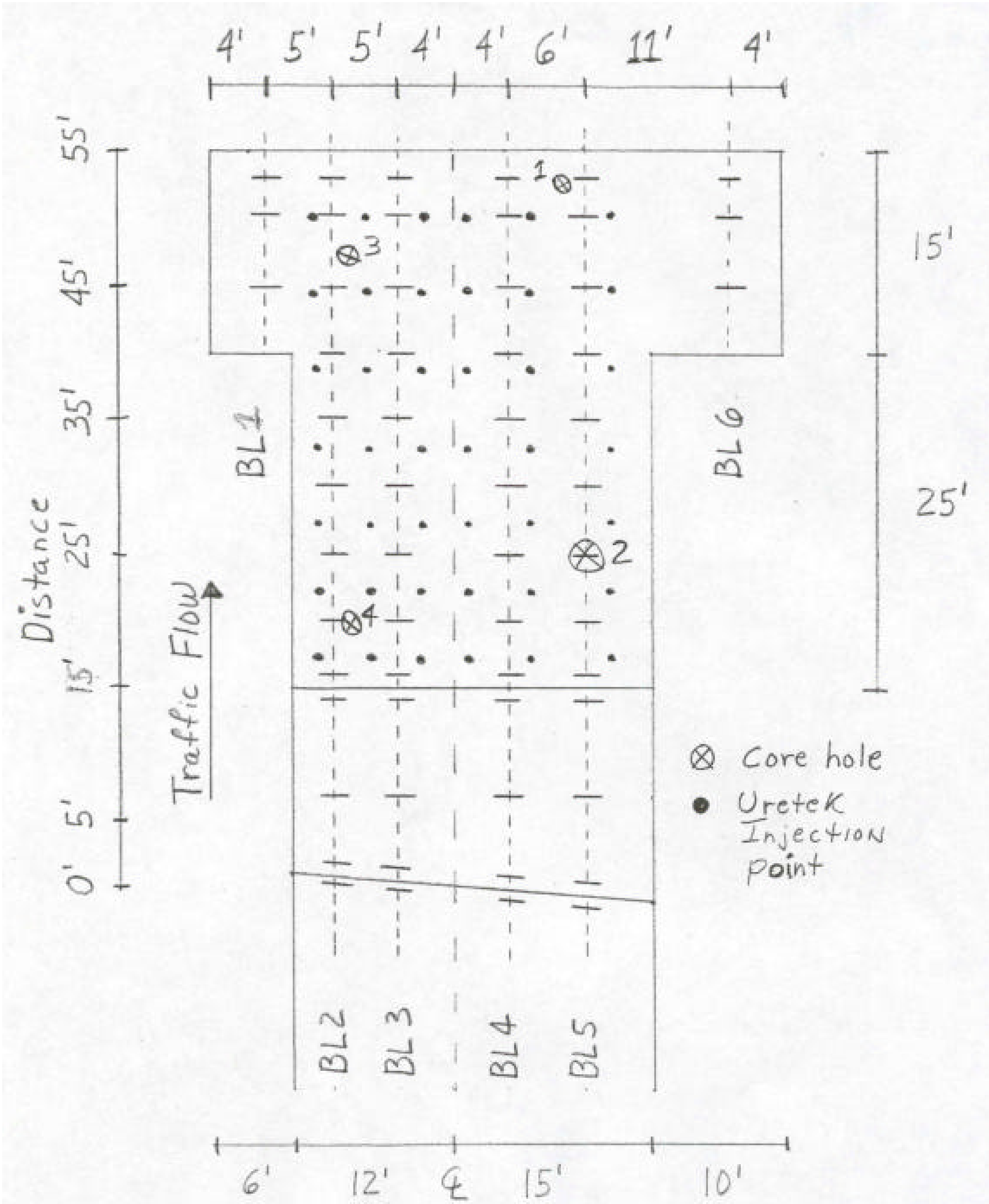

Figure 4
Testing layout for Bayou Duplente approach slab

Testing Factorial

CRCP Leveling

The test section was evaluated before and after the pavement depression was leveled by injecting polyurethane into the pavement structure. Prior to injection, the pavement structure was evaluated with the Falling weight Deflectometer (FWD), Dynaflect, High speed profiler, and walking profiler. After injection, the pavement was reevaluated with the equipment previously described, and core samples were taken.

JCP Faulting

Uretek injection locations: In order to determine the effectiveness of injecting polyurethane between the concrete slab and base course, drilling patterns and hole depths were established, as shown in table 1. Figure 5 illustrates the trench detail and typical testing patterns.

Two main treatments were targeted: raising and undersealing. Raising meant lifting the slabs so that the faults could be removed from the joints. The contractor was instructed to raise the slabs until the fault was removed or until the joints would lock up during the process. When this occurred in the past, the contractor would saw cut through the joint and then continue to raise the slab until the fault was removed. This practice was not allowed on this project. Undersealing refers to the process where polyurethane is injected to fill any voids. This process entails injecting polyurethane and carefully monitoring the slab for any changes in elevation. Once a 1 mm change is noticed, the injection process is halted.

Testing in Areas 1, 2, and 3: Areas 1 and 3 were tested with the Falling Weight Deflectometer (FWD), Dynaflect, and High speed profiler, as conditions permitted, before and after the pavement structure was injected with polyurethane. Slab 74 underwent trenching and slab removal to acquire samples and observe polyurethane spread over the base course.

The slabs in Area 2 had been injected with polyurethane in April 2002 and were evaluated prior to patching or removal with the equipment previously mentioned. The initial distress conditions of the slabs were not documented in the April 2002 polyurethane injection process. After the center lane slabs were removed, the adjacent slabs, previously injected with polyurethane (April 2002), and base course were visually inspected.

Table 1
Uretek injection locations

Panel	Purpose	Injection location	Proposed hole depth (in)	Actual hole depth (in)	Panel (ft) L x W	Net Quantity (lbs.)
26	Raise	Full panel	10	18	22 x 11	139.8
29	Raise	Full panel	18	18	20 x 11	108.6
32	Underseal	Transverse joints	10	18	17 x 11	33.0
53	Underseal	Transverse joints	10	18	20 x 11	34.2
56	Underseal	Full panel	10	18	20 x 11	55.8
60	Raise	Full panel	10	18	20 x 11	73.2
63	Underseal	Corner	18	18	20 x 11	14.4
68	Underseal	Full panel	10	18	20 x 11	72.6
71	Underseal	Transverse joints	18	18	20 x 11	48.6
72	Underseal	Full panel	10	18	20 x 11	87.0
74	Raise	Full panel	10	10	20 x 11	73.8
75	Underseal	Longitudinal joint	10	10	20 x 11	35.4
77	Raise	Full panel	18	18	14.5 x 11	256.8
78	Underseal	Corner joint	10	18	14.5 x 11	16.2
			Total Uretek quantity			1049.4

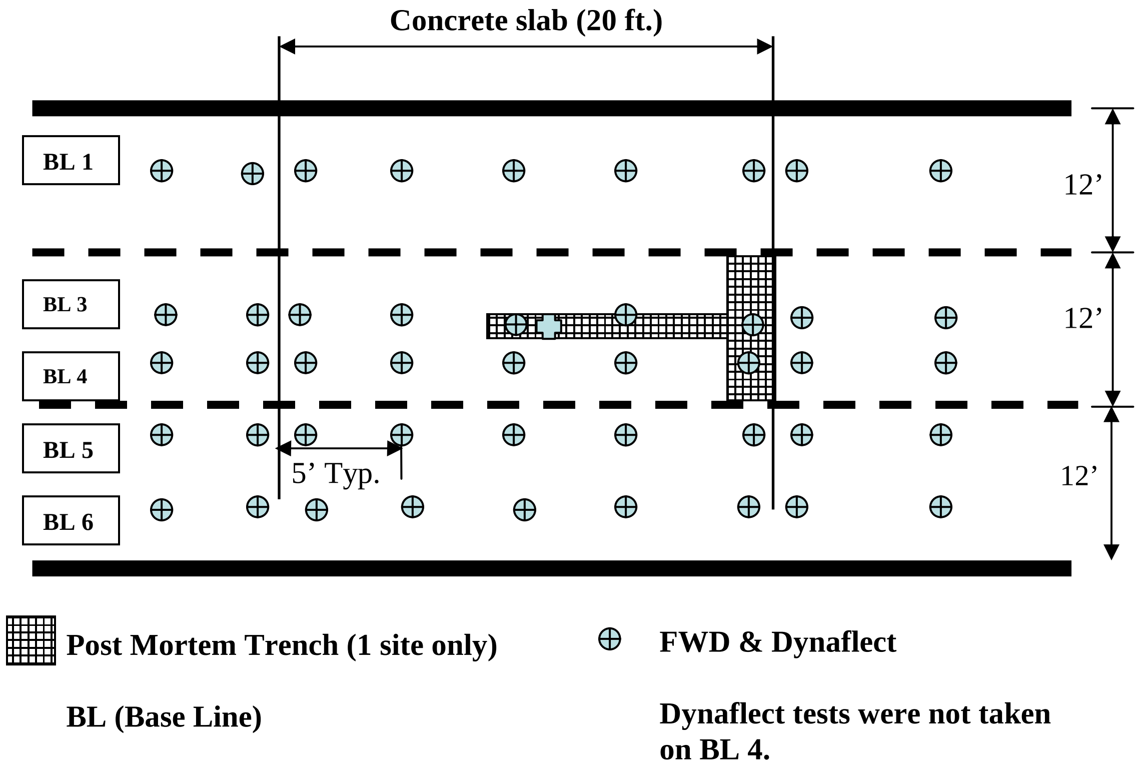

Figure 5

Typical diagram for trenching and testing

Bridge Approach Slab Leveling

The bridge approach slabs were tested before and after the pavement depressions were leveled by injecting polyurethane into the pavement structure. Prior to injection, the pavement structure was evaluated with the FWD, Dynaflect, High speed profiler, and walking profiler. After injection, the pavement was reevaluated with the equipment previously described, and core samples were taken.

Testing Equipment

High speed and walking profilers were used to determine the pavement profiles and IRI.

Walking Profiler

The ARRB Walking Profiler is a precision instrument designed to facilitate the efficient collection and presentation of continuous paved surface information, including distance, profile, grade, and International Roughness Index (IRI) measurements. The Walking Profiler enables accurate recording of measurements for the actual profile, grade, and level for surfaces such as paved roads, footpaths, runways, building slabs, and sporting surfaces.

This compact and easy-to-use device is pushed over the surface to be surveyed. The on-board computer calculates and displays results (graphics and tables). The IRI output from this device meets World Bank Class 1 Profilometry requirements. LTRC has verified the system by comparing the IRI measurements to pavement profiles obtained using a precision rod and level survey. The system comes with a basic Footworks software package that provides profile and IRI computation.

High Speed Profiler

High-speed profilers evaluate the smoothness of a pavement by measuring its surface profile. The high-speed profiler produces precise profile measurement at speeds up to 65 MPH. This permits rapid, real-time measurements, thus eliminating the need for lane closures or traffic control to test existing pavements. The system consists of an industrial-hardened PC with printer, precision accelerometer, laser height sensor, data acquisition sub-system (DAS), and distance measuring instrument (DMI).

The system uses the measurement to calculate a profilograph index (PI), international roughness index (IRI), and ride number (RN), which are used to rate the surface smoothness.

The system also generates a profilograph-type plot with defect locations and must-grind lines, which tells the user where the roughness exists and what corrective action to take.

The profiler is a non-contact measuring device. The data collected is not affected by vehicle variation (i.e., speed, weight, and suspension). Measurements are not affected by changes in temperature, pavement color or texture, sunlight, wind, or speed. The equipment meets the requirements of an ASTM E950 Class 1 profiling device.

FWD

The FWD was used to determine the structural layer moduli, deflections, and void potential at the testing locations. The structural layer moduli and void potential was determined using Dynatest's ELMOD 5 backcalculation software. The deflections from the load plate (first sensor) were used to determine the differences in pavement deflections. The void detection process is outlined in Appendix 2.

The Falling Weight Deflectometer (FWD) is a device that closely approximates the effect of a moving wheel load, both in magnitude and duration. The 9,000 pound load is applied through a circular plate which causes the pavement to deflect. Once the load is applied, it is measured by a precision heavy duty load cell which is above the loading plate. By means of a high speed transducer, the deflection data is acquired by a computer. Through a backcalculation process, the resilient modulus (elastic modulus) is determined for each layer. Dynatest's ELMOD 5 was the backcalculation software used on this project.

Dynaflect

The Dynaflect was used to determine the overall structural number of the pavement structure. It is a trailer mounted device which induces a dynamic load on the pavement and measures the resulting slab deflections by using geophones spaced under the trailer at approximately one-foot intervals from the application of the load. The pavement is subjected to a 1,000 pound dynamic load at a frequency of eight cycles per second, which is produced by a counter rotation of two unbalanced flywheels. The generated cyclic force is transmitted vertically through two steel wheels spaced 20 inches apart, center to center. The dynamic force during each rotation of the flywheels at the proper speed varies from 1,100 to 2,100 pounds. The deflection measurements induced by the system are expressed in terms of milli-inches of deflection. Through a series of equations and graphs, the structural number (SN) is determined.

Core Samples (CRCP and bridge approach slab sites only)

Four-inch diameter cores were taken through the pavement structure after the polyurethane injection for visual inspection of the core and subgrade.

Trenching (JCP site only)

A trench was saw cut into slab 74 after polyurethane injection and removed so that visual inspection of the base course and pavement joints could be conducted. Additionally, polyurethane samples were collected.

DISCUSSION OF RESULTS

I-10 CRCP leveling

The work for this project occurred from September 22–24, 2003.

Appendix 3 contains the figures and tables for I-10 CRCP that are not included in the body of this text.

Profiles

The data obtained from the high speed and walking profilers were used to determine profile changes, IRI, and establish a procedure for estimating quantities.

Walking Profiler

Figure 6 illustrates the profile and table 2 illustrates the IRI values before and after the polyurethane injection. The remaining walking profiler figures can be found in Appendix 3. Based on the point of maximum depression, the pavement was raised 2.019 inches on average. IRI was significantly reduced from 57 to 68 percent.

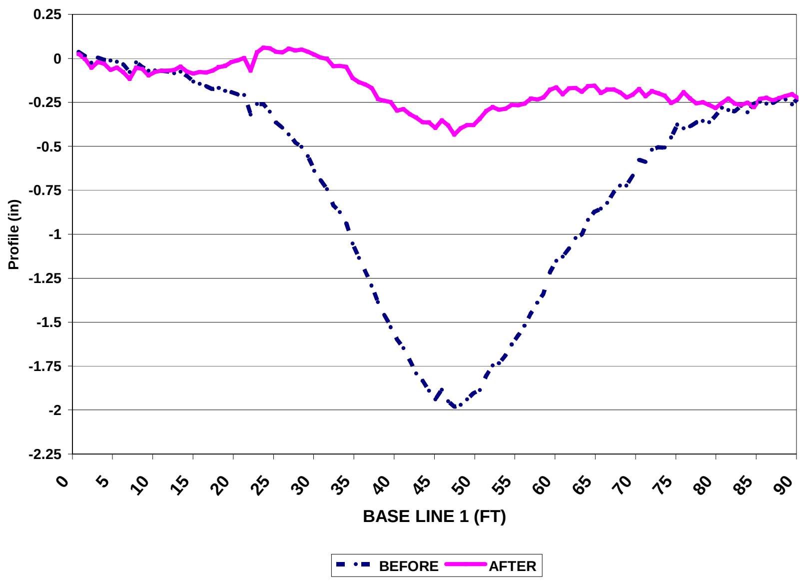

Figure 6
Walking Profiler base line 1

Table 2
IRI data from ICC High speed and ARRB Walking Profilers

ICC HIGH SPEED PROFILER					
	INSIDE LANE (IRI)			OUTSIDE LANE (IRI)	
	WHEELPATH			WHEELPATH	
	LEFT	RIGHT		LEFT	RIGHT
BEFORE	192	198		213	177
AFTER	106	86		121	111
ARRB WALKING PROFILER					
	INSIDE LANE (IRI)			OUTSIDE LANE (IRI)	
	WHEELPATH			WHEELPATH	
	LEFT	RIGHT		LEFT	RIGHT
BEFORE	218	259		296	221
AFTER	94	84		121	95

High Speed Profiler

Table 2 illustrates the IRI values before and after the polyurethane injection. IRI values were significantly reduced from 37 to 57 percent. Figures 7 and 8 illustrate the profiles before and after polyurethane injection. Linear regressions were taken through both profiles. Lesser slopes on the linear regression line indicate a smoother profile. It should be noted that the polyurethane injection process significantly lessened the slope, indicating an improvement.

In April 2004, the outside lane was profiled again with the high speed profiler. Figure 9 displays both the April 2004 profile graph and the graph from the profile taken after the polyurethane injection. The graphical representation of the results indicated that the profiles were similar, which means that, in regards to profile, the polyurethane injection process is still functioning.

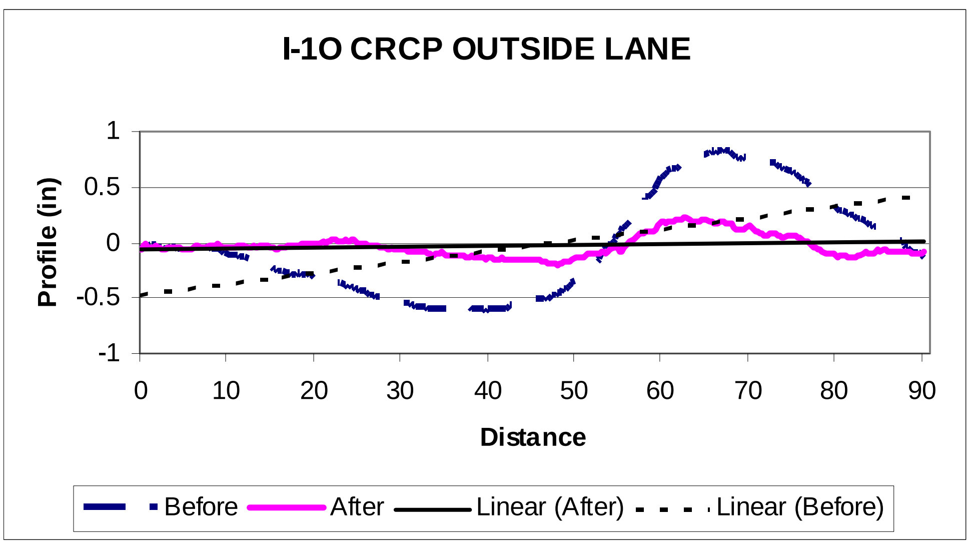

Figure 7
I-10 CRCP profile (outside lane)

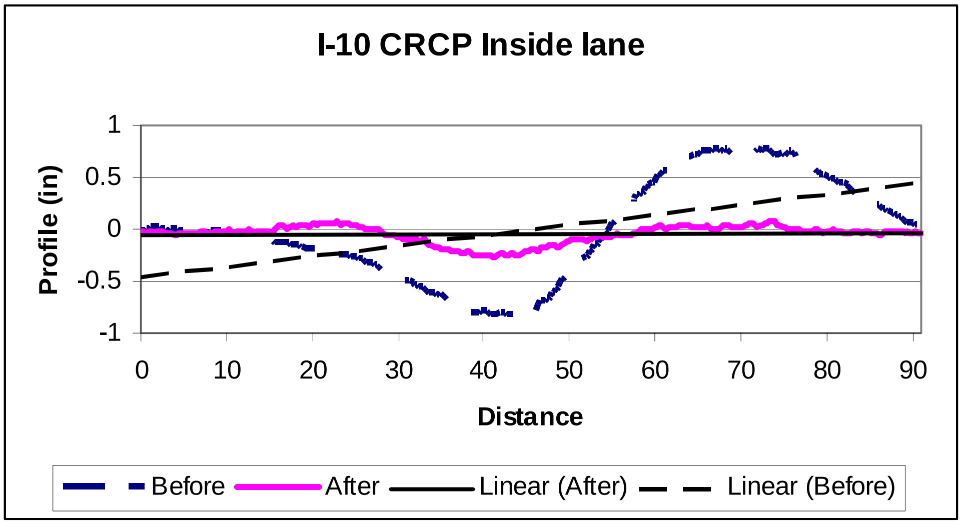

Figure 8

I-10 CRCP profile (inside lane)

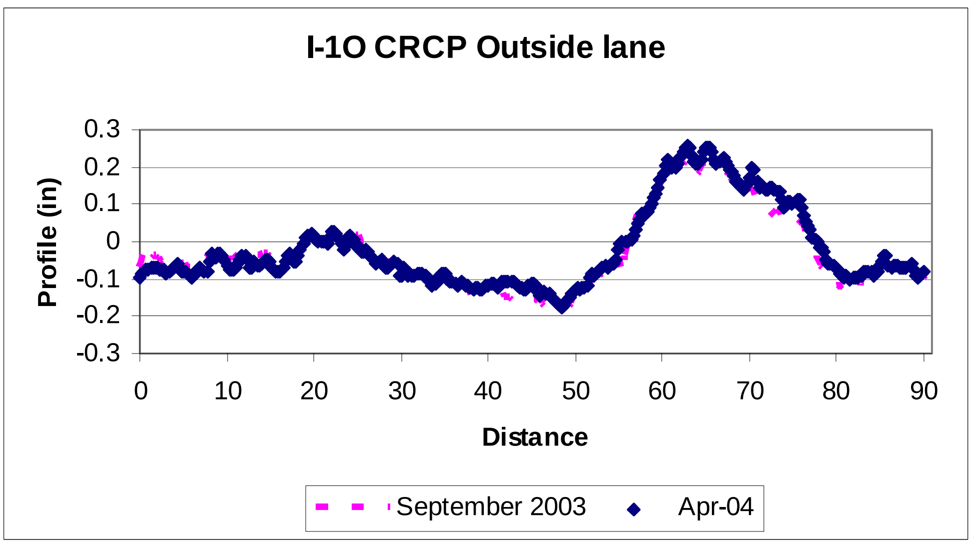

Figure 9

I-10 CRCP profile (outside lane) (Sept. 2003 and April 2004)

FWD Testing Results

Deflections

Figure 10 illustrates the deflections at the load plate (first sensor). The remaining figures can be found in Appendix 3. These deflections are based on a load of approximately 14,500 pounds. There is a trend towards higher deflections after the slabs were injected with polyurethane.

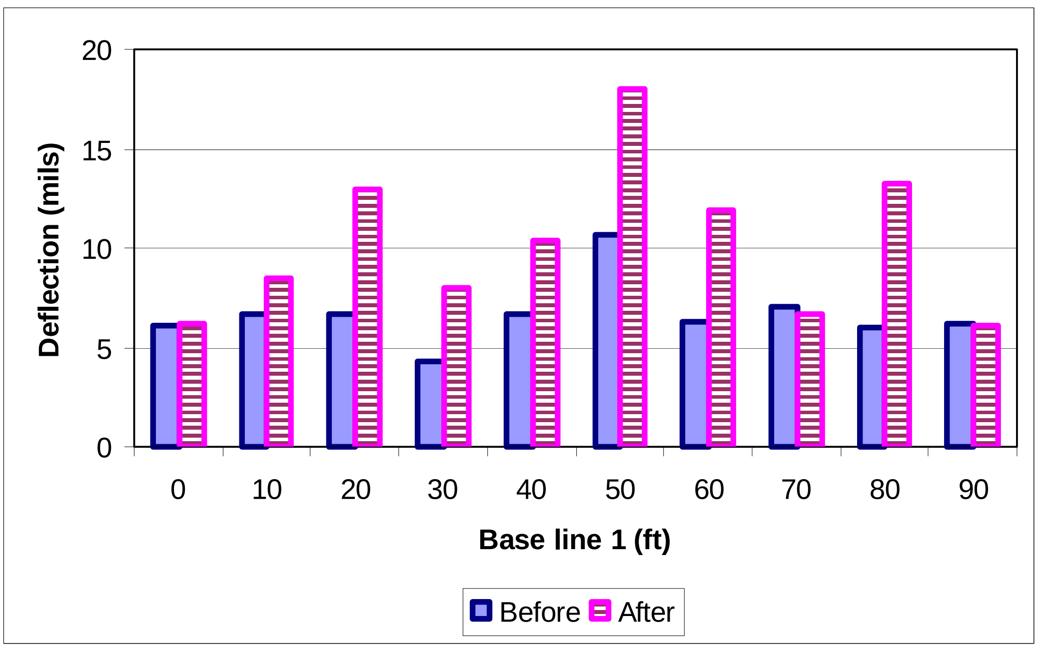

Figure 10

FWD first sensor deflections (14,500 lb load)

Y Intercepts

Figure 11 illustrates the Y intercepts. The remaining figures can be found in Appendix 3. There was a trend towards higher Y intercepts after the slab was injected with polyurethane.

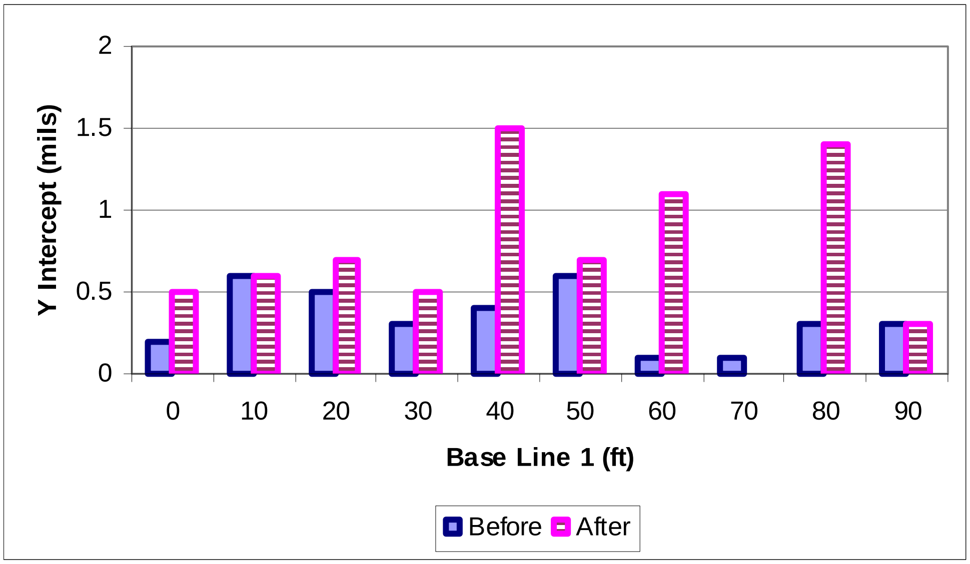

Figure 11

FWD void potential for base line 1

Discussion

The results indicated that both the Y intercepts and deflections increased as a result of the polyurethane injection. Trends toward higher deflections in the pavement structure after the polyurethane injection could be problematic. These trends may be due to the fact the polyurethane is softer than the surrounding pavement structure (concrete, asphaltic concrete, and sand-shell). The long term effect of these deflections is unknown and should be researched. According to the AASHTO design guide, a Y intercept value greater than 0.002 inches indicates that either a void or loss of support is probable. Prior to injection, all test points were less than 0.002 inches. After the injection, only 2 out of the 50 test points from the data set showed values (0.0023 and 0.0029) greater than the AASHTO value. It should be noted that water was seen bubbling through the cracks of the CRCP during the injection process.

Dynaflect Test Results

Structural Number

Figures 12 and 13 illustrate the structural numbers obtained from Dynaflect tests. The results indicated that the polyurethane injection did not adversely impact the structural number of the pavement.

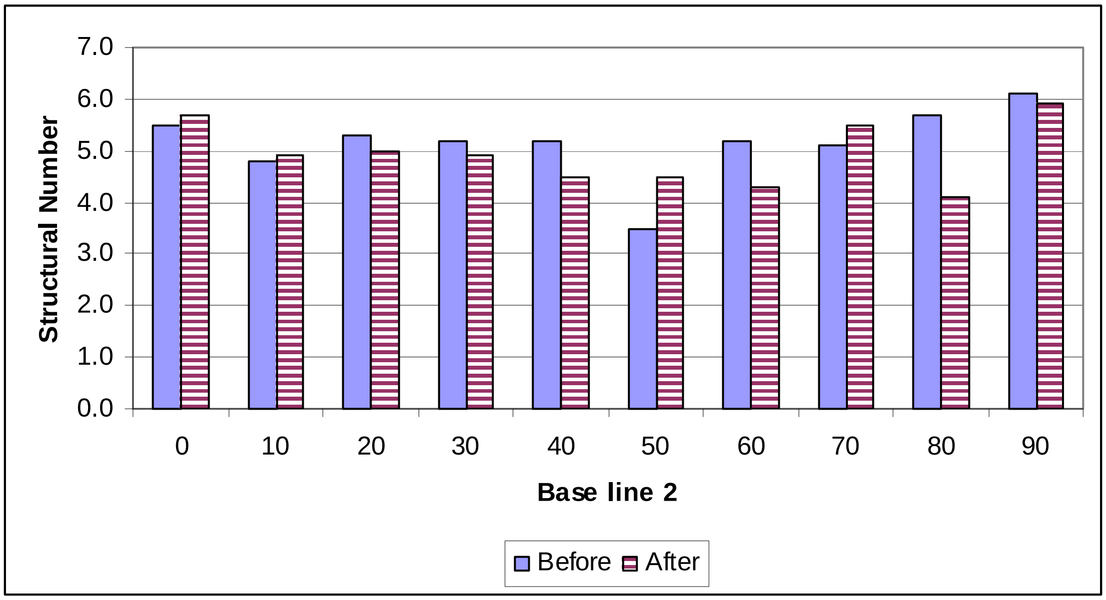

Figure 12

Dynaflect readings base line 2

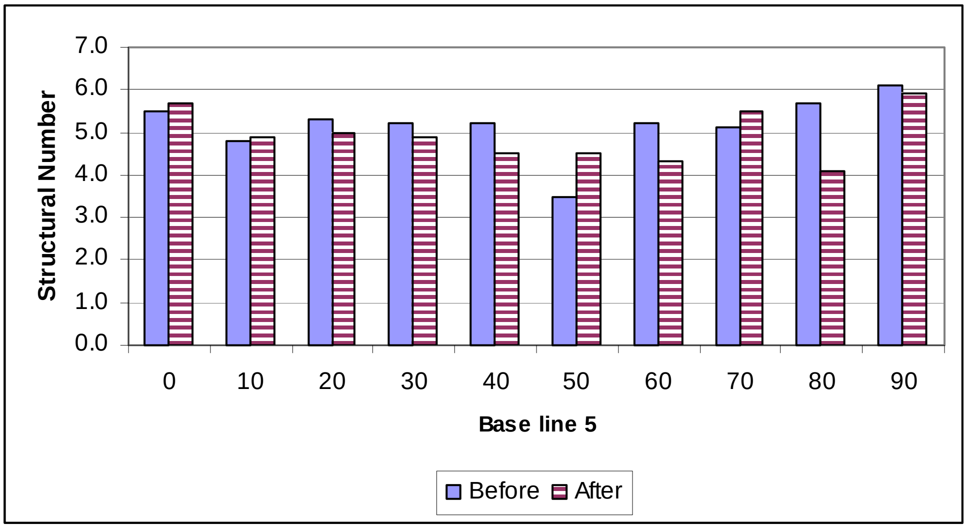

Figure 13

Dynaflect readings base line 5

Concrete Cores

Concrete cores were taken at the locations listed in table 3. The concrete pavement in core number 1 taken from the outside lane broke as it was being removed from the hole. The asphaltic concrete base course was permeated with polyurethane, as shown in figure 14. It is speculated that the asphaltic concrete in this area was stripped and weak which allowed the polyurethane to infiltrate it. The polyurethane specimens were so dense that a ball point pen could not be pushed into the specimen. Since the core hole was filled with water, the sand-shell base course could not be observed. The concrete pavement in core number 2, which was taken from the inside lane, was intact, but the asphaltic concrete base course in the core broke when it was removed from the core hole. The asphaltic concrete base course did not show any signs of being infiltrated as did core number 1. The sand shell base course was clearly visible and no signs of polyurethane foam could be seen, as shown in figure 15. Based upon visual inspection, it is unknown if a void was created by the polyurethane injection process. However, data from FWD tests did indicate a slightly higher intercept (0.5) after injection. Y intercepts less than 2.0 indicated that no voids were present.

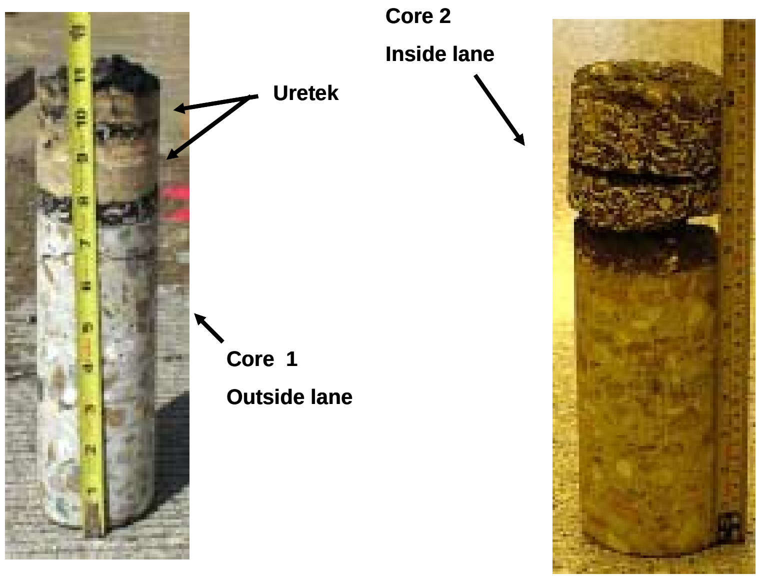

Figure 14
Concrete cores

Core Hole 2 (inside lane)

Figure 15
Concrete core hole (inside lane)

Table 3
Core locations

Core Number	Base line distance (ft)	Distance from Edge line (ft)
1 (outside lane)	49.0	8.17
2 (inside lane)	40.0	6.0

Polyurethane Quantity Estimation

One of the objectives of this study was to develop a method and equation(s) to allow the DOTD Design Engineers to estimate quantities. To develop such equations, the volume of the treatment area and the amount of polyurethane needed to fill it is required. The volume of the treatment area can be determined by using rod and level surveys, profile data from the walking profiler, and curves that match the profile of the pavement depression. The profile data from the walking profiler was used to determine the volume of the treatment area for the development of the estimation equation and method.

Quantity Used

The walking profiler data from base lines 1, 3, 4, and 6 were used to determine the amount of polyurethane (pounds) per cubic foot. The area between the profile before and after the injection was as follows:

Baseline 1 = 4.2951 sq.ft.

Baseline 2 = 6.3559 sq.ft.

Baseline 4 = 7.3689 sq.ft.

Baseline 6 = 6.2051 sq.ft

These areas were calculated by Steve Perault using Intergraph's In Roads design software. The total volume of the treatment area was computed using the average end area method typically used in earth work computations.

Volume = [2' x 4.2951 ft^2] + [8' x ((4.2951 ft^2 + 6.356 ft^2) / 2')] + [4' x ((6.3569 ft^2 + 7.3689 ft^2) / 2')] + [8' x ((7.3689 ft^2 + 6.2051 ft^2) / 2')] + [2' x 6.2051 ft^2]

= 145.35 ft^3

Polyurethane used in treatment area = 913.8 pounds

Polyurethane (pounds) per volume = 913.8 / 145.35 = **6.287**

Quantity for estimation purposes = 7 pounds per cubic foot

Equation Development

As previously mentioned, the volume can be determined by several methods. In order to simplify the process as much as possible, the profile was simulated with a parabolic curve ($y = ax^2$) and straight lines. Since the area of the sections previously mentioned were known and represented true field conditions, they were used as a bench mark to evaluate the equations.

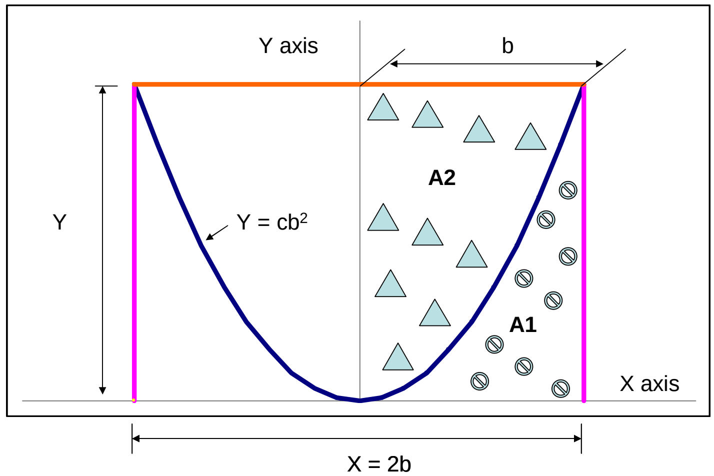

Figure 16

Parabolic equation diagram

Parabolic equation

$Y = cb^2$ then $b = (y/c)^{0.5}$

$A1 = cb^3 / 3$ with $b = (y/c)^{0.5}$ then $A1 = yb / 3$

$A2 = yb – A1 = 2/3yb$

A2 represents half of the area within the parabola, therefore 2*A2 equals the entire area.

2*A2 = 4/3yb and b=x/2, so the area within the parabola (Atotal) = 2/3xy.

Using the figure below as an example, the Designer measures the horizontal length (X) and the vertical distance (Y). These values are placed in the equation (2/3*X*Y) and the area within the depression can be calculated.

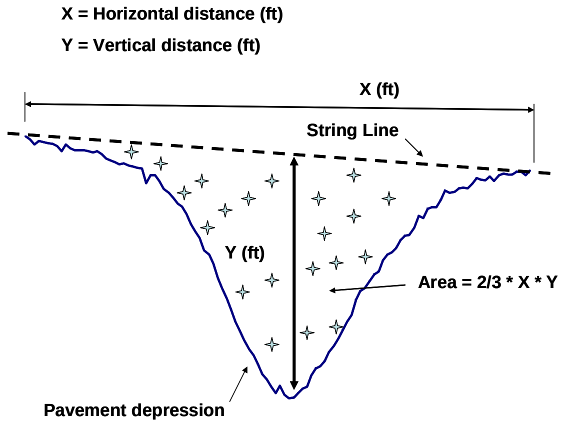

Figure 17

Depression measurement diagram

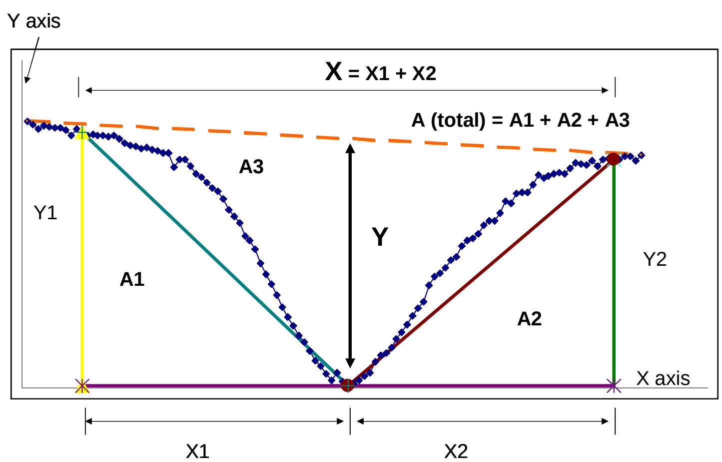

Figure 18

Linear model

Linear Model

The area (A3) simulates the area within the pavement depression. Using standard geometry, the follow relationships can be deduced:

A (total) = A1 + A2 + A3

A (total) = X * [(Y1 + Y2) / 2]

A1 = X1 * Y1 / 2

A2 = X2 * Y2 / 2

X = X1 + X2 (total horizontal distance)

Y = (Y1 + Y2) / 2 (vertical distance at midpoint)

A3 = A (total) – A1 – A2 = (½ * X * Y)

The accuracy of the equations were tested by comparing them to the values obtained from the In Roads software for each base line previously mentioned. The results are shown in table 4.

Table 4

Equation comparison

Base line	Y (ft)	X (ft)	Area (sqft)				
			Parabola	% (Actual)	Line	% (Actual)	Actual
1	0.1563	66	6.88	158	5.16	119	4.3403
3	0.1975	72	9.48	149	7.11	112	6.36013
4	0.2083	76	10.55	143	7.92	107	7.3689
6	0.1802	76	9.13	147	6.85	110	6.2073
			Avg	**149**		**112**	

Formula	
Parabola	**Area = 2/3 (X*Y)**
Line	**Area = 1/2 (X*Y)**

The X and Y values were obtained from the Walking profiler data, which indicated the line method better approximates the depression area than the parabolic method.

The volume of the depression equals the area multiplied by the width of the treatment area.

