# Detailed Visual Inspection

Concrete was the principal material used in the construction of the Bonner Bridge. Concrete elements include the following:

- Prestressed concrete piles
- Cast-in-place conventionally reinforced pile caps, bents and bent caps
- Prestressed concrete girders
- Cast-in-place conventionally reinforced bridge deck.

Accordingly, the assessment of concrete structural elements is important to the overall assessment of the Bonner Bridge. To this end, WJE was tasked with conducting materials evaluation including up-close visual examination of selected elements. The work in Task 2 addressed the high level spans from Bent 129 to Bent 166, and the work in Task 3 examined the approach spans from End Bent 1 to Bent 128B and Bent 167 to End Bent 2.

For the field investigation, locations for inspection were selected to provide a sampling of various observed conditions and components. Based on a preliminary rating, representative bents from each of the rating categories were selected for up-close inspection. Refer to Table 3 for the preliminary inspection and rating of high level bent structures.

In addition to the bents, a series of girder spans were selected for detailed inspection, based on a similar preliminary rating system. The areas below the expansion joints typically exhibited the worst corrosion-induced damage. Consequently, representative girders and slabs at these locations were selected for detailed study.

## *Methodology*

### Delamination Surveys

During the assessment phase, WJE performed a detailed inspection of the bents and spans identified in Table 3. Using sounding techniques, the presence of delaminations was evaluated on the bent structures, prestressed girders, and bridge deck using the methods outlined in ASTM D4580 *Standard Practice for Measuring Delaminations in Concrete Bridge Decks by Sounding*. The location, extent, and nature of the deterioration were documented on field sketches. The size and shape of delaminated or spalled areas were estimated to provide a basis for generating the cost estimates discussed later in this document.

### Crack Survey and Mapping

In addition to the delamination survey, cracking in the bents, girders, and deck was recorded on the field sketches. In addition, the width of cracks was typically noted. The objective of this procedure was to help identify the deterioration mechanisms present in these components. WJE field sketches are located in Appendices D.1A-D.1D.

**Table 3. Preliminary inspection and rating of High Level Span Bent[1]**

| Bent No. | Bent Type | Preliminary Rating | Up-close Inspection | Comments |
|---|---|---|---|---|
| 129 | 1 Frame Bent | Poor | Yes | |
| 130 | 2 Frame Bent | Moderate | No | Corrosion of reactive aggregates on girders. |
| 131 | 2 Frame Bent | Moderate | No | |
| 132 | 2 Frame Bent | Moderate | No | |
| 133 | 2 Frame Bent | Moderate | No | |
| 134 | 2 Frame Bent | Moderate | No | Location of previous cathodic protection |
| 135 | 2 Frame Bent | Severe | Yes | Location of previous cathodic protection |
| 136 | 2 Frame Bent | Poor | No | |
| 137 | 2 Frame Bent | Poor | No | |
| 138 | 3 Frame Bent | Poor | No | |
| 139 | 3 Frame Bent | Poor | No | |
| 140 | 3 Frame Bent | Moderate | Yes | |
| 141 | 3 Frame Bent | Moderate | No | |
| 142 | 3 Frame Bent | Moderate | No | |
| 143 | 3 Frame Bent | Moderate | No | Start of steel span. |
| 144 | 3 Frame Bent | Moderate | No | Steel span |
| 145 | 3 Frame Bent | Severe | Yes | Steel span |
| 146 | 3 Frame Bent | Poor | No | End of steel span |
| 147 | 3 Frame Bent | Poor | No | |
| 148 | 3 Frame Bent | Poor | No | |
| 149 | 3 Frame Bent | Moderate | Yes | |
| 150 | 3 Frame Bent | Severe | No | Extensive patching. |
| 151 | 3 Frame Bent | Poor | No | |
| 152 | 2 Frame Bent | Poor | No | |
| 153 | 2 Frame Bent | Severe | Yes | |
| 154 | 2 Frame Bent | Poor | Yes | Large patches on columns. |
| 155 | 2 Frame Bent | Poor | No | |
| 156 | 2 Frame Bent | Severe | No | Large patches on columns. |
| 157 | 2 Frame Bent | Severe | No | |
| 158 | 2 Frame Bent | Poor | No | |
| 159 | 2 Frame Bent | Poor | No | |
| 160 | Pile Bent | Severe | Yes | |
| 161 | Pile Bent | Poor | Yes | |
| 162 | Pile Bent | Moderate | No | |
| 163 | Pile Bent | Moderate | Yes | |
| 164 | Pile Bent | Poor | Yes | |
| 165 | Pile Bent | Moderate | No | |
| 166 | Pile Bent | Moderate | No | |

[1] Grey shading indicates bents where up-close inspections and testing were conducted.

## *Visual Inspection – Approach Spans (Bents and Spans)*

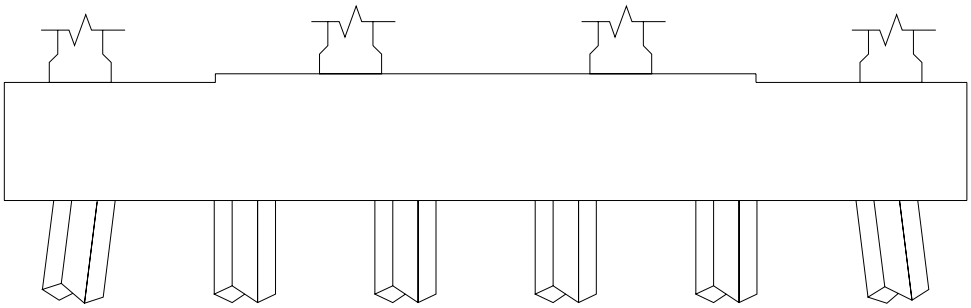
Of the 160 pile bents in the approach spans, 22 were chosen for detailed visual inspection. The selected pile bents were chosen to achieve a good distribution along the length of the bridge. Fig. 5 illustrate the original configurations of the selected bents, although many of the bents have since been retrofitted with various types of crutch bents.

The detailed visual inspection consisted of documenting observed deterioration or unusual features of pile caps and photographing typical conditions as well as any noteworthy distress. In addition, a delamination survey was performed on all surfaces of each selected pile bent. Many of the conditions observed were typical throughout the 22 pile bents surveyed.

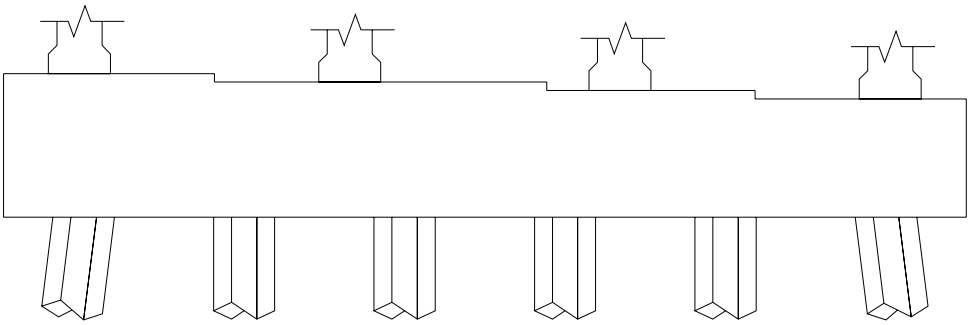
The following is a list of the typical conditions observed:

- Every pile bent inspected had had repairs made at some point in the form of either a troweled cementitious patch and/or shotcrete repair. The extent of the observed patching varied from very minor to approximately 50 percent of the vertical surfaces of the pile cap.
- Each inspected bent contained delaminated areas within the concrete. The delaminated areas vary in size and quantity, but every pile cap inspected had some amount of delaminated areas. Of the 22 pile bents surveyed, most of the delaminated areas were found in original concrete, whereas a relatively small percentage was found in patched areas.
- Many of the pile bents inspected had one or more spalls, frequently with exposed reinforcing steel.

