City of Bellingham Wood-Stave Intake Pipeline: Condition Assessment (Task 2.1.5)

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4. Summary of Repair Work from 2002
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1. Introduction

As part of its overall efforts to assess the condition of its supply facilities between Lake Whatcom and its Whatcom Falls Water Treatment Plant (WTP), the City of Bellingham (City) undertook an assessment of the condition of the existing 72-inch diameter wood stave intake pipe that extends approximately 1,225 feet into Basin 2 of Lake Whatcom from the City’s Gate House facility. The wood-stave intake has provided the City excellent service over the years, was inspected and rehabilitated in 2000 and 2002, respectively, and has continued to function effectively.

The purpose of this work is to document the current condition of the intake pipeline, including the rehabilitation improvements implemented in 2002, identify repair needs, develop estimated costs for those repairs (if any repair needs are identified), and develop a rehabilitation and inspection strategy. As is the case for each of the key facilities that comprise the City's water supply system between Lake Whatcom and the WTP, there are no redundant facilities for the wood-stave intake pipeline. As a result, its continued reliable service is essential to enabling uninterrupted supply to the City's customers.

This report documents the in-water inspection work completed in June of 2014. A key element of this documentation is the dive report prepared by the dive inspection subcontractor for this project, Ballard Marine Construction. The Ballard Marine Construction report that documents their in-water inspection activities is presented as Appendix A to this report.

2. Description of Existing Intake Pipeline

The wood-stave intake pipeline was constructed in 1939. It was constructed within the same time frame as the adjacent downstream Gate House, tunnel, and Screen House. These four key facility elements comprise the Bellingham's primary water supply transmission system for both municipal needs as well as industrial needs on Bellingham's waterfront. The key components of the City's current water supply system are shown in Exhibit 2-1, along with the pipelines that extend from the Screen House to the City's single industrial supply user and to the City's WTP.

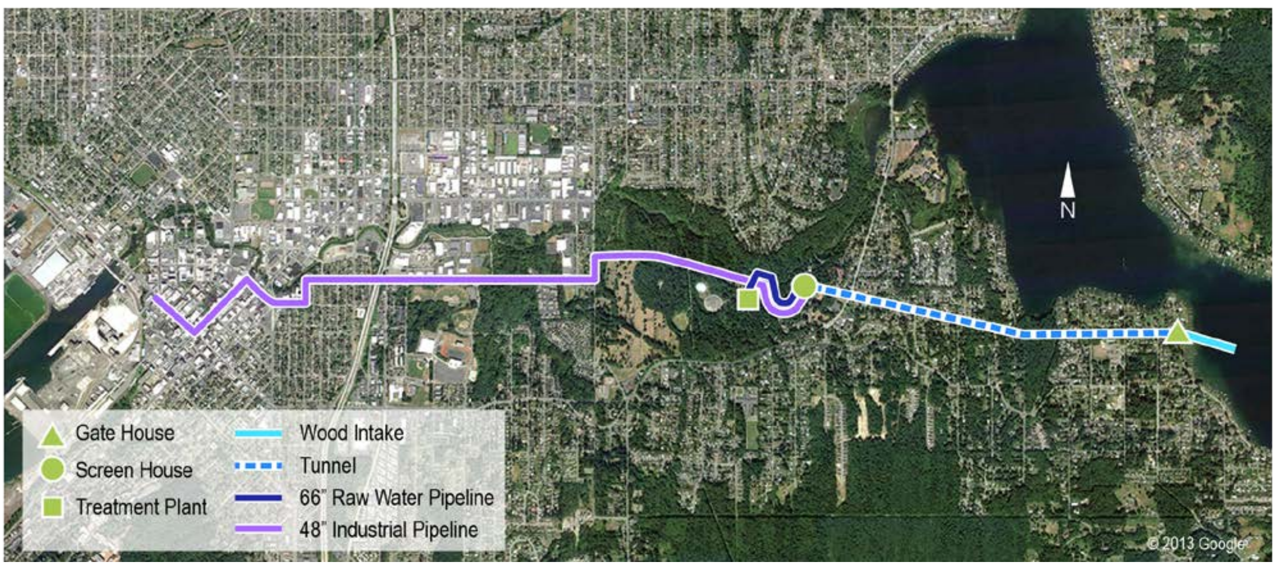


Exhibit 2-1. City of Bellingham Water Supply Facilities

Approximately 350 feet of the 1,225 linear feet of wood-stave intake pipeline are buried in the shore of Lake Whatcom. As the water depth becomes deeper, the rest of the intake pipeline is supported on 44 bent structures spaced at twenty feet. The bent structures are comprised of two wood piles, a wood cross member, and a concrete saddle that serves as a weight to keep the intake pipeline in place. Concrete saddle weights are also attached to the underside of the pipe half-way between each of the bents (originally by two steel rods and more recently by two stainless steel straps).

The intake to the pipeline is set at a point where the water depth is approximately 40 feet above the lake bottom. This intake is surrounded by a submerged timber crib structure measuring approximately 12.5 feet wide by 12.5 feet long and 8 feet tall. This timber crib serves to keep large debris and objects from entering the intake pipeline. With 9-inch wide openings, it does not prevent fish and smaller debris and objects from entering the intake pipeline. The timber crib structure is shown schematically in Figures 3 through 6 of the Ballard Marine Construction dive report included as Appendix A.

Detailed description of the existing intake is presented in Appendix B. This description is excerpted from Golder and Associates' September 2000 report documenting their inspection of the wood-stave intake pipeline. The description addresses that project's week-long efforts to collect samples, collect video documentation, conduct a geophysical investigation of the lake-bottom, and use of a submersible remove-operated-vehicle (ROV).

Two drawings of the intake pipeline from the same 2000 condition assessment work by Golder and Associates are presented in Appendix C. On the second of the two drawings, there is a cross section detail and a longitudinal section detail, from the original design drawings. Other than these two section details, the original design or as-built drawings for the intake pipeline were not available for this work. A schematic diagram of the intake pipeline, modified from work done by Golder and Associates, is presented in Figure 1.

3. Description of Prior Work

The City has inspected and maintained the wood stave intake pipeline at various times over the years since it was first installed in 1939. At the time this memorandum was originally drafted, the only available documentation of recent inspection and repair work on the intake pipeline was from 2000 and 2002. Reports developed from these timeframes are summarized briefly in the following sections. The 2000 report references previous inspection work on the intake pipeline, including:

- 1984 – Video inspection (partial inspection)
- 1998 – Video inspection (partial inspection)
- 1998 – Harza Engineering Company, Intake Report

These video inspection documents from 1984 and 1998 and intake report from 1998 were not originally available for this work. However, the 1998 Harza Engineering Report was discovered prior to finalizing this report. The 1984 and 1998 videos were not discovered. The reports from 1998, 2000, and 2002 are summarized below.

3.1 1998 Harza Engineering Intake Report

The Harza Engineering Report consisted of a detailed review of the video inspections completed in 1984 and 1998. Harza Engineering was also apparently provided the original design and as-built drawings for their review. These original drawings appear to no longer be available.

Key aspects and findings from the Harza Engineering Report worthy of note, include the following:

- Stainless steel straps were installed prior to 1984, apparently to provide supplemental pipeline banding restraint (supplemental to the original carbon steel pipe bands). It is unclear whether additional stainless steel straps were installed after 1984.
- Some stainless steel straps were installed prior to 1984 to restrain some of the anchor weights that had become detached from the intake pipe because their carbon steel restraint rods had corroded. Note that additional stainless steel restraint straps were installed on more anchor weights in 2002.
- There was no documentation available in 1998 related to the stainless steel straps (When they were installed? Why they were installed? What design criteria was used for tensioning, spacing, and size of the straps?).
- The spacing of the stainless steel straps on the intake pipeline was not defined. The report does indicate more stainless steel straps installed on the in-shore portion of the pipeline.
- Harza Engineering noted that the condition of the buried portion of the intake pipeline is not known. They expressed concern regarding this portion of the pipeline.
- Harza Engineering recommended the City consider developing an alternative supply source.

3.2 2000 Golder and Associates Investigation Report

In 2000, Golder Associates Inc. in coordination with Komax International Ltd. and Can-Dive Construction Ltd. completed a condition assessment of the intake using commercial divers to inspect the exterior of the pipe, and a free-swimming ROV to inspect the interior of the pipe (*Engineering Services - Water Intake - For Underwater Investigation and Evaluation of Whatcom Lake. Golder Associates Inc. September 2000*). During the assessment the divers recorded visual observations of the pipe components, used hammer taps on the wood staves to check for soft areas, and cleaned portions of the pipe with intermittent water blasting and scraping of the wood exterior to expose the sound wood underneath.

As part of the assessment, the divers also extracted core samples from the wood staves in order to conduct tests on the physical properties of the wood and look for signs of degradation. In addition, they collected samples of corroded metal fittings, screws, and the original carbon steel hoops that were used in the construction of the original pipe. The core samples exhibited the properties of "sound wood" and no clear indicators of deterioration were observed. The metal fittings and hoops however, were severely corroded and one of the recommendations of the report was to reinforce much of the pipeline with stainless steel straps.

Some of the other inspection work tasks included a geophysics investigation with bathymetric survey, sediment depth readings, and measurements of the pipe alignment in relation to the lake floor and shoreline. These readings were to provide a baseline against which future measurements could be compared to evaluate the possibility of settling of shifting of the pipeline. The interior ROV inspection used sonar technology to produce cross-section scans of the inside of the pipe to look for deformation or debris accumulation. No significant deformation or sediment buildup was observed. The overall condition of the pipe from this assessment was good, and the report provided recommendations for minor repairs and reinforcing with steel straps, as well as guidelines for long-term inspection and maintenance.

The report also noted the supplemental stainless steel flat straps that had been installed at some time previous to provide restraint supplemental to the original carbon steel hoop rods serving as the primary pipe bands. There is no indication of the spacing of these straps other than to indicate more of them in-shore than farther out in the lake.

3.3 2002 Golder and Associates Design Report

In early 2002, the findings and recommendations of the 2000 report were used to produce the final design report for the underwater repairs project, (*Underwater Repairs for the Lake Whatcom Water Intake Pipeline, Golder Associates Inc., January 2002*). The report included an alternatives evaluation for implementation of the repairs, including reinforcement of the flanged areas, steel strap installation, concrete ballast strapping, replacement of missing/broken piles, new ballast mats, and repair of damaged bent support members. The report also included permitting, cost, and schedule analysis as well as technical plans and specifications for executing the work.

This report (Section 3.2) indicated that the approximate spacing of the existing (existing at the time of the 2002 report) supplemental stainless steel straps was 3.5 feet along the length of the intake pipeline. The stated plan in Section 3.2 was to install three additional stainless steel straps between each pipe bent. This corresponds to roughly 130 new stainless steel straps between each bent. This was to be in addition to installing two new stainless steel straps to restrain concrete anchor weights that were continuing to be restrained by the original carbon steel rods that were noted to be corroded.

3.4 2002 Golder and Associates Construction Report

In October 2002, Global Diving & Salvage, Inc. performed the underwater repairs and collaborated with Golder & Associates to produce a log of the construction activities performed (*Summary Report of Construction Work for Underwater Repairs for the Lake Whatcom Water Intake Pipeline. Golder Associates Inc., October 2002*). As part of the work, the contractor installed several stainless steel straps (leaving the carbon steel hoops in place), repaired and installed new timber piles, repaired flanges, installed wear plates at the cable crossing, repaired bents and wedges, trimmed piles, and installed new articulated concrete ballast weight mats. They also installed stainless steel alignment screws at specific locations along the pipeline, with the intent that future inspections could verify the alignment of the screws and check for settling or shifting. No additional core samples or internal inspection work was performed as part of the construction. The report included daily construction logs, record drawings, daily construction logs, and photographic documentation of the work.

A key aspect of the construction report is that in Section 2.1 of the report, it indicates that approximately 176 stainless steel bands were installed. This number of new bands would appear to indicate that the supplemental stainless steel bands indicated in the 2002 design report (3 new SST bands per pipe section between bents) were, in fact, installed. It is understood that approximately 114 new stainless steel bands were installed to restrain concrete weights. There is no indication, however, in the more detailed construction summaries in Appendices B and C of the 2002 construction report that these supplemental bands were installed. There is indication in these appendices that approximately 57 concrete weights were restrained with two additional stainless steel straps, each.

4. Summary of Repair Work from 2002

As the City inspects, monitors, rehabilitates, and maintains the existing wood-stave intake pipeline, and documents these activities, it is critical that actual physical improvements implemented be tracked into the future. Rehabilitation improvements must be inspected in regular future condition assessments, so that the effectiveness of these rehabilitation approaches can be evaluated for repeat-use on other portions of the intake system, or for replacement with other rehabilitation approaches that are more effective. Over the near-term and longer-term future many elements, in particular the metal parts, of the intake pipeline and support structure will need rehabilitation and replacement to keep the intake system in a serviceable condition.

The 2000 Golder and Associates report included improvement recommendations for the City to address the findings of the 2000 inspection work. The 2002 Golder and Associates report documents the design and contract documents for implementing the recommended improvements. The 2002 report also included evaluation of optional approaches for some of the recommended improvements. The repair recommendations from the 2002 Golder and Associates report, included evaluated approaches not implemented, is presented in Appendix D. Not all of these repair recommendations were implemented as originally conceived, but deviations from the original design were relatively minimal. The 2002 Golder and Associates Construction Report from October 7, 2002 documents the work actually completed. Detailed drawings, summary tables, photographs, and daily construction log narratives are included in the construction report that thoroughly document the work completed. A summary table (identified as "Appendix C" from the original report) from the October 2002 construction report reflecting work completed is included as Appendix E to this report.

A summary of the improvements actually implemented include:

- **Steel Flange Joints:** Flexible corrosion-protection coating was applied, and the corroding carbon steel nuts and bolts were replaced with stainless steel nuts and bolts.
- **Near Shore Transition Area:** The near-shore transition area relates to the 75-foot long area where the pipeline transitions from being buried in the lake bottom to being exposed and supported on bents. The improvement approach included adding articulated concrete ballast mats and stainless steel bands.
- **Concrete Ballast Weights:** Where concrete ballast weights under the pipeline were still connected by the original steel rods to the pipeline, new stainless steel straps were added to hold these weights and keep them from dropping from the underside of the pipe upon failure of the original rods. At two locations in between bents, where original saddle weights were missing (already fallen to the lake bottom), articulated concrete ballast mats were placed over the top of the pipe. Several concrete

ballast weights at bent locations were not restrained with stainless steel straps because there was insufficient clearance between the weights and the horizontal bent members.

- **New Pile Installation:** New pile was installed at Bent 18. Sheared pile at Bent 35 was retrofitted with a new stainless steel pipe clamp over pile.
- **Bent Repairs:** The tops of near-shore bent piles were cut because they extended to within a few feet of the water surface (safety and damage concerns). Other bent repairs were implemented as well as several bents, including new bent-support wood and metal hardware, new support saddles, and other miscellaneous improvements.
- **Cable Crossing Protection:** Thin, HDPE wear plate material was placed under each cable crossing to avoid potential cable wear on the wood staves of the pipeline.
- **Supplemental Stainless Steel Straps:** As described in Section 3 above, it is unclear whether additional supplemental stainless steel straps were installed on the pipeline as pipe bands. The total number of stainless steel bands cited in the 2002 Golder construction report as being installed suggests that some additional bands were installed.

These improvements from 2002 were observed during the June 2014 inspection, and the assessment of the condition of these improvements is presented in Section 6.

5. Inspection Approach

The wood-stave intake pipeline was inspected over the course of three days beginning on June 24, 2014. The exterior of the intake pipeline was inspected on June 24 and 25. And, approximately 400 linear feet of the interior of the pipeline was inspected on June 26 from the on-shore Gate House. Access into the intake pipeline was via the Gate House wet well.

Ballard Marine Construction conducted the underwater dive inspection as a subcontractor to CH2M HILL. CH2M HILL's condition assessment lead was present during the inspection along with the City of Bellingham's water treatment plant operations lead to provide direction to the Ballard Marine Construction dive team. City and CH2M HILL staff observed from Ballard Marine Construction's dive boat. Ballard Marine Construction prepared a dive inspection report, which as referenced above, is included as Appendix A to this report. The underwater dive was also documented on video.

Specifically, the scope of the inspection work included:

- External components of the intake in an offshore-to-inshore direction, beginning at the intake crib. The inspection included the wood stave surface, carbon steel bands, hardware, stainless steel straps, pile bents, cross and support braces, and ballast weights. Special attention was given to the condition of the carbon steel fittings and carbon steel hardware.
- Soundness testing with a hammer along the pipe's external surface.
- Intermittent water blasting to expose the condition of the pipe, fittings, and hardware.
- A hydraulic drill and hole saw to take two wood stave pipe core samples. The voids left by the core samples were plugged with 2" mechanical plugs.
- Recovered broken carbon steel bands for further inspection.
- Measured sediment depth, pipe-to-pile, and pipe-to-sediment at each bent to check for shifting from prior inspection in 2000.
- Visually inspected and photographed the cable crossing.

- Visually inspected the internal components of the wood stave intake pipe, beginning from the Gate House entrance to a distance of 400 linear feet. Special attention was given to the internal flanges, fittings, and biological growth.
- Performed soundness taps and wood scraping to assess the condition of the internal wood staves.
- Intermittently took internal horizontal and vertical measurements to check for intake deformation.

6. Summary of Field Observations

Details of the inspection findings are presented in the Ballard Marine Construction report in Appendix A. These field observations are further summarized in the table in Appendix F. Summaries are presented in the following sections of these main elements of the intake system:

1. Wood
2. Metal bands
3. Metal fasteners
4. Pipe flange Joints
5. Concrete weights
6. Pipe deformation
7. Cable crossings
8. Stainless Steel Bent Repair Materials
9. Pipe Plugs
10. Timber crib
11. Biological growth
12. Buried Pipe

6.1 Wood

All wood components of the intake structure were observed by the diving team. Periodically, the soundness of the wood was checked by wrapping with a hammer. A thin layer of soft wood was observed. No signs of wood rot or significant deterioration was found on any of the crib structure, bent pile components, or wood staves.

Two core samples were removed from the wood stave pipe – one near Bent 22 and one near Bent 44. The samples were found to have a thin, soft layer on the external surface (less than ¼-inch), but the remaining portion of the wood was hard with no other signs of deterioration. A laboratory analysis of the core samples was performed to evaluate the physical strength of the wood. The results of this work is summarized later in this report.

6.2 Metal Bands

Metal bands refer to the steel elements that are wrapped around the wood-stave pipe to hold the pipe together. These elements are comprised of round carbon steel rods that were installed on the original wood-stave pipeline at 6-inch intervals along the length of the pipeline and stainless steel straps that were installed at some time prior to 1999.

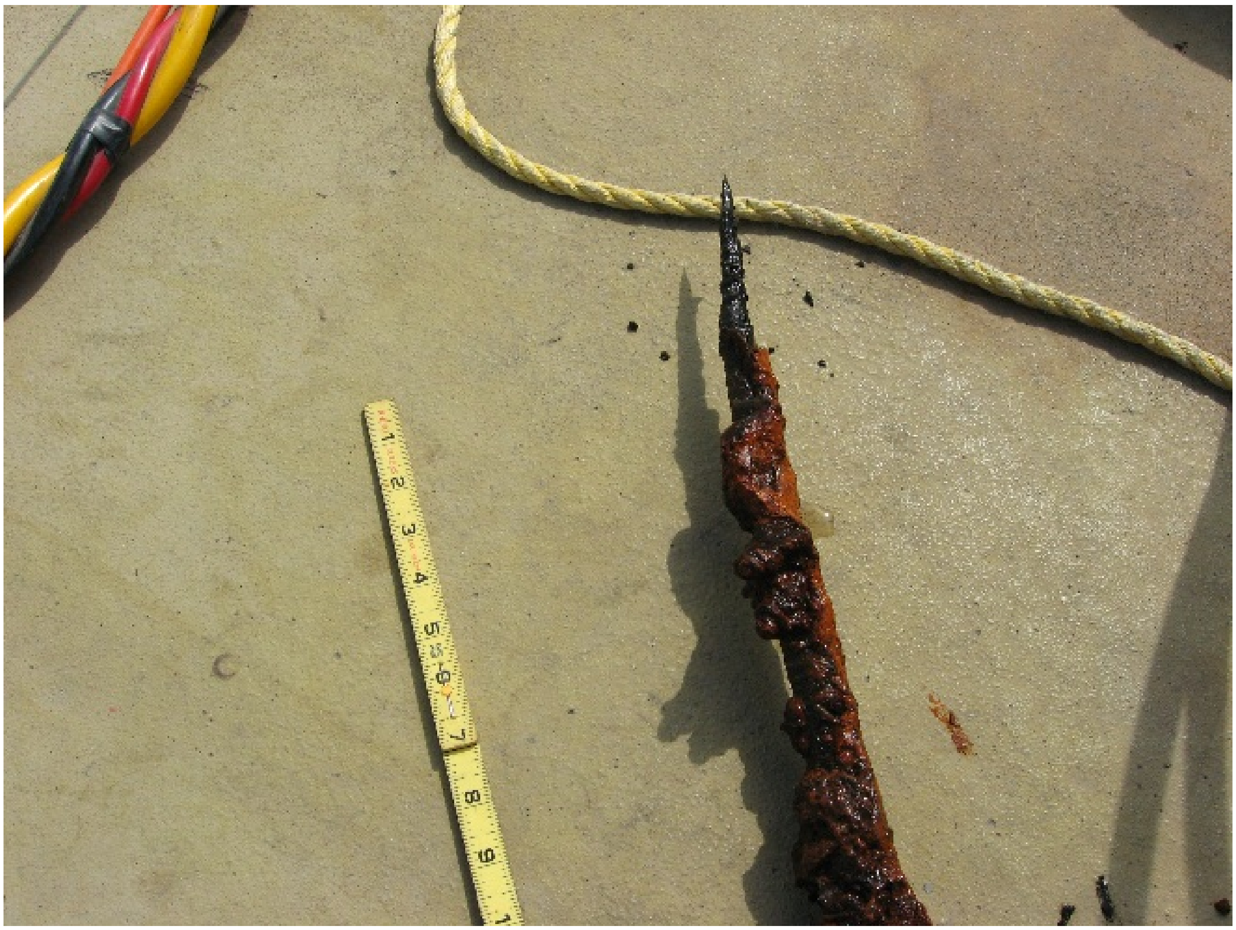
6.2.1 Original Steel Rods

The 2000 Golder and Associates reports identified carbon steel bands or rods (‘hoops’) at approximate 6-inch spacing along the full length of the pipe. This approximate 6-inch spacing was confirmed by the diving team during this inspection.

The carbon steel hoops consist of a 5/8-inch diameter rod with a button head on one end and threads on the other. Metal “shoes” are used to join the bands and allow them to be tightened and cinched tight around the wood stave pipe. Each individual full circumference hoop consists of two half circular rods with connecting shoes.

The carbon steel hoops are subject to corrosion, and very heavy corrosion products were observed on all of the carbon steel hoop components (rods, shoes, and nuts). The corrosion products were removed from a typical intact retaining rod by high pressure water jetting. The shoe was found to be severely corroded, while the threaded portion of the rod and the nut had some remaining thickness (see Photograph No. 14 in the Ballard Marine Construction report in Appendix A).

Three pieces of broken rods that were recovered from the pipe, which still appearing to be attached and connected around the circumference of the pipe, exhibited excessive thinning, which resulted in actual failure of the hoops at some time in the past, as reflected in Photograph No. 1. What is important from this information is not only that the original rods holding the wood-stave pipe together are in an active, advanced state of corrosion, but likely many of the rods that appear to still be holding the pipe together are actually already broken at some point, and are only hanging on the pipe.



Photograph No. 1 – Failure of Original Pipe Band

Overall, 13 of these hoop rods were observed to be missing or broken during the 2000 inspection. An additional 8 broken or missing hoops were observed during this inspection. Whether these were additional to the 13 observed in 2000 or some of the same is not clear, and is also not critical information. As stated above, additional hoops are likely already broken or very near failure, but were not observed as such because they are still intact around the pipe. Some failed hoops may be held in place only by corrosion products. The original steel rods should be considered to be entirely or nearly entirely at failure and in need of replacement. The subject of how these should be replaced is presented in Section 8.

6.2.2 Supplemental Stainless Steel Straps

The 2000 Golder and Associate reports also identified flat stainless steel straps around the pipe at regular locations along the full length of the pipe. The stainless steel straps are ¾-inch wide and appear to be austenitic stainless steel, based on previous tests and observations by Golder and Associates. Austenitic stainless steel refers to the 300-series of stainless steel, which has excellent corrosion-resistant properties. The two most common types of 300-series stainless steel used are 304 and 316. Presumably the supplemental stainless steel straps at 3.5-foot intervals (as reported in the 2000 Golder and Associates inspection report) along the length of the pipeline is either 304 or 316.

The installation date of these stainless steel straps is unknown beyond the fact that it pre-dates 2000 and a referenced March 22, 1999 Harza report (referenced in Section 1 of the 2000 Golder and Associates report). One band near the crib exhibited surface corrosion. Some straps had a slight discoloration, but most of the stainless steel straps were bright and shiny under a thin layer of silt deposit. None of the stainless steel straps exhibited signs of significant deterioration and all of the straps of the pipe appeared to be intact and tight.

While additional 316 stainless steel straps were used in the 2002 repairs to support concrete ballast weights (discussed below), it is unclear whether additional such straps were installed in 2002 for supplemental support of the wood-stave intake pipeline. That stated, the spacing observed during the June 2014 dive inspection appears to be approximately 2 feet along the length of the intake pipeline, not the 3.5-foot interval reported in the 2000 Golder and Associates inspection report. This reduced-spacing suggests that additional straps were installed in 2002. But, there is variation in the spacing of the stainless steel straps, as observed in the June 2014 inspection. The interval is not consistent along the length of the pipeline, and appears to be somewhere between a minimum of 2 feet and a maximum of 3.5 feet.

6.3 Metal Fasteners

Wood components at the crib and pipe support bents are connected with metal fasteners. These metal fasteners are comprised of threaded carbon steel rod and nuts or carbon steel nuts and bolts. Heavy corrosion products were observed on the exposed surfaces of the steel fasteners, and it appeared that the corrosion products were heavier on metal components located further offshore.

When the corrosion products were removed by the divers, the flats on the nuts and bolt heads were still discernable, as were the hardware threads. This is consistent with previous observations and tests by Golder and Associates, in which a bolt removed from Bent #37 was observed and tested and found to be in serviceable condition.

6.4 Pipe Flange Joints

There are two carbon steel pipe flange joints installed as part of the original intake design and construction. Their primary purpose appears to be to enable a change of slope in the intake pipe at these two locations. These two pipe flanges are between Bents No. 40 and 41 and between Bents No. 27 and 28.

The exterior surfaces of the metal flanges were found to be corroded by Golder and Associates in the year 2000 project. The metal flanges were cleaned and coated with a petroleum wax tape, and the fasteners were replaced with stainless steel bolts and nuts. Stainless steel straps were installed over the wax tape at terminations on each side of the joint to secure it to the pipe.

The petroleum wax tape was found to be generally intact. However, some of the stainless steel bolts were protruding through the tape and some of the tape appeared to slightly dislodged and no longer in contact with the metal surface of the flange. The reinforcing fabric of the tape also appeared to contain less wax than would be expected.

A portion of the tape was gently pulled back by the divers to allow visual examination of the metal surfaces of the flange. The stainless steel bolts were found to be in excellent condition. The carbon steel surface of the flange exhibited some rust formation, but did not appear to be substantially more corroded than previously observed in 2000, as presented in Photograph No. 24 from the June 2014 inspection in the Ballard Marine Report in Appendix A). The tape was placed back in its original position after the observations were made.

The condition of deteriorated welds observed in the 2000 work were not observed by divers during this inspection, since it was not possible to remove the wax tape from these areas without cutting or damaging the tape. The wax tape is in fair condition with bolts, nuts, and portions of the joint flanges protruding. The wax tape protective coating should be replaced to continue protection of the flange joints.

Stainless steel alignment screws were installed on each side of the flanged joint. These screws were still aligned, indicating no movement of the joint has occurred since the screws were installed in 2002.

6.5 Concrete Weights

Ballast weights are installed along the full length of the intake pipeline. Generally, the ballast weights consist of a concrete block attached to the pipeline at each bent and one concrete block attached to the pipeline approximately mid-way between bents. The majority of the concrete blocks were secured to the pipeline with two stainless steel straps (316 stainless steel, per the 2002 Golder and Associates design specifications), which were installed as part of the 2002 repair project. All of the stainless steel straps securing concrete weights were intact.

Stainless steel straps were not observed around twelve of the concrete weights at the bents. According to the Golder and Associates reports, the concrete weights were resting on the wood cross beams under the pipe at these locations. There was insufficient gap between the bottom of the concrete weight and the top of the wood beam to allow placement of stainless steel straps. The original steel rod hoops supporting these weights appeared, in some cases, to be intact, but in others it was not clear whether the rods were broken at some point around the pipeline. These steel rods are at or near the end of their service life and their connection to the concrete weights should be considered only temporary, at most.

Articulated concrete ballast mats were installed near the transition area (approximately 75 feet of intake pipeline length) where the intake pipe goes from being fully-buried to being exposed and supported on bents. It appears that these mats were installed to provide supplemental restraint to the pipe in the event that the carbon steel hoops fail. Articulated concrete mats were also placed over the pipe near Bents 27 and 29 to replace a missing weights. All of the articulated concrete ballast mats were found to be intact and in very good condition.

The 2002 Golder and Associates design report recommended installation of stainless steel straps in 75-foot long transition area, in addition to the ballast mats installed. They recommended pulling these straps under the pipe, where the pipe is partially buried, by attaching the straps to the original carbon steel rods, and pulling the carbon steel rods from the opposite side of the pipe. However, the stainless steel replacement straps were not observed in this transition area. Stainless steel straps in this area are also not indicated anywhere in the 2002 Golder and Associates construction summary report. Therefore, it is assumed, that this replacement did not occur. The reason the stainless straps were not installed in this transitional area is not clear, but it is presumed that the approached described in the 2002 design report was subsequently determined to be not feasible. The need for re-banding of this transition portion of the intake pipe is similar to the need to address the buried portion of the intake pipeline. Refer to Section 8.5 for discussion of alternative approaches to address the buried portion of the intake pipeline.

6.6 Pipe Deformation

During the internal inspection, the divers made manual horizontal and vertical measurements of the pipe diameter to check for deformation up to 400 feet from the Gate House. No measurable deviation from the original round configuration of the pipe was observed. The pipeline does not appear to be experiencing any deformation in this buried section. No such measurements were collected for the unburied portion of the intake pipeline, but no obvious pipe deformation was observed.

6.7 Cable Crossings

The intake pipeline is crossed by four underwater cables. Three of these cables pass over the top of the pipe and one crosses underneath. High density polyethylene (HDPE) pads were secured to the pipe under the cables that cross over the top of the pipe to reduce the potential for abrasion and wear of the wood by cable movement. Two of the three cables were found centered on the wearing pads. The third cable, a 2-inch cable just off-shore of Bent 23, was not on the wearing pad. It was pried back onto the pad by the divers. There was no damage to the pipeline from this “wayward” cable. The City should consider restraining this cable if it is found to be off its pad in future inspections.

6.8 Stainless Steel Bent Repair Materials

Repairs were made to components of Bent 35 where the south pile was broken. Repair materials included a two-piece Type 304 stainless steel pile clamp with stainless steel hardware. All of the stainless steel components were found to be in good condition.

6.9 Pipe Plugs

Pipe plugs were previously installed during the 2000 inspection at six locations where core samples of the wood stave pipe were collected. All of the pipe plugs were in place and tight.

6.10 Timber Crib

The timber crib structure is shown in Figures 3 through 6 of the Ballard Marine Construction Report in Appendix A. The condition of the beams comprising this structure appeared to generally be good with no signs of significant rot or deterioration. The carbon steel nuts and bolts were heavily corroded, as observed in other locations on the intake. However, the corrosion products on these fasteners appear to be heavier than those at other locations, particularly closer to shore. The actual condition of these fasteners is uncertain. No samples were collected for observation and testing.

6.11 Biological Growth

Although much sediment and settled organic material (likely algae) was observed on the exterior of the intake pipe and timber crib, negligible biological growth was observed to be adhered to these wood surfaces. However, on the interior of the intake pipeline, sponge-like growth was observed in spot locations evenly throughout the 400 linear feet from the Gate House that was inspected. It is known that in some cases, sponges can develop of a micro-habitat between the sponge and the wood that facilitates the growth of bacteria and fungi. However, this is generally not known to be a major source of wood degradation. In the case of the 2014 inspection, hammer taps by the diver on the sponge-covered areas indicated that the underlying wood remains sound.

6.12 Buried Pipe

Soil corrosivity measurements were made to estimate the potential for corrosion of the original carbon steel hoop rod hoops where the pipe is buried in the lake bottom near the lake shore and on shore near the Gate House. Soil resistivity in this area was measured by the Wenner 4-pin method at depths of 2.5, 5, 7.5, 10 and 15 foot depths. The test results indicate the soil resistivity ranges from 4,400 to 9,100 ohm-cm. Soil in this resistivity range indicates the soil is moderately corrosive. However, lack of oxygen in the buried condition will tend to decrease corrosion rates below what would be observed in the underwater, exposed lake condition.

Despite the lack of available oxygen, based on the moderate corrosivity of the soil, it can be assumed that the buried metals, including the pipe hoop rods, will have corroded to some degree – likely somewhat less than what has been observed in the underwater, exposed lake condition. However, this assertion would need to be confirmed by direct inspection of a portion of the buried metal hoop rods.

Inspecting the buried metal hoop rods could be undertaken in one or more spot locations. Conducting such a direct inspection will present challenges related to groundwater, but would have high value because the rate of corrosion of the buried metal hoop rods can be expected to be relatively consistent throughout. The reason for this relatively consistent rate of corrosion is that the pipe is in a consistently-submerged condition lacking oxygen. If direct inspection of the metal hoop rods can be achieved, it will provide a minimum level of supporting data to inform whether or not an improvement approach is necessary for the buried portion of the intake pipeline is necessary.

7. Laboratory Analyses

Laboratory analyses (strength tests) were conducted on two core samples taken from the wood stave pipe. These samples were taken at bent numbers 20 and 44 of the intake pipeline. Laboratory analysis was also completed on a single, isolated unknown concretion that was observed during the interior inspection of the wood-stave pipeline at approximately 20 linear feet from the Gate House. The results of these analyses is presented in the following sections.

7.1 Wood Strength Test Results

The two samples were tested by Dr. Mark Tuttle, PhD, professor of Mechanical Engineering at the University of Washington. Coincidentally, Dr. Tuttle also strength-tested core samples of the wood-stave pipeline that were collected during the inspection in 2000.

The wood that comprises the wood staves of the intake pipeline was identified as western red cedar by the University of Washington, College of Forest Resources staff per the report dated January 30, 2000 included as Appendix G. This identification was not duplicated, nor confirmed for the analyses completed in 2014. Biological and strength laboratory analyses from the 2000 Golder and Associates inspection of the intake pipeline is also included in Appendix G. The strength testing results presented in the 2000 report indicate that the wood staves were in good condition at the time of inspection.

After reviewing the results from the 2000 testing, it was determined that the same compressive strength testing would be completed on the core samples collected in June 2014. Elasticity values were also developed. Biological testing was not completed for this work given that the condition of the wood was observed from June 2014 dive to be good. A report summarizing the results of the strength testing on the 2014 core samples is presented in Appendix H. Future biological testing may be warranted, but only if there is a marked degradation in the condition of the wood, as evidenced by future inspection and strength testing.

The results of the strength testing from the 2014 laboratory analyses are presented in Table 1.

TABLE 1
Laboratory Strength Testing of Intake Pipe Wood

Sample Location	Compressive Strength Perpendicular to Grain at 0.1-inch Deflection (psi)	Modulus of Elasticity (psi)
Bent 20, north side, 2:00 position, facing downstream	306	11,900
Bent 44, north side, 2:00 position, facing downstream, 6” below mud-line	366	15,200

Notes:
1) According to the United States Department of Agriculture’s Wood Engineering Handbook, Table 5-3b, typical compressive strength values (perpendicular to grain at 0.1-inch deflection) = 460 for dry wood and 240 for “green” (wet) wood.

The compressive strength testing presented in Table 1 was completed, not only to duplicate the testing conducted in 2000, but also because the compressive strength values could be compared with "typical" wood values as a reference to assess the relative condition of the wood staves of the intake pipeline. The two core samples collected in June 2014 had compressive strengths greater than what is typically reported for "green" (wet) western red cedar in the current (2010) Wood Engineering Handbook (see Note 1 in Table 1 for reference). The saturated core samples collected more closely compare to "green" wood than dry wood with a moisture content of 12 percent. As such, based on these two samples, the wood staves that comprise the intake pipeline appear to generally be in good condition given they still have compressive strength greater than typical green wood values.

The compressive strength results from 2014 are somewhat less than those from the core samples collected in 2000. The reason for this difference is not clear, but is not a concern. Multiple factors could account for this difference, including material saturation, variability in wood properties, and variability in laboratory equipment and analysis procedures. Note that the 2000 core samples were held for 54 days prior to testing whereas the 2014 core samples were held for 26 days. The difference could include loss of saturation, which could explain the higher strength values from the 2000 testing. However, what is clear is that the strength properties of the wood staves remains high – higher than typical values for western red cedar – and these results reflect the continued good condition of the wood.

7.2 Isolated, Unknown Concretion

At a distance of approximately 20 linear feet from the Gate House (10:00 position looking upstream [incorrectly reported as 8:00 position in the Ballard Marine Construction report]), an unknown concretion was observed during the internal inspection of the intake pipeline. This object is shown in Photograph No. 40 near the end of the Ballard Marine Construction report in Appendix A. A sample of this object was collected for laboratory analysis to aid its identification. The primary concern with this unknown material was whether or not it is organic, and therefore, contributing to decay of the wood staves comprising the intake pipeline.

The results of the laboratory analysis are presented in Appendix I. These results reflect testing of the main concretion and the biological growth covering the concretion – the same biological growth covering the entire inside of the pipeline.

The main, hard material tested was determined to be primarily calcium carbonate and silica – as indicated in the footnote of Appendix I. These two compounds are the chief components in cement. The high aluminum content indicates it could also be a bauxite material. It is possible that this material could be the formation of a plug that was intended to cover a hole in the wood intake pipeline from the surface at this location, which is still on shore.

8. Metal Band Structural Analysis

The hoop rods (typically referred to as "bands") around a wood stave pipe are one of the most critical elements of this type of pipe. The hoop rods keep the wood staves in tight compression. Loss of this compression and the potential loss of a single wood stave could result in total loss of the pipe structure.

8.1 Original Design Strength

The City's existing Lake Whatcom wood-stave pipeline was constructed using 5/8" carbon steel hoop rods at a 6-inch spacing. Carbon steel from the 1930s is known to commonly have had a tensile strength of 55 to 65 kips per square inch (ksi).

Considering this original design and discounting any of the stainless steel straps that were put in subsequently as a rehabilitation improvement, the tensile hoop strength of the original carbon steel rods at the time of construction can be calculated using the equation below:

$$Hoop\ strength\ \left({}^{lbf}/_{LF}\right) = \frac{\left(Cross\ sectional\ area\ of\ steel\ (in^2)\right) \times \left(Steel\ tensile\ strength\ \left({}^{lbf}/_{in^2}\right)\right)}{\left(Hoop\ spacing\ (LF)\right)}$$

Using this equation the original design and construction included hoop strength per linear foot along the length of the intake pipeline of 36,800 lbf/LF.

8.2 Common Design Criteria

While the use of wood-stave pipe was more common in the distant past than today, criteria for its design and construction was not as standardized as that for commonly-used pipe materials today. That stated, there is some documentation of wood-stave pipe design criteria. One such document is a 1918 American Society of Civil Engineers (ASCE) publication entitled: *Modern Practice in Wood Stave Pipe Design and Suggestions for Standard Specifications*. In this document carbon steel hoop rods for a 72-inch diameter wood-stave pipe document, the following parameters are listed for similar 72-inch pipe.

- 5/8-inch rods at 8-inch spacing
- ¾-inch rods at 10-inch spacing
- 55 to 65 ksi tensile strength

Using the equation presented in Section 8.1, the hoop strength can calculated as 25,300 to 34,500 lbf/LF depending on the rod diameter and spacing. These values are somewhat less than the design employed for the City's wood-stave intake pipeline, but they are within the same order of magnitude.

Given the lack of standardization of wood-stave pipe design, the relatively small community of engineers practiced in wood stave pipe projects, the wide geographic variation in available timber materials, the geographic distribution of design approaches, much of wood-stave pipeline design was heavily influenced by the experience and judgment of the local designer. Considering these factors, it is reasonable to conclude that the original intake was designed following appropriate design guidance and practices of the time.

8.3 Existing Supplemental Stainless Steel Straps

As described above, supplemental stainless steel straps were added at some time in the past to mitigate the corrosion and loss of strength of the original 5/8" carbon steel hoop rods. The stainless steel straps are ¾" by 0.030" and are 316 stainless steel. While precise spacing of the straps is unclear, as described in Section 6.2.2, for the purpose of this exercise, the spacing is assumed to be 2 feet along the length of the pipe. The tensile strength of the bands are assumed to be approximately 75 ksi based on typical stainless steel tensile strength.

Using the same tensile strength equation cited above for these stainless steel bands, the hoop strength they impart to the pipe can be calculated as 844 lbf/LF. This amount of strength is only a fraction (2.3%) of the strength imparted per the original design. Given the condition of the carbon steel hoop rods, it can be assumed the combined hoop strength of the original carbon steel rods is either negligible or soon to be negligible because of eventual failure. Therefore, the loss of confining pressure on the wood staves from the original design condition to the current condition is very concerning.

8.4 Approach to Replacement of Original Hoop Rods

As stated above, there is minimal published design criteria for wood stave pipe. While implementation of wood-stave pipeline design and construction remains an approach that is employed in applications for which it is best suited, its overall use with respect to other pipeline materials is relatively uncommon. As a result, there is no readily-available recent published design criteria for wood-stave pipelines. The available published design criteria for wood-stave pipe, in particular for the hoop rods, are those cited in Section 8.2.

In addition to these design criteria resources, there remains the knowledge and experience of the technologists that continue to implement wood-stave pipeline design and construction. Two companies that continue to engage in wood-stave pipeline design, construction, and rehabilitation are International Wood Pipe and Tank Company in Portland, Oregon and the Canbar Division of Goodfellow, Inc. in Waterloo, Ontario, Canada. These two companies rehabilitate wood-stave pipeline with respect to the replacement of pipe bands on a band-per-band basis using the same size replacement band (and type) as the original band. Neither company uses or recommends use of flat straps as pipe bands in lieu of larger-diameter bended rod. There is no way to assess the adequacy of the supplemental stainless steel straps with respect to maintaining the integrity of the intake pipeline. What is clear is that the use of such flat-strap banding is not a rehabilitation approach deemed adequate by the remaining wood-stave pipeline specialty firms.

If this band-per-band approach were taken for replacement of the original 5/8-inch carbon steel hoop rod bands, approximately 1,600 new stainless steel or carbon steel hoop rod bands would be necessary. This approach is based on the assumption that the restraining force imparted by the existing stainless steel flat straps that were put on at some time prior to 1999 is negligible. Given that the stainless steel straps are only imparting 2.3% of the strength of the original carbon steel hoop rods, it makes sense to avoid accounting any beneficial service from their installation. Furthermore, due to the nature of the clamping mechanism used to cinch the straps, it is not clear whether or not they were tightened to impart the necessary restraining force or if the clamps can practically maintain the necessary tension.

One thing to consider is whether it is necessary to install as many as 1,600 new steel hoop rods on a pipe that has no internal or external pressure. Band spacing and size design criteria is somewhat dependent on the internal pressure of the contained fluid, but it is also dependent on the potential for impact forces such as waves, boat anchors, seismic, and any other forces that might serve to deform the pipe. Deformation of the pipe shape can lead to irreversible collapse of the pipe and complete loss of its functionality. An engineering assessment of the potential options and opportunities to reduce the number of new steel hoop rod bands could be undertaken during a subsequent evaluation of design criteria options for rehabilitating the wood-stave intake pipeline.

However, for the purpose of this evaluation and the estimated costs presented in Section 9, it is assumed that approximately 1,200 new hoop rod bands would be necessary for an effective rehabilitation of the wood-stave intake pipeline. Estimated costs for both 316 stainless steel hoop rod bands and carbon steel bands were developed to bracket the range of potential capital costs. The stainless steel approach comes with a higher cost but a much greater life expectancy for the bands. Pursuing the carbon steel approach is based on a recognition that the overall longevity of the intake pipeline may be only 30 to 50 more years.

For the buried portion of the pipeline, whether or not replacement of the bands is necessary is not known. However, options for band replacement in this area or other mitigation options for addressing corrosion of the metal bands in this area should be addressed to aid selection of a path forward for this portion of the intake pipeline. These issues are addressed in Section 8.5.

8.5 Metal Bands in the Buried Portion of the Intake Pipeline

As stated above in Section 6.12, the buried bands are presumably in a lesser state of corrosion than the underwater bands, but that the actual extent of corrosion cannot be confirmed without direct inspection. Similar to what could happen with the exposed, submerged portion of the wood-stave intake pipeline, failure of the metal bands could result in failure by collapse of the buried portion of the wood-stave intake pipeline.

Also, as stated in Section 6.12, consideration of excavating one or more locations of the buried portion of the intake pipeline should be considered to assess the condition of the metal bands in this portion of the intake pipeline. It should also be noted that pipe diameter measurements were collected within the buried portion of the intake pipeline. These measurements showed no deformation of the pipe or dislodgment of the wood staves in the buried portion of the pipeline.

Excavating buried wood-stave pipelines and replacing bands has been completed for shallow-bury pipelines in dry-trench conditions in rural settings. Such rehabilitation approaches, however, are understood to be uncommon and mostly have occurred in the distant past. Such rehabilitation of the City's 72-inch wood-stave intake pipeline is not feasible given that it is buried partly in the lake bottom and partly below the high water table of the lake shore. As a result, if rehabilitation of the buried portion of the intake pipeline is deemed warranted, other approaches would be necessary.

These other rehabilitation approaches would be challenging, but possible to implement. One approach would be to slip-line the buried portion with a smaller-diameter high density polyethylene or fiberglass-reinforced pipeline. Another approach would be to install multiple structural support sleeves along the length of the buried portion of the pipeline. A third approach would be to pro-actively replace the buried portion of the intake pipeline – in its current alignment – via open-cut trench methods.

Prior to consideration of these rehabilitation approaches, inspection of a portion of the metal banding in the buried portion of the pipeline should be completed. Even more important than the metal banding inspection is the continued rapid development of an alternative, backup, emergency source of supply – as is currently being pursued by the City. Evaluation of rehabilitation approaches for the buried portion of the intake pipeline, and whether or not to implement any rehabilitation on this portion of the pipeline, in the context of the urgent pursuit of the alternative, backup, emergency supply.

9. Estimated Capital Cost

The estimated initial capital cost for improvements recommended for implementation are presented in Table 2. These improvements include:

- Replace Original Hoop Rods (with new SST pipe bands)
- Install New Concrete Ballast Weights
- Replace Wax Tape on Steel Flange Joints

The pipe band materials cost presented in Table 2 is based on the use of 5/8-inch 316 stainless steel bands. Using 5/8-inch carbon steel bands would cut the materials cost of the bands approximately by half. This change would save approximately $200,000 off the total project cost presented in Table 2. These estimated costs were developed to the "concept level" or "Class 5" level of accuracy as defined by the Association for the Advancement of Cost Engineering International (AACEI). This level of cost estimating is considered accurate to +50 to -30 percent.

These estimated costs were prepared for guidance in project budgeting and in evaluating which phasing and configuration alternative to pursue based on information available at the time of the estimate. The final cost of the project will depend upon the actual labor and material costs, competitive market conditions, implementation schedule, and other variable factors. As a result, the final project costs will vary from the estimates presented herein. Because of this variation, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions.