The recommended equation for volume determination is as follows:

Volume = ½ * X * Y * W

The recommended equation for polyurethane quantity estimation purposes is:

P = 0.5 * X * Y * W * U

Where,

P = pounds of polyurethane required to level the slab

X = longitudinal distance (ft) of treatment area

Y = depth of depression (ft) at midpoint

W = width of treatment area (ft)

U = 7 pounds of polyurethane per cubic foot

US 167 / 90 JCP faulting

Testing Dates and Locations

The initial plan was to test the areas before polyurethane injection (Wednesday, October 8, 2003), perform polyurethane injections (Thursday, October 9, 2003), retest after injections, and perform trenching operations (Friday, October 10, 2003). However due to heavy rains, see table 5, on Thursday evening and Friday morning, polyurethane injections took place on Friday and trenching occurred on Saturday. Prior to polyurethane injection on Friday, Area 1 base line 4 was retested so that a comparison could be made before and after the rain. Testing after polyurethane injection occurred on Friday and Sunday. Testing in the left lanes occurred at later dates.

Table 5
Weather data (October 2003, Lafayette, LA)

Day	Temp (Max)	Temp (Min)	Temp (AVG)	Rain fall (in.)
1	81	53	67	0
2	73	53	63	0
3	78	48	63	0
4	82	55	69	0
5	85	57	71	0
6	83	66	75	1.69
7	84	66	75	0
8	83	67	75	0
9	78	68	73	1.29
10	**74**	**70**	**72**	**2.34**
11	**80**	**68**	**74**	**0**
12	**82**	**66**	**74**	**0**
13	**81**	**67**	**74**	**0**
14	84	57	71	0
15	76	50	63	0
Monthly Avg	**80.1**	**58.5**	**69.3**	**5.44**

FWD Evaluation

Deflections

Figure 19 illustrates the first sensor deflections. The remaining figures and tables can be found in Appendix 1. The deflection analysis that follows is based upon a review of all data points (joints, intermediate, and center) for the areas and base lines listed.

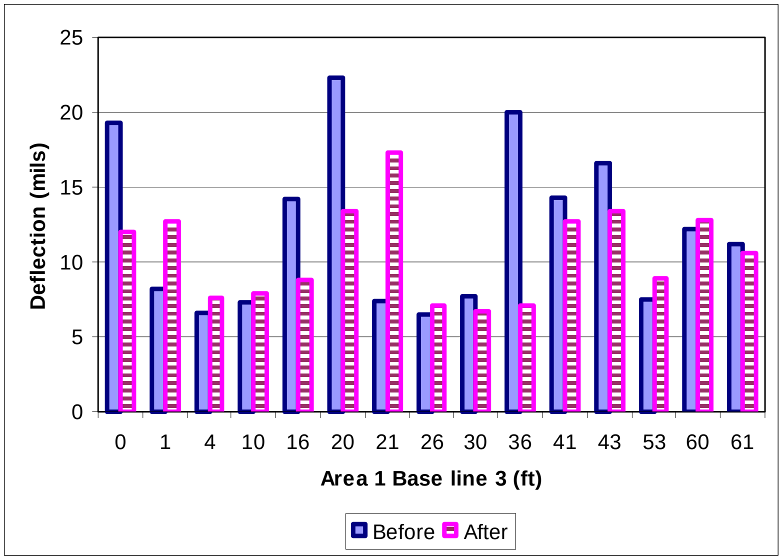

Figure 19

FWD first sensor deflections Area 1 Base line 3

Area 1 (Center and intermediate points): These deflections are based on a load of approximately 16,000 lbs. The average deflections before and after polyurethane injection were 9.7 and 9.4 mils, respectively.

Area 1 (Joints): Deflection readings were taken at both the approach and leave side of the joints. At the approach side, the deflections before and after polyurethane injections were 16.7 and 15.5 mils, respectively. On the leave side, the deflections before and after polyurethane injections were 13.5 and 17.9 mils, respectively.

Area 1 (Base line 3): Due to heavy rainfall on Thursday, October 9, 2003, testing was delayed, as previously mentioned. In order to ensure no variance in the data due to the rainfall, testing was repeated prior to injection on Friday, October 10, 2003, as shown in figure 20. The average deflections before and after the rainfall were 15.2 mils and 14.6 mils, respectively. Since the average deflections decreased slightly after the rainfall, it can be concluded that the rainfall did not adversely impact the pavement structure at the time of this testing.

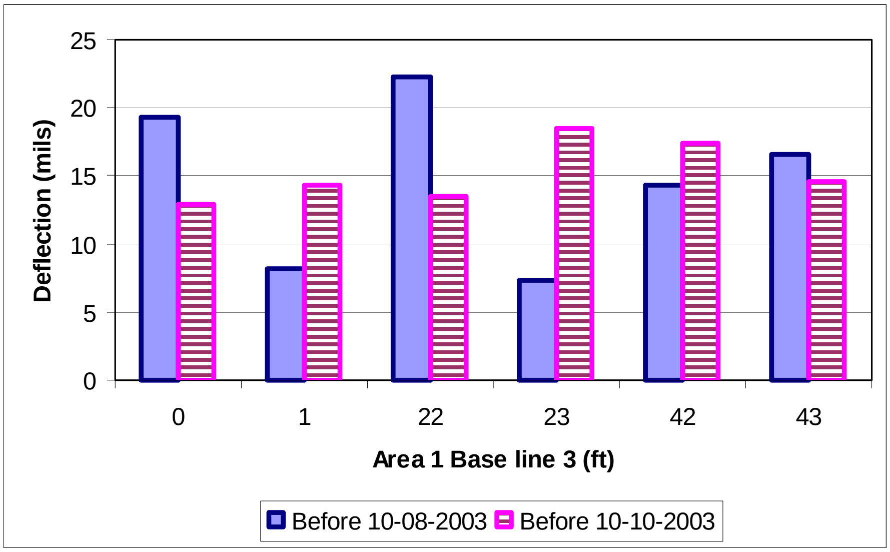

Figure 20

FWD first sensor deflections (comparison before and after rainfall)

Area 2 (Base lines 1, 3 & 5): The slabs in the center lane were scheduled for removal due to their deteriorated condition. Tests were conducted prior to slab removal, but not after they were replaced. Most of the slabs in the inside and outside lane, had been injected with polyurethane in April 2002, and the initial condition of the slabs in the center lane prior to injection with polyurethane in April 2002 is unknown. The slabs in the left lane showed no visible signs of distress.

Area 2 (Slabs 52, 55, 58, 59, 61, 62, 64, & 65) (Uretek injected in April 2002): The slabs tested in these locations were injected with polyurethane in April 2002. The average deflection for these slabs was 19.9 mils.

Area 2 (Slabs 53, 56, 57, 60, 63, 66): The slabs tested in these locations were not injected with polyurethane. The average deflection for these slabs was 24.6 mils.

Area 3 Base line 1 (Uretek injected in April 2002): This slab was injected with polyurethane in April 2002. The average deflection for the center points was 25.18. The average deflection for the approach and leave joints was 15.9 and 25.2, respectively.

Area 3 (Center and intermediate points): The average deflections before and after polyurethane injection were 10.9 and 9.0 mils, respectively.

Areas 3 (Joints only): Deflection readings were taken at both the approach and leave side of the joints. At the approach side, the deflections before and after polyurethane injections were 31.1 and 15.2 mils, respectively. On the leave side, the deflections before and after polyurethane injections were 23.5 and 18.8 mils, respectively.

Y intercepts

Figure 21 illustrates the Y intercepts. The remaining figures and tables can be found in Appendix 1. The void analysis that follows is based upon a review of all data points (joints, intermediate, and center) for the areas and base lines listed.

Area 1 (Center and intermediate points): The average Y intercepts before and after polyurethane injection were 0.5 and 0.4, respectively.

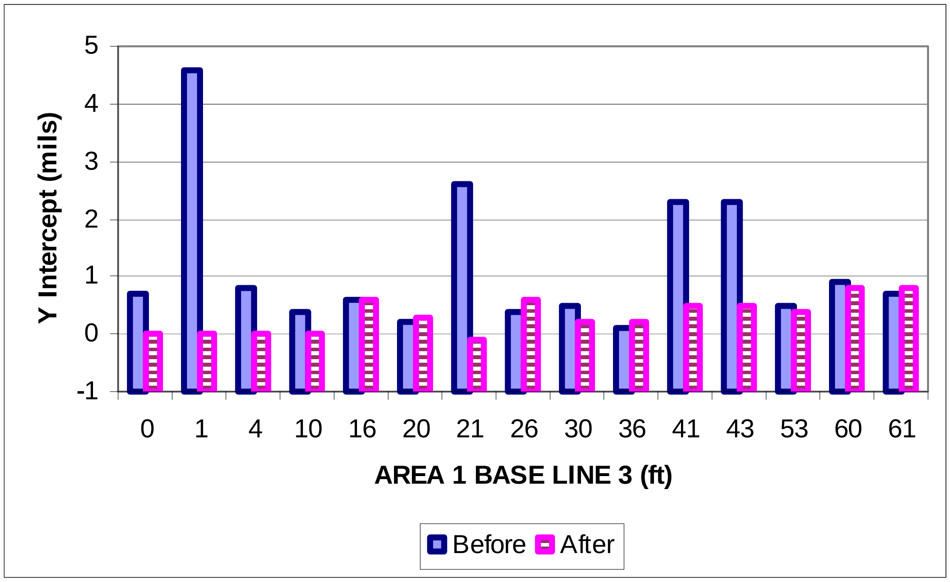

Figure 21

FWD void potential Area 1 Base line 3

Area 1 (Base line 3): Due to heavy rainfall on Thursday, October 11, 2003, testing was delayed as previously mentioned. In order to ensure no variance in the data due to the rainfall, testing was repeated prior to injection on Friday, October 12, 2003, as shown in figure 22. The average y intercept values before and after the rainfall were 1.7 and 1.1, respectively. Since the average y intercept values decreased slightly after the rainfall, it can be concluded that the rainfall did not adversely impact the pavement structure at the time of this testing.

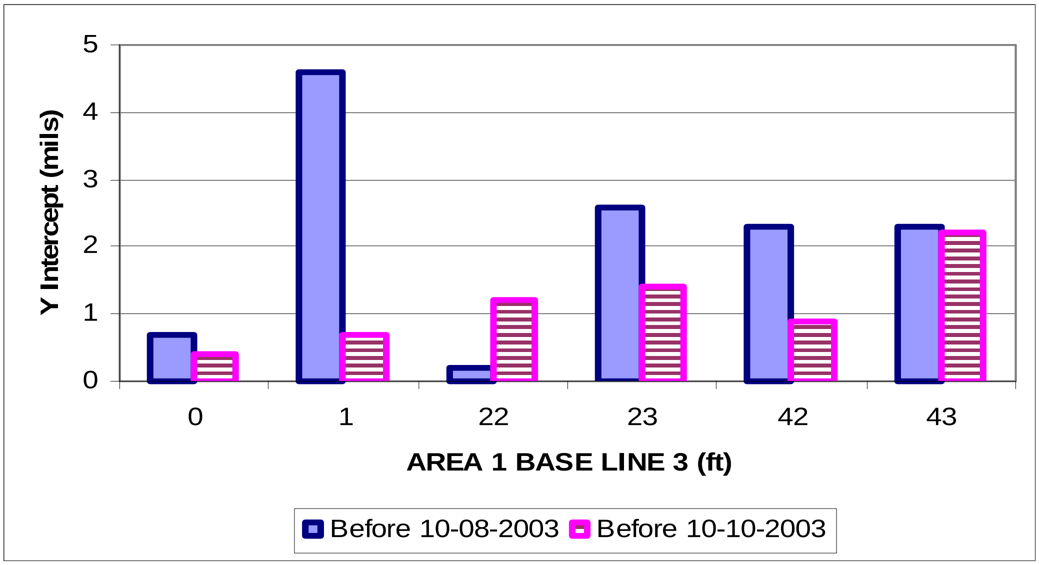

Figure 22

FWD void potential Area 1 Base line 3 (Comparison before and after rainfall)

Area 2 (Slabs 52, 55, 58, 59, 61, 62, 64, & 65) (Uretek injected in April 2002): The slabs tested in these locations were injected with polyurethane in April 2002. The average y intercept for these slabs was 2.47.

Area 2 (Slabs 53, 56, 57, 60, 63, 66): The slabs tested in these locations were not injected with polyurethane. The average y intercept for these slabs was 2.27.

Area 3 Base line 1 (Uretek injected in April 2002): This slab was injected with polyurethane in April 2002. The average y intercept for the center points was 0.4. The average y intercept for the approach and leave joints were 0.73 and 1.46, respectively.

Area 3 (Center and intermediate points): The average y intercepts before and after polyurethane injection were 0.9 and 0.3, respectively.

Area 3 (Joints): A void analysis was conducted for both the approach and leave side of the joint. At the approach side, the y intercept values before and after polyurethane injection were 4.8 and 0.6, respectively. On the leave side of the joint, the y intercept values before and after the polyurethane injection were 2.8 and 1.3, respectively.

Discussion: Based on the test results, the injection of polyurethane, in general, reduces or maintains pavement deflections and significantly decreases the number of locations with voids.

Load Transfer Efficiency

Figures 23 and 24 illustrate the results of the load transfer efficiency tests. There was a trend towards an increase in load transfer efficiency after the slabs were injected with polyurethane.

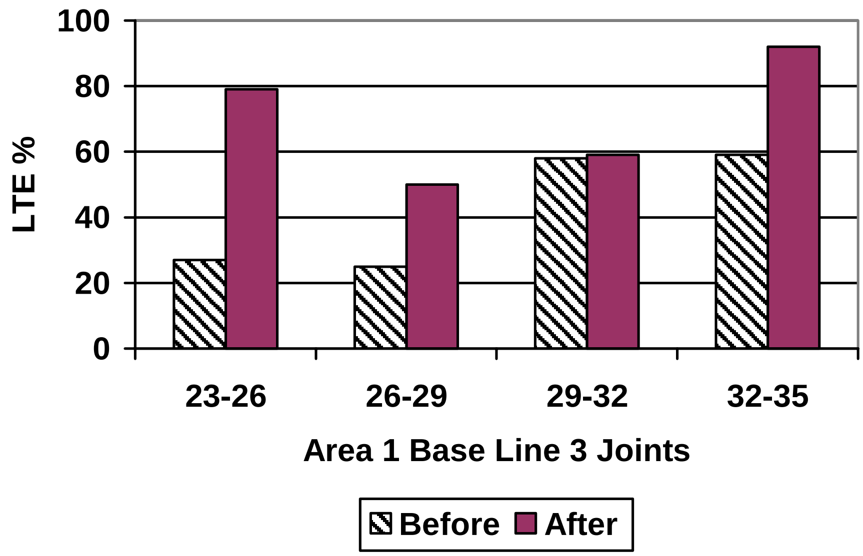

Figure 23
Load transfer efficiency for Area 1 Base Line 3

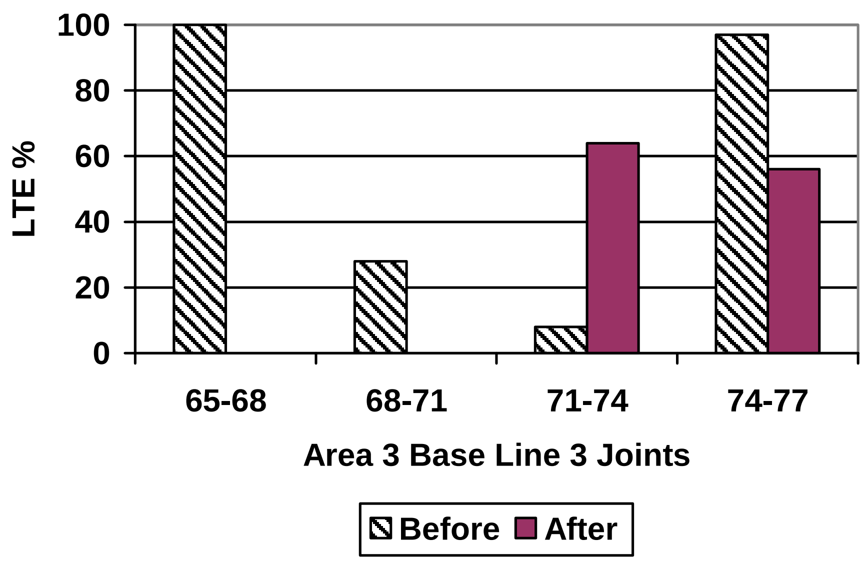

Figure 24
Load transfer efficiency for Area 3 Base Line 3

Dynaflect

Figure 25 illustrates the first sensor deflections. The remaining figures and tables can be found in Appendix 1.

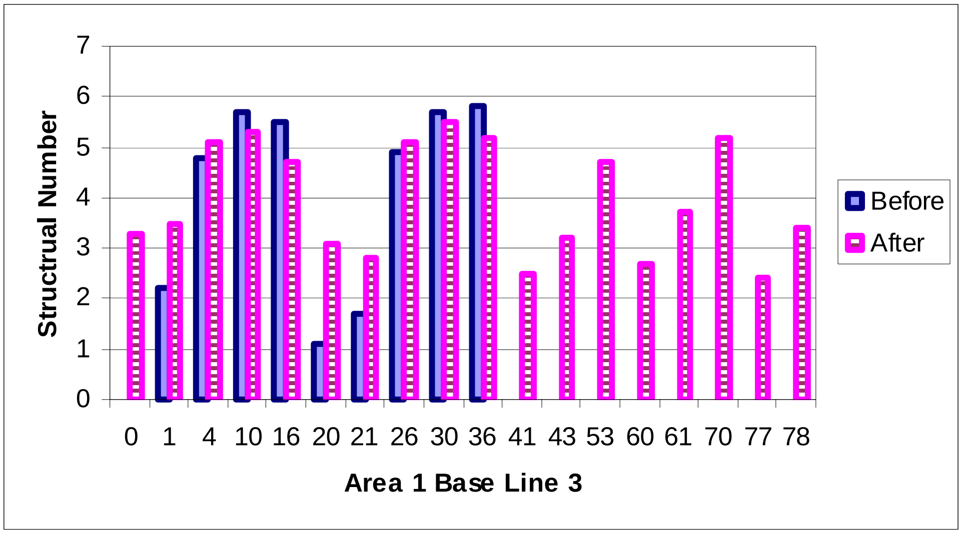

Figure 25

Dynaflect Area 1 Base line 3

Area 1 (Base lines 3 & 5): The average SN values before and after polyurethane injection were both 3.6.

Area 2 (Slabs 52, 55, 58, 59, 61, 62, 64, & 65) (Uretek injected in April 2002): The slabs tested in these locations were injected with polyurethane in April 2002. The average SN for these slabs was 3.2.

Area 2 (Slabs 53, 56, 57, 60, 63, 66): The slabs tested in these locations were not injected with polyurethane. The average SN for these slabs was 2.8.

Area 3 Base line 1 (Slabs 67, 70, 73, 76, & 79): The slabs tested in these locations were injected with polyurethane in April 2002. The average deflection for these slabs was 3.4.

Area 3 (Base lines 3 & 6): The average deflections before and after polyurethane injection was 3.6 and 3.7, respectively.

Discussion: The injection of polyurethane into the pavement structure did not adversely impact its overall strength.

Polyurethane Injection

Ten locations were selected with injection depths of 10 inches. The polyurethane injections located at that depth were between the concrete slab and base course and occurred at only 2 of the 10 targeted testing locations, as shown in table 1. This caused the contractor to drill through the base course (18 inches deep) and inject into the subgrade. Based upon the quantities of polyurethane used on slabs 26 and 74, 89 percent more was needed polyurethane to raise the panel when injection took place in the subgrade (18 inches deep) rather than between the slab and base course (10 inches deep). Additionally, in 33 percent of the slabs, the transverse joints locked up during raising. Therefore, the faults were not completely removed. While the faults could have been removed if the joints had been saw cut, DOTD believed that saw cutting would further deteriorate the load transfer at the joints.

Trench Inspection (Slab injected with polyurethane on October 11, 2003)

Area 3: Slab 74 was trenched after being injected and raised with polyurethane. The following observations were made:

- There was a layer of polyurethane approximately 0.25 inches thick under the slab. Therefore, the polyurethane did underseal the slab.

- The polyurethane samples acquired near the joints ranged from 2 to 3 inches thick and all voids appeared to be filled. Therefore, the polyurethane did fill the voids, as shown in Figures 26, 27, and 28. (FWD readings did indicate a void either before or after injection)
- Layers of varying stiffness were observed in the polyurethane sample acquired near the joint. The density of the polyurethane appears to be depend upon the confining pressure. The contractor's normal procedure is to inject a small quantity, wait for it to set up, and then inject again. This procedure is followed until the desired outcome is obtained. These layers could be observed in the sample. Having different densities in the polyurethane can be problematic, as shown in Figure 27. It should be noted that the injection process took place when the voids were filled with water present. Because the effect that this has on density is unknown, it should be researched further.
- When the adjacent left lane slab, 73, which had been injected with Uretek the previous year, was observed, the polyurethane between the base course and slab was clearly visible, as shown in figure 28. Even though polyurethane was present, water could be seen trickling out from the layer between the polyurethane and soil cement base course, as shown in figure 29. The joint at panel 73 could be seen deflecting under traffic loads. Whether the source of the pavement deflections was from the polyurethane, base course, subgrade, or a combination of the layers is unknown and warrants further investigation. The rainfall data for that month is shown in table 5, and 2.34 inches of rain fell the day previous to these observations.

Figure 26
Polyurethane in trenched area (Area 3 Slab 74)

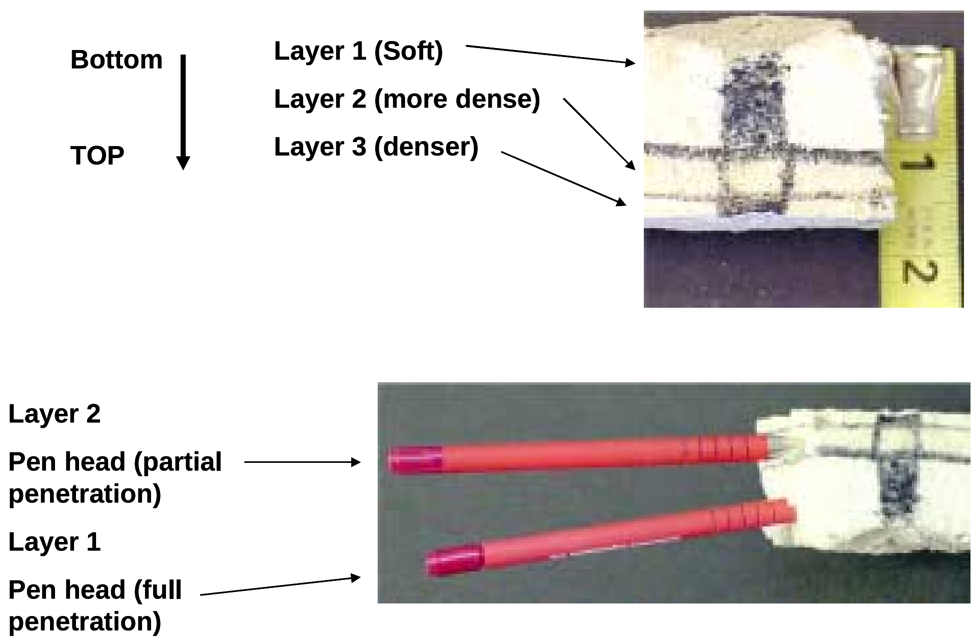

Figure 27
Polyurethane densities (sample acquired from joint area (slab 74))

Figure 28
Polyurethane between slab and base course

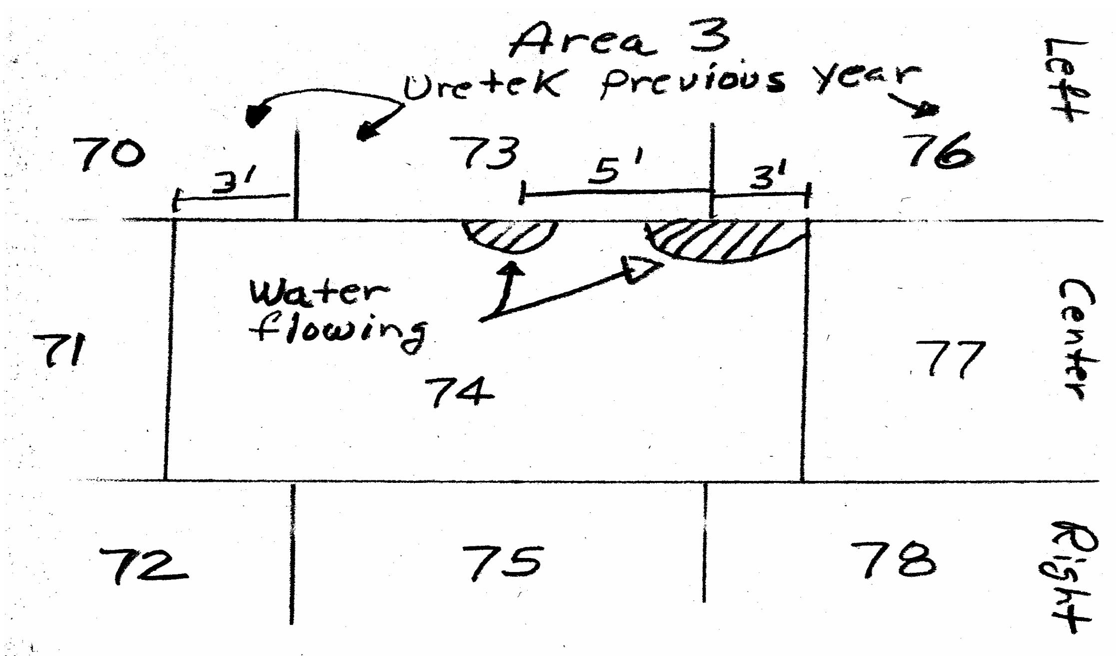

Figure 29
Area 3 pumping locations

Inspection of patched area (Slabs were injected with polyurethane in April 2002)

Area 2: Because of patching in the center lane, left lane slabs 61, 64, and 67, which were injected the previous year could be observed and are shown in figures 30 and 31. As traffic moved across the slabs, the joints were observed deflecting, which indicates poor load transfer. As time progressed, water was observed pumping through the joints and flowing onto the subgrade. Similar to slab 73 (Area 3), previously injected polyurethane was observed at these locations. Whether the source(s) of the pavement deflections was from the polyurethane, base course, subgrade, or a combination of the layers is unknown and warrants further investigation.

Figure 30

Pumping locations (Area 2)

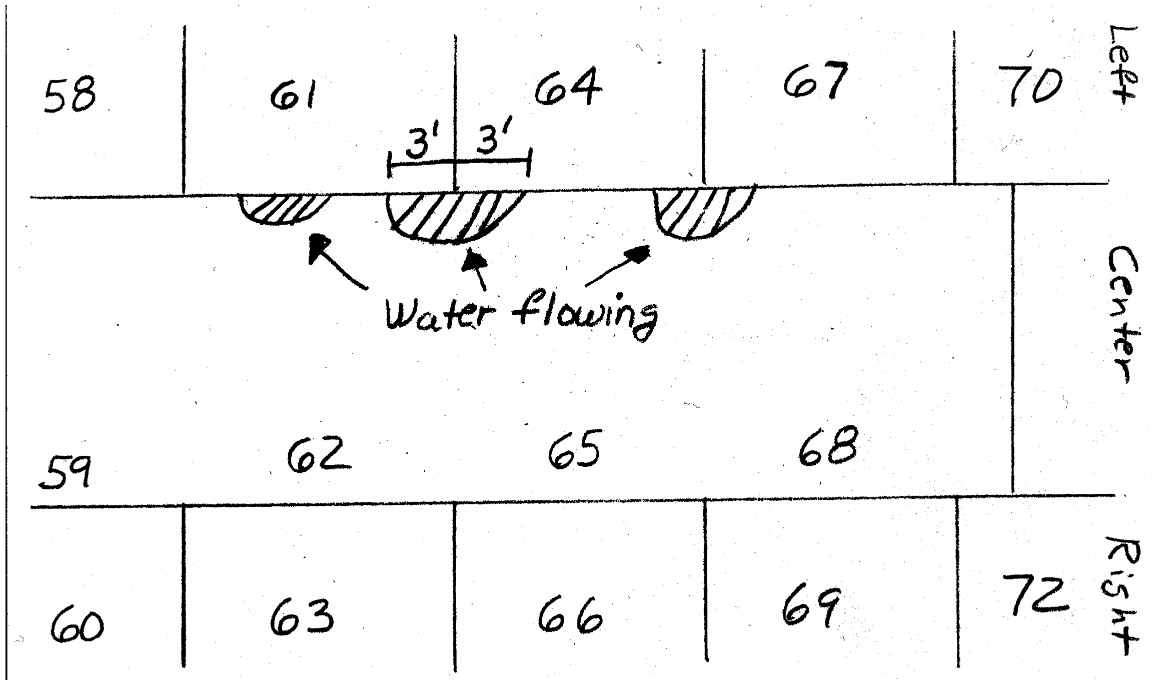

Figure 31

Sketch of area 2 pumping locations

Slabs Previously Injected with Polyurethane in April 2002 (Includes locations outside of Areas 1, 2, and 3)

In this location of Evangeline Thruway, 21 slabs were injected with polyurethane in April 2002. Eighteen of those slabs were removed and replaced during this construction process. The initial distress conditions of these slabs were not documented. However, regardless of the initial condition of the slabs, (faulted, cracked, failed, etc.) the polyurethane injection process did not increase the service life of these slabs.

Panel Patching vs. Polyurethane Costs

Using polyurethane to patch full concrete slabs and raise full panels costs $115 and $40.25 per sq.yd., respectively. The polyurethane cost was determined by using the quantities and panel sizes for the slabs that were targeted for full panel raising.

Faulting and Profiles from the High Speed Profiler

Because the contractor was not allowed to remove the faults if the joints locked up during panel raising, and the pavement roughness was initially very high, the faulting and profile data presented in Appendix 1 are for information purposes only. The primary purpose of this project was to patch distressed slabs and reduce faulting.

Bridge Approach Slabs

The approach slabs were tested on May 24, 2004 prior to polyurethane injection. Testing was repeated on the approach slabs after injection on June 9, 2004.

Appendix 4 contains the figures and tables for bridge approach slabs that are not included in the body of this text.

Profiles

Walking Profiler, US 167 N.B

The walking profiler performs very well on roadways with gentle or no slopes. Steeper grades, such as those encountered at overpasses, can make differences in the profile difficult to determine. Upon profiling the approach slab prior to injection with polyurethane, a clear representation of profile differences could not be viewed. Therefore, the walking profiler readings were not taken on US 167 after injection with polyurethane and are not included in this report.

Walking Profiler (Bayou Duplente S.B.)

Figure 32 illustrates the profile before and after polyurethane injection. Based on the point of maximum depression, the pavement was raised approximately one inch on average. Figure 33 represents the depression profile based upon the readings from Bayou Duplente SB. It should be noted that the existing profile deflects in a linear fashion for about 10 to 15 feet (X1). After that, the remainder of the approach slab (X2) deflects in a curved fashion.

The remainder of the depression (X3) extends 10 to 20 feet into the adjacent slab. As shown in figure 32, a slight lifting ranging from 0.1 to 0.6 inches occurs in the slab (15 to 31 feet on base line) adjacent to the approach slab. This could be problematic since polyurethane was injected only into the approach slab. Even though the FWD tests did not reveal a void in the adjacent slabs after injection, a potential for one exists due to the lifting. Because of this, the slab adjacent to the approach slab should be injected with polyurethane to fill any voids caused by the lifting of the approach slab.

High Speed Profiler (US 167 N.B. and Bayou Duplente S.B.)

Figures 34 and 35 illustrate the profiles before and after polyurethane injection. Linear regressions were taken through both profiles. Lesser slopes on the linear regression line indicate a smoother profile. The polyurethane injection process significantly lessened the slope, indicating an improvement. Table 6 presents the IRI values before and after the polyurethane injection process. The IRI values are based on the 40 feet approach slab length. Since IRI values should be based upon a minimum length of 300 feet, the values reported are subject to inaccuracies and should be used for informational purposes only. Base upon the results, the IRI values were reduced from 33 to 58 percent by the leveling that resulted from the polyurethane injection process.

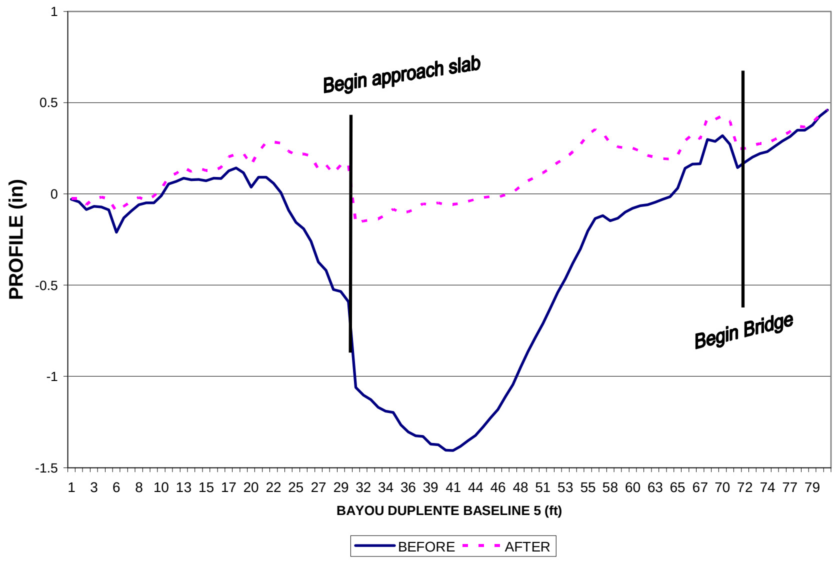

Figure 32
Walking Profiler Bayou Duplente SB base line 5

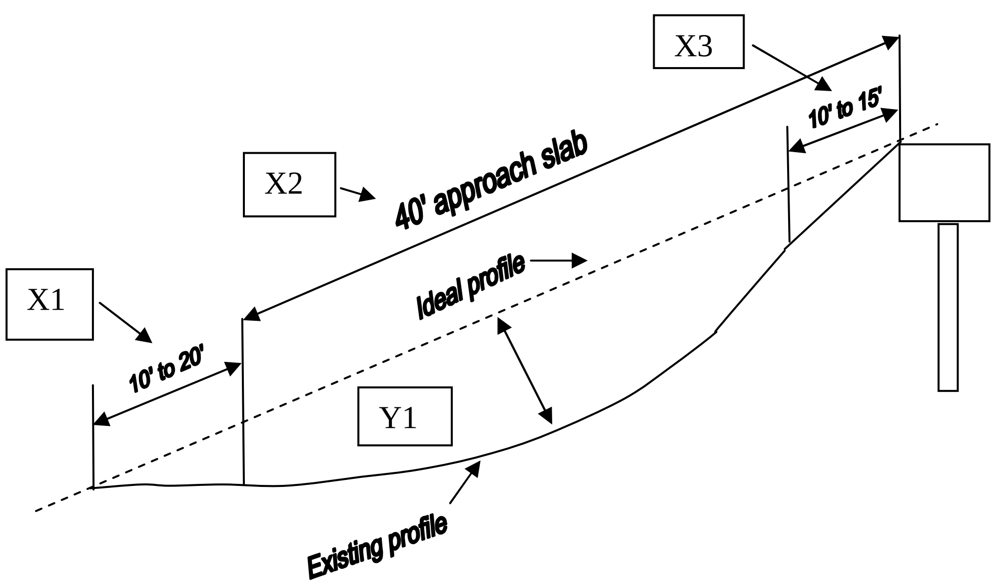

Figure 33
Profile of approach slab and adjacent pavement

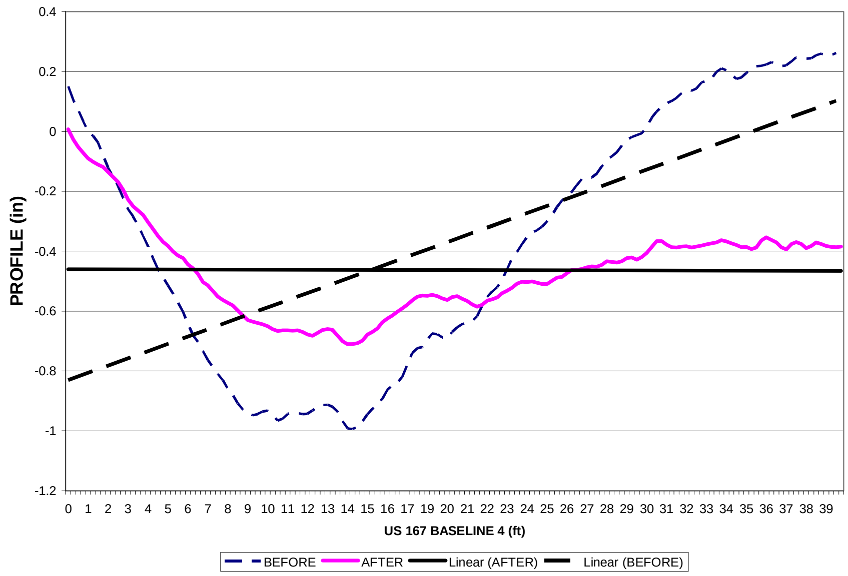

Figure 34
High speed profile for US 167 NB base line 4

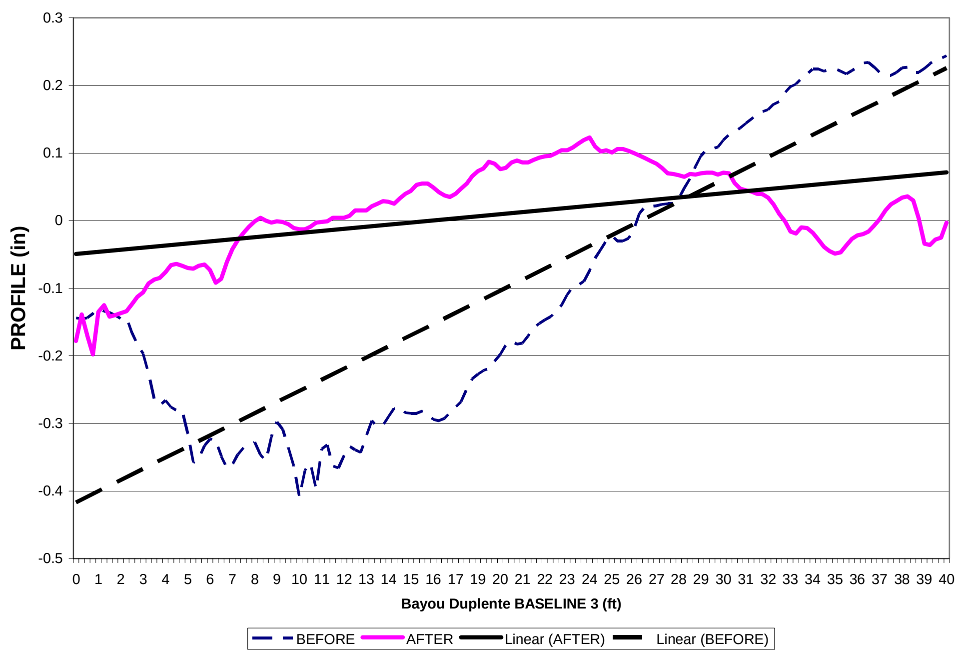

Figure 35
High speed profile for Bayou Duplente SB base line 3

Table 6
IRI values for bridge approach slabs

ICC HIGH SPEED PROFILER					
NORTH BOUND AT US 167					
	INSIDE LANE (IRI)			OUTSIDE LANE (IRI)	
WHEELPATH			WHEELPATH		
	LEFT	RIGHT		LEFT	RIGHT
BEFORE	440	365		363	369
AFTER	291	217		201	227
SOUTH BOUND AT BAYOU DUPLENTE					
INSIDE LANE (IRI)			OUTSIDE LANE (IRI)		
WHEELPATH			WHEELPATH		
	LEFT	RIGHT		LEFT	RIGHT
BEFORE	195	134		267	386
AFTER	130	87		135	164

FWD Testing Results

Deflections (US 167 NB and Bayou Duplente SB)

Figure 36 illustrates the deflections at the load plate (first sensor). The remaining figures can be found in Appendix 4. These deflections are based on a load of approximately 16,000 pounds. The deflections were generally maintained or lowered as a result of injecting with polyurethane.

The deflections from the tests taken within the first five feet from the bridge end may be not be useful for this study. The deflections at these locations are less than 50 percent of the readings taken at 10 feet from the bridge end. The deflections are believed to be less since the steel-reinforced approach slab is anchored to a pile-supported abutment.