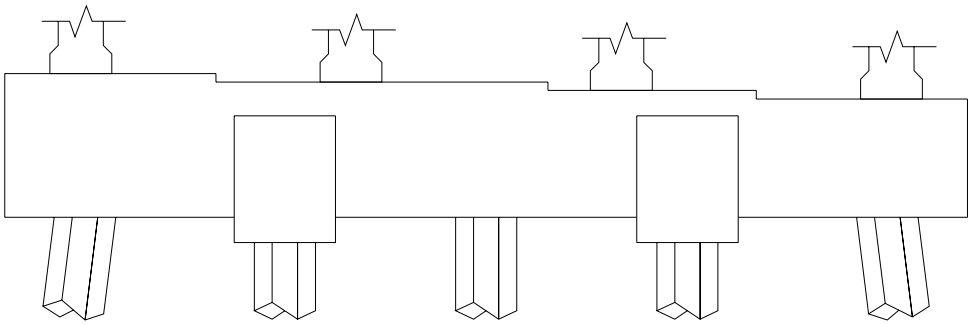
Most of the previous repairs are 20 years old or older. These repairs are at the end of their useful service life and can be expected to be in various stages of deterioration.



Bent configuration A: Bents 21, 31 and 117

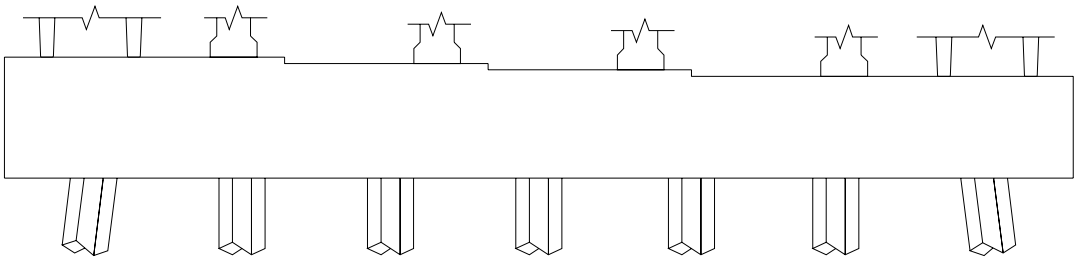


Bent configuration B: Bents 53, 75, 93, 102, 103, 176, 177 and 178

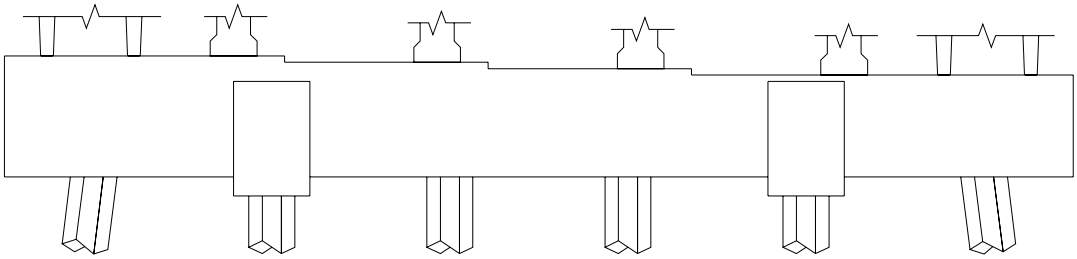


Bent configuration C: Bents 88, 116, 167 and 175

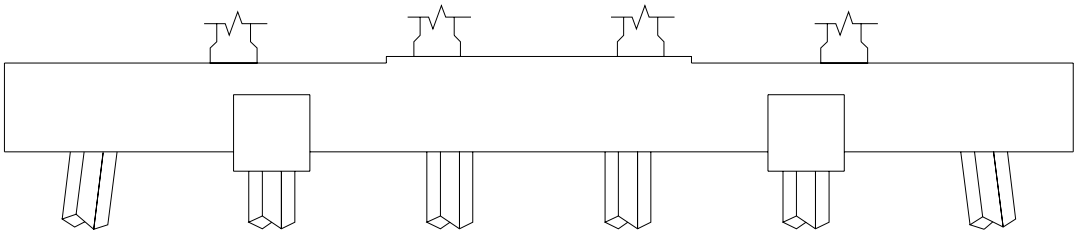
*Figure 5. The various pile bent configurations of the inspected pile bents.*



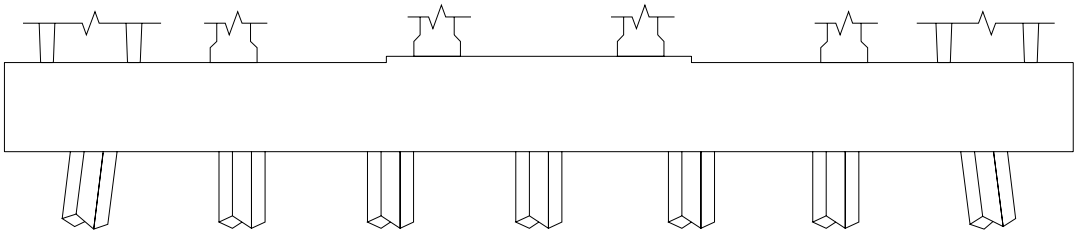
Bent configuration D: Bents 190 and 193



Bent configuration E: Bent 187



Bent configuration F: Bent 12



Bent configuration G: Bents 7, 13 and 201

*Figure 6. The various pile bent configurations of the inspected pile bents, continued.*

## Detailed Visual Inspection of Approach Bents

A summary of the visual survey for each bent follows:

Bent 7

Eight relatively small patches were observed on the pile cap, the majority of which were sound. Two patches on the south face contain map cracking. Two small delaminated areas were detected on the pile cap, at the lower edges and wrapping under to the cap soffit. A rather large spall with exposed reinforcing steel was observed on the lower edge of the south face. Bent 7 is a type G configuration (see Appendix D.2C, pp. D.2C-1, 2).

Bent 12

Approximately 60 percent of the north face contained shotcrete repair, with relatively small shotcrete repairs on the south face and pile cap soffit. The shotcrete repair on the north face contained map cracking throughout. Patching existed along three north-south lower edges of the battered pile caps. A few small delaminated areas were detected on the pile cap. A large crack (~ 3/16") was observed on the south face, and one location of spalled concrete with exposed reinforcing steel was observed on the north face of a battered pile cap. Bent 12 is a type F configuration (see Appendix D.2C, pg. D.2C-3).