TABLE 2
Summary of Estimated Initial Capital Costs for Intake Pipeline Improvements

Project Element	Cost
Construction Costs:	
Mobilization & demobilization	$87,000
Installation of New SST Pipe Bands	
Materials	$312,000
Installation	$338,000
Installation of New Concrete Ballast Weights	$154,000
Replace Wax Tape on Steel Flange Joints	$49,000
CONSTRUCTION SUBTOTAL	**$940,000**
Construction w/ Contingency (30%)	$1,222,000
Construction w/ Escalation to June 2016 (7.1%)	$1,309,000
Construction w/ Sales Tax (8.7%)	$1,423,000
Non-Construction Costs:	
Permitting Allowance	$50,000
Engineering and Construction Management[1]	$327,000
TOTAL	**$1,800,000**

Notes:
[1] Engineering and Construction Management costs estimated as 25 percent of construction subtotal with sales tax.

10. Recommendations

The existing wood-stave intake system is in relatively good overall condition, considering that it has been in service for approximately 75 years. In general, the wood is in good condition. Under constant immersion in a fresh water lake it is anticipated that the wood elements will provide many more years of the service. The fasteners connecting the wood bent components and the timber crib elements appear to have several years of remaining service life as well, based on observations from the June 2014 inspection as well as previous testing by Golder and Associates from 2000. However, corrosion product on the exposed portions of fasteners indicate eventual deterioration of these metals is likely and should be anticipated at some point in the future.

The original carbon steel hoop rods and connecting shoes are at or very near the end of their service life. While some portion of the original tensile strength of these hoops remains, quantifying this remaining strength is difficult, impractical, and subject to error. Correspondingly, assessing the point in time after which there is insufficient tension on the pipe via the pipe bands, is not possible. However, what is clear is that at some point, all of the strength of theses rods will be gone. Replacement of the confining strength function these hoops provide is necessary and should be completed as soon as practical, while the opportunity to rehabilitate the intake pipe remains. Should the intake pipe suffer a full or partial collapse because of insufficient pipe banding, it will not be possible to rehabilitate the pipe (it will need to be replaced). Re-banding of the intake pipe should be undertaken as soon as the City has re-established emergency, backup use of its old supply currently serving the fish hatchery adjacent to the Screen House, and made the repairs to the Screen House that it is currently planning.

While the existing wood-stave intake system remains useful and in relatively good condition, preserving this usable condition for the long-term will require regular monitoring, inspection, analysis, improvements, and replacement, or supplement of key elements. The actions necessary to preserve the existing wood-stave intake system should be considered in the context of the cost and challenge associated with a potential new intake system in the event the existing system cannot perform effectively.

Additionally, as mentioned above, the City should continue expedited pursuit of developing its old (approximately 100 years old) Lake Whatcom supply system as an emergency, backup supply and make this pursuit among its highest priorities. This old supply system includes an existing wood-stave intake pipeline that extends off-shore from Donovan-Bloedel Park and a combination of brick-lined tunnel and concrete-encased steel pipe that connects Donovan-Bloedel Park with the Washington State Department of Fish and Wildlife hatchery adjacent to the Screen House. Development of this old system as an emergency, backup supply is necessary for the following reasons:

- While the existing wood-stave pipeline is in relatively good condition with respect to many of its component elements, given its age and need for rehabilitation, its continued use comes with some level of risk. The consequence to the City's supply of failure of the intake pipeline is great if there is not an alternative means of conveying Lake Whatcom supply to the City's WTP.
- The known rehabilitation improvement of the steel pipelines at the City's Screen House cannot be implemented without development of the City's old supply as an emergency, backup supply. This rehabilitation is understood to be among the City's highest priorities and continued rapid, expedited pursuit of this improvement should be pursued. Delay of development of the City's old supply and implementing the pipeline rehabilitation at the Screen House places the City at substantial risk of supply disruption if one or all of the three steel pipelines fails.
- The tunnel between the Gate House and Screen House is the only means of conveying water between Lake Whatcom and the City's WTP. While this tunnel is not known to be in danger of failure or collapse, the consequence of failure or collapse is great – disrupting the entire water supply to the City.

While it is important for the City to implement the specific improvement recommendations listed below, the City should pursue development of its old supply as an equal or higher priority. It should consider development of this old supply as an emergency, backup supply prior to undertaking any improvements to the intake pipeline.

A summary of key observations from the June 2014 inspection dive and recommendations for rehabilitation, and further inspection, is presented in Figure 2. The following specific rehabilitation actions are recommended for implementation as soon as practical:

- **Replace Original Hoop Rods:** As presented in Section 8, replace the strength function of the original hoop rods with new stainless steel rods as soon as practical. This rehabilitation is top priority for maintaining the existing intake system.
- **Concrete Ballast Weights:** Install articulated ballast mats at the twelve locations where the original concrete ballast weights are either no longer connected to the pipeline or are soon to be disconnected via corrosion of the original steel rods. Since it is not possible to connect these ballast weights via the dual stainless steel strap method used in 2002, the articulated ballast mats will serve as an excellent replacement. These ballast mats should be placed on both sides of the bent structure where the ballast weights are being replaced.
- **Steel Flange Joints:** The wax tape on the steel flanges is in fair condition and in need of replacement soon. It should be removed and replaced at the same time as the addition of the new stainless steel straps described above. When the tape is removed, the steel flanges should be closely inspected to determine if corrosion has progressed since what was observed in 2000. The condition of the welds should also be observed and documented. After the metal flanges are inspected, they should be cleaned with high pressure water to remove surface corrosion and contaminants and re-wrapped with wax tape. If the condition of these flange joints has deteriorated substantially since 2000, a repair approach for these joints should be developed and implemented at a subsequent time.

The following two inspection activities should be conducted as soon as practical. The first of the two can completed as separate, stand-alone activity. The second of the two should be completed as part of the same project to implement rehabilitation activities recommended above.

- **Inspect Bands on Buried Portion of Intake Pipeline:** Inspect the pipe bands on the buried portion of the intake between the lake shore and the Gate House. Options for exposing a small portion of the intake pipe in this area will need to be evaluated. The high ground water table in this area will make pumping and treating the pumped water necessary. The depth from ground surface to the top of intake pipe is approximately 10 feet mid-way between the lake shore and the Gate House. Shoring or other structural means of maintaining the excavation should be expected. The results of this inspection should be factored into assessing whether or not to pursue mitigation of the buried portion of the wood-stave intake pipeline.
- **Metal Fasteners:** Based on the 2014 inspection and 2000 inspection by Golder and Associates, the original carbon steel fasteners connecting the supports for the bent structures, as well as the beams that comprise the timber crib, appear to be generally in good condition. Wholesale replacement of these elements is not anticipated to be necessary in the near future. However, additional confirmation of this assertion is necessary because no additional bolts were collected during the 2014 inspection and only a single bolt was collected during the 2000 inspection. Six carbon steel fasteners from the timber crib and selected bents should be removed and evaluated at a testing laboratory to determine remaining strength and metal loss due to corrosion.

Beyond the rehabilitation improvements and additional inspection and testing cited above, the existing wood-stave intake system should be inspected on a frequency cycle of no greater than 5 years. This inspection frequency is based on an assumption that moving forward the City should anticipate the need for making some repairs and rehabilitation improvements to the intake system approximately every 5 years. Regular, five-year inspections should include observations and appropriate testing of the following:

- The new replacement stainless steel hoop rods.
- Stainless steel straps around concrete weights at the bents and between bents.
- Original metal fasteners.
- Wood components (crib, bents, staves) to document any potential rot or deterioration.
- Cable crossings to verify that cables are centered on wearing pads and not damaging the intake pipeline.
- Pipe plugs to verify that they are intact and tight.

Figures

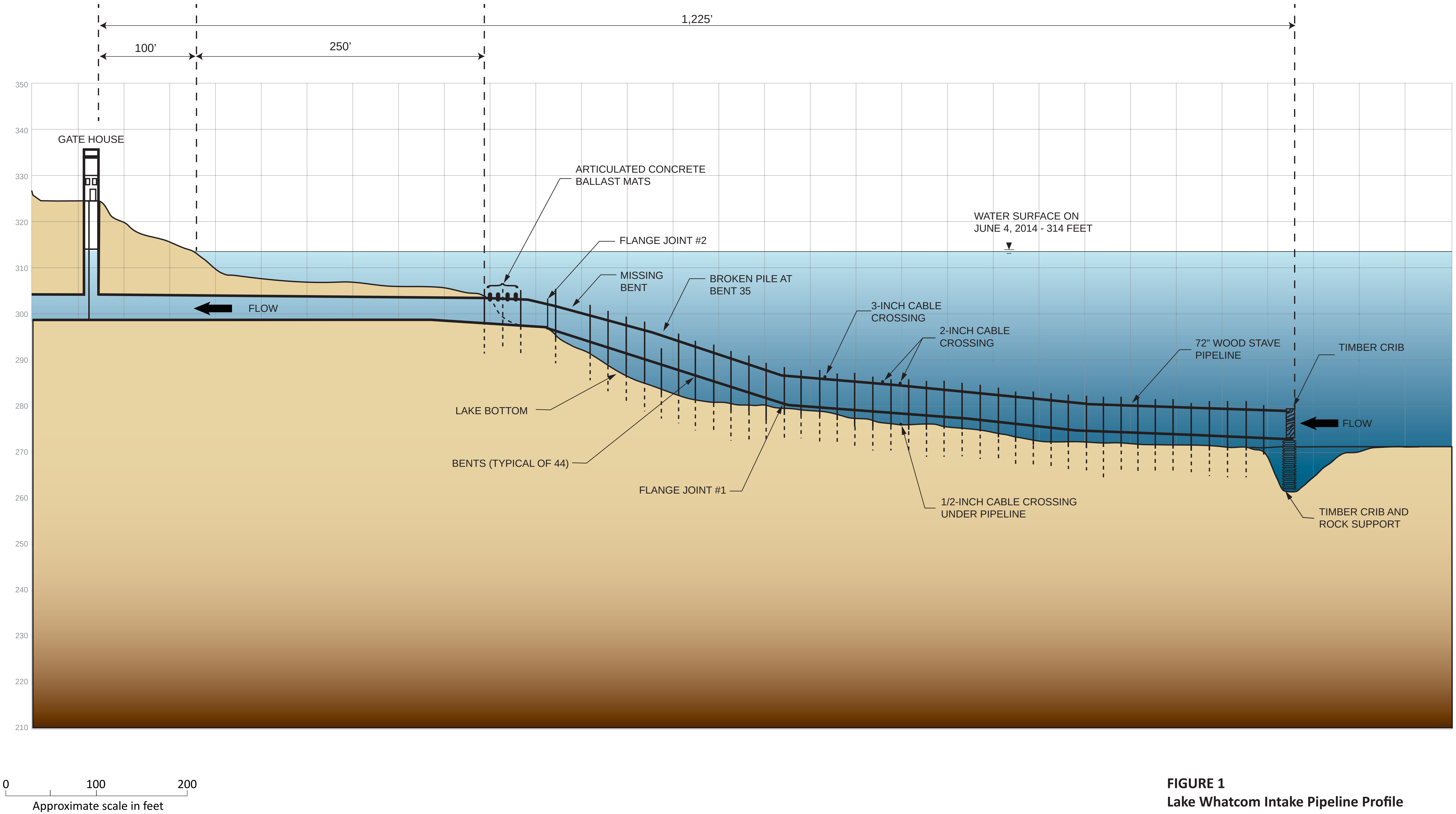
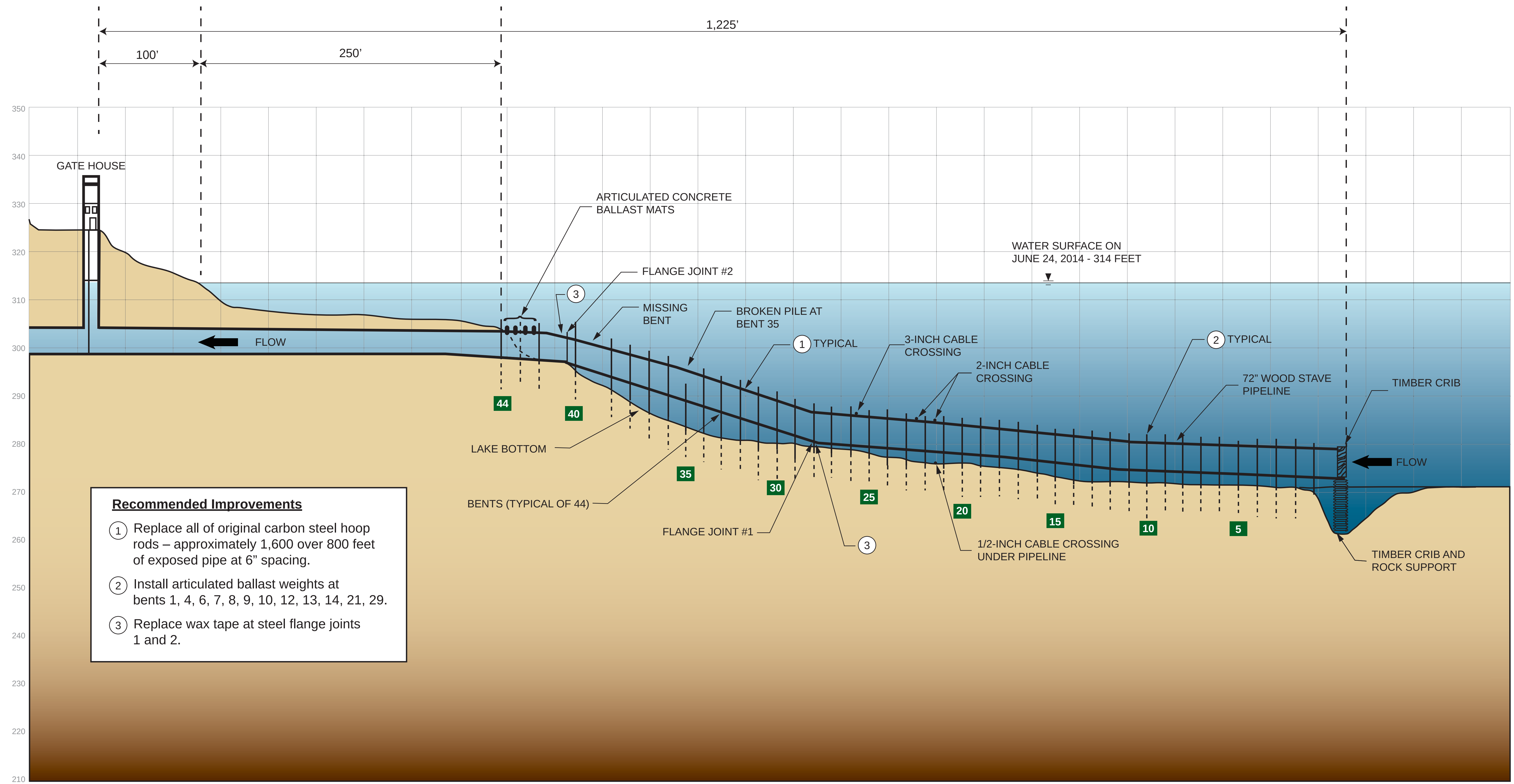


FIGURE 1
Lake Whatcom Intake Pipeline Profile



Recommended Improvements

1. Replace all of original carbon steel hoop rods – approximately 1,600 over 800 feet of exposed pipe at 6" spacing.
2. Install articulated ballast weights at bents 1, 4, 6, 7, 8, 9, 10, 12, 13, 14, 21, 29.
3. Replace wax tape at steel flange joints 1 and 2.

15 Bent Number

0 100 200
Approximate scale in feet

FIGURE 2
Whatcom Intake Pipeline
Summary of Recommended Improvements

CH2MHILL

WBG091114135542SEA

Appendix A
Ballard Marine Construction Report: Lake Whatcom Wood Stave Intake Inspection

CH2M Hill

Lake Whatcom Wood Stave Intake Inspection

Report Date: 6/28/2014

Prepared For:
Phil Martinez
CH2MHill
Phil.Martinez@CH2M.com

Prepared By:
Ballard Marine Construction, LLC
Dana Gordon, Diving Supervisor
BMC Project Number 0114066

BALLARD
MARINE CONSTRUCTION

June 28, 2014

Phil Martinez, PE
CH2M Hill
1100 - 112th Avenue NE, Suite 500,
Bellevue, WA, 98004-4504
Phil.Martinez@CH2M.com

RE: Lake Whatcom Wood Stave Intake Inspection

Mr. Phil Martinez,

Attached is our report summarizing the findings of the inspection Ballard Marine Construction divers performed at the Lake Whatcom wood stave intake from June 24th 2014 through June 26th 2014. Underwater video was recorded during the course of the project and copies of the DVDs are included with this report.

Should you have any questions and/or comments please feel free to contact myself or Jesse Hutton at the phone numbers and/or emails listed below. Thank you for allowing us to provide these services for you and we look forward to working with you again in the near future.

Sincerely,

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Introduction

Ballard Marine Construction (BMC) performed underwater inspection diving operations on June 24th through June 26th 2014 at the Lake Whatcom Wood Stave Intake in general accordance with the U.S. Coast Guard (USCG)-accepted Association of Diving Contractors International, Inc. (ADCI) *Consensus Standards for Commercial Diving and Underwater Operations* (6th Ed.), the U.S. & Oregon Occupational Safety and Health Administration (OSHA) 29 CFR Part 1910, *Subpart T – Commercial Diving Operations* (Dir. CPL 02-00-151; 2011), Washington State's *Standards for Commercial Diving Operations* (Chapter 296-37 WAC; 2008), and the *U.S. Navy Dive Manual*, Rev. 6 (April 2008).

Project Location

The Lake Whatcom Wood Stave Intake is located on the North West side of Lake Whatcom at a latitude/longitude of 48°44'55.4"N 122°23'44.1"W where it becomes exposed in the lake.

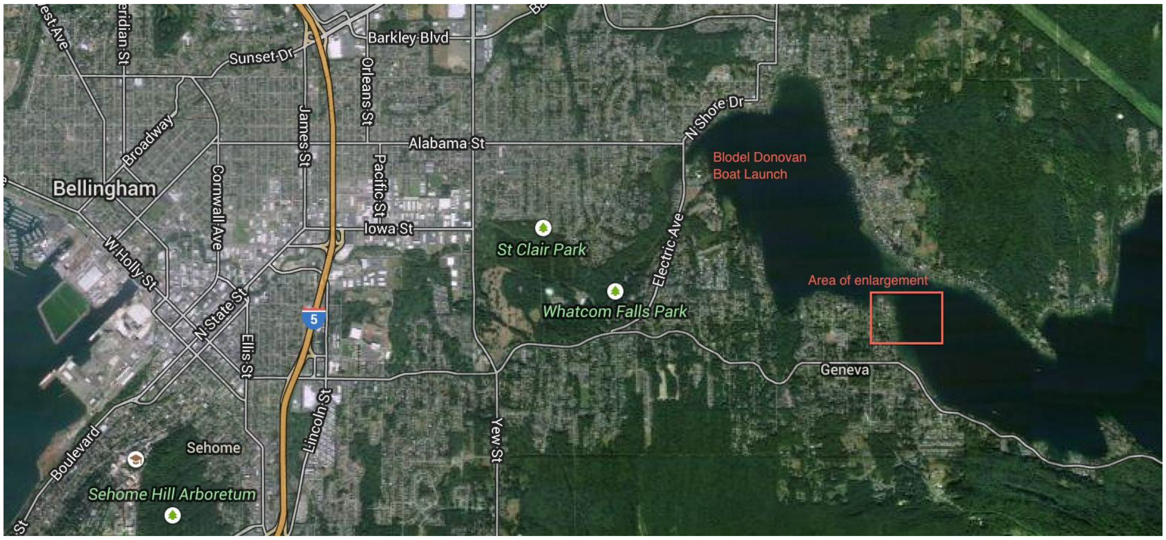


Figure 1 – Overview of Area

Figure 2 – Close in aerial view of Intake and Gate House

Scope of Work
BMC's Scope of work consisted of inspecting the existing intake structure, crib, wood stave intake pipe, and bents. In addition the scope included an internal inspection of the gate house vault and of the internal wood stave intake pipe to 400 linear feet. Documentation of the underwater work was done using an underwater video system and recorded on DVD for subsequent viewing by the project Dive Supervisor, Dana Gordon and the client, Phil Martinez.

Inspection Methods
BMC inspected the external surface of the intake in an offshore to inshore direction, beginning at the intake crib, and continuing toward shore. During the inspection, BMC divers visually inspected the external components of the intake, including the wood stave surface, the carbon steel bands, hardware, stainless steel bands, pile bents, cross and support braces, and ballast weights. Special attention was given to the condition of the carbon steel fittings and carbon steel hardware. Soundness testing with a hammer was performed along the length of the external surface of the pipe, and intermittent water blasting was performed to expose the condition of the pipe, fittings and hardware. Two core samples of the staves were taking using a hydraulic drill and hole saw for further inspection by CH2M Hill. Broken carbon bands were also recovered to the surface and turned over to CH2M Hill for further analysis and inspection. Measurements of sediment depth and pipe to pile and pipe to sediment were taken at each bent to check for the occurrence of shifting. Cable crossings were visually inspected and photographed. Visual inspection of the gate house vault was performed, including cleaning algae from the concrete surfaces to allow detection of any cracking, and soundness taps of the concrete were performed. Steel components in the gate house vault were cleaned to remove oxidation and scale, and a pit gauge was used to assess the extent of the corrosion to the steel components, including the sluice gate, shaft, and stop log slots. Visual inspection of the internal components of the wood stave intake pipe was performed, and special attention was given to the flanges and fittings internally and to the algae and other marine growth noted internally. Scraping of the wood and soundness taps were used to assess the soundness of the internal wood staves. Horizontal and vertical measurements were taken intermittently to check for deformation of the intake. An underwater video system was used to document the diver's inspection.

Inspection Findings
BMC's Inspection of the Lake Whatcom wood stave Intake consisted of 4 Main Components; the Intake Crib inspection at the far offshore end of the intake, the pile bents/intake pipe inspection of all 44 exposed bents, the gate house vault/sluice gate inspection, and the internal wood stave pipe inspection.

-Intake Crib Inspection
The intake crib is a square structure 12.5' wide and standing 8' tall above the support structure. It is constructed primarily of 9" x 9" timbers, fastened with carbon steel hardware, as depicted in the following figures. The timber components of the structure were appeared to be in good condition with no signs of rot or severe deterioration noted. The carbon steel components are corroded, and covered with heavy oxidation and scale. See Photo #1 in project photographs for a close up of the Intake crib hardware. The top of the crib structure is constructed of 9" x 3" boards spanning the 12.5' width of the intake. The intake pipe enters the structure from the West and is contacting the South West vertical timber of the crib. The intake pipe extends into the crib terminating just 9" to the West of the South East Pile. The offshore end of the intake pipe appears to bell out, becoming a larger diameter, however, without diver access to the inside of the crib, we were unable to take an exact measurement on the exact dimension of the end of pipe. On the East face of the intake crib, BMC diver found a 3' x 19" screen that had been bolted to the crib. It appeared to be constructed of PVC zip tied to steel screen. See Photo #2 in the project photographs section of this report for a close up of this component. The Intake crib rests on a support structure of similar construction, with dimensions of 16' x 16' extending into bottom, and filled with 2" minus cobble. Though flows through the intake were reported to be 14 million gallons per day on the day of our crib inspection, diver was unable to feel any noticeable current into the intake. Copy of the video inspection has been included in this report. The inspection of the intake crib can be found at the beginning of the June 24th 2014 Video.

Figure 3: View of the Intake Crib from the North East Corner

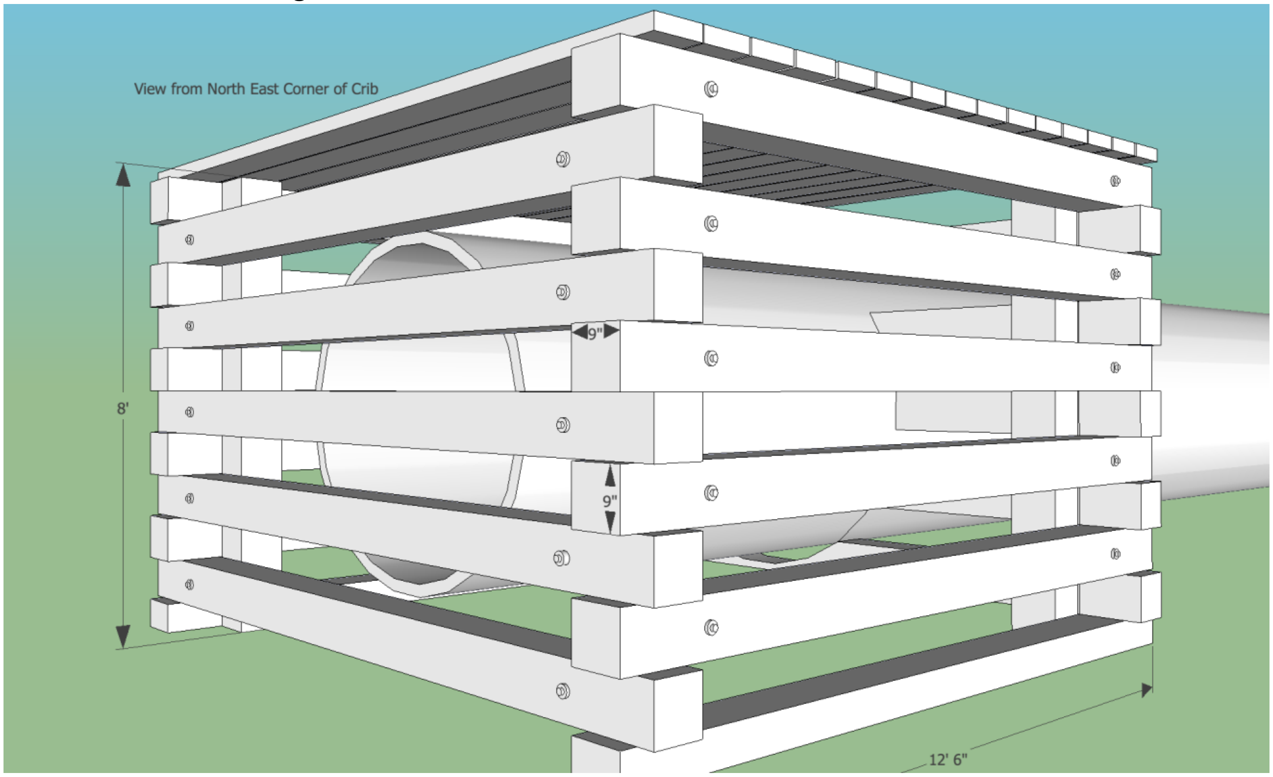


Figure 4: View of Intake Crib from the North West Corner

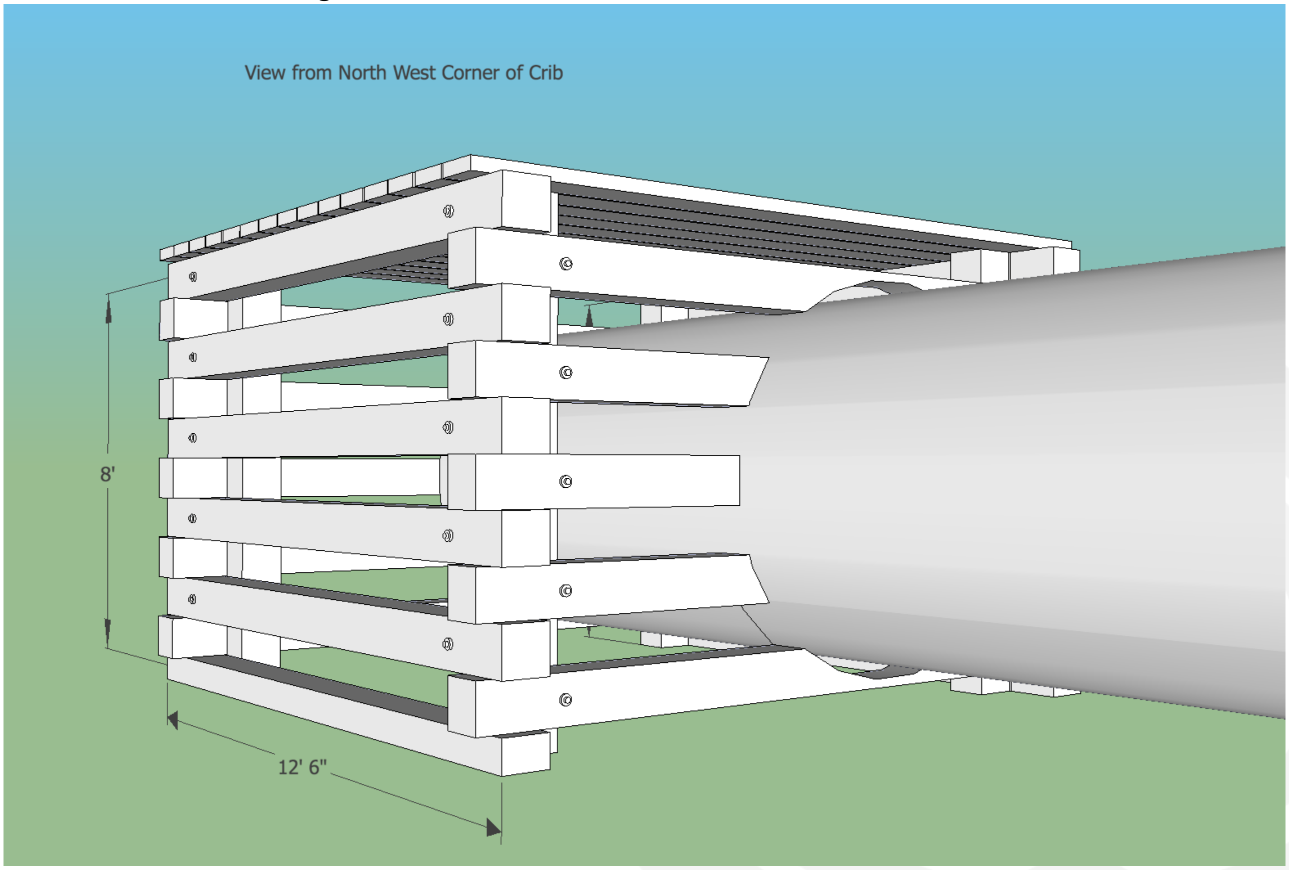


Figure 5: View of Intake Crib from South West Corner

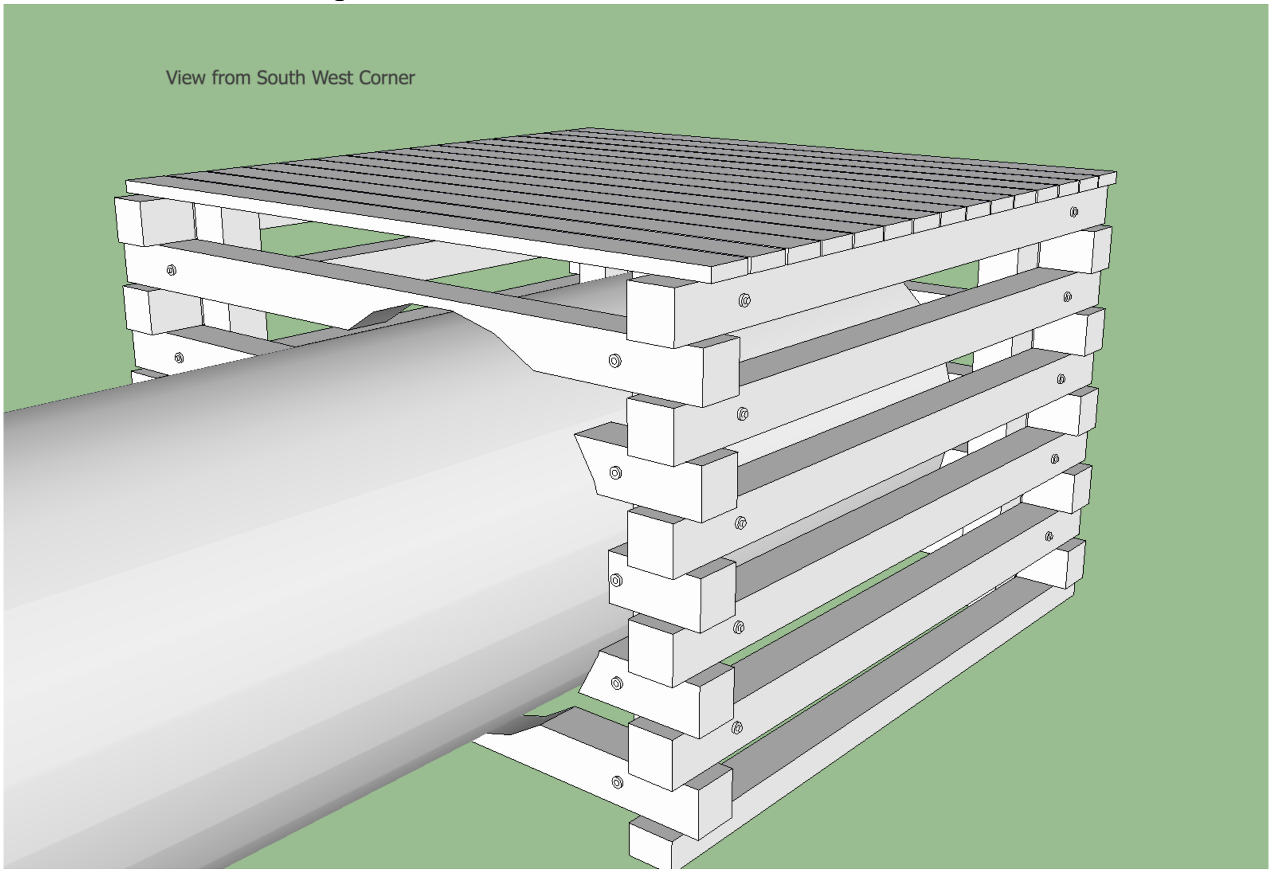
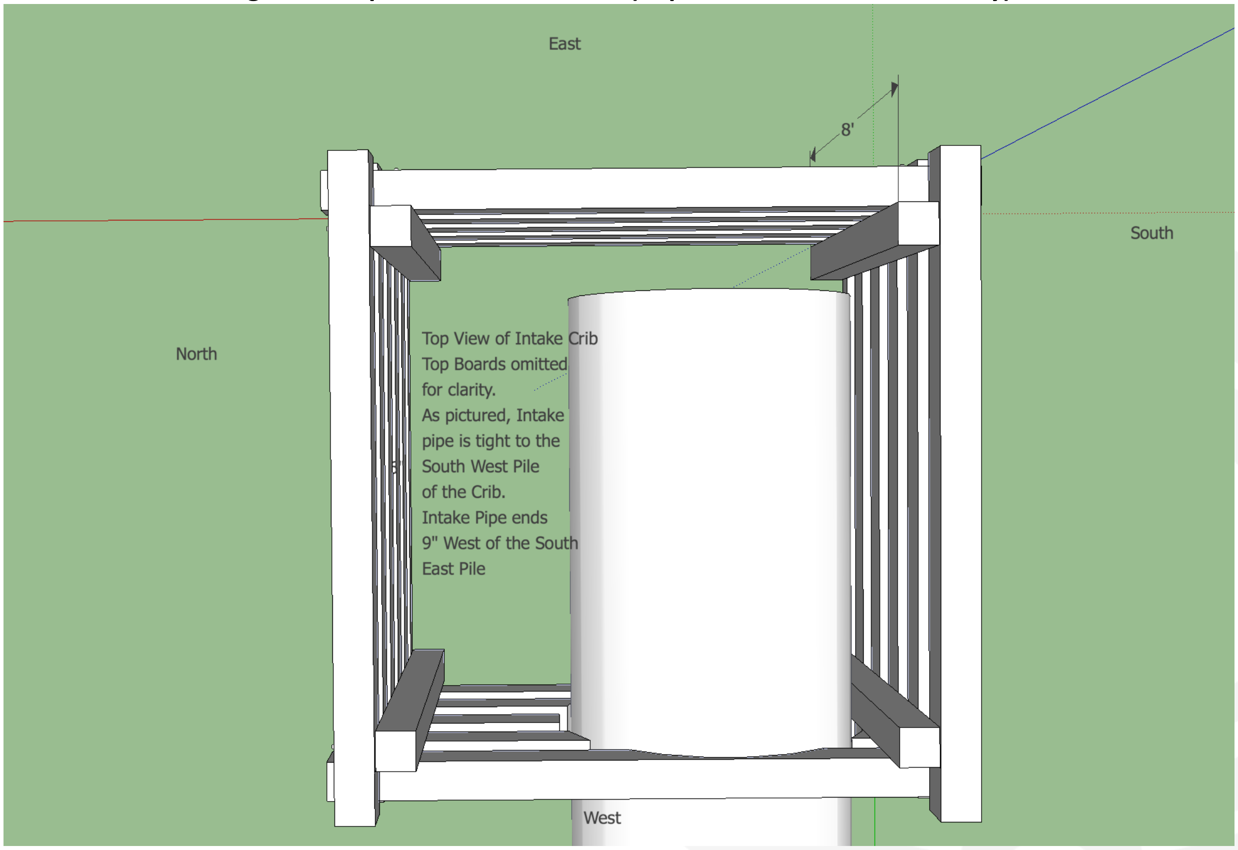


Figure 6: Top View of Intake Crib (Top boards omitted for clarity)



-External Intake Pipe and Pile Bents

BMC divers surveyed the external components of the intake structure from the offshore end where it exited the West side of the intake crib to the inshore end where it became buried in soft sediment approximately 15 feet inshore of pile bent 44. The intake pipe itself is a wood stave constructed 72" diameter pipe, with approximately 2 ¼" to 2 ½" wall thickness. The condition of the wood was found to be very good, with approximately 1/8" of soft wood material at the surface that removed easily with a hand scraper or paint knife, before reaching hard wood with no visible signs of rot. Intermittent pressure washing, hand scraping and sounding taps were performed to investigate the integrity of the wood components. While BMC divers found no signs of wood rot or damage, two 2" core samples of the wood staves were taken by BMC and turned over to CH2M Hill for further investigation. The voids left by the core samples were plugged with 2" mechanical plugs.

The steel components of the external portion of the intake showed varying degrees of corrosion. The original carbon steel bands in place on the pipe at intervals of 6" showed heavy corrosion and in some cases were completely corroded through and had fallen off of the pipeline. BMC divers cleaned the oxidation and scale off of these bands intermittently to investigate the amount of remaining steel, and documented this on video and still camera, and recovered samples of the broken bands for further investigation by CH2M Hill. The pile bent hardware appeared to be corroded to a lesser degree than the carbon steel bands. It exhibited heavy oxidation and scale, but once the scale was removed, the threading on the hardware was often still discernable, and the flats on the nuts were still intact as well. Stainless bands that were part of a previous repair effort were present on the pipe at approximately 24" intervals, and in nearly every case were intact, tight and not corroded.

Concrete ballast weights were present at nearly every pile bent and at the majority of pipe spans between the bents. Most of these concrete ballast weights were secured to the pipe positively with two stainless bands each. Two of these concrete weights were cracked, and had been secured from breaking apart with a 3rd stainless band.

BMC divers noted 3 cable crossings over the top of the intake pipe, and one cable crossing below the intake pipe. Divers also noted a timber lying on bottom parallel to the intake pipe, of about 20" diameter, in contact with the cross brace of bent 28 on the North side of the intake pipe.

Figure 7: Overview of Lake Whatcom Intake

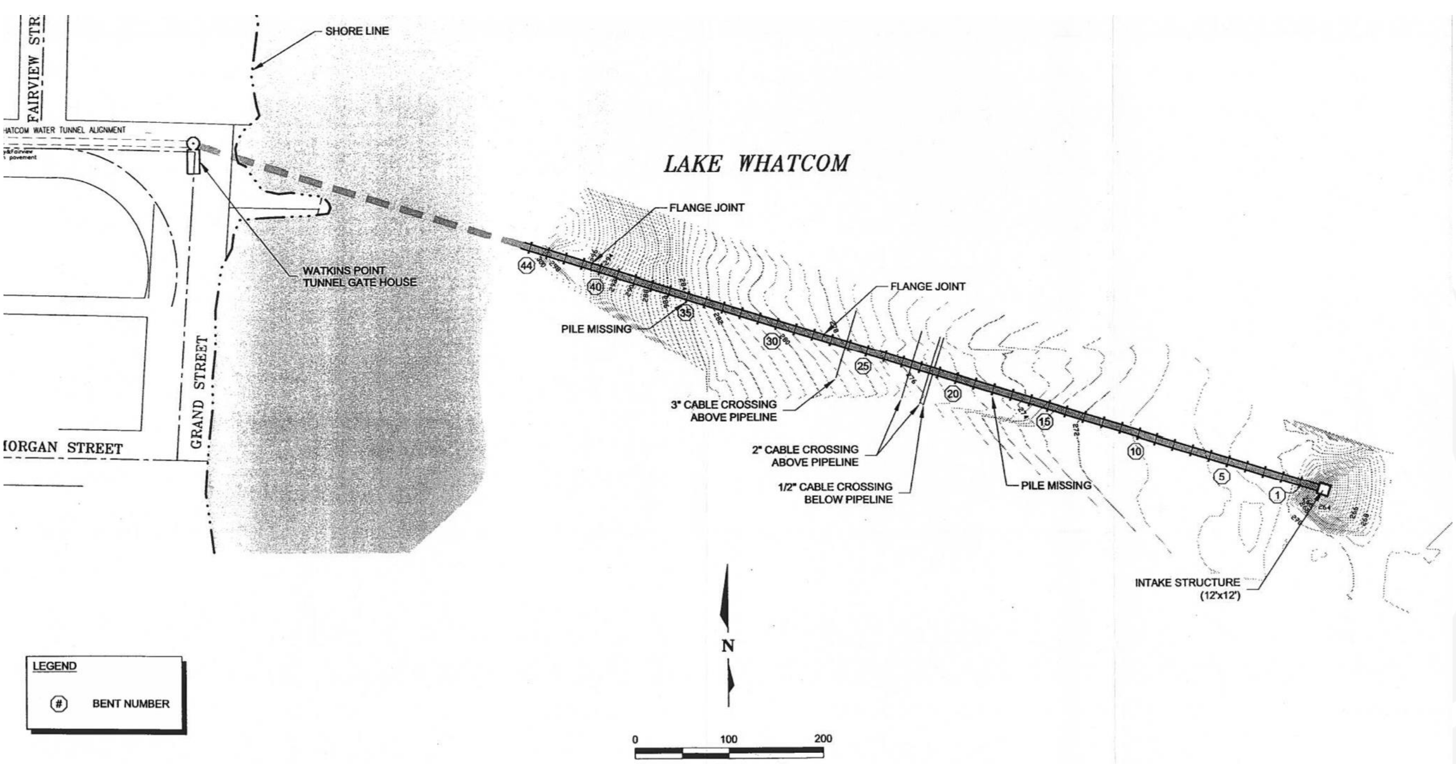


Figure 8: Cross Section of Typical Bent from Original Record Drawings

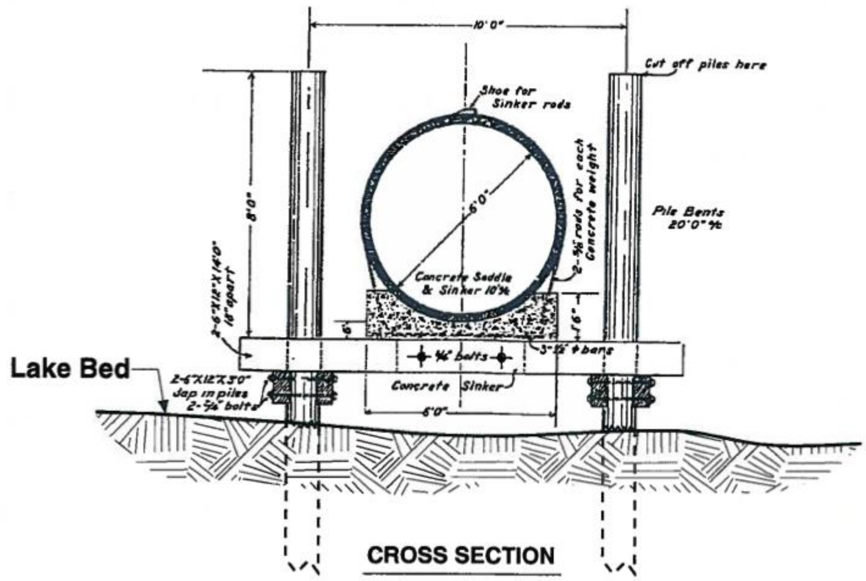
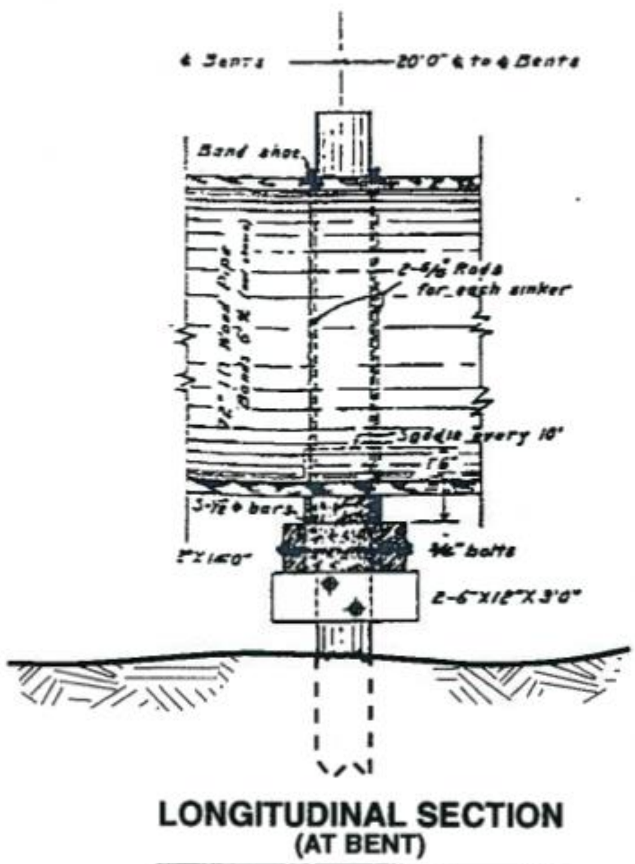


Figure 9: Longitudinal Section of typical bent from original record drawing.