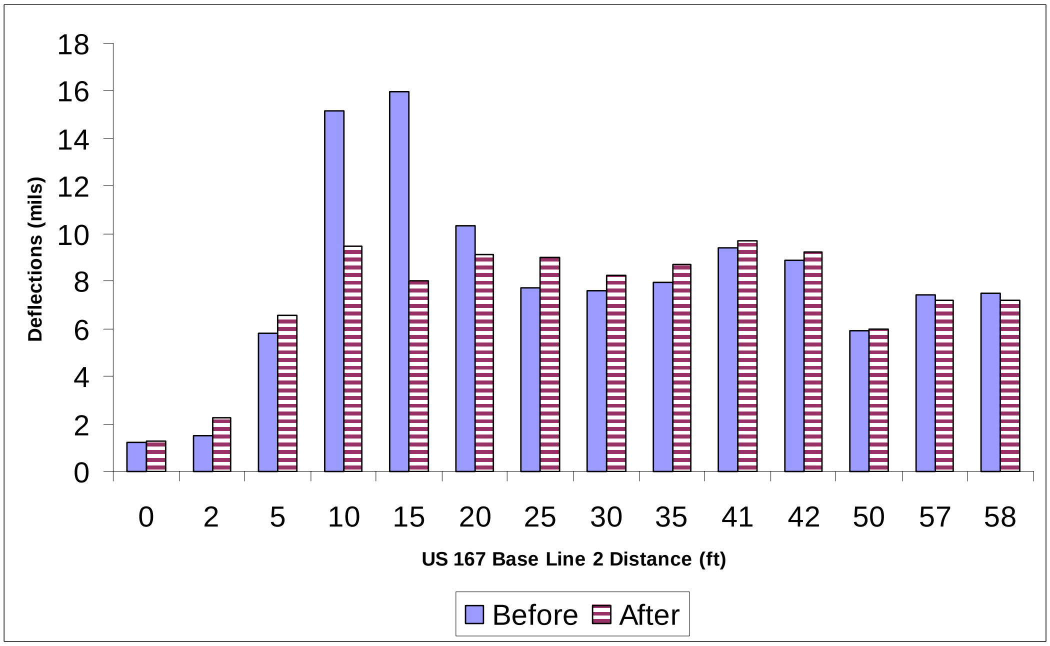

Figure 36

FWD first sensor deflections US 167 NB base line 2

Y Intercepts – Core Verification (US 167 NB)

Figure 37 illustrates the Y intercepts. For further details about the cores, refer to section on core samples. It should be noted that polyurethane found in the core samples was dense throughout the specimen. The Y intercepts were generally maintained after injection with polyurethane. Out of 50 test points, 8 had Y intercept values near or exceeding 2.0 prior to injection. After injection, 4 out of the 50 test points had Y intercept values exceeding 2.0.

Four cores were taken at this location:

- Core N1: The Y intercepts did not reveal any voids before or after injection. However, a 5-inch void was found between the concrete and stone base course. Polyurethane was not seen at this location.

- ❖ Core N2: The Y intercepts did not reveal any voids before or after injection. One-half inch of polyurethane was observed on one side of the core.
- ❖ Core N3: The Y intercept revealed a void before and no void after the polyurethane injection process. Five inches of polyurethane plus seven inches of gravel-polyurethane core were found.
- ❖ Core N4: The Y intercepts did not reveal any voids before or after the polyurethane injection. Polyurethane was not found at this location. A 6-inch soil cement core was removed.

Y Intercepts – Core Verification (Bayou Duplente SB)

Figure 38 illustrates the Y intercepts. The Y intercepts were generally reduced after injection with polyurethane. Out of 48 test points, 7 had Y intercept values near or exceeding 2.0 prior to injection. After injection, no test points had Y intercept values exceeding 2.0.

Four cores were taken at this location:

- ❖ Core S1: The Y intercepts did not reveal any voids before or after injection. Polyurethane was not seen at this location.
- ❖ Core S2: The Y intercept revealed a void before and no void after the polyurethane injection process. There was a 2.5-inch thick polyurethane core found.
- ❖ Core S3: The Y intercept revealed a void before and no void after the polyurethane injection process. Polyurethane was not found at this location.
- ❖ Core S4: The Y intercepts did not reveal any voids before or after the polyurethane injection. Polyurethane was not found at this location.

Discussion

A review of the data indicates that the readings obtained within the first five feet from the bridge end are not representative of the approach slab conditions. This is probably due to the fact that the approach slab is supported by a pile-supported abutment and that the loads applied by the FWD are not large enough to adequately deflect the approach slab at this location. In the three locations where voids were suspected and core samples were taken, polyurethane was found at two of the three locations. Therefore, with the exception of the area near the bridge end, the Y intercept method based on FWD values can be used to predict voids.

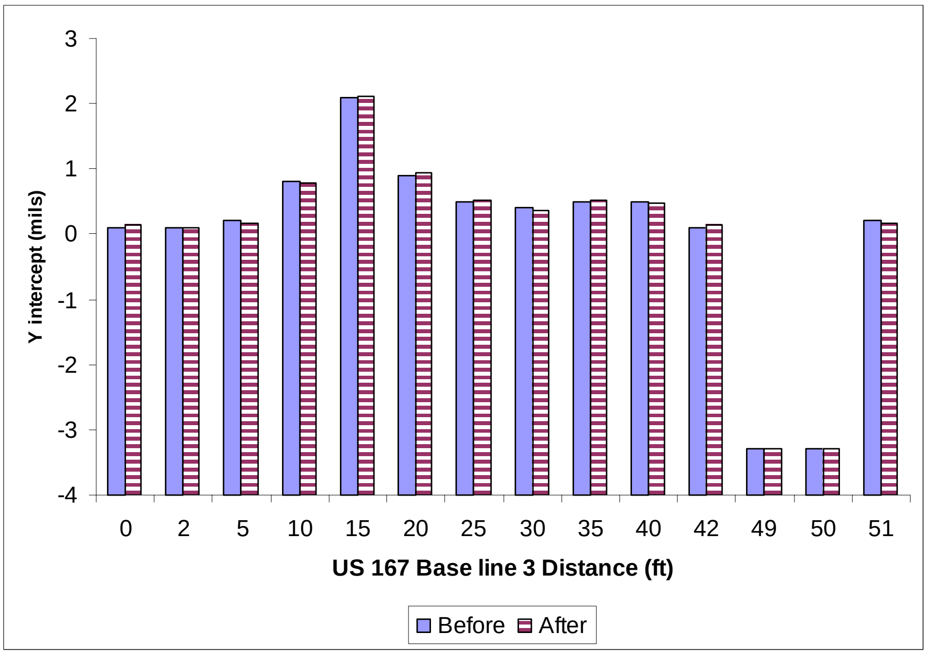

Figure 37

FWD void potential for US 167 NB base line 3

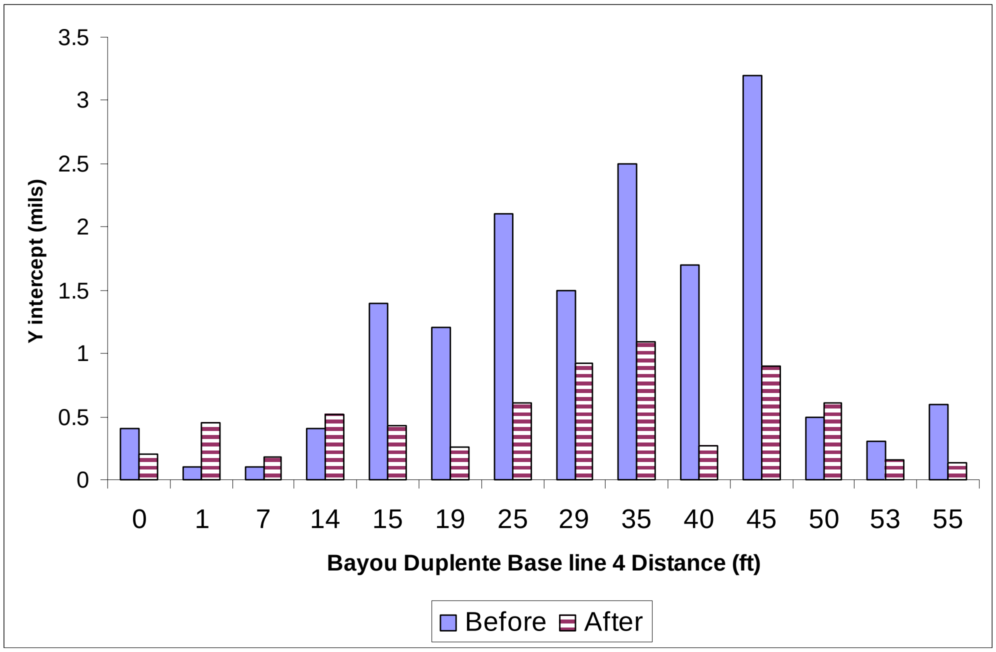

Figure 38

FWD void potential for Bayou Duplente base line 4

Dynaflect Test Results

The Dynaflect readings showed that there was basically no change in the Structural number of the pavement before and after injection with polyurethane. The values could not be computed on some base lines because the Dynaflect was not able to induce enough load to adequately deflect the pavement. Figure 39 illustrates the results. The remaining figures may be found in Appendix 4.

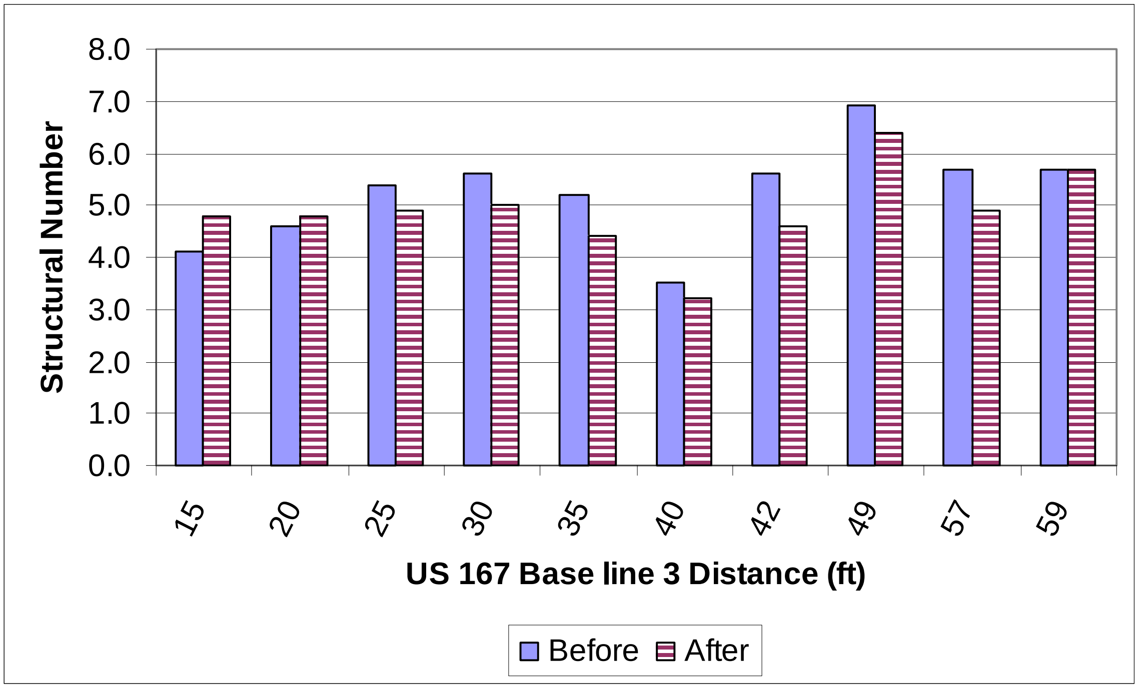

Figure 39

Dynaflect results for US 167 Base line 3

Concrete Cores and Polyurethane Specimen Condition

Concrete cores were taken. Table 7 presents the results, and figures 40 to 42 illustrate the cores in which polyurethane specimens were found.

Polyurethane was found at three out of the eight core locations. The polyurethane specimens were so dense that a ball point pen could not be pushed into the specimen. Though polyurethane was injected into the base course and subgrade on an approximately 4 x 4 feet grid pattern, it was found at only three locations. Perhaps the polyurethane is deeper than the core depths or it did not spread out to the locations cored. At core N1 (US 167 NB) , a 5-inch void was found. Core N1 is located about 2.5 feet from the bridge end and about 2 feet from the nearest injection point. According to the contractor, Uretek USA, polyurethane can be expected to spread approximately 2 feet from the nearest injection point which is why they normally use 4- to 5-foot injection patterns. Since the first row of injection points was 4 feet from the bridge end, the polyurethane understandably did not spread from the injection point to the bridge end. After the void was located, a new set of injection points about 2.5 feet from the bridge end was established to fill the voids at that location.

Table 7

Concrete cores

Core location	Concrete Thick. (in)	Poly. Thick. (in)	**Comments (Conditions found at field inspection)**	Poly. Density **(1)**
US 167				
N1	11.5	N/A	Polyurethane was not found. However, there was a 5" void	N/A
N2	9.5	0.5	0.5" of polyurethane found on one side of the core	Dense
N3	11.0	12	12" of polyurethane found. 5" was polyurethane and 7" was gravel/polyurethane mixture.	Dense
N4	10.0	N/A	Polyurethane was not found. 6" soil cement core extracted.	N/A
Bayou Duplente				
S1	12	N/A	Polyurethane was not found.	N/A
S2	9	2.5	2.5" of polyurethane found	Dense
S3	10	N/A	Polyurethane was not found.	N/A
S4	9.5	N/A	Polyurethane was not found.	N/A
(1) Dense means that the head of an ink pen could not be pushed into the polyurethane.				

Figure 40

Concrete core hole (US 167 NB, Core N1)

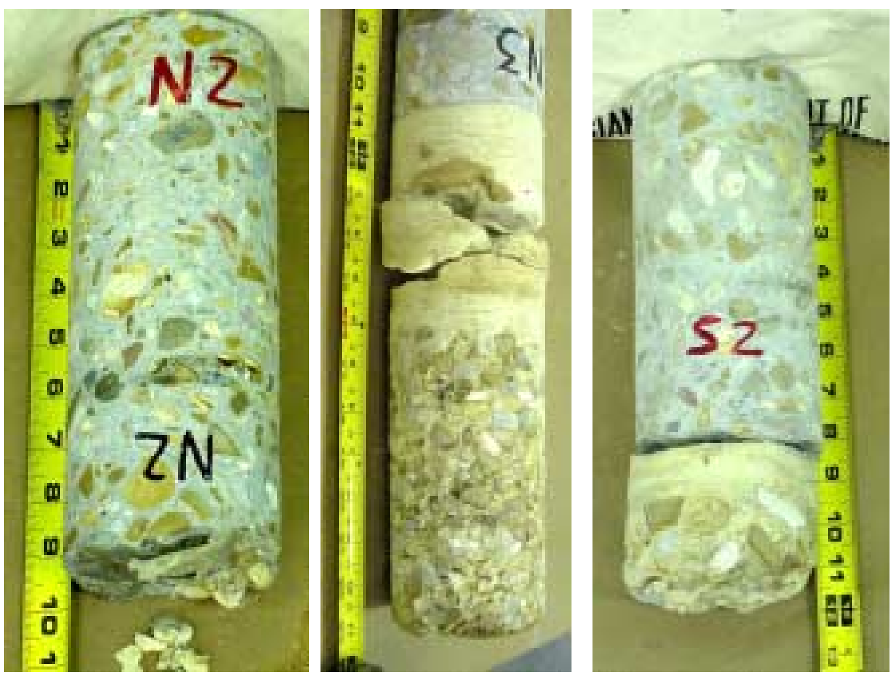

Figure 41

Concrete cores with polyurethane (N2, N3, and S2)

Figure 42

Concrete core with soil cement specimen

Polyurethane Quantity Estimation for Bridge Approach Slabs

In order to accurately develop an equation to estimate quantities, the volume of the treatment area and the amount of polyurethane required to fill must be known. Unlike the CRCP, the approach slab pavement will not settle completely with the embankment. Bridge approach slabs are steel-reinforced concrete pavement that rests on pile-supported abutments. Even though the embankment settles at the bridge end, the approach slab at that location will rotate, but will not settle unless the approach slab fails. Because of this, developing an accurate equation to predict the void totally based on the string line and maximum vertical deflection method used on the CRCP may be difficult and will be subject to inaccuracies. It is impossible to determine the depth of the void near the bridge end without coring through the pavement or using some other method, such as ground penetrating radar. Figure 43 shows the typical profile seen at the approach slabs on the US 167 NB and Bayou Duplente SB locations.

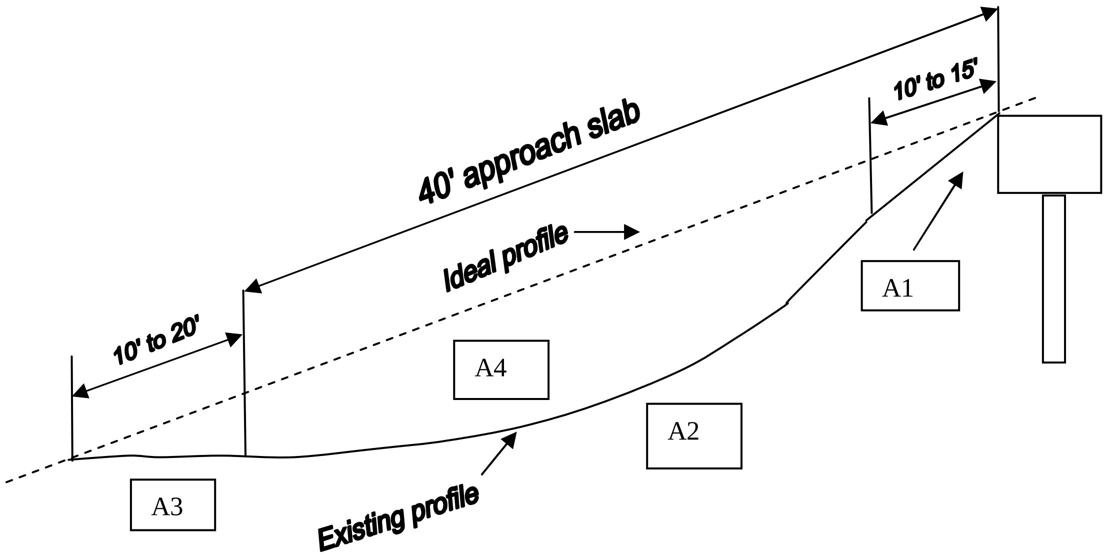

Figure 43

Typical approach slab profile

Equation Development / Verification (Bayou Duplente SB)

The profile data from the walking profiler tests were used to determine the volume of the area filled by the polyurethane injection. The amount of polyurethane used at each bridge approach slab on this project is presented in table 8. This theoretically should correspond to the point (A4) in figure 43. The volume is determined by computing the area at each base line before and after the polyurethane injection.

Base line 1 = 0.12081 sq.ft.

Base line 2 = 0.75016 sq.ft.

Base line 3 = 1.15616 sq.ft.

Base line 4 = 2.58091 sq.ft.

Base line 5 = 3.01334 sq.ft.

Base line 6 = 0.29679 sq.ft.

These areas were calculated by Steve Perault using Intergraph's In Roads design software. The total volume of the treatment area was computed using the average end area method typically used in earth work computations.

The volume using the average end method is 59.1263 cu.ft.
Polyurethane used in treatment area = 846.12 lbs.
Polyurethane (pounds) per volume = 846.12 / 59.126 = 14.31

The volume of polyurethane determined for the CRCP was 7 pounds per cu.ft. If the formula derived from the CRCP evaluation is used for the bridge approach slab condition, the following results are obtained:

P = 0.5 * X * Y * W * U

Where,
P = pounds of polyurethane required to level the slab
X = longitudinal distance (ft) of treatment area
Y = depth of depression (ft) at midpoint
W = width of treatment area (ft)
U = 7 pounds of polyurethane per cubic foot

With a vertical depression of one inch as determined from the Bayou Duplente profile:
P= 40*27*(1/12)*0.5*7 = 315 lbs (U=7)
P= 40*27*(1/12)*0.5*14.3 = 643.5 lbs (U=14.31)
Quantity used on Bayou Duplente bridge = 846 lbs

As shown in the calculations, the formula (U= 14.3) under-predicts the amount of polyurethane required to level the slab and fill the voids by 23 percent. The formula was also tested for the US 167 NB location with the following results:
P = 40*27*(1.5/12)*0.5*14.3 = 965 lbs

The quantity of polyurethane used on the US 167 NB location was 2,426 lbs. Once again, the formula under-predicted by 60 percent the amount of polyurethane required to level the approach slab and fill the voids.

In order for the formula (P = 0.5 * X * Y * W * U) to be more accurate for bridge approach slabs, an extensive database with at least 30 samples should be developed. Alternatively, the formula could be factored to compensate for the inaccuracies. Based on the data from US 167 NB and Bayou Duplente SB, increasing the quantity by 41 percent (midpoint between 23 and 60 percent) could be viable. The formula would then be modified as follows:

P (approach slabs) = 0.5 * X * Y * W * U * F

Where,

P = pounds of polyurethane required to level the slab

X = longitudinal distance (ft) of treatment area

Y = depth of depression (ft) at midpoint

W = width of treatment area (ft)

U = 14.3 pounds of polyurethane per cubic foot

F = 1.41 (adjustment factor)

Table 8

Polyurethane quantities (estimated and used)

Structure 455-02	**Quantity used**	**Quantity estimated**	**Difference**
1473-1 (US 167 NB)	2426.25	2600	-173.75
1877-1	5467.77	4700	-767.77
1877-2	5934.39	5500	+434.39
1473-2	3210.24	3600	-389.76
1280-2 (Bayou Duplente SB)	846.12	2100	+1253.88
1280-2	2165.79	4000	-1834.21
Total	**20,050.56**	**22,500**	**-2,449.44**
1170-2	1162.2	0	
1119-2	1408	0	
Note: Estimated quantities were provided to DOTD by the contractor, Uretek USA			

Guidelines for Polyurethane Injection

CRCP Leveling

1. The CRCP should not be failed.
2. Use the string line method to determine the pavement depression area.
3. Begin polyurethane injections 20 feet prior to and after the pavement depression area.
4. Use a polyurethane injection pattern grid of 3 to 4 feet.
5. Polyurethane injection holes should be drilled through the pavement and base course into the subgrade.

6. Use the equation, **P = 0.5 * X * Y * W * U,** to estimate quantities.

Where,

P = pounds of polyurethane required to level the slab

X = longitudinal distance (ft) of treatment area

Y = depth of depression (ft) at midpoint

W = width of treatment area (ft)

U = 7 pounds of polyurethane per cubic foot

JCP Faulting

1. Use in emergency situations only. It is not recommended to use this process for long term mitigation of faulting or improvements to load transfer.
2. When correcting faulting in emergency situations:
    - 2.1 Begin injection 1 foot from the joint.
    - 2.2 Use a polyurethane injection pattern grid of 3 to 4 feet.
    - 2.3 Drill the Polyurethane injection holes through the pavement and base course into the subgrade.
3. For quantity estimation:
    - 3.1 Raising the entire slab: 0.7 lbs. polyurethane per sq.ft. of slab
    - 3.2 Undersealing the entire slab: 0.4 lbs. polyurethane per sq.ft. of slab
    - 3.3 Undersealing along joint: 3.0 lbs polyurethane per lin.ft. of slab

Bridge Approach Slab Leveling

1. In addition to injecting the approach slab at the same time as the adjacent shoulders, the pavement slab adjacent to the approach slab should be undersealed. If the approach slab is severely distressed, it should be reconstructed.
2. Use a polyurethane injection pattern grid of 3 to 4 feet.
3. Begin injections 2 to 2.5 feet from the bridge end.
4. Drill the polyurethane injection holes through the pavement and base course into the

subgrade.

5. Use the string line method to determine the point of maximum depression

6. Use the equation, **“P = 0.5 * X * Y * W * U * F”** to estimate quantities.

Where,

P = pounds of polyurethane required to level the slab

X = longitudinal distance (ft) of treatment area

Y = depth of depression (ft) at midpoint

W = width of treatment area (ft)

U = 14.3 pounds of polyurethane per cubic foot

F = 1.41 (adjustment factor)

CONCLUSIONS

Testing results indicated that injecting polyurethane into the pavement structure is an effective method of leveling CRCP and bridge approach slabs. On the CRCP and bridge approach slabs, IRI values were reduced from 33 to 68 percent while as much as 2 inches of depression was removed from the slabs.

Pavement voids were filled by the polyurethane injection process as demonstrated by trenching in the JCP along with core samples in the CRCP and bridge approach slabs. In the CRCP and bridge approach slab, the polyurethane was dense. However, varying layers of stiffness, ranging from soft to dense, were found in samples taken from the JCP. This could be problematic, and the causes should be further investigated.

The pavement structure did not appear to be adversely impacted by the polyurethane injection. On the JCP and bridge approach slabs, the deflections were generally maintained or reduced after polyurethane injection. The Y intercept values used to predict voids were generally reduced on the JCP and bridge approach slabs.

Forensic investigation of both the trenched slab and patched areas on the JCP proved to be valuable. In addition to the information previously listed about void filling, the trenched slab area, Slab 74 – Area 3, allowed the adjacent slabs in the left lane to be viewed under traffic loading. The slabs in the left had previously injected with polyurethane in April 2002. The joints could be seen significantly deflecting under traffic loading, and water was seen flowing through the joint and slab. This observation indicated that the polyurethane did fill the voids, but it did not appear to provide much support to the joints or waterproof the pavement. This scenario was also witnessed at the slabs in Area 2. Because the star lug load transfer devices were not functioning, only aggregate interlock and polyurethane at injection locations were available for load transfer.

Void determination with the FWD can be used with confidence, except in locations between 0 and 10 feet from the bridge end on approach slabs. Core samples and trenching did generally show voids in the areas that were predicted with the FWD. However, an indication of voids being filled with polyurethane does not necessarily translate into increases in long term pavement performance.

RECOMMENDATIONS

It is recommended that polyurethane injection be included as an alternative to other rehabilitation methods, such as patching and asphaltic concrete overlay, for leveling CRCP and bridge approach slabs. Factors such as cost and traffic disruptions should be reviewed when determining which rehabilitation method would be most feasible. As a result of this research, DOTD and FHWA have endorsed this process for CRCP and bridge approach slabs. Further research should be conducted to refine the quantity estimation models.

The long term performance of these sections should be carefully monitored to establish the life expectancy of the polyurethane injection.

To move forward with the future use of polyurethane injection for pavement preservation, the following issues need to be addressed by polyurethane suppliers and contractors:

1. Characterization of stiffness/strength/density of polyurethane under different confinement conditions (i.e., open air curing & curing under different pressures simulating field conditions)
2. Effect of moisture on the stiffness/strength/density and quantity of polyurethane during the injection process
3. Long term durability of polyurethane
    a. Under repeated load applications
    b. Under different to environmental conditions (i.e., moisture, temperature, exposure to chemical spills, natural soil compositions such as sulfates, alkaline, acidic, etc.)
4. Testing methods and values for Quality Assurance in the field

The polyurethane supplier and contractor will be responsible for developing a detailed laboratory testing protocol for addressing the above issues. The testing plan shall include methods of sample preparation and test procedures to be utilized. The testing plan and testing laboratory shall be approved by DOTD prior to commencement of work. Verification samples will also be required for LTRC testing.

The laboratory testing provides for characterization of material properties. Additional concerns that need to be addressed deal with site-specific conditions, injection processes, and general bidding details.

1. Methods for determining appropriate quantities for cost estimates and bidding
2. Polyurethane patents for applications requiring proprietary bidding
3. Guidelines for selecting appropriate projects for pavement application including specifications and methods of application
4. Benefits of soil improvement and foundation support from deep injection
    a. Soft saturated clays
    b. Weak saturated silts
    c. Saturated sands
5. Applications as they relate to various base courses and pavement types.

The polyurethane supplier and contractor will be responsible for developing a detailed field testing program to evaluate conditions not previously addressed by LTRC. The testing plan shall recommend evaluation equipment and target values for acceptance. LTRC availability for field evaluations will be predicated on funding and manpower priorities.

ACRONYMS, ABBREVIATIONS, & SYMBOLS

Mils = 0.001 inches

AASHTO	American Association of State Highway and Transportation Officials
CRCP	Continuously reinforced concrete pavement
DOTD	Louisiana Department of Transportation and Development
FHWA	Federal Highway Administration
FWD	Falling Weight Deflectometer
IRI	International roughness index
JCP	Jointed concrete pavement
LTRC	Louisiana Transportation Research Center