Bent 13

Moderate to light patching was observed on the pile cap, with more patching occurring on the north face. The majority of the patches observed seemed sound. A few small delaminated areas were detected on each face and the pile cap soffit, and a minor spall was observed on the north face. Bent 13 is a type G configuration (see Appendix D.2C, pg. D.2C-3).

Bent 21

A moderate amount of patching was observed on faces and top of the pile cap. The majority of the patched areas were sound, although there were many delaminated areas detected on the pile cap. A fairly large spall and exposed reinforcing steel existed on the lower edge of the pile cap on the north elevation. Bent 21 is a type A configuration (see Appendix D.2C, pg. D.2C-5).

Bent 31

A significant amount of patching was observed on the north face and soffit of the pile cap, with slightly less patching occurring on the south face. Two sizable delaminations were detected on the south face and one fairly large delamination existed on the pile cap soffit. Except for the patch on the pile cap soffit, all of the delaminations occurred in original concrete and not in patched areas. Bent 31 is a type A configuration (see Appendix D.2C, pg. D.2C-7).

Bent 53

Significant patching was observed on the south face of the pile cap and more extensive patching exists on the north face. Several large delaminated areas were detected on both the north and south faces at the

upper edge and wrap up onto the top surface of the pile cap. One fairly small spall with exposed reinforcing steel was observed on the south face, at midspan, at the upper edge. Bent 53 is a type B configuration.

Bent 75

Significant patching was observed on the north elevation and slightly less patching on the south elevation. Several small delaminated areas were detected on the north face, one larger delaminated area was detected on the south face and several small areas were delaminated on the top of the pile cap. One spall (approximately 1 sq. ft.) with exposed reinforcing steel was observed on both the north and south elevations and two larger spalls were found on the top and soffit of the pile cap. Bent 75 is a type B configuration (see Appendix D.2C, pg. D.2C-8).

Bent 88

Several large patched areas (approximately 2-4 sq. ft.) were observed on the north face of the pile cap and one medium size patch existed on the south face. All of the patched areas were sound. Several relatively small delaminated areas were detected on the north and south faces and the pile cap soffit. A large spall with exposed reinforcing steel was observed on the south face, along the lower edge, as well as along the lower edges of the short beams atop the north-south battered piles. Bent 88 is a type C configuration (see Appendix D.2C, pp. D.2C-9, 10).

Bent 93

Relatively minor patching existed on the pile cap, with one patch observed on both the north and south faces. Several delaminated areas were detected in the north elevation, ranging in size from approximately 1 to 2 sq. ft., and a couple smaller delaminated areas were detected on the south face. A fairly small spall with exposed reinforcing steel was found on the north face at the top edge. Bent 93 is a type B configuration (see Appendix D.2C, pg. D.2C-10).

Bent 102

Several patches were observed on the north elevation of the pile cap, with the largest patch containing many vertical hairline cracks. A couple of small patches were found on the south face of the pile cap. Several relatively small (approximately 1-1.5 sq. ft.) delaminated areas were detected in both the north and south face of the pile cap, as well as in the pile cap soffit. Several cracks were found in the pile cap, with a length of 2’ or less, with two measured crack widths equal to approximately 0.01”. A small spall with exposed reinforcing steel was observed in the south face towards the east end, at the bottom edge. Bent 102 is a type B configuration (see Appendix D.2C, pp. D.2C-10, 11).

Bent 103

Moderate patching was observed on both the north and south elevations of the pile cap, with patch sizes ranging from approximately 1 sq. ft. to 5 sq. ft. Many small to medium size delaminated areas were detected in the north and south faces of the pile cap, as well as the pile cap top and soffit. Several spalls were found in the pile cap, along the lower edge of both the north and south faces, with four locations of exposed reinforcing steel. A crack with a measured width of 0.05” was observed in the north face at the lower west end. Bent 103 is a type B configuration (see Appendix D.2C, pg. D.2C-11).

Bent 116

Medium sized patches (approximately 2-4 sq. ft.) were observed on both the north and south elevations. A moderate number of delaminated areas were detected on both the north and south faces and the pile cap top; all in the original concrete. Several of the delaminations contained horizontal cracks; a few with measured widths of 0.04". One delamination on the north face, when sounded, spalled off and released trapped water. Other cracks were observed in the original concrete of both the north and south faces and the top of the pile cap. Some of these cracks had measured widths of 0.04". Bent 116 is a type C configuration.

Bent 117

One medium size patch (approximately 2-4 sq. ft.) was observed on both the north and south elevations and a smaller patch was observed on the lower east end of the pile cap. A few delaminated areas were detected on the north and south elevations, all approximately 1 sq. ft. or less. Several horizontal cracks were found in the pile cap - on the north and south faces and the top of the pile cap. One measured crack width on the south face was 0.04" and one crack on the top of the pile cap measured 0.05" in width. Bent 117 is a type A configuration (see Appendix D.2C, pg. D.2C-11).

Bent 167

Several small to medium size delaminations were detected on the south elevation, a couple on the top of the pile cap, and on the north elevation. Several horizontal cracks with measured widths ranging from 0.015" to 0.1" were observed on the north and south faces, as well as the west end of the pile cap. Several cracks were also observed in the short, cross-pile caps, with one crack measuring 0.125" in width. A large spall was observed in the south face of the western cross pile cap. Bent 167 is a type C configuration, and was retrofit with concrete transfer girders (see Appendix D.2C, pg. D.2C-12, 13).

Bent 175

Several fairly small delaminated areas were detected on the pile cap south elevation and the south faces of the cross-pile caps. A couple small delaminated areas were also detected on the north face and the pile cap top. Several short cracks were observed on the top of the pile cap, the north elevation, the north and south faces of the cross-pile caps and on the east end of the pile cap. The range of measured crack widths was 0.015" to 0.075". Two spalls were observed on the south faces of both of the southern cross-pile caps, one of which had exposed reinforcing steel. Bent 175 is a type C configuration and was retrofit with concrete transfer girders.

Bent 176

Very little delaminated concrete was detected on the vertical faces of the pile cap, while several small to medium delaminated areas were detected on the top of the pile cap. One spall was observed on the pile cap soffit at the east end. A couple of horizontal cracks were observed on both the north and south elevations, with measured crack widths ranging from 0.015" to 0.075". Cracks on both the north and south faces had corrosion staining adjacent to them. Bent 176 is a type B configuration and had been retrofit with concrete transfer girders (see Appendix D.2C, pg. D.2C-13).

Bent 177

Light to moderate patching was observed on the pile cap. A couple fairly small delaminated areas were detected on the north and south elevations, one of which was in a previous patch. Two somewhat larger delaminated areas were detected on the top of the pile cap. Several short cracks were observed on the north, south, and west faces of the pile cap with measured crack widths ranging from 0.015" to 0.125". Three cracks on the north face had corrosion adjacent to the cracks. Bent 177 is a type B configuration and had been retrofit with concrete transfer girders.