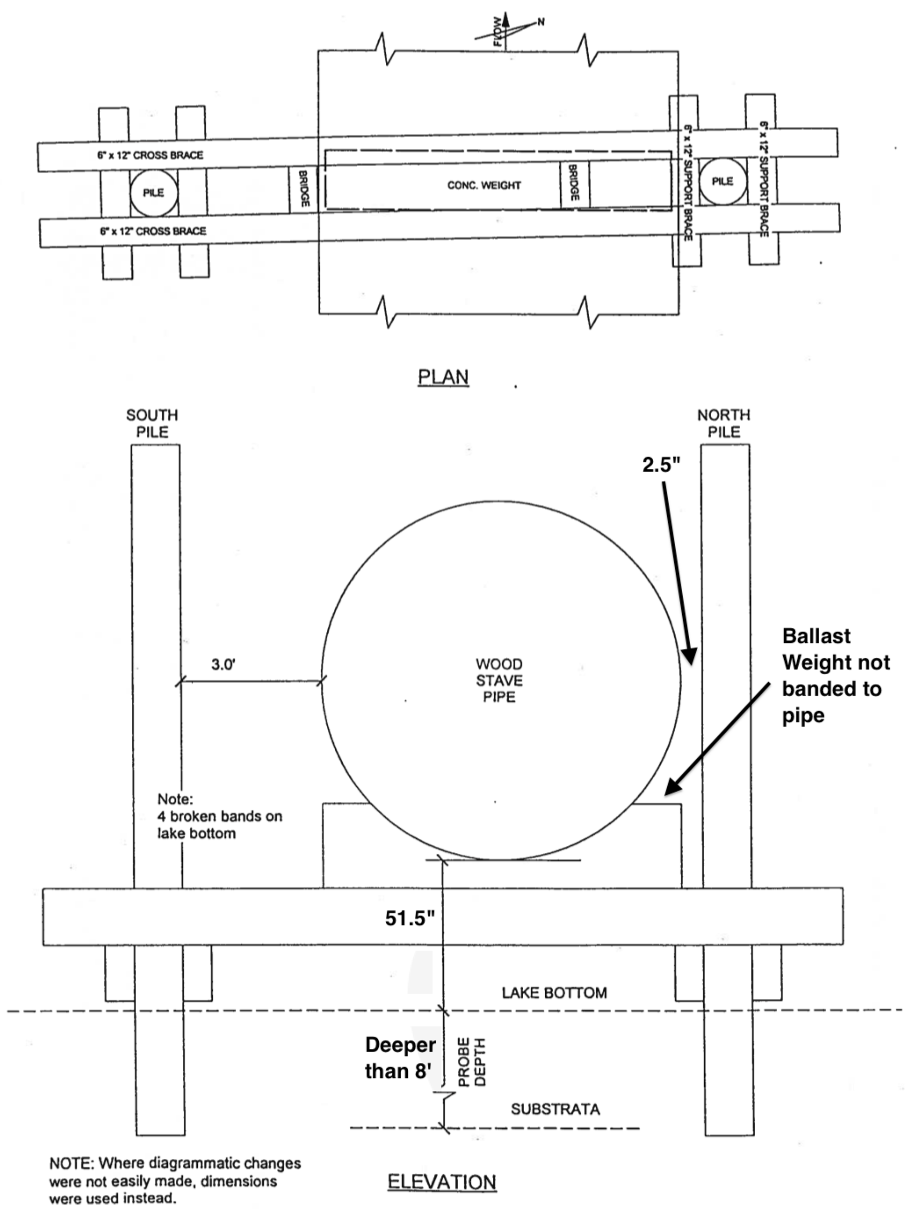
Pipe Condition Intake Crib to Bent 1

Wood Condition	Marine Growth	Carbon Steel Component condition	Stainless Component Condition	Broken/Missing Bands Evident	Intermediate Ballast Weight Present
Very good	Light/Moderate Algae	Heavily Corroded	Tight and intact, with the exception of one band corroded and loose.	None	No

Notes:

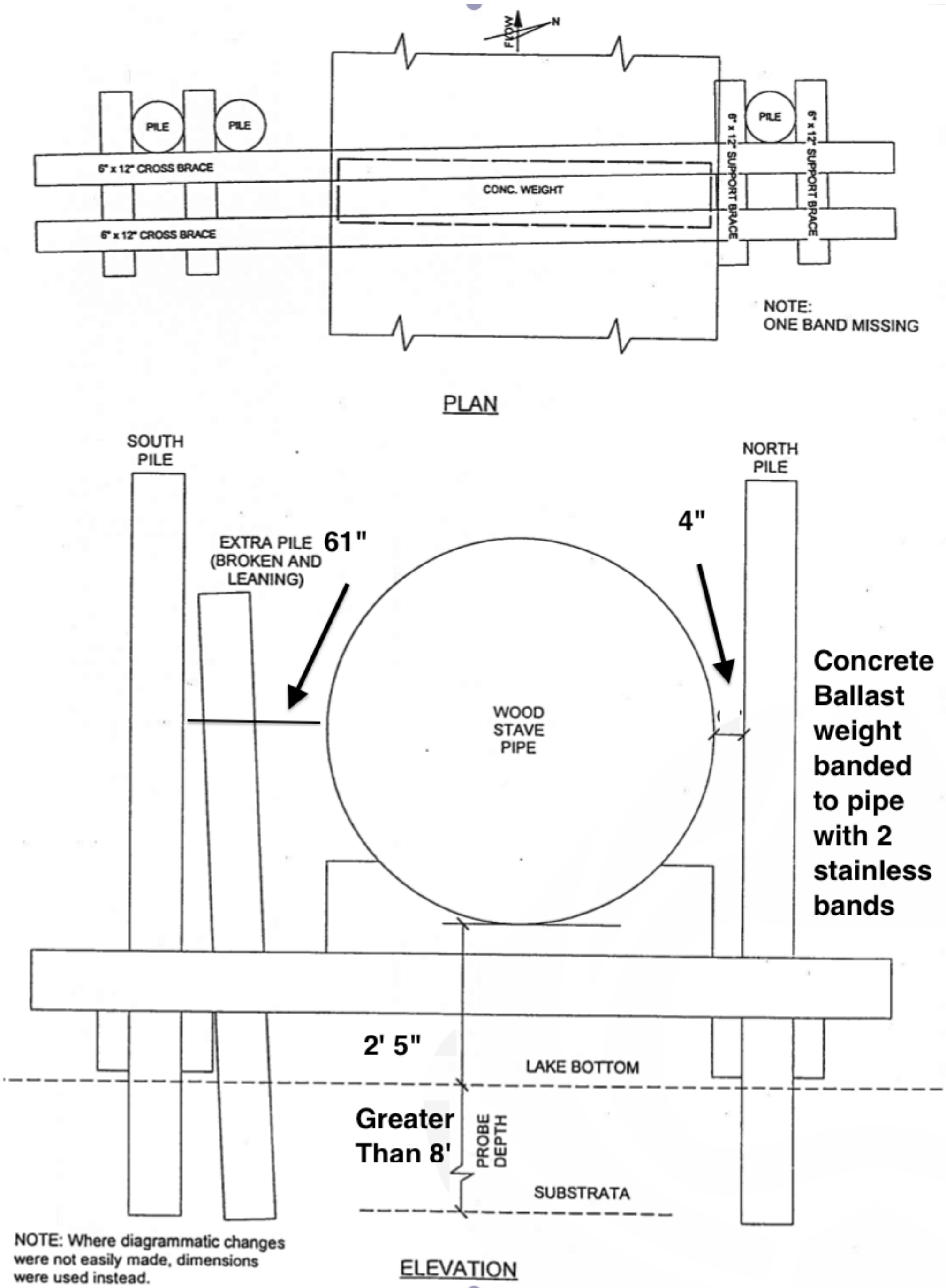
One stainless band loose and showing light surface corrosion (Pictured in Photo #4 in project photographs section of this report). All other stainless bands tight and showing no corrosion. See Photo #3 for typical condition of Stainless and Carbon bands. No intermediate ballast weight noted here.

Bent 1



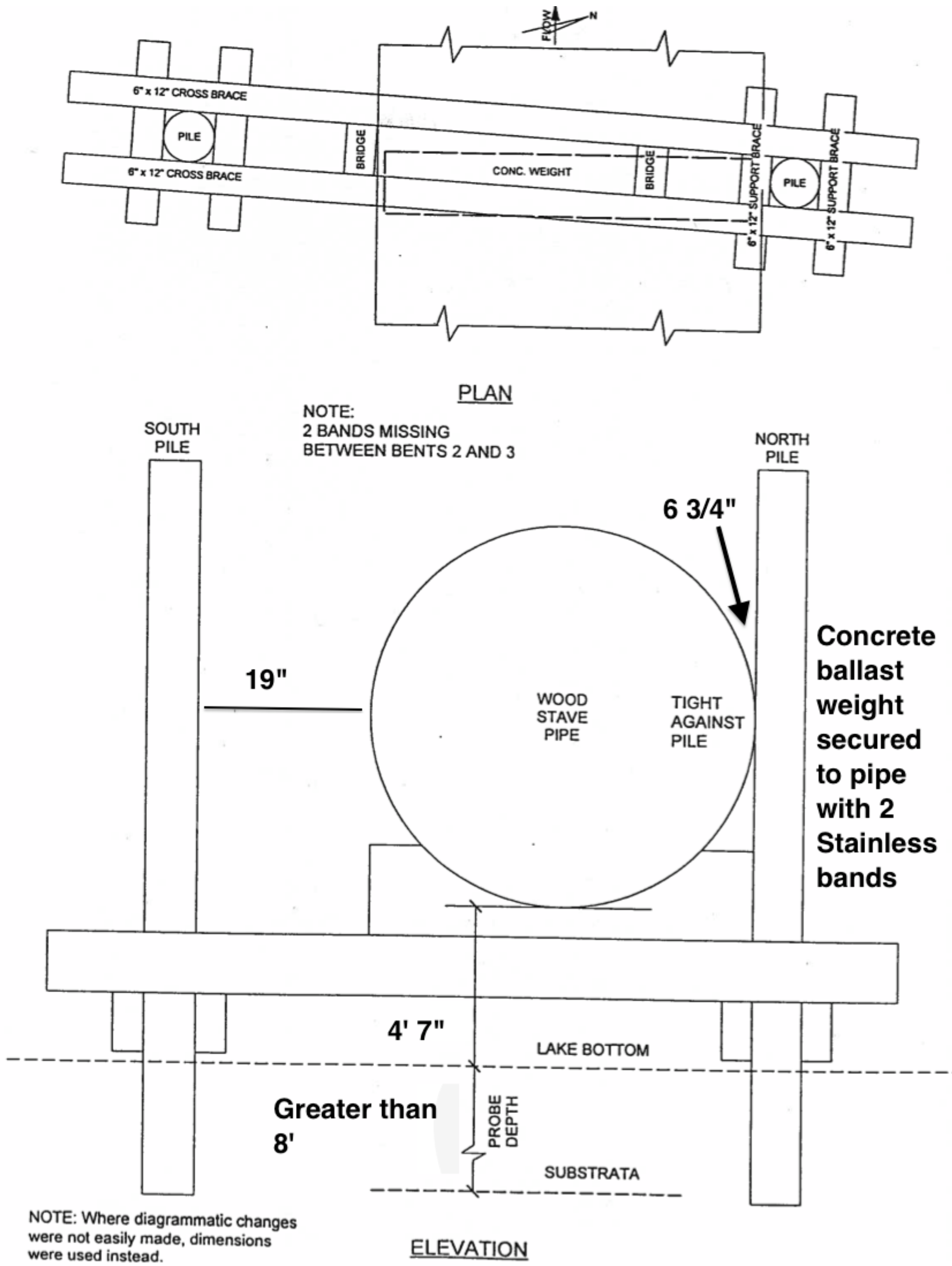
Pipe Condition Bent 1 to Bent 2					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Tight, not corroded	None evident	No
Notes:					
Bent 2 Piles are not in the typical location. As shown in the top view, they are inshore of the cross braces. An extra broken pile is leaning against the South side of the bent.					

Bent 2



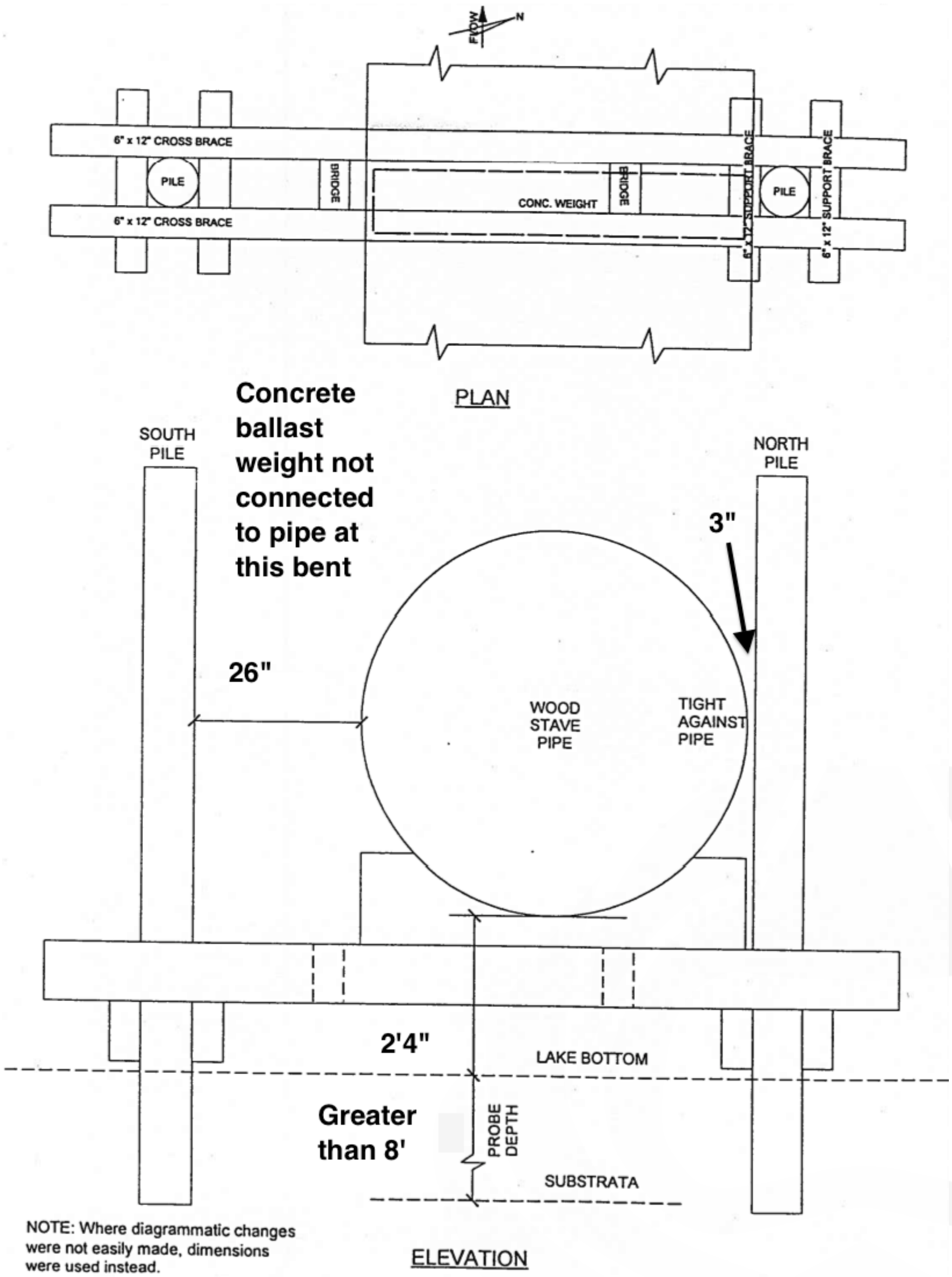
Pipe Condition Bent 2 to Bent 3					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Tight, not corroded	None evident	No
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands.					

Bent 3



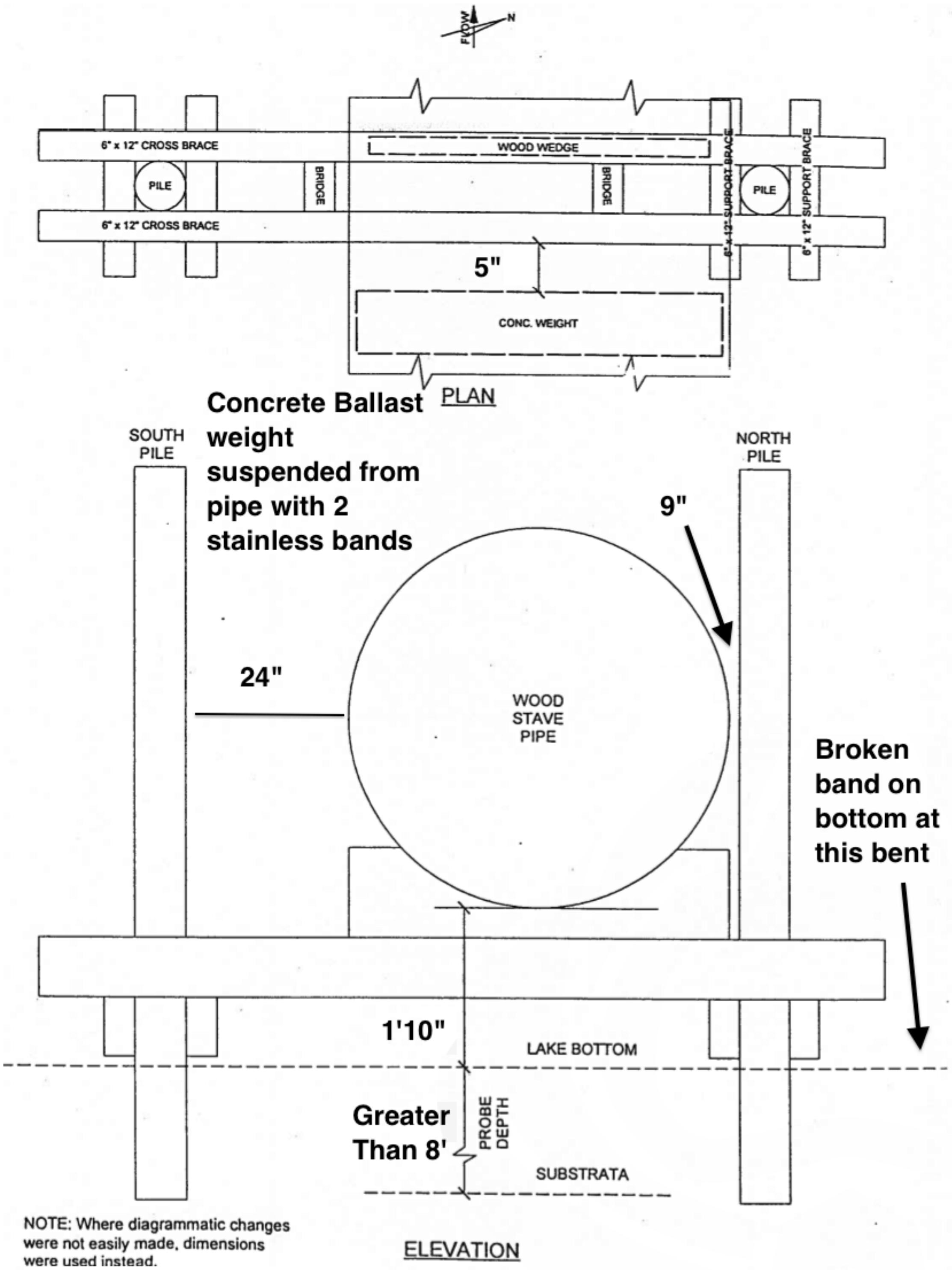
Pipe Condition Bent 3 to Bent 4					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Tight, not corroded	None evident	No
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands.					

Bent 4



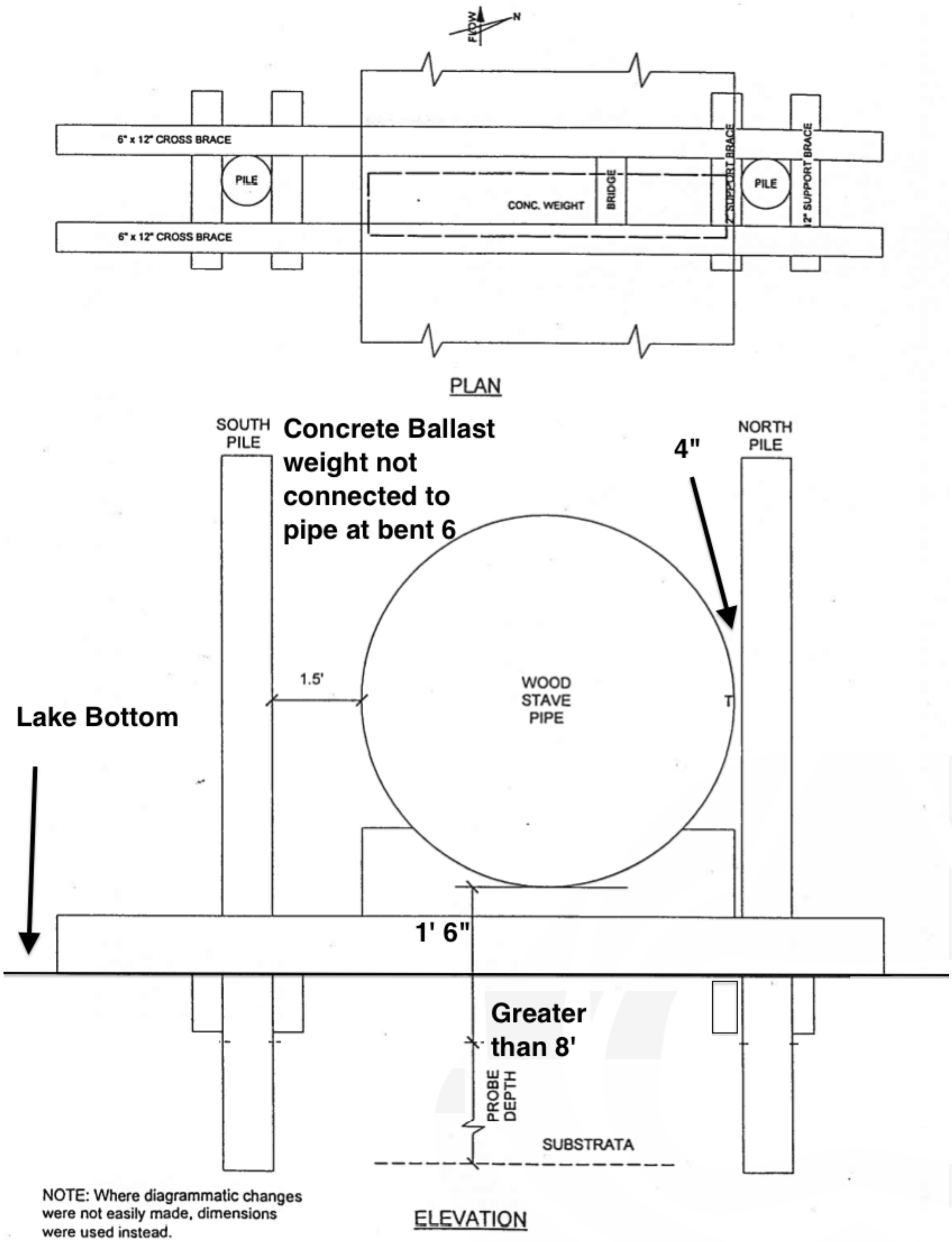
Pipe Condition Bent 4 to Bent 5					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Tight, not corroded	Band on bottom at bent 5	No
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands.					

Bent 5



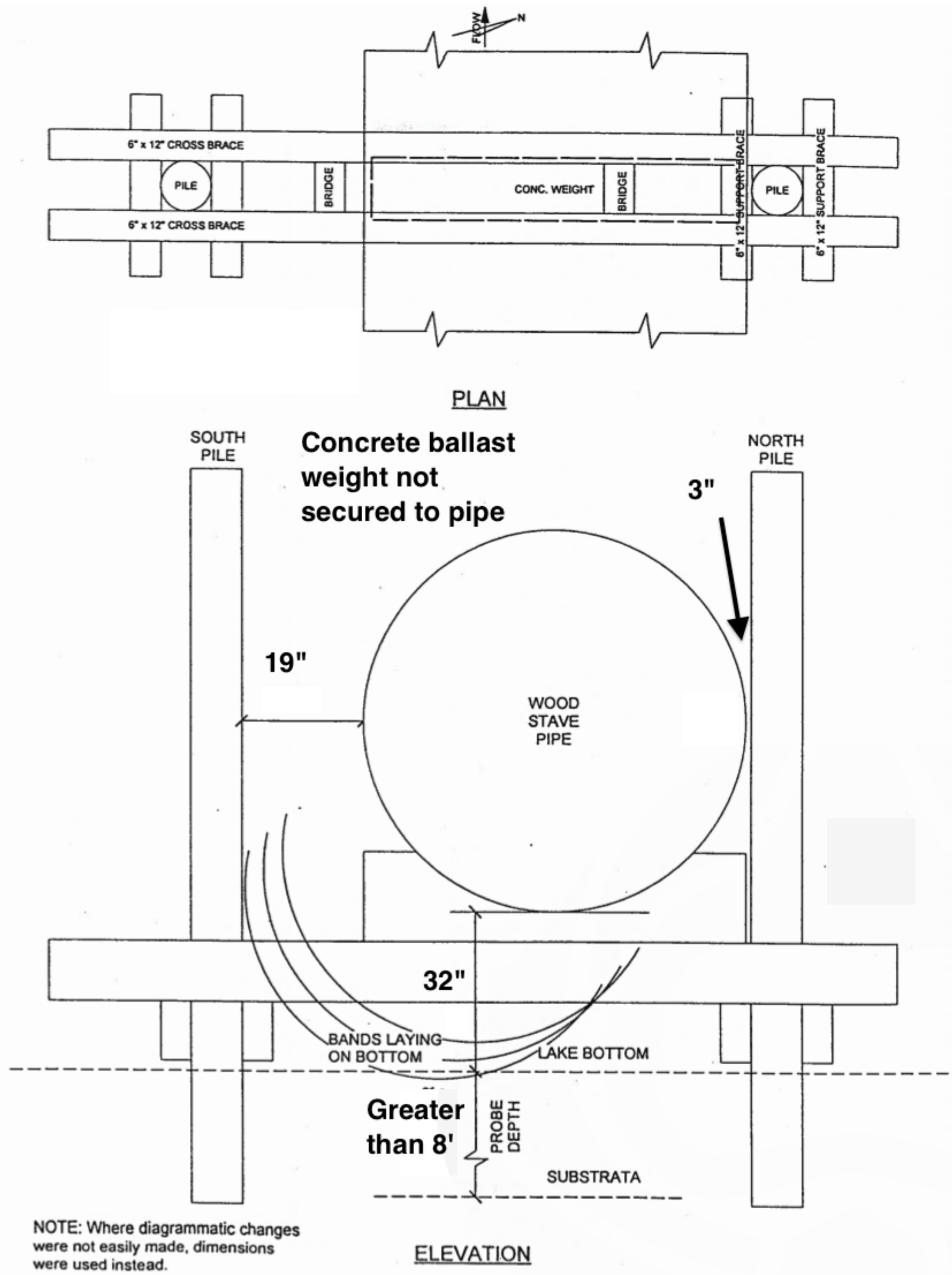
Pipe Condition Bent 5 to Bent 6					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Tight, not corroded	No	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands. First section of pipe with intermediate ballast weight.					

Bent 6



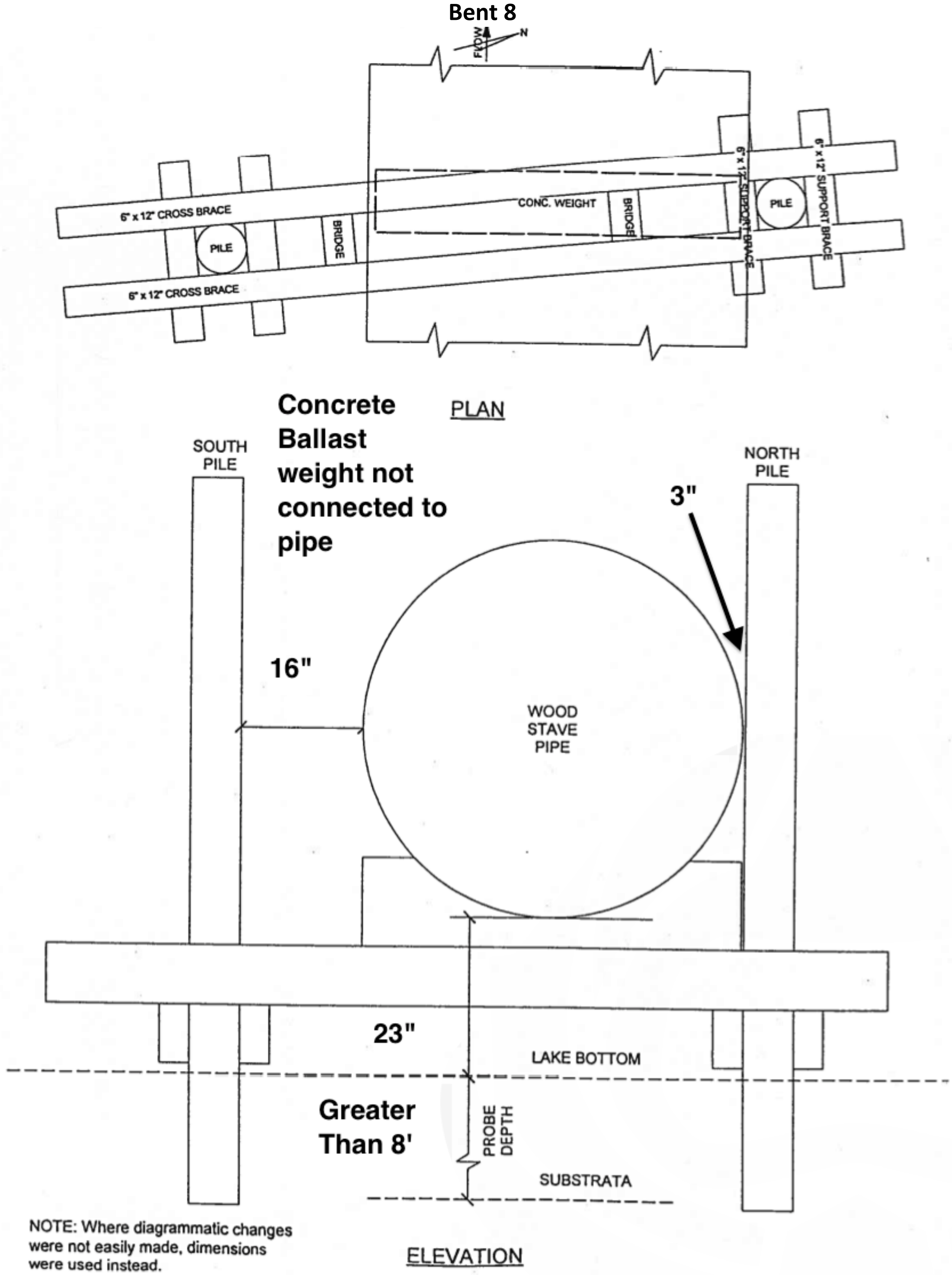
Pipe Condition Bent 6 to Bent 7					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not corroded, tight	Broken bands on bottom at bent 7	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands. Ballast weight not secured to pipe at bent 7.					

Bent 7



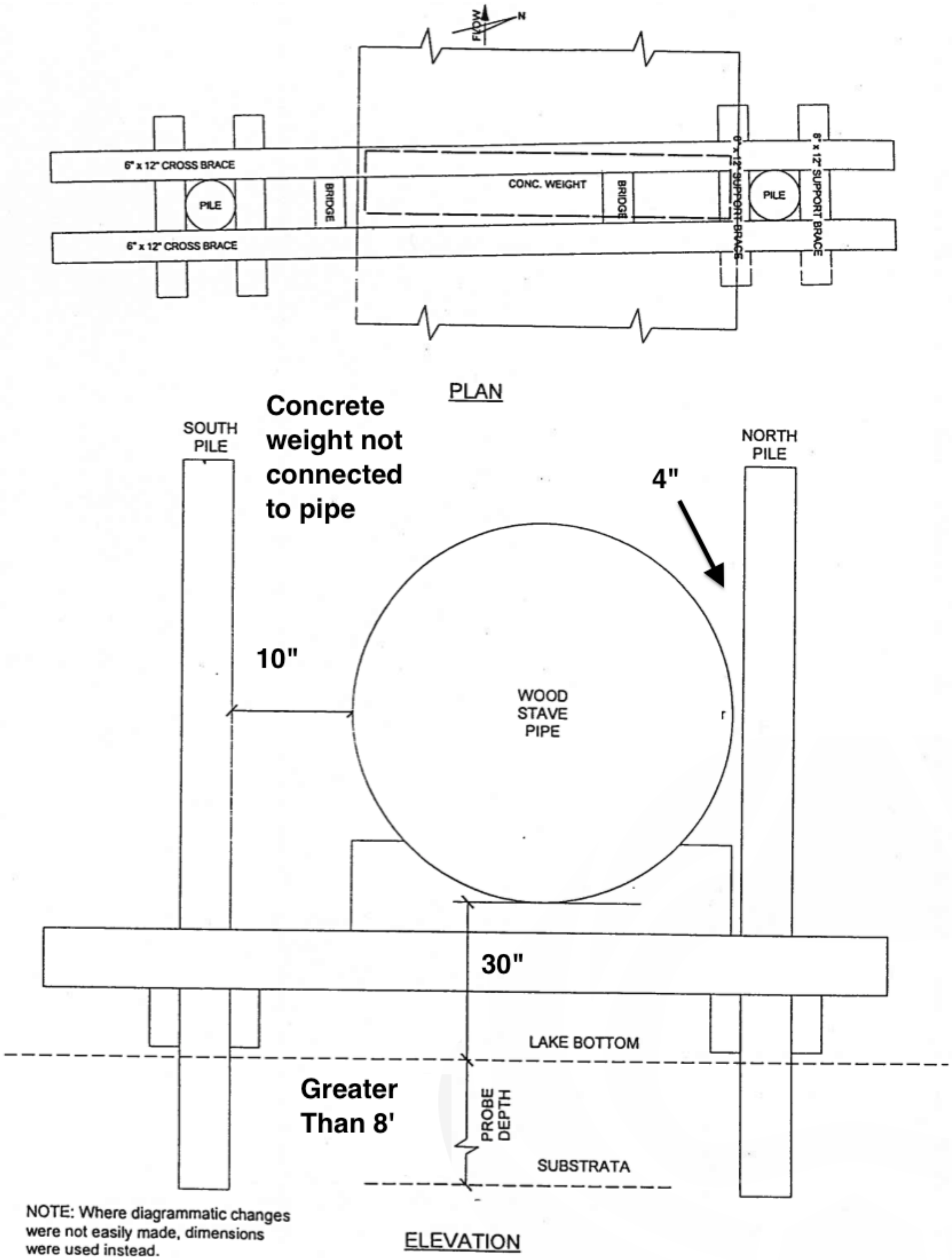
Pipe Condition Bent 7 to Bent 8					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not corroded, tight	Broken bands on bottom at bent 7	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands.					

Bent 8



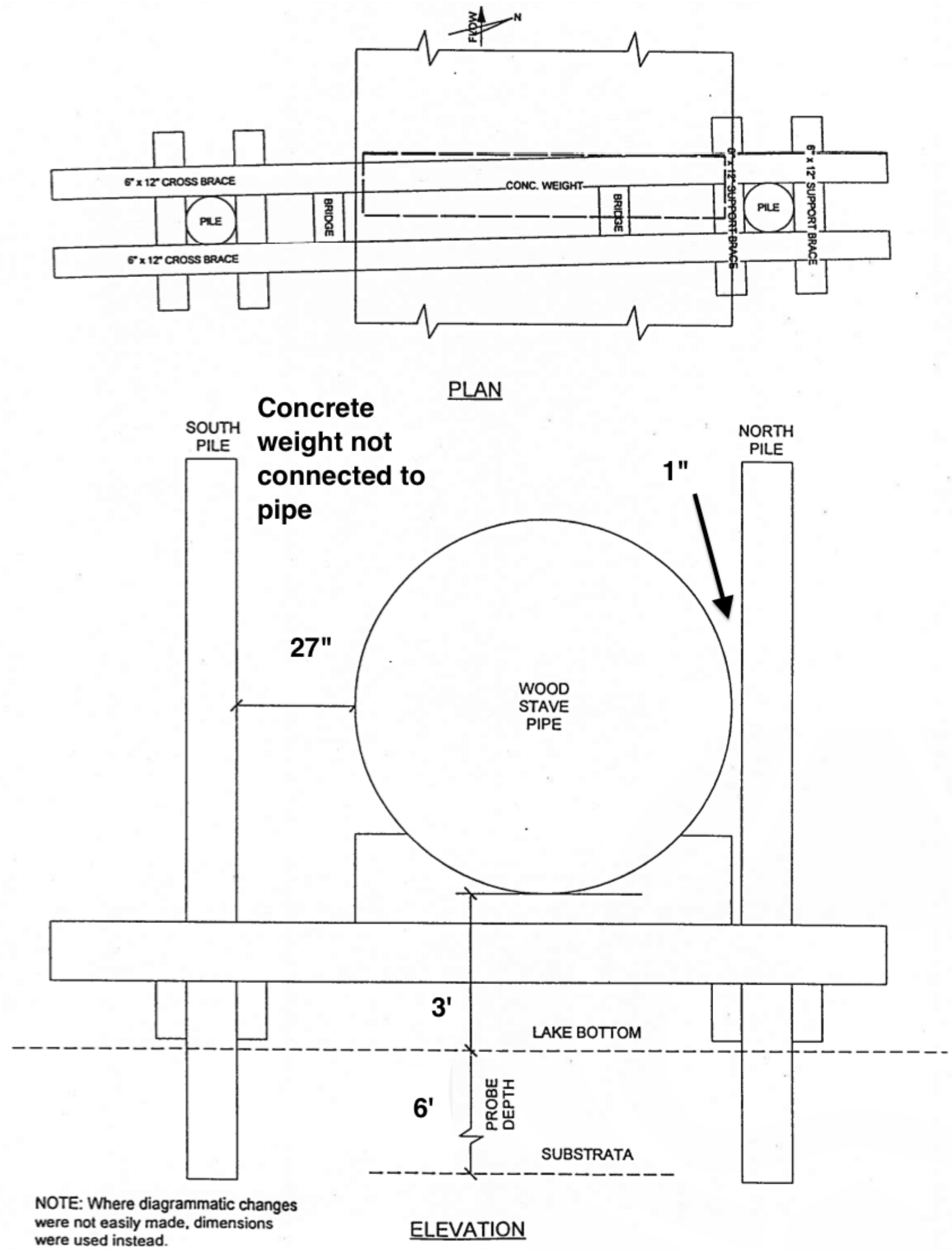
Pipe Condition Bent 8 to Bent 9					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not corroded, tight	None Seen	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands.					

Bent 9



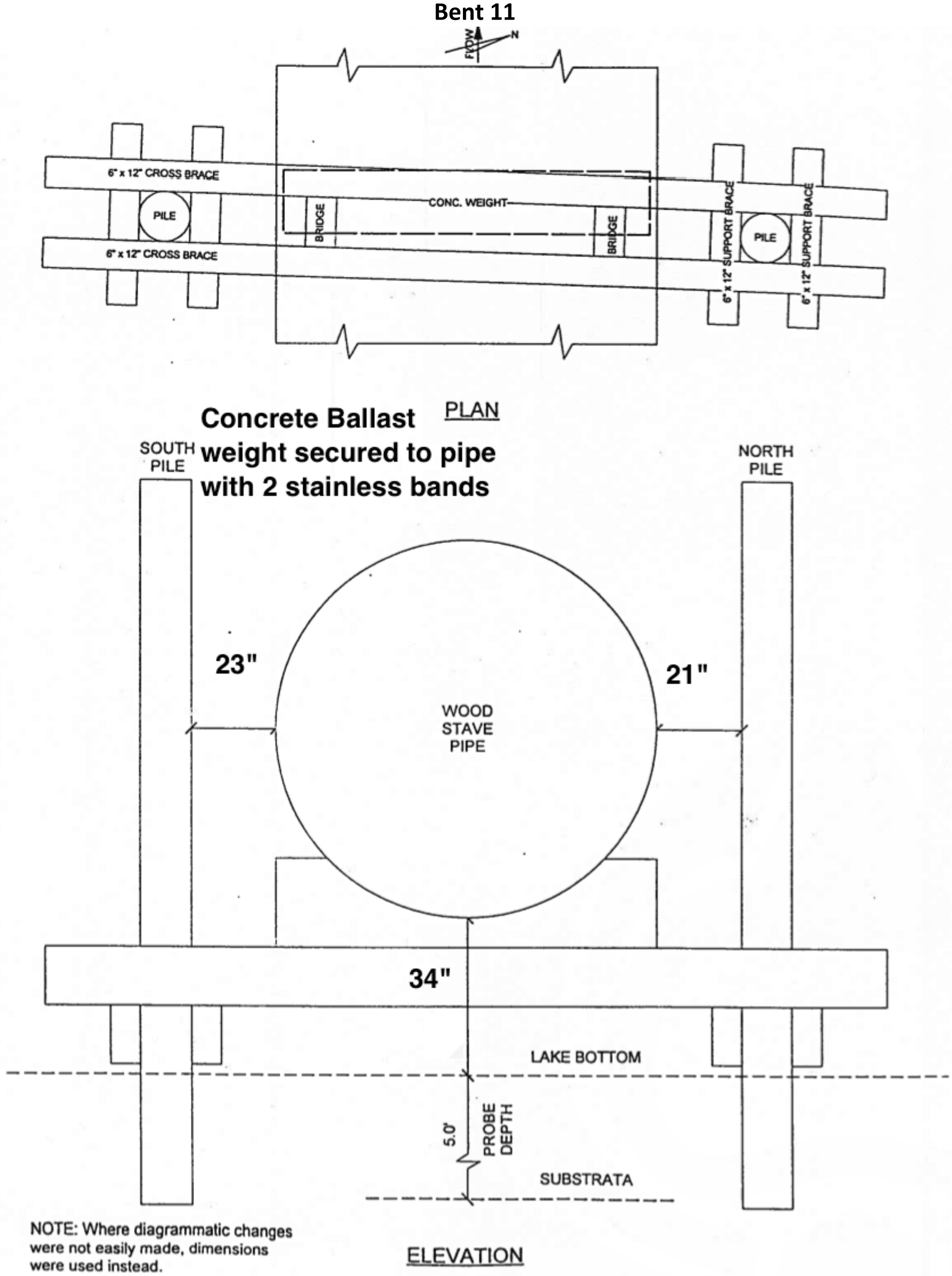
Pipe Condition Bent 9 to Bent 10					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not corroded, tight	None Seen	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands.					

Bent 10



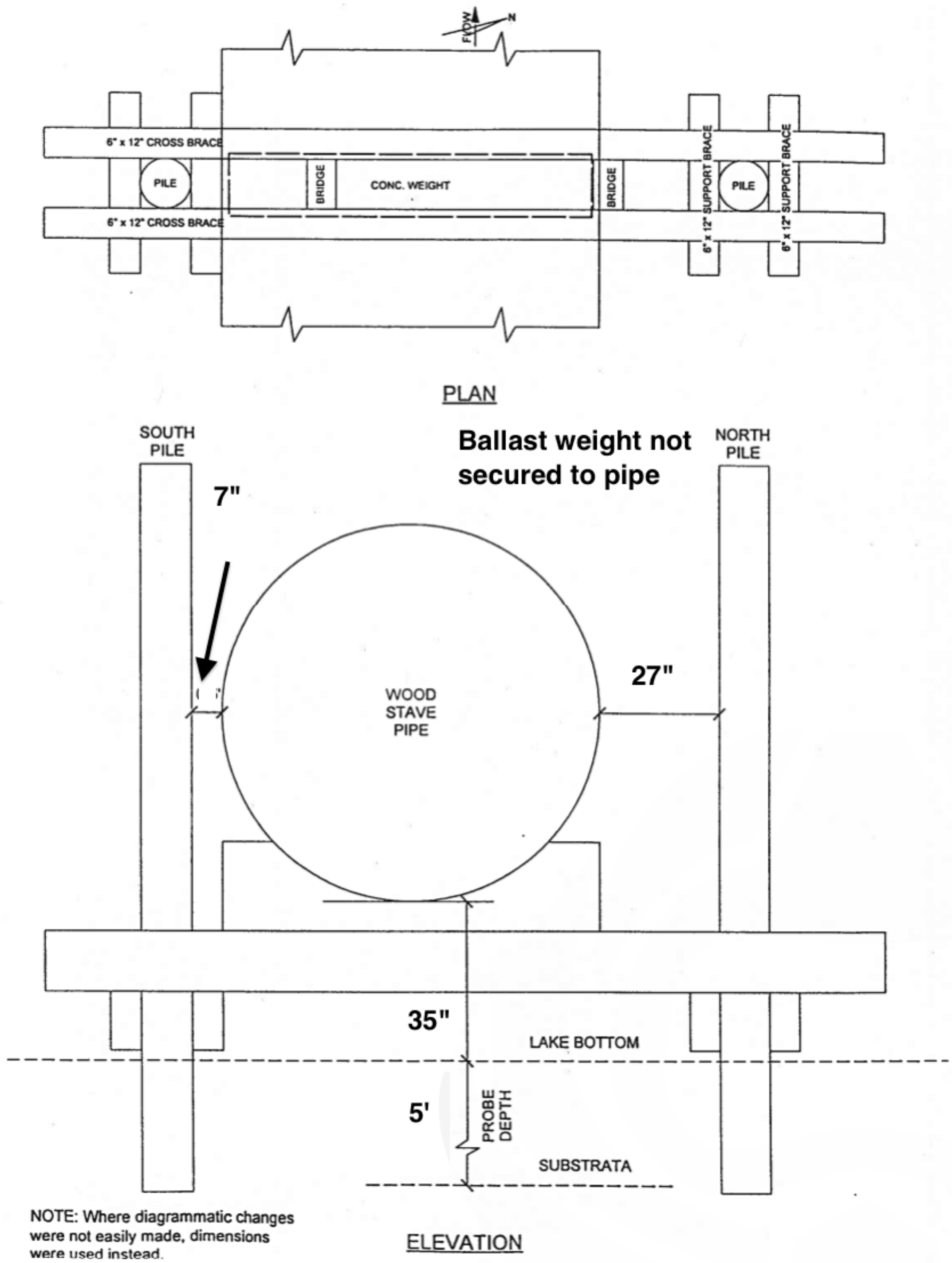
Pipe Condition Bent 10 to Bent 11					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	One corroded band at bent 11	None Seen	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands. See Photo #5 for detail of corroded stainless band at bent #11					

Bent 11



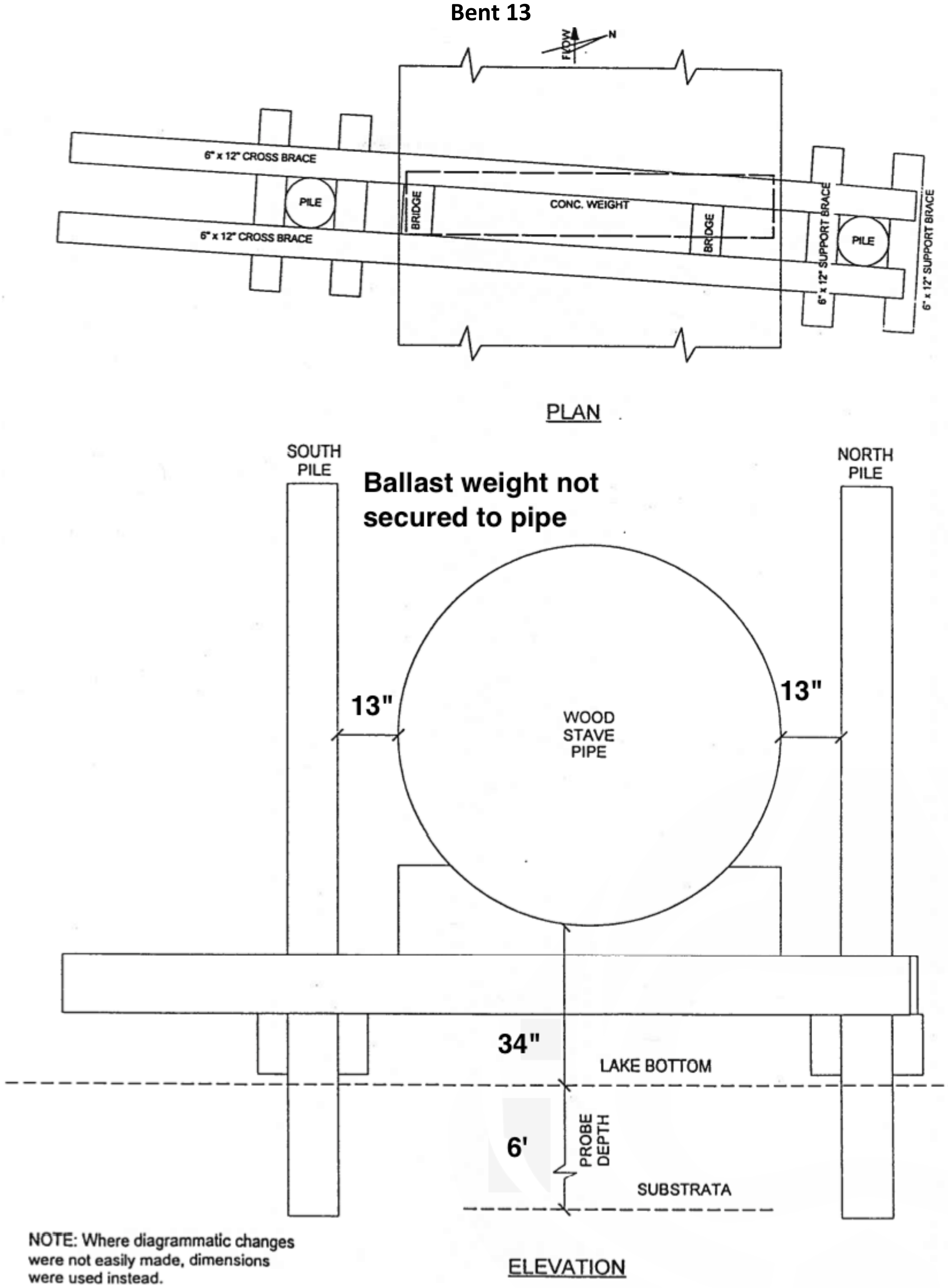
Pipe Condition Bent 11 to Bent 12					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	One corroded band at bent 11	None Seen	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands. See Photo #5 for detail of corroded stainless band at bent #11					

Bent 12



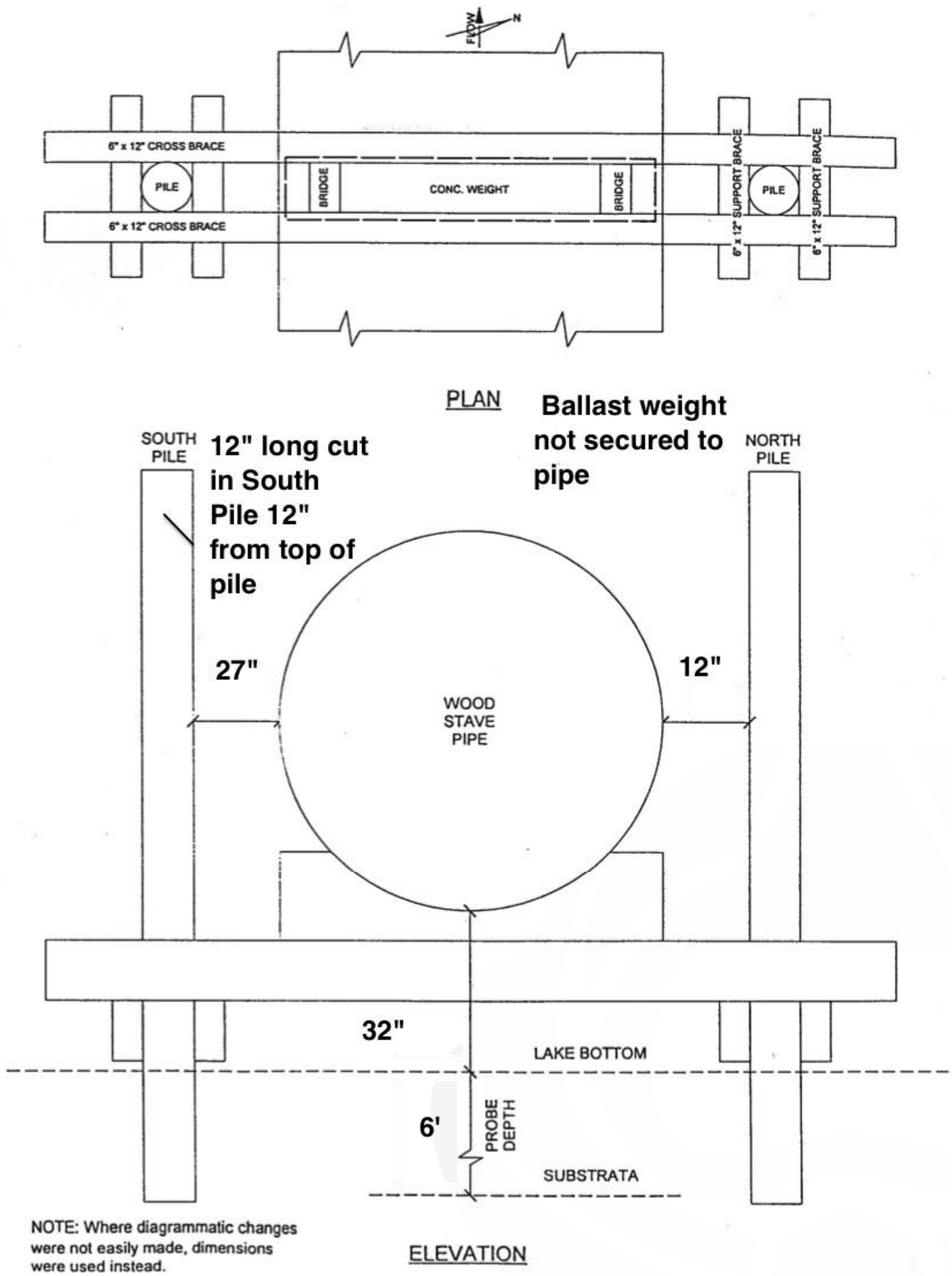
Pipe Condition Bent 12 to Bent 13					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None Seen	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands.					