APPENDIX 1
Evangeline Thruway

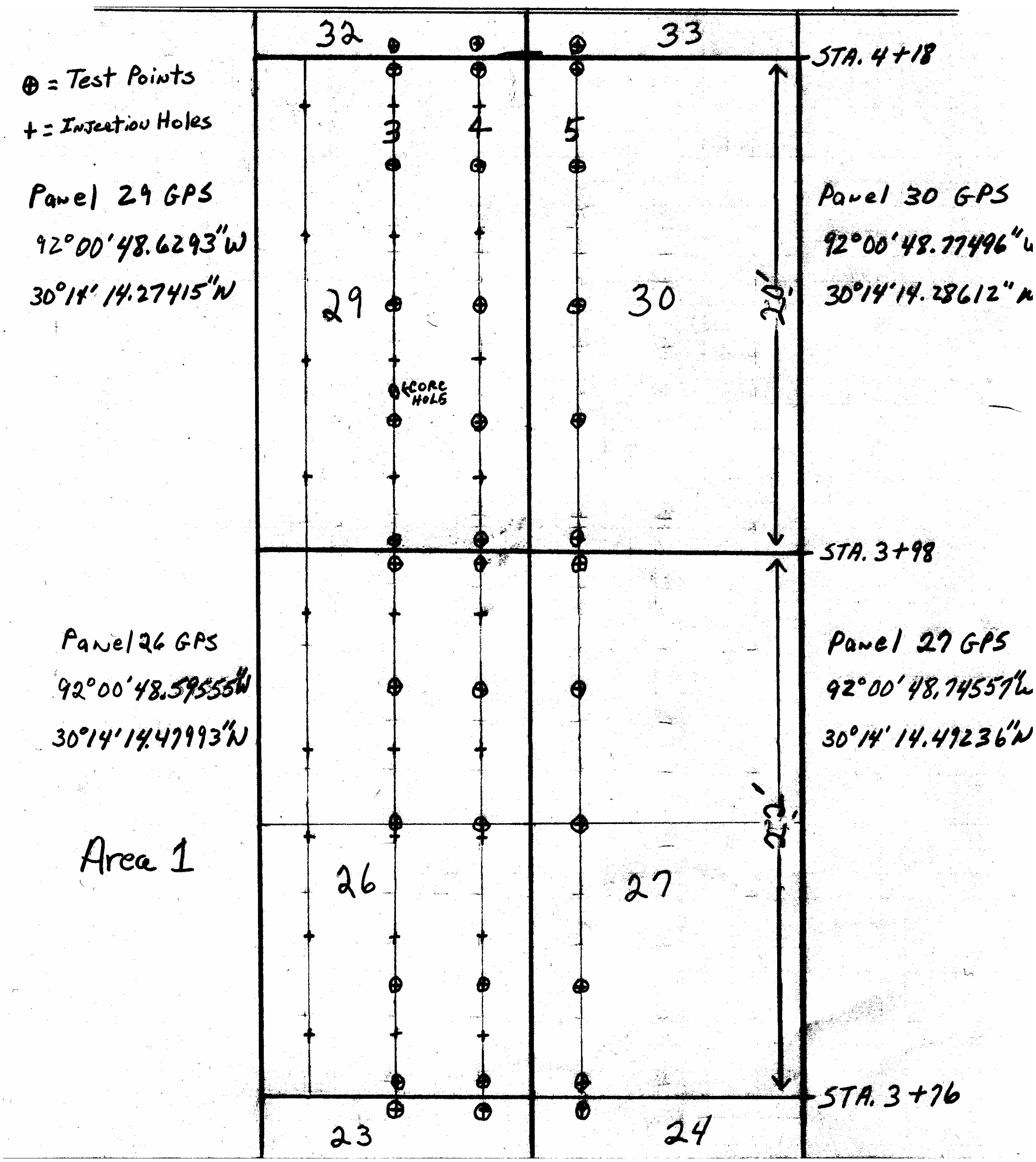

Figure 44
Area 1 layout

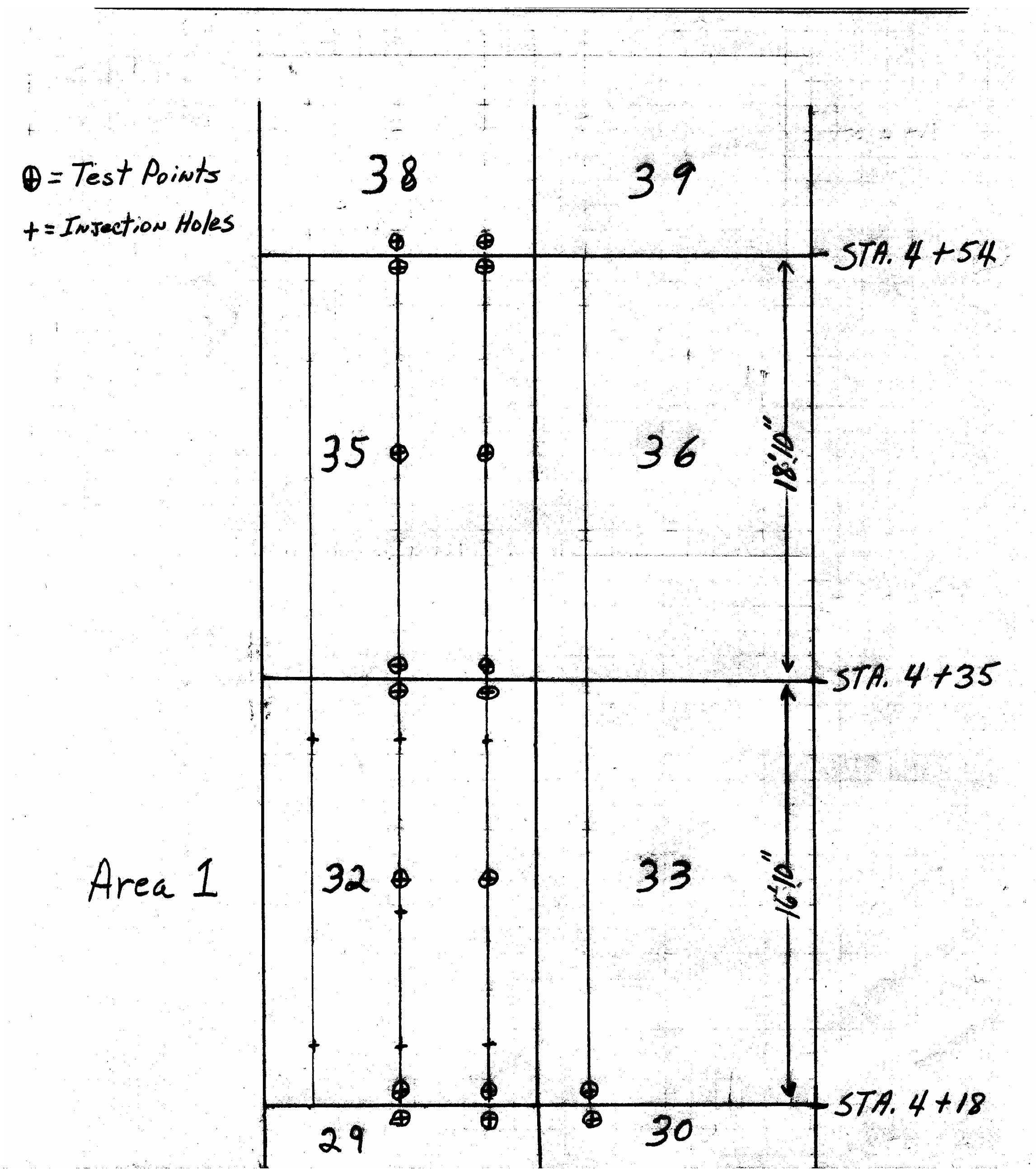

Figure 45
Area 1 layout

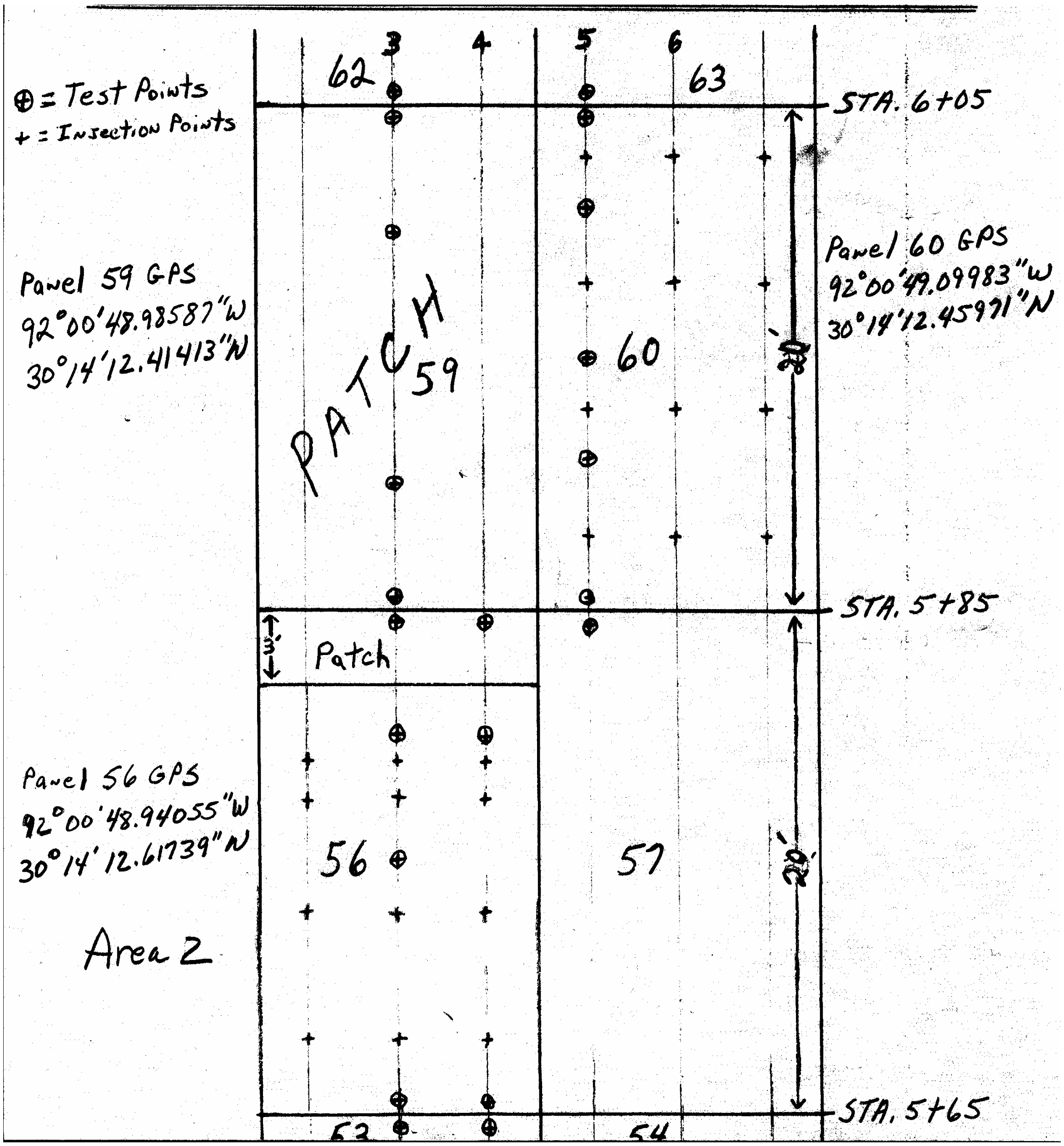

Figure 46
Area 2 layout

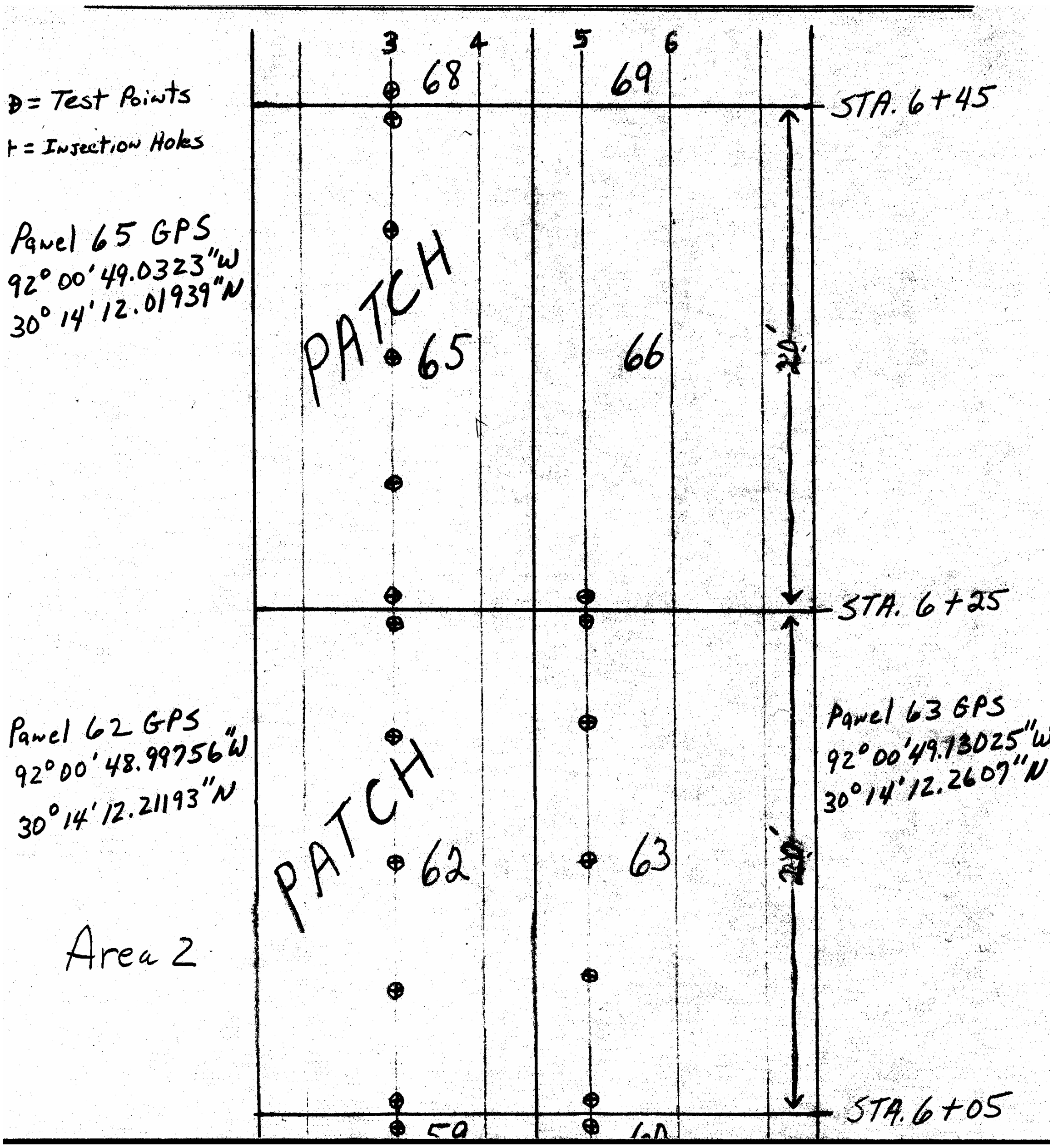

Figure 47
Area 2 layout

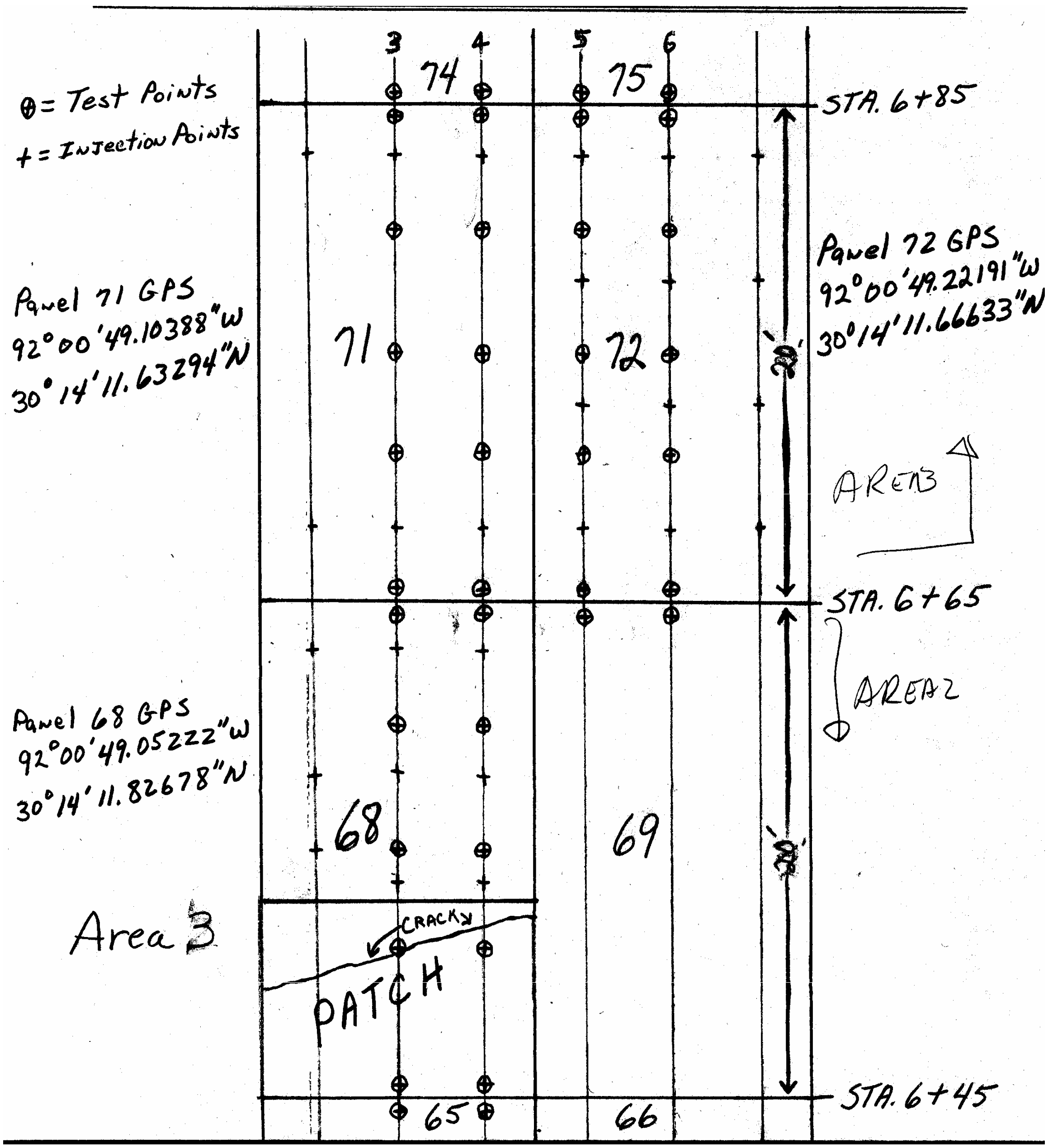

Figure 48
Area 3 layout

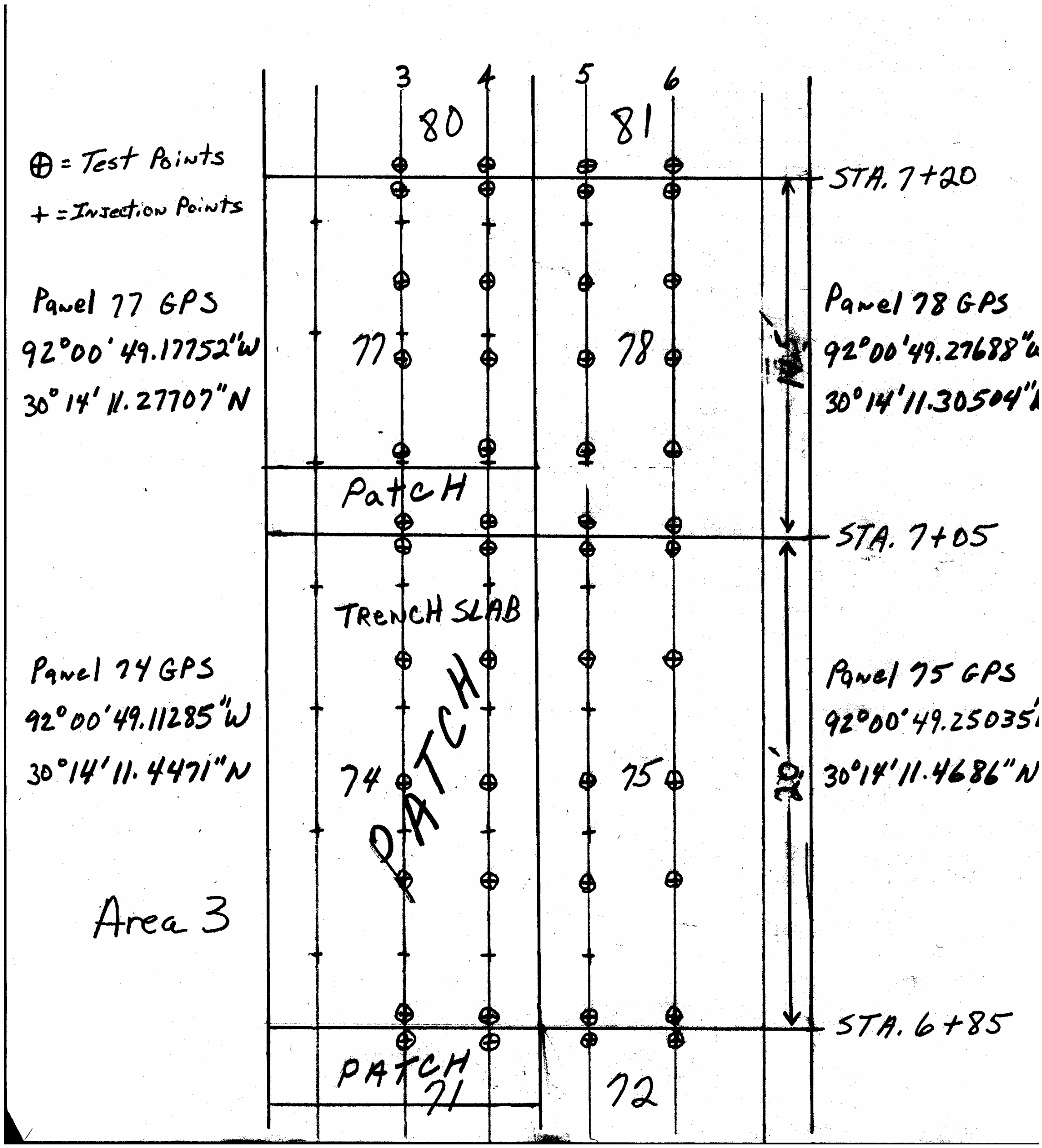

Figure 49
Area 3 layout

Table 9
Manual fault measurements

Table provided by Mr. Lynn Evans, ERES engineers

				Tvs Joints		Lgt Joints	
Lane	**Slab**	**Location1**	**Type**	**Before**	**After**	**Before**	**After**
2	26	E joint, center	Raise			0.29	-0.08
2	29	E. joint, center	Raise			0.18	0.14
2	29	N joint, center	Raise	0.75	0.33		
2	26	N. joint, center	Raise	0.7	0.04		
2	32	N. joint, center	Underseal	0.49	-		
2	56	N. joint, center	Underseal	0.13	-		
2	59	N. joint, center	None	0.48	Patched		
2	62	N. joint, center	None	0.2	Patched		
2	65	N. joint, center	None	0.54	Patched		
2	68	N. joint, center	Underseal	0.31	Patched		
2	71	N. joint, center	Underseal	0.34	0.4		
2	74	N. joint, center	Raise	0.54	Patched		
2	77	N. joint, center	Raise	0.54	Patched		
2	80	N. joint, center	None	0.19	Patched		
2	26	N. joint, RWP	Raise	0.75	0.1		
2	29	N. joint, RWP	Raise	0.65	0.46		
2	32	N. joint, RWP	Underseal	0.45	0.27		
2	68	N. joint, RWP	Underseal	0.29	Patched		
2	71	N. joint, RWP	Underseal	0.47	0.43		
2	74	N. joint, RWP	Raise	0.41	Patched		
2	77	N. joint, RWP	Raise	0.48	Patched		
2	80	N. joint, RWP	None	0.24	Patched		
3	60	E. joint, center	Raise			0.25	Patched
3	63	E. joint, center	Underseal			0.38	Patched
3	66	E. joint, center	None			0.48	Patched
3	69	E. joint, center	None			0.3	Patched
3	72	E. joint, center	Underseal			0.38	Patched
3	75	E. joint, center	Underseal			0.19	Patched
3	78	E. joint, center	Raise			0.06	Patched
3	72	N. joint, center	Underseal	0	-0.01		
3	75	N. joint, center	Underseal	0.18	0.21		
3	78	N. joint, center	Raise	0.29	0.13		
3	81	N. joint, center	None	-0.02	0.06		
3	27	N. joint, LWP	None	-0.01	-0.12		
3	33	N. joint, LWP	None	0.25	0.24		
3	30	N. joint, LWP		0.11	0.28		
3	60	N. joint, LWP	Raise	0.34	-0.07		
3	63	N. joint, LWP	Underseal	0.24	Patched		
3	66	N. joint, LWP	None	0.22	Patched		
3	72	N. joint, LWP	Underseal	0.04	0.04		
3	75	N. joint, LWP	Underseal	0.19	0.19		
3	78	N. joint, LWP	Raise	0.34	0.01		
3	81	N. joint, LWP	None	0.07	0.21		

Table 10
Testing locations

Area	BL	Lane	Pan.	Type	Dist.	Yb	Ya	D1b	D1a	SNb	Sna	UPY
1	3	c	23	JA	0	0.7	0	19	11.99		3.3	n
1	3	c	26	JL	1	4.6	0	8.2	12.7	2.2	3.5	n
1	3	c	26	i	4	0.8	0	6.7	7.56	4.8	5.1	n
1	3	c	26	C	10	0.4	0	7.4	7.87	5.7	5.3	n
1	3	c	26	i	16	0.6	0.6	14	8.83	5.5	4.7	n
1	3	c	26	JA	20	0.2	0.3	22	13.39	1.1	3.1	n
1	3	c	29	JL	21	2.6	-0.1	7.4	17.35	1.7	2.8	n
1	3	c	29	i	26	0.4	0.6	6.5	7.14	4.9	5.1	n
1	3	c	29	C	30	0.5	0.2	7.7	6.72	5.7	5.5	n
1	3	c	29	i	36	0.1	0.2	20	7.14	5.8	5.2	n
1	3	c	29	JA	41	2.3	0.5	14	12.7	0.0	2.5	n
1	3	c	32	JL	43	2.3	0.5	17	13.39		3.2	n
1	3	c	32	C	53	0.5	0.4	7.5	8.89		4.7	n
1	3	c	32	JA	60	0.9	0.8	12	12.76		2.7	n
1	3	c	35	JL	61	0.7	0.8	11	10.65		3.7	n
1	3	c	35	C	70		0.2		6.92		5.2	n
1	3	c	35	JA	77		0.2		11.96		2.4	n
1	3	c	38	JL	78		0.5		12.02		3.4	n
1	4	c	23	ja	0	1	0.9	15	14.5			n
1	4	c	26	jl	1	2.4	-1.6	23	20.74			n
1	4	c	26	i	5	0.7	-0.6	9.5	13.49			n
1	4	c	26	c	11	0.3	0	7.9	12.9			n
1	4	c	26	i	17	0.4	0.2	9	12.18			n
1	4	c	26	ja	22	0.9	0	17	21.85			n
1	4	c	29	jl	23	1.8	0.7	23	34.5			n
1	4	c	29	i	28	0.6	0	9.3	10.82			n
1	4	c	29	c	32	0.3	0.4	8.5	8.03			n
1	4	c	29	i	38	0.5	0.5	9.2	8.32			n
1	4	c	29	ja	42	2.4	0.4	21	11.35			n
1	4	c	32	jl	43	1.6	0.2	16	12.82			n
1	4	c	32	c	52	0.6	1	9.4	11.15			n
1	4	c	32	ja	59	1.1	1.3	14	13.96			n
1	4	c	35	jl	60	1.2	1.8	13	12.13			n
1	4	c	35	c	69	0.8	0.9	7.8	7.11			n
1	4	c	35	ja	76	1.1	0.7	14	13.63			n
1	4	c	38	jl	77	0.9	1.3	15	15.21			n

BL Base line

Pan Panel

JA approach joint

JL leave joint

I intermediate point

C center

Yb intercept before injection

Ya intercept after injection

D1b deflection before injection

D1a deflection after injection

SNb structural num before injeciton

Sna structural num. after injection

UPY Uretek previous year (April 2002)

Table 11
Testing locations

Area	BL	Lane	Pan.	Type	Dist.	Yb	Ya	D1b	D1a	SNb	Sna	UPY
1	5	r	24	ja	0	1.2	1.7	16	14.58		2.9	n
1	5	r	27	jl	1	1.3	-2.1	8.7	21.42	3.3	3.0	n
1	5	r	27	i	4	0.7	0.4	7.6	10.91	4.9	4.5	n
1	5	r	27	c	11	0.5	0.4	8.5	10.83	5.1	4.6	n
1	5	r	27	i	17	0.4	0.3	15	10.11	4.8	5.2	n
1	5	r	27	ja	22	0.3	3	18	29.45	1.7	-1.8	n
1	5	r	30	jl	23	-0.2	5.1	8.4	24.2	2.7	1.7	n
1	5	r	30	i	28	0.6	1.1	7.7	10.18	4.4	3.7	n
1	5	r	30	c	33	0.6	0.5	8.4	8.36	4.9	4.9	n
1	5	r	30	i	38	0.5	0.1	15	9.25	5.0	4.3	n
1	5	r	30	ja	42	1.1	0.9	17	16.11	1.2	1.3	n
1	5	r	33	jl	43	1.2	1.7	13	20.03		1.8	n
2	1	l	52	ja	0		-0.2		15.72		3.9	y
2	1	l	55	jl	1		1.4		13.48		3.6	y
2	1	l	55	c	10		0.6		8.67		4.9	y
2	1	l	55	ja	19		-4.8		18.5		3.4	y
2	1	l	58	jl	20		0.5		12.89		3.4	y
2	1	l	58	c	30		0.4		7.87		5.1	y
2	1	l	58	ja	40		0.2		15.82		3.2	y
2	1	l	61	jl	41		0.8		19.14		3.3	y
2	1	l	61	c	51		0.4		7.02		5.4	y
2	1	l	61	ja	60		0.2		16.26		0.8	y
2	1	l	64	jl	61		2.8		17.41		2.5	y
2	1	l	64	c	70		-0.2		7.33		5.4	y
2	1	l	64	ja	80		-0.3		15.69		2.6	y

BL Base line

Pan Panel

JA approach joint

JL leave joint

I intermediate point

C center

Yb intercept before injection

Ya intercept after injection

D1b deflection before injection

D1a deflection after injection

SNb structural num before injeciton

Sna structural num. after injection

UPY Uretek previous year (April 2002)

Table 12
Testing locations

Area	BL	Lane	Pan.	Type	Dist.	Yb	Ya	D1b	D1a	SNb	Sna	UPY
2	3	c	53	ja	0	1.9		22			3.7	n
2	3	c	56	jl	1	4.7		34		1.2	0.0	n
2	3	c	56	c	10	0		7.6		5.2	5.2	n
2	3	c	56	i	15	1.2		8.9		5.4		n
2	3	c	56	ja	19	-0.3		29		0.0		n
2	3	c	59	jl	20	3.6		23		1.7		y
2	3	c	59	i	24	0.9		11		4.8		y
2	3	c	59	i	34	0.4		9.6		5.3		y
2	3	c	59	ja	38	3.2		44		0.0		y
2	3	c	62	jl	39	17		45		0.0		y
2	3	c	62	i	43	2.1		18		4.5		y
2	3	c	62	c	48	2.4		15		1.8		y
2	3	c	62	i	53	0.1		9.8		5.1		y
2	3	c	62	ja	58	-0.7		39		2.0		y
2	3	c	65	jl	59	6.8		35		0.2		y
2	3	c	65	i	63	1.8		18		4.4		y
2	3	c	65	c	68	4.8		23		0.9		y
2	3	c	65	i	73	1.2		12		4.7		y
2	3	c	65	ja	78	11		64		0.0		y
2	4	c	56	c	0	1.2		14				n
2	4	c	56	ja	5	2		40				n
2	5	r	57	ja	0	2.5		41				n
2	5	r	60	jl	1	12		34		1.1		n
2	5	r	60	i	6	0.7		17		3.3		n
2	5	r	60	c	10	0.2		12		4.5		n
2	5	r	60	i	15	1.1		22		4.2		n
2	5	r	60	ja	19	5.5		61		0.0		n
2	5	r	63	jl	20	4.3		43		1.1		n
2	5	r	63	i	25	1.1		14		3.3		n
2	5	r	63	c	30	-1.1		11		3.7		n
2	5	r	63	i	35	1		15		4.4		n
2	5	r	63	ja	40	4.1		49		0.0		n
2	5	r	66	jl	41	4.1		27				n

BL Base line

Pan Panel

JA approach joint

JL leave joint

I intermediate point

C center

Yb intercept before injection

Ya intercept after injection

D1b deflection before injection

D1a deflection after injection

SNb structural num before injeciton

Sna structural num. after injection

UPY Uretek previous year (April 2002)

Table 13
Testing locations

Area	BL	Lane	Pan.	Type	Dist.	Yb	Ya	D1b	D1a	SNb	Sna	UPY
3	1	l	67	jl	0	2.2			14.4		3.3	y
3	1	l	67	c	10	0.2			7.86		5.3	y
3	1	l	67	ja	20	0.1			14.82		2.9	y
3	1	l	70	jl	21		0.6		11.55		3.6	n
3	1	l	70	c	30		0.5		8.24		5.1	n
3	1	l	70	ja	39		0.5		16.37		0.3	n
3	1	l	73	jl	40		1.2		16.63		2.7	n
3	1	l	73	c	50		0.5		7.81		5.2	n
3	1	l	73	jl	59		-0.3		14.96		1.9	n
3	1	l	76	ja	60		1.7		19.35		3.0	n
3	1	l	76	c	66		0.6		8.96		4.6	n
3	1	l	76	ja	73		-0.6		12.91		2.1	n
3	1	l	79	jl	74		3		20.57		2.7	n
3	1	l	79	c	81		0.2		9.39		4.8	n
3	3	c	68	jl	0	1.2		25		1.2		n
3	3	c	68	i	5	0.4		13		3.5		n
3	3	c	68	c	9	0.5		6.5		5.1		n
3	3	c	68	i	15	0.3		7.5		5.5		n
3	3	c	68	ja	19	2.2		23		0.0		n
3	3	c	71	jl	20	4.5		26		1.5		n
3	3	c	71	i	25	0.6		7.2		4.8		n
3	3	c	71	c	30	-0.4	0.4	7.5	7.53	5.2		n
3	3	c	71	i	35	0.4	0.2	8.3	7.46	5.7		n
3	3	c	71	ja	39	3.5	-0.5	35	13.95	0.0		n
3	3	c	74	jl	40	2	-0.4	32	13.27	2.0		n
3	3	c	74	i	45	0.8	0.3	8.3	7.2	5.4		n
3	3	c	74	c	50	0.4	0.2	7.3	7.07	5.4		n
3	3	c	74	i	55	1.2	0.3	12	7.2	4.4		n
3	3	c	74	ja	59	9.3	0.2	52	11.92	0.0		n
3	3	c	77	jl	60	2.1	-1.1	23	13.89	1.8		n
3	3	c	77	i	63	0.6	0.2	9.3	6.88	3.3		n
3	3	c	77	c	67	0.4	0.1	7	6.38	5.0		n
3	3	c	77	i	70	1.1	0.1	6.7	6.06	5.4		n
3	3	c	77	ja	74	0	-0.1	12	8.49	1.8		n
3	3	c	80	jl	75		0.3		8.2			n

BL Base line

Pan Panel

JA approach joint

JL leave joint

I intermediate point

C center

Yb intercept before injection

Ya intercept after injection

D1b deflection before injection

D1a deflection after injection

SNb structural num before injeciton

Sna structural num. after injection

UPY Uretek previous year (April 2002)

Table 14
Testing locations

Area	BL	Lane	Pan.	Type	Dist.	Yb	Ya	D1b	D1a	SNb	Sna	UPY
3	4	c	68	jl	0	8.6		49				n
3	4	c	68	i	5	1.6		20				n
3	4	c	68	c	9	0.5		12				n
3	4	c	68	i	15	0.8		12				n
3	4	c	68	ja	19	2.8		35				n
3	4	c	71	jl	20	5.1		40				n
3	4	c	71	i	25	1.6		15				n
3	4	c	71	c	30	1.2	0.8	15	15.23			n
3	4	c	71	i	35	1.7	0.1	20	12.62			n
3	4	c	71	ja	39	6.9	-1.3	58	21.67			n
3	4	c	74	jl	40	4.8	-2.1	31	23.79		b	n
3	4	c	74	i	45	1.2	-0.1	11	10.96		a	n
3	4	c	74	c	50	2.4	0.6	11	9.69			n
3	4	c	74	i	56	3.9	0	25	9.22			n
3	4	c	74	ja	60	27	0	71	11.99			n
3	4	c	77	jl	61	1.9	-1.1	22	12.93			n
3	4	c	77	i	64	0.9	-0.2	14	7.75			n
3	4	c	77	c	68	1	0.3	13	7.56			n
3	4	c	77	i	71	0.6	0.3	11	7.21			n
3	4	c	77	ja	74	1	0.4	15	11.44			n
3	4	c	80	jl	75		0.5		11.1			n
3	5	r	72	jl	20	2.1		31				n
3	5	r	72	i	25	1		10				n
3	5	r	72	c	30	0.8	0.8	10	15.5			n
3	5	r	72	i	35	4.4	0.5	13	11.17			n
3	5	r	72	ja	39	3.2	1.1	38	24.31			n
3	5	r	75	jl	40	4	3	33	28.98		b	n
3	5	r	75	i	46	-0.2	0.1	10	12.02		a	n
3	5	r	75	c	50	0.1	0.4	9.1	8.82			n
3	5	r	75	i	56	0.6	0.5	10	8.87			n
3	5	r	75	ja	60	2.3	1.8	28	20.53			n
3	5	r	78	jl	61	4.4	1.1	21	22.87			n
3	5	r	78	i	63	1.1	0.4	8.1	12.13			n
3	5	r	78	c	68	0.6	0.5	7.6	10.72			n
3	5	r	78	i	71	0.5	0.6	15	9.83			n
3	5	r	78	ja	74	0.6	0.6	12	12.72			n
3	5	r		jl	75		1		12.43			n

BL Base line

Pan Panel

JA approach joint

JL leave joint

I intermediate point

C center

Yb intercept before injection

Ya intercept after injection

D1b deflection before injection

D1a deflection after injection

SNb structural num before injeciton

Sna structural num. after injection

UPY Uretek previous year (April 2002)

Table 15
Testing locations

Area	BL	Lane	Pan.	Type	Dist.	Yb	Ya	D1b	D1a	SNb	Sna	UPY
3	6	r	69	ja	19		0.8		17.39		0.7	n
3	6	r	72	jl	20	1.2	1.1	17	19.3	2.5	2.3	n
3	6	r	72	i	25	-0.1	0.2	7.1	7.67	5.0	4.9	n
3	6	r	72	c	29	0.2	0.4	7.3	7.69	5.2	5.0	n
3	6	r	72	i	34	0.5	0.4	8.1	7.54	5.6	5.1	n
3	6	r	72	ja	38	1.5	0.5	23	12.62	0.0	1.5	n
3	6	r	75	jl	39	3.5	1.6	18	15.97	2.0	2.8	n
3	6	r	75	i	44	0.4	0.4	7.3	7.43	5.0	4.9	n
3	6	r	75	c	48	0.4	0.3	6.6	7.13	5.3	5.2	n
3	6	r	75	i	54	0.5	0.4	7.7	7.91	5.5	5.7	n
3	6	r	75	ja	58	2.3	0.8	19	16.6	0.0	0.9	n
3	6	r	78	jl	59	1.5	0.4	14	17.81	2.6	2.5	n
3	6	r	78	i	63	0.7	0.2	8	9.13	4.4	4.7	n
3	6	r	78	c	66	0.2	0.2	7.1	8.33	5.3	4.9	n
3	6	r	78	i	69	0.3	0.2	7	9.27	5.4	5.0	n
3	6	r	78	ja	72	0.9	-0.2	11	16.41	2.5	2.7	n
3	6	r	81	jl	73		0.7		17.22		3.4	n

BL Base line

Pan Panel

JA approach joint

JL leave joint

I intermediate point

C center

Yb intercept before injection

Ya intercept after injection

D1b deflection before injection

D1a deflection after injection

SNb structural num before injeciton

Sna structural num. after injection

UPY Uretek previous year (April 2002)

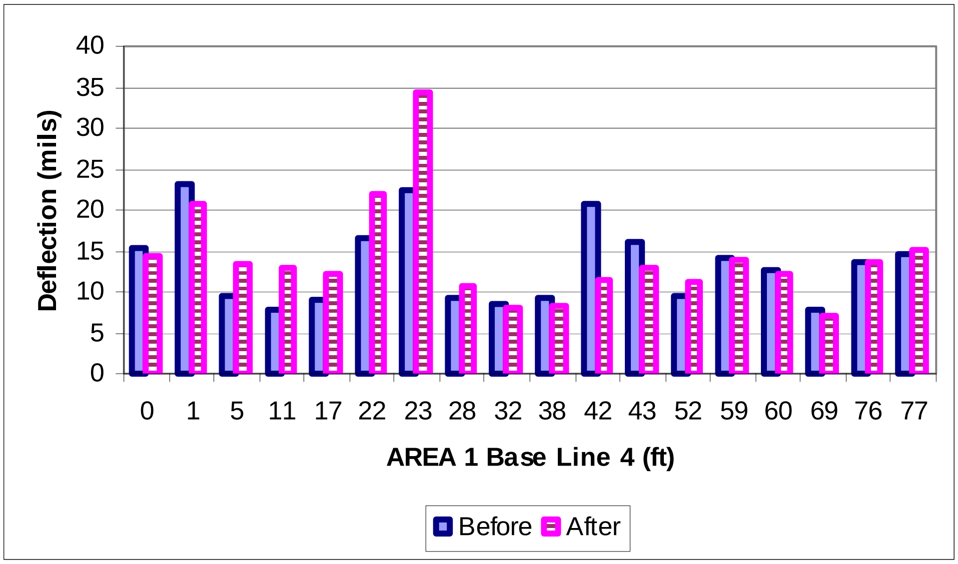

Figure 50
FWD first sensor deflections (16 kips) area 1 base line 4

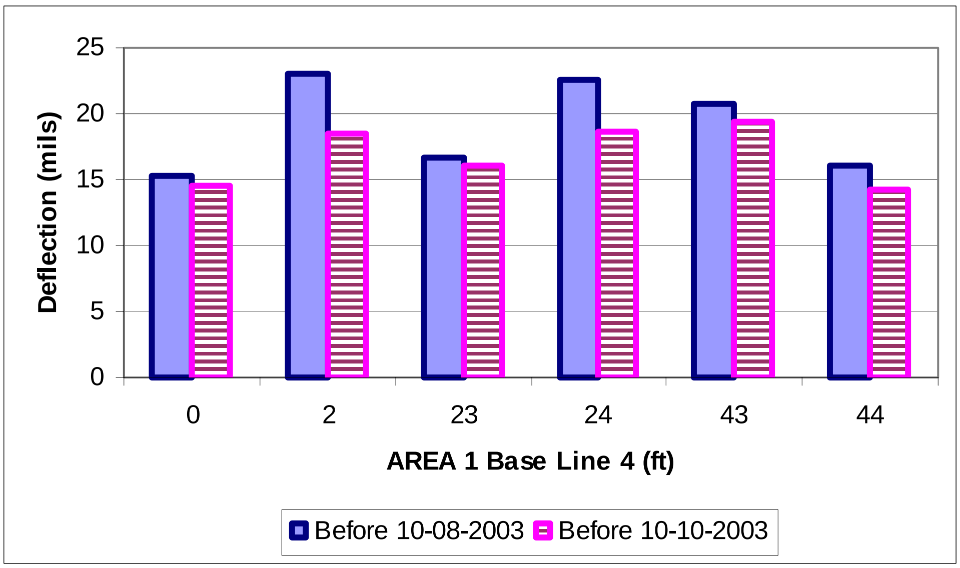

Figure 51
FWD first sensor deflections (16 kips) area 1 base line 4 (Comparison before and after rain on 10-09-2003)

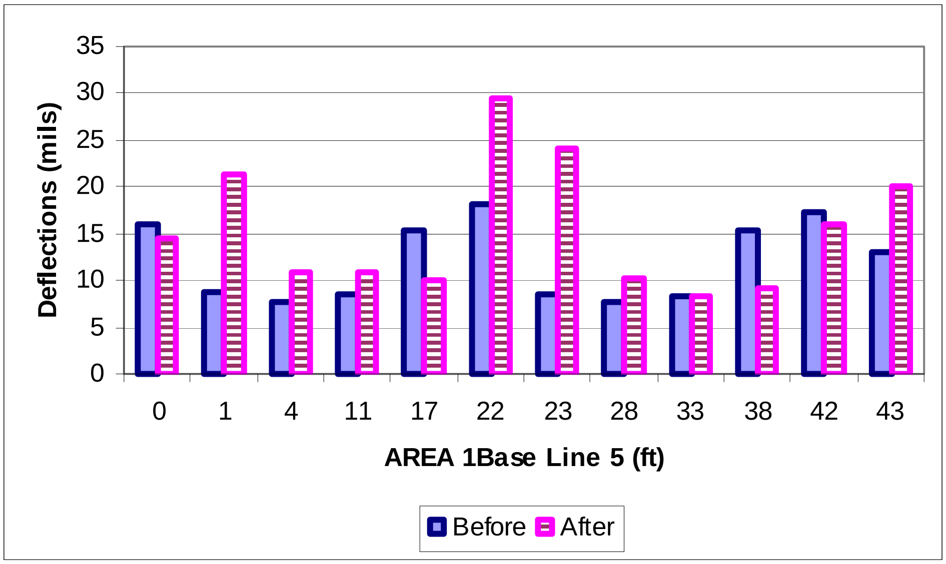

Figure 52
FWD first sensor deflections (16 kips) area 1 base line 5

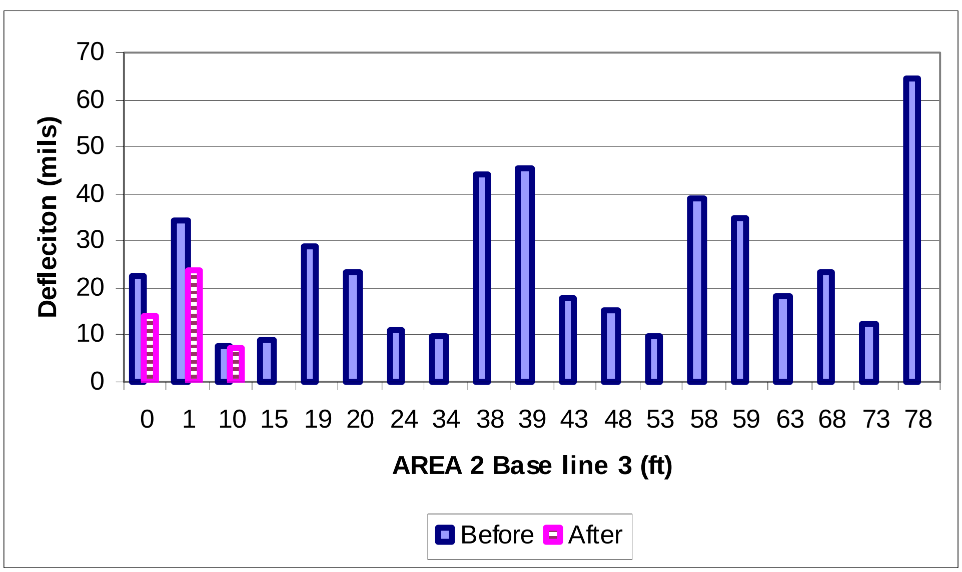

Figure 53
FWD first sensor deflections (16 kips) area 2 base line 3

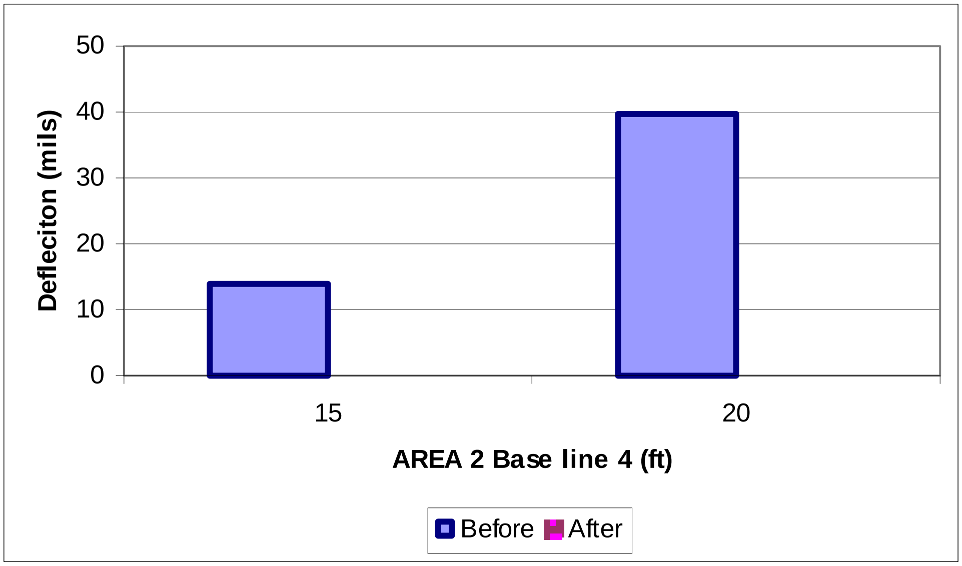

Figure 54
FWD first sensor deflections (16 kips) area 2 base line 4

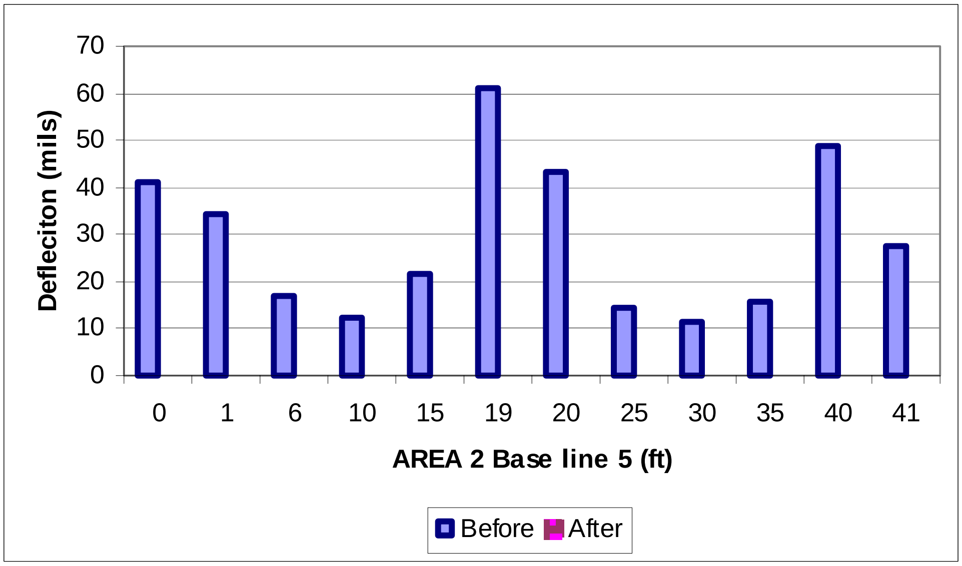

Figure 55
FWD first sensor deflections (16 kips) area 2 base line 5

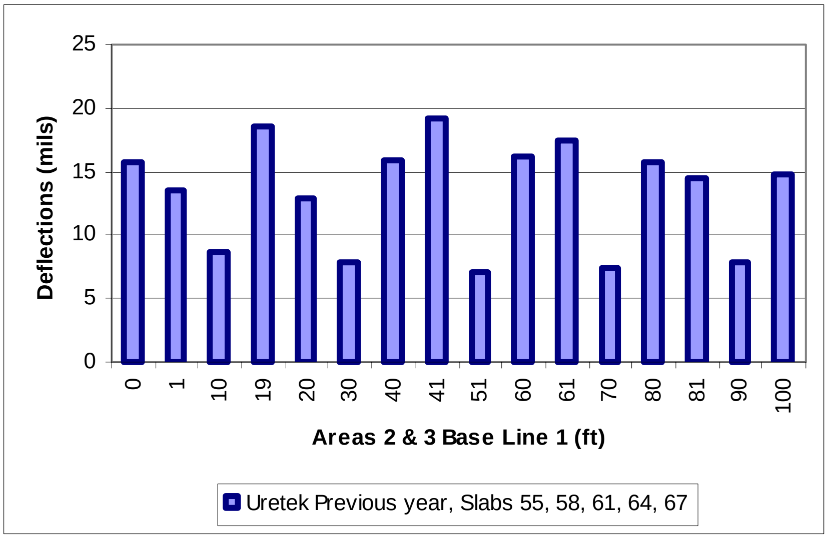

Figure 56
FWD first sensor deflections (16 kips) area 2 & 3 base line 1 (Injected with Uretek the previous year)