Bent 178

Light patching was observed on the pile cap vertical faces as well as relatively small areas of delaminated concrete. A significant portion of the pile cap soffit had delaminated areas. Several, primarily horizontal, cracks were observed on each vertical face of the pile cap as well as several cracks on the top of the pile cap. Many of the existing cracks had corrosion staining and were of significant width (0.03" to 0.25"). Bent 178 is a type B configuration and was retrofit with concrete transfer girders. (see Appendix D.2C, pg. D.2C-13)

Bent 187

Delaminated areas were fairly light with the exception of one medium area (~2 sq. ft.) located on the north elevation on the upper edge, near midspan, and, two small areas on the south elevation near midspan. Several small delaminated areas were detected on the cross-pile caps, as well as several spalls. Two spalls on the southern cross-pile caps had exposed reinforcing steel. Several cracks with measured widths of approximately 0.075" were observed on both the north and south faces of the pile cap. Bent 187 is a type E configuration and had been retrofit with concrete transfer girders (see Appendix D.2C, pg. D.2C-13, 14).

Bent 190

Light to moderate patching was observed on the south elevation, and several small delaminated areas were detected on this elevation as well. Several horizontal cracks were observed in the north and south elevations, with measured crack widths ranging from 0.015" to 0.05". A few of the observed horizontal cracks extended from the location where the concrete transfer girder joined the pile cap. Bent 190 is a type D configuration and was retrofit with concrete transfer girders (see Appendix D.2C, pg. D.2C-14).

Bent 193

Several small to medium size delaminated areas were detected in the north and south faces of the pile cap, as well as in the soffit of the pile cap. A few horizontal cracks were observed on the north and south faces, with measured crack widths ranging from 0.015" to 0.1". Bent 193 is a type D configuration and was retrofit with concrete transfer girders (see Appendix D.2C, pg. D.2C-14, 15).

Bent 201

Several small to medium size delaminated areas were detected in both the north and south faces of the pile cap. Moderate patching was observed on the pile cap. Several cracks were observed on the north,

south, and west faces of the pile cap, with one measured crack width approximately 0.05". Bent 201 was a type G configuration (see Appendix D.2C, pg. D.2C-15, 16)

## Detailed Visual Inspection of Approach Spans

Span 21

A couple very small delaminated areas were detected in the deck soffit, at the north end of the east bay and one small delamination was detected on the east soffit cantilever at midspan. Four small spalls with exposed reinforcing steel were identified: one on the north end of the east soffit cantilever, one on the north end of the west soffit cantilever, one at the north end of the east soffit bay and one on the south expansion joint beam of the east bay. Approximately four locations were observed of corroded aggregate in the deck soffit. Small patches were identified on several girder ends in the bottom flange at the bearing: on Girders 1, 3, and 4. A couple of the patches were delaminated and one patch contained a spall with exposed strands. A spall with an exposed strand was located on the west side of Girder 2 and Girder 1 along the bottom edge. The top of deck contains map cracking throughout the entire north bound lane.

Span 32

A moderate amount of delaminated areas were identified on the deck soffit at the south end of the west bay, both ends of the middle bay and at both ends of the east bay. A few small delaminated areas were detected on the east soffit cantilever. Four locations were observed with a spall and exposed reinforcing steel in the soffit: one at the south end of the middle bay, and three at the north end of the east bay. Almost no patching was found on the soffit. Three of the four girders contain patches, which were sound, in the bottom flange at the bearing. Girders 1 and 3 contain delaminated areas at this location. A spall with an exposed strand was observed on the northern east side of Girder 4 and on the southern west side of Girder 2. Cracks were observed on both ends of Girder 3, running along the bottom layer of strands. Map cracking was observed throughout the deck surface along the entire north bound lane; cracks widths range from 0.01" to 0.04" (see Appendix D.2D, pg. D.2D-1).

Span 35

A few small delaminated areas were identified in the deck soffit at the south end of the west bay and at the north end of the east bay. A couple of delaminations were also identified in the expansion joint beam at the south end of the east and west bays. Five locations of spalls with exposed reinforcing steel were observed: two on the south-western soffit and expansion joint beam, and three at the north-western area of soffit and corner of the expansion joint beam. Girders 2, 3, and 4 contain patches at the girders ends at the bearing, and Girders 2 and 4 had spalls and exposed strands in these patches on the north end of the east side. Girder 3 contained three spalls with exposed strand along the bottom flange edge: two on the west side, and one on the east side. Horizontal cracking was observed in the north end of Girder 3 and the south end of Girder 4 along the bottom layer of strands. The deck surface had map cracking throughout the entire north bound lane (see Appendix D.2D, pg. D.2D-1).

Span 48

One small patch was observed on the slab soffit at the north end of the east bay. Four delaminated areas were identified on the soffit: three at the south end of the soffit, and one at the north end of the west bay. Two shallow spalls were observed in the west soffit cantilever. A few locations of corroded aggregate were noted on the soffit in the middle and east bays. A spall with exposed reinforcing steel was observed on the expansion joint beam at the north end of the west bay. Three locations of exposed reinforcing steel were found on the outside edge of the slab curb, on the east side. Girder 4 contained two spalls with exposed strand on the east side. Girders 1 and 2 contain delaminated areas on the girder soffit, near the bearings, at both the north and south ends. Two short horizontal cracks were observed on the south end of Girder 3 at the level of the bottom strands. Map cracking was observed along the center of the north bound lane deck surface (see Appendix D.2D, pg. D.2D-1).

Span 54

Four fairly small delaminated areas were detected on the slab soffit: three at the south end, and one at the north end. A patch was observed in both the middle and east bays, at the north end of the soffit. One location of exposed reinforcing steel was found on the north face of the southern diaphragm in the east bay. Four spalls with two or more exposed strands were observed in the girder bottom flanges at the bearings: one at the north-east end of Girders 3 and 4, and one on each side of the north end of Girder 2. Three additional locations of spalls with exposed strand were observed in the girders: one on the east side of Girder 3, and two on the west side of Girder 1. Three girder ends contain delaminated areas in the bottom flange at the bearing: the northwest ends of Girder 3, both sides of the north end of Girder 1, and the southwest end of Girder 2. One spall with exposed reinforcing steel and one delamination were observed on the east and west sides, respectively, in the thickened web at the north end of Girder 3 (see Appendix D.2D, pp. D.2D-1, 2)

Span 65

A few small delaminated areas were identified in the slab soffit at the south end of each bay and on the north end in the west and middle bays. Several delaminations were also observed in both the north and south expansion joint beams. Two spalls with exposed reinforcing steel were observed in the soffit: one at the middle bay's south end, and one at the west bay's north end. Four locations of exposed reinforcing steel were found at the south end of the west bay soffit. Three spalls with exposed reinforcing steel were observed in the expansion joint beams: two on the west end of the north beam, and one on the south beam of the east bay. Girder 2 contains two spalls with exposed strands: one with three exposed strands in the lower flange, at the bearing, on the north west end, and one on the east side at midspan, along the girder's lower edge. Girder 1 contained four small spalls with exposed reinforcing steel in the thickened web at the north end, west side. Girder 2 contained one small spall at the south end, west side. The deck surface of the north bound lane contained some minor map cracking throughout and the slab edge at the north end was raveled at the expansion joint (see Appendix D.2D, pp. D.2D-2, 3).