Bent 13



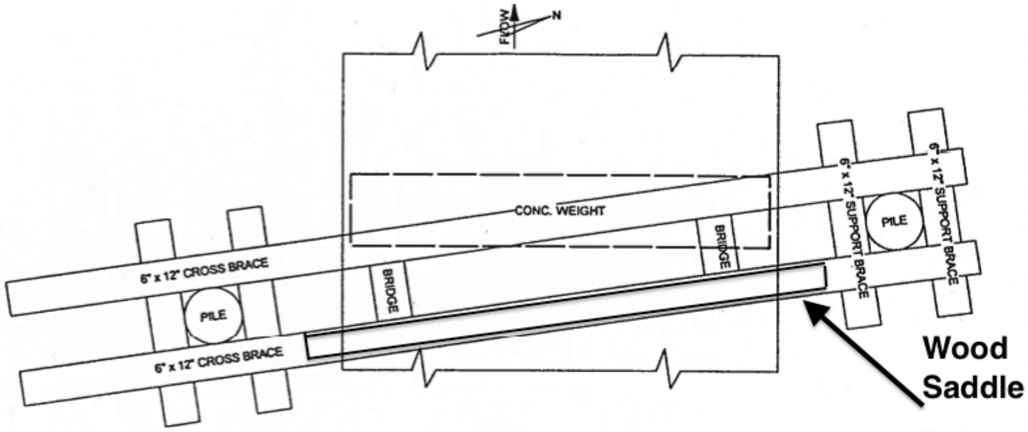
Pipe Condition Bent 13 to Bent 14					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None Seen	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands.					

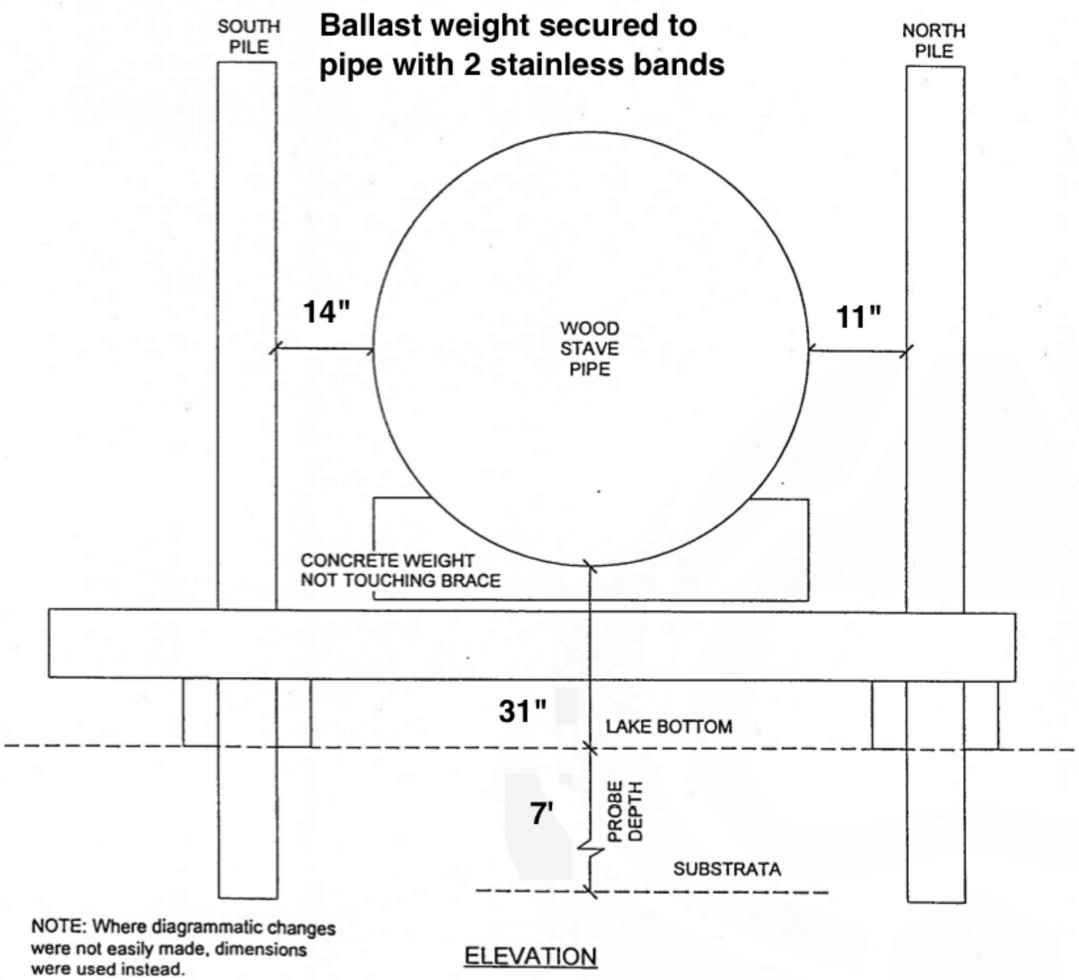
Bent 14



Pipe Condition Bent 14 to Bent 15					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None Seen	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands. Wood saddle at bent 15 on offshore cross brace, see photo 6 for image of saddle.					

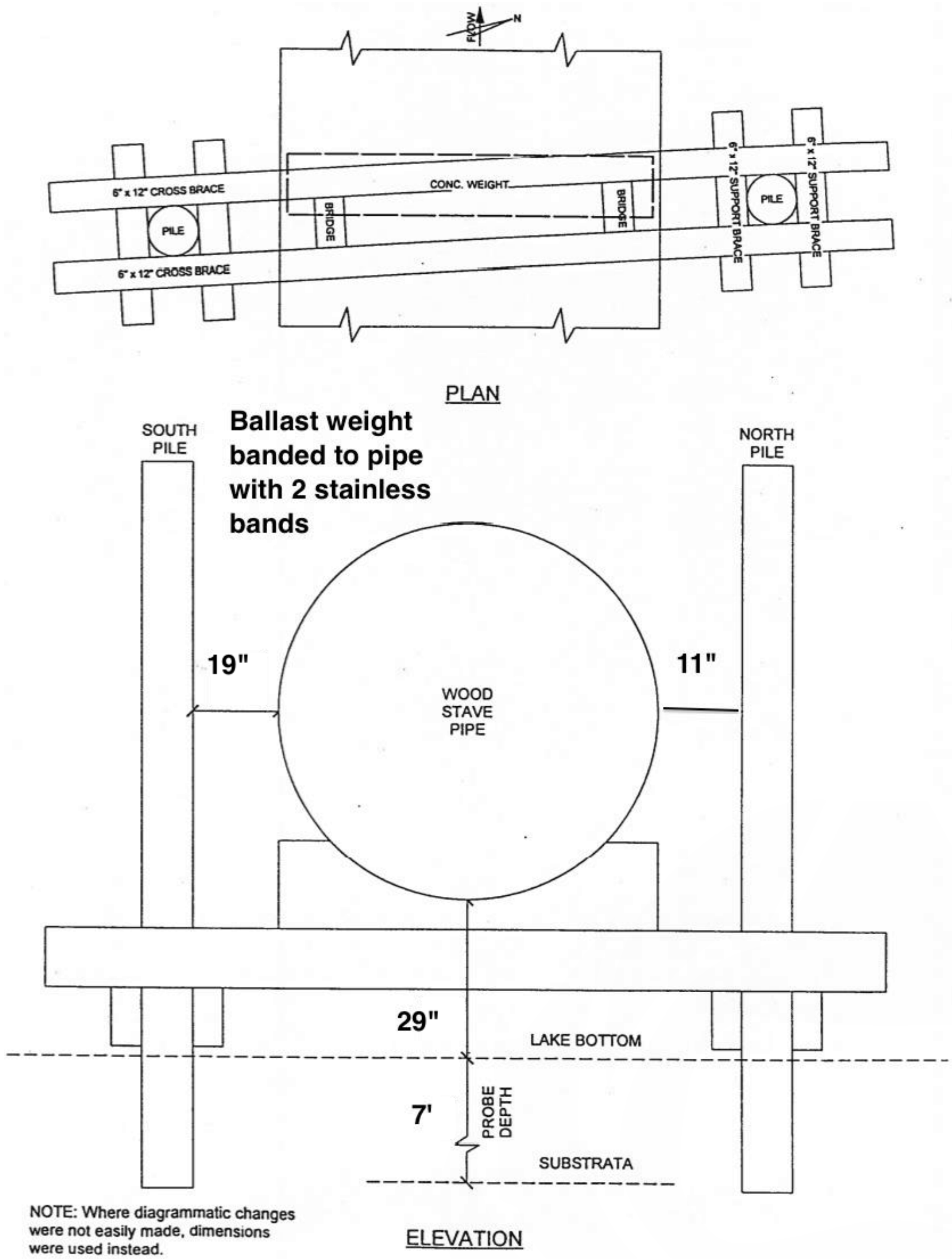
Bent 15





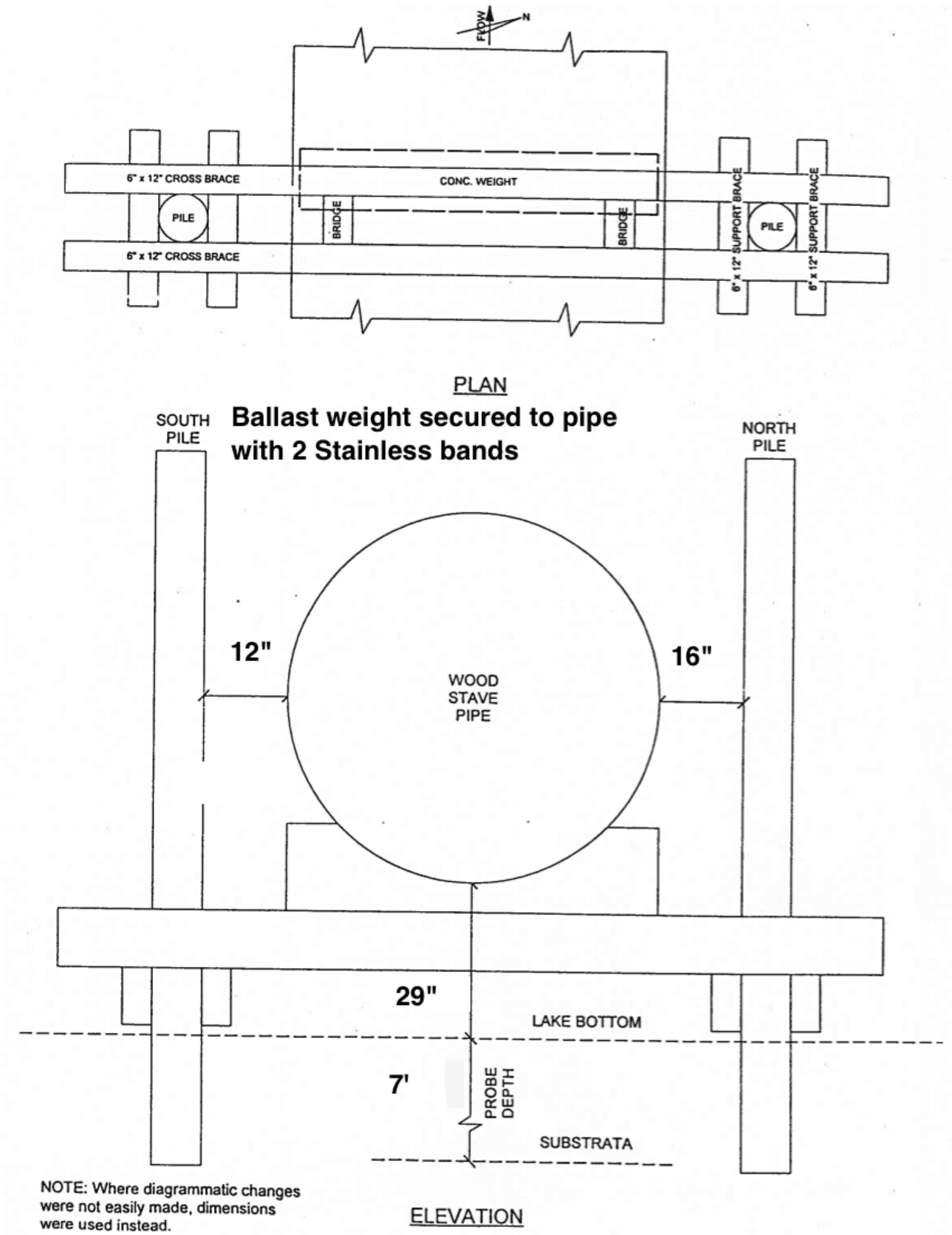
Pipe Condition Bent 15 to Bent 16					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	Broken band offshore of 16	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands. Broken Band Just offshore of Bent 16					

Bent 16



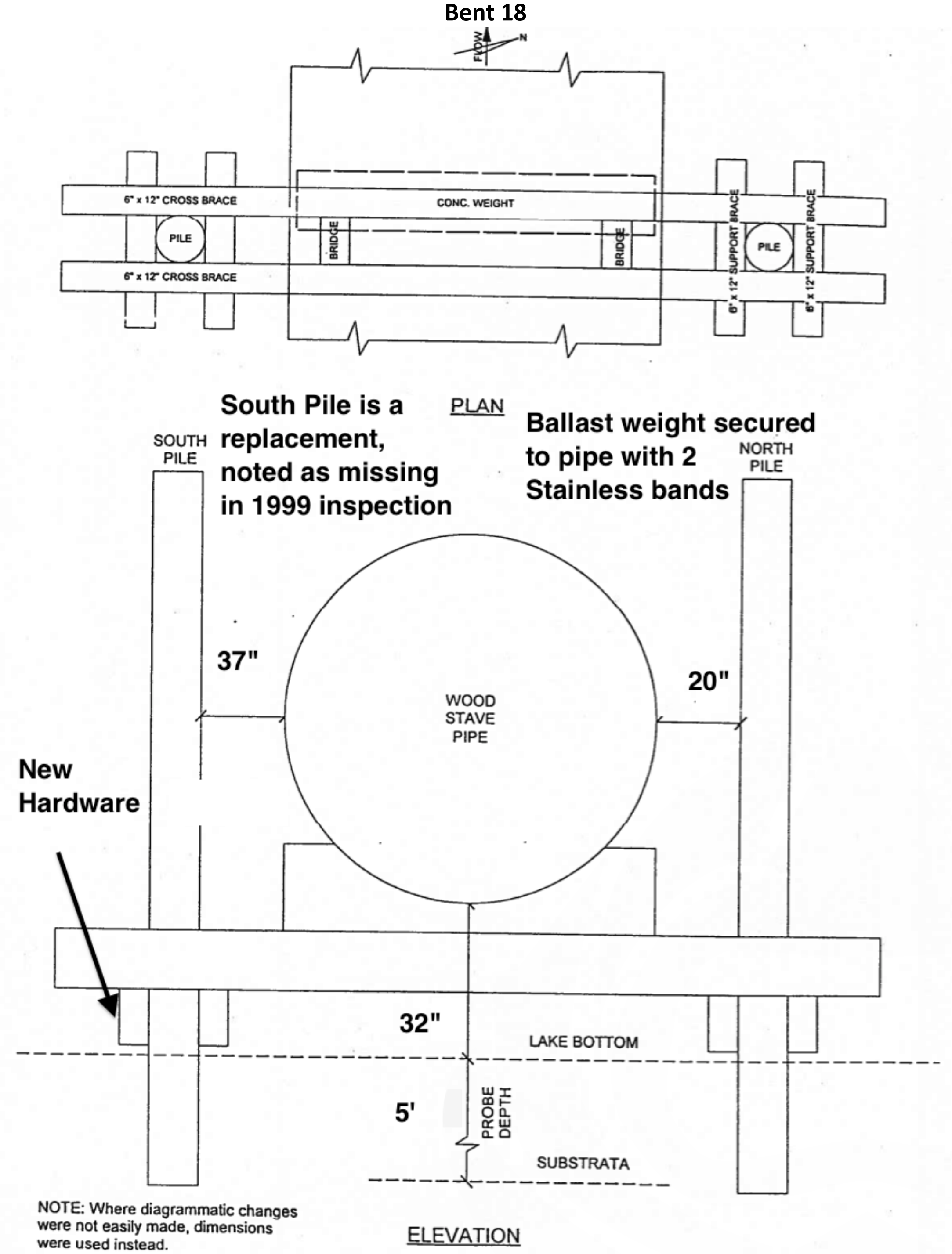
Pipe Condition Bent 16 to Bent 17					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None Seen	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands.					

Bent 17



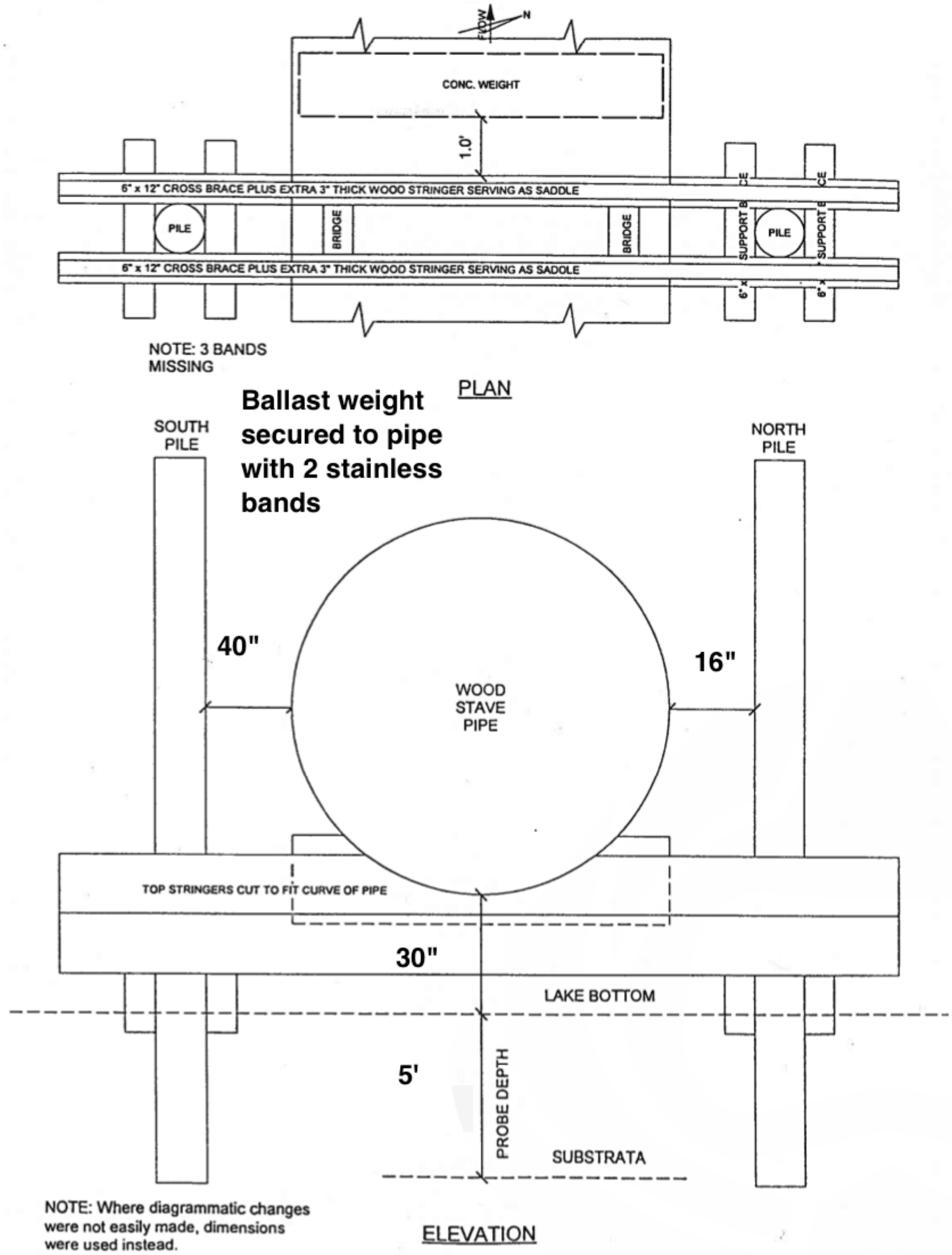
Pipe Condition Bent 17 to Bent 18					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None Seen	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands. South Pile has been replaced at bent 18, so new support brace hardware was installed. See photo #7 for detail of new hardware.					

Bent 18



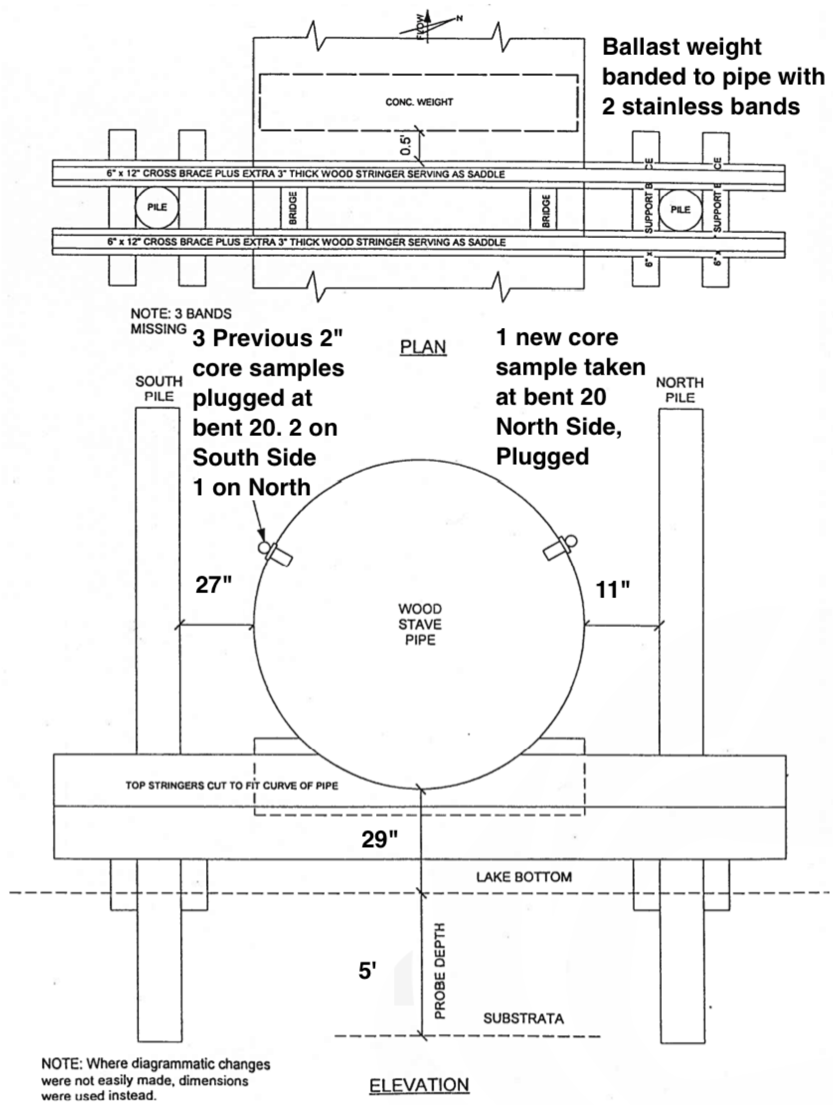
Pipe Condition Bent 18 to Bent 19					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	carbon band missing 1' offshore of bent 19	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands.					

Bent 19



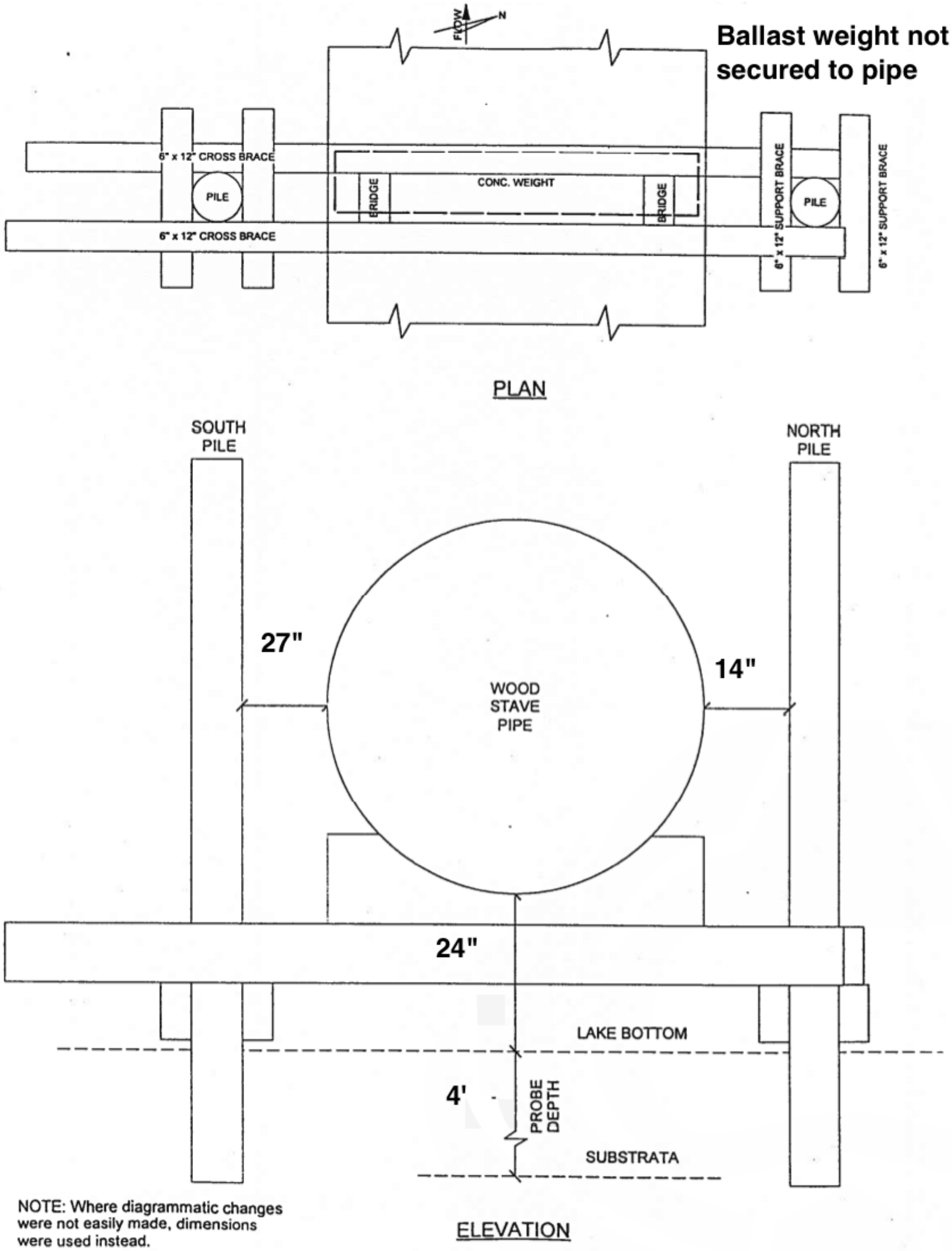
Pipe Condition Bent 19 to Bent 20					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes 2 each, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands. Two concrete ballast weights installed between bents 19 and 20. Three core samples had been previously taken from bent 20, two on the South side of the pipe, and one on the North side of the pipe. As part of our inspection we took another core sample from the North Side. See Photo #8 for detail of this core sample. Void in pipe plugged with a mechanical plug, See Photo 9 for detail of previously installed plugs. See Photo #10 for detail of new mechanical plug. See Photo # 11 for view of void left by core sample.					

Bent 20



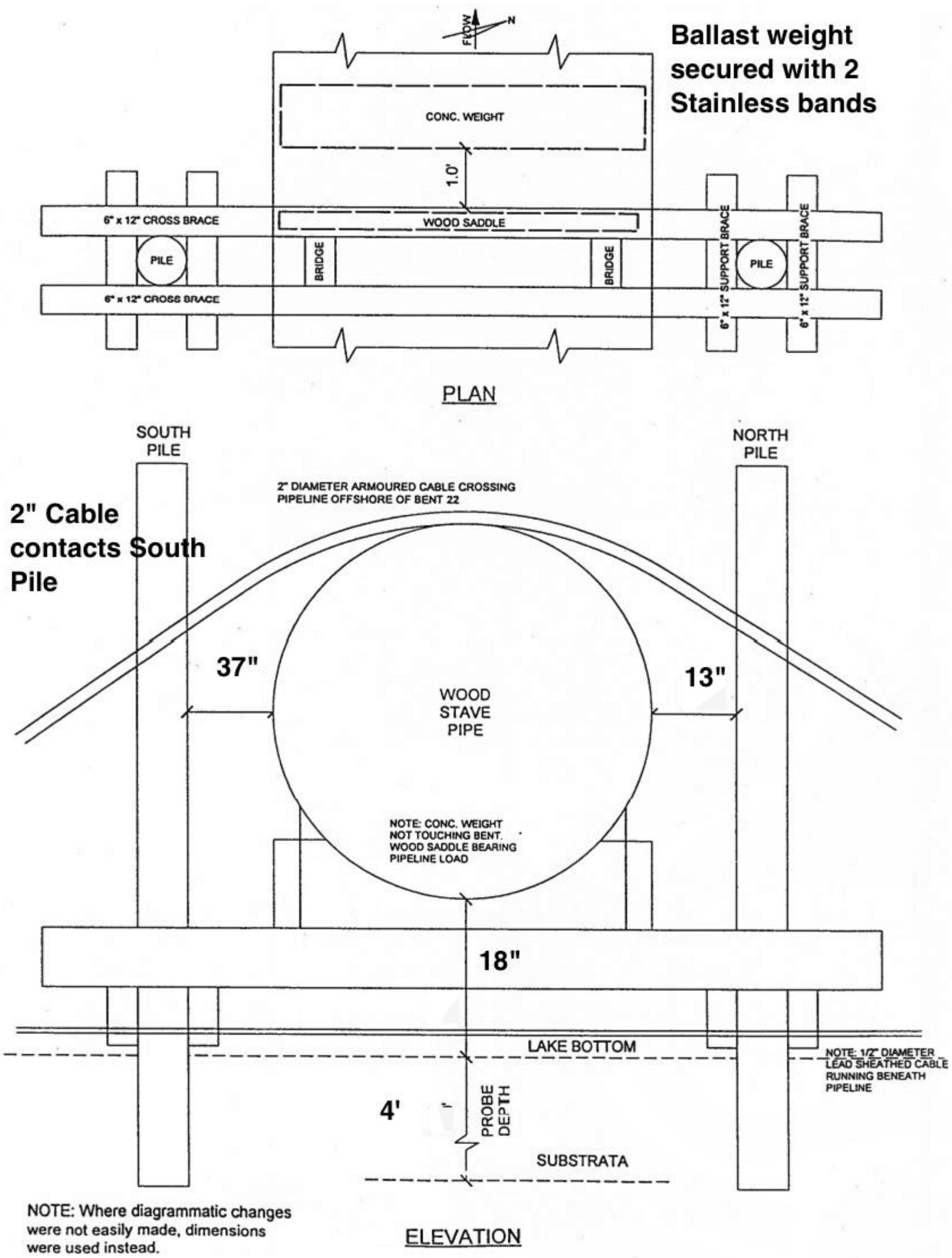
Pipe Condition Bent 20 to Bent 21					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for typical condition of Stainless and Carbon bands.					

Bent 21



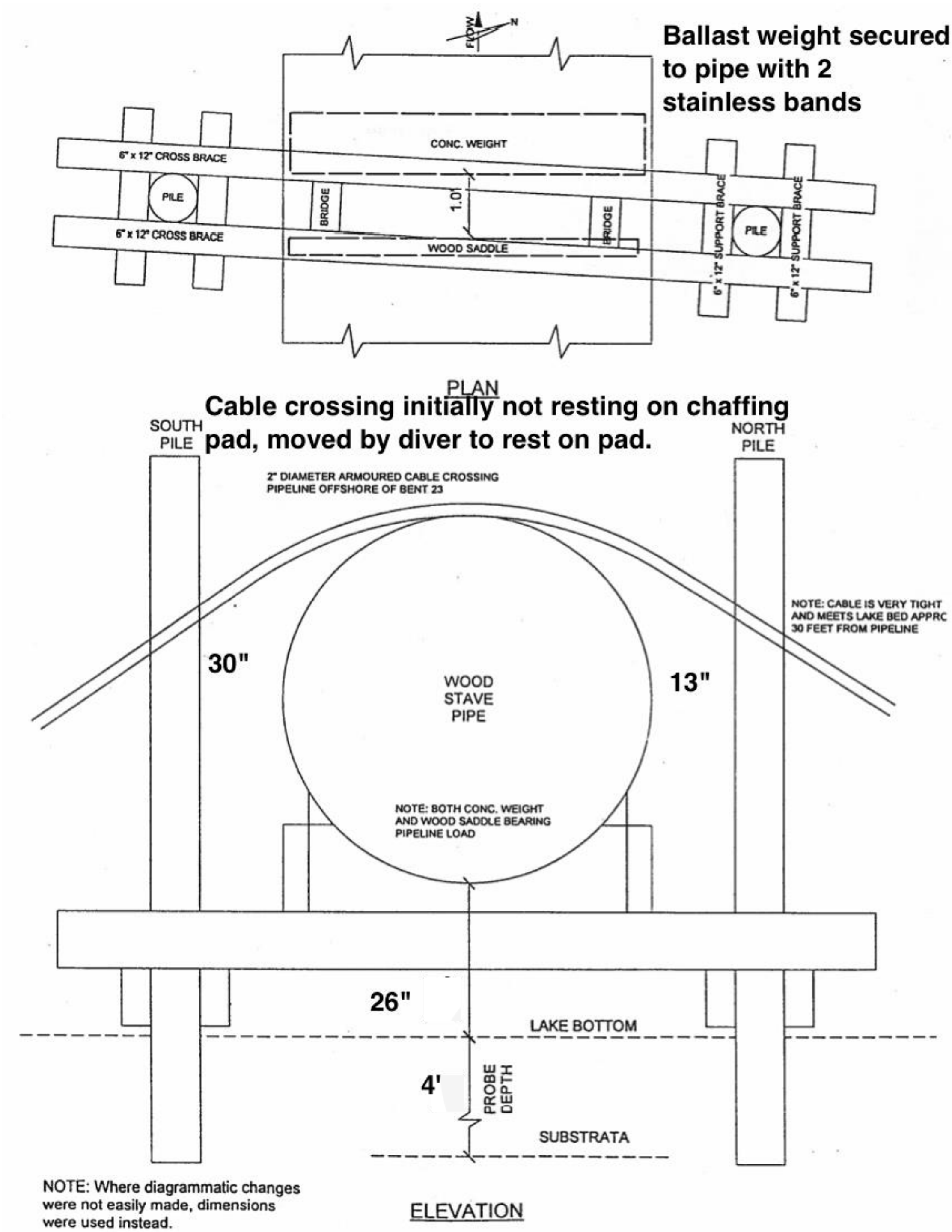
Pipe Condition Bent 21 to Bent 22					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, 2 bands, stainless, tight
Notes:					
2” Diameter Cable crossing over top of pipe just offshore of bent 22. Cable contacts an anti-chaffing pad installed on the 12 o’ clock position of pipe and the South pile of bent 20, but contacts the pipe at no other location. Cable can be moved by hand. ½” Cable Crossing below pipe at bent 22, not in contact with intake components. See Photos 12 and 13 for views of the cable crossing, and photo #14 for a view of a carbon band in this area with the oxidation and scale removed, showing severe deterioration of the fastening hardware.					

Bent 22



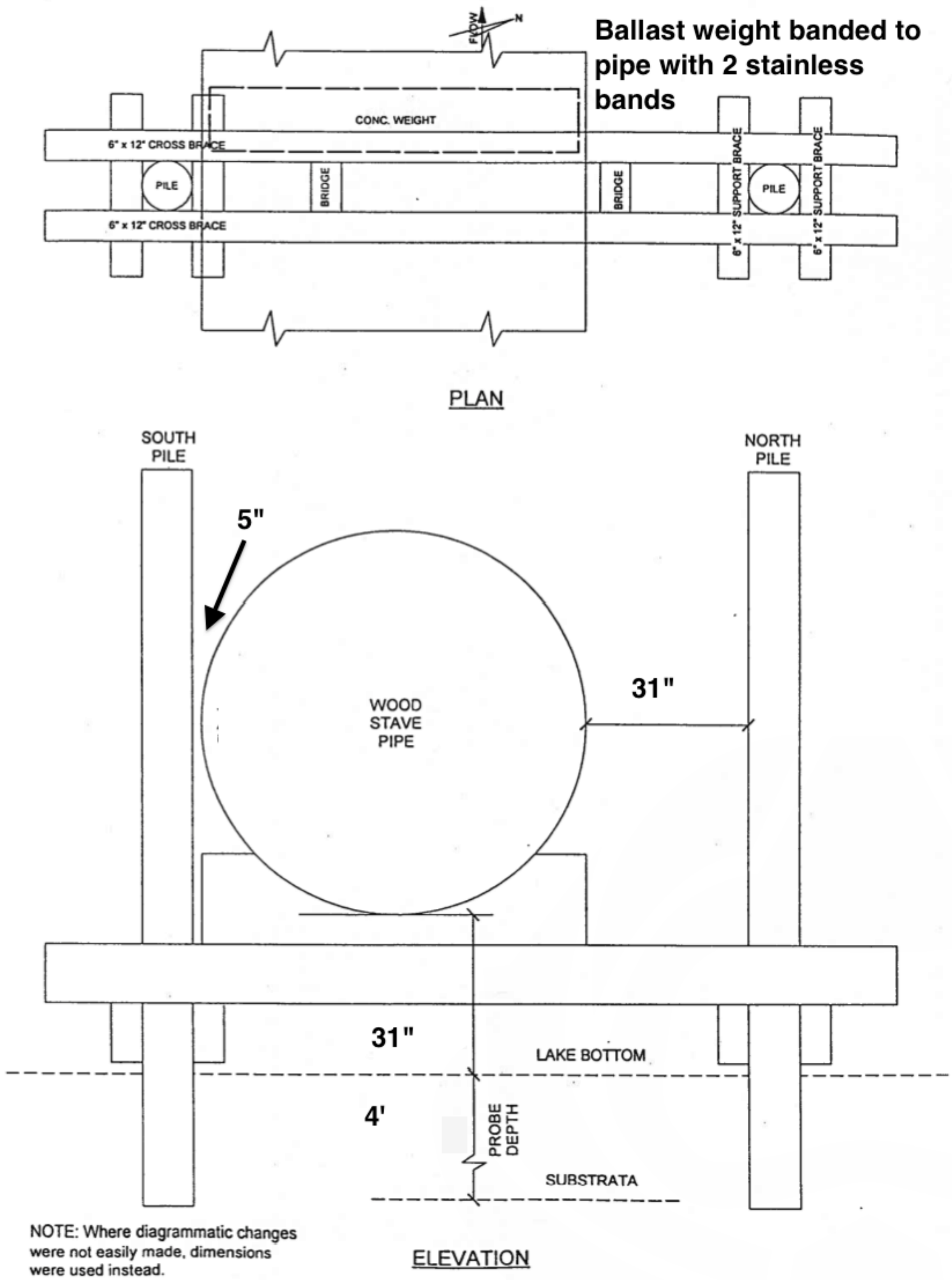
Pipe Condition Bent 22 to Bent 23					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, 2 bands, stainless, tight
Notes:					
2" cable crossing just offshore of bent 23 contacting the intake pipe several inches offshore of the anti chaffing pad. Cable was relocated by diver to rest on anti-chaffing pad. Photo #15 Shows the original location of the 2" cable crossing.					

Bent 23



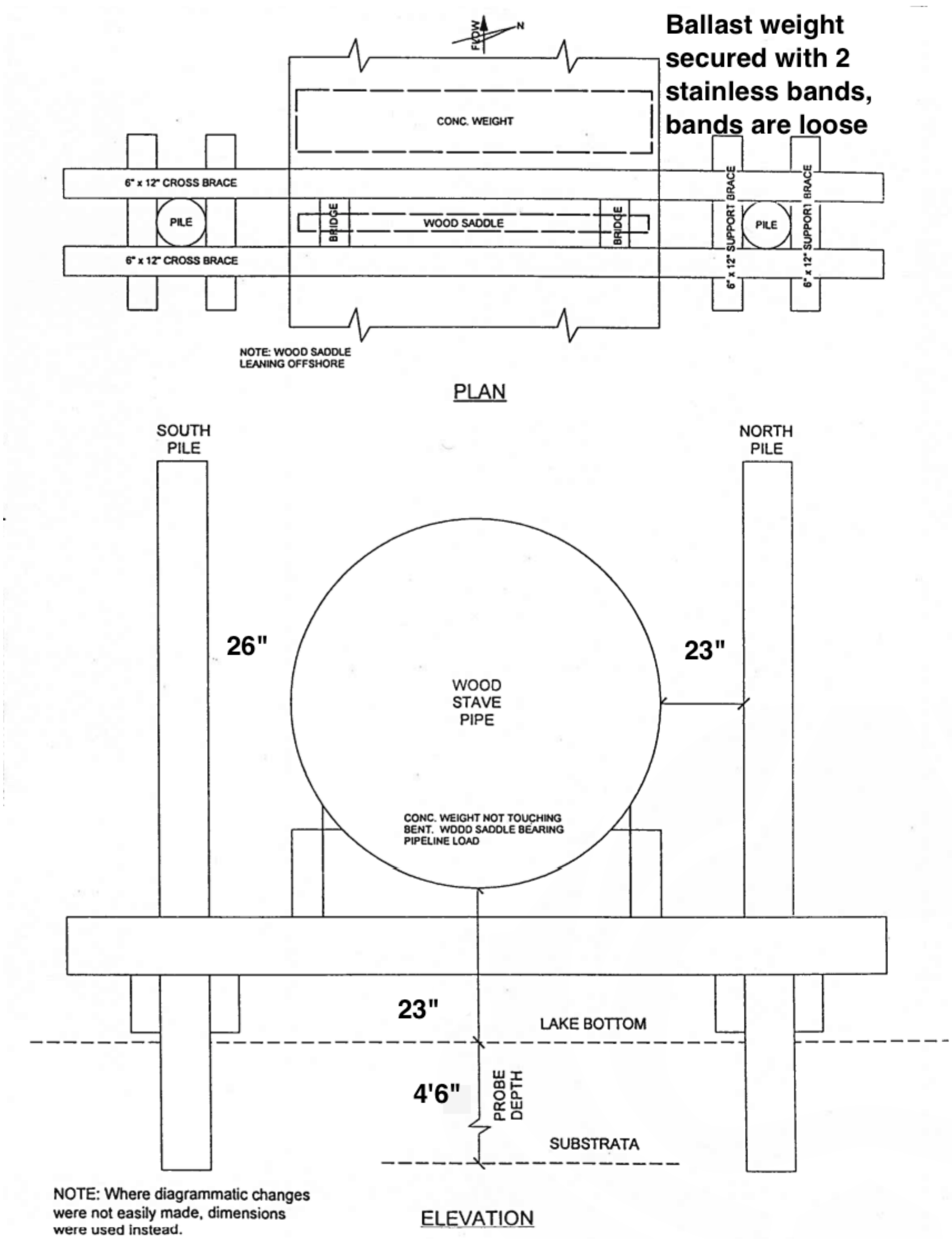
Pipe Condition Bent 23 to Bent 24					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for Typical condition of stainless and carbon bands.					