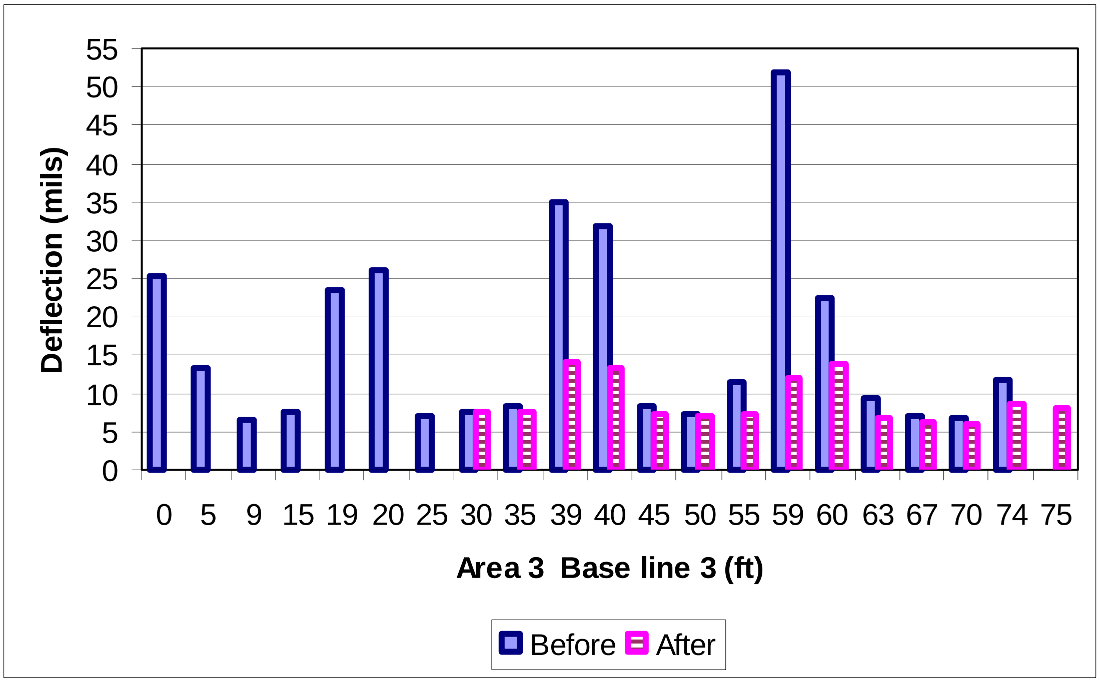

Figure 57
FWD first sensor deflections (16 kips) area 3 base line 3

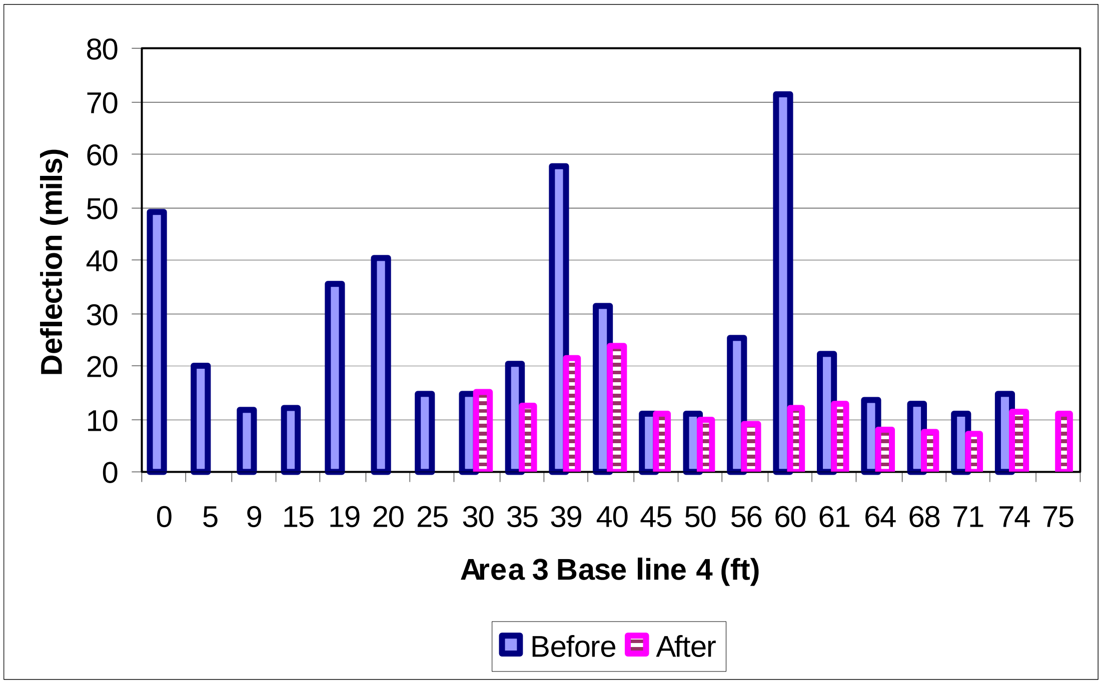

Figure 58
FWD first sensor deflections (16 kips) area 3 base line 4

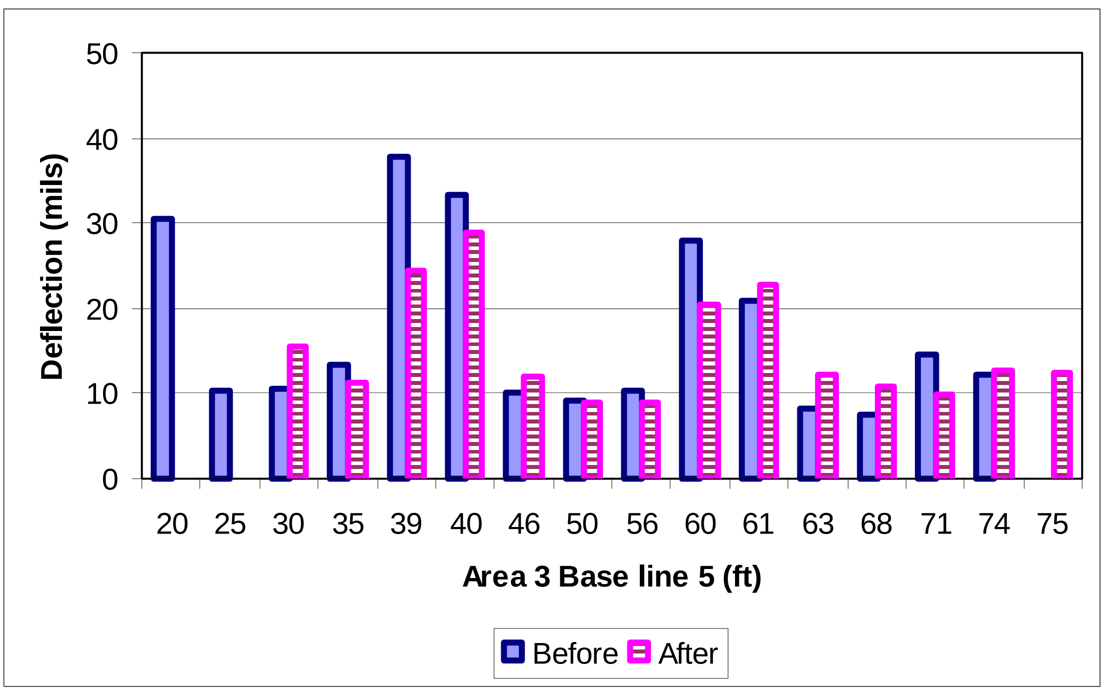

Figure 59
FWD first sensor deflections (16 kips) area 3 base line 5

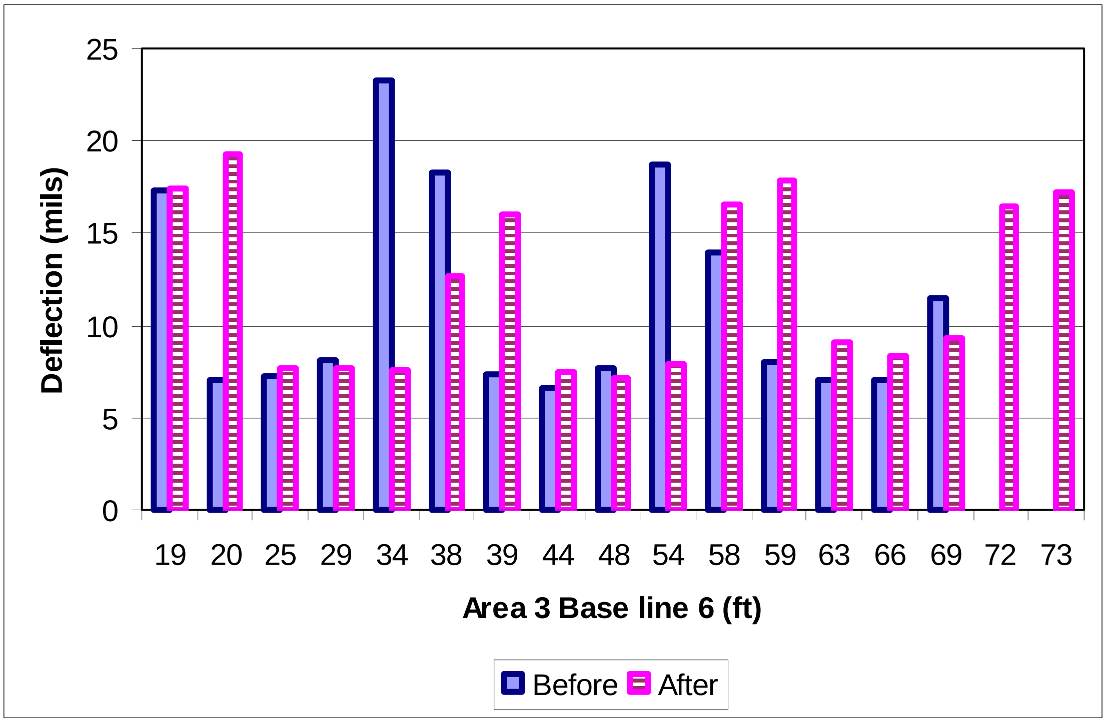

Figure 60
FWD first sensor deflections (16 kips) area 3 base line 6

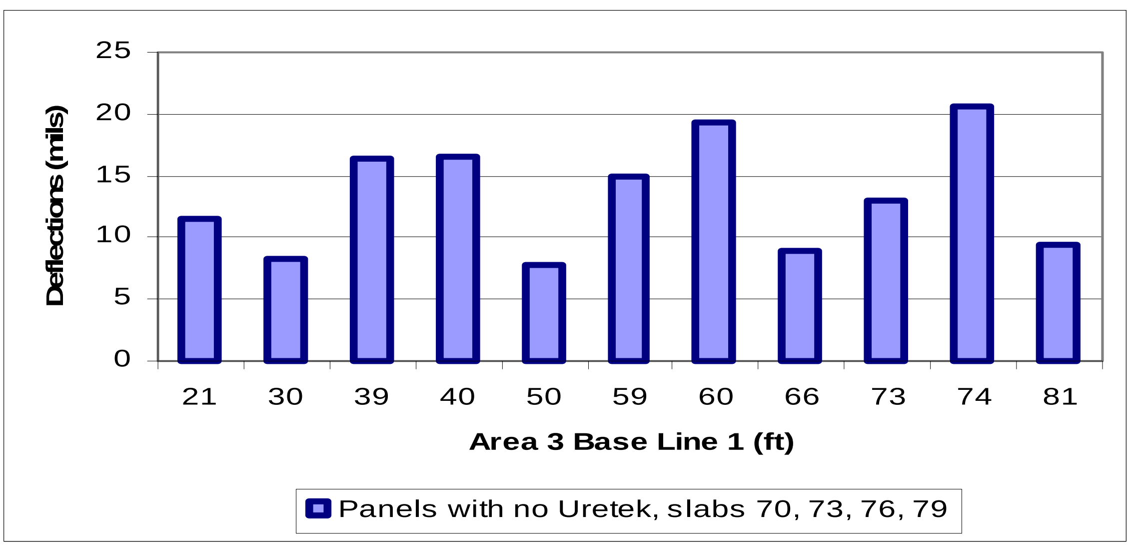

Figure 61
FWD first sensor deflections (16 kips) area 3 base line 1

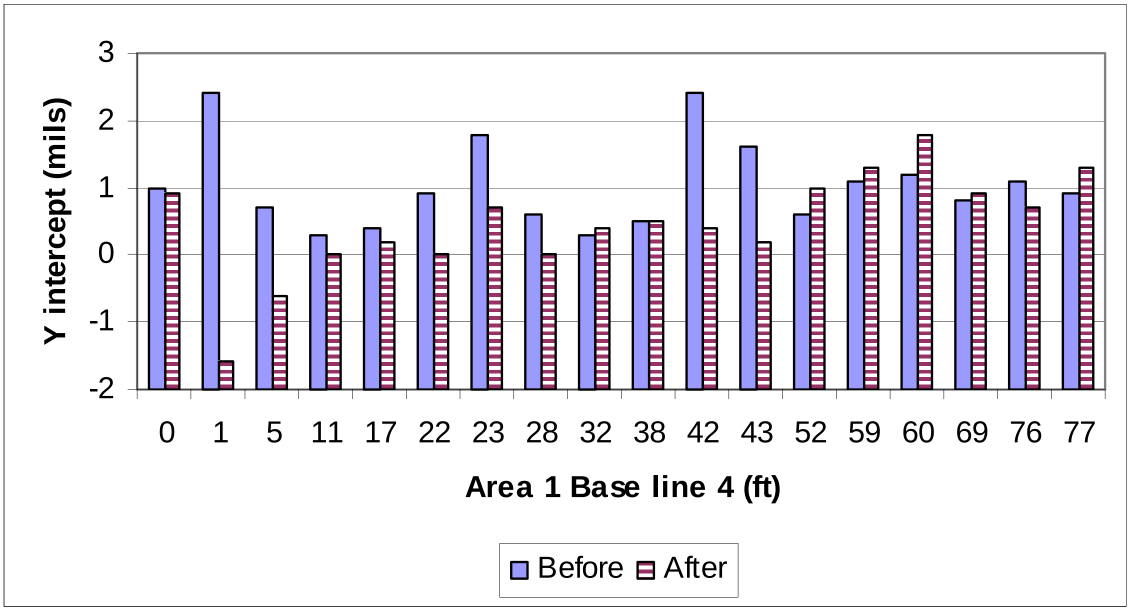

Figure 62
FWD potential void detection for area 1 base line 4

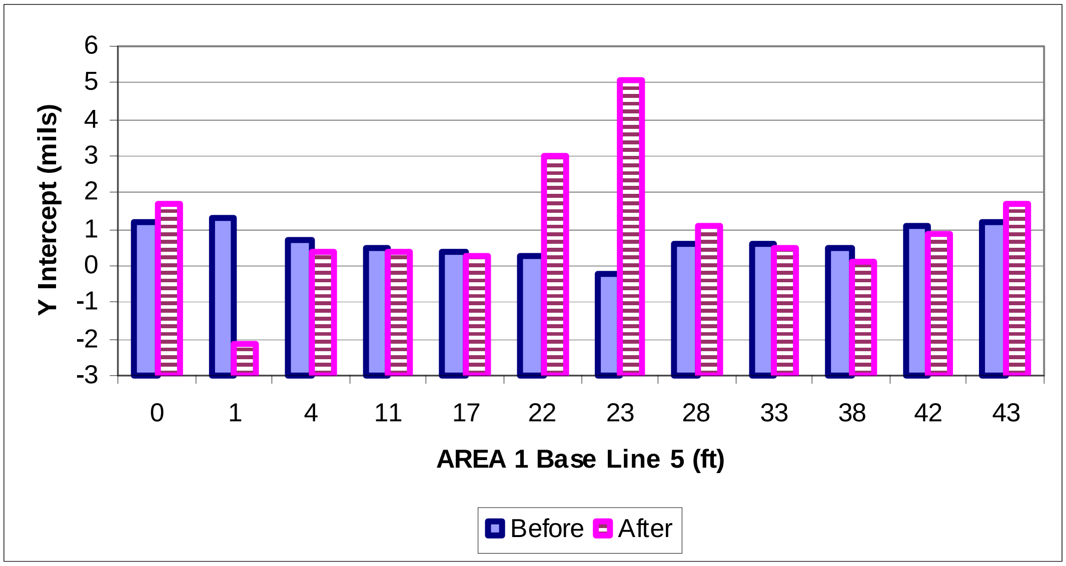

Figure 63
FWD potential void detection for area 1 base line 5

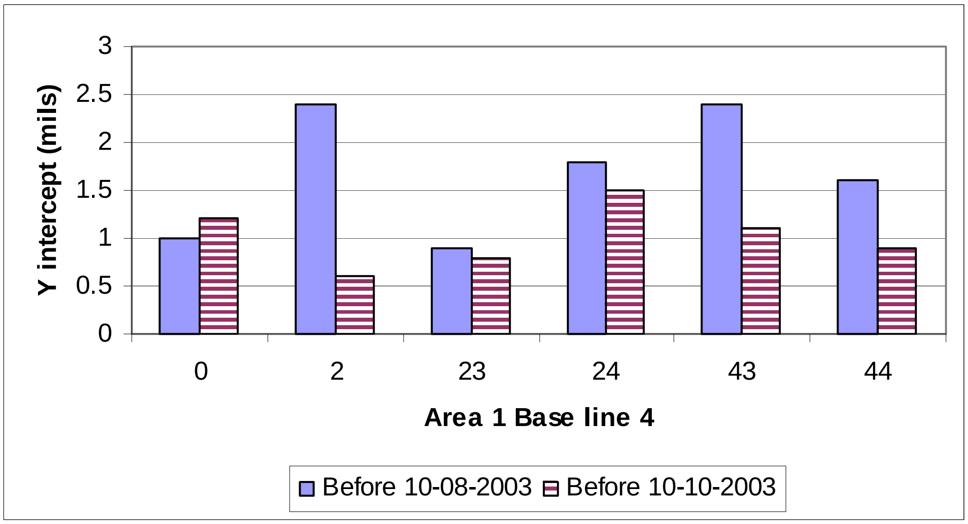

Figure 64
FWD potential void detection for area 1 base line 4
(Comparison of values before and after rain on 10-09-2003)