Span 75

Many small to medium delaminated areas were identified in the deck soffit, primarily at the ends of each bay. Several delaminations were also detected in the south expansion joint beam in each bay. Spalls with exposed reinforcing steel were observed in the soffit at the ends of each bay, with a fairly large spall containing seven exposed bars at the south end of the middle bay. Two spalls with exposed reinforcing

steel were also observed in the north expansion joint beam, in the middle bay and the west end of the beam. Three spalls with exposed strand were observed in the girders along the bottom edge: one at the south end, east side of Girder 3 and one on each side of Girder 3. Spalls with exposed reinforcing steel exist on the east side of Girder 4, in the thickened web at each end, and in the west side of Girder 1, at the thickened web at the south end. The deck surface of the north bound lane contained a couple of areas of map cracking, one at each end, and two locations of exposed reinforcing steel in the east curb.

Span 88

No patching was observed in the deck soffit. Four small delaminated areas were found in the soffit, all at the south end in the east and middle bays and in the soffit cantilever on the east side. Four spalls with exposed strand were observed on the girders: one on the side of Girder 2 towards the south end and two on the west side of Girder 1 near midspan. A couple of small delaminated areas were identified on two girders: one along the bottom edge of Girder 3 on the southeast side and, one at the north end of Girder 1 in the west bottom flange near bearing. Several cracks were observed in the deck surface of the north bound lane with crack widths ranging from hairline to 0.015".

Span 93

No patching was noted on the deck soffit. Several small delaminated areas were detected on the slab soffit, with the majority at the south end in each bay and one at the north end of the east and middle bays. Four spalls with exposed strand were observed in the girders: one at the southeast end of Girder 4, one with three exposed strands at the bearing on the northeast end of Girder 4, one at the bearing at the southeast end of Girder 3 and one on the west side of Girder 1 at midspan. A few small delaminations and two small spalls were observed in Girder 2 at both ends, in the thickened web. The deck surface of the north bound lane contained map cracking throughout, with widths ranging from hairline to 0.015" (see Appendix D.2D, pg. D.2D-3).

Span 94

No patching was observed on the deck soffit. A few small delaminated areas were detected on the deck soffit on the south end of the west and middle bays. Three small spalls with exposed reinforcing steel were observed on the soffit at both ends of the west bay. Two small delaminations and one small spall with exposed reinforcing steel were observed on the north face of the south diaphragms in the west and middle bays. Six spalls with exposed strand were observed in the girders along the bottom edge: one on the southeast side of Girder 4, one on the east side of Girder 3 near midspan, three on the west side of Girder 2, and one on the northeast side of Girder 2, at the bearing. Two of the spalls on Girder 2 had three strands exposed. Two spalls with exposed reinforcing steel were observed on the northeast end of Girder 3 and one on the northeast side of Girder 2, all in the thickened web. A horizontal crack was observed in the north end of Girder 2 at the level of the bottom strand layer. Two small areas were observed with map cracking in the deck surface of the north bound lane and one crack with a measured width of 0.025" were observed at the north end of the deck surface at midspan (see Appendix D.2D, pg. D.2D-3).

Span 102

No patching was observed in the deck soffit. Several relatively small delaminated areas were identified in the deck soffit, primarily at the south end of the west and middle bays with one area in the middle of the west bay and one at the north end of the east bay. A few small delaminations were detected on the

diaphragms with one spall containing exposed reinforcing steel on the south diaphragm of the middle bay. Five spalls with exposed strand were observed along the bottom edge of the girders: one at the southwest end of Girder 1, one at the south-east end of Girder 2, one with three exposed strands at the north-east end of Girder 3 at the bearing, and one at each end of the east side of Girder 4. Three small spalls with exposed reinforcing steel were observed on Girder 1 at the northeast end and the southwest end within the thickened web. Hairline map cracking was observed throughout the entire north bound lane of the deck surface in addition to several fairly long transverse cracks with widths of approximately 0.015" to 0.02". Several spalls with exposed reinforcing steel were observed in the north bound deck both near midspan and at the north expansion joint, all with approximately 0.25" of concrete cover. A patch with some delaminations was observed at the north expansion joint of the north bound lane (see Appendix D.2D, pg. D.2D-3, 4).

Span 103

Extensive areas of delamination were observed at the south end of the deck soffit while light areas of delamination were detected at the mid-span and north end of the deck soffit. No patching was observed on the deck soffit. Light spalling and delaminations exposing reinforcing steel were identified at the north and south ends of the deck soffit. Spalls and exposed strands were documented along the bottom edges of all girders. Bearings of all girders were severely corroded. Spalls and exposed reinforcing steel were identified at girder ends on Girder 4. Map cracking was observed throughout the top of the entire north bound lane of the deck.

Span 116

Extensive areas of delamination were observed at the north and south ends of the deck soffit. Patching was observed at the north and south deck soffits. Significant spalling and delaminations exposing reinforcing steel were identified at the north and south ends of the deck soffit. Light areas of spalling and exposed reinforcing steel were observed along the underside of the south diaphragm. Light areas of delamination were documented on the sides of the north diaphragms. The sides of the north diaphragm revealed exposed reinforcing steel. Spalls and exposed strands were documented at the bearing of Girder 3. Spalls and exposed strands were documented along the bottom edges of Girders 2 and 4. Corrosion staining from aggregates occurred at numerous locations on Girder 3 (see Appendix B, pgs B2.4). Map cracking was observed at the north and south ends of the entire north bound lane of the deck along with a severely raveled edge of the deck at the south end (see Appendix D.2D, pg. D.2D-4).

Span 117

Extensive areas of delamination were observed at the north and south ends of the deck soffit. Patching was observed at the south deck soffit. Significant spalling and delaminations exposing reinforcing steel were identified at the north and south ends of the deck soffit. Spalls and exposed strands were documented along the bottom edges of Girders 1 and 2. Spalls and exposed reinforcing steel was identified at midspan of Girder 1. Shrinkage cracking was observed at the bearing ends of Girders 1, 2, and 4. Map cracking was observed at the north and south ends of the entire north bound lane of the deck (see Appendix D.2D, pp. D.2D-3, 4).

Span 176

Extensive areas of delamination were observed at the north and south ends of the deck soffit. Extensive patching was observed at the south deck soffit. Significant spalling and delaminations exposing reinforcing steel were identified at the north and south ends of the deck soffit. Patching was observed along the bottom edges of Girders 2 and 3. Horizontal cracks in the range of 0.125" were documented at the bearings of Girders 2, 3, and 4 (see Appendix D.2D, pp. D.2D-5, 7).

## *Visual Inspection – High Level Spans (Bents and Spans)*

Of the 38 bents in the high level spans, 12 bents were chosen for detailed visual inspection. The selected high bents were chosen based on a preliminary assessment. In addition, the selected bents were chosen to achieve a good distribution along the high level span section of the bridge. Refer to Table 3 for the preliminary inspection and rating of high level bent structures. The detailed visual inspection consisted of documenting observed deterioration or unusual features of bent members and photographing typical conditions as well as any noteworthy distress. In addition, a delamination survey was performed on all surfaces of each selected bent.

Many of the conditions observed were typical throughout the 12 high bents surveyed. The following is a list of the typical conditions observed:

- Every bent inspected had repairs made at some point in the form of either troweled cementitious patches and/or shotcrete repairs. The extent of the patching varies but was typically observed on each member type of each bent to some degree: pile caps, columns, struts, and bent caps.