Bent 24



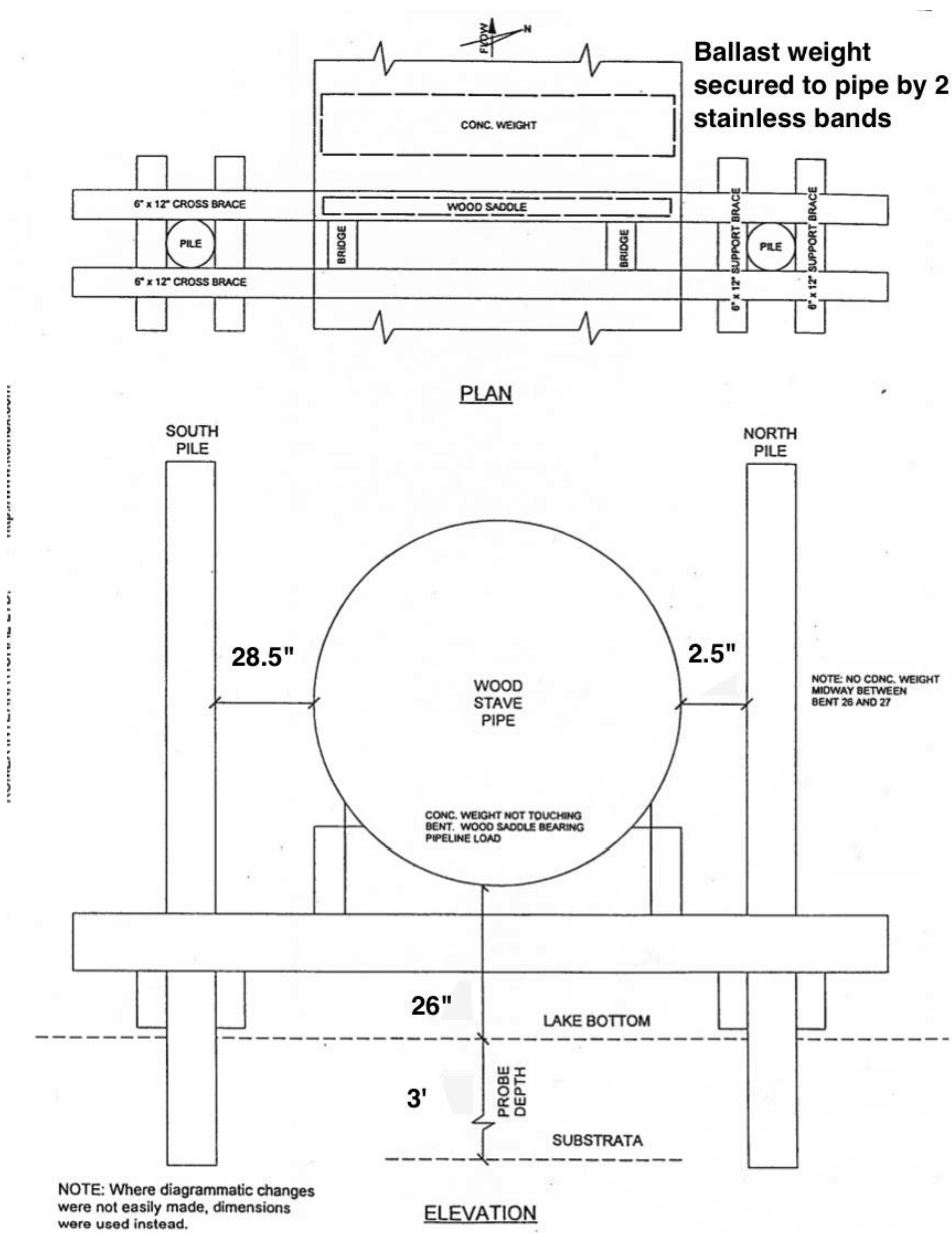
Pipe Condition Bent 24 to Bent 25					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for Typical condition of stainless and carbon bands.					

Bent 25



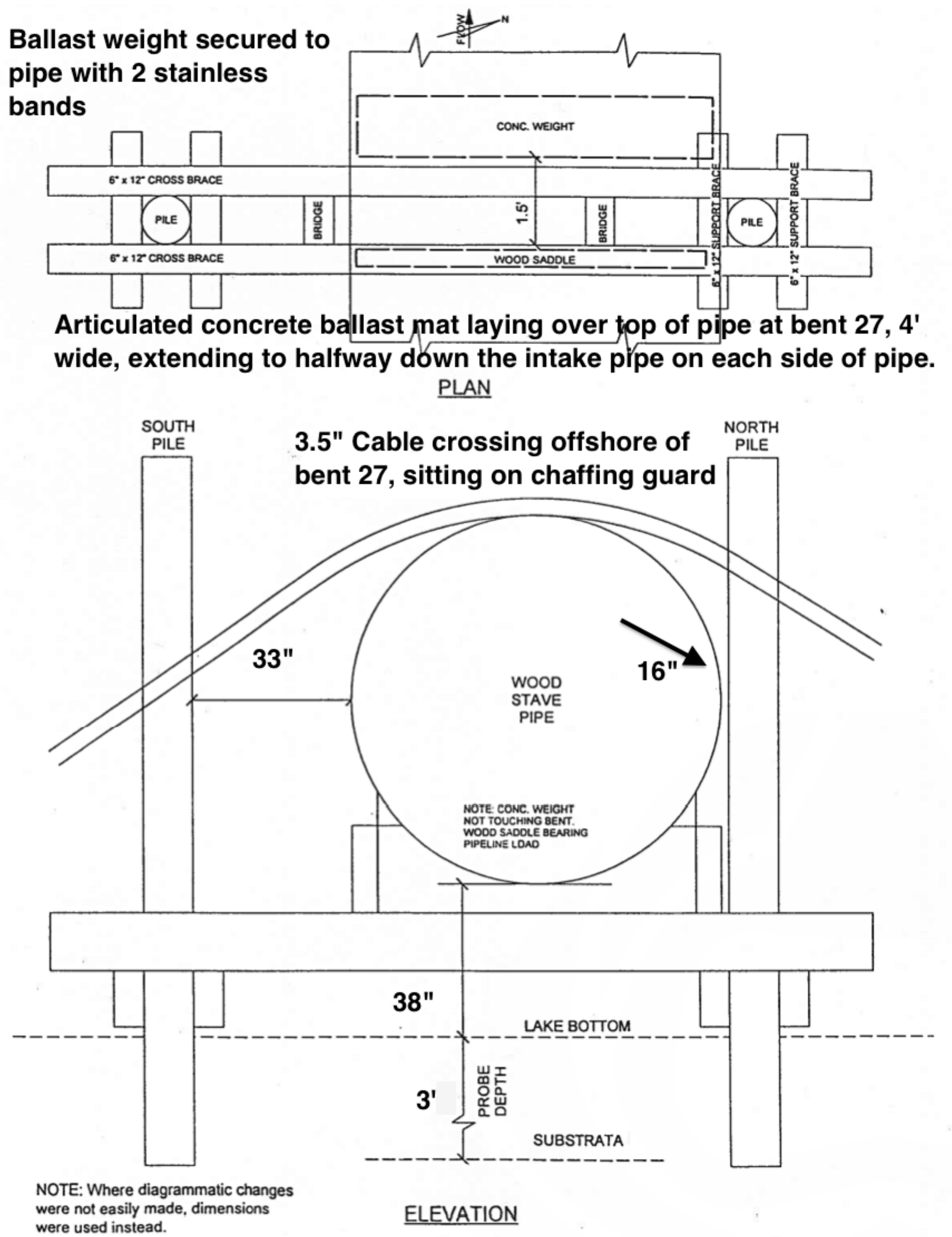
Pipe Condition Bent 25 to Bent 26					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	3rd carbon band offshore of bent 26 broken	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for Typical condition of stainless and carbon bands. 3rd band offshore of bent 26 broken 3.5" cable crossing inshore of bent 26					

Bent 26



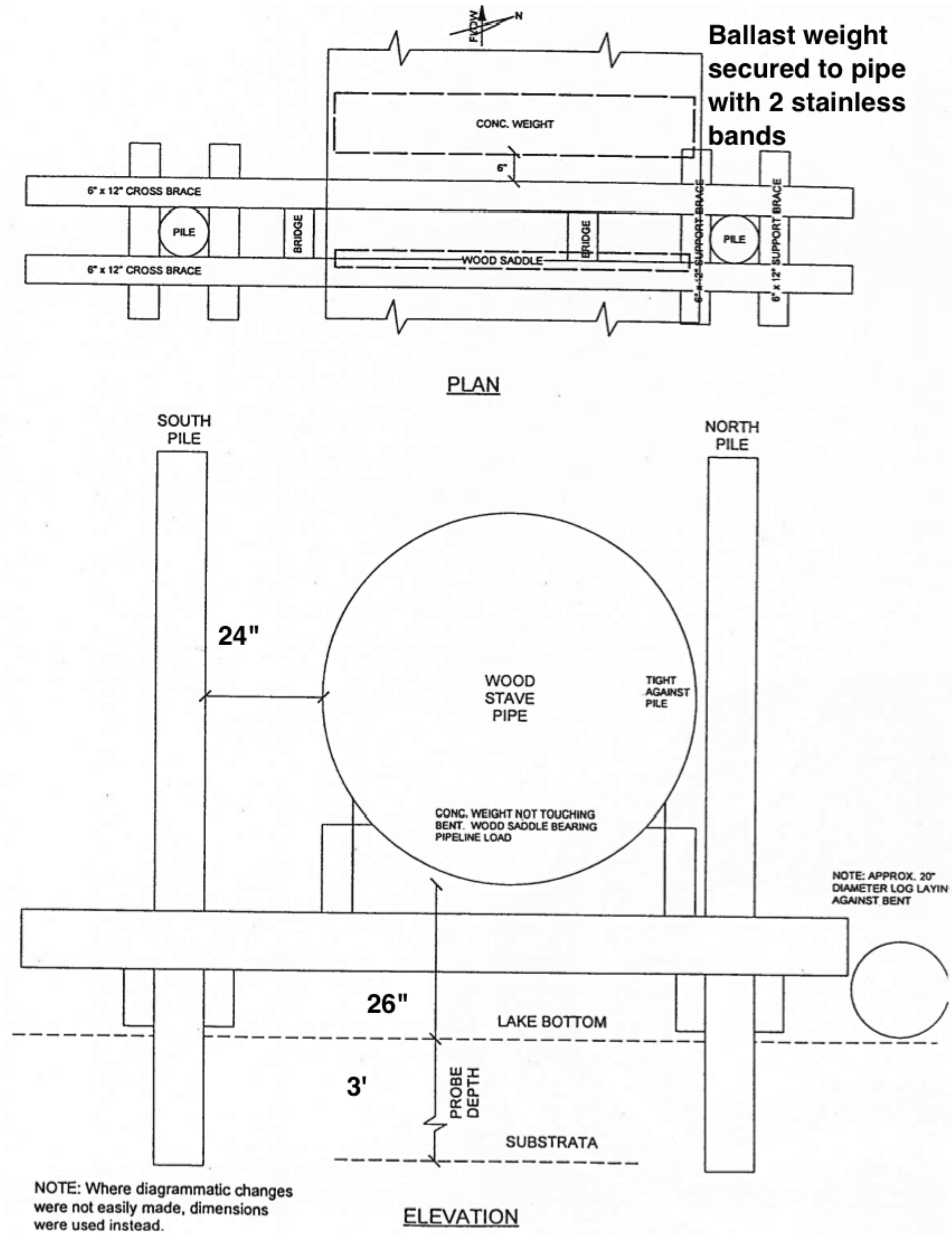
Pipe Condition Bent 26 to Bent 27					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, 2 bands, stainless, tight
Notes:					
See Photo #3 for Typical condition of stainless and carbon bands. 3.5" Cable crossing sitting on chaffing guard just offshore of pile bent 27. See Photo# 17 Articulated concrete ballast mat laying over top of intake pipe at bent 27. See Photo #18					

Bent 27



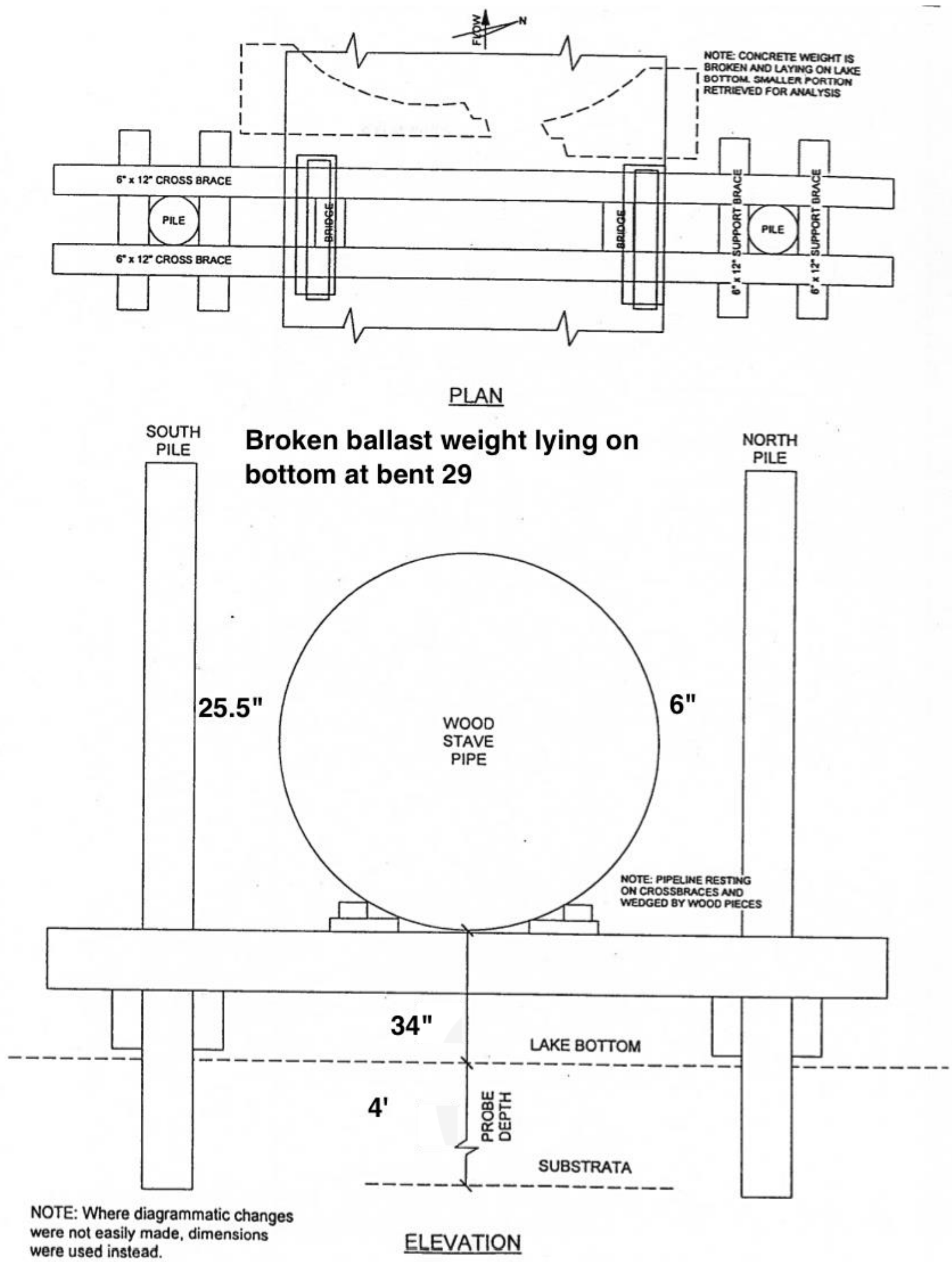
Pipe Condition Bent 27 to Bent 28					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	None Seen
Notes:					
Flange connection 9' Inshore of bent 27- Flange is concealed under denso wax tape for corrosion protection, hardware exposed through the tape appears to be in place and tight, stainless alignment screws placed at the 12 o' clock position still at the 12 o' clock position and in line with each other. No signs of inflow or outflow through flange noted. See Photos 19 and 20 for detail. See Photo #3 for Typical condition of stainless and carbon bands.					

Bent #28



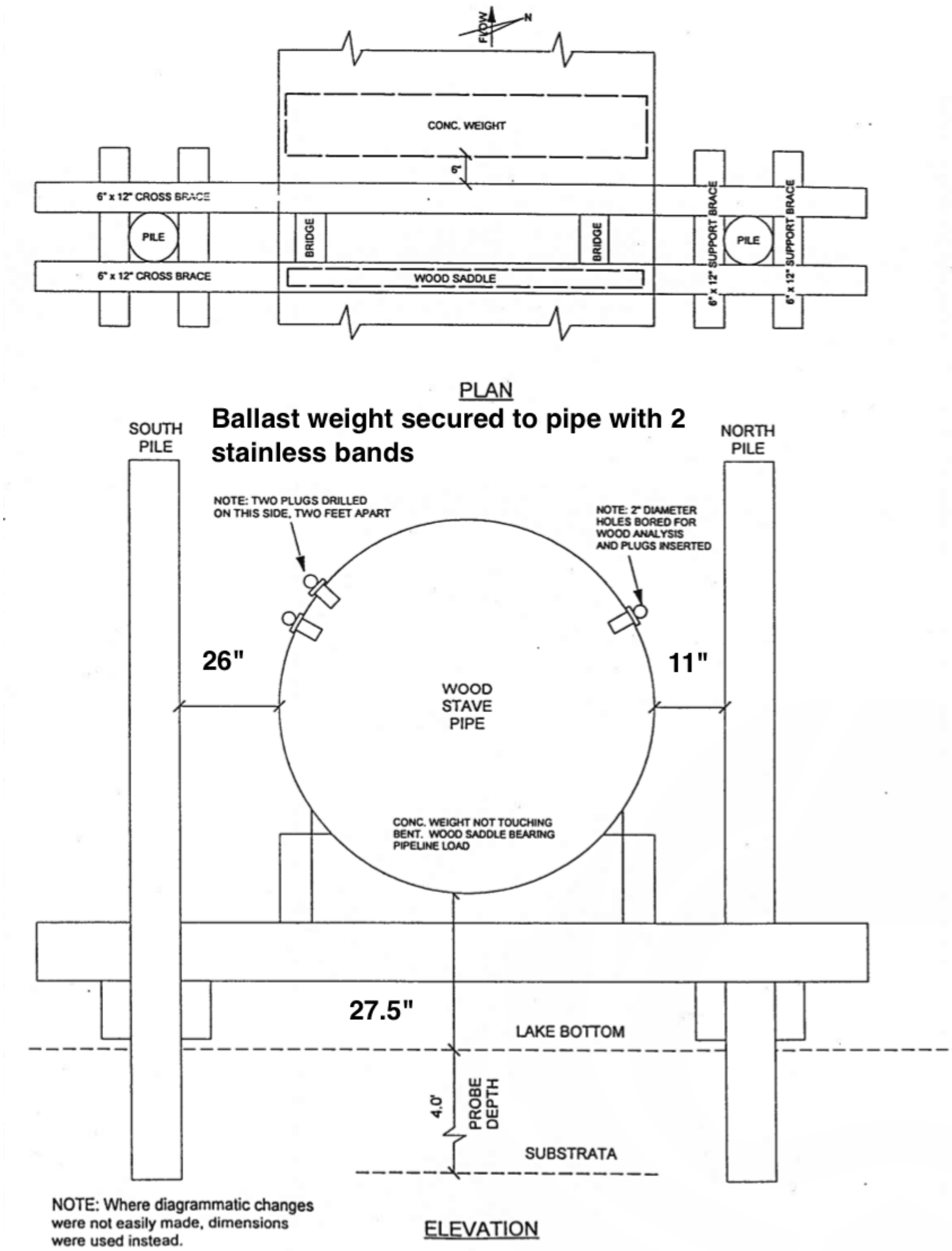
Pipe Condition Bent 28 to Bent 29					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, Stainless bands not corroded, tight
Notes:					
Articulated concrete ballast weight laying over top of pipe 4' inshore of bent 28, 4' wide, typical of previous concrete mat noted at bent 27. See Photo #3 for Typical condition of stainless and carbon bands.					

Bent #29



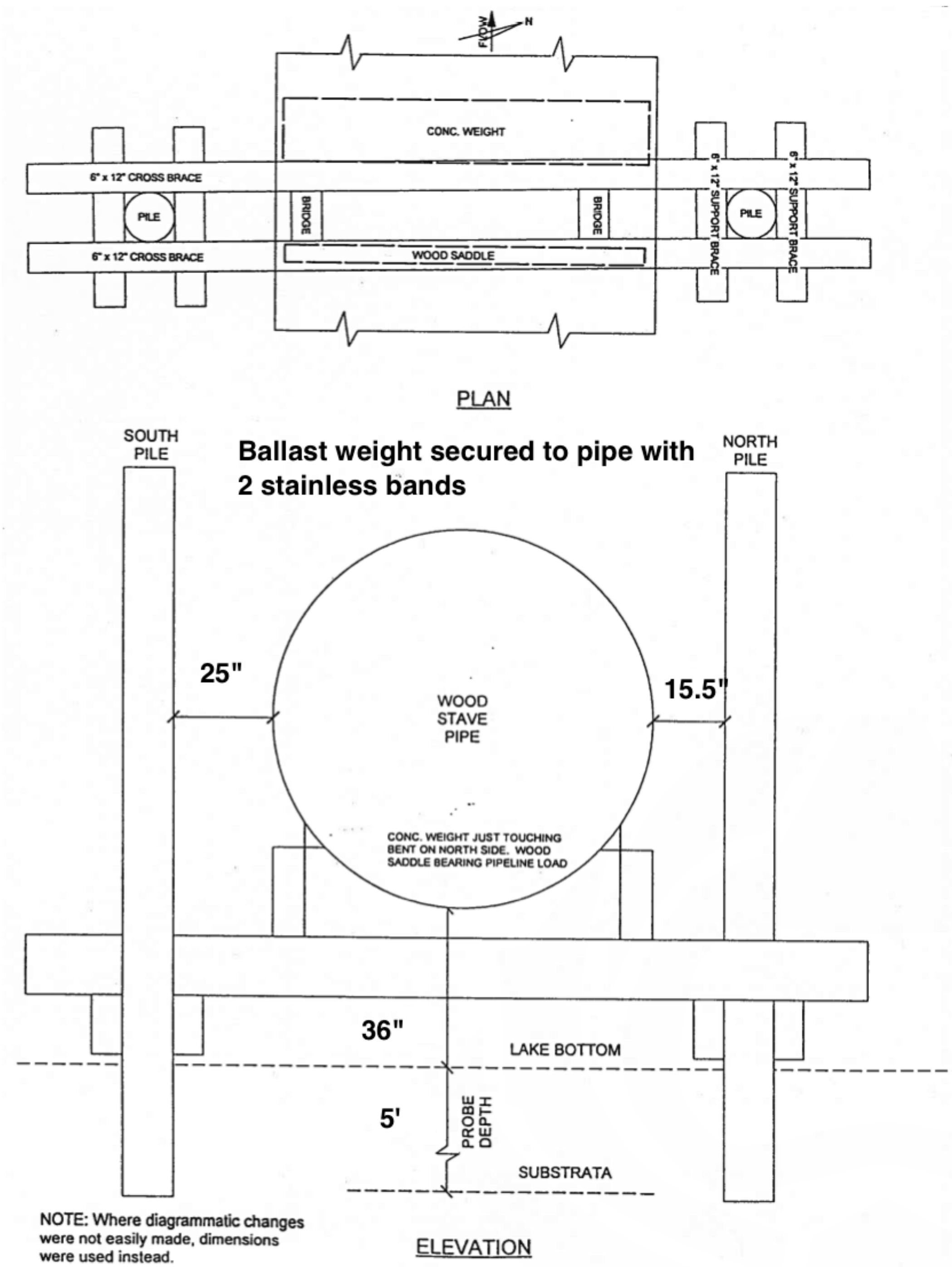
Pipe Condition Bent 29 to Bent 30					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, Stainless bands not corroded, tight
Notes:					
Previous cores taken at bent 30 and plugged, plugs typical of those noted at bent 20 and pictured in photo #9. See Photo #3 for Typical condition of stainless and carbon bands.					

Bent 30



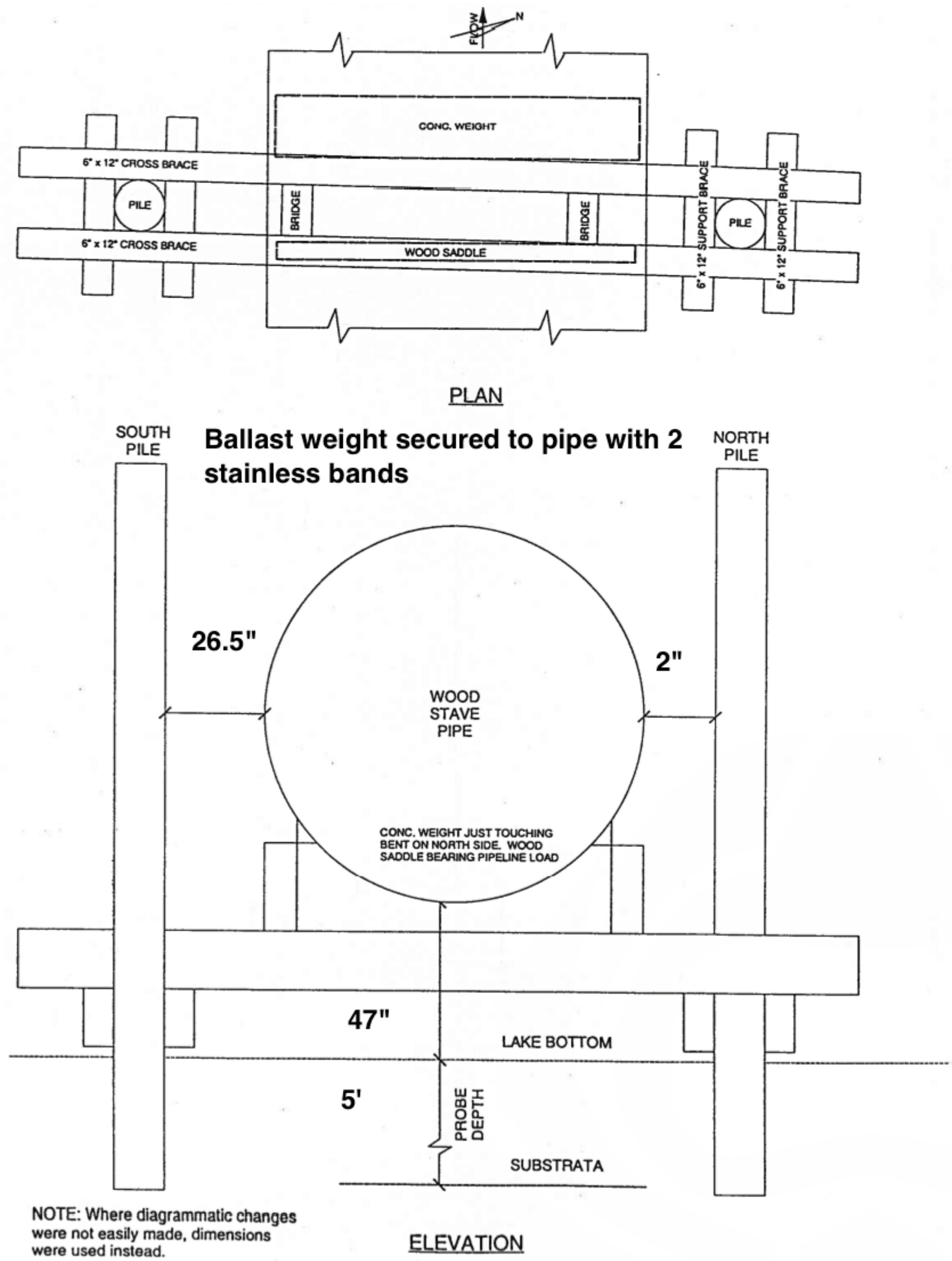
Pipe Condition Bent 30 to Bent 31					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, Stainless bands not corroded, tight
Notes:					
See Photo #3 for Typical condition of stainless and carbon bands.					

Bent 31



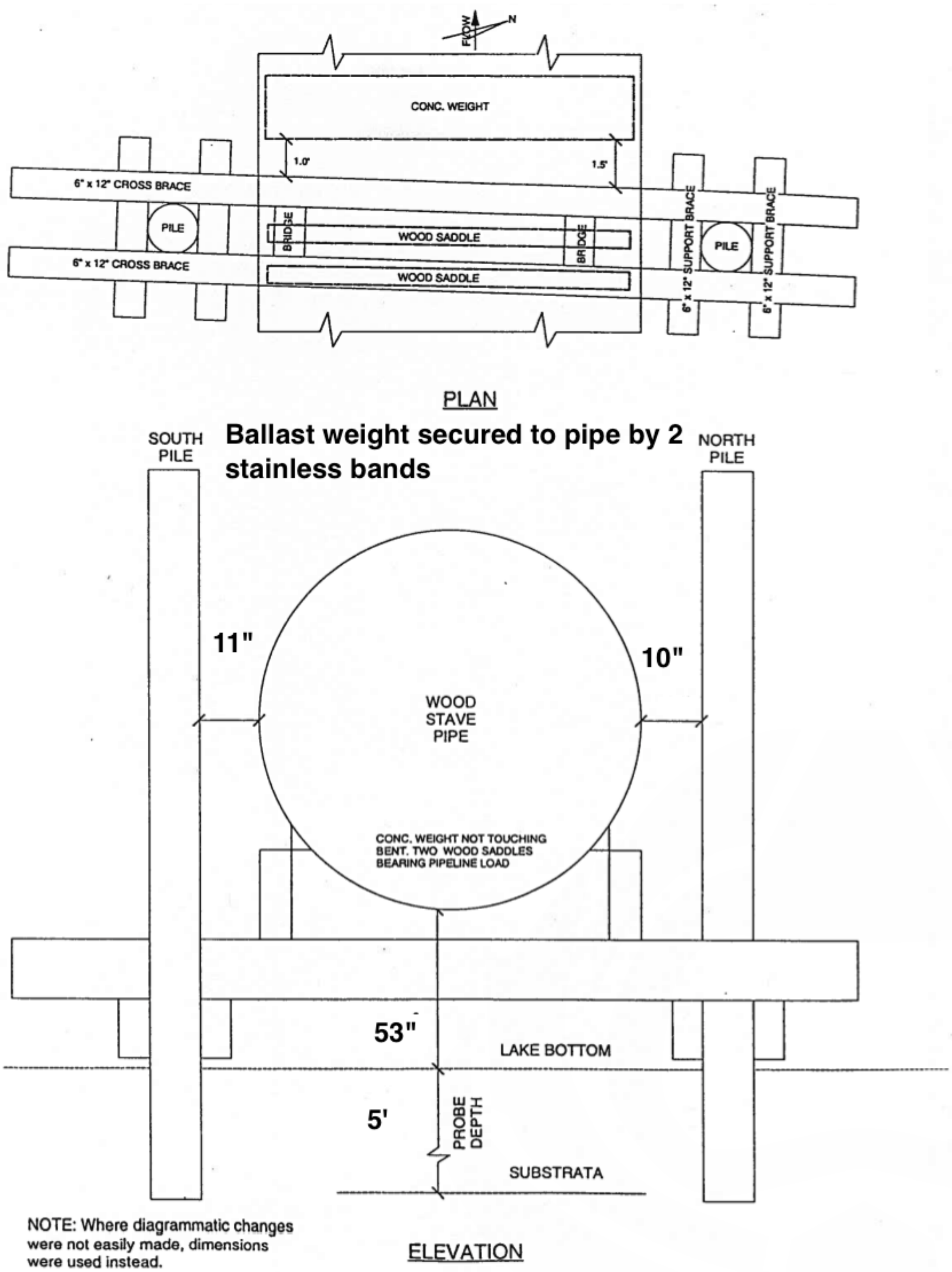
Pipe Condition Bent 31 to Bent 32					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, Stainless bands not corroded, tight
Notes:					
See Photo #3 for Typical condition of stainless and carbon bands.					

Bent 32



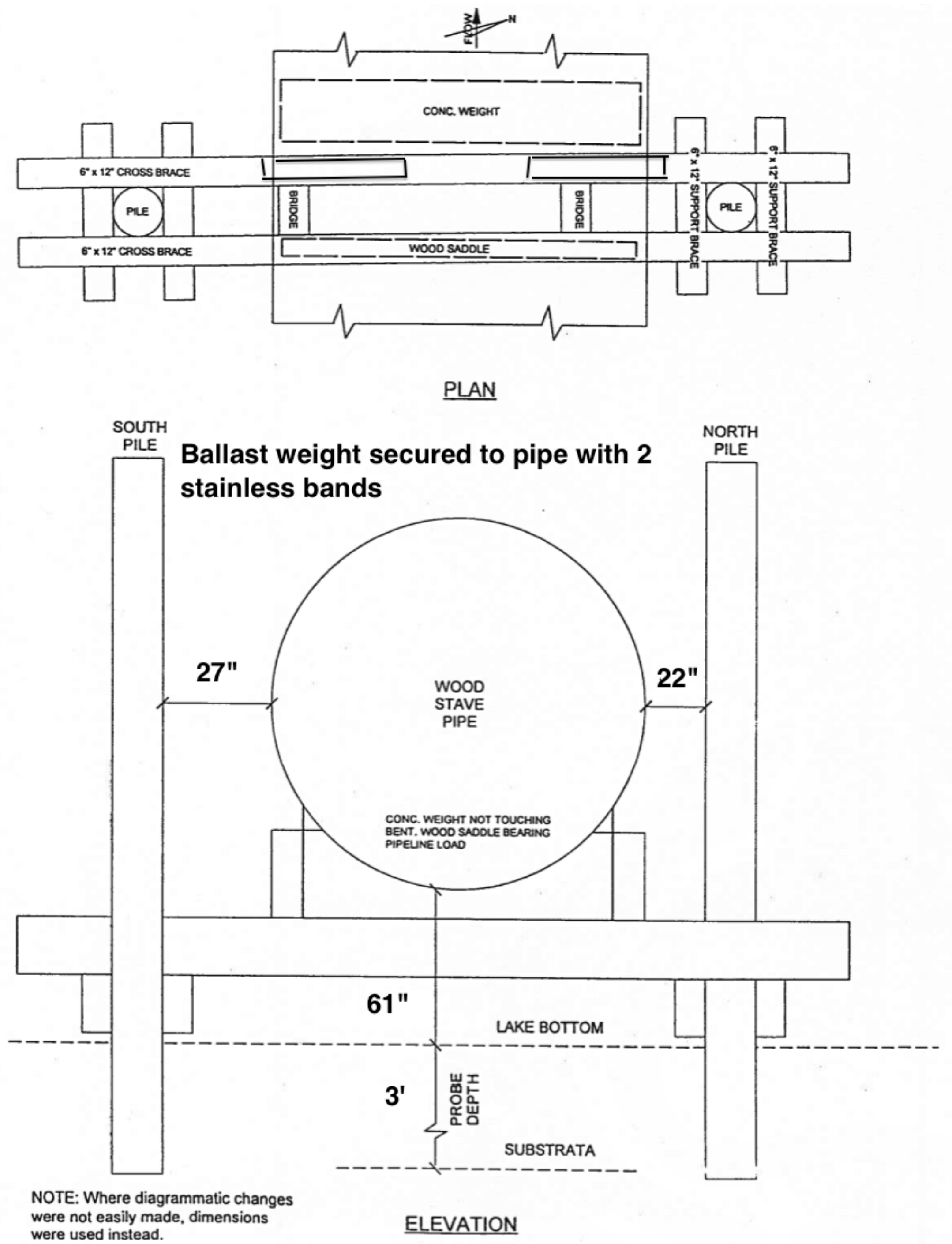
Pipe Condition Bent 32 to Bent 33					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	Broken Carbon band 6' Inshore of bent 32	Yes, Stainless bands not corroded, tight
Notes:					
See Photo #3 for Typical condition of stainless and carbon bands.					

Bent 33



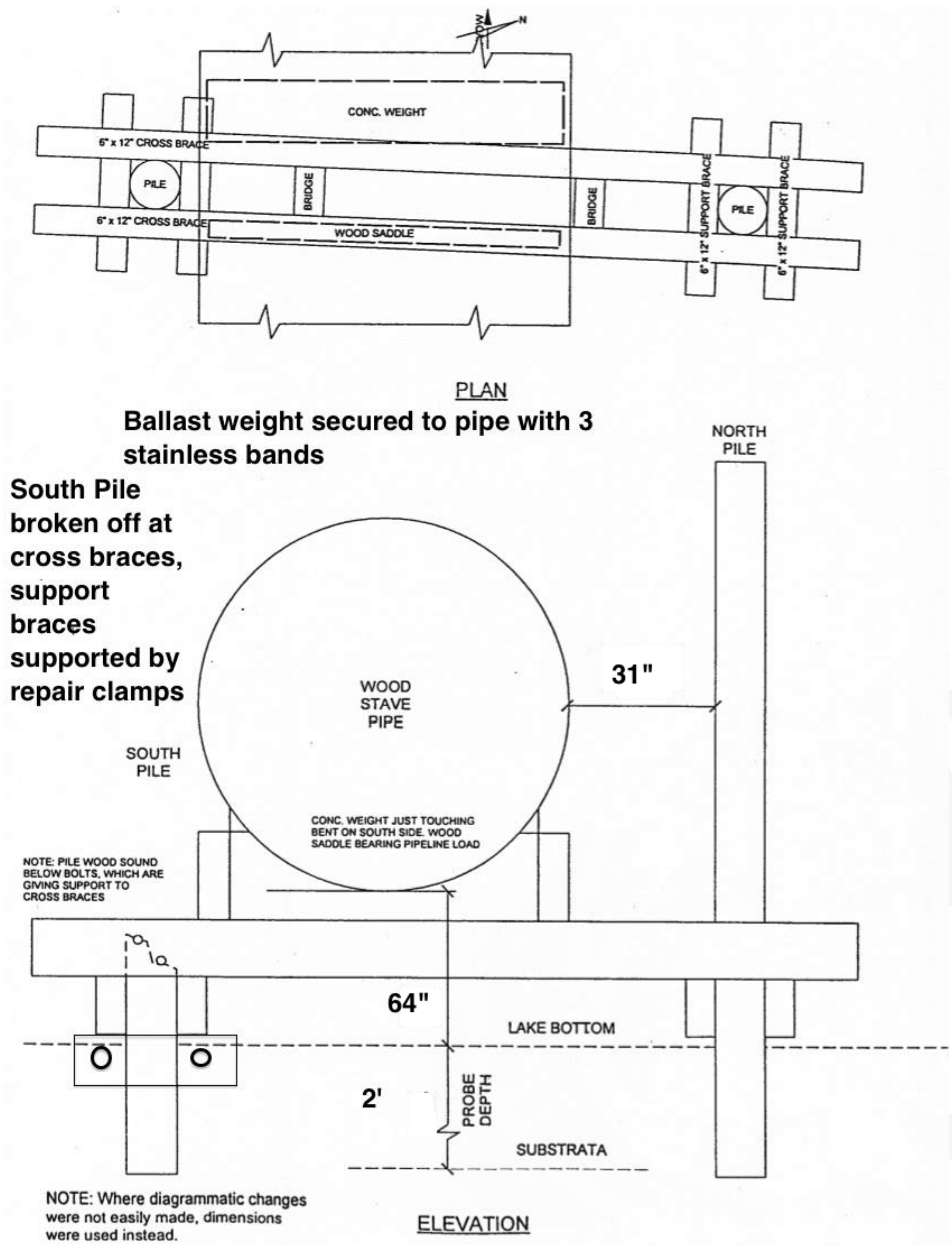
Pipe Condition Bent 33 to Bent 34					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, Stainless bands not corroded, tight
Notes:					
See Photo #3 for Typical condition of stainless and carbon bands.					

Bent 34



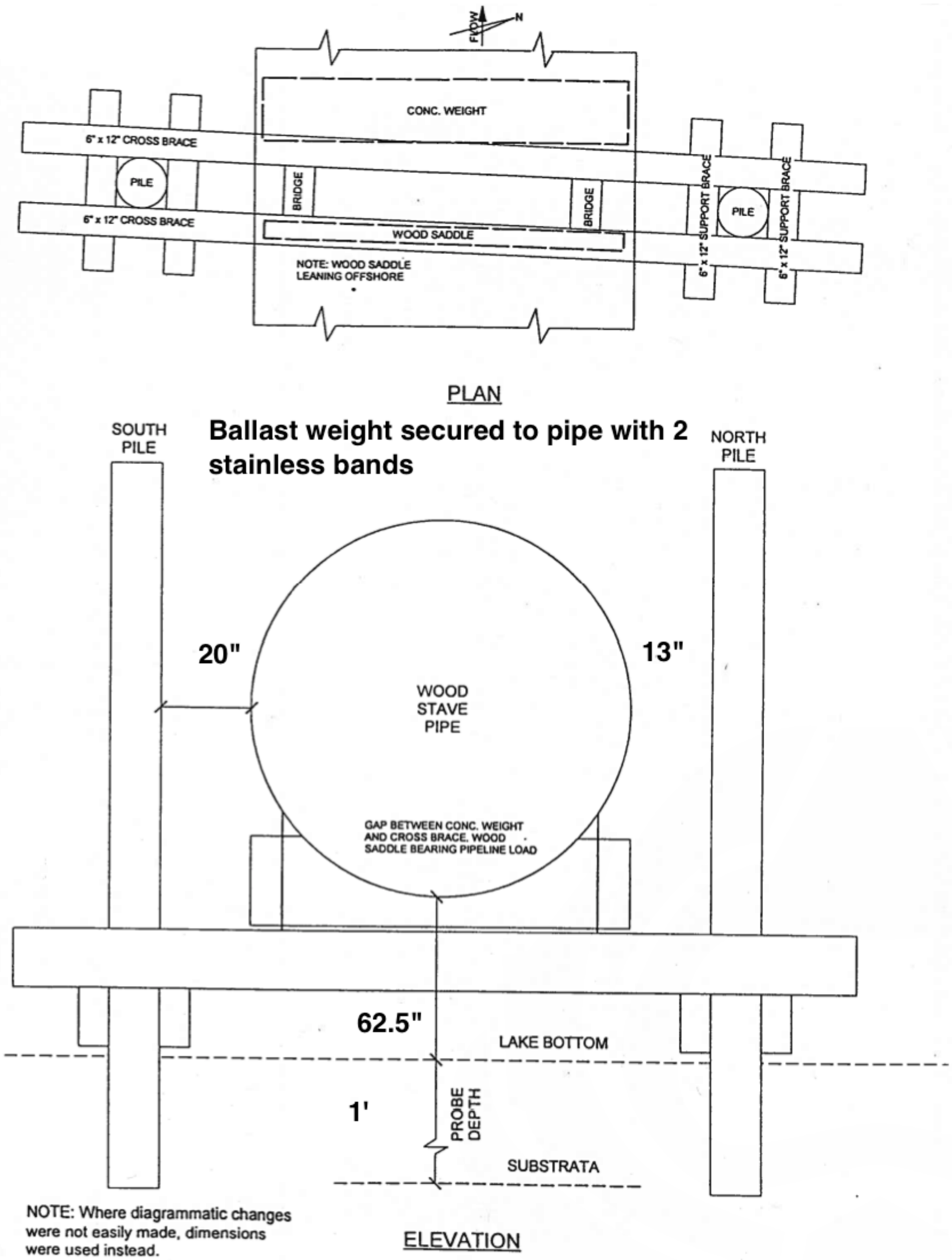
Pipe Condition Bent 34 to Bent 35					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, Stainless bands not corroded, tight
Notes:					
South Pile at bent 35 broken off at the level of the cross braces. Hardware still in place and intact, support braces supported by 2 stainless repair clamps. See photos 21 and 22 for detail of old hardware and new clamps. See Photo #3 for Typical condition of stainless and carbon bands.					

Bent 35



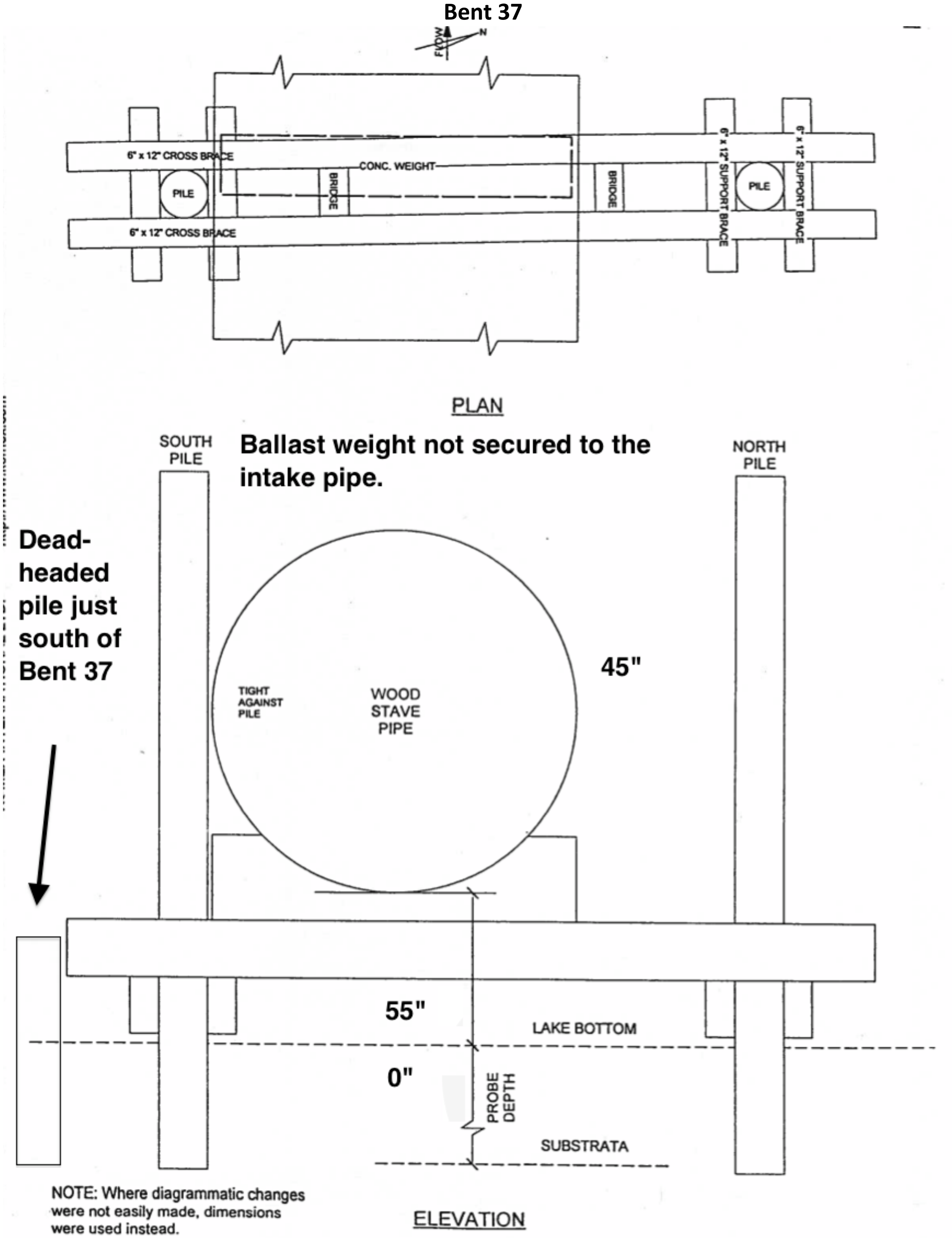
Pipe Condition Bent 35 to Bent 36					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, Stainless bands not corroded, tight
Notes:					
See Photo #3 for Typical condition of stainless and carbon bands.					