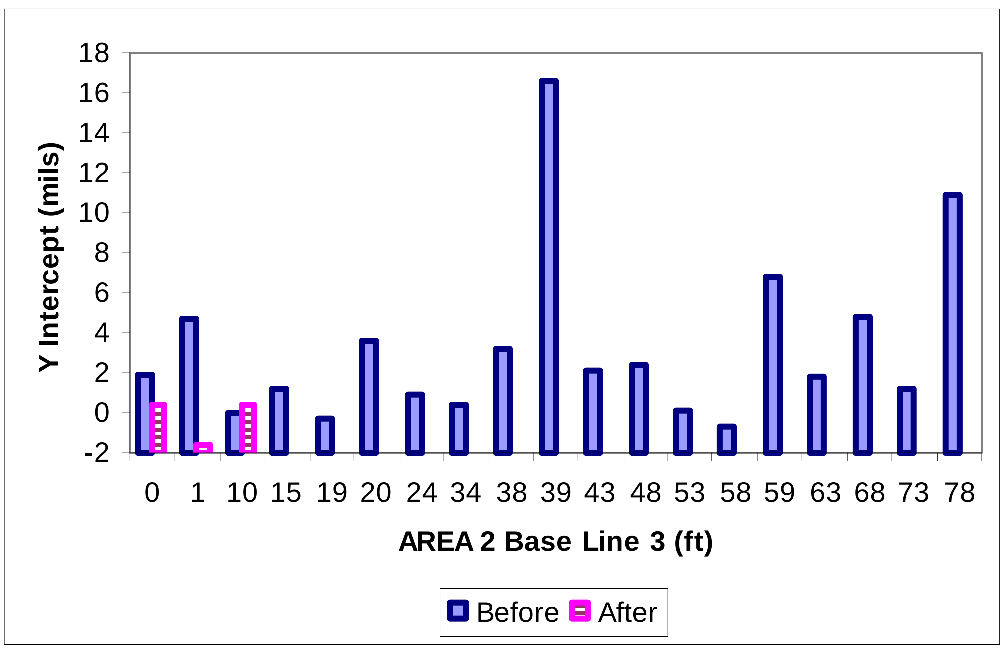

Figure 65
FWD potential void detection for area 2 base line 3

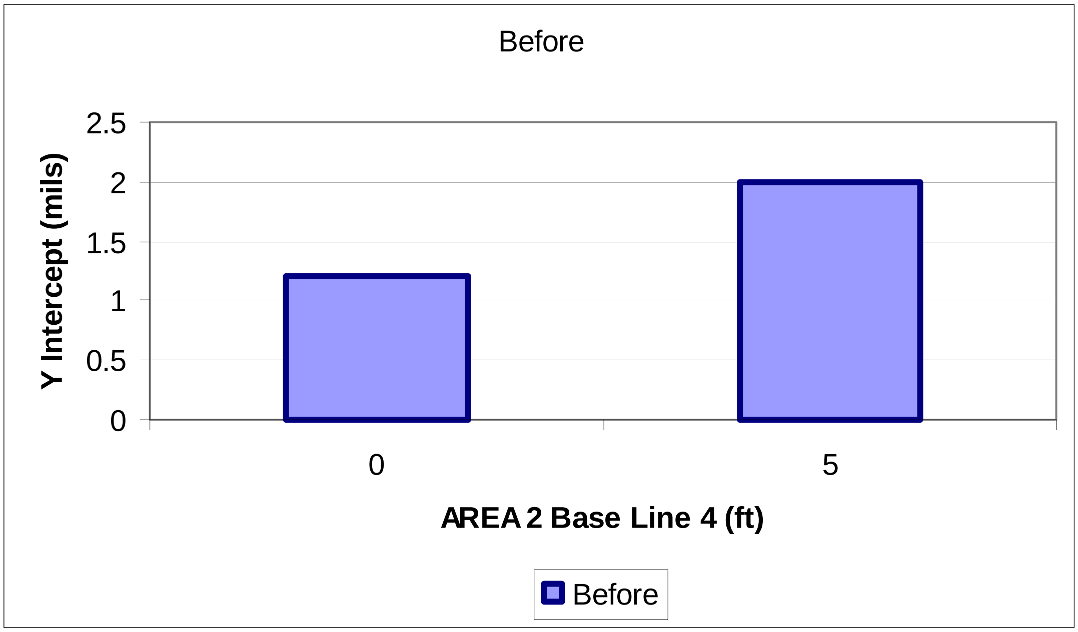

Figure 66
FWD potential void detection for area 2 base line 4

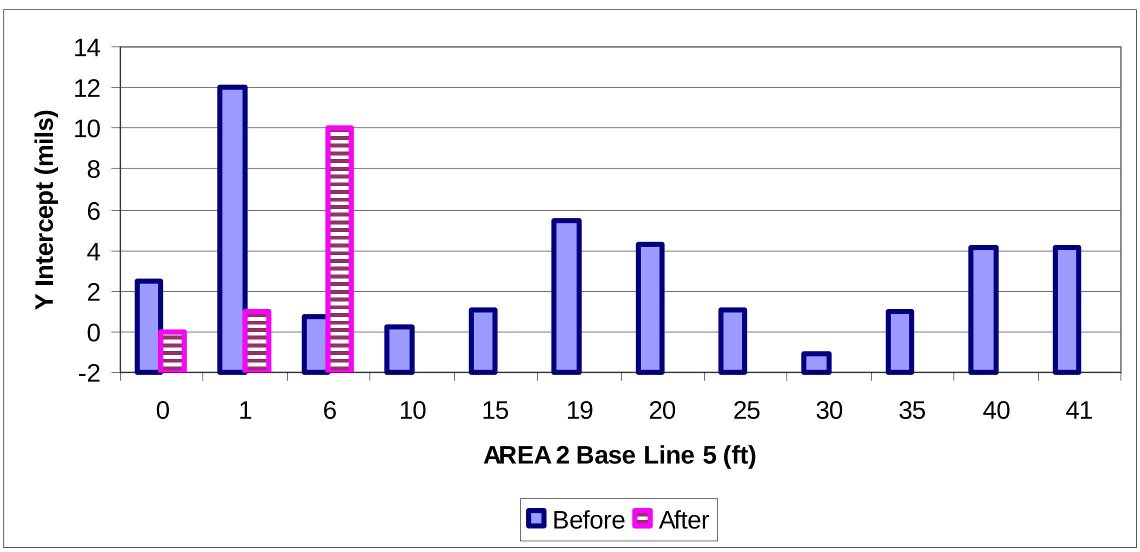

Figure 67
FWD potential void detection for area 2 base line 5

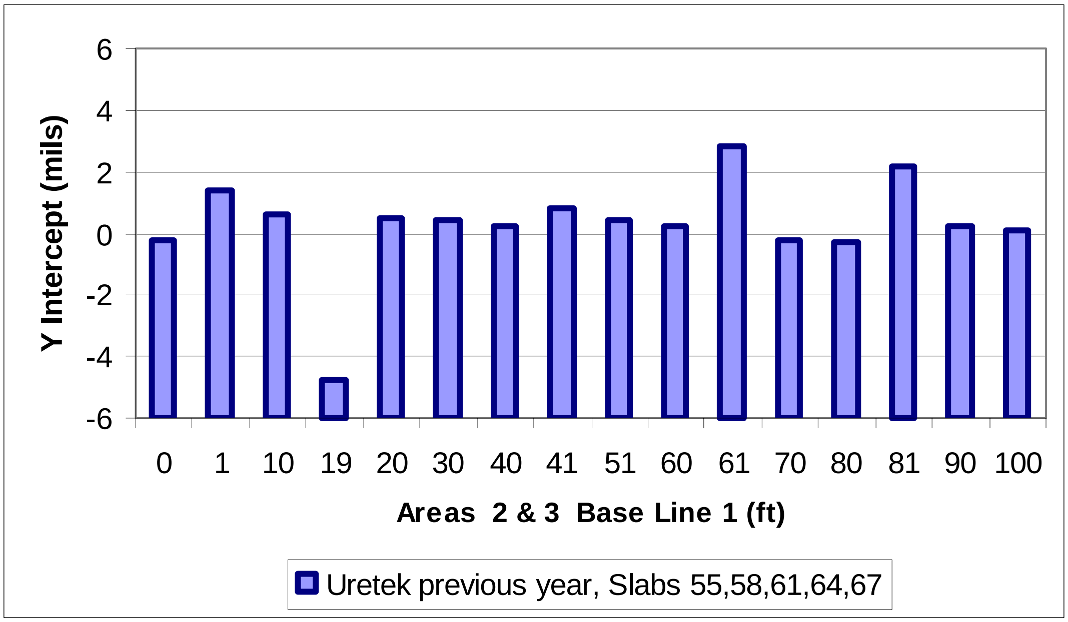

Figure 68
FWD potential void detection for areas 2 and 3 base line 1

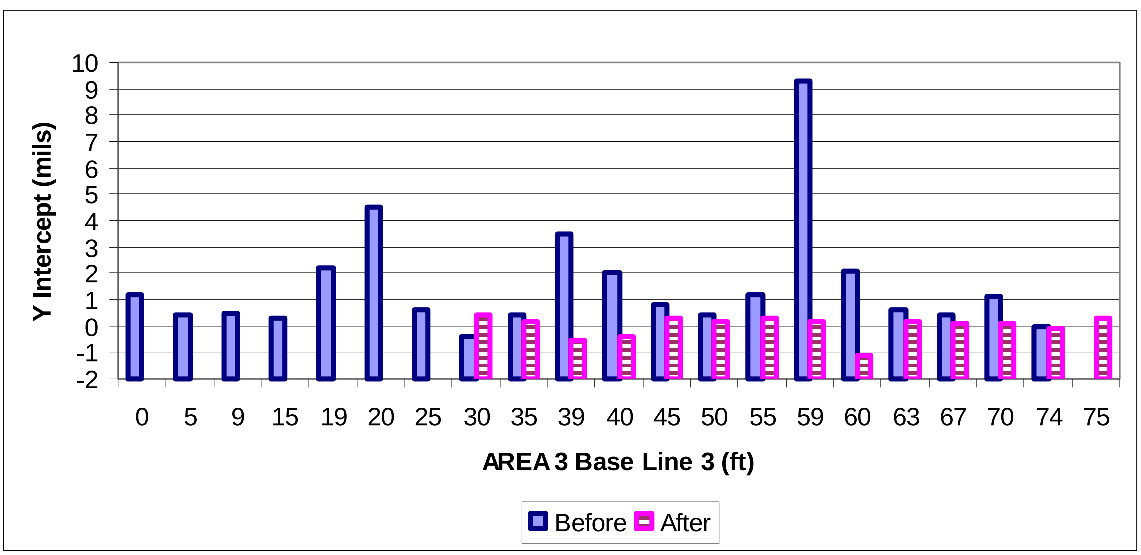

Figure 69
FWD potential void detection for area 3 base line 3

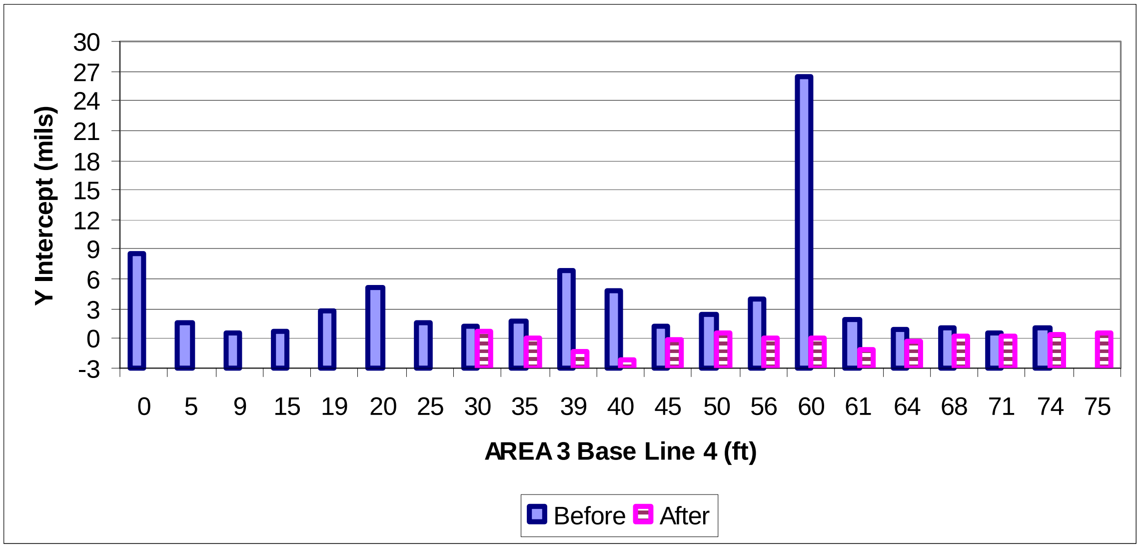

Figure 70
FWD potential void detection for area 3 base line 4

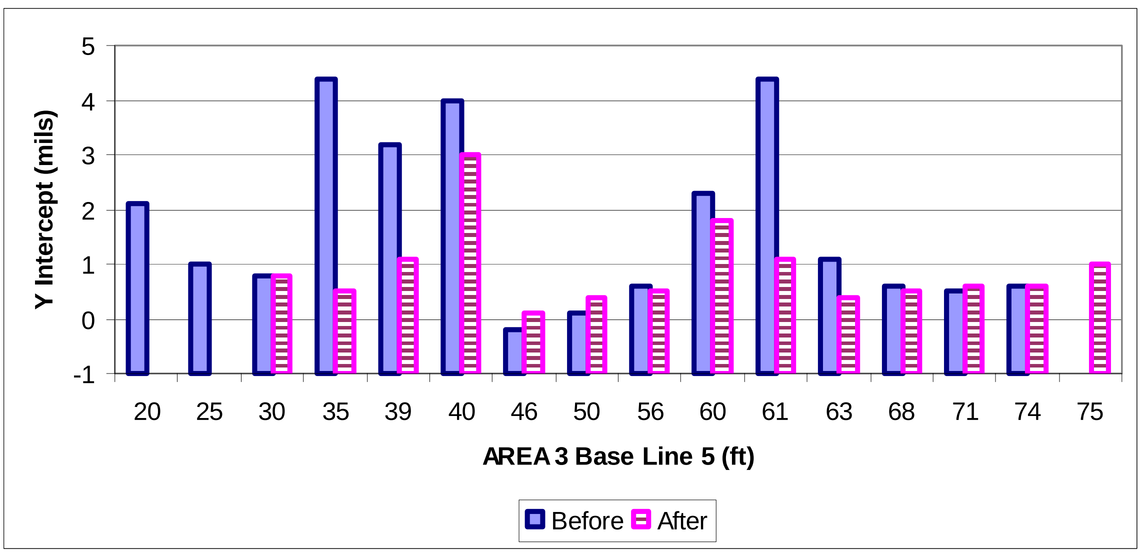

Figure 71
FWD potential void detection for area 3 base line 5

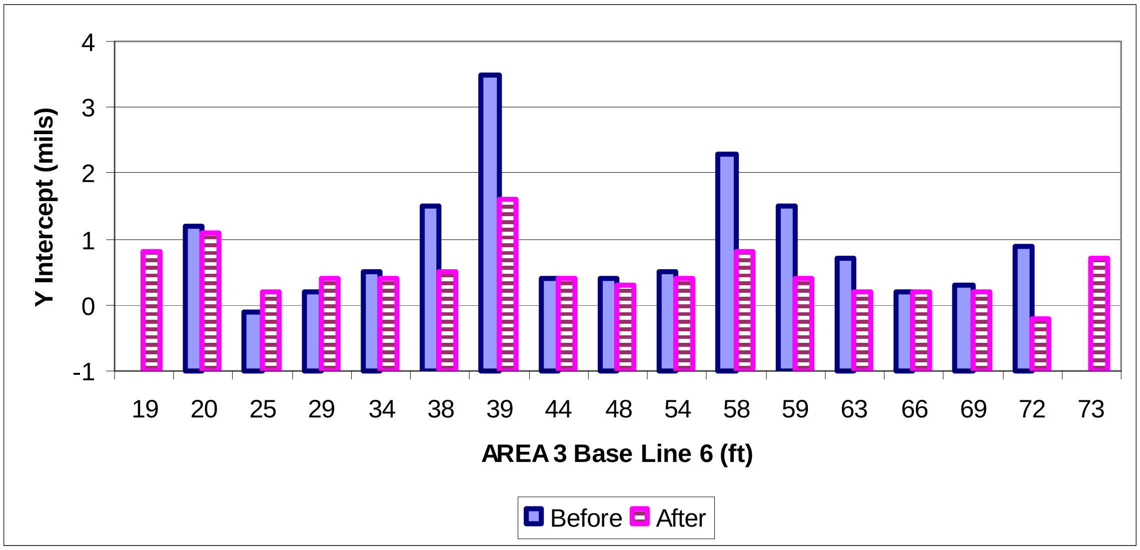

Figure 72
FWD potential void detection for area 3 base line 6

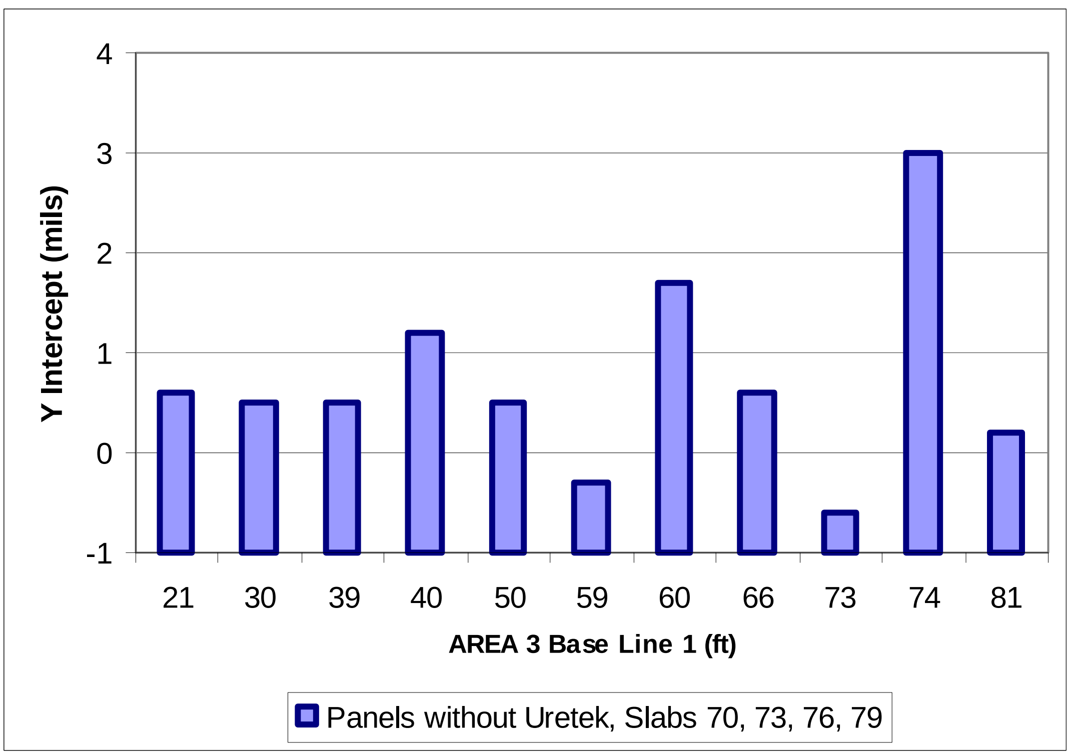

Figure 73
FWD potential void detection for area 3 base line 1

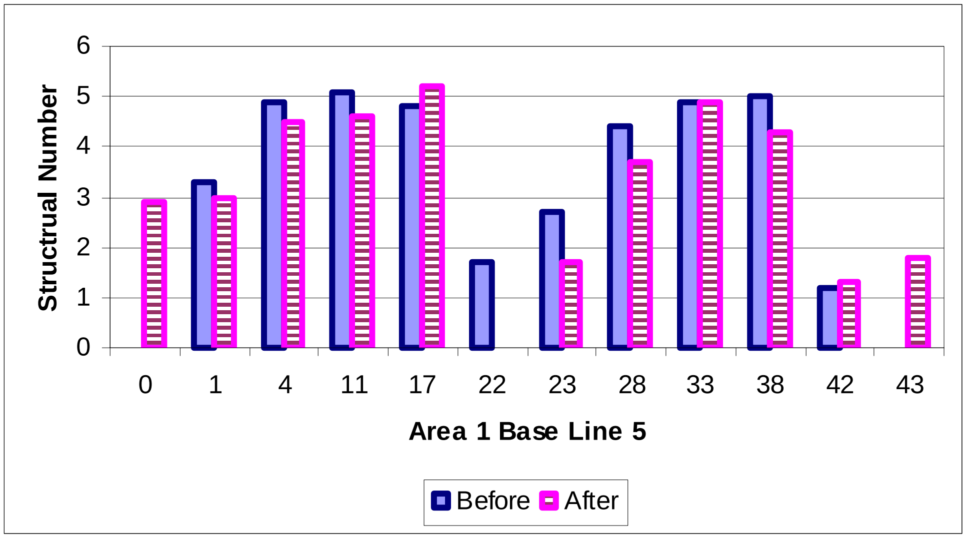

Figure 74
Dynaflect area 1 base line 5

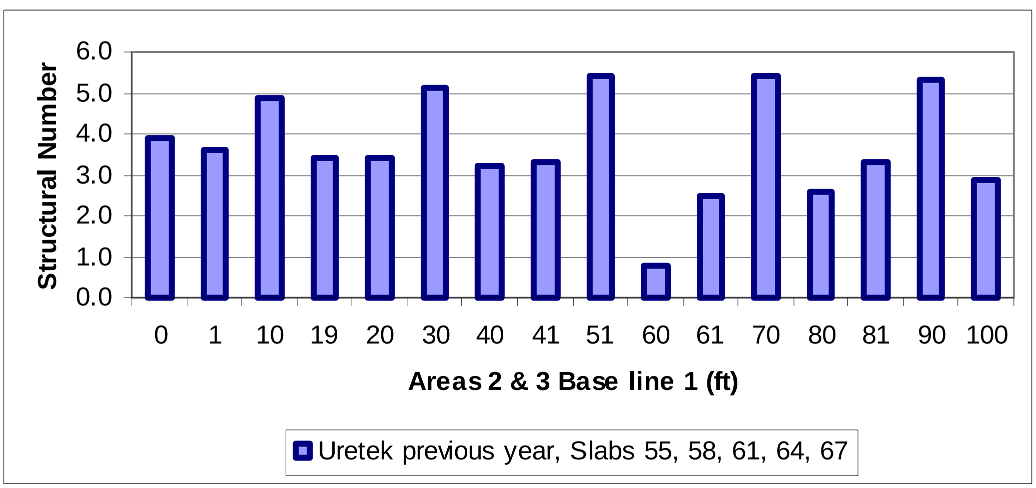

Figure 75
Dynaflect area 2 & 3 base line 1

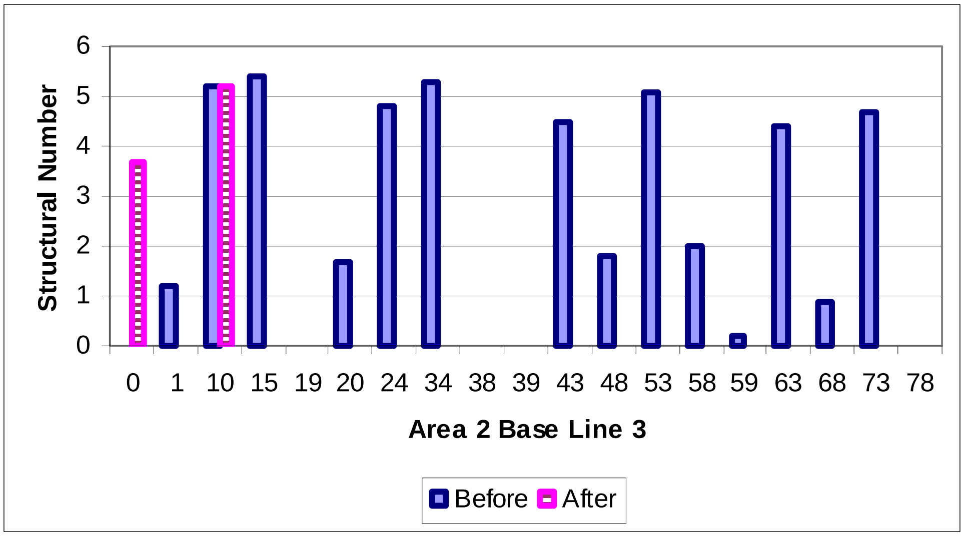

Figure 76
Dynaflect area 2 base line 3

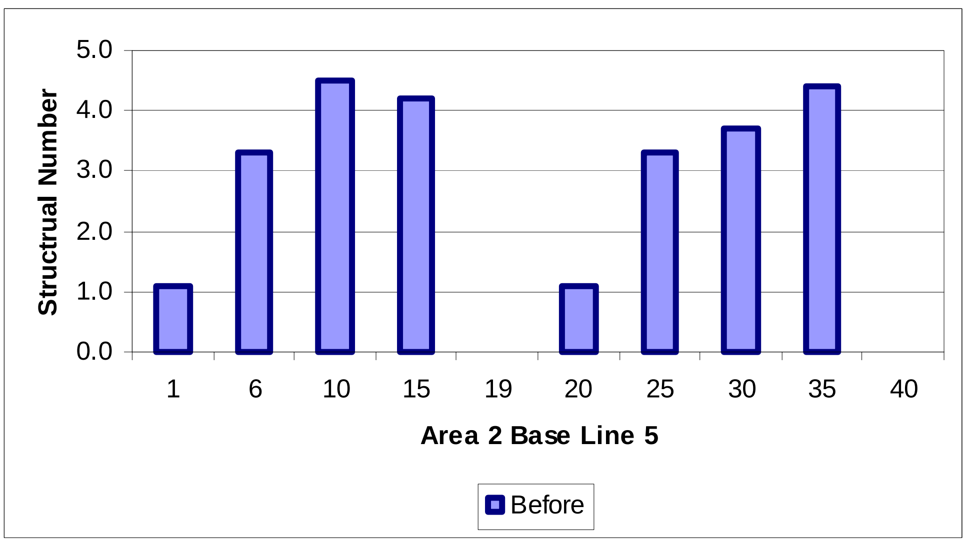

Figure 77
Dynaflect area 2 base line 5

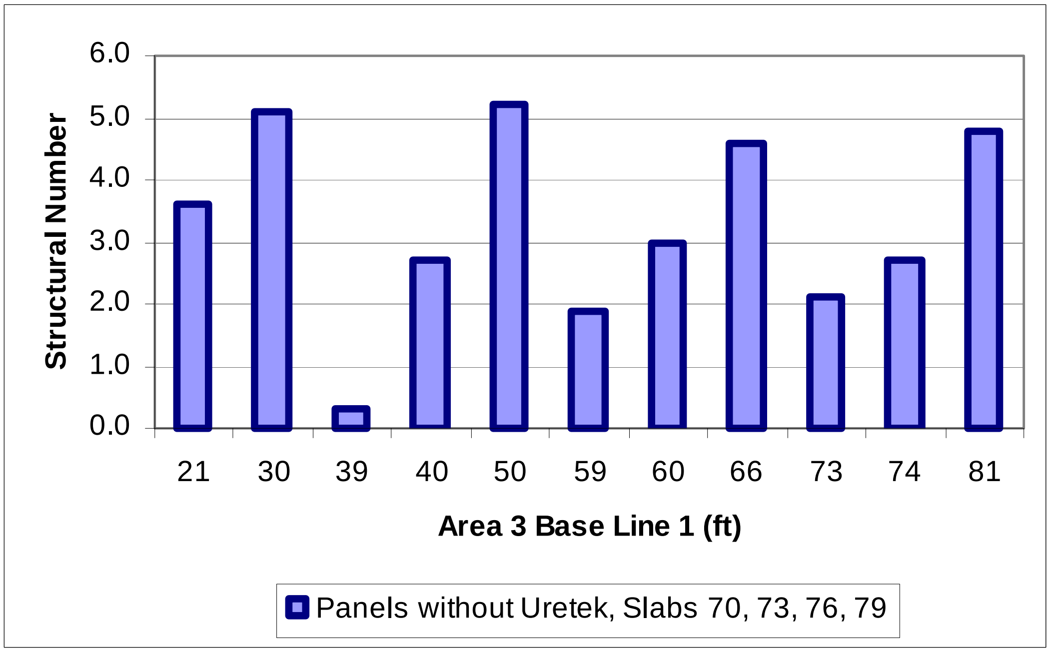

Figure 78
Dynaflect area 3 base line 1

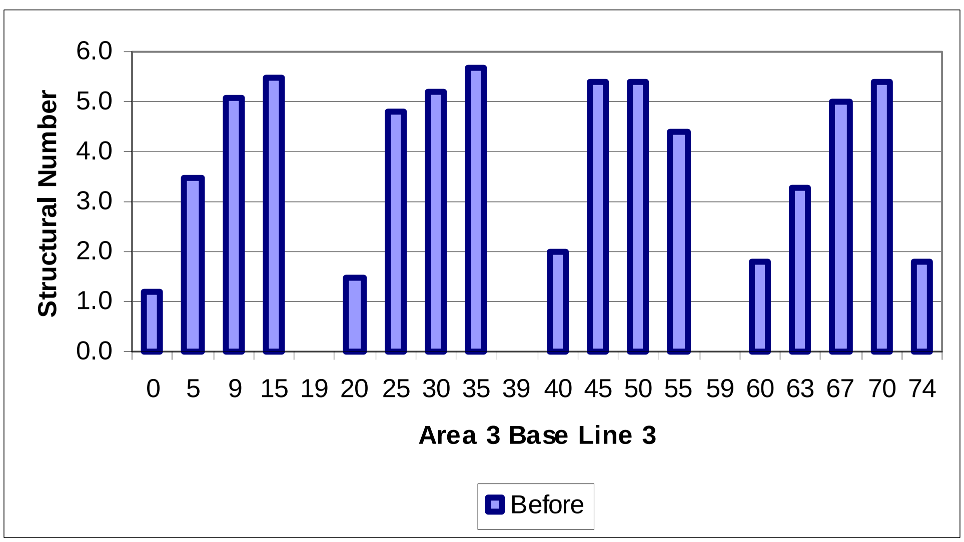

Figure 79
Dynaflect area 3 base line 3

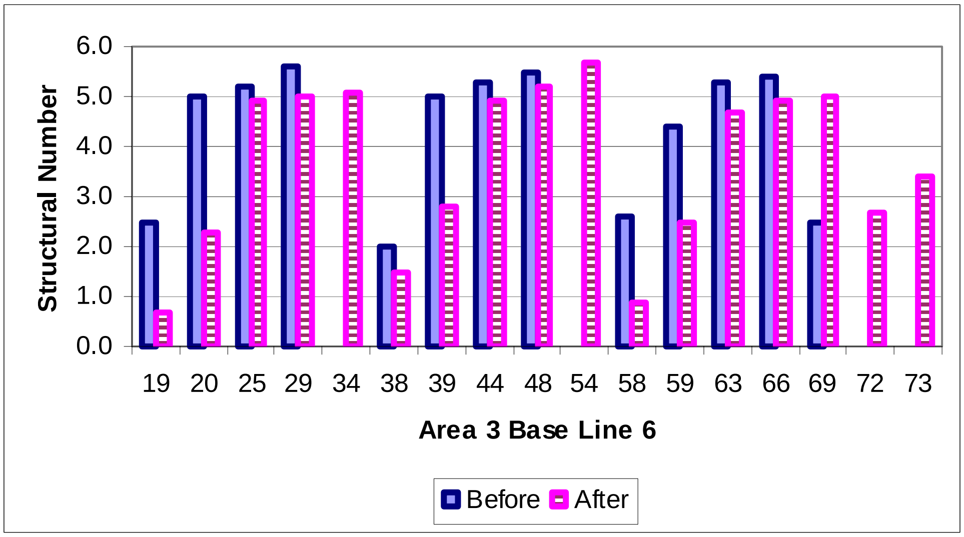

Figure 80
Dynaflect area 3 base line 6

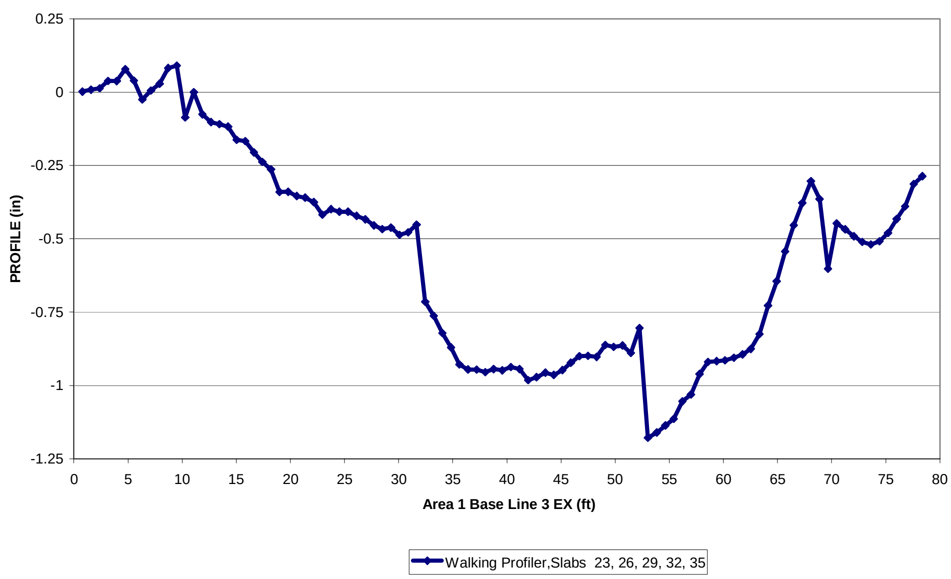

Figure 81
Walking Profiler area 1 base line 3 EX

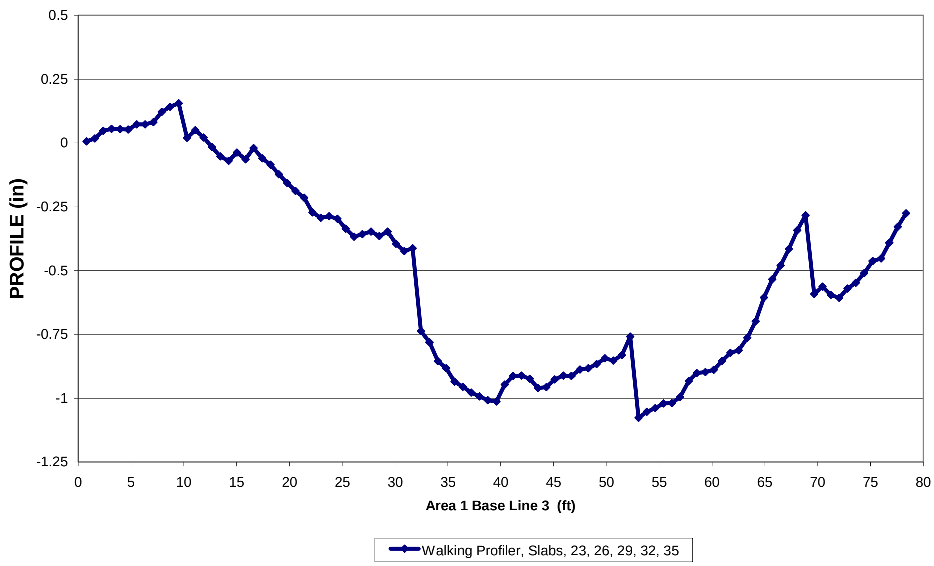

Figure 82
Walking Profiler area 1 base line 3

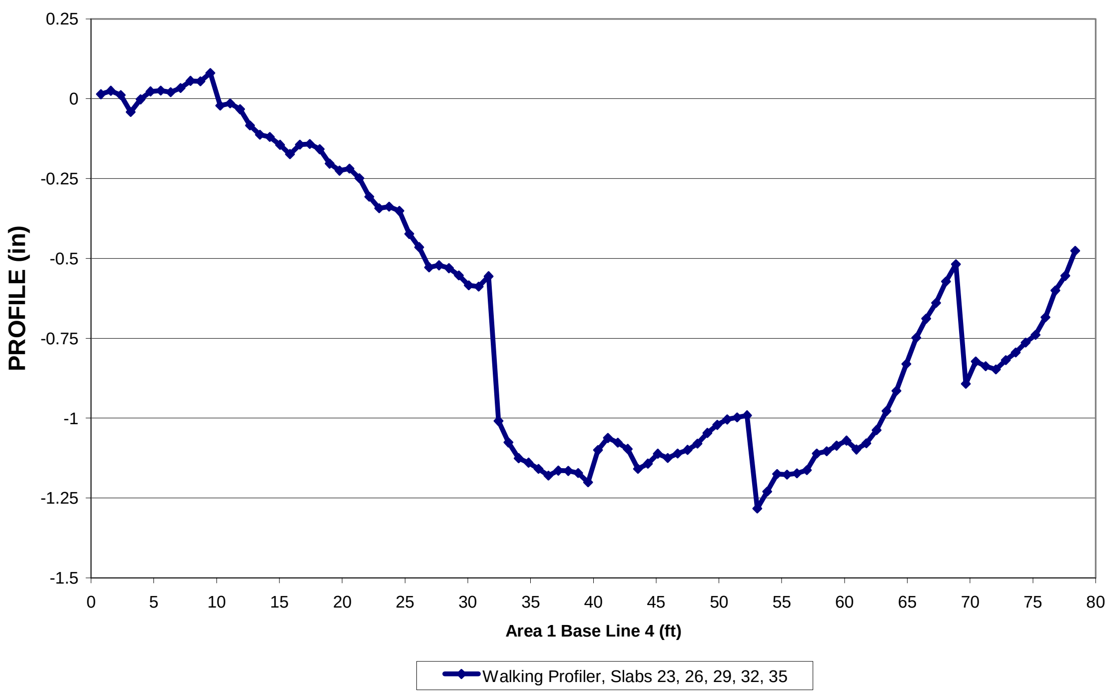

Figure 83
Walking Profiler area 1 base line 4

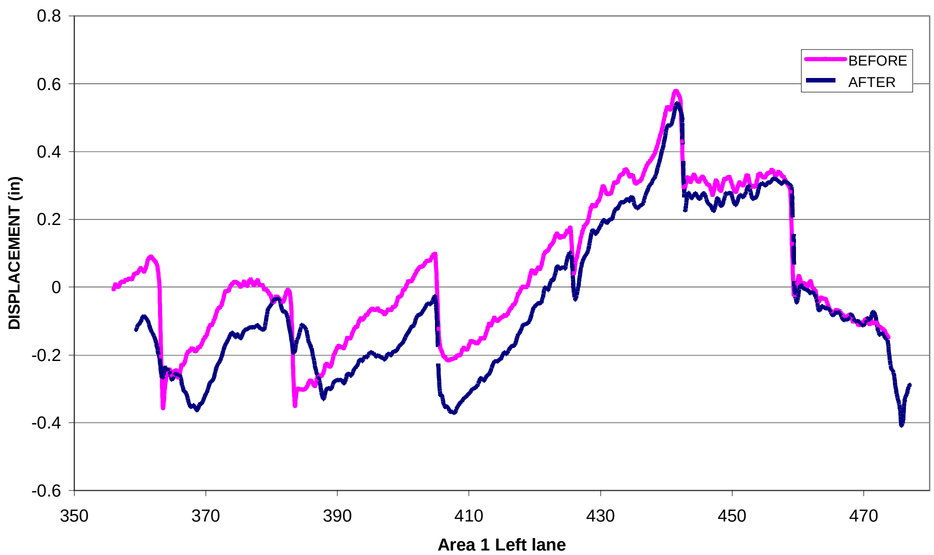

Figure 84
Profile from high speed profiler area 1 left lane

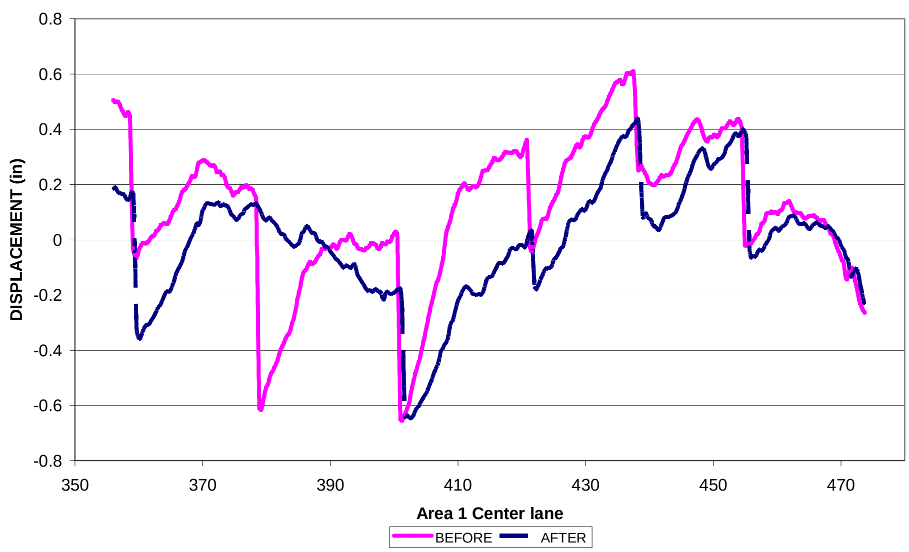

Figure 85
Profile from high speed profiler area 1 center lane

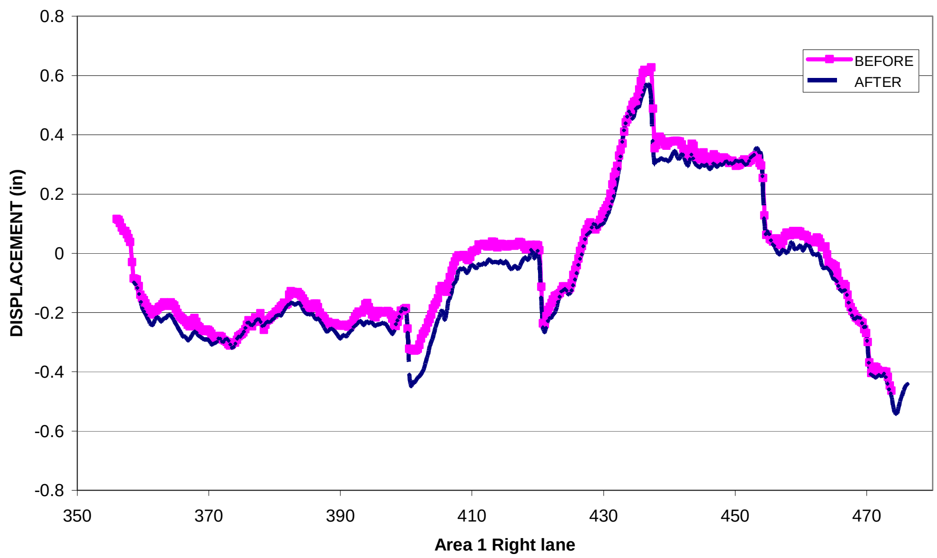

Figure 86
Profile from high speed profiler area 1 right lane

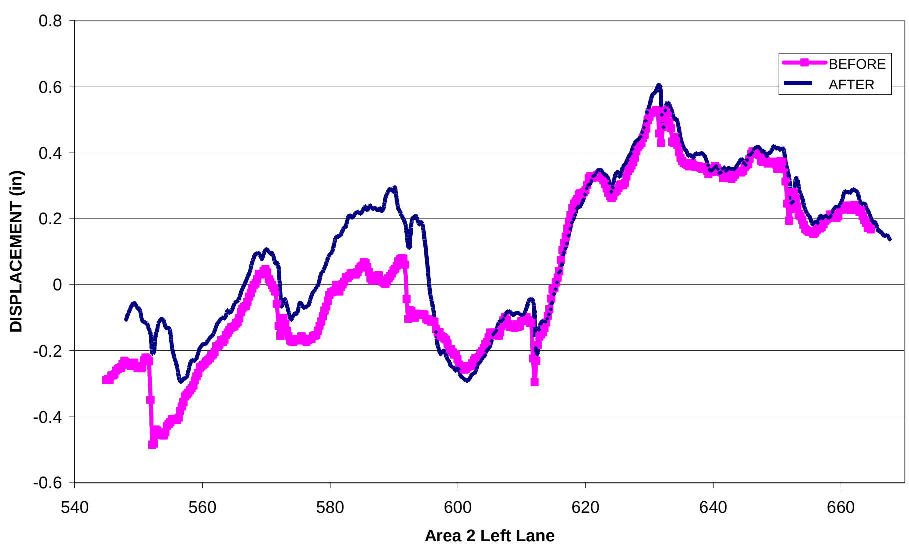

Figure 87
Profile from high speed profiler area 2 left lane

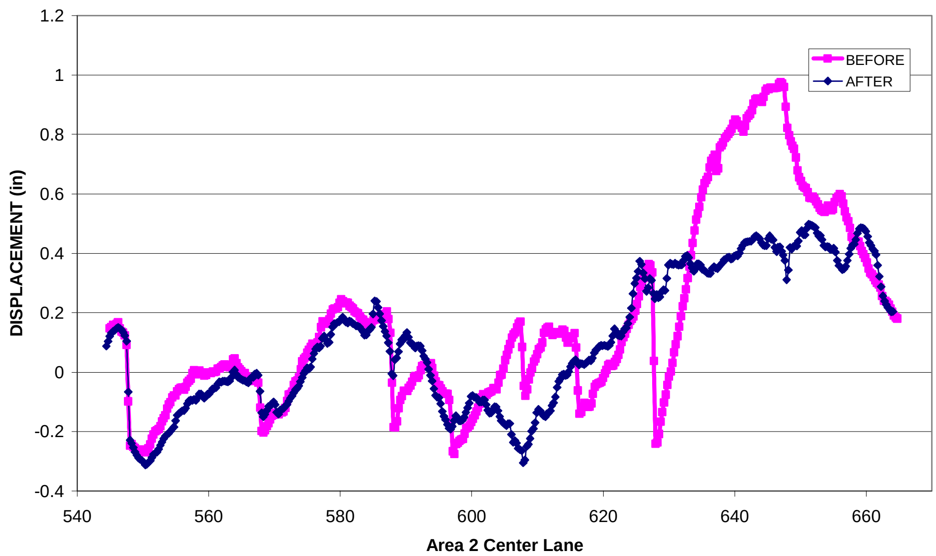

Figure 88
Profile from high speed profiler area 2 center lane

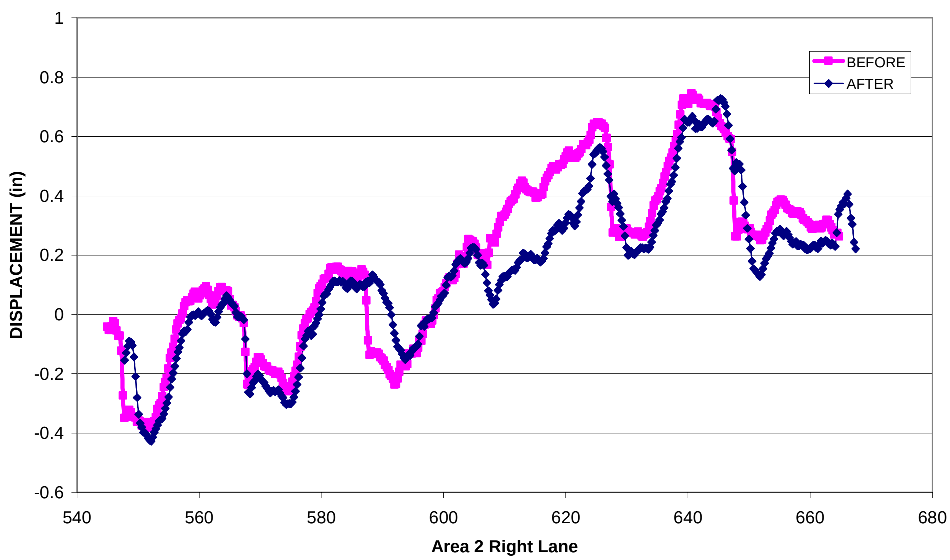

Figure 89
Profile from high speed profiler area 2 right lane

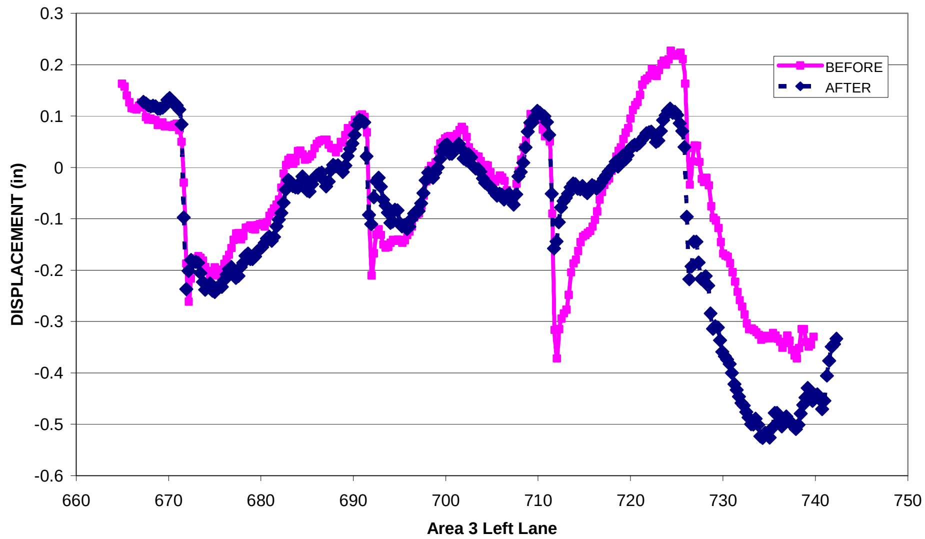

Figure 90
Profile from high speed profiler area 3 left lane

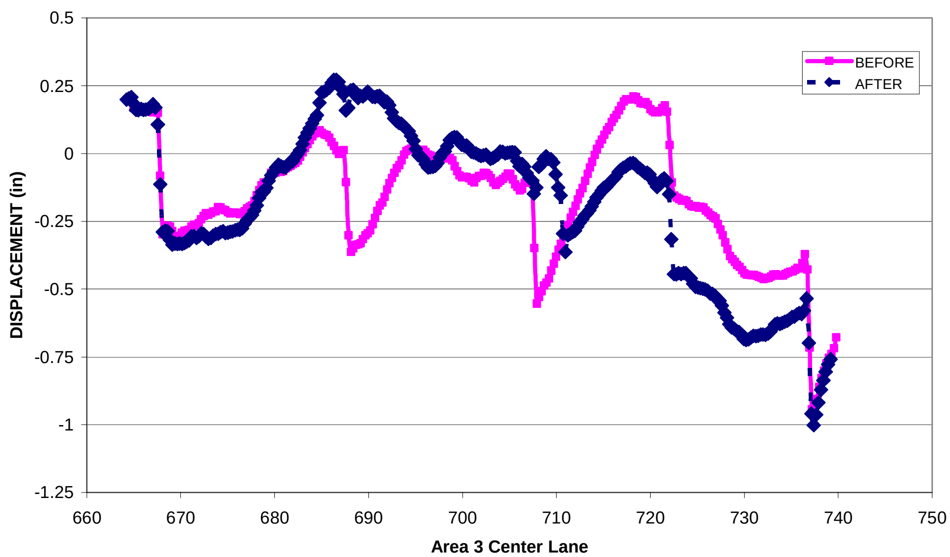

Figure 91
Profile from high speed profiler area 3 center lane

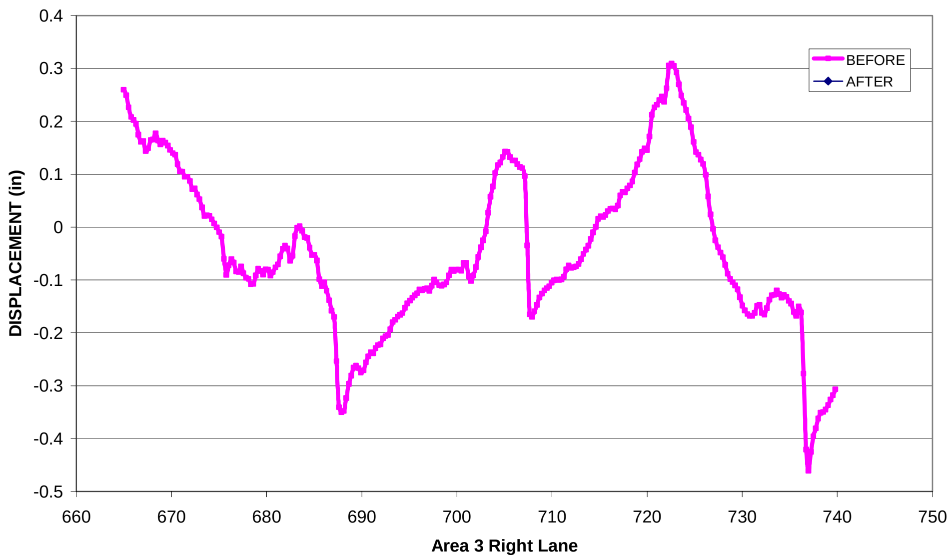

Figure 92
Profile from high speed profiler area 3 right lane

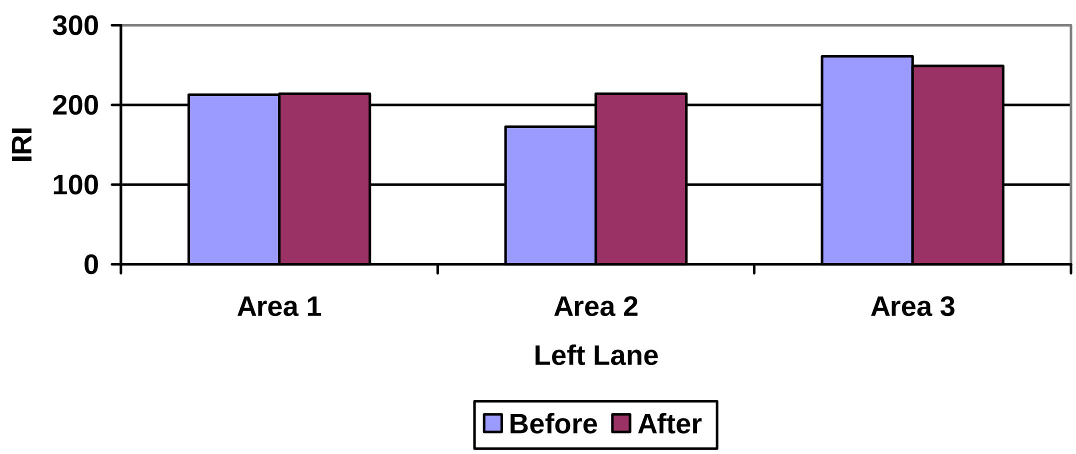

Figure 93
IRI from high speed profiler areas 1, 2, and 3 left lane

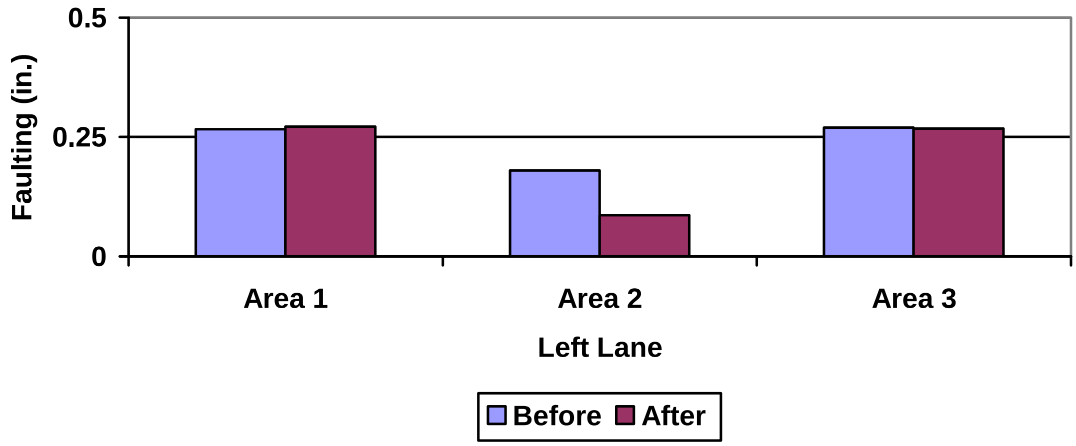

Figure 94
Faulting from high speed profiler areas 1, 2, and 3 left lane

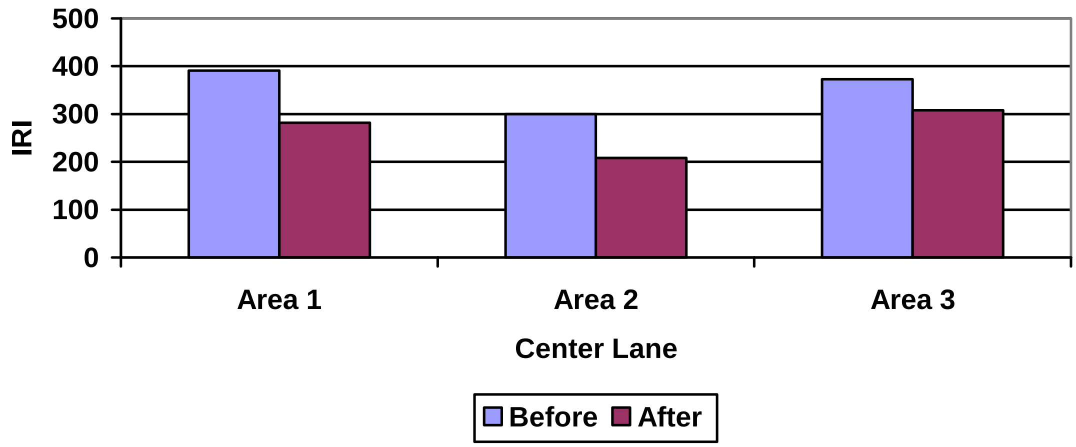

Figure 95
IRI from high speed profiler areas 1, 2, and 3 center lane

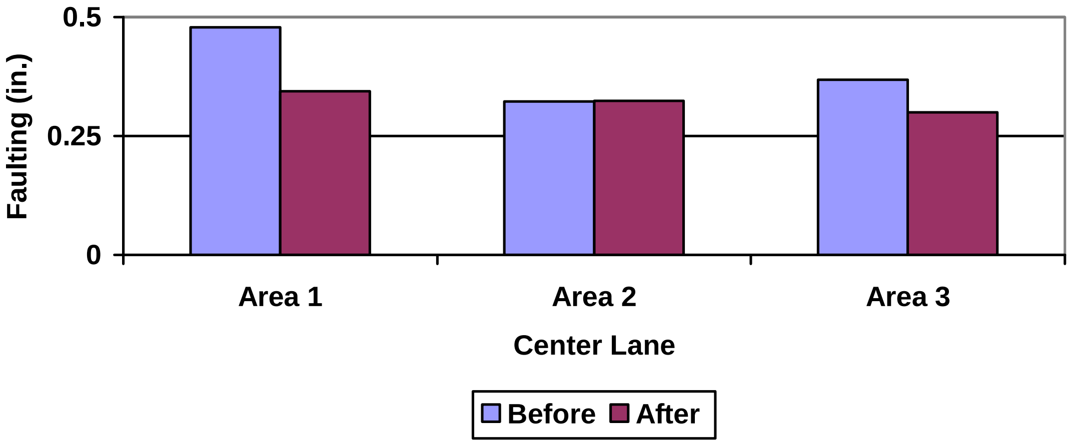

Figure 96
Faulting from high speed profiler areas 1, 2, and 3 center lane

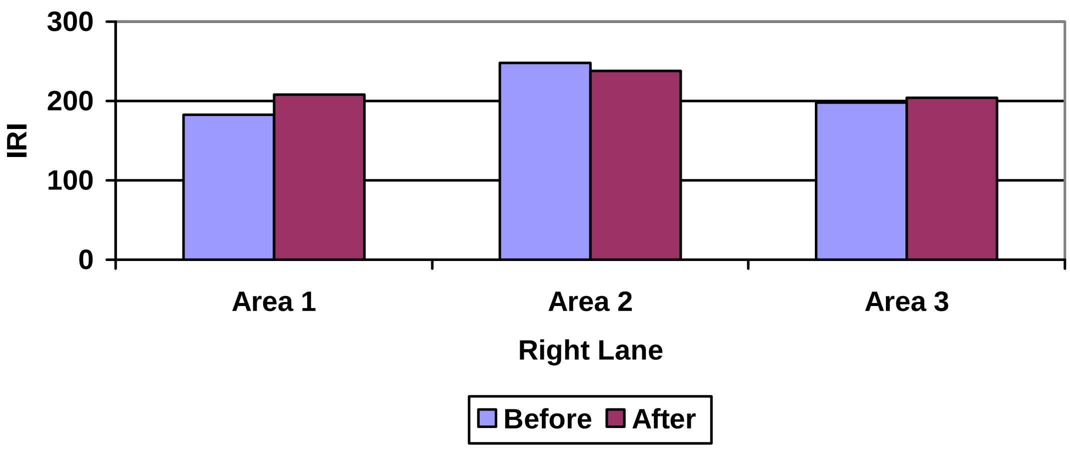

Figure 97
IRI from high speed profiler areas 1, 2, and 3 right lane

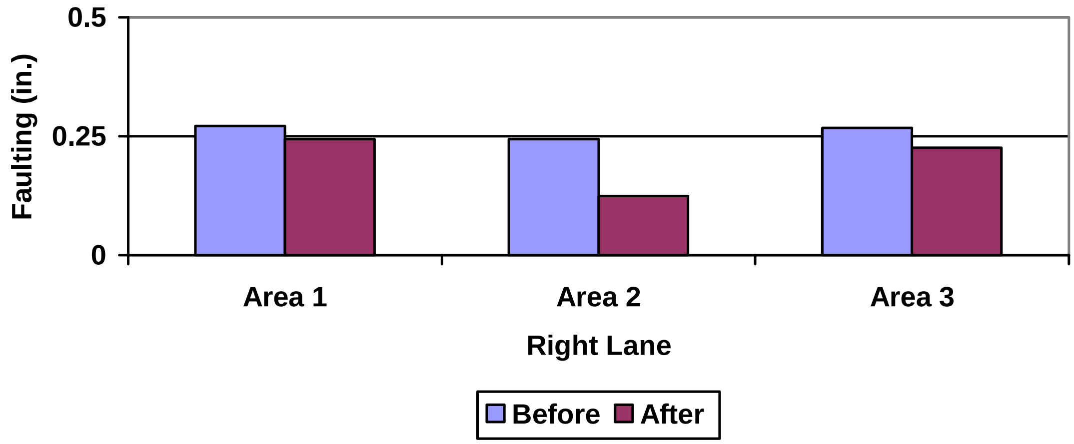

Figure 98
Faulting from high speed profiler areas 1, 2, and 3 right lane

APPENDIX 2
Y intercept diagram

The Y intercept refers to the linear regression of a line through three points. The point at which the line crosses the Y axis is the intercept value. For this study, the Y intercept is based upon deflection versus load. The loads used on this project were 9000, 12,000, and 14,500 pounds. The load and its corresponding deflection at the load plate were plotted and a linear regression was performed. The figures below illustrate this process. According the AASHTO design guide, a Y intercept value greater than 0.002 inches means that there is either a void or loss of support.