- Each inspected bent contained delaminated areas within the concrete. The delaminated areas varied in size and quantity, but were found on every member type. The amount of delaminated area varied from approximately 15 percent to 75 percent of each bent.

- Cracking was observed in each bent to varying degrees. The location of the most severe cracking was typically in the columns and the pile caps, whereas the bent caps typically contained moderate cracking. Typical cracks in the columns were vertical and ranged in width from hairline to approximately 0.125". The typical cracks observed on the pile caps were horizontal, on the vertical faces and ranged in size from hairline to approximately 0.25".

- Many locations of surface corrosion staining were observed on the inspected bents. The most severe corrosion staining existed on the vertical faces of the pile caps, typically adjacent to existing cracks.

### Detailed Visual Inspection of High Level Bents

A summary of the visual survey for each bent follows:

Bent 129

A significant amount of patching was observed on the west column of the bent, which seemed to be sound. A moderate amount of delamination was detected on the bent cap and pile cap as well as a few delaminated locations on the east column. Vertical cracking was typically observed on the columns. Moderate horizontal cracking was present on the bent cap and pile cap. Corrosion staining was present on the north elevation of the pile cap (see Appendix D.2A, pg. D.2A-1). Cathodic protection devices were observed on the bent.

Bent 135

All surfaces of the columns, beams, bent cap and top surface of the pile cap were previously repaired with shotcrete. The shotcrete repair areas were delaminated over approximately 85 percent of the entire surface. In addition, the shotcrete repair areas contained craze cracking throughout and efflorescence staining in limited areas. The pile cap contained several locations of corrosion staining and exposed reinforcing steel on the vertical faces. A large spall with exposed reinforcing steel was observed on the southwest corner of the pile cap top (see Appendix D.2A, pp. D.2A-2, 3).

Bent 140

The extent of the patching on the columns was moderate to light, whereas the patching was more extensive on the bent cap and the lower strut. A few relatively small delaminated areas were detected on the columns, primarily on the lower third of the bent. The delaminated areas were more extensive on the bent cap. The majority of the delaminated areas exist in the original concrete and not in previous repairs. The pile cap contained moderate patching and somewhat extensive horizontal cracking on the vertical faces. Many locations of surface corrosion staining were present on the vertical faces of the pile cap (see Appendix D.2A, pp. D.2A-3, 4).

Bent 145

The south elevation of the columns contained moderate to heavy patching, whereas the patching on the remaining column elevations was less severe. The extent of the delaminated areas detected was fairly severe on the south, west and east column elevations as well as the south elevation of the bent cap. The majority of the delaminated areas were detected in the original concrete, not in patched areas. A moderate amount of vertical cracking was observed on the west column with measured crack widths of up to approximately 0.1 inch. The pile cap had moderate patching primarily near or at the top corner and several corrosion stains were observed on the north elevation of the pile cap. The south, west, and east pile cap faces were partially blocked by existing fenders and were not inspected (see Appendix D.2A, pp. D.2A-4, 5).

Bent 149

Moderate to extensive patching was observed on the west column and slightly less on the east column. Extensive patching existed on the north elevation of the bent cap with moderate to severe delaminated areas detected on each side of the bent cap. Significant vertical cracking was observed on each column with occasional corrosion or efflorescence staining and measured crack widths as large as approximately 0.075”. The pile cap contained patching along the top edge of both the north and south elevations, with

moderately delaminated areas on the pile cap top surface. Several corrosion stains were observed on the vertical faces of the pile cap (see Appendix D.2A, pp. D.2A-6 - 8).

Bent 150

Moderate patching was observed on the columns, and light patching was present on the bent cap. Moderate to severe delaminated areas were detected on the north and south faces of the bent cap. Extensive vertical cracking was observed on both columns with some efflorescence staining. Measured column crack widths were as large as 0.1". Minor patching was observed on the pile cap primarily on the south elevation at the top edge. Several horizontal cracks were observed on the pile cap vertical faces and two large (0.075") cracks were noted on the top surface of the pile cap. Several corrosion stains existed on the vertical faces and top of the pile cap (see Appendix D.2A, pp. D.2A-8 - 11).

Bent 153

Observed patching was moderate to extensive on the columns and slightly less extensive on the bent cap. Fairly extensive vertical cracking was observed on the columns with measured crack widths of approximately 0.1". Efflorescence and corrosion staining was observed adjacent to many cracks. A moderate amount of delaminated areas were detected on the columns, on the lower portion of the bent. The majority of the delaminations were in the original concrete as opposed to previously repaired areas. Several delaminated areas were detected on the bent cap, along with a spall at mid-span on the south face. Light to moderate patching was observed on the pile cap top surface and vertical faces along the top corner (see Appendix D.2A, pp. D.2A-11 - 13).

Bent 154

Significant patching was observed on both columns, the bent cap, and the lower strut. Fairly extensive delamination was detected on the north and south faces of the bent cap. Moderate vertical cracking was observed in the columns, with measured crack widths as large as 0.075". Light to moderate patching was identified on the pile cap around the top edge. Several large delaminations were detected on the vertical faces and top corner of the pile cap. Several large cracks with corrosion staining were noted on the south elevation of the pile cap (see Appendix D.2A, pp. D.2A-13 - 15).

Bent 160

Light to moderate patching was observed on the columns and light patching had been performed on the north elevation of the bent cap. Several large delaminated areas were detected on both the north and south faces of the bent cap, along with a few cracks of widths ranging from hairline to approximately 0.06". Detected delaminated areas were less frequent on the columns, with most delaminations occurring in the original concrete. Vertical cracking in the columns was moderate, with maximum measured crack widths of 0.1". Several efflorescence and corrosion stains were adjacent to these cracks. Extensive horizontal cracking with corrosion staining was observed on the pile cap vertical faces with some crack widths measuring approximately 0.125" (see Appendix D.2A, pp. D.2A-15 - 18).

Bent 161

Extensive patching was performed on the south, west, and east elevations of the columns, while the north elevation contains less extensive patching. Moderate to extensive delaminations were detected on the

north elevations of both columns and the east and west sides of the east column, all of which exist in the original concrete. Moderate cracking with efflorescence and corrosion staining was observed on the columns. The majority of observed cracks exist adjacent to delaminated areas. The bent cap contains light patching and several small delaminated areas, on both the north and south faces. A small spall with exposed reinforcing steel was observed, one on each face of the bent cap. The pile cap contained light patching and moderate to severe horizontal cracking with corrosion staining. Two large (0.25") cracks were observed on each end elevation of the pile cap (see Appendix D.2A, pp. D.2A-18 - 19).

Bent 163

Moderate to extensive patching was observed on the north side of the west column and on the west side of the east column. Extensive delaminations were detected on the majority of the column surfaces. Associated with the extensive column delaminations was fairly significant vertical cracking, with measured crack widths of approximately 0.125". Extensive patching was observed on both the north and south faces of the bent cap, with moderate delaminations detected as well. Fairly extensive horizontal cracking existed on the vertical faces of the pile cap with several locations of corrosion staining (see Appendix D.2A, pp. D.2A-19 - 22).