Bent 36



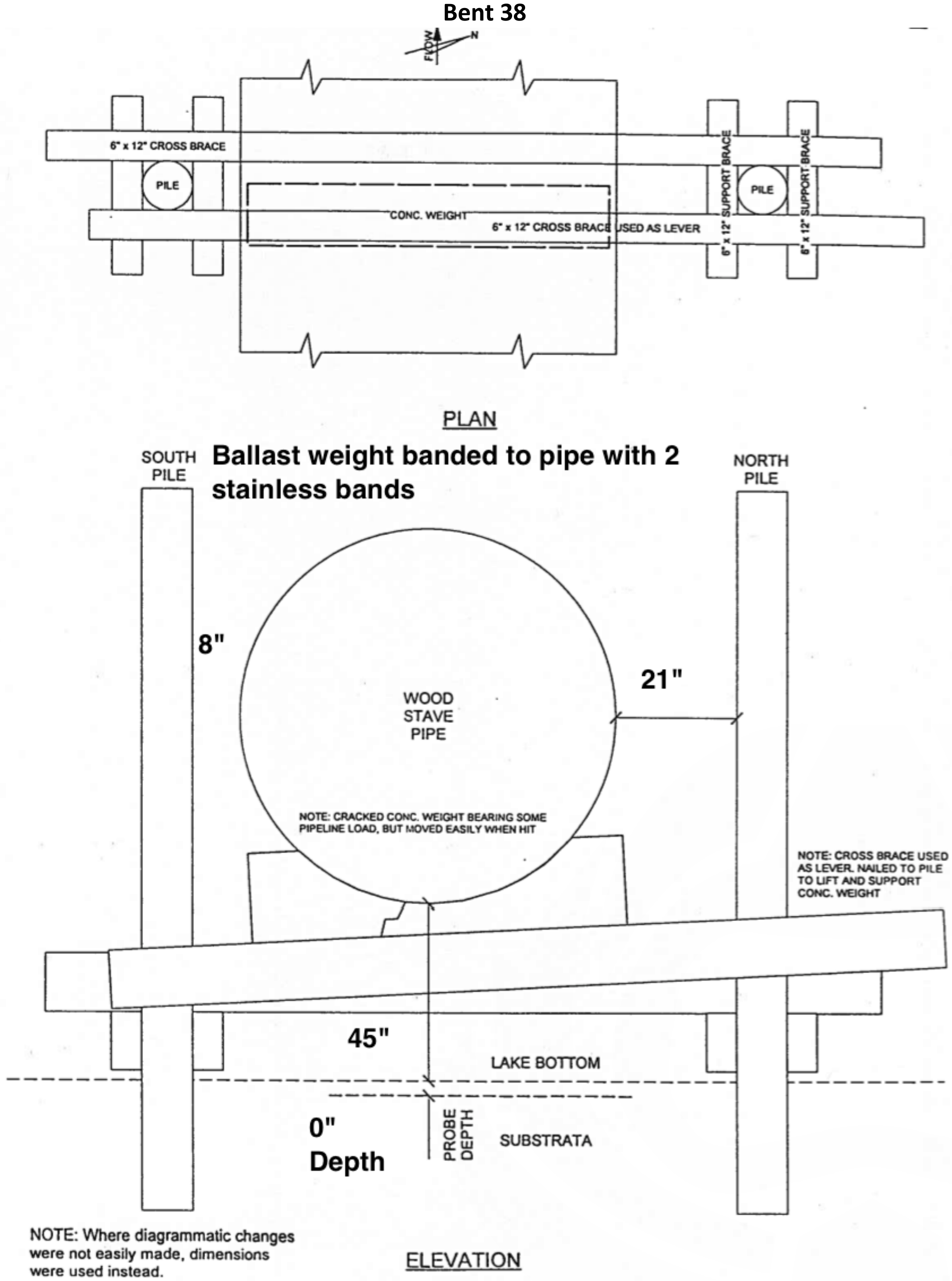
Pipe Condition Bent 36 to Bent 37					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, Stainless bands not corroded, tight
Notes:					
See Photo #3 for Typical condition of stainless and carbon bands.					

Bent 37



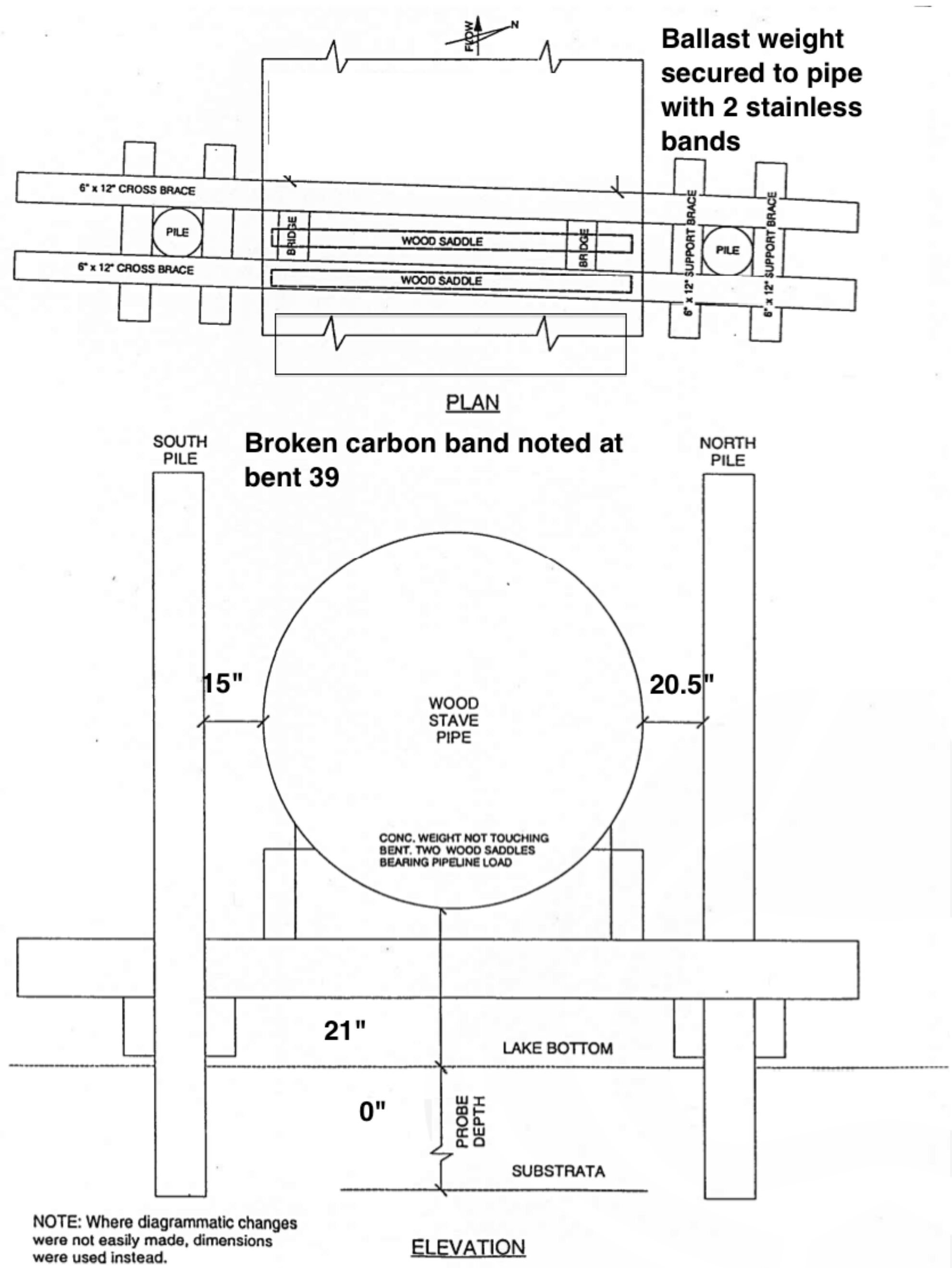
Pipe Condition Bent 37 to Bent 38					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	Yes, Stainless bands not corroded, tight
Notes:					
Intermediate concrete ballast weight broken, secured together with a third stainless band running horizontally around the weight. See Photo #3 for Typical condition of stainless and carbon bands.					

Bent 38



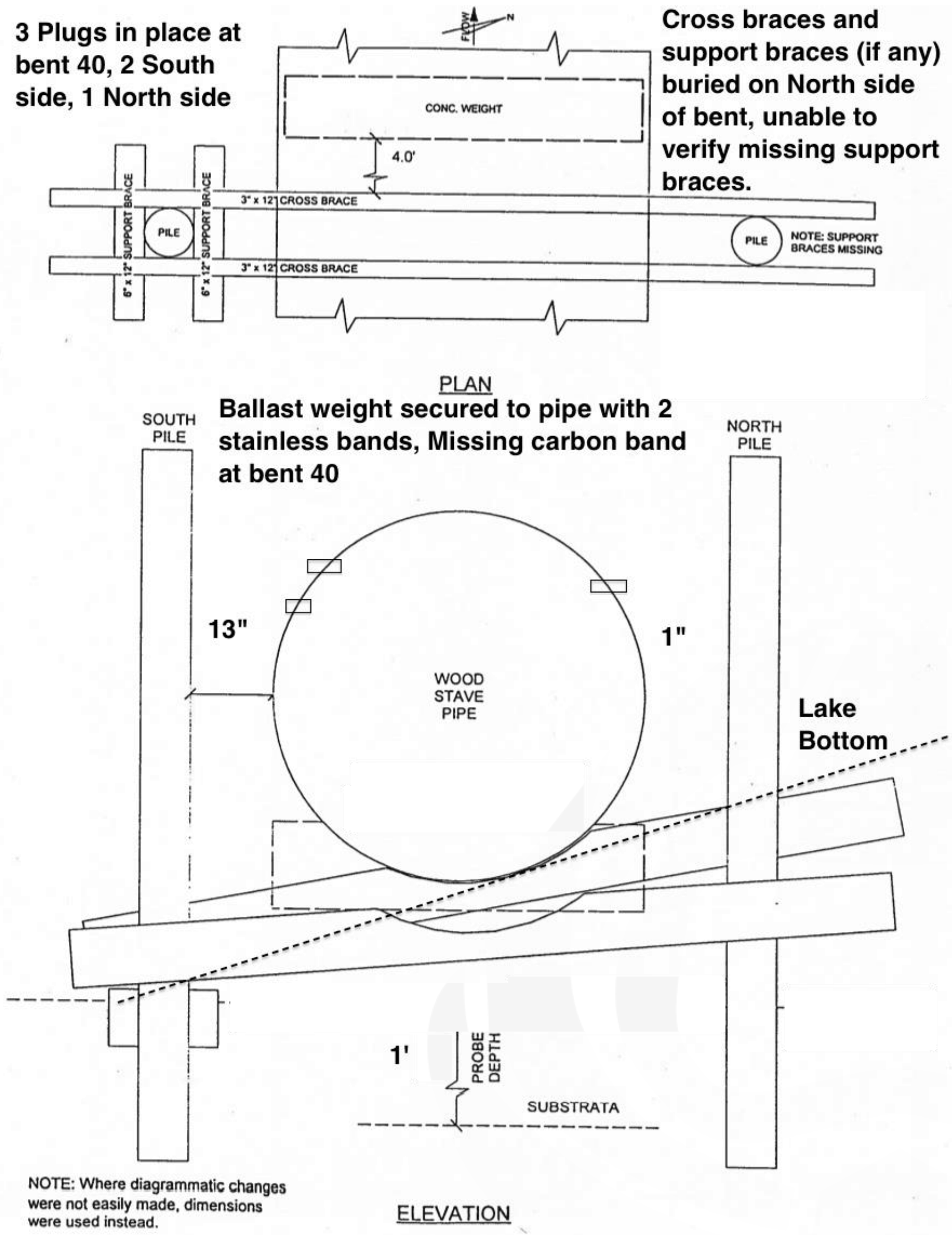
Pipe Condition Bent 38 to Bent 39					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	5' Inshore of bent 38, carbon band missing band missing at bent 39	Yes, Stainless bands not corroded, tight
Notes:					
Intermediate concrete ballast weight broken, secured together with a third stainless band running horizontally around the weight. See Photo #3 for Typical condition of stainless and carbon bands.					

Bent 39



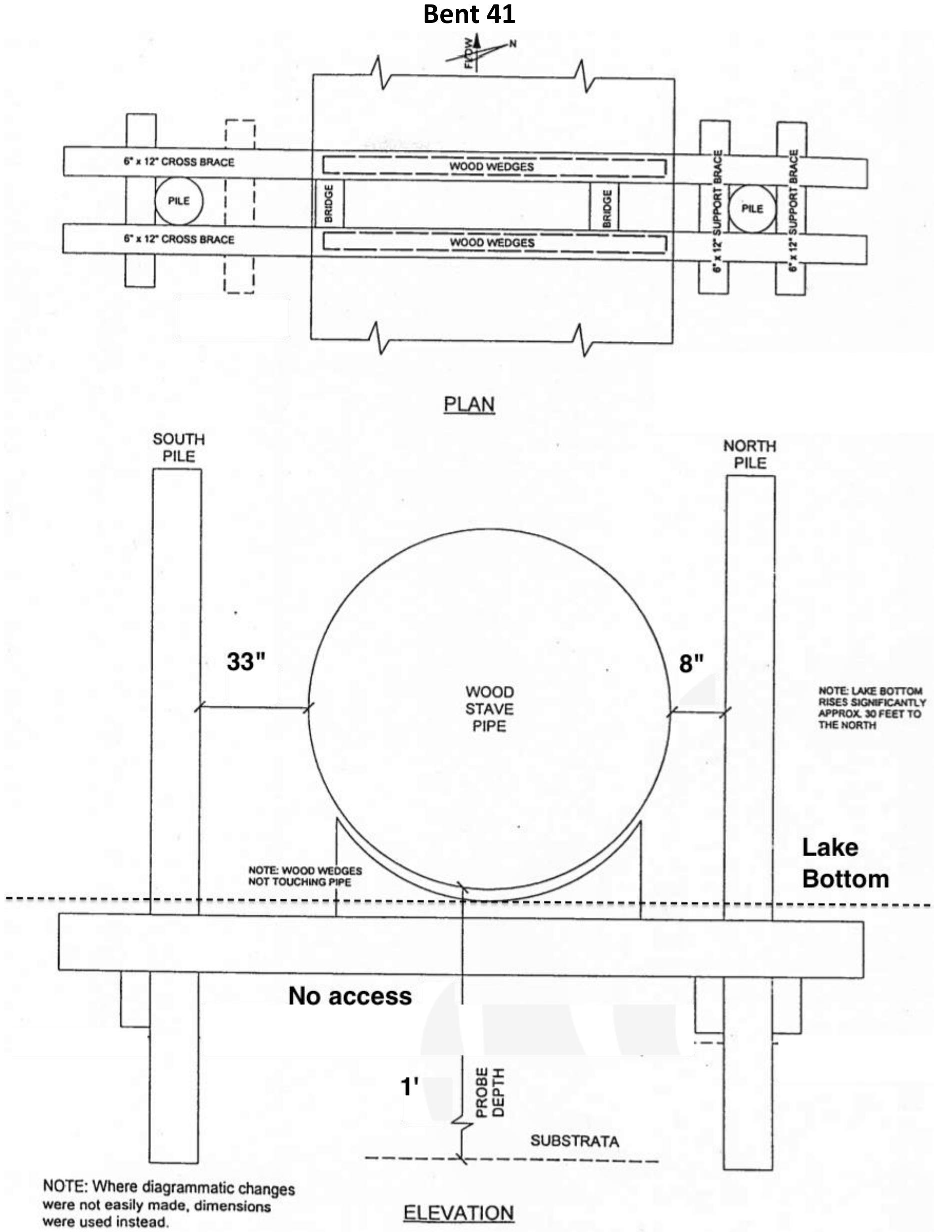
Pipe Condition Bent 39 to Bent 40					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	Band broken at bent 39, band broken 5' inshore of bent 39 missing band at bent 40	Yes, 5 each Stainless bands not corroded, tight
Notes:					
Pipe span between bent 39 and 40 is longer than previously 20' spaced bents. There are 5 intermediate ballast weights between bent 39 and 40, spaced approximately 10' apart. See Photo #3 for Typical condition of stainless and carbon bands. 3 Mechanical plugs from previous cores at bent 40. 2 on South side, 1 on North side.					

Bent 40



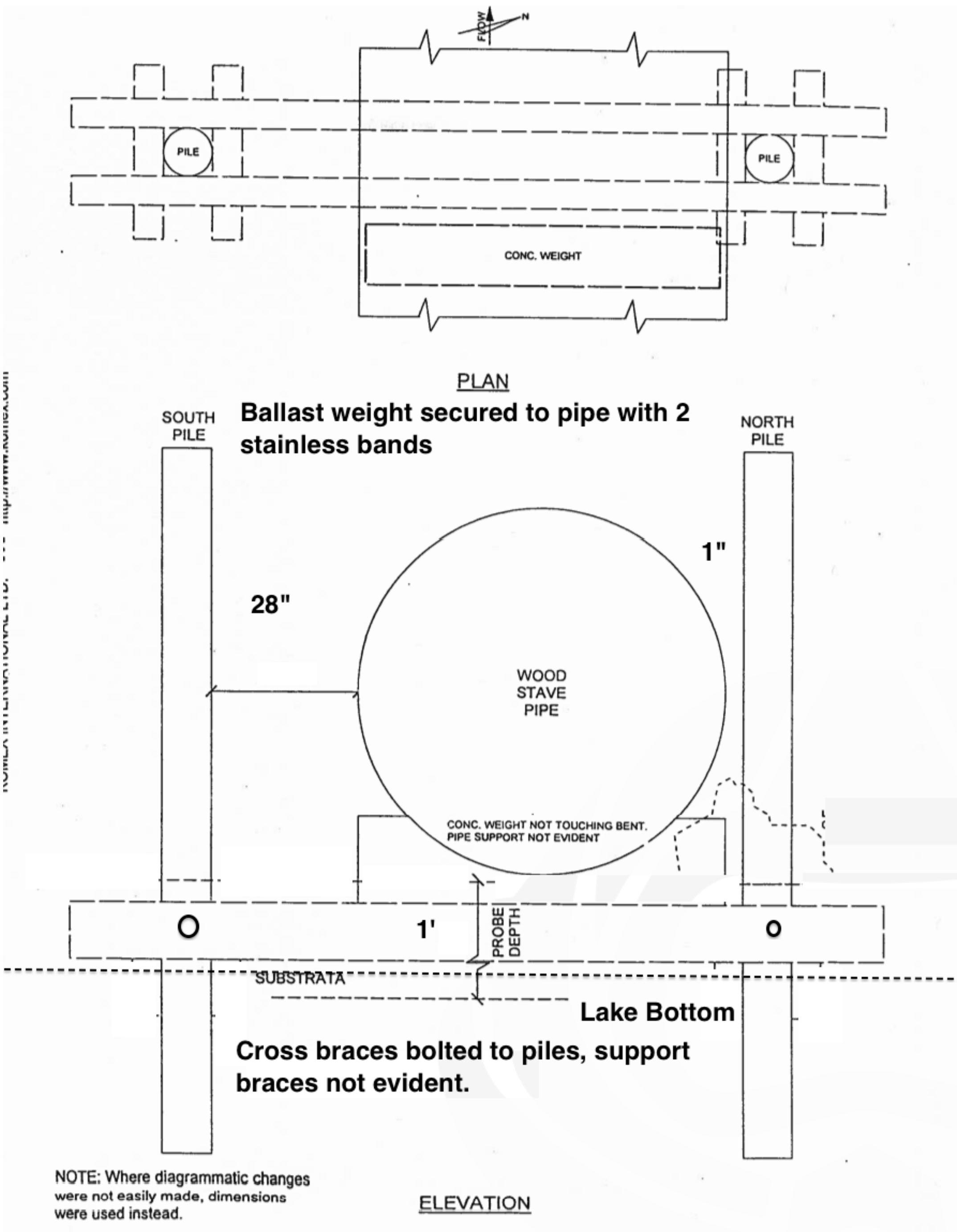
Pipe Condition Bent 40 to Bent 41					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	Broken Band at bent 41, carbon	Yes, Stainless bands not corroded, tight
Notes:					
Flange connection 12' Inshore of bent 40. Similar condition to previous flange encountered. Wrapped in Denso tape, denso tape tightly wrapped, still waxy, some stainless hardware exposed. 3 alignment screws at 12 o clock position still in line. See Photo 23 for a view of the flange wrapped in Denso tape. See Photo 24 for a view of the flange surface exposed by diver moving denso tape. See photo 25 for a view of the alignment screws at 12 o clock position. No inflow or outflow detected at flange. See Photo #3 for Typical condition of stainless and carbon bands					

Bent 41



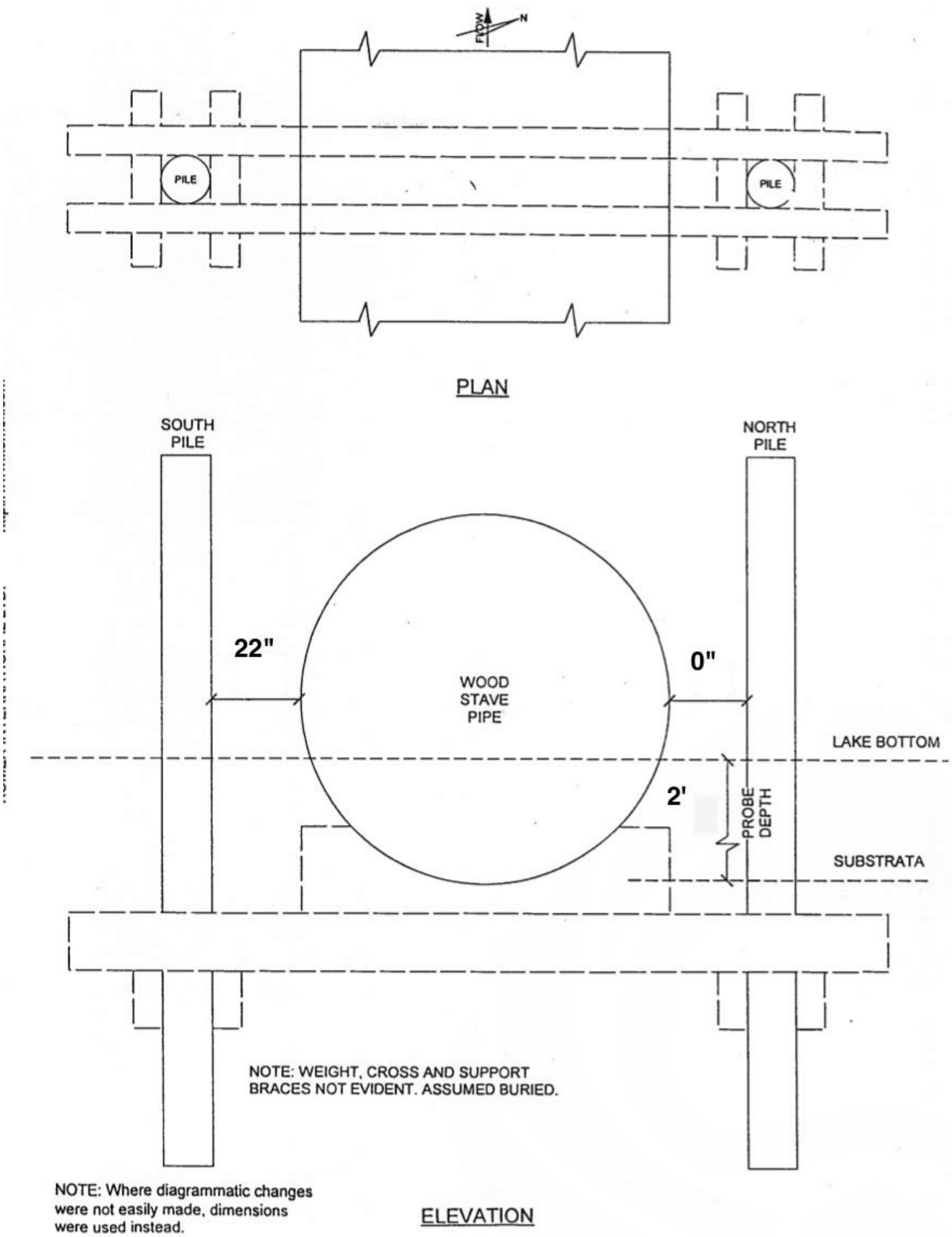
Pipe Condition Bent 41 to Bent 42					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	Broken Band at bent 41, carbon	Yes, Stainless bands not corroded, tight
Notes:					
Cross braces on bent 42 are bolted to piles, no support braces evident. See Photo #3 for Typical condition of stainless and carbon bands					

Bent 42



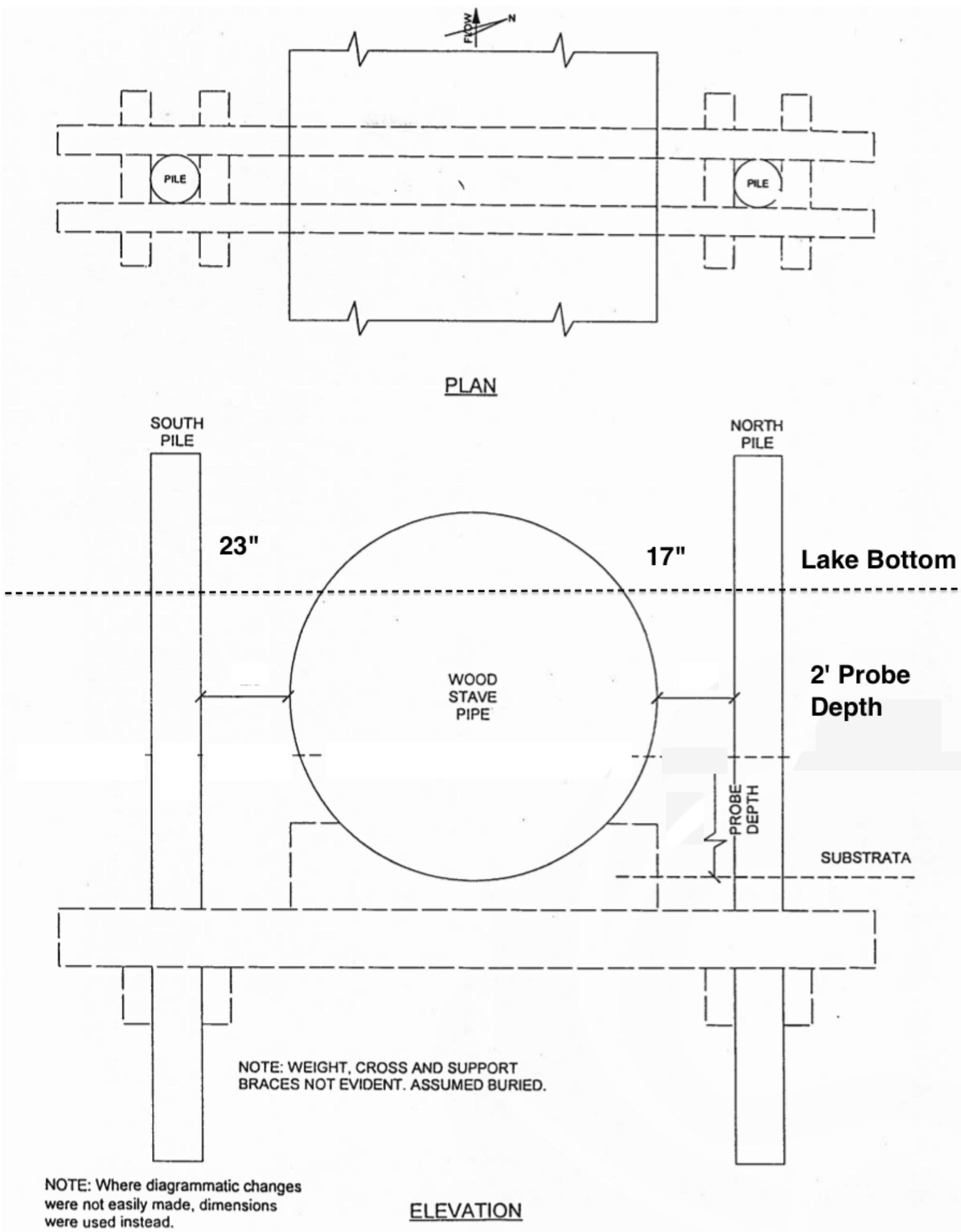
Pipe Condition Bent 42 to Bent 43					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	2 Articulated concrete mats
Notes:					
Concrete ballast mat 4' inshore of bent 42, 4' wide, 4' past 1st mat, there is a second concrete mat 4' wide. Concrete mats are typical of the articulated concrete mats seen previously and pictured in photo 18 See Photo #3 for Typical condition of stainless and carbon bands					

Bent 43



Pipe Condition Bent 43 to Bent 44					
Wood Condition	**Marine Growth**	**Carbon Steel Component condition**	**Stainless Component Condition**	**Broken/Missing Bands Evident**	**Intermediate Ballast Weight Present**
Very good	Light to Moderate Algae growth	Heavily Corroded	Not Corroded, Tight	None seen	2 Articulated concrete mats
Notes:					
Concrete ballast mat 6' inshore of bent 43, 4' wide, 4' past 1st mat, there is a second concrete mat 4' wide. Concrete mats are typical of the articulated concrete mats seen previously and pictured in photo 18 See Photo #3 for Typical condition of stainless and carbon bands Pipe at bent 44 is buried so that just 2' of pipe exposed, cross braces and support braces assumed. 2" Core sample taken 6" below mud line at the 2 o clock position 6' inshore of bent 44. Core plugged with 2" mechanical plug and splash zone applied over plug. Pipeline becomes completely buried at 10' inshore of bent 44, concluding our inspection of the external intake components.					

Bent 44



-Gate House Vault and Sluice Gate Valve Inspection
On the 26th of June 2014 BMC divers mobilized to the gate house to perform the inspection of the gate house vault, access ladder, sluice gate valve, stop log slots, and the internal components of the wood stave intake pipe. BMC mobilized a team of 7 divers to the site to perform this inspection. A supervisor, main diver, in water tender, standby diver, and tenders for each diver were utilized. The inspection of the access ladder, gate valve, stop logs and vault were performed first.

Figure 10: Gate House Vault Record Drawing

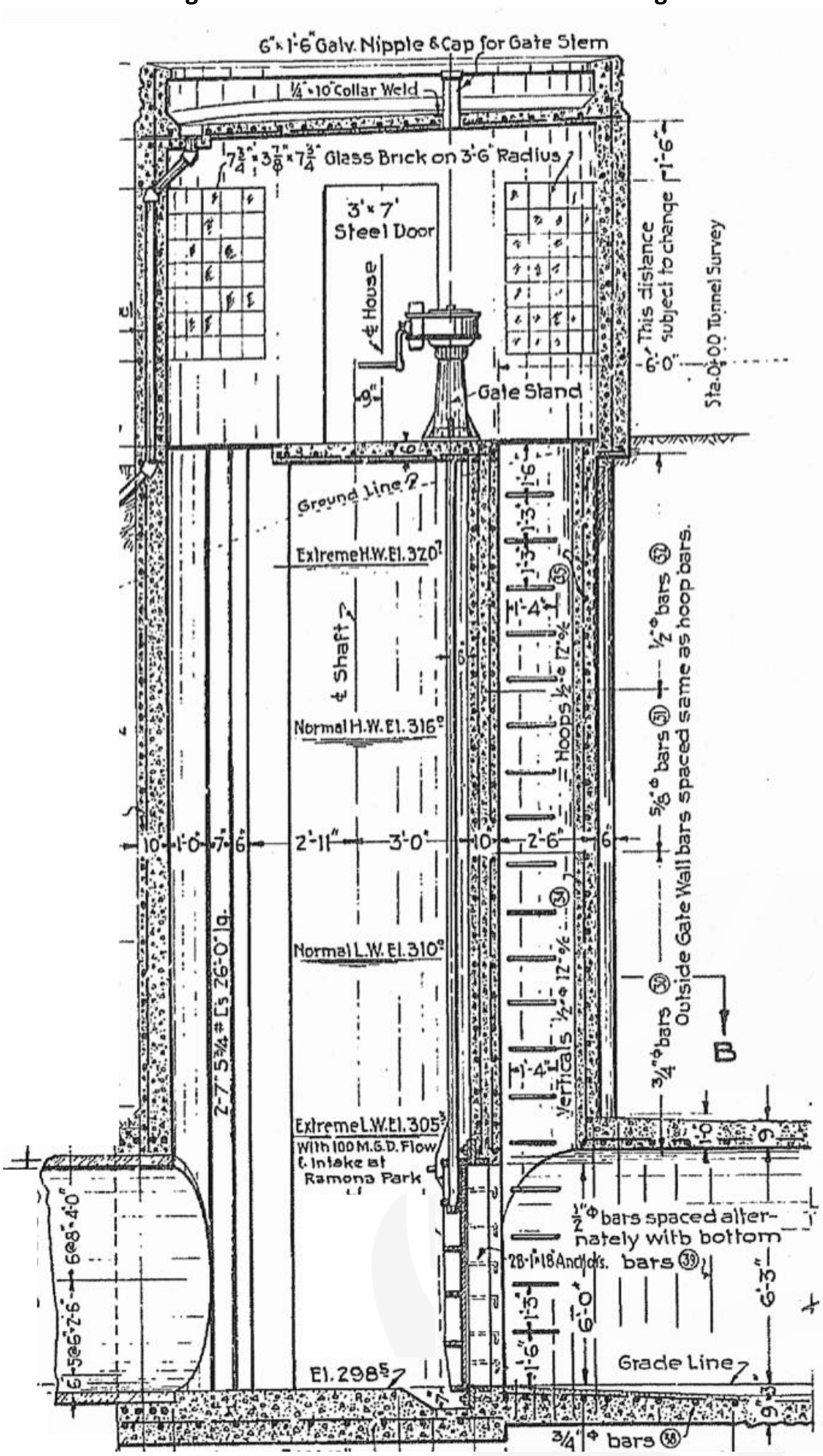
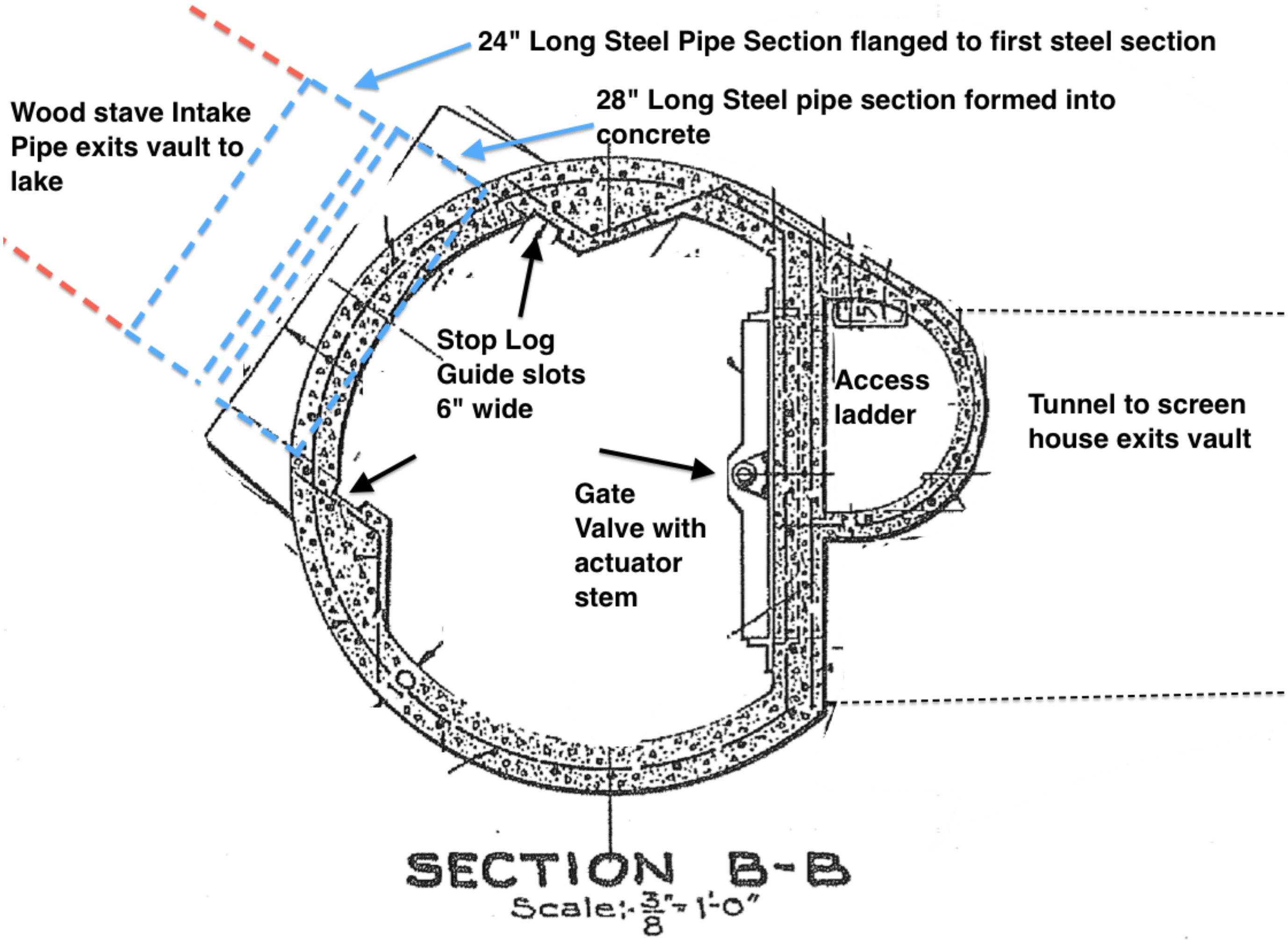


Figure 11: Top View of Gate House Vault



Access ladder condition:

Access ladder and ladder shaft appear to be in good condition. BMC divers inspected the ladder rungs, concrete surface, and riser pipe inside ladder shaft. Ladder rungs showed some corrosion and rust scale, removal of the scale revealed the rungs to have nearly ¾" of non corroded steel underneath the scale. BMC diver noticed one small area of spalling to the right of the access ladder just below where the 2" riser terminates. 4" square area showed exposed aggregate and a depth of 1/2" at the deepest point. Concrete around this area showed no signs of deterioration when tapped with a sounding hammer. Ladder extends all the way to the bottom of the vault, at which point it opens up into the tunnel to the screen house.

See Photos 27 and 28 for access ladder condition. See Photo 29 for view of bottom of 2" riser pipe in ladder shaft.

Gate Valve condition:
The gate valve itself consists of a 76"x 76" steel gate with a thickness of 2", with a brass or bronze sealing surface along the sealing edges. On the vault side of the gate, there are 4 Vertical stiffeners extending 3" out from the plate of the gate itself, these are spaced on 16" centers. There are 7 horizontal stiffeners extending 6" out from the plate of the gate, spaced on 12" centers. The gate rides up and down in a 6' x 6' steel frame with slots for the gate. On the Vault side of the gate there are 4 brass or bronze wedge plates on each side of the gate that match up with 4 plates on the frame to wedge the gate into the closed position and create a tight sealing surface. The sealing surface of the frame is also made of a brass or bronze surface. The steel actuator shaft rises from the center of the top of the gate, and continues above waterline though the roof of the vault. It is spaced 5" off of the vault wall and held in position with two steel brackets anchored to the vault wall, one below waterline, and one above waterline. Hardware on these brackets is all in place. No signs of loose or missing hardware noted on the brackets.

Very minor corrosion was noted to the brass components of the gate system, with pitting depths of 1/16th of an inch or less. Minor to moderate corrosion of the steel components was noted, with pitting to depths of 1/8" measured with a pitting gauge once the scale was removed and oxidation was cleaned off with a wire brush and pressure washer.

Stop Log guide slots condition and measurements:
The internal dimensions of the stop log guide slots are 2" deep and 6" wide. Full length of the stop log guide slots just above bottom of the vault measured at 75.25" Condition of the steel in the guide slots show heavy oxidation scale built up inside of the slots. Once the scale is removed the guide slots show 1/16" to 1/8" pitting. At the bottom of the guide slots there is one board sitting on the concrete floor to a height of 7". Collected between this board and the end of the intake pipe is 2" minus cobble. In order to use the stop logs to seal off the intake, the stop log guides would likely need to have all of the oxidation scale removed. See Photo #30 for detail of the stop log guide slot. See Photo 33 for detail of the stop log guide slot above water line.

Concrete Surfaces of Gate House Vault:
The general condition of the concrete surfaces of the gate house vault appeared to be in very good condition, with very little spalling and exposed aggregate noted. The exception to this would be the band between 1' and 3' below the waterline. In this area the concrete felt soft and chipped away with sounding taps of the hammer. See Photo #34 for detail of this area. No signs of cracking or exfiltration were noted anywhere in the vault. The only other irregularity noted in the concrete surface of the vault were two 1" copper pipes penetrating into the vault approximately 1' long, 8' above bottom and 18" to the South of the gate valve. The hole they penetrated through appeared to have been re-finished with an epoxy or grout. See Photo 37 for detail.

-Internal Inspection of wood stave intake pipe
BMC diver inspected the wood stave intake pipe starting at the gate house entrance to the pipe. The wood structure of the intake pipe appears to be in very good condition, with light algae growth covering 100% of the surfaces and soft sponge growth covering an estimated 5% of the surfaces. The growth removes easily by hand, and the wood underneath is consistent with all other wood components, soft for approximately 1/8" and hard sound wood beneath that. Two steel flange sections were visible on the inside of the pipe in the section of the internal pipe that we inspected. The steel on the flanges and short sections of pipe was 3/8" thick and covered in marine growth and oxidation scale. Once this was removed, the steel underneath was shown to be pitted to a depth of 1/8". Other areas of interest noted were a break in continuity of the pipe at 120' from the gate house entrance, and the internal view of the mechanical plug we installed in place of the core sample we took at 280' from the gate house entrance. For a further detail of the inspection, see the table below.

Feet from Gate House	Growth	Sediment Depth	Notes
0	Algae	None	72” ID Steel pipe 28” long enters gate house, appears to be flanged to a second steel pipe with same ID 24” long, which then transitions to wood staves. Steel condition is heavy oxidation and scale, once removed, pitting to a depth of 1/8” is revealed. Wood condition is soft for the first 1/8” then hard and sound when this soft layer is removed with a paint knife. See Photo 38 for detail of steel condition
10’	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
20	Algae/sponge	None	Unknown hard white penetration at the 8’ o clock position looking offshore. See Photo 40 for detail. Sample recovered and turned over to Dan Buonnadonna with CH2M Hill
30	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
40	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
50	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
60	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
70	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
80	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
90	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
100	Algae/sponge	None	72” Horizontal measurement 72” Vertical measurement Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
110	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
120	Algae/sponge	None	**Break in continuity of staves, possible slip joint in pipe, 5-7” wide full circumference of the pipe 3” deep. No infiltration or exfiltration observed, 2” minus cobble collected in 6 o clock. ID measures 73” Vertically and 72” Horizontally at this location.**
130	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
140	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
150	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
160	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
170	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife, hard wood exposed underneath.
180	Algae/sponge	None	Wood sound, 1/8” of soft wood, once removed with paint knife,

			hard wood exposed underneath.
190	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
200	Algae/sponge	None	**72" Vertical measurement of ID 72" Horizontal Measurement of ID** Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
210	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
220	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
230	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
240	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
250	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
260	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
270	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
280	Algae/sponge	None	**2" Mechanical plug Installed at the 10 o clock position of pipe that we installed 6' inshore of bent 44 visible see Photo 43 for detail. No infiltration or exfiltration detected at this location.** Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
290	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
300	Algae/sponge	None	**72" Vertical Measurement 72" Horizontal measurement**
310	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
320	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
330	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
340	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
350	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
360	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
370	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
380	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
390	Algae/sponge	None	Wood sound, 1/8" of soft wood, once removed with paint knife, hard wood exposed underneath.
400	Algae/sponge	None	**Steel flange 3/8" thick steel, condition consistent with steel seen previously. 1/8" deep pitting. No sign of exfiltration and infiltration. End of inspection.**

Daily Project Logs

24th June 2014	
Time (24 Hour Clock)	**Task/Event**
0700	Crew and Equipment onsite at Bloedel Donovan Board ramp. Tailboard safety meeting with dive crew and begin setup and launch of both vessels. Secure pontoon barge to dive boat.
0800	Jerry Duppong (CH2M Hill) and Bill Evans (City of Bellingham) onsite. Pre-Dive and Pre-Departure safety meeting with all onsite.
0819	Depart Bloedel Donovan Boat ramp for site.
0847	Anchoring near location of intake as directed by Bill Evans.
0915	Diver #1 Leaves surface to locate intake and begin inspection of intake crib
1047	Diver #1 Reaches Surface, Diver is on a 50’ table due to a depth of 46’, out of bottom time. Diver located intake and completed the inspection of the intake crib.
1116	Diver #2 Leaves surface to begin inspection of intake pipe and bents
1315	Diver #2 Reaches surface after inspecting intake pipe and bents 1-9, Diver had a maximum depth o 43’ and was on a 45’ table
1345	Diver #3 L/S to inspect intake pipe and pile bents
1540	Diver #3 R/S after inspecting intake pipe and bents 9-22. Diver had a maximum depth of 40’ and was on a 45’ table
1545	Placing buoy on Intake down-line for the evening and travelling back to the Bloedel Donovan boat ramp.
1630	At Bloedel Donovan Boat ramp, separating and trailering Dive vessel and pontoon barge, securing for evening. Boats being re-sealed for re-entry into Lake Whatcom the following day.
1700	Crew and equipment offsite for evening.

Daily Project Logs

25th of June 2014	
Time (24hr Clock)	**Task/Event**
0700	Onsite at Bloedel Donovan boat ramp, setting up, launching vessels
0800	Jerry Duppong (CH2M Hill) and Bill Evans (City of Bellingham) onsite. Pre-Dive and Pre-Departure safety meeting with all onsite.
0815	Depart Boat Launch
0850	Moored on location at Bent 22 of Intake
0908	Diver #4 Leave Surface to clean specified areas with pressure washer for still photos and closer inspection.
1147	Diver #4 Reach Surface after performing detailed inspection of components and of cable crossing and inspecting intake pipe and bents to bent 25. Headed to boat ramp to pick up Hydraulics for core sampling.
1304	Diver #5 Leave Surface to take core sample and inspect pipe and pile bents
1528	Diver #5 Reach surface after recovering core sample and inspecting bents 25 to 31
1550	Diver #6 Leave Surface, Resetting down line, moving vessel inshore, continuing inspection inshore
1841	Diver #6 Reach Surface after inspecting pipe and bents 31-44 and recovering core sample
1900	Returned to Bloedel Donovan boat ramp, recover vessels and break down dive spread
1930	**Crew and equipment offsite, core samples and carbon bands turned over to Bill Evans(City of Bellingham)**

Daily Project Logs

25th of June 2014	
Time (24hr Clock)	**Task/Event**
0700	Drop Trailers at Bloedel Donovan Park
0715	**Onsite setting up at Gate House**
0730	Pre-Dive Safety Meeting with 7 Man dive crew, Dan Buonadonna(CH2M Hill), and Bill Evans(City of Bellingham)
0800	Dive Station set up
0900	Diver #1 Leave Surface to Inspect Vault
1205	Diver #1 Completed Vault Inspection
1210	Diver #2 Leave Surface to act as in water tender
1215	Diver #1 Begins internal inspection of Wood Stave intake pipe
1330	Stave pipe inspection completed
1344	Divers #1 and #2 on surface, breaking down dive spread, Cleaning up area
1500	Equipment and Personnel off-site.

Summary

Wood components of the intake system appear to be in good to very good condition throughout the intake. No signs of rot or major damage to any wood structures were observed. Wood core samples were recovered and delivered to CH2M Hill during the inspection and will be used for further evaluation of the condition of the wood components.

Condition of the original carbon steel components of the intake system appeared very corroded. Support brace hardware and carbon bands both showed heavy scale and advanced corrosion once this scale was removed. Many of the carbon bands were broken or missing, as indicated in the body of this report. Several broken bands were recovered to the surface and delivered to CH2M Hill for further analysis of the condition of the original carbon steel components.