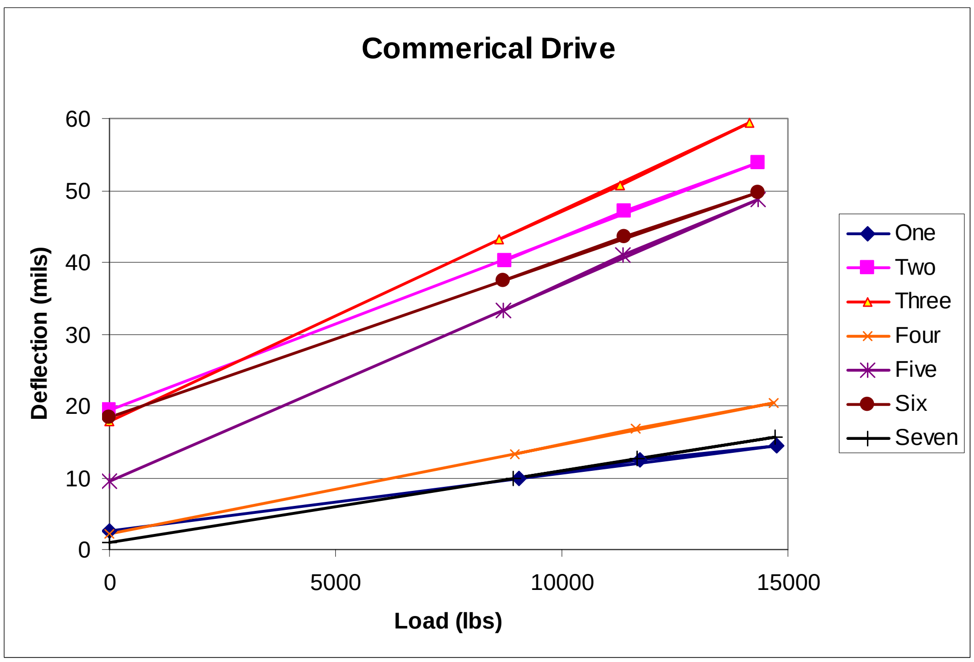

Figure 99
Y intercept diagram

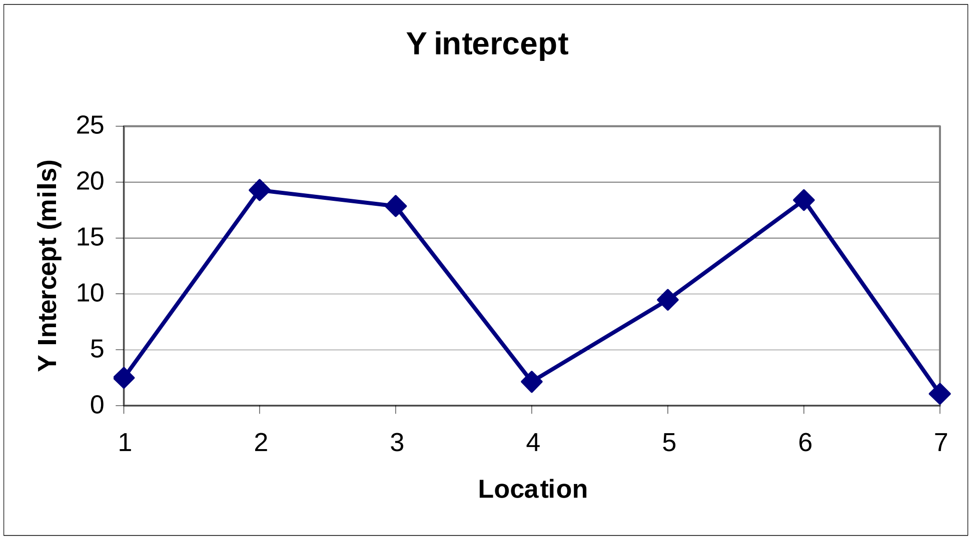

Figure 100
Y intercept location diagram

APPENDIX 3
CRCP

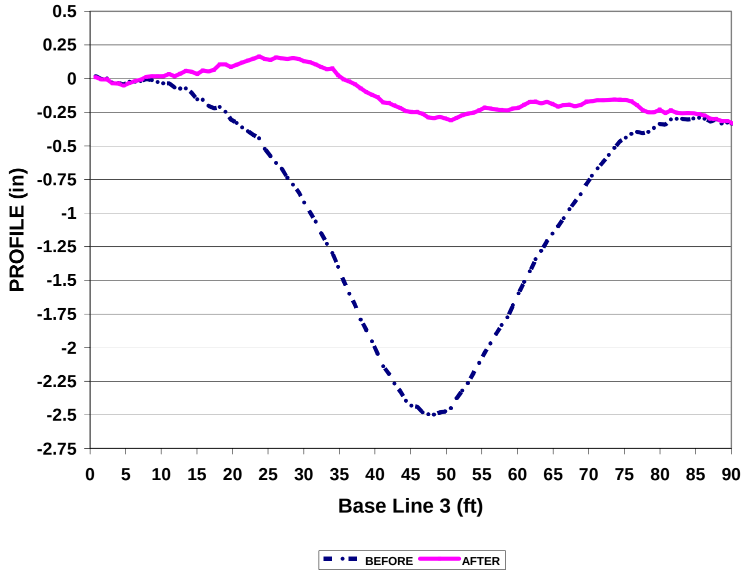

Figure 101
Walking profiler base line 3

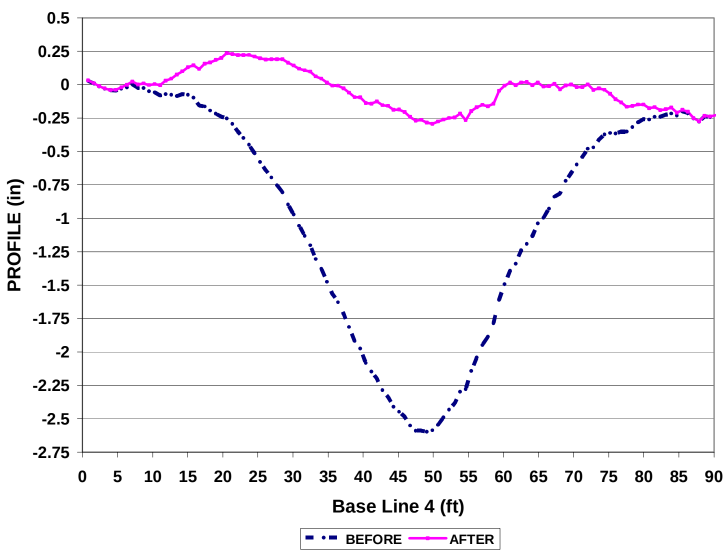

Figure 102
Walking profiler base line 4

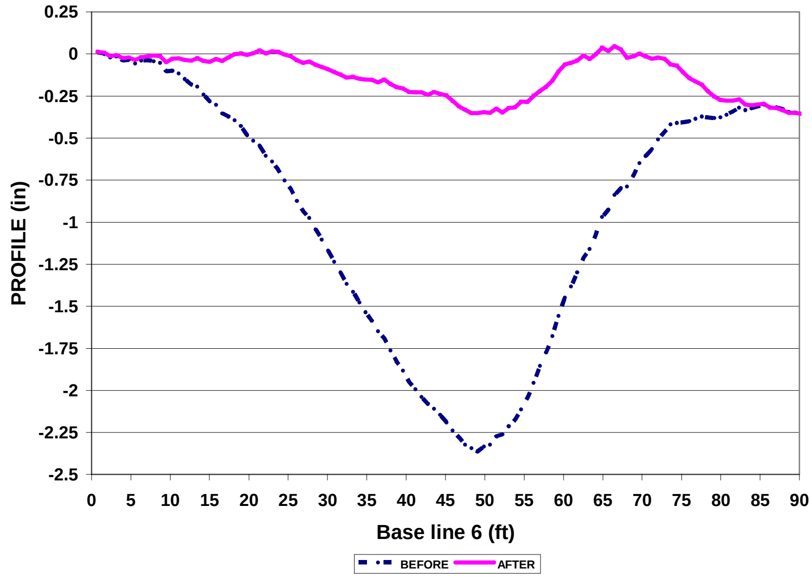

Figure 103
Walking profiler base line 6

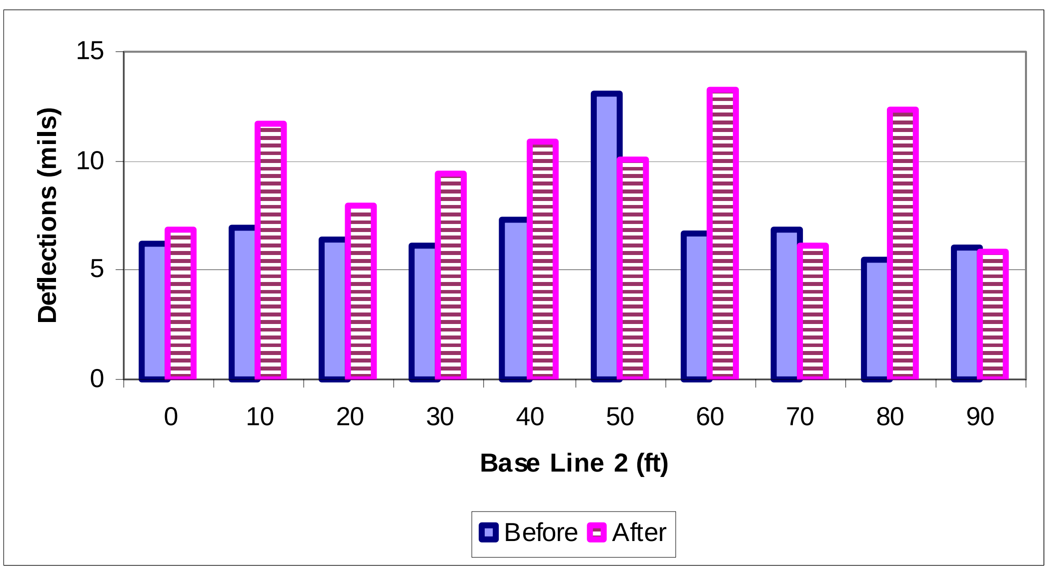

Figure 104
FWD first sensor deflections for base line 2

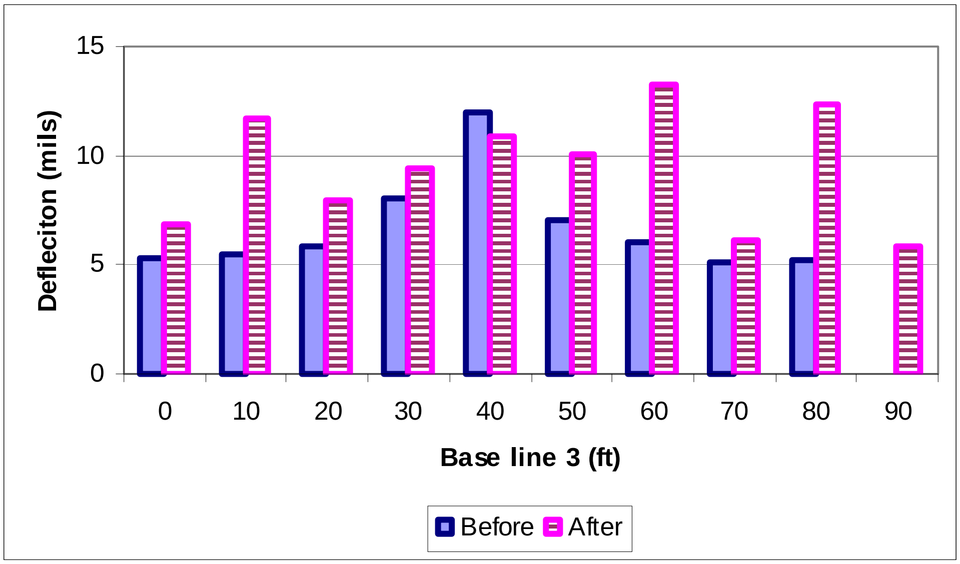

Figure 105
FWD first sensor deflections for base line 3

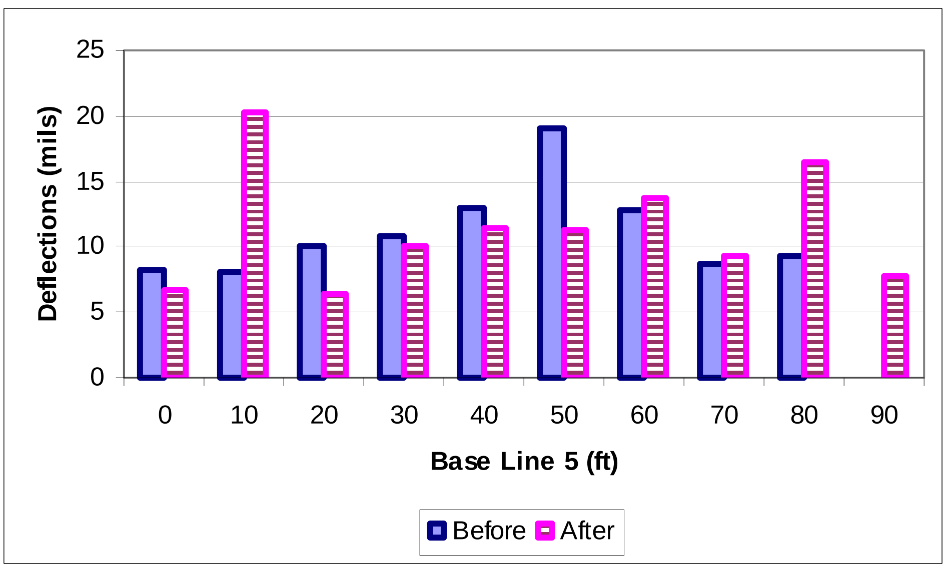

Figure 106
FWD first sensor deflections for base line 5

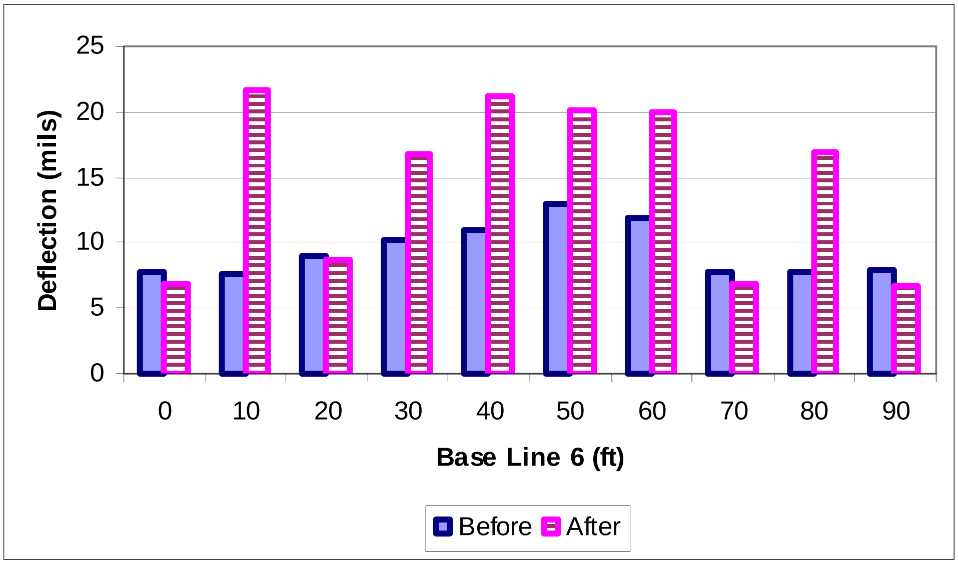

Figure 107
FWD first sensor deflections for base line 6

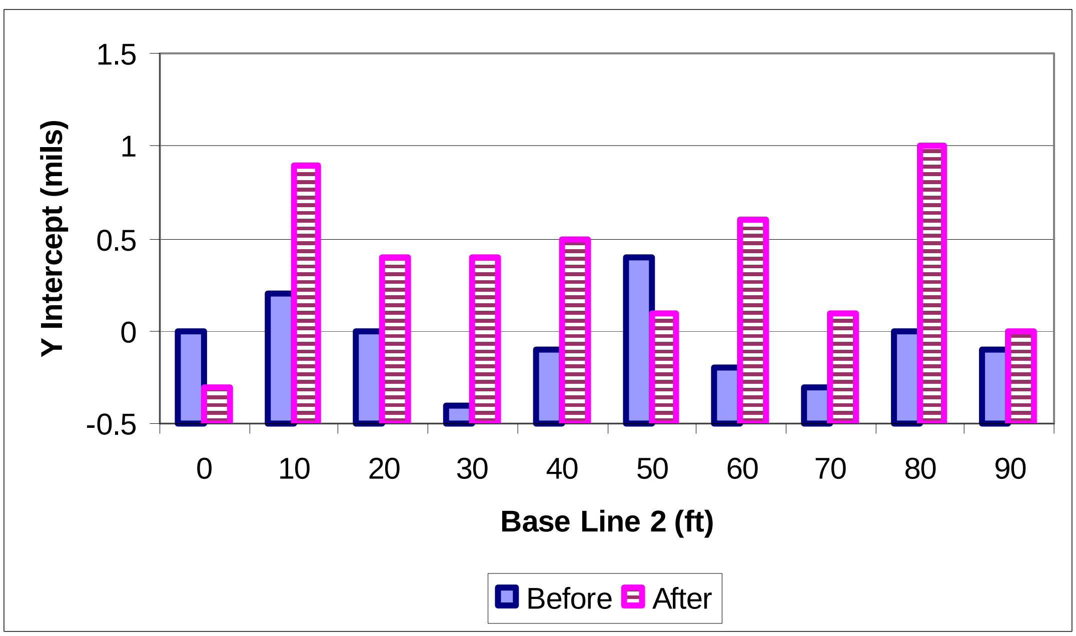

Figure 108
FWD potential void detection for base line 2

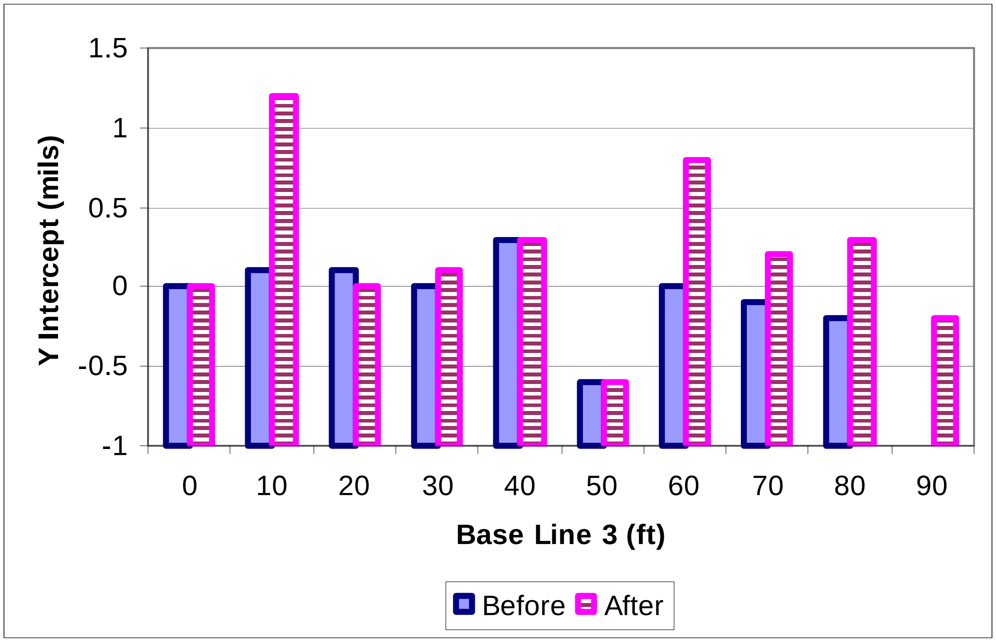

Figure 109
FWD potential void detection for base line 3

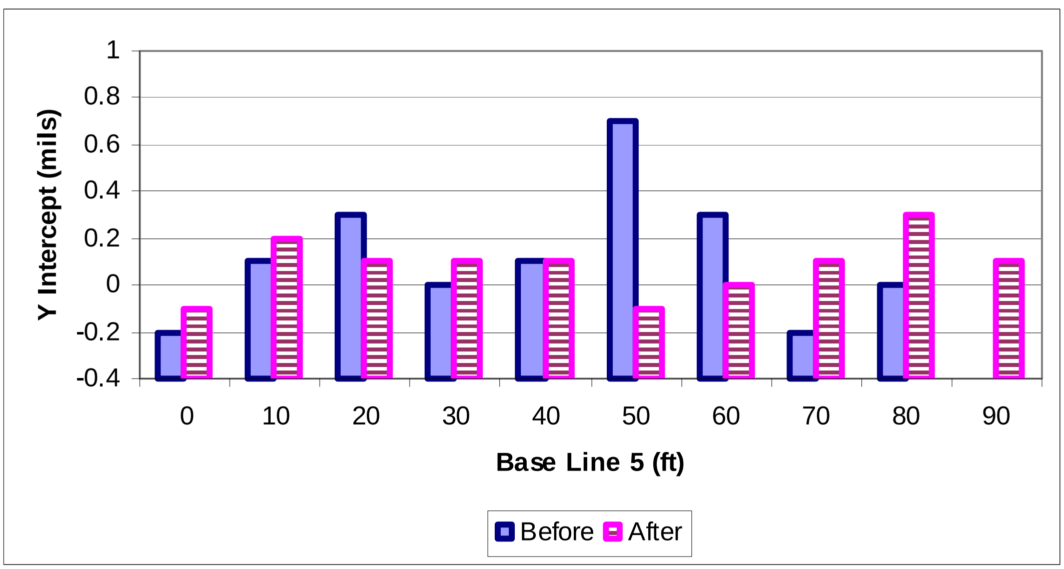

Figure 110
FWD potential void detection for base line 5

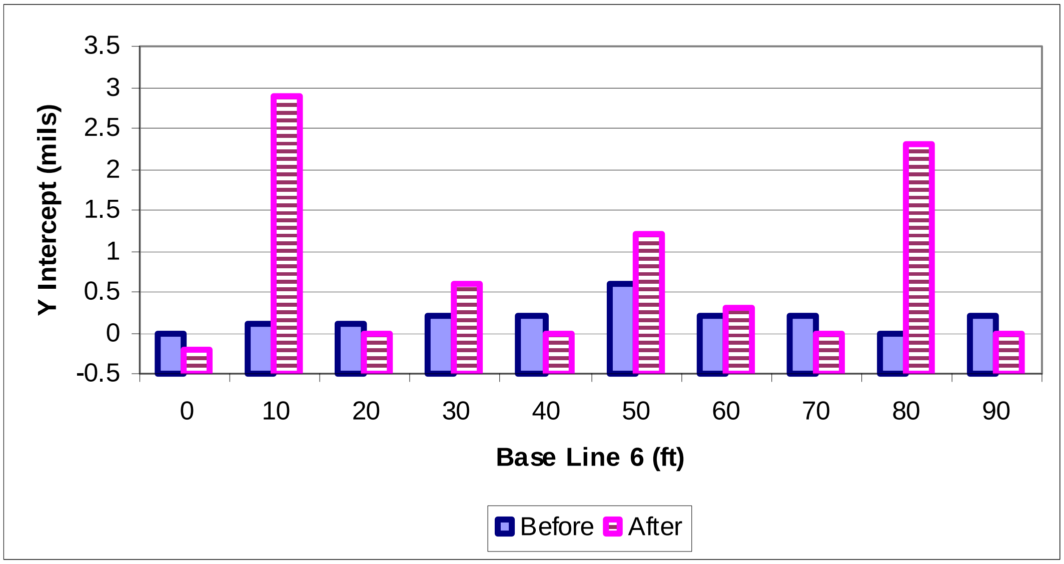

Figure 111
FWD potential void detection for base line 6

APPENDIX 4

Bridge Approach Slabs

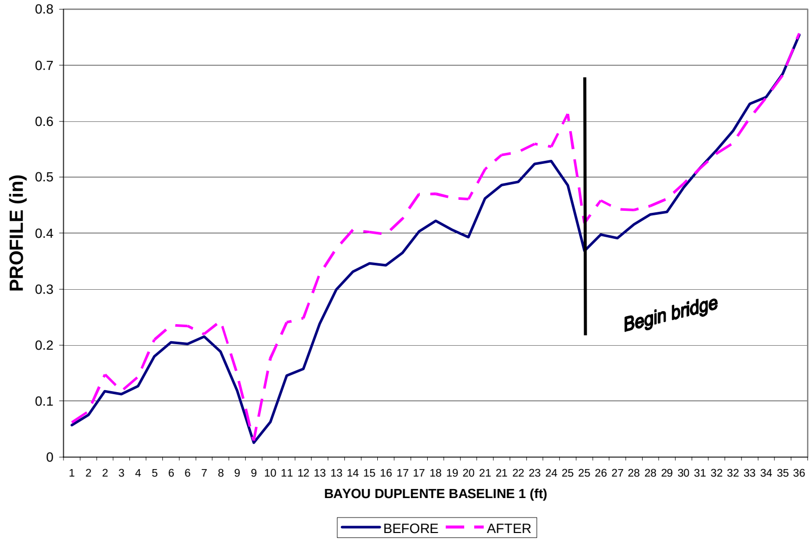

Figure 112
Walking profiler Bayou Duplente SB baseline 1

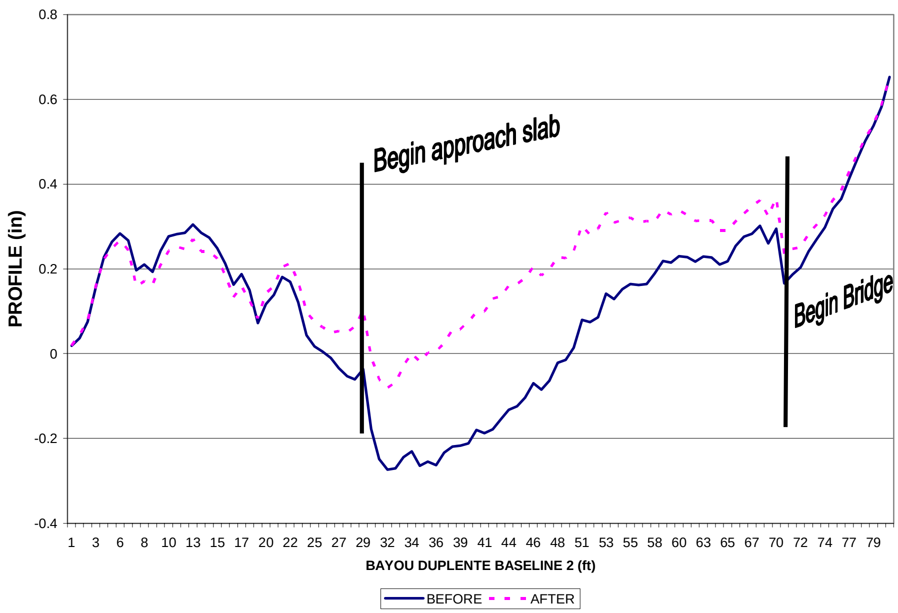

Figure 113
Walking profiler Bayou Duplente baseline 2

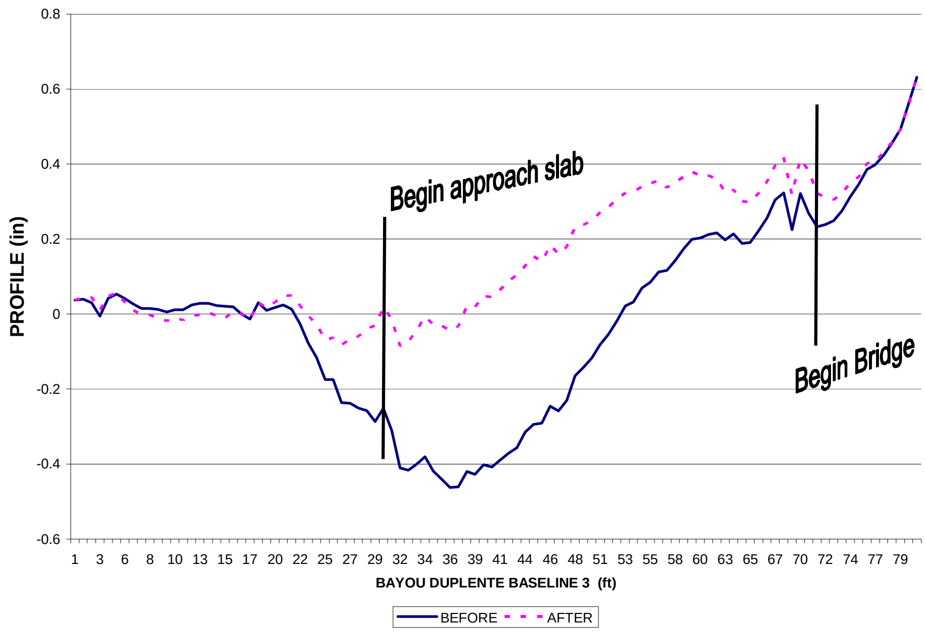

Figure 114
Walking profiler Bayou Duplente base line 3

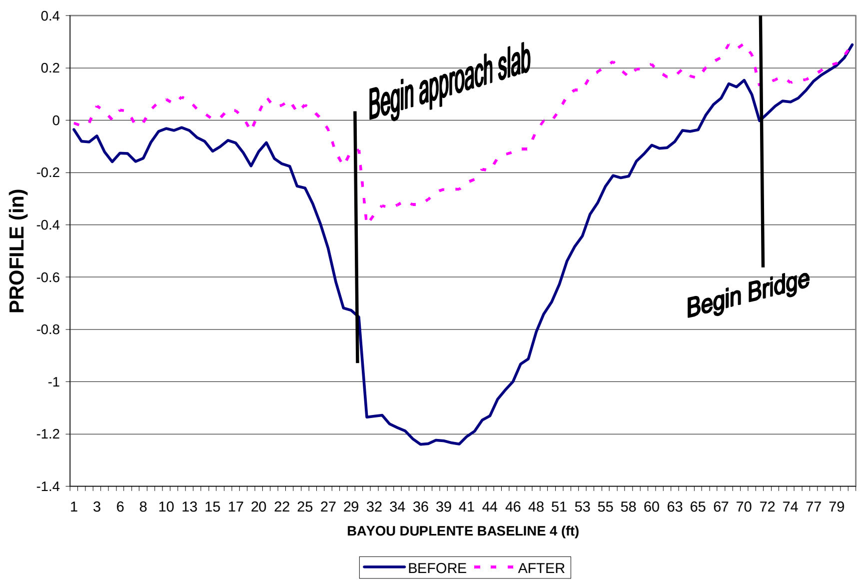

Figure 115
Walking profiler Bayou Duplente base line 4

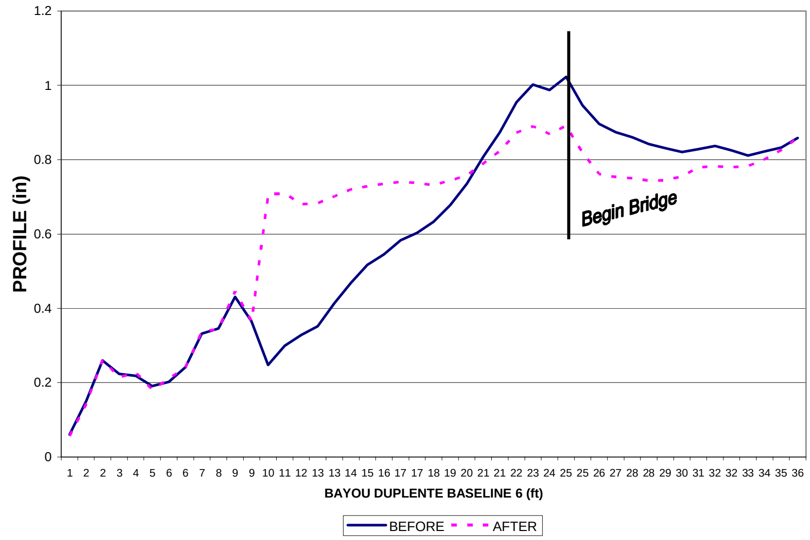

Figure 116
Walking profiler Bayou Duplente base line 6

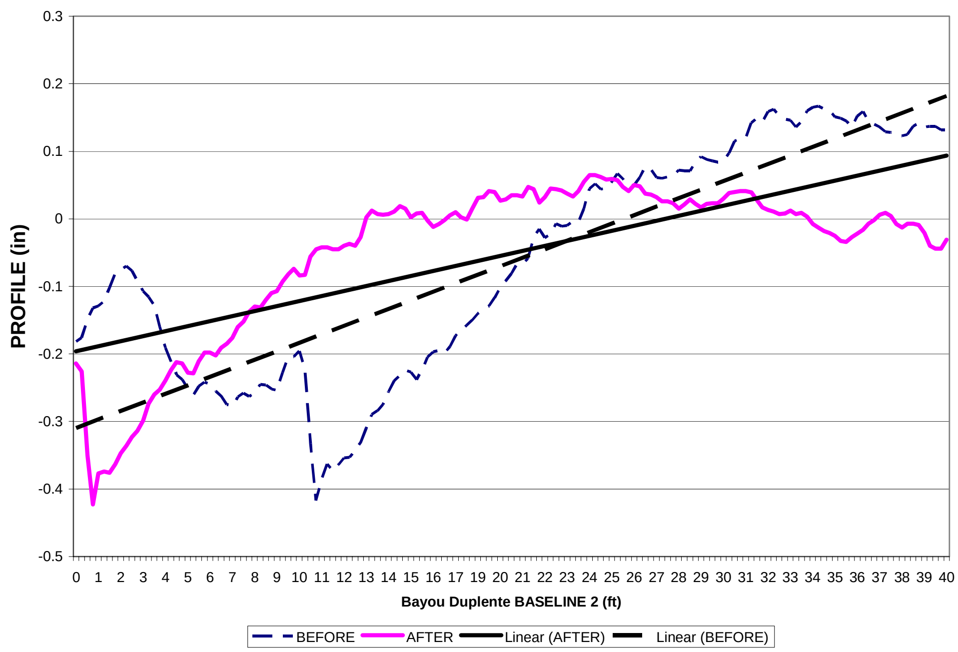

Figure 117
High speed profiler Bayou Duplente SB baseline 2

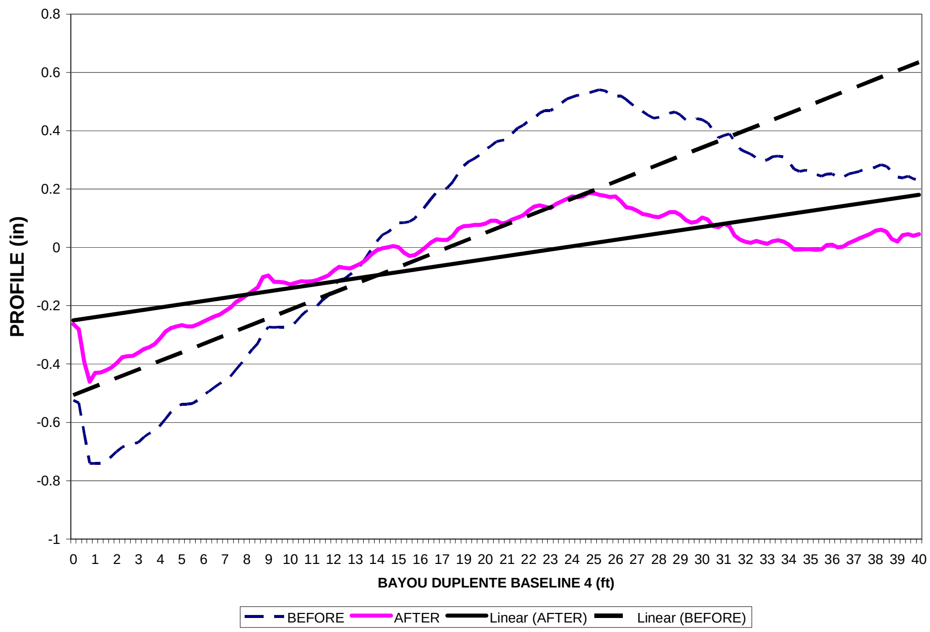

Figure 118
High speed profiler Bayou Duplente SB baseline 4

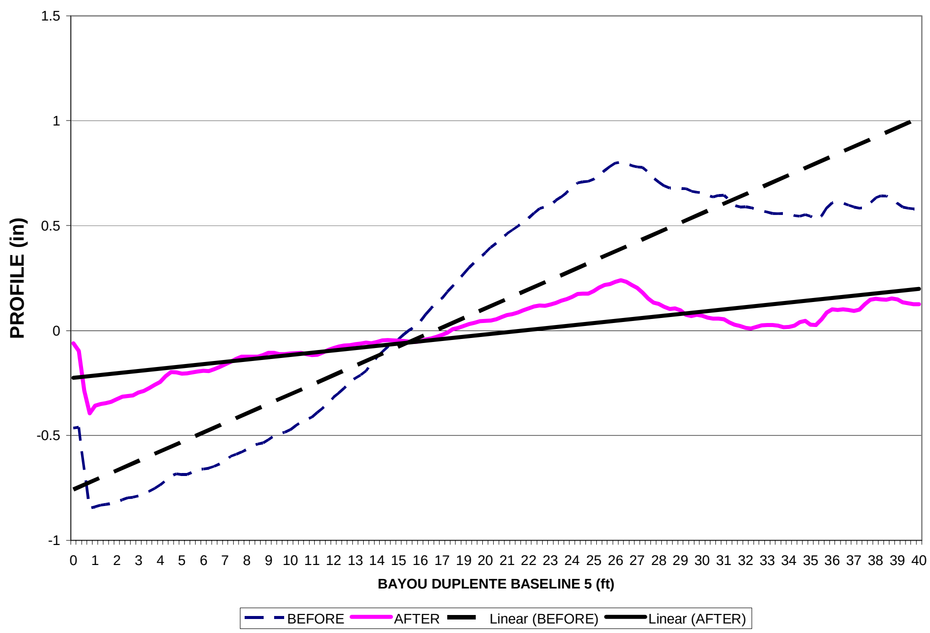

Figure 119
High speed profiler Bayou Duplente SB baseline 5

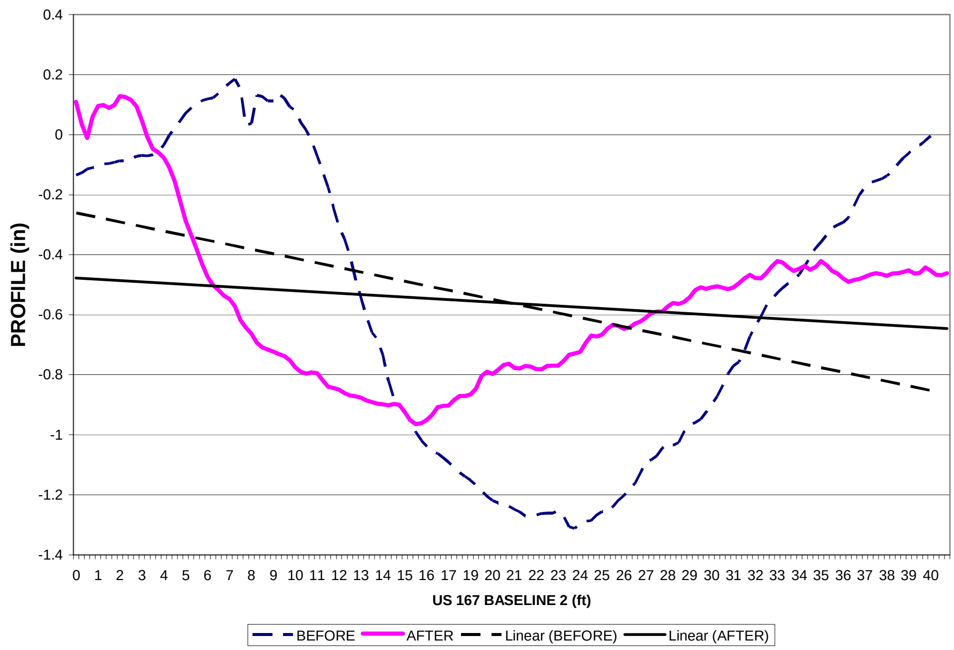

Figure 120
High speed profiler US 167 NB baseline 2

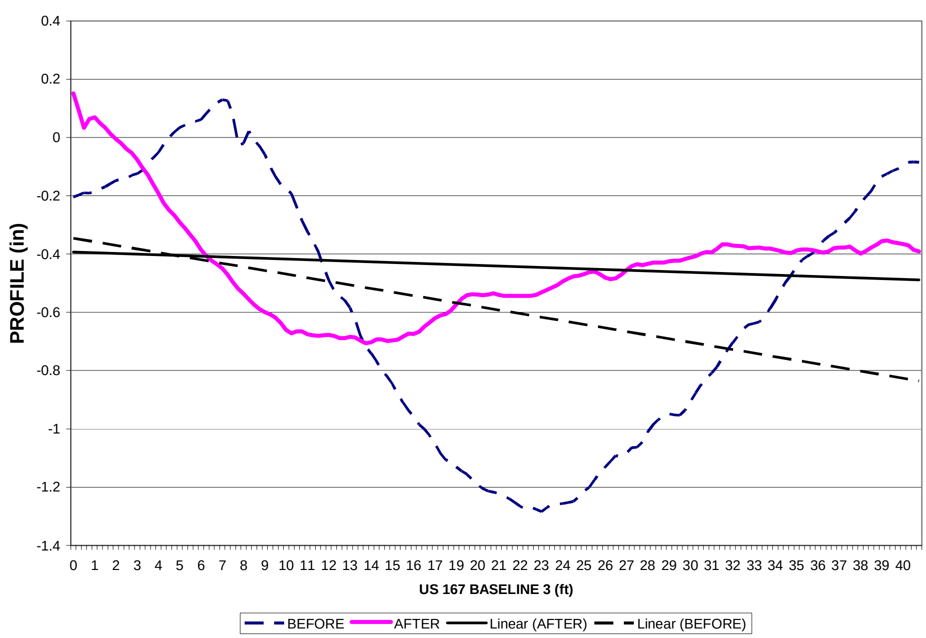

Figure 121