Bent 164

Light patching was observed on the columns and moderate patching was observed on the north elevation of the bent cap. The delaminated areas detected on the north elevation of the bent cap were fairly extensive, and moderate to light delaminations were found on the remaining portions of the bent. Significant vertical cracking was observed on each column, with corrosion or efflorescence staining and measured crack widths as large as approximately 0.125". The pile cap contained several horizontal cracks, some with corrosion staining and one crack approximately 0.375" in width. A spall with exposed reinforcing steel was also observed on the northwest corner of the pile cap (see Appendix D.2A, pp. D.2A-22 - 24).

## Detailed Visual Inspection of High Level Spans

Span 130

Extensive areas of delamination were detected at the north and south ends of the deck soffit while light areas of delamination were detected at mid-span. Light patching was observed at the north deck soffit and moderate patching was documented on the south deck soffit. Significant spalling and delaminations revealing exposed reinforcing steel were identified at the north and south ends of the deck soffit. Numerous smaller areas of exposed reinforcing steel were observed in spalls at the north end of the deck soffit. Large areas of delamination existed at the sides of the diaphragms. Spalls and exposed strands were detected along the bottom edges of Girder 2. Corrosion staining from aggregates occurred at numerous locations on all girders (see Appendix D.2B, pp. D.2B-1, 2).

Span 132

Extensive areas of delamination were detected at the north and south ends of the deck soffit while moderate areas of delamination were detected at mid-span. Delaminations were observed along the underside of the north diaphragm. Light patching was observed at the north and south deck soffits.

Significant spalling and delaminations exposing reinforcing steel were identified at the north and south end of the deck soffit and at the mid-span deck soffit. Corrosion staining due to aggregates was documented along the length of the deck soffit. Delaminations and spalls were identified on the sides of the north and south diaphragms. Exposed reinforcing steel was documented on the sides of the north diaphragm. A 0.05" wide horizontal crack was identified on the side of the north diaphragm. Corrosion staining from aggregates occurred at numerous locations on Girders 1, 2, and 4 (see Appendix D.2B, pp. D.2B-2, 3).

Span 135

Extensive areas of delamination were detected at the south end of the deck soffit while moderate areas of delamination were detected at the north end. Moderate patching was observed at the north and south deck soffits. Moderate spalling and delaminations exposing reinforcing steel were identified at the south end of the deck soffit and at the mid-span deck soffit. A smaller area of exposed reinforcing steel was observed in a spall at the north end of the deck soffit. Moderate spalls and delaminations in addition to vertical cracks in the range of 0.005" to 0.01" were documented on the sides of the diaphragms. Spalls and exposed strands were detected along the bottom edges of Girders 2 and 3. Spalls were identified at girder ends on Girders 2 and 3. Spalls with exposed strands were documented at the bearing of Girder 2 (see Appendix D.2B, pp. D.2B-3, 4).

Span 136

Extensive areas of delamination were observed at the north and south ends of the deck soffit while light areas of delamination were detected at mid-span. Moderate patching was observed at the south deck soffit. Numerous areas of spalling and delaminations exposing reinforcing steel were identified at the south ends of the deck soffit. Moderate areas of delamination were documented on the sides of the north and south diaphragms. Spalls and exposed strands were detected along the bottom edges of Girders 2 and 3. Spalls and exposed reinforcing steel were identified at girder ends on Girder 1.

Span 140

Extensive areas of delamination were detected at the north and south ends of the deck soffit while light areas of delamination were detected at mid-span. Extensive patching was observed at the south deck soffit. Numerous small areas of patching were documented on the north deck soffit. Significant spalling and delaminations exposing reinforcing steel were identified at the north and south ends of the deck soffit. Light areas of spalling and exposed reinforcing steel were observed along the underside of the south diaphragm. Large areas of delamination were documented on the sides of the north and south diaphragms. The sides of the north diaphragm revealed exposed reinforcing steel. Spalls and exposed strands were documented at the bearing of Girder 2. Corrosion staining from aggregates occurred at numerous locations on Girders 1 and 3 (see Appendix D.2B, pp. D.2B-4).

Span 149

Extensive areas of delamination were detected at the south ends of the deck soffit while light areas of delamination were detected at mid-span. Moderate delaminations were identified on the north deck soffit. Delaminations were observed along the underside of the north and south diaphragm. Exposed reinforcing steel was documented on the sides of the north and south diaphragms. Spalls and exposed strands were detected along the bottom edges of all girders. Spalls and exposed reinforcing steel were identified at

girder ends on Girder 4. Horizontal cracks in the range of 0.05" to 0.075" were documented at the bearings of Girders 2, 3, and 4. Corrosion staining from aggregates occurred at numerous locations on Girder 4.

Span 150

Extensive areas of delamination were detected at the south ends of the deck soffit while light areas of delamination were detected at mid-span. Moderate delaminations were identified on the north deck soffit. Delaminations revealing exposed reinforcing steel were identified at the north end of the deck soffit. Light spalling and exposed reinforcing steel were observed along the underside of the north diaphragm. Delaminations and horizontal cracking exposing reinforcing steel were documented on the sides of the diaphragms. Spalls and exposed strands were detected along the bottom edges of Girder 3 (see Appendix D.2B, pp. D.2B-4 - 6).

Span 161

Extensive areas of delamination were detected at the north and south ends of the deck soffit while light areas of delamination were detected at mid-span. Light patching was observed at the north deck soffit. Exposed reinforcing steel was identified within spalled areas at the south end of the deck soffit and on the sides of the diaphragms. Horizontal cracking was documented along the underside of the north diaphragm. Extensive delaminations and spalling were identified along the underside of the diaphragms. Spalls and exposed strands were detected along the bottom edges of the girders. Spalls and exposed reinforcing steel were identified at girder ends on Girders 2, 3, and 4. Bearings at girder ends were observed to be severely corroded at all girders (see Appendix D.2B, pg. D.2B-6).

Span 162

Extensive areas of delamination were detected at the south ends of the deck soffit while light areas of delamination were detected at mid-span. Moderate delaminations were identified on the north deck soffit. Light patching was observed at the north deck soffit. Significant spalling and delaminations revealing exposed reinforcing steel were identified at the south end of the deck soffit and at the mid-span deck soffit. Numerous smaller areas of exposed reinforcing steel were observed in spalls at the north end of the deck soffit. Spalling and exposed reinforcing steel were observed along the underside of the north diaphragm. Spalls and exposed strands were detected along the bottom edges of Girders 2, 3, and 4. Spalls and exposed reinforcing steel were identified at girder ends on Girder 1. Spalls and exposed strands were documented at the bearings of Girders 1 and 3 (see Appendix D.2B, pp. D.2B-6 - 8).

Span 163

Extensive areas of delamination were detected at the north and south ends of the deck soffit while light areas of delamination were detected at mid-span. Moderate patching was observed at the north and south deck soffits. Significant spalling and delaminations exposing reinforcing steel were identified at the south end of the deck soffit and at the mid-span deck soffit. Smaller areas of exposed reinforcing steel were observed in spalls at the north end of the deck soffit. Moderate delaminations and spalling were identified along the underside and sides of the diaphragms. A 0.025" wide horizontal crack was observed along the bottom edge of the south diaphragm. Horizontal crack widths in the range of 0.05" to 0.1" were detected extending from the bearings of the girders on Girders 1, 2, and 4. Spalls and exposed strands were

detected along the bottom edges of the girders. Spalls and exposed reinforcing steel were identified at girder ends on Girders 3 and 4 (see Appendix D.2B, pp. D.2B-8, 9).