The stainless steel components of the intake appear to be in good to very good condition. Only two bands over the span of the entire intake system showed any sign of corrosion, and only one band appeared to be loose.

Concrete components of the intake system were with few exceptions in good condition. In only a few cases were there signs of concrete damage. One bent had a broken concrete ballast weight on bottom, one of the intermediate concrete ballast weights was broken and banded back together, and in the gate house vault, the area 1' to 3' below water line showed signs of soft concrete, spalling and exposed aggregate for the full circumference of the vault. Articulated concrete ballast mats in place over top of pipeline show no signs of damage or deterioration.

For review of the entire video footage, please refer to the DVD provided with this report. BMC thanks you for your business and please don't hesitate to contact me should you have any questions or comments.

Sincerely,

Dana Gordon
Diving Supervisor
Ballard Marine Construction
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Dana.Gordon@BallardMC.com

Reviewed by:
George Birch, Operations Manager
(206) 604-7388
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Project Photographs

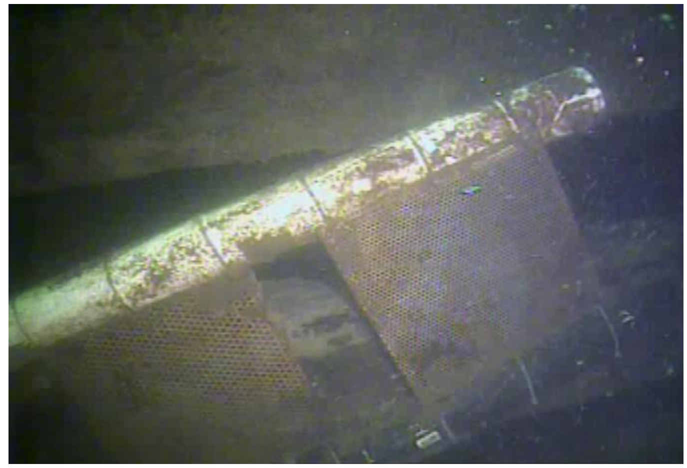
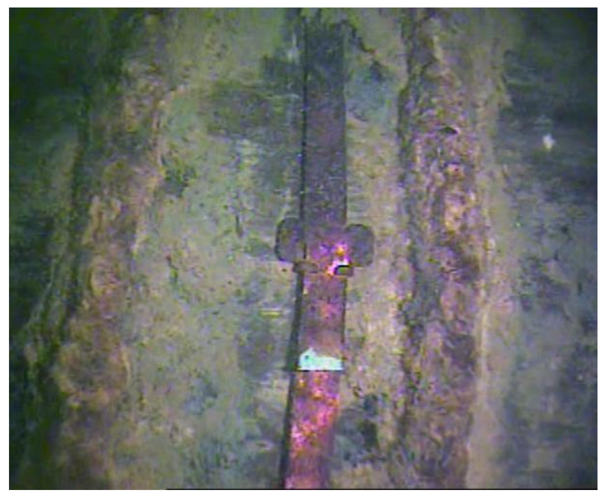
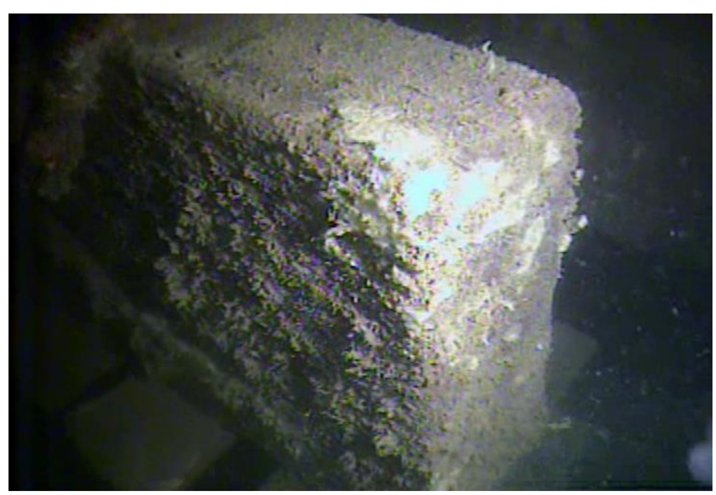
	
Photo #1: Typical Condition of Hardware of Intake Crib	Photo #2: PVC and Steel Screen 3’x9” bolted to Crib
	
Photo #3: Typical Condition of Stainless and Carbon bands	Photo #4: Corroded and Loose Stainless band between intake crib and bent #1
	
Photo #5: Corroded Stainless band at Bent 11	Photo #6: Wood Saddle Support at bent 15

Photo #7: Newer Hardware at replaced pile at Bent 18

Photo #8: Core Sample from North side of pipe, bent 20

Photo #9: Previously Installed Plug at bent 20

Photo #10: Mechanical plug installed over void from new core

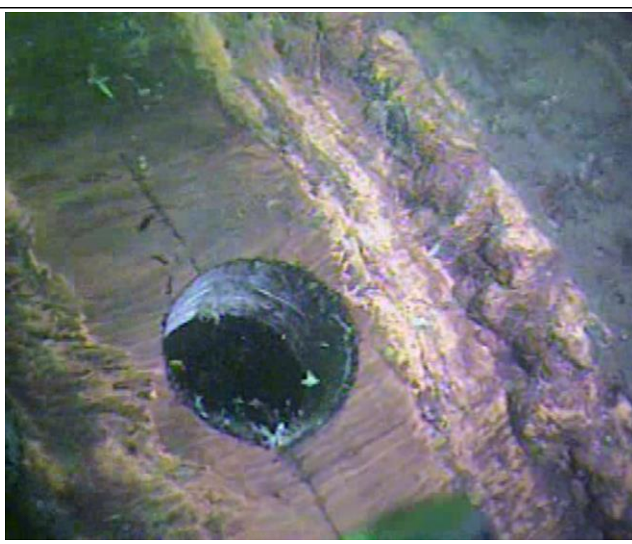


Photo #11: Core sample void prior to plugging

Photo #12: Cable crossing contacting South Pile Bent 22

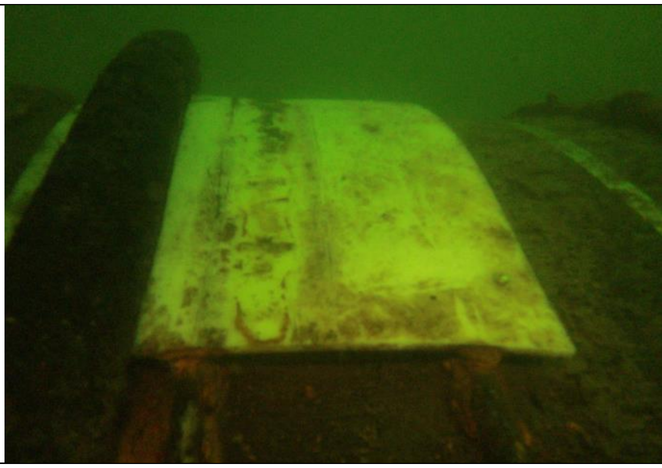
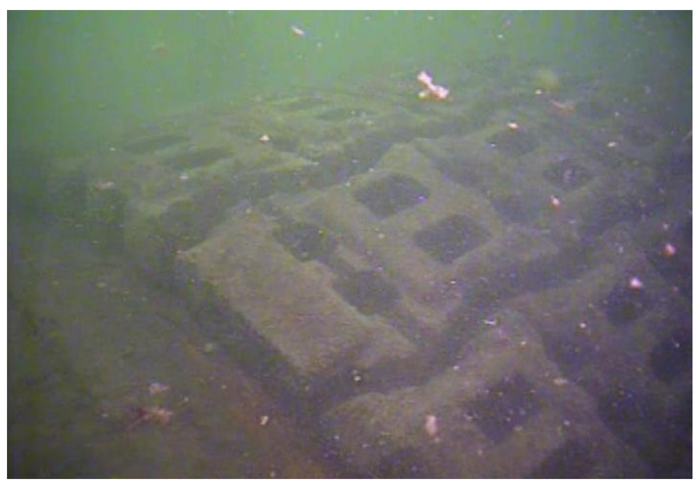


Photo #13: cable crossing on anti-chaffing pad - bent 22	Photo #14: Carbon steel hardware with scale removed showing severe deterioration of fastener
	
Photo #15: Cable crossing at bent 23 off of pad	Photo #16: Typical stainless banded concrete ballast weight at bent
	
Photo #17: 3.5” Cable crossing offshore of bent 27	Photo #18: Articulated concrete ballast mat offshore of 27

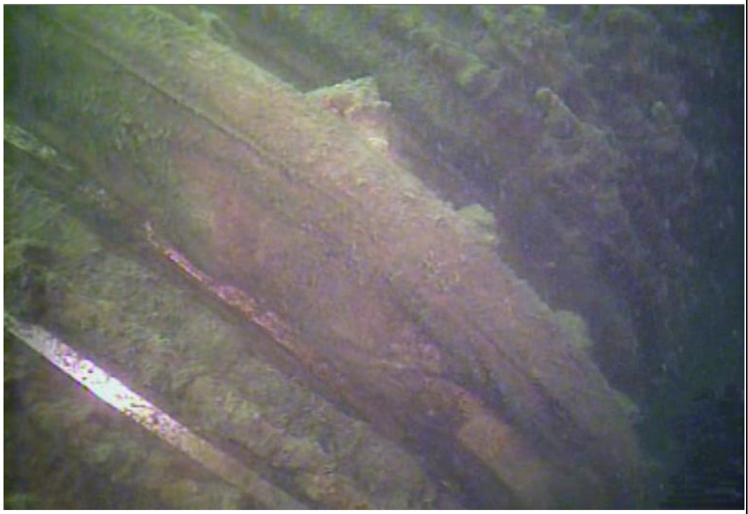


Photo #19: Flange between bents 27 and 28 covered in Denso wax tape secured by stainless bands

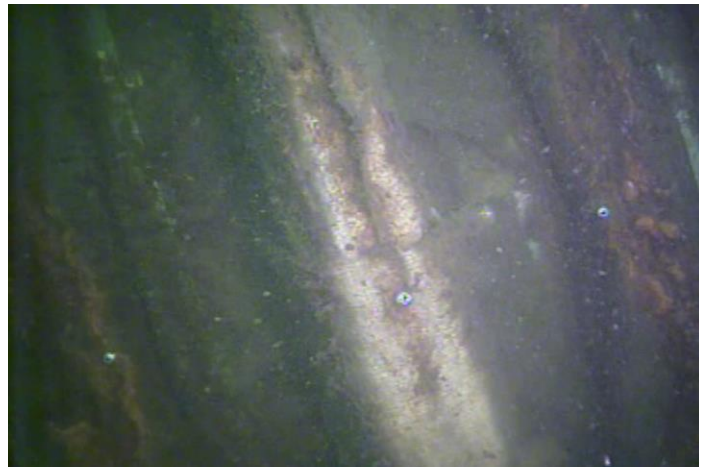


Photo #20:Top View of Flange between 27-28, alignment screws visible at 12 o clock position in line.

Photo #21: Through pile hardware exposed at broken pile #35

Photo #22: Repair Clamps at South Pile Bent 35 beneath support braces

Photo #23: Flange between bent 40 and 41

Photo #24: Flange surface exposed by diver at bent 40-41, showing condition of steel flange/stainless hardware

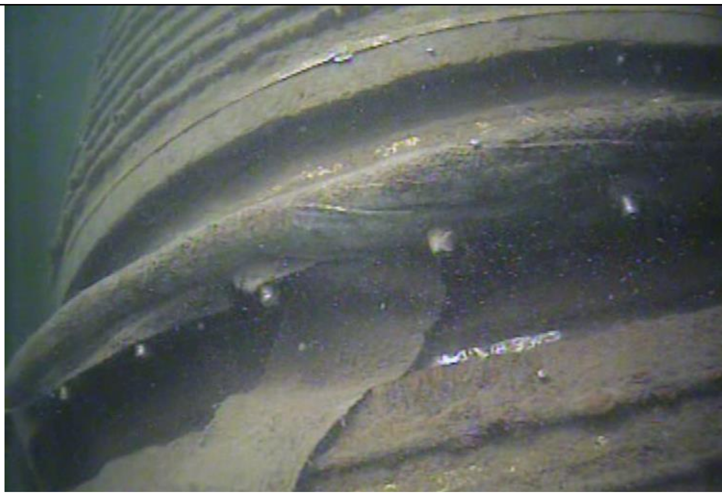


Photo #25:Flange at Bents 40-41 showing 12 o clock position alignment screws

Photo #26: Main Diver umbilical staged in gate house, access hatch open

Photo #27: Ladder rungs above surface in access ladder shaft

Photo #28: Ladder rung underwater condition

Photo #29: Bottom flange of 2" riser where it terminates in the access ladder shaft.

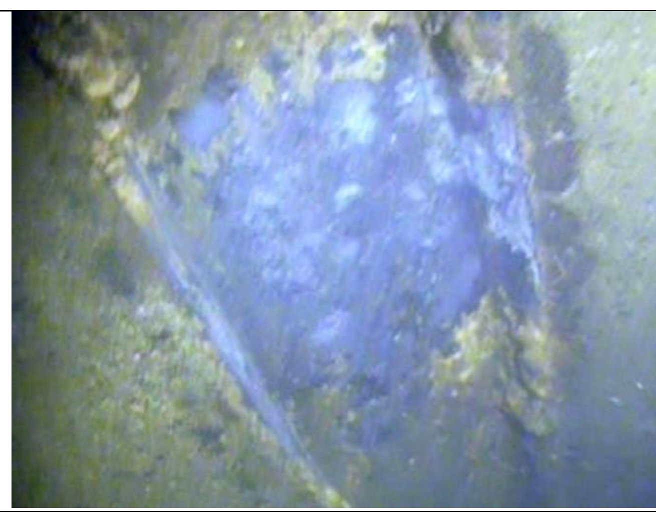


Photo #30: Stop log guide slot with scale removed in center, and scale visible at top and bottom.

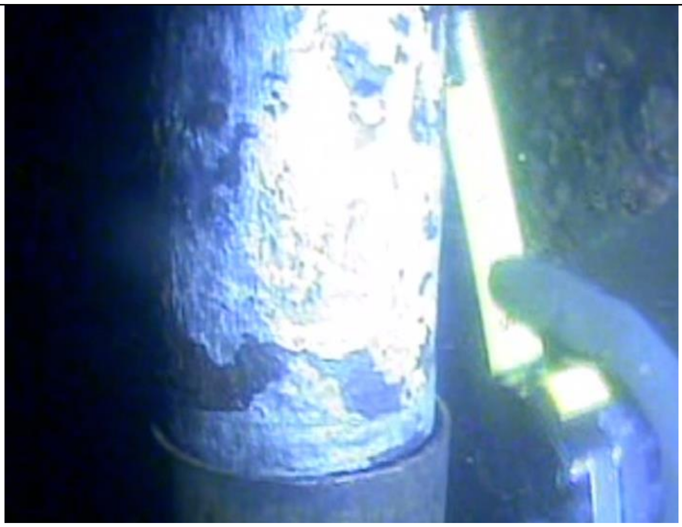


Photo #31 Gate Valve Actuator shaft cleaned by diver to show corrosion and pitting to a depth of 1/8"

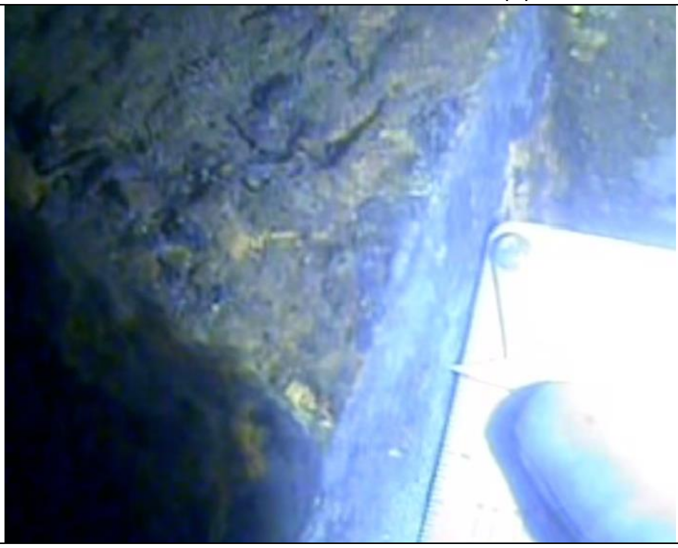


Photo #32 Diver using pit gauge to check depth of pitting on actuator bracket

Photo #33 Stop log guide slot just above waterline, oxidation scale visible.

Photo #34 Soft concrete and aggregate 1-3' from water's surface, this was consistent all the way around the vault

Photo #35 Gate sealing surface

Photo #36: Brass Wedge block on frame and sealing surface on frame

Photo #37 2 1" Copper pipes extending approximately 1' into vault 18" to the south of the gate and 8' above bottom

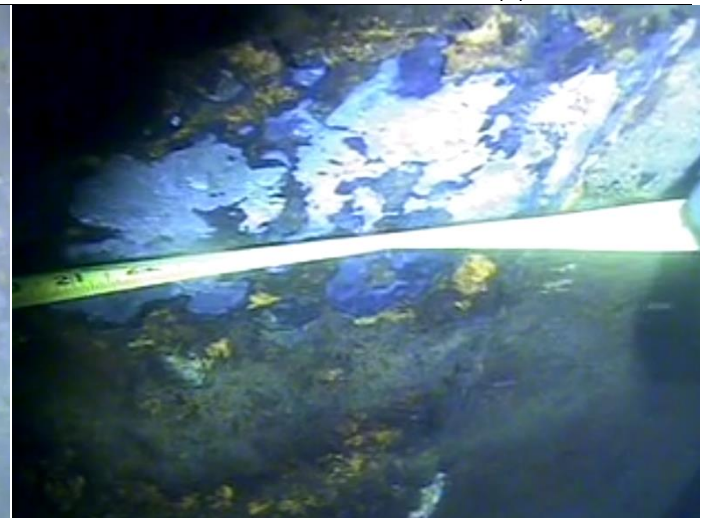


Photo #38 Steel to concrete joint between Intake pipe and vault

Photo #39 Steel to Wood interface approximately 4' from gate house

Photo #40 Hard penetration in to pipe at 8 o clock position. Sample recovered and provided to CH2M Hill

Photo #41 Sponge growth In pipe

Photo #42: Pipe joint at 130' from gate house in intake pipe, 7" gap in staves all around pipe

Photo #43 Mechanical plug installed in place of core observed at 280’ from gate house

Photo # 44 Detail of Wedge block on gate valve frame

Photo #45 Detail of Actuator Shaft of gate valve where it meets the gate. Visible above is the bottom of the bracket

Photo #46 Valve Actuator Bracket showing anchor bolts in place

Photo #47 Upper North side corner of gate, showing stiffener plates and upper wedge block

Photo # 48 Support brace Hardware detail

Appendix B
Description of Wood-Stave Intake from September 2000 Golder and Associates Inspection Report

1. INTRODUCTION

The City of Bellingham contracted with Golder Associates Inc. (Golder) to conduct a detailed underwater investigation and evaluation of the integrity of the City's water supply intake pipeline system and associated components in Lake Whatcom. The Lake Whatcom water supply intake system consists of the tunnel gatehouse, the 72-inch diameter, 1,225 feet long (approximately) wood stave pipeline and the intake structure. The pipeline was constructed in 1939 through 1940. The tunnel gatehouse is located about 40 feet from the high water mark of Lake Whatcom. The wooden intake pipeline extends off shore from the gatehouse, and is buried for the first 350 feet, whereupon it enters slightly deeper water and becomes exposed. The pipeline continues offshore to the rock filled, timber crib supported intake structure. This exposed segment of the pipeline is supported on by 44 sets of wood piles spaced every 20 feet. The bents are numbered from 1 to 44, starting at the intake structure. Figure 1-1 shows a plan view of the intake pipeline. Figure 2-1 presents a profile of the intake pipeline and a cross section of a typical bent.

Golder was authorized to begin work in November 1999. To attain a familiarity with the project and develop the scope of work, Golder conducted reviews of the 1984 and 1998 video inspections, participated in discussions with the City regarding the pipeline history, and reviewed Harza's March 22, 1999 report. In Harza's review of the 1984 and 1998 videos, they noted that "the previous inspections did not cover all portions of the intake and supports." Harza recommended that an additional inspection and study be conducted to determine the extent of any remedial actions that may be required to stabilize the pipeline. Harza suggested that future inspections include an internal inspection of the pipeline and collection of cores from the pipeline's wood staves. The cores were to be collected from both the buried portion of the pipeline and the portion that is exposed in the Lake.

The investigation of the pipeline and associated components was divided into two phases. Phase 1 of the investigation consisted of inspecting and video documenting the integrity of the exterior of the intake structure, pipeline, and wood-pile bents using commercial divers. This work was performed for about one week, starting at the end of November 1999. The divers videotaped the exterior of the pipeline. The interior was inspected and documented using a remote-operated, submersible vehicle (ROV). The divers also collected samples from the pipeline to assist in determining the condition of the pipeline. Samples collected were: pipeline steel rods, clamps, nuts from the flanges, and wood plugs cored from the pipe staves. The videotapes and photographs were reviewed, and the samples analyzed. This report summarizes the data collected and the results of our analysis. One additional follow-up dive was conducted to complete the investigation phase of this project. This report also presents recommendations for several repairs to ensure continued service of the pipeline.

Phase 2 consisted of a set of follow-up dives and a geophysics investigation conducted in May 2000. During Phase 2, a steel bent bolt was removed for sampling, and one additional wood cores were obtained from the pipeline – this time from a section of buried pipeline. The geophysics portion of the investigation included the following:

- Bathymetric profiling of lakebed.
- Side scan sonar of surficial features of lakebed.
- Electromagnetic utility location.

This report is organized into the following sections:

- **Section 1:** Provides an introduction and project overview.
- **Section 2:** Provides a description of the underwater investigations of the pipeline and associated components and field tests.
- **Section 3:** Discusses the laboratory and material tests conducted on the wood cores, steel rods, stainless steel bands, steel bolt brackets which are referred to as shoes on original pipeline drawings, and other associated hardware and summarizes the results.
- **Section 4:** Presents our recommendations for repairs and modifications to the intake pipeline to maintain the overall integrity of the pipeline and components.
- **Appendices:** The report's appendices provide a copy of the divers' Daily Construction Logs, supplementary project photographs and video clips, comment tables of underwater investigation videotape, schematics of each bent, and supporting laboratory reports.

Relevant photographs of the underwater inspection activities are provided in the body of the report. Supplementary photographs of the underwater inspection activities are provided in Appendix B. A log describing scenes from each video tape is provided in Appendix C. Sketches of each bent as observed by the divers are in Appendix D. A copy of the University of Washington's laboratory report on the wood core samples is in Appendix E. Photographs associated with Section 3, Laboratory Analysis and Material Testing, are provided in Appendix F.

2. UNDERWATER OBSERVATIONS AND FIELD TESTS

2.1 Divers and Equipment

Golder subcontracted Komex International Ltd. (Komex) of Victoria, British Columbia, to provide commercial divers and equipment to conduct the underwater investigation activities. Komex and the divers (Can-Dive Construction Ltd.) were onsite for the underwater field investigation from November 30, 1999 to December 7, 1999. November 30 was used for gearing up and barge preparation. The actual underwater investigation activities were conducted from December 1 through December 7. Komex submitted Daily Construction Logs that documented the activities of each day (Logs are provided in Appendix A).

Diving operations were conducted from a sectional barge equipped with an enclosure for overseeing and supporting diving operations (Photograph 1). The diver's surface supply equipment, including communications, compressor and pressure washer were also stored on the barge. The divers used a Sony Video8 Camcorder in an aluminum underwater housing, with 100 watt lighting (Photograph 2) to video tape and document the exterior condition of the pipeline and components. The divers were deployed from the barge into the water to initiate the underwater inspection of the wood pipeline exterior. A feed wire from the camera set ran along the diver's umbilical to a viewing console on the barge, and a second video record of the inspection was made, which included the audio communications between the surface and the diver. Komex personnel recorded and monitored the video images from the surface, and added commentary regarding the inspection procedures.

A Phantom DHD2 Remotely Operated Vehicle (ROV), equipped with a pan and tilt high-resolution video eye and sector scanning sonar (Photographs 3, B2, and B3) was used to inspect and record the condition of the wood pipeline interior. The internal inspections utilized the ROV that was deployed from inside the tunnel accessway located in the gatehouse. A guideline was introduced into the intake structure and intercepted at the gatehouse accessway, where it was connected to the ROV. The barge was anchored at the intake structure and winched the towline and ROV through the pipeline as per verbal radio instructions given by the ROV operator. During the internal inspection, the ROV and recording equipment were stationed inside the gatehouse (Photograph 4). Logs of project videotapes are provided in Appendix C.

2.2 Intake Structure

The diving inspection of the intake crib confirmed that the crib was constructed with 8" by 8" timbers. From the December 7 video, it appears that to construct the crib, vertical timbers were placed in the corners of the intake crib, and horizontal timbers were then placed on the outside of the vertical timbers on opposing sides. Two additional timbers were than placed across the ends of the first timbers to form the adjacent sides. This alternating fashion creates 8-inch openings on all sides of the intake structure (Photograph 5). The diver verified the soundness of the intake crib wood, using his hammer and communicating to the surface that the timbers (Photograph B4) were "pretty good wood." Fungus or fresh water sponge was noted on the surface of the intake crib structure in several places (Photographs B5 and B11). The top of the intake crib is a solid cover built from 4" x 8" timbers (Photograph 6). Two inch minus gravel was noted in the bottom of the intake crib. It is assumed the gravel was used as weight to submerge the intake structure and keep it from floating.

During the inspection of the intake crib, water blasting cleaned two bolts, used to fasten the horizontal timbers to the vertical timbers of the intake crib. Subsequent video showed the bolts to be in good condition, with little to no corrosion. Upon inspection, the diver reported the bolts were in "really good condition."

The 72-inch wood pipe entered the intake crib on the west side. A steel bell shaped fitting was located at the terminal end of the pipe, approximately three feet inside the intake crib (Photograph B5). It was noted that approximately nine steel hoop bands were placed on the pipe between the bell fitting and where the pipe exits the intake crib. During the inspection of the outside of the intake crib, some debris was knocked loose from the timbers and drawn into the bell and pipeline. It is apparent from the video that the intake system draws quite proficiently from the lake. The City of Bellingham reported that the flow at the time of the inspection was approximately 45 million gallons per day.

2.3 Wood Pipeline Exterior

The previous 1984 and 1998 videos did not provide the degree of detail in viewing the pipeline wood staves or joints as does the Golder 1999 video. Generally the exterior of the wood pipe was very sound (Photograph 7). The exterior of the pipeline was covered with varying amounts of silt and algae. There was noticeably more silt on the pipe closer to the shore than at the end of the pipeline near the intake crib. The wood staves were water blasted approximately every 100 feet along the pipeline alignment to allow for a more complete visual inspection of the condition of the wood. Video of the water blasted wood staves exhibit the coarse grain of the wood. In general, the pipe wood joints and seams appeared to be tight and in good condition. The divers tested the wood staves at several locations with a hammer, and reported the wood to be sound (Photograph 8).

To provide for closer inspection and testing, the divers collected two 2-inch diameter wood cores from the wood staves using an underwater pneumatic drill at bent #20 (Photograph 9). The cores were visually inspected to evaluate the interior condition of the wood. The interior wood did not appear to be substantially deteriorated and appeared to be fresh and in good condition (Photographs 10, B7, and B8). Three additional wood cores were collected from the wood staves at bent #30. One core was taken at the joint between two staves. The sample confirms that there are tongue and groove joints longitudinally between each stave. Two-inch diameter plastic compression duct plugs with rubber seals manufactured by Jackmoon (model 20D236U) were placed in each of the core holes left in the pipeline wood staves (Photograph B9).

The wood cores were subjected to material testing and submitted to the University of Washington's College of Forest Resources for analysis. The results and discussion of the laboratory analysis and material testing are provided in Section 3. Condition and observations of the bands that hold the wood staves together are discussed in more detail in Section 3.

2.4 Wood Pipeline Interior

The ROV was used to inspect the general condition of the inside of the pipeline along its entire length and take sonar images of the pipeline at selected locations. Portions of the wood surface inside the pipeline were covered with a thin layer of silt and some algae, but overall the wood and pipe appeared to be in excellent condition. White fungus or bacteria colonies were noted inside the pipeline in a number of locations (Photograph 11 and B11).

The internal inspection provided evidence of the continuity of the butt joints, for individual wood staves (Photograph B10). However, a break in the continuity of the wood pipe staves was noted inside the pipeline in the buried portion of the pipe, approximately 130 feet from the gatehouse. The location of the break is depicted the profile in Figure 2-1. A 4- to 6-inch gap was present around the complete circumference of the pipe (Photograph 12). It appeared that the pipe was incased by a wood sleeve that had been placed around the outside of the pipe. It is possible the gap and outer sleeve is associated with a type of expansion or slip joint. Gravel that was likely pulled into the pipe from the intake crib had collected in the invert portion of the gap (Photograph 13). There were a number of crayfish present in the gravel that were also likely drawn in through the intake structure (Photograph 12). Air was observed being trapped in the top of the pipe gap.

Sonar images (Photograph 14) were recorded from inside the pipe to evaluate the roundness of the pipeline. The sonar images were recorded on 100-foot intervals over the full length of the pipeline. These images confirm that the pipeline is round and has not been deformed or forced out of round.

2.5 Flanges and Sleeves

Flange joints were identified in the pipeline alignment between bents #27 and #28 and between bents #40 and #41. The locations of the joints are presented on Figure 2-1. Divers water blasted the flange joints to provide for a more complete visual inspection.

The flange joint between bents #27 and #28 was constructed with a standing 3 to 4-inch steel angle (used to form the flange) welded to a metal sleeve (Photograph 15) that was inserted inside the wood pipe. The standing flanges were butted together with a wood gasket placed between them. Nuts and bolts were used to hold the flanges together. The video showed the wood staves were closer to the standing flange on the flange joint (approximately 2 to 3 inches) on top of the pipeline, and farther apart on the bottom (approximately 4 to 5 inches). It is assumed that difference in the distance between the ends of the wood staves and the standing flange on top and on bottom were established during construction. The sleeve welded to the flange was constructed with an off-set or wedge to create an angle in the pipeline. The angle of the flange joint changes the slope of the pipeline from -1.3% to -6.4%. The bolts holding the flange together were corroded and overall appeared to be in marginal condition. Additional discussion of flange bolt inspection is provided in Section 3.

Upon closer inspection of the flange joint at bent #27, it was found that the welds holding the angle and the metal sleeves together were in an advanced state of deterioration. The welds holding the wedge to the sleeve and angle were also in very poor condition (Photograph 16, B14, and B15). The welds had broken way from the metal sleeve in several places and cracks developed in the weld bead. A non-continuous, large-beaded, stitch weld appears to have been placed over the original weld to hold the joint together.

A second flange joint was located between bent #40 and #41 appeared quite similar in welding and construction to the flange between bents #27 and #28. It had the same sleeve and flange construction with a 3 to 4 inch standing angle. The distance between the wood staves across the joint is 3 to 4 inches on the top of the pipe and 5 to 6 inches on the bottom of the pipe. There were two stainless steel bands on each side adjacent to the flange, in addition to several steel rods. The gasket between the flanges appears to be made of wood and remains continuous around the joint. The bolts holding the flange together were also corroded at this flange joint. However, it was noted that the top bolt in the flange was missing (Photograph B13).

A review of the videotapes taken by the ROV of the interior pipeline showed the metal sleeve portions of the wood/sleeve flange joints. Closer review of the interior side of the metal sleeves showed that some corrosion of the metal has taken place (Photograph 17). However, the wood appeared to be in excellent condition.

2.6 Steel Rods

The wood staves forming the pipeline are held together by what appeared to be 1/2-inch diameter circular steel rods or hoops. The steel rods are placed approximately every six inches along the length of the pipe (Photograph 18). One complete hoop is composed of two half circular rods with a connecting bracket ("shoe" per the original design drawings) at each end. The ends of each hoop are threaded. Nuts are placed on the end of each hoop and the bracket serves to hold the two nuts together, similar to a clip. Once in place, the nuts were tightened to draw the hoop tight to the pipe (Photographs 19 and B16).

Clearly all of the steel rods and/or brackets demonstrated some degree of corrosion, some to the point of failure (Photograph 20). A number of the rods or brackets were corroded to the point that rods (bands) had fallen off, or were not functional. There were a number of bands that had fallen off at bent #19. At bent #2, in addition to some other bents, extra rods were noted lying on the lake bed. The rods did not apparently fall off the pipe, since there were no missing rods on the pipeline in these locations.

2.7 Stainless Steel Bands

Flat stainless steel bands (Photograph 21) were noted along the pipeline in various places. The bands were most notably located where the steel hoop bands appeared to be failing or exhibited the most corrosion. It appeared as though there were more stainless steel band located closer to shore. The bands did not appear to exhibit signs of corrosion and maintained their metallic luster. See Section 3 for analysis results of an extra piece stainless steel band that was salvaged from the lake bed.

2.8 Wood Piles

The wood piles were driven into the lake bed and support braces were bolted to the piles (Photograph 22). The braces support cross members that run under the pipeline (Photographs B18 and B19). The piles appear to be approximately 12 to 14 inches in diameter. The divers tested the soundness of several piles with a hammer. The claw-end of a hammer was used to peel or splinter the exterior surface of the piles and exposed the inner wood (Photograph 23). These field tests showed that the wood just under the surface of the piles was in good condition and appeared as if it were fresh wood. Videotape shows the test being conducted on one of the piles at bent #14.

An extra pile was noted at bent #2 near the south pile of the bent. With the exception of two piles (bents #18 and #35), all of the piles appeared to be in good condition. The south pile at bent #18 was missing. It is not known if this pile was ever driven. The south pile at bent #35 was broken off where the bolts connect the cross braces to the pile (Photograph B20). The wood pile below the bolts remains sound. It was not evident if the pile was broken off sometime during or after installation this may be the extra pile located at bent #2.

2.9 Support Braces and Cross Members

Two 6" by 12" cross members were set on each side of the pile on top of two 6" by 12" support braces (per pile), which were bolted to the wood piles. The nuts used to bolt the support braces to the piles were inspected and appear to exhibit little corrosion and were in over all fair condition (Photograph B18). Fresh water crayfish were noted at several of the bents crawling around on the support and cross braces.

Concrete ballast weights (sinkers) or wood saddles were installed between the pipeline and the cross braces to support the pipe (Photograph 24). The degree to which the concrete weights rest on the cross braces varies as can be seen in the individual bent (plan view) diagrams provided in Appendix D. At approximately 18 to 20 of the bents the concrete weights do not rest on the cross braces at all or just catch the edge of the braces. Wood saddles, bridges, or wedges are used at these locations in substitute of the concrete weights to support the pipe on the cross braces. The cross braces at bents #42, #43, and #44 are below the current lake bed, and were not viewed. Plan view sketches of 41 of the pipeline bents are provided in Appendix E.

As noted in the previous section, the south pile at bent #18 was missing. At this bent the cross brace lays on the lake bed and a wood wedge is used to compensate for the angle of the cross brace. Although piles were present at bent #29 and #40 the cross braces were also at an angle, and wedges or saddles are used to compensate for the angle. A large wedge, approximately 10 feet long, is used to support the pipe at bent #38; the need for the length of the wedge is not clear. At bent #39 both of the wood cross braces rest together on the support brace on the East side of the north pile. The west cross brace at bent #39 does not support any weight. The east cross brace at bent #39 supports all the weight, but is lifted off the support braces and is nailed with two spikes to the south pile (Photograph B21).

2.10 Concrete Weights

Concrete weights (sinkers) are used to weight the pipeline down and for supports when they align with the cross braces on the bents (Photograph 24). The concrete weights are saddle shaped and are attached to the invert of the pipe. Each weight is approximately 60 inches long, 16 inches wide, 18 inches high at the ends, and 5 inches high in the middle. It is estimated that the dry weight of each block is approximately 1,200 pounds. The concrete weights are attached to the pipe with a steel pipeline hoop cast into each weight.

Generally, the weights were spaced at approximately the same intervals as the bents, with an additional weight placed midway between the bents. The video shows the diver chipping the concrete weight at bent #14. The concrete appeared competent and solid and did not break easily. One weight was missing between bents #26 and #27. The weight at bent #29 had fallen off the pipe and broke in half due to corrosion of the steel hoop. One of the halves of the weight was brought to the surface by the dive team for inspection (Photograph 25). It was noted during the dive that the concrete weight at bent #38 was cracked in the middle of the block (Photograph B23); however, the weight was supported by a long wedge and remained in place. Five of the concrete weights were placed between bents #39 and #40.

Concrete cylinders were also observed in several locations along the pipeline. The cylinders appeared to be approximately 8 inches in diameter and approximately 1 foot long. All of the cylinders were lying about the lake bed near the pipeline and not attached to the pipeline in any manner. It is assumed that these cylinders may have been used as additional ballast weights when submerging the pipe during construction.

2.11 Geophysics Investigation

A geophysical survey was conducted in May 2000 to facilitate the water supply pipe inspection. Acoustic bathymetry profiling, side scan sonar imagery and marine electromagnetic utility detection were used for the geophysical survey. Diver support was provided to assist in sediment and pipeline component sampling. The following is a brief description of the geophysical methods, field results and conclusions.

2.11.1 Methods

Three geophysical investigation methods were employed in this portion of the study: an acoustic bathymetric survey, a side scan sonar profile, and a marine electromagnetic utility location.

Acoustic bathymetric profiling systems use acoustic pulses, emitted at regular intervals to detect the lake bottom depth below the survey vessel. The acoustic pulses generated by the transducer are reflected from the lakebed. The acoustic reflections are received by a transducer that converts the acoustic pressure waves into electrical signals. The electrical signals are processed and displayed with navigation event marks as a lake bottom profile. An Odom Hydrotrack digital echo sounder with internal chart recorder was used for the acoustic bathymetric survey.

The side scan sonar system used acoustic pulses to record images of the lakebed features to the left and right of the survey trackline. The image produced is called a sonargram. Acoustic reflections from the lakebed or features on the lakebed appear as varying shades of intensity on the sonargram. High intensity reflections represent coarse-grained material usually rocks or boulders, vegetation, and debris. Low intensity reflections represent fine-grained sediment such as silt and fine sand. The surficial features on the lakebed were imaged with an Edgetec Model 260 image correcting side-scan sonar.

Marine electromagnetic utility location or EMUL uses applied or re-radiated electrical and/or radio signals emitted from the utilities to locate utilities. The electrical signal received from the utility may also give clues as to the nature of the utility.

2.11.2 Field Procedures

This section discusses the field procedures used for the navigation bathymetry survey, the side scan sonar, and the marine electromagnetic utility location.

The navigation bathymetry survey was completed by using a Laser tracking unit at a fixed shore station to follow the boat during the survey. Location fix-marks were radio relayed to the boat for addition to the bathymetric records. The bathymetry data were turned over to Komex International for interpretation. Navigation for the survey was provided by Komex International Ltd.

Side scan sonar tracklines were run parallel to the pipeline at a 50-meter range (100-meter swath). Side scan sonar lines were also run parallel to the shore line at a extended range (150 to 300-meters per side) to check the lake bed for slump features or other features that may indicate slope instability in the area.

Four utility cables were known to cross the pipeline corridor. Three cables cross over the pipeline, and one cable crosses under the pipeline. The EMUL was used to 'listen' to the electromagnetic signals from the cables to aid in determining their origin. Divers carried the sensor to the individual cables while shipboard personnel interpreted the electromagnetic emissions from each cable.

The survey vessel and or Golder personnel assisted in the divers operations to collect sediment and pipeline component samples.

2.11.3 Results and Conclusions

Bathymetric data for the pipeline route was collected and turned over to Komex International Ltd. for interpretation. Side scan sonargrams were collected to identify anomalies on the lake bottom around the pipeline (Figure 2-2). The sonargram in Figure 2-2 shows the pipeline and lakebed features, such as a log and a patch of debris or vegetation adjacent to the pipeline. The lighter areas below the pipeline in the figure are the acoustic shadows from the pipeline and the bent piles. Side scan sonargram revealed a cable crossing the pipeline (not shown in figure 2-2), however the cable is buried in the soft sediment just beyond the pipeline and was not traced to a source. An example of how a sonargram is created is shown in Figure 2-3.

Side scan sonar imagery did not reveal any slope failure features directed at the pipeline. A possible slump deposit was imaged on a steep slope northeast of Watkins Point, approximately 900 feet north of the pipeline.

The electromagnetic utility location resulted in detection of electromagnetic emissions from three of the underwater cables. The first cable encountered (near Bent 26) emitted 60 Hz noise, a one-second-clock pulse, and digital communication noise. The cable is interpreted to be a possible communications utility. The second cable (at bent 23) was interpreted to emit a clear 60 Hz noise. The cable is interpreted to be a possible power utility. The third and fourth cables are above and below the pipeline in the same location (Bent 22) and it was not possible to differentiate between the two as to which produced the signal. A very strong radio emission was detected from this location (AM radio station). The utility was interpreted to be an abandoned power utility or a possible ground line.

Assistance was provided to the divers for the collection of a pipeline core sample, retrieval of a bent bolt, and collection of sediment samples from the around the intake structure.

The pipeline core sample and the bolt were brought back to our office for analysis. The sediment samples were left with Komex personnel.

2.12 Miscellaneous Observations

The cables that were described during the geophysical investigation were first noted during the pipeline investigation. The cable that crosses over the pipeline (one of two possible cables with a strong AM radio signal) is approximately 2 inches in diameter and upon inspection appeared to be in good condition. The other cable possible of contributing to the AM radio signal crosses under the pipeline in the same location and is smaller, approximately ½ inch in diameter and is lead-sheathed. The cable interpreted to be a possible power utility (at bent # 23) is 2 inches in diameter and appears to be in good condition, however the wires were not observed. The diver observed that the cable appeared to be "tight" and that the cable traveled in mid-water approximately 30 feet from either side of the pipeline before it met the lake bottom. The cable interpreted to be a possible communications utility (crossing over the pipeline between bents #26 and #27) had the largest diameter of all the cables, approximately three inches (Photographs 26 and B24).

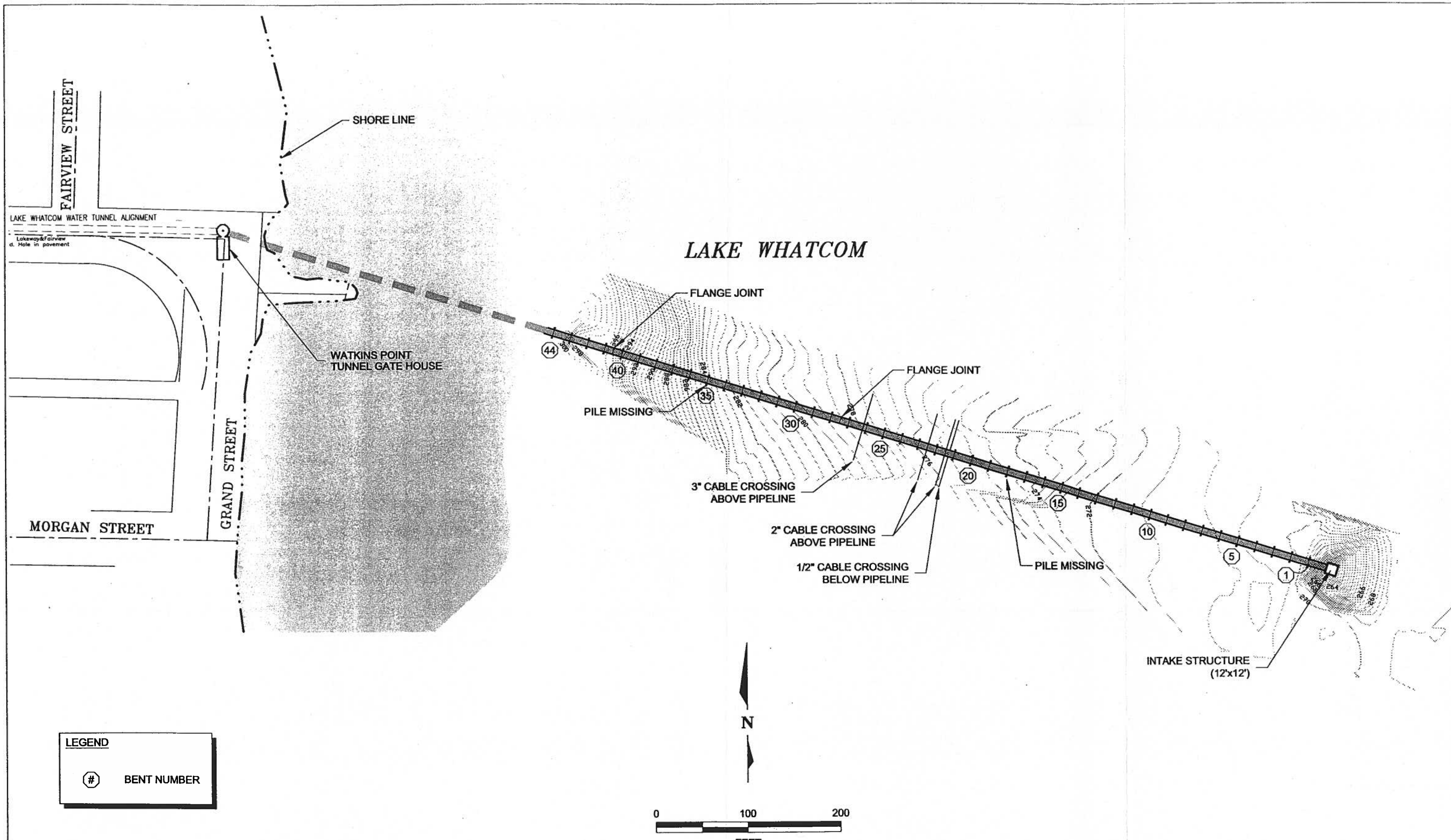
Silt and algae were observed on top of the pipe. The silt appeared to be less than 1/4 inch deep near the intake. The silt on top of pipe reaches depths of approximately two inches in some areas near bent #36 and closer to the shore.

The lake bed near the pipeline is soft and composed of fine silts and debris. Fresh water clams were noted in several locations along the pipeline in the soft silty materials. There was relatively little vegetation observed in proximity to the pipe. Aquatic plants were not observed until closer to the shoreline near bent #42.

The invert of the pipeline is approximately 3 feet above the lake bed from bent #2 to #17. The distance between the invert and the lake bed decreases to approximately 2.5 to 2.0 feet between bent #18 and bent #23. The interval appears to be a little less at bent #22. From bent #24 to bent #29 the interval is approximately 1 to 1.5 feet. The distance between the invert and the lake bed at bent #30 interval appears to be approximately 2 feet. The interval increases to 3 - 4 feet between bents #31 and #38. Between bents #38 and #39 the interval below the pipe drops from 3 feet to 1.5 feet. From that point the interval remains approximately 2 feet until bent #42 where the bottom of the concrete weight rests below the lake bed. At bent #43 the pipeline is almost half buried in the lake bed.

The diver observed and measured the sediment depth of the lake bottom on one side of each set of piles. A 4-foot aluminum carpenter's measure was thrust into the lake bed until it hit a refusal layer, and measured the depth at that point. The sediment (or soft bottom) depth of the lake varied considerably along the length of the pipe. From bent #1 to #15, the depth ranged from 4.0 to 5.0 feet, but between bents #2 to #3, #7 to #10, and #12 to #15, the depth was beyond the reach of the measure plus the length of the diver's arm. From bent #16 to #23, the depth was about 4.0 feet. From bent #24 to #28, the depth ranged from 2.0 to 3.0 feet, and then deepened to about 4.0 feet until about bent #34, where it became shallower again and ranged between 2.0 and 3.0 feet. Between bent #38 and #39, the resistance layer rose to within 2 or 3 inches of the surface of the lake bed. It then deepened to between 1.5 and 3.0 feet for the remainder of the bent locations.