High speed profiler US 167 NB baseline 3

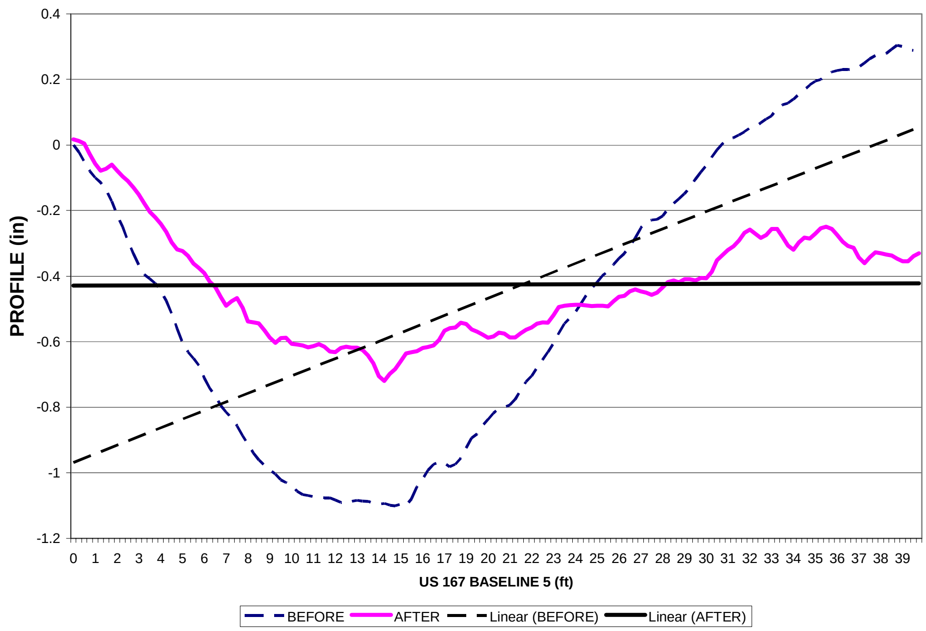

Figure 122
High speed profiler US 167 NB baseline 5

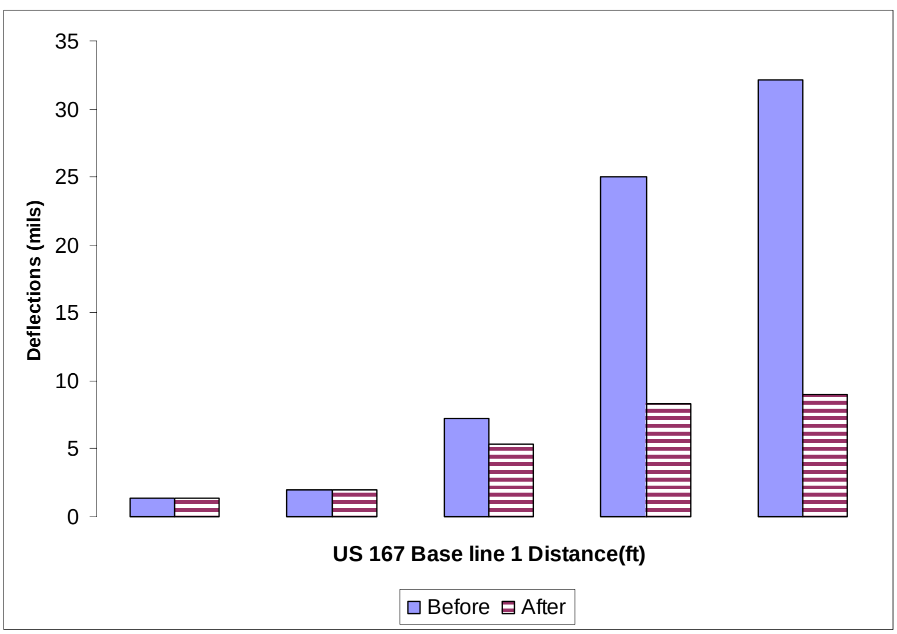

Figure 123
FWD first sensor deflections US 167 base line 1

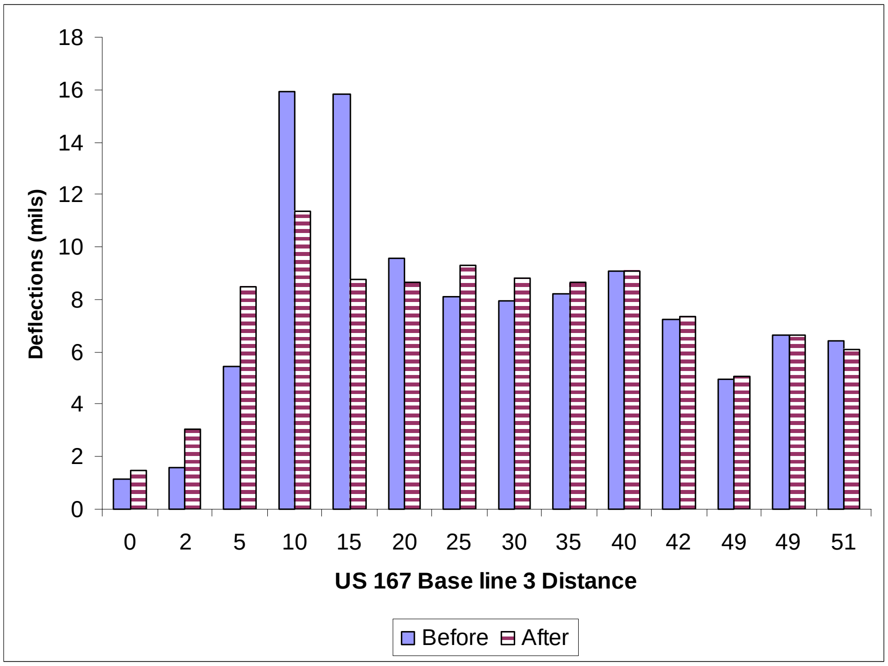

Figure 124
FWD first sensor deflections US 167 base line 3

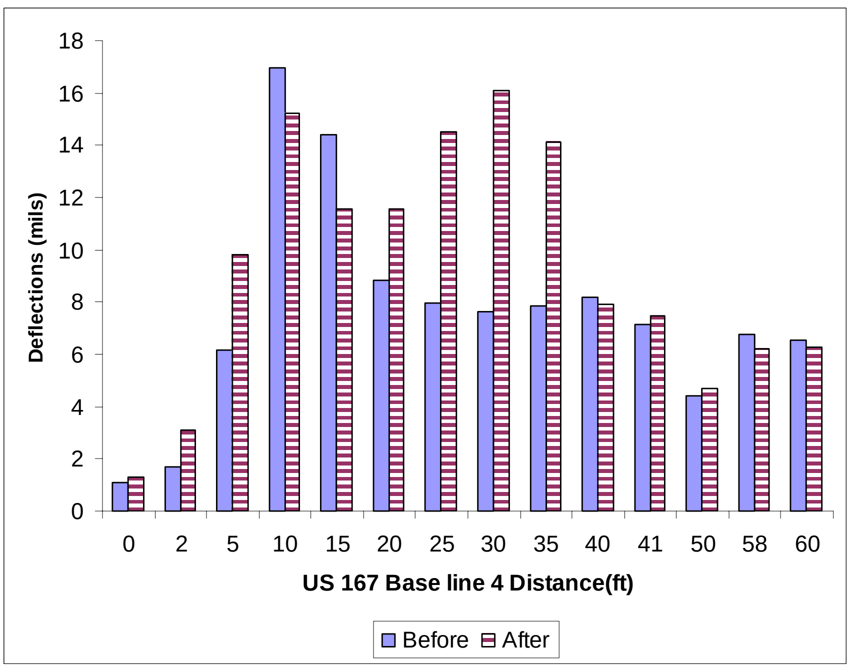

Figure 125
FWD first sensor deflections US 167 base line 4

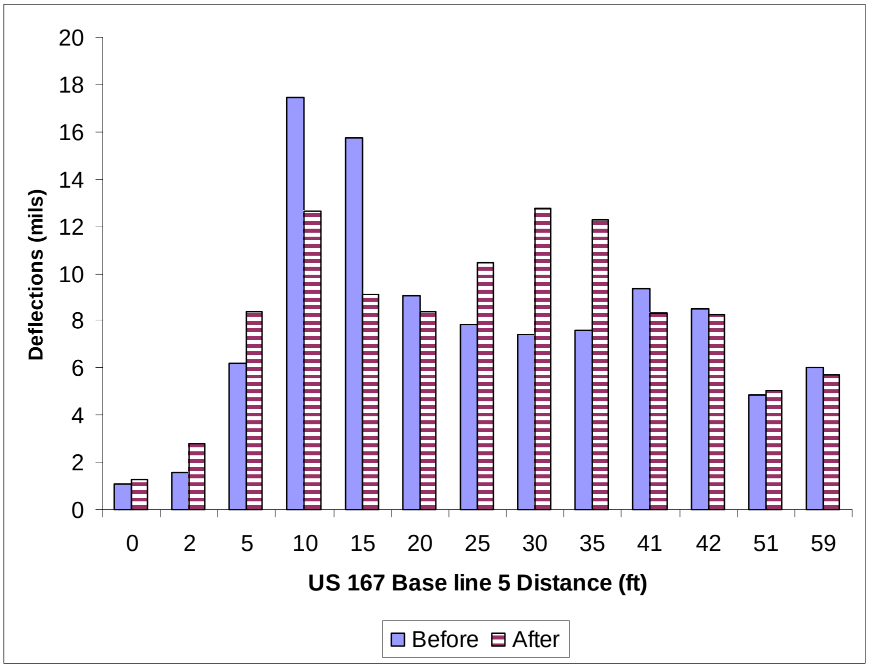

Figure 126
FWD first sensor deflections US 167 base line 5

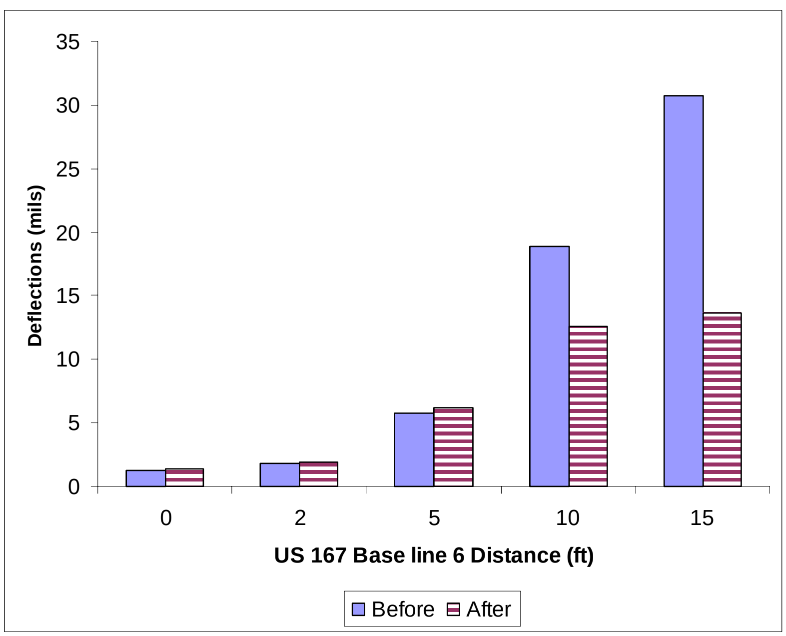

Figure 127
FWD first sensor deflections US 167 base line 6

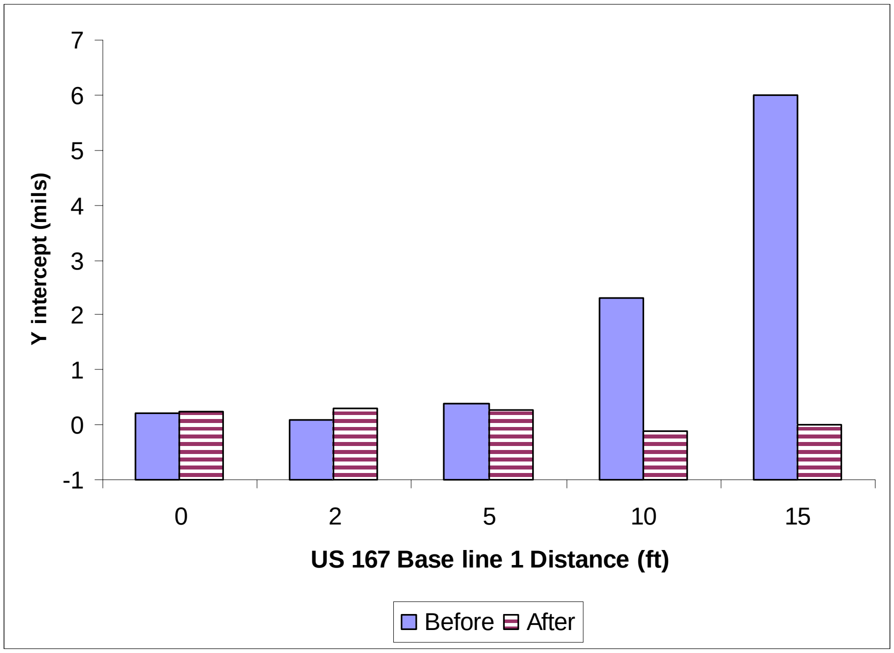

Figure 128
FWD Y intercept values US 167 base line 1

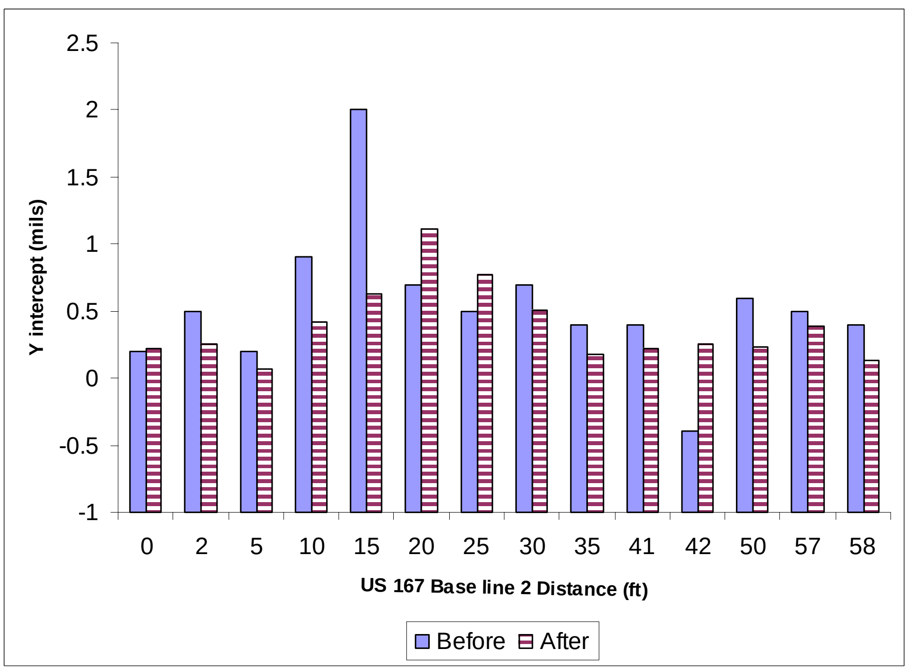

Figure 129
FWD Y intercept values US 167 base line 2

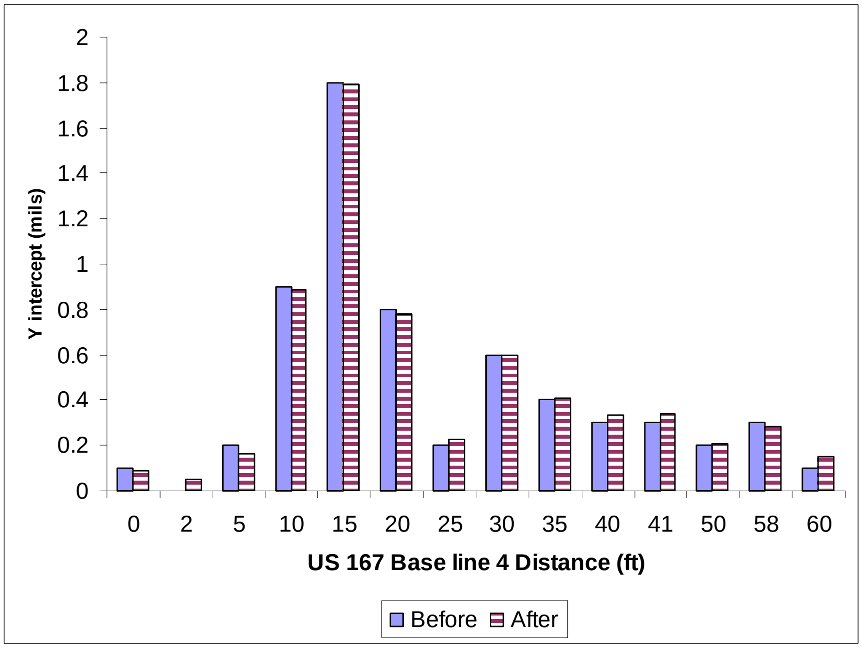

Figure 130
FWD Y intercept values US 167 base line 4

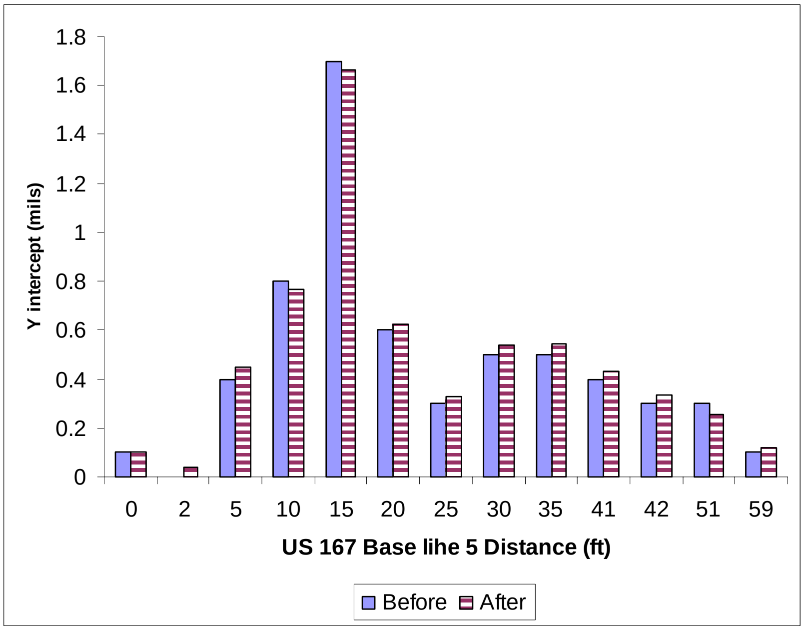

Figure 131
FWD Y intercept values US 167 base line 5

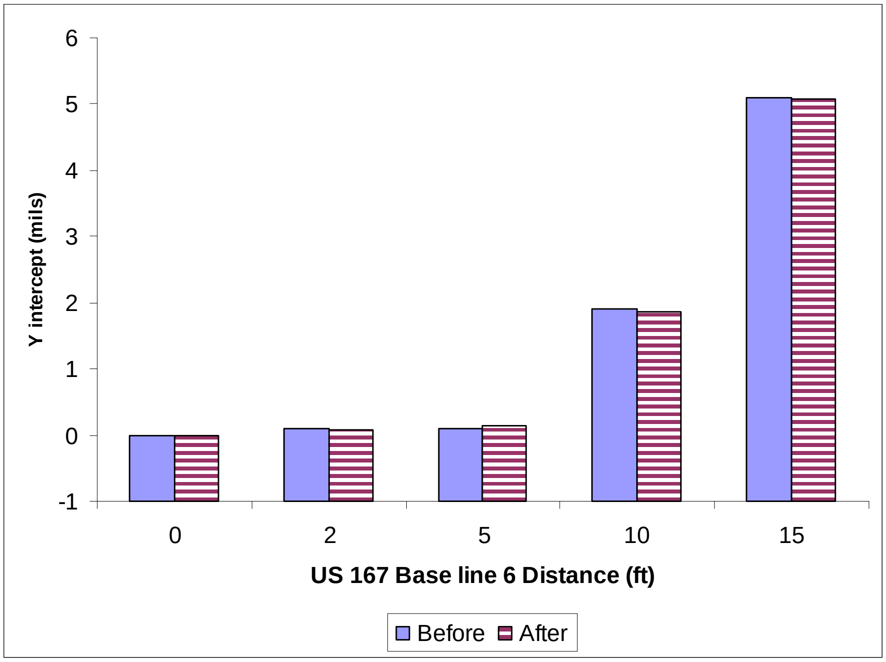

Figure 132
FWD Y intercept values US 167 base line 6

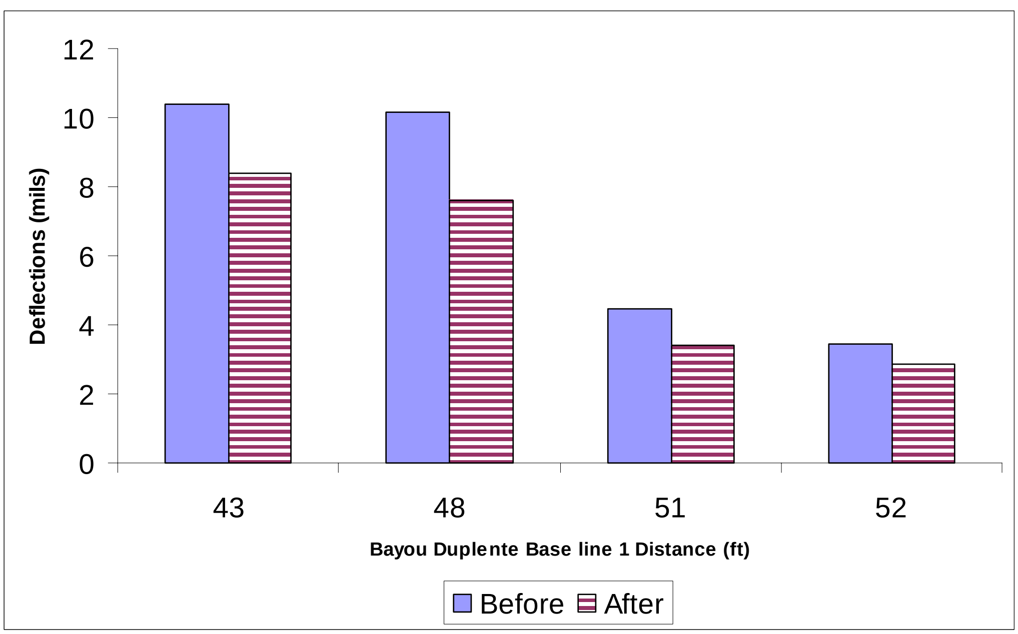

Figure 133
FWD first sensor deflections Bayou Duplente base line 1

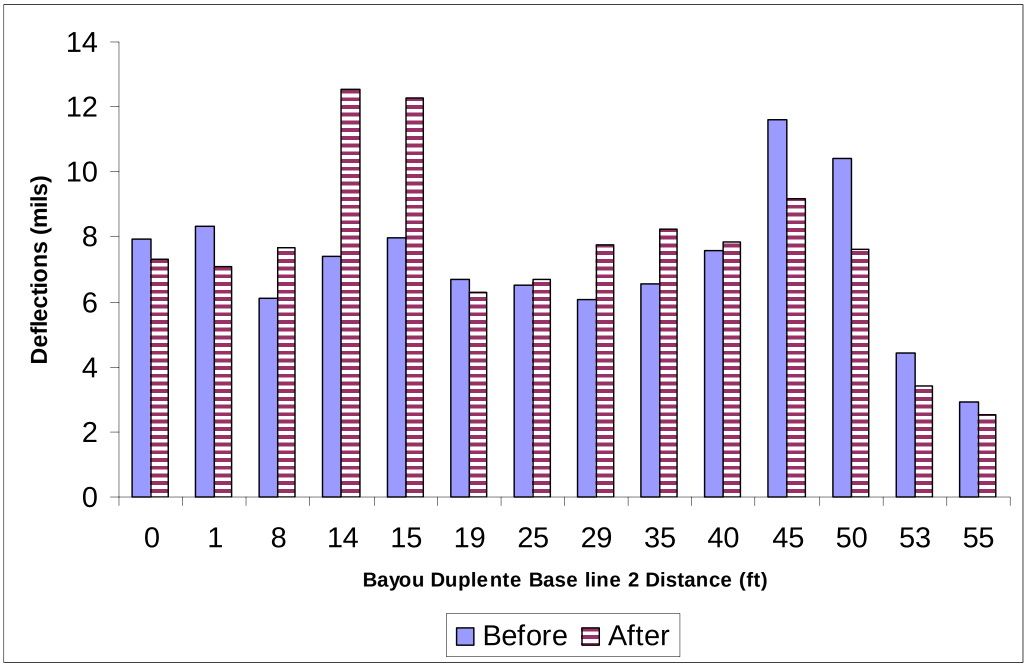

Figure 134
FWD first sensor deflections Bayou Duplente base line 2

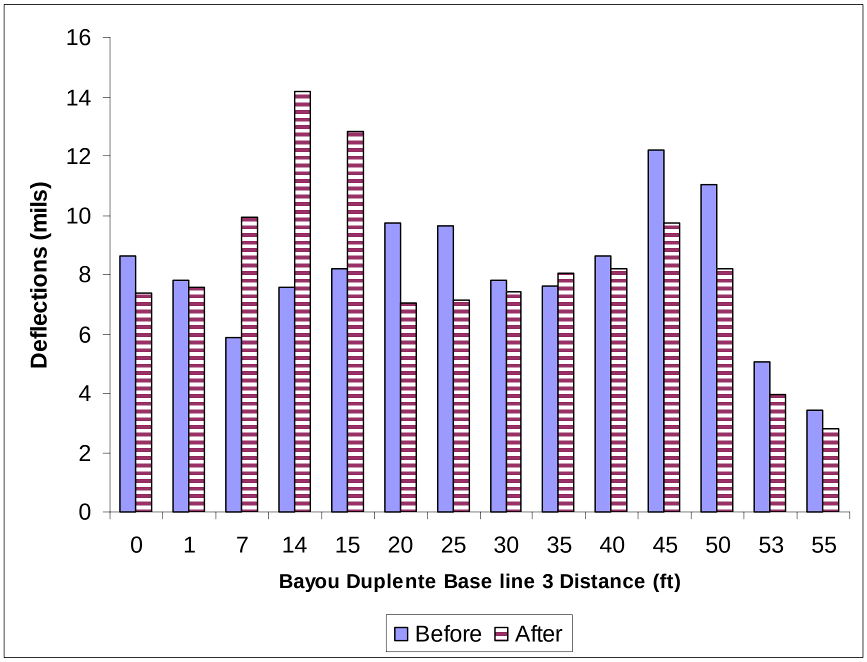

Figure 135
FWD first sensor deflections Bayou Duplente base line 3

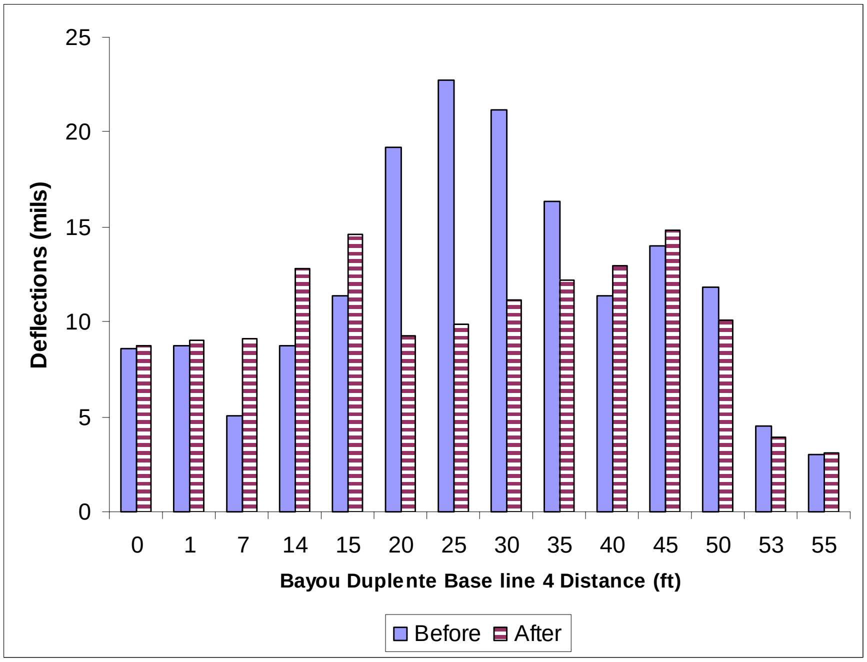

Figure 136
FWD first sensor deflections Bayou Duplente base line 4

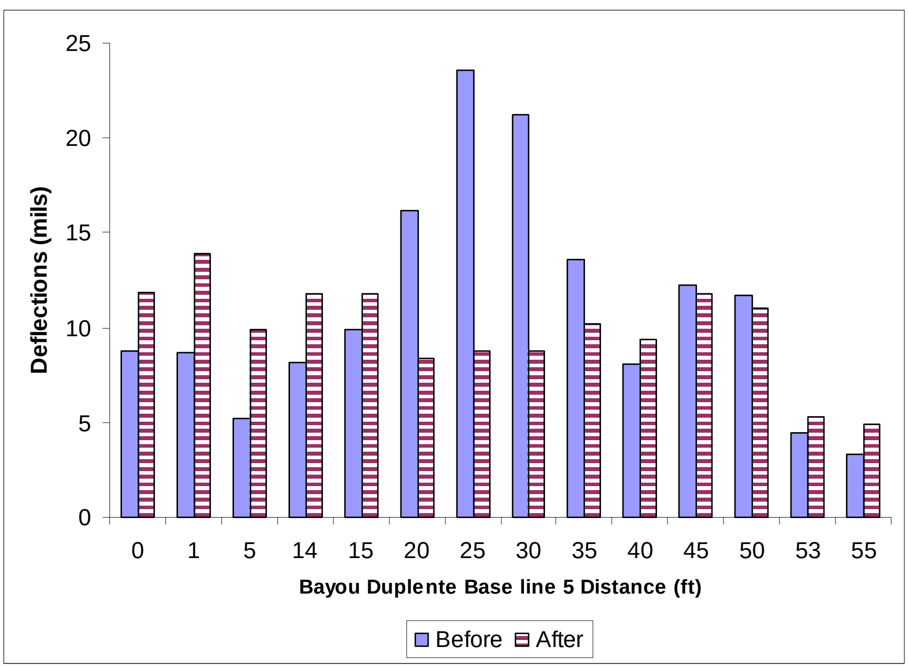

Figure 137
FWD first sensor deflections Bayou Duplente base line 5

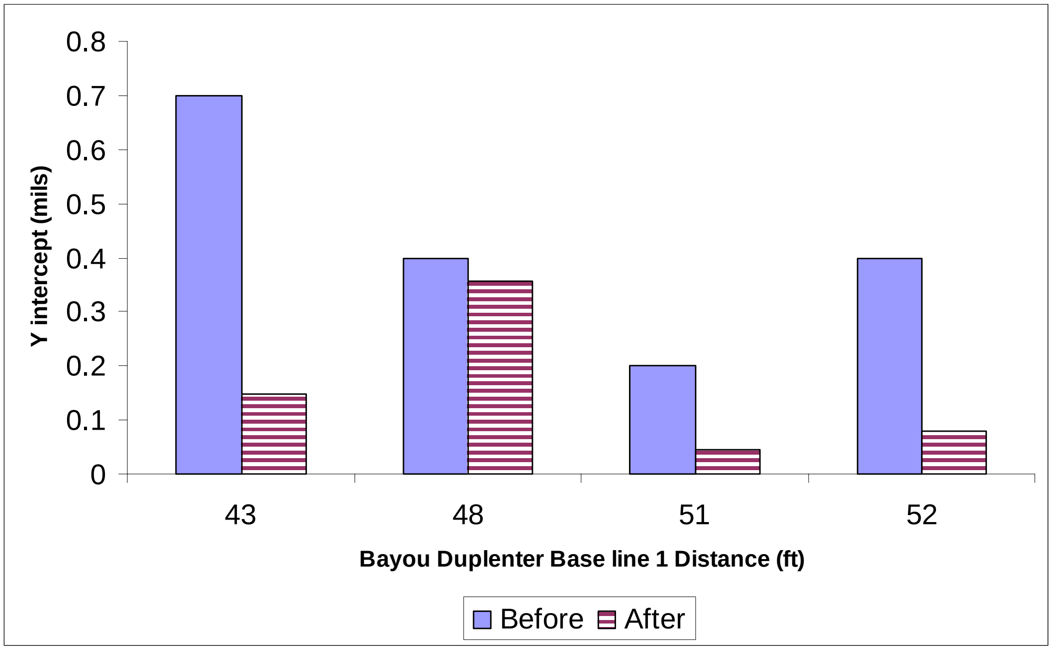

Figure 138
FWD Y intercept values Bayou Duplente base line 1

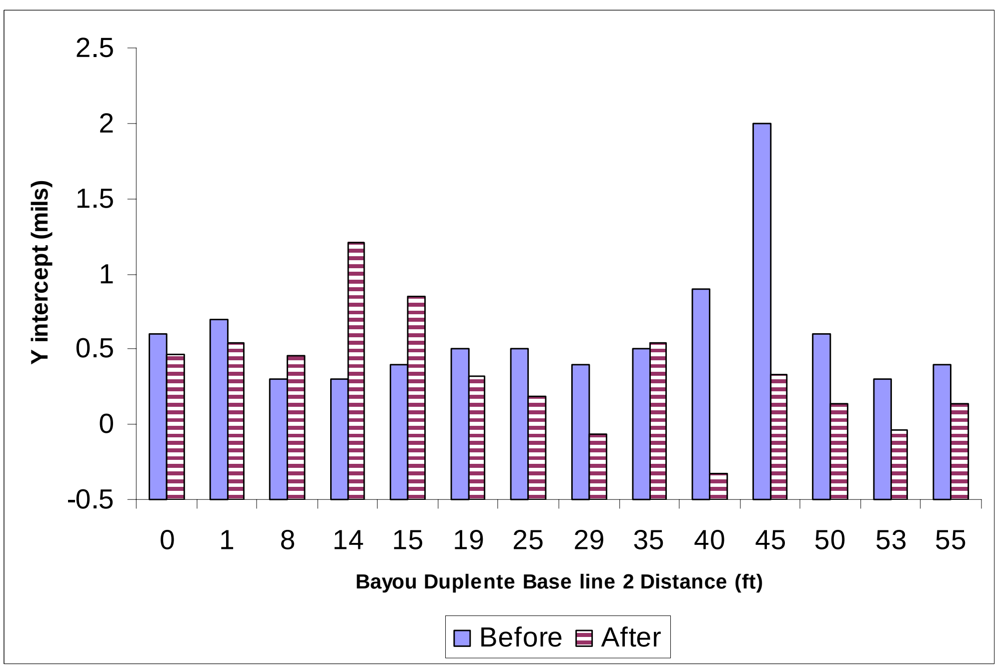

Figure 139
FWD Y intercept values Bayou Duplente base line 2

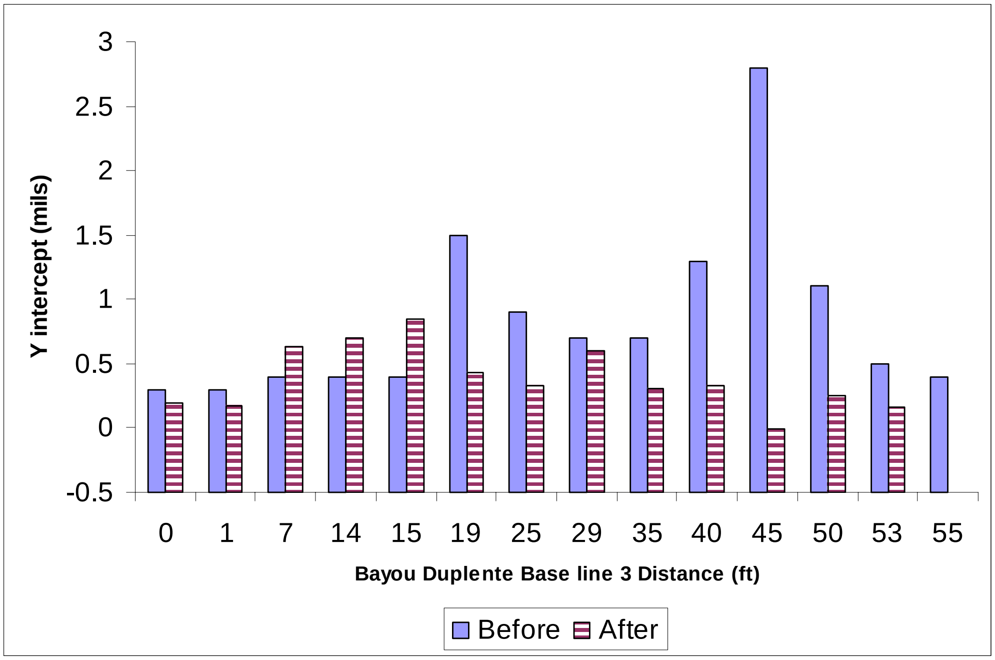

Figure 140
FWD Y intercept values Bayou Duplente base line 3

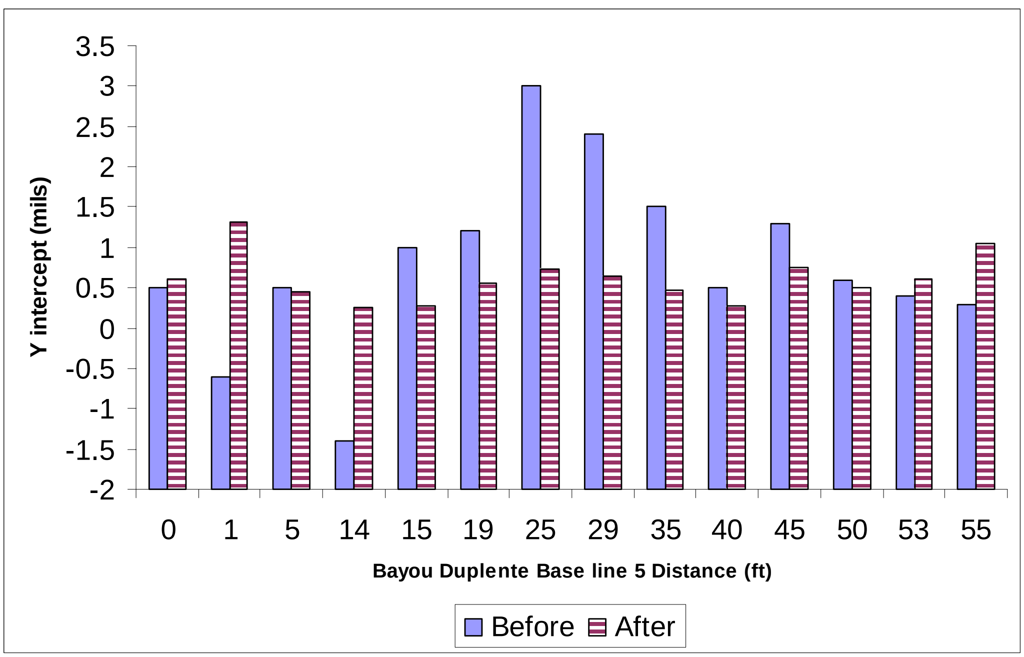

Figure 141
FWD Y intercept values Bayou Duplente base line 5

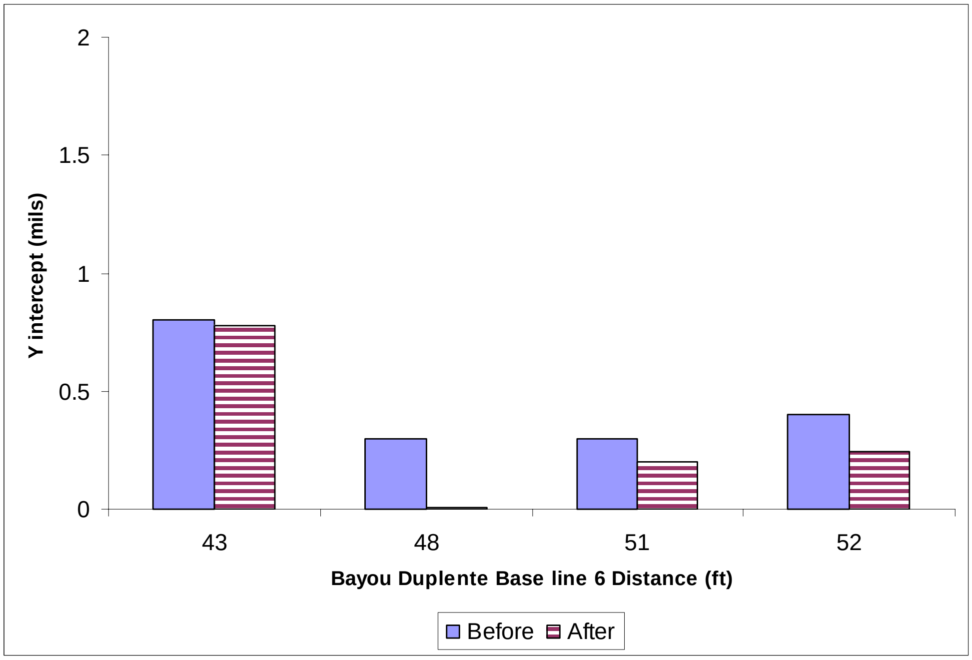

Figure 142
FWD Y intercept values Bayou Duplente base line 6