# *Underwater Assessment*

## Overview

An underwater field investigation of the substructure of the Bonner Bridge was conducted by Lochner between April 4 and May 19, 2006. The purpose of the underwater field investigation was to assess the observed conditions of the substructure elements from the water surface to the channel bottom. The investigation began with Bent 2 at the north end of the structure and included either a Level I and/or Level II inspection (as described below) of principal load-bearing elements of the substructure units through, and including, Bent 200 near the south end of the bridge. A Level I inspection was performed on underwater elements and a Level II inspection was performed on at least two piles at each bent from Bent 90 south. Bents 2 through 89 were either over land or in two feet or less of water.

## Methodology

This inspection was not part of the National Bridge Inspection Standards (NBIS) underwater inspection. Field activities were performed between April 4, 2006 and May 19, 2006 by a three-person inspection team. Personnel were rotated due to the length of the assignment, but at any given time, there were a minimum of two experienced, NBIS qualified team leaders present. An underwater (diving) investigation was performed at Bents 89 through 200. A combination of surface-supplied air diving equipment and commercial SCUBA diving equipment was used and diving operations were staged from Lochner's 25' long boat. The inspectors used underwater lights and hammers during the inspection. Underwater photographs were taken using an Olympus digital camera in an Ikelite waterproof housing.

The underwater investigation consisted of two levels of inspection effort as defined by the Federal Highway Administration's Bridge Inspector's Reference Manual and Underwater Inspection of Bridges Manual.

A **Level I** inspection effort, consisting of a visual and tactile swim-by of the submerged elements with no surface cleaning, was performed on 100 percent of the piling in Bents 89 through 166. The higher number bents (Bents 167 through 200) all had additional support elements or crutch bents to supplement the original substructure units. For these higher number bents, the scope of the investigation included Level I inspection of the most recent crutch bent elements. This effort was designed to detect major structural damage or distress.

A **Level II** inspection effort was performed on a minimum of two piles at each bent. This technique included removal of marine growth in one foot high bands around the pile perimeter at three locations: the low water line, near the mud line, and midway between the low water line and the mud line. For the 66" diameter piles in the south approach crutch bents, two of the four piles were given a Level II inspection, which consisted of scraping one foot high by one foot wide patches at four locations around the pile perimeter, at three elevations: the low water line, near the mud line, and midway between the low water line and the mud line. Marine growth was removed using inspection hammers and pneumatic chipping guns fitted with a wide scraping blade. Refer to the Table 1, "Level II Inspection Locations Table" in Appendix G for a list of the piles given a Level II Inspection effort.

**Level III** inspection efforts, which consist of performing physical measurements, non-destructive testing, or partially destructive testing on a limited but representative sampling of components, were not within the scope of this investigation.

Soundings were not required nor were they taken along the bridge fascias; however, maximum water depths were obtained by the inspection divers at each bent using their depth gauges. Refer to Table 2, "Approach Bent Water Depths" and Table 3, "High Level Bent Pile Exposure Heights" in Appendix G for the water depth measurements obtained by the divers.

The complete underwater assessment is included in Appendix G.

## Summary of Findings

The following paragraphs summarize the findings and the repairs recommended as a result of the underwater assessment.

There was widespread vertical cracking throughout the original 22" octagonal prestressed concrete piles from Bent 55 southward, with cracks typically up to 1/16" wide. Vertical cracks over 1/16" wide were observed on the following piles: 66-1, 95-3 and 95-4.

At Bents 108 through 123, the original bridge bents have been supplemented with steel H-pile crutch bents on either side of the original bent. From the high water mark down, the steel H-piles have patches of corrosion loss and light to moderate areas of corrosion, but no significant loss of cross-section.

The original bridge between Bents 123 and 129 was replaced after a vessel collision in 1990. The replacement substructure elements (Bents 124 through 128B) appeared in good condition with no observed deficiencies; however, two piles on Bent 128A had been previously jacketed below the waterline.

Bents 129 through 166 are located in the high level spans. The piles and the undersides of the pile caps for these bents were inspected. At six of the pile caps of these bents, the lower edges were spalled and exhibited exposed reinforcing steel. At more than half of these bents, the undersides of the pile caps had cracks up to ¼" wide which generally ran parallel to the pile cap perimeter. Salt water is penetrating the concrete and causing corrosion of the reinforcing steel resulting in the large cracks and the spalls in the edges of the pile caps. It is recommended that the spalls in the pile cap edges be repaired.

The piles in the high level bents exhibit widespread vertical cracking, most of which is 1/16" wide or less. The most severe pile deterioration is at Bents 144 and 146. Piles 144-2, 144-9, 146-6, 146-12, and 146-16 had significant spalling of the cover concrete (the outer 3-1/2"); Piles 146-6, 146-12, and 146-16 had exposed reinforcing and prestressing strands. Similar spalling was observed on Pile 129-5. It is recommended that these six piles be jacketed to repair the spalls. There was horizontal cracking to 1/8" wide in Piles 129-5, 146-13, 146-17, and 146-20 near the cap. Pile 159-7 was observed to have apparent deterioration of two splices below the waterline. It is recommended that the upper splice on Pile 159-7 be repaired with a jacket. It is recommended that a total of seven piles be repaired with jackets: Piles 129-5, 144-2, 144-9, 146-6, 146-12, 146-16 (two locations), and 159-7.

At Bents 167 through 172, and Bents 187 through 200 the original bents have been supplemented with crutch bents. At each bent, the new crutch bent consists of several subcaps supporting the original bent cap with the subcaps resting on precast AASHTO sub-girders. The AASHTO sub-girders are in turn supported on piles caps at the east and west ends of the bent. At each of the pile caps there were two 66" diameter concrete piles. As requested, only the 66" diameter concrete piles and the portions of the pile caps that were below the high water mark were inspected by the dive team. No significant deficiencies were observed on the large diameter piles. Nearly all the caps, however, exhibit widespread horizontal cracks, typically to 3/16" wide but observed up to ¼" wide, and generally located between 1' and 1.5' above the lower edges. The cracks are predominantly located in the north and south faces of the pile caps, but several of the cracks extend around the corners into the east and west faces. Similar to the high level bent pile caps, the cracks were likely caused by salt water infiltration into the concrete and will eventually lead to reinforcement corrosion and spalling of the lower edge. It is recommended that spalls in the pile caps be repaired as they occur.

At Bents 173 through 186, the original bents have been supplemented with crutch bents comprised of 20" square prestressed piles to support the existing original pile bent cap. As requested, only the new square piles were inspected at these bents. Thirteen of the square piles exhibited cracks from hairline width up to 1/8" wide. The only observed crack over 1/16" wide is on Pile 186-6. Pile 174-1 has a delaminated area in its southwest edge near the waterline. It is recommended that the delamination in Pile 174-1 be repaired