Appendix C
Drawings of the Intake Pipeline from September 2000 Golder and Associates Inspection Report



NOTES:
1. The City of Bellingham has developed this map for its own use and is not responsible for use by others. Persons using this map do so at their own risk and agree to defend, indemnify, and hold harmless the City of Bellingham as to any claims or suits arising out of such use.
2. Bathymetry contours based on May 2000 survey by Golder Associates.

FIGURE **1-1**

PLAN VIEW WATER INTAKE PIPELINE

CITY OF BELLINGHAM/LAKE WHATCOM/WA

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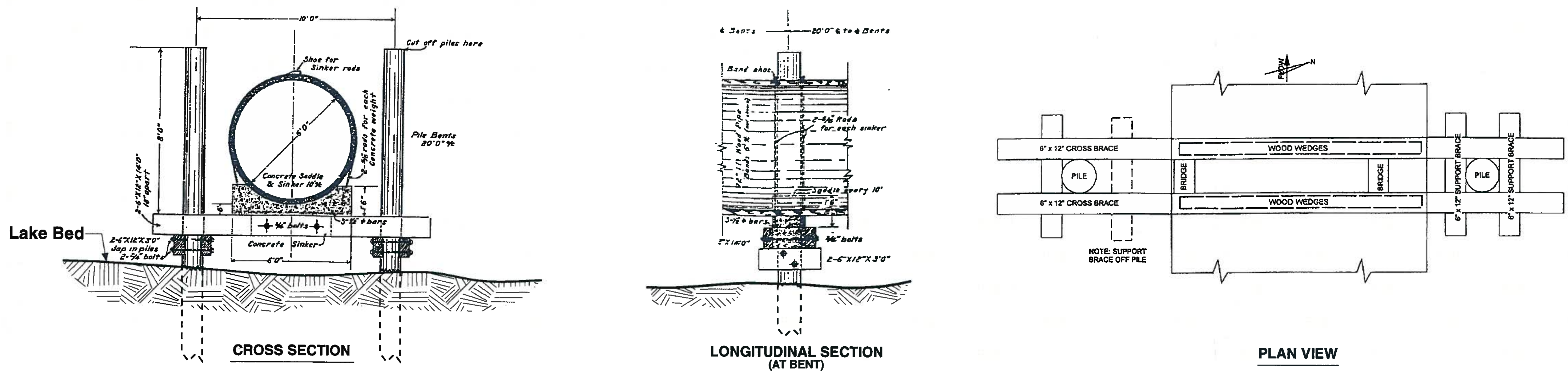
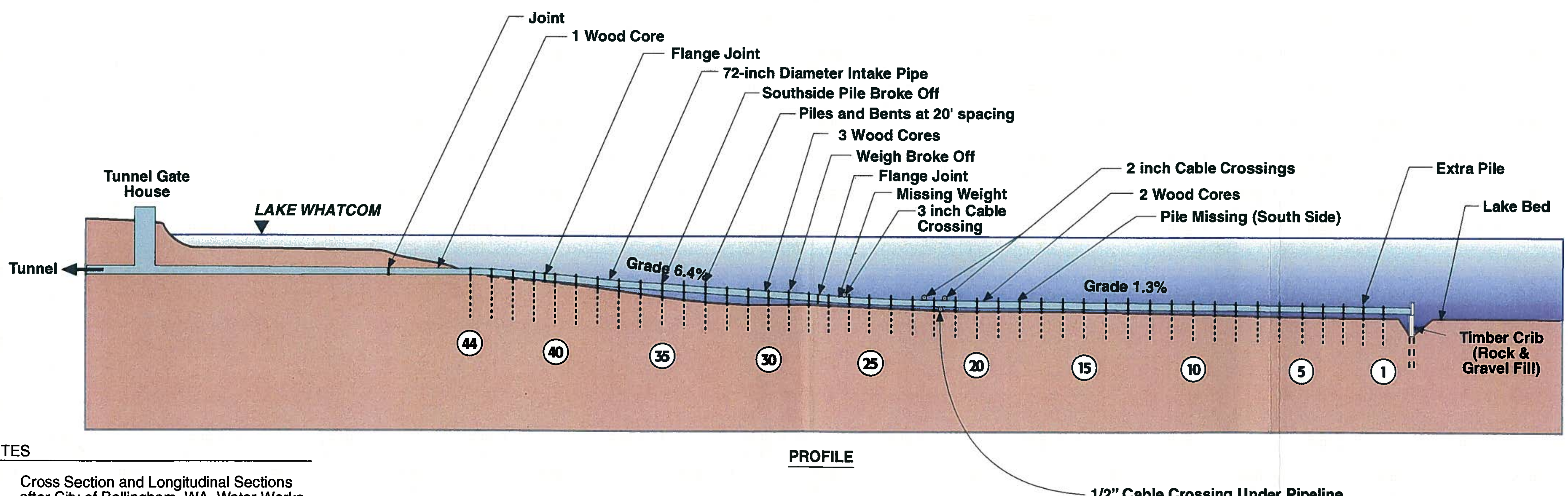
Golder Associates





PROFILE

NOTES

1. Cross Section and Longitudinal Sections after City of Bellingham, WA, Water Works Improvement Profile of Intake Pipe and Construction Details. Drawing #WA-48.

2. The profile of the pipeline and lake bed has been updated based on side scan sonar survey, May 3, 2000 and diver observations.

FIGURE **2-1**

LAKE WHATCOM INTAKE LINE

CITY OF BELLINGHAM

PROJECT NO. 993 1668.110 DRAWING NO. 91661a DATE 9/27/00 DRAWN BY TK

Golder Associates

Appendix D
Repair Recommendations from January 4, 2002
Golder and Associates Design Report

LAKE WHATCOM INTAKE
BENT REPAIRS

The following is a summary of the observations of the Lake Whatcom Intake and support system recorded by diving inspection on October 12, 2000. The observations are specific to pile sets where peculiarities had been previously recorded. The purpose of the inspection of October 12, 2000 was to confirm the previous observations for development into a detailed remedial work plan. The observations and work plan items relative to the particular pile set are recorded in Table 1. The observations are summarized graphically on the appended figures.

Table 1 – Required Repairs

Pile Set	Observations	Work Plan Items
15	- Pile set is skewed, NE/SW per dwg. - Weight is suspended above cross brace by 1'' on south side and 2" on north side	- Insert saddle supports to fit on east side of weight – one from north side, 2 from south side - Double band weight
18	- Missing pile on south side - Cross braces resting directly on mud bottom on south side - Existing wedging in good condition, - Bottom soft and unlikely to providing any support	- Replace pile. (drive new 10 to 12" non-treated wood pile). - Bolt support braces to new pile. - Reset cross braces onto support braces. - Double band weight (confirm weight is there)
19	- Concrete weight approximately 1 foot west of support system - Two stringers cut to fit sitting on top of cross brace – major support system	- Double band weight
22	-	- Insert saddle supports, see figure.
Cable @ 22 (E)	- 2 inch diameter cable over pipe - no distress on pipe - easily moved by diver - tight looped close to pipe	- Place thin, flexible, high density molecular plastic saddle between pipe and cable. - Mark saddle to provide visual aid for future assessment of movement
23	-	- Insert saddle support, see figure.
Cable @ 23 (East)	- 2 inch diameter cable over pipe - No distress on pipe - Cable easily moved by diver - Long sweep to either side (+/-40 ft)	- Place thin, flexible, high density molecular plastic saddle between pipe and cable. - Mark saddle to provide visual aid for future assessment of movement

Pile Set	Observations	Work Plan Items
26	-	- Insert saddle supports, see figure.
Cable @ 26 (E)	- 3.5 inch diameter cable over pipe - No distress on pipe - Cable cannot be moved by diver - Long sweep to either side (+/-25 ft)	- Attempt to lift cable with lift bag - Place thin, flexible, high density molecular plastic saddle between pipe and cable. - Mark saddle to provide visual aid for future assessment of movement
29	- Spacing to north pile 3" - North pile leaning north - Spacing to south pier 24" - Pipe is blocked with 2" stock, on flat spanning cross brace - Blocking is toe nailed into cross brace and possibly pipe - Area of previous weight retrieval	- Replace blocks with circle cut wedges for more complete circumferential bearing – minimum 2 on each side required – place on bridge and shim tight. Toe nail to bridge. - Replace weight with new ballast weight (see detail).
33	- Concrete is west of support structure. - Cross Brace is not supported on south support brace on south side - ½ inch space on NE bearing, south side - 2" space in NW bearing, south side	- Double band concrete - Shim south side between cross brace and support braces - Insert saddle supports, see figure.
34	- Pipe wedge is nailed to pipe - Sitting on 2'x3" flat stock - Concrete is off bridge - Only one saddle	- Double band concrete - Provide additional wedge on each side, tight to bridge and bottom of pipe. Toe nailed to bridge - Remove saddle support and replace with blocks, see figure.
35	- South side pile broken off at bolts for cross brace supports - Space between cross brace frame – 19" - Pile diameter – 11" - Cross brace extension to south beyond brace is 3" - Single wedge toenailed to pipe - Slight lean on wedge toward N - Concrete weight just touching bridge on SW	- Install new 2 piece stainless steel pipe clamp over pile – see detail - Double band weight - Insert saddle supports, see figure.
36	- Distance to pile on N = 12" - Concrete bearing by 6" on SW - Single saddle	- Double band concrete - Provide additional wedge on each side, tight to bridge and bottom of pipe. Toe nailed to bridge - Insert saddle supports, see figure.

Pile Set	Observations	Work Plan Items
38	- Pipe supported on cracked concrete weight - Concrete weight supported on angled (levered?) cross brace. - No shim or saddles	- Place wood saddle support on west cross brace. - Remove east cross brace. Re-install level and bolt to pile. - Band existing weight to itself (horizontally) and circumferentially. Insert wedges to east cross brace to shim concrete - Cut off pile tips
39	- East cross brace loose - Concrete to east - Salvaged circle cut wedge from this pile set - No bridges – just cross braces - Both cross braces on same side of north pile - Cross braces on lake bed on south side (no support braces)	- *NOTE: Take care when working on this bent. Long span to bent 40.* - Replace cross braces - Place on proper side of pile - Saddles cut to suit. 2 needed - Double band concrete block - Cut tops off of piles
40	- Approximately 40 ~ 45 feet west of 39 (i.e one pile set missing) - Pipe tight to north pile - Form fitted cross braces (3x12) - West cross brace levered high on north side to get contact - East cross brace not touching pipe - No support braces on north side - cross braces nailed in levered positions - East cross brace, south side nailed to pile - West brace south side secured to pile with lag bolts.	- *NOTE: Take care when working on this bent. Long span to bent 39.* - Double band weight to pipe - Remove east cross brace and confirm fit to pipe – then use as a pattern if appropriate. - Remove and replace cross braces, - Insert new saddle supports, cut to suit - Install appropriate support braces - Cut tops off of piles
41	- Both support saddles on north side are loose - Saddles nailed to pipe and not sitting on cross brace nor supporting pipe. - - Support brace on north side of south pile lying on side – not touching cross brace.	- Double band weight to pipe - Remove and replace cross braces - Insert new saddle supports, see figure. - Install appropriate support braces - Cut tops off of piles - Provide and install pile number tag
42	- Pipe tight to north pile - Pile tops are above top of pipe and are potentially hazardous to boat / recreational traffic	- Cut tops off of piles approximately ½ way up pipe wall - Excavate area to either side to expose cross braces or make room for new

Pile Set	Observations	Work Plan Items
	- Bottom material to underside of pipe – could not see cross braces – no saddles	cross braces - Fabricate and install wedges and saddle supports to provide support - Provide and install pile number tag - Double band weight
43	- Piles extend above top of pipe and could be hazardous to boat / recreational traffic - Bottom half of pipe buried to springline of pipe. - Weight between bents 42/43 sitting on bottom	- Cut tops off of piles - Excavate beneath exposed weight - Double band weight - Provide and install pile number tag
44	- Piles extend above top of pipe and could be hazardous to boat / recreational traffic - Bottom 3/4 of pipe buried	- Cut tops off of piles - Provide and install pile number tag

GENERAL OBSERVATIONS:

1. New(er) stainless steel banding is present on 3.5 foot average spacing (every 7th spacing of the original steel bands)
2. The existing 3" wide support saddles are nailed to the pipe.

CONSTRUCTION REQUIREMENTS:

Considering the above observations and work plan items, we recommend that:

1. The contractor shall cut new support saddles to suit (on site) with the intention providing circumferential support on the bottom of the pipe at each pile set.
2. Wherever existing support saddles are to be removed, the contractor should exercise caution to not damage the pipe wall. New scars may provide new opportunities for in water fungus / bacteria to attack the wood.
3. The weights are the main component providing stability to the system. The negative buoyancy imparted by the weights must be maintained. Wherever possible each weight should be banded (2 steel bands recommended) to the pipe. Where weights have broken off the pipe, they should be replaced with an equivalent weight. Replacement weights shall be Saddle weights over the crown of the pipe (see drawings).
4. The pipe should not be "fixed" to any bent, to allow for differential movements.
5. Do not toe nail support saddles to pipe.
6. Support saddles shall be at least 3 inches (actual) thick.

7. Fabricate the support saddles to taper to nothing beneath the pipe and shim them tight to the pipe with appropriate thickness stock between the shims and the bridge on the cross brace.

Appendix C.doc

3. REPAIR RECOMMENDATIONS

3.1 Steel Pipe Flanges

The pipeline contains two flange joints. The flanges are used to change the degree of slope in the pipeline. The flange assembly consists of a standing 3 or 4 inch steel angle welded to an approximately 6-inch wide steel flange sleeve. The flange sleeve is welded to another approximately 12" wide sleeve extension that inserts into the wood pipe. The weld between the flange sleeve and the extension is in poor shape and could fail (see photographs 6 and 9 in Appendix E). Three alternatives for repairing the steel flanges were considered:

Alternative 1 – Rigid Coating

This method does not damage the pipe and protects the joint area by allowing longitudinal movement. This approach to reinforce the flange sections involves applying the following steps:

- Removing any surface debris in the flange area by high-pressure water spray.
- Replacing all of the flange bolts
- Protect badly pitted areas and missing welds with an underwater epoxy.
- Bridge the flange assembly with a thick geo grid mesh. The mesh would extend 18 inches into the wood section on each side and be strapped to each pipe section with stainless steel banding.
- Covering the mesh area with a continuous geotextile 'diaper'. The diaper would extend 24" inches to each side of the flange and be strapped to each pipe section with stainless steel banding. The ends of the diaper would meet and be sealed at the crown of the pipe. Prior to placing the diaper, four grout tremmie tubes would be inserted, extending from the invert of the pipe to the crown, on each side of the flange face.
- Hydraulic grout would be pumped into the diaper through tremmie tubes, coating the enclosed wood and metal surfaces and embedding the geogrid mesh, as the tubes are systematically withdrawn.

Alternative 2 – Flexible Coating

This method provides a more flexible coating system than the encased grout. This option involves the following steps to be applied.

- Removing any surface debris in the flange area by high-pressure water spray.
- Replacing all of the flange bolts.
- Protect badly pitted areas and missing welds with a petrolatum based, water repellent primer containing moisture displacing, corrosion inhibiting compounds (Denso Paste).

- Press water repellant paste into irregular surfaces (flange and nut/bolt assemblies).
- Wrap all of the exposed metal surfaces with two wraps of a cloth tape impregnated with protective coating, such as 'Denso Tape'. Seal ends of tape wrap with several stainless steel bands.

Alternative 3 – Straps

This method is similar to Alternative 2, except longitudinal ties are placed over the repair area to provide some longitudinal support to the joint area. This option involves the following steps to be applied.

- Removing any surface debris in the flange area by high-pressure water spray.
- Replacing all of the flange bolts.
- Protect badly pitted areas and missing welds with an underwater epoxy.
- Press water repellant paste into irregular surfaces (flange and nut/bolt assemblies).
- Wrap all of the exposed metal surfaces with two wraps of a cloth tape impregnated with protective coating, such as 'Denso Tape'.
- Span the flanged section with several (6 to 8) evenly spaced prefabricated stainless steel tension bars. The bars would be anchored to the wood pipe walls on either side of the flange section using lag bolts or a large circumferential clamp.

The pros and cons of each alternative are discussed in the following table.

TABLE 1

Flange Repair Alternatives

Alternative	Pros	Cons
1 Rigid Coating	• Good protection for steel. • Maintains longitudinal alignment. • Can monitor longitudinal movement with gage.	• Rigid joint, no flexibility. • No longitudinal restraint. • Most expensive. • Difficult to inspect condition of steel.
2 Flexible Coating	• Joint has some flexibility • Can inspect condition of steel. • Least cost.	• No longitudinal restraint.
3 Straps	• Offers some longitudinal resistance (depending on securing force).	• Slightly more expensive

Normally there is no longitudinal force applied to the intake pipeline, however, in the event of an earthquake, a longitudinal force could be applied. If the force is too large, damage could occur to the pipe, if it is completely longitudinally restrained, as with the lag bolts in Alternative 3. We therefore recommend Alternative 2 for the flange repair method.

Stainless steel pins should be set in the pipe and at the flange to monitor movement between the wood pipe and steel flanges.

3.2 Steel Hoops and Bands

The wood staves forming the pipeline are held together by approximately 1/2-inch diameter circular steel rods or hoops. The steel hoops are placed approximately every six inches along the length of the pipe. One complete hoop is composed of two half-circular rods with a connecting bracket ("shoe" per the original design drawings) at each end. As observed by the physical investigation and materials analysis, the steel hoops are near or at the end of their serviceable life. Stainless steel banding has been previously applied as a remediative measure to provide pipe circumferential support. The stainless steel bands are spaced approximately every 3.5 feet, and remain in excellent condition. Although the stainless steel bands around the pipe are in excellent condition, the placement of additional stainless steel bands is necessary to reinforce and replace the steel hoops that are holding the concrete ballast weights in place (see additional discussions below). A number of the steel hoops supporting the concrete weights have already failed.

Two stainless steel bands will be used to support each ballast weight at bents and between bents. Also, three additional bands will be installed on the pipeline between each bent.

3.3 Near Shore Transition Area

The near shore transition segment is the pipe section between the off shore pile supported segment, and the fully backfilled, cut and cover on shore segment (see photograph 10). This segment is about 75 feet long. There was some concern expressed by the City of Bellingham that this segment may not contain adequate outside restraint should the steel hoops fail. This area was probed on a recent dive to determine ground conditions around the pipeline.

Several approaches were considered to ensure long term stability of the wood stave pipe in this segment. These were:

Option 1 – Stainless Steel Bands
One option to reinforce the pipe is to push new stainless steel bands around the pipe, using a rigid guide. The probing indicated a hard bottom near the invert of the pipe. It may therefore be difficult to push the bands under the existing pipe.

Option 2 – Ballast Rock Ballast
This option would add ballast material over the pipeline. Rock ballast would be placed over the exposed pipe in this segment. If rock were placed over the pipe, we have several concerns. These include:

- Rock could settle into soft bottom, particularly in near shore wave area; and
- The rock toe could become a maintenance problem.

Option 3 – Concrete Ballast
This option would add ballast material over the pipeline. Precast concrete weights could be precast and placed over the exposed pipe in this segment. Articulated concrete ballast mats are also available.

Option 4 – Stainless Steel Bands
This option would entail strapping the new band to the old band and using the old band to pull the new stainless steel band around the pipe.

Since the Contractor needs to provide several additional concrete ballast weights, we recommend a combination of Options 3 & 4. The articulated ballast weights would be placed over the pipeline in this segment. New stainless steel bands would be installed using the old rods to pull the new bands into place wherever possible. Please see the drawings (in Appendix A) for design details.

3.4 Concrete Ballast Weights

Concrete ballast weights (sinkers) were used to weigh the pipeline down and are also used for supports when they align with the cross braces on the bents. The concrete weights were saddle shaped and were suspended below the pipe. The weights were attached to the pipe with steel two hoops cast into each weight. Divers then connected the two hoops together with a steel clip, or shoe, at the top of the pipe.

Generally, the weights were spaced at approximately the same intervals as the bents (20 feet spacing), with an additional weight placed midway between the bents. The concrete appears to be competent and solid and does not break easily. One weight was missing and the weight at another bent had fallen off the pipe and broke in half due to corrosion of the steel hoop. The steel connecting clips (shoes) are failing due to corrosion.

Since the steel hoops attaching the ballast weights to the pipe are failing, it is recommended that the ballast supports be rehabilitated. Two stainless steel straps are to be added to each concrete ballast weight along the pipeline. This will provide support in the eventuality of the failure of the existing support rods. Any new concrete ballasts will be placed on top of the pipeline, and secured with bands. This will provide weight for the pipeline even in the event that the bands fail.

3.5 Broken and Missing Piles

The woodpiles supporting the pipeline were driven into the lake bed and support braces were bolted to the piles. The braces support cross members that run under the pipeline. The piles are approximately 12 to 14 inches in diameter. Field tests showed that the wood just under the surface of the piles was in good condition and appeared as if it were fresh wood. With the exception of two piles (bents #18 and #35), all of the piles appeared to be in good condition.

The south pile at bent #18 was missing. It is not known if this pile was ever driven. The depth at this location is approximately 35 feet, thus if the pipe were to be replaced, the new pile would need to be approximately 60 feet long.

The following options were consider for repairs to Bent 18.

1. Install a new wood replacement pile.
2. Raft the south end of the whaler to spread out support on lakebed. Will require removal and replacement of whaler and wedges. Movement will be limited by concrete sinker weight.
3. Suspend pipe from existing single pile and provide instrumentation to monitor movement.

Contact with a local (Lake Whatcom) pile driver indicated that the cost of installing a new pile would be relatively minor. Problems associated with placement of new piles include vibration during placing, accuracy of placement, disassembly and reassembly of support system. Discussions were undertaken with a local pile-driving contractor. They stated that based on their past experiences and recent work in the area, there was no reason to think installation of a new pile would disturb other existing piles. They also stated that placement in any desired location was likely possible due to the consistency of the lakebed. They stated that as their equipment stays on the lake from April to October, and mobilization is not a major expense. We therefore recommend driving a new pile into position at Bent No. 18.

The new pile shall be a timber pile, driven at least 15 feet into the lakebed, or driven until refusal. The pile shall be non-treated timber, 10 to 12 inches in diameter (similar to the existing woodpiles).

The south pile at bent #35 was broken off where the bolts connect the cross braces to the pile. The woodpile below the bolts remains sound. It was not evident if the pile was broken off sometime during or after installation. Currently, the upper bolt is exposed, and therefore is more susceptible to corrosion. We recommend that a heavy duty, galvanized steel pipe support be installed over the existing pile, just below the existing 6x12 support brace. The new pipe support will ensure that the loads on the timbers are transferred to the pile. This will be much more economical than replacing the pile.

3.6 Bent Repairs and Modifications

Most of the bents were constructed utilizing two 6" by 12" cross members were set on each side of the pile on top of two 6" by 12" support braces (per pile), which were bolted to the woodpiles (see drawings for details). Near shore, the cross braces were smaller. Wood saddles, bridges, or wedges were installed between the pipeline and the cross braces to support the pipe (see photographs 2 and 3). At a few of the bents, the concrete ballast weights were installed between the pipe and the cross braces (see photograph 4).

It was observed that as the pile supported section approaches the shore, and the pipeline rises up, a number of the existing piles extend to within 3 or 4 feet of the water surface, especially when the lake is low. This could present a hazard to boaters, as well as water skiers. We recommend that the upper section of these piles be cut off.

Appendix C contains diagrams of each bent requiring repairs. A table listing in detail specific repairs required at each bent is also included in Appendix C.

3.7 Cables Over Pipeline

As noted in the inspection report, and as detailed more specifically in the bent repair table, there are a number of cables that cross over the pipeline (see photograph 8). There is also one existing cable that crosses under the pipeline near bent 21. To minimize any future damage to the intake pipeline caused by the cables, we recommend placing high density molecular plastic (HDMP) wear plates under each of the three cables that pass over the pipeline.

Each wear plate shall be approximately 3/16 inches thick, 12 inches wide, and 39 inches long. These plates are to be shaped to the approximate radius of the intake pipeline. Each plate will be anchored to the pipeline with 6 stainless steel lag screws (3/8" diameter by 1.5 inches long).

3.8 Permitting

Several permits will be required to perform the pipeline repairs. These permits include:

- SEPA Checklist
- Shoreline Exemption
- JARPA – including Hydraulic Project Approval (HPA) [Pending approval as of 1/2002]
- A Right-of-Entry Permit may also be required.

The Washington Department of Fish and Wildlife has requested that fish screens be installed on the intake structure. The City of Bellingham has taken this request under advisement. Currently, Golder is performing additional studies to determine the feasibility and need for fish screens. The results of these studies will be published separately.

Appendix E
Repairs Completed in 2002 from the October 7, 2002 Golder and Associates Construction Report

Appendix C

Repairs Completed in 2002 on the Bellingham Intake Pipeline

The following tabular format summarizes specific work items completed at or between bent locations.

Bent Set	Work items completed in 2002	Comments
1	- No banding completed on weight at bent - Double banded intermediate weight between Bent #1 and #2	Could not install bands because the weight is tight/flush on wood brace structure
2	- Double banded weight - Double banded intermediate weight between Bent #2 and #3	
3	- Double banded weight - Double banded intermediate weight between Bent #3 and #4	
4	- No banding completed on weight at bent - Double banded intermediate weight between Bent #4 and #5	Could not install bands because the weight is tight/flush on wood brace structure
5	- Double banded weight - Double banded intermediate weight between Bent #5 and #6	
6	- No banding completed on weight at bent - Double banded intermediate weight between Bent #6 and #7	Could not install bands because the weight is tight/flush on wood brace structure
7	- No banding completed on weight at bent - Double banded intermediate weight between Bent #7 and #8	Could not install bands because the weight is tight/flush on wood brace structure
8	- No banding completed on weight at bent - Double banded intermediate weight between Bent #8 and #9	Could not install bands because the weight is tight/flush on wood brace structure
9	- No banding completed on weight at bent - Double banded intermediate weight between Bent #9 and #10	Could not install bands because the weight is tight/flush on wood brace structure
10	- No banding completed on weight at bent - Double banded intermediate weight between Bent #10 and #11	Could not install bands because the weight is tight/flush on wood brace structure

Bent Set	Work items completed in 2002	Comments
11	- Double banded weight - Double banded intermediate weight between Bent #11 and #12	
12	- No banding completed on weight at bent - Double banded intermediate weight between Bent #12 and #13	Could not install bands because the weight is tight/flush on wood brace structure
13	- No banding completed on weight at bent - Double banded intermediate weight between Bent #13 and #14	Could not install bands because the weight is tight/flush on wood brace structure
14	- No banding completed on weight at bent - Double banded intermediate weight between Bent #14 and #15	Could not install bands because the weight is tight/flush on wood brace structure
15	- Insert saddle supports - Double banded weight - Double banded intermediate weight between Bent #15 and #16	
16	- Double banded weight - Double banded intermediate weight between Bent #16 and #17	
17	- Double banded weight - Double banded intermediate weight between Bent #17 and #18	
18	- Replace pile. (Drive new 10" to 12" non-treated woodpile). - Bolt support braces to new pile. - Reset cross braces onto support braces. - Insert saddle support - Double banded weight - Double banded intermediate weight between Bent #18 and #19	
19	- Double banded weight - Double banded intermediate sinker between Bent #19 and #20	
20	- Double banded weight	
21	- No banding completed on weight at bent - Double banded intermediate weight between Bent #21 and #22	Could not install double bands on ballast weights on Bent 21.
22	- Insert saddle supports	

Bent Set	Work items completed in 2002	Comments
Cable @ 22 (E)	- Place thin, flexible, high-density molecular plastic saddle between pipe and cable. - Mark saddle to provide visual aid for future assessment of movement - Double banded weight - Double banded intermediate weight between Bent #22 and #23	
23	- Insert saddle support	
Cable @ 23 (E)	- Place thin, flexible, high density molecular plastic saddle between pipe and cable - Mark saddle to provide visual aid for future assessment of movement - Double banded weight - Double banded intermediate weight between Bent #23 and #24	
24	- Double banded weight - Double banded intermediate weight between Bent #24 and #25	
25	- Double banded weight - Double banded intermediate weight between Bent #25 and #26	
26	- Insert saddle supports	
Cable @ 26 (E)	- Place thin, flexible, high-density molecular plastic saddle between pipe and cable. - Mark saddle to provide visual aid for future assessment of movement - Double banded weight - Install one articulated concrete mat between Bent #26 and #27	No ballast weight observed between Bent 26 and 27.
27	- Double banded weight - Replaced bolts, denso paste and taped, installed 3 alignment screws and 4 S.S. bands - flange #1	
28	- Double banded weight - Double banded intermediate weight between Bent #28 and #29	
29	- Insert saddle supports - Install one articulated concrete mat between Bent #28 and #29	No ballast weight observed at Bent 29.
30	- Double banded weight - Double banded intermediate weight between Bent #30 and #31	
31	- Double banded weight - Double banded intermediate weight between Bent #31 and #32	

Bent Set	Work items completed in 2002	Comments
32	- Double banded weight - Double banded intermediate weight between Bent #32 and #33	
33	- Double banded weight - Shim south side between cross brace and support braces - Insert saddle supports. - Double banded intermediate weight between Bent #33 and #34	
34	- Double banded weight - Insert saddle supports - Double banded intermediate weight between Bent #34 and #35	
35	- Install new 2-piece stainless steel pipe clamp over pile. - Double banded weight - Insert saddle supports - Double banded intermediate weight between Bent #35 and #36	
36	- Double banded weight - Insert saddle supports - Double banded intermediate weight between Bent #36 and #37	
37	- No banding completed - Double banded intermediate weight between Bent #37 and #38 vertically and single banded horizontally	
38	- Place wood saddle support on west cross brace. - Remove east cross brace. Re-install level and bolt to pile. - Band existing weight to itself (horizontally) and circumferentially. Insert wedges to east cross brace to shim concrete - Cut off pile tips - Double banded intermediate weight between Bent #38 and #39	

Bent Set	Work items completed in 2002	Comments
39	- Replace cross braces - Place on proper side of pile - Saddles cut to suit as needed - Double banded weights - Cut tops off of piles - Double banded all intermediate weight between Bent #39 and #40	Next bent on 20 ft center is missing. Next bent is 40 feet from bent 39. Regular weights at 10 spacing are present.
40	- Remove and replace cross braces, - Insert new saddle supports - Install appropriate support braces - Cut tops off of piles - Replaced bolts, denso paste and taped, installed 3 alignment screws and 4 S.S. bands - flange #2	
41	- No weight - Remove and replace cross braces - Insert new saddle supports - Install appropriate support braces - Cut tops off of piles - Provide and install pile number tag - Double banded intermediate weight between Bent #41 and #42	
42	- Cut tops off of piles - Fabricate and install support braces - Insert new saddle supports - Provide and install pile number tag - Double banded weight - Install two articulated concrete mat between Bent #42 and #43	
43	- Cut tops off of piles - Provide and install pile number tag - Install two articulated concrete mat between Bent #43 and #44	Could not expose concrete weight to install bands. Therefore, installed concrete mat as ballast.
44	- Cut tops off of piles - Provide and install pile number tag	

Golder Associates Inc.

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Redmond, WA 98052-3333
Telephone (425) 883-0777
Fax (425) 882-5498

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OCT - 9 2002
Dept. of Public Works

Golder Associates

October 4, 2002

Our ref: 993-1668.210

City of Bellingham
Department of Public Works
210 Lottie Street
Bellingham, Washington 98225

Attention: Ms. Ravyn Whitewolf, P.E.

RE: INSPECTION AND MAINTENANCE RECOMMENDATIONS FOR THE LAKE WHATCOM WATER INTAKE PIPELINE STRUCTURE

Dear Ravyn:

Thank you for the opportunity to work on the Lake Whatcom Water Intake Pipeline project. The underwater location and historical significance of the City of Bellingham's water intake pipeline included both challenging and unique design and construction requirements. A summary report addressing recent construction work on the intake pipeline is provided including construction observation notes, photographs, diagrams, and an inspection video of the completed repairs.

We would like to provide additional comments on the long-term maintenance and inspection requirements for the water intake pipeline. The following summarizes recommended future inspections and maintenance issues for the intake structure. These recommendations are based on previous inspections and conditions observed during the recent construction repair work:

- Inspections along the entire length of the intake pipeline should be completed, at a minimum every other year. More frequent inspections should be completed in response to any potentially damaging events that may impact the pipeline. Examples include boat or barge collisions, anchor drag across the pipeline, or other construction or recreational impacts to the pipeline;

- A separate inspection along the length of the intake pipeline, in addition to the regularly scheduled inspections, should be completed immediately after the occurrence of any local seismic activity;

- Inspections along the intake pipeline should observe and track the rate of corrosion of the original steel hoops that hold the concrete sinker weights to the pipeline, and the steel hoops wrapped around the pipeline itself. Detailed inspection and repair recommendations for broken hoops should be made on a site-by-site basis if needed;

- Inspections along the intake pipeline should observe and track the potential rate of deterioration or any other damage noted on the concrete sinker weights installed along the pipeline. Detailed inspection and repair recommendations for broken sinkers should be made on a site-by-site basis if needed;

- Inspections should closely track the status of the concrete weights that were not double-banded during the recent repair activities. These locations are noted in Appendix B. It was not possible to secure the weights to the pipeline at these locations during the recent repair construction because of the lack of clearance between the sinker weight and the pipeline or corresponding wood bracing materials. The potential failure of the original steel hoops at these locations could result in a positive lift force to that section of the pipeline. Alterative methods for ensuring the integrity of ballast weights at these locations should be evaluated on a site-by-site basis as long-term monitoring identifies potential issues;

- Inspections along the intake pipeline should observe and track the three cables that cross over the top of the pipeline for movement. During the original inspection along the pipeline structure, Golder checked the cables using an electromagnetic utility sensor. Two of the cables were determined to be communications cables, one cable was determined to be an abandoned power cable;

- We would recommend the City acquire any available information pertaining to existing right-of-way agreements that may have been secured for any of the cables. Utility easements or other applicable solutions should be developed where no right-of-way agreements are existing and should address the ownership and potential future issues or uses with each cable;

- We recognize that the water intake pipeline is in remarkable condition considering its age and location, and assume that continued monitoring of the intake pipeline will identify potential future repair requirements. We also recognize that redundancy and flexibility in water system operation is advantageous. With this in mind, we recommend that alternatives be investigated for the replacement or modification of the intake pipeline structure to meet the City of Bellingham's long-term water supply needs. A feasibility study looking at alternate locations, construction and design feasibility, new technologies, and operation approaches for the existing pipeline and any new intake structures would provide the City with the information needed to address long-term planning of the City of Bellingham's water intake system.

We would like to thank you again for the opportunity to assist the City of Bellingham on this project. If we can provide additional information or answer any question please contact us at (425) 883-0777.

Sincerely,

GOLDER ASSOCIATES INC.

A. Kammereck

Andreas Q. Kammereck, P.E.
Senior Engineer

Michael L. Brown

Michael L. Brown, P.E.
Principal Engineer

AQK/MLB/lag
1007aqk1.doc

Enclosure: Summary Report of Construction Work for Underwater Repairs for the Lake Whatcom Water Intake Pipeline, October 2002.

Appendix F
Summary of Observations from June 2014 Lake Whatcom Wood Stave Pipeline Inspection

Summary of Observations from June 2014 Dive Inspection of Lake Whatcom Intake Pipeline

Bent (Note 1)	Pipe Between Bents (Note 1)	Fasteners	Broken Bands (Note 2)	Stainless Steel Bands (Note 3)	Notes
Crib		Corroded/Intact			Flats on hardware rounded due to corrosion; fastener still intact.
	Crib-1		(4)	1 Band Loose and Rusty	Four broken carbon steel bands on lake floor (previous observation) SST band approx. 6" inshore of crib is loose and rusty
1		Corroded/Intact		None around Weight at Bent	
	1-2		0		
2		Corroded/Intact		Tight around Weight at Bent	
	2-3		(2)	Tight around Weight andPipe	Two carbon steel bands missing (Year 2000 observation)
3		Corroded/Intact		Tight around Weight at Bent	
	3-4		0	Tight around Weight and Pipe	
4		Corroded/Intact		None around Weight at Bent	
	4-5		0	Tight around Weight and Pipe	
5		Corroded/Intact		Tight around Weight at Band	
	5-6		0	Tight around Weight and Pipe	
6		Corroded/Intact		None around Weight at Bent	
	6-7		(3)	Tight around Weight and Pipe	Three carbon steel bands missing (previous observation)
7		Corroded/Intact		None around Weight at Bent	
	7-8		0	Tight around Weight and Pipe	
8		Corroded/Intact		None around Weight at Bent	
	8-9		0	Tight around Weight and Pipe	
9		Corroded/Intact		None around Weight at Bent	
	9-10		0	Tight around Weight and Pipe	
10		Corroded/Intact		None around Weight at Bent	
	10-11		1	Tight around Weight and Pipe	One broken carbon steel band at bent
11		Corroded/Intact		Tight around Weight at Bent	
	11-12		0	Tight around Weight and Pipe	
12		Corroded/Intact		None around Weight at Bent	SST band 2' inshore of Bent 11 is rusty; monitor condition as part of future observations
	12-13		0	Tight around Weight and Pipe	
13		Corroded/Intact		None around Weight at Bent	
	13-14		0	Tight around Weight and Pipe	
14		Corroded/Intact		None around Weight at Bent	
	14-15		0	Tight around Weight and Pipe	
15		Corroded/Intact		Tight around Weight at Bent	Previously installed saddle supports are intact
	15-16		0	Tight around Weight and Pipe	SST band crosses carbon steel band, 6' inshore of Bent 15
16		Corroded/Intact	1	Tight around Weight at Bent	One broken carbon steel band; may be old band attached to concrete weight
	16-17		(1)	Tight around Weight and Pipe	Missing band not observed during this inspection
17		Corroded/Intact		Tight around Weight at Bent	
	17-18		0	Tight around Weight and Pipe	

Summary of Observations from June 2014 Dive Inspection of Lake Whatcom Intake Pipeline

Bent (Note 1)	Pipe Between Bents (Note 1)	Fasteners	Broken Bands (Note 2)	Stainless Steel Bands (Note 3)	Notes
18		Corroded/Intact		Tight around Weight at Bent	Cross beams that were previously reset are intact on the support braces; previously installed wood saddle also intact
	18-19		1	Tight around Weight and Pipe	Possible missing carbon steel band
19		Corroded/Intact		Tight around Weight at Bent	
	19-20		0	Tight around Weight and Pipe	Two concrete weights in this section; second weight is approx 8' from Bent 19
20		Corroded/Intact		Tight around Weight at Bent	
	20-21		(3)	Tight around Weight and Pipe	Plugs in three previous core holes intact, tight, and in good condition Remove new pipe core and install plug Pressure wash carbon steel band; nut and threads in fair condition but bracket corroded
21		Corroded/Intact		None around Weight at Bent	
	21-22		0	Tight around Weight and Pipe	2" armored cable crossing; see Note 4 1/2-inch lead sheath cable under pipe; see Note 5
22		Corroded/Intact	0	Tight around Weight at Bent	New notch cut into wood supports to allow future alignment check.
	22-23		0	Tight around Weight and Pipe	2" armored cable crossing; see Note 6
23		Corroded/Intact		Tight around Weight at Bent	
	23-24		0	Tight around Weight and Pipe	
24		Corroded/Intact		Tight around Weight at Bent	Previously cut notch in cross beam aligns with face of saddle; no movement
	24-25		0	Tight around Weight and Pipe	
25		Corroded/Intact		Slightly Loose around Weight	
	25-26		0	Tight around Weight and Pipe	3.5" armored cable crossing; see Note 7
26		Corroded/Intact		Tight around Weight at Bent	Concrete weight is not touching cross beam; installed wood saddle is bearing the pipeline load; pipe tight against north pile; alignment mark not located
	26-27		0	Tight around Weight and Pipe	
27		Below silt		Tight around Weight at Bent	South pile out of alignment
	27-28		1	Tight around Weight and Pipe	Flange 9' inshore of Bent 27; See Note 8 Second offshore band broken; break at bottom of pipe
28		Corroded/Intact		Tight around Pipe at Bent	20" diameter log laying against bent Pipe is tight against north pile Concrete weight not touching cross beam
	28-29		0	Tight around Weight and Pipe	Concrete weight mat 4' inshore from Bent 28; good condition
29		Corroded/Intact			No concrete weight at this bent
	29-30		0	Tight around Weight and Pipe	
30		Corroded/Intact		Slightly Loose around Weight	Two core samples previously removed; hole plugs intact and tight
	30-31		0	Tight around Weight and Pipe	
31		Good Condition		Tight around Weight at Bent	

Summary of Observations from June 2014 Dive Inspection of Lake Whatcom Intake Pipeline

Bent (Note 1)	Pipe Between Bents (Note 1)	Fasteners	Broken Bands (Note 2)	Stainless Steel Bands (Note 3)	Notes
	31-32		0	Tight around Weight and Pipe	
32		Good Condition		Tight around Weight and Pipe	
	32-33		1		Broken carbon steel band 6 ft inshore of Bent 32; recovered
33		Good Condition		Tight around Weight at Bent	Previouly installed shims intact between between cross brace and cross beams Previosly installed saddle supports intact
	33-34		0	Tight around Weight and Pipe	
34		Good Condition		Tight around Weight at Bent	Previously installed saddle supports intact
	34-35		0	Tight around Weight and Pipe	
35		Good Condition		Three Bands Two Tight, One Loose	2-piece previously installed stainless steel pipe clamps around pile in very good condition
	35-36		0	Tight around Weight and Pipe	
36		Good Condition		Tight around Weight at Bent	
	36-37		0	Tight around Weight at Bent	
37		Good Condition		None around Weight at Bent	Pipe is tight against the south pile
	37-38		1	Tight around Weight and Pipe	Concrete weight is broken; 3rd SST band placed around horizontal axis of weight Carbon steel band missing 5' inshore from bent 38; broken piece recovered
38		Good Condition		Tight around Weight at Bent	
	38-39		0	Tight around Weight and Pipe	
39		Good Condition		Three Bands; Two Tight, One Loose	Flange 10 feet inshore of bent 39; see Note 9
	39-40		1	Tight around Weight and Pipe	Broken carbon steel band, first inshore from Bent 39; recovered by divers
40		Good Condition		Tight around Weight at Bent	Next bent assembly on 20 foot center missing; Bent 41 is 40 feet inshore from Bent 40 Two plugs in pipe observed, See Note 10 Weights at 10 foot centers; one concrete weight is 4 feet from Bent 40
	40-41		0	Tight around Weight and Pipe	Missing carbon steel band; no sign of missing band on lake bottom
41		Good Condition			No concrete weight at Bent 41 Weights at 10 foot centers between bents Lake bottom rises significantly, approximately 30 feet to the north
	41-42	Good Condition	1	Tight around Weight and Pipe	Top half of broken carbon steel band sitting on top of pipe; bottom section not located
42				Not Observed	Pipe support not observable; silted over
	42-43		0		Two concrete weight mats between Bents 42 and 43 are intact and in good condition

Summary of Observations from June 2014 Dive Inspection of Lake Whatcom Intake Pipeline

Bent (Note 1)	Pipe Between Bents (Note 1)	Fasteners	Broken Bands (Note 2)	Stainless Steel Bands (Note 3)	Notes
43		Not Observed		Not Observed	Concrete weight, cross beams, and support braces not evident (assumed buried in silt) Concrete mats, one 6' inshore of bent, other 4' inshore of first mat-both in good condition
	43-44		0	Not Observed	Core No. 2 removed 6' inshore of Bent 43; installed plug and coated with underwater curing epoxy Two concrete weight mats between Bents 43 and 44 are intact and in good condition
44		Not Observed			Small gap at ends of stave noted near pipe crown, approximately 1/2" wide

Notes

1 Wood in good condition unless otherwise noted; some surface softness (1/8-inch deep or less), but otherwise good condition.

2 All carbon steel bands were covered with heavy corrosion product indicating advanced stages of corrosion; "0" indicates that no breaks were observed on the carbon steel bands. Numbers in parantheses indicate number of broken carbon steel bands reported in 2000 Golder and Associates inspeciton report.

3 All concrete ballast weights are held in place by two stainless steel bands, unless otherwise noted. SST bands are also in place around pipe barrel between bents. The note "Tight around Weight and Pipe" indicates that SST bands around pipe and around concrete weights between bents are all tight.

4 2" diameter armored cable crossing top of pipeline just offshore of Bent 22. Cable is tight against pipe and centered on plastic wear pad.

5 1/2" diameter lead sheathed cable under pipeline; no apparent change in condition since previous survey.

6 2" diameter armored cable crossing pipeline offshore of Bent 23. Cable is very tight against pipe. Meets lake bed approximately 30 feet from pipeline contact point. Cable had slipped off wear pad; cable was 'pried' back onto pad with a small bar. Wear pad between cable and pipe intact and shows little to no abrasion loss.

7 3.5" diameter armoured cable crossing the pipeline offshore of bent 26. Cable is sitting on wear pad and wear pad shows little or no sign of wear.

8 Flange is 9' inshore of Bent 27; wax tape (Denso) is intact and in good condition. Metals under wax tape appear to be in good condition. The three SST alignment screws are intact and in alignment.

9 Flange is 12' inshore of Bent 40; wax tape (Denso) is intact and in good condition. Metals under wax tape appear to be in good condition. The three SST alignment screws are intact. and in alignment.

10 Two plugs observed where previous core samples appear to have been taken. One plug is 2' offshore of Bent 40, south side of pipe. Second plug is 16" inshore of Bent 40 at the 2 o'clock position (looking inshore). Plugs in both positions are intact, tight and in good condition.

Appendix G
Wood Core Sample Condition Testing from January 30, 2000

REPORT ON THE CONDITION AND SERVICEABILITY OF THE WOOD PLUGS FROM THE SUBMERGED FRESH WATER PIPELINE BELONGING TO THE CITY OF BELLINGHAM.

Robert L. Edmonds
College of Forest Resources
University of Washington
Box 352100
University of Washington
Seattle, WA 98195

January 30, 2000

Two basic tests were conducted on the four 1.75" diameter plugs taken from the City of Bellingham pipeline which had been underwater since about 1930: (1) culturing fungi from the softened outer layers of the wood, and (2) compression tests perpendicular to the grain on the central portion of the plugs. The specimens had to be squared off to conduct the compression tests. The wood was identified as western redcedar based on odor and wood properties.

1. Fungi Cultured from Wood

Table 1 shows that a number of mold fungi, particularly *Trichoderma* spp. were cultured from all the samples, as well as bacteria and yeasts. These organisms grow commonly on wood and cause little degradation. However, there was a basidiomycete decay fungus isolated from specimen 40N indicating that some decay is present. We do not know what species of decay fungi it is. Basidiomycetes may have been present in the other samples, but if so they were outgrown by the molds. Specimen 40N also had the lowest compressive strength as can be seen in Table 2.

Table 1. Fungi cultured from pipeline samples

Each sample was cultured on 3 media: malt extract agar (MEA), potato-dextrose agar (PDA), and selective medium for basidiomycetes (SM).

Sample	Fungi
20S	*Trichoderma sp.*, *Aspergillus sp.*, *Alternaria*, bacteria, white mold (unidentified)
20N	*Trichoderma sp.*, a zygomycete
30N	*Trichoderma sp.*, *Aspergillus sp.*, *Mucor*
40N	*Trichoderma sp.*, *Aspergillus sp.*, *Penicillium sp.*, bacteria, yeasts, a basidiomycete decay fungus

2. Compressive strength perpendicular to the grain

These tests were conducted on an Instron wood testing machine in the Department of Mechanical Engineering at the University of Washington. Table 2 shows the compressive strength of the four specimens. The test data sheets and graphs for each specimen are also attached.

Table 2. Stress test data on the four wood samples taken from the pipeline

Sample	Compressive strength perpendicular to grain at 2.5 mm deflection		Ultimate stress		Modulus of Elasticity	
	psi	Mpa	psi	Mpa	psi	Mpa
20S	653	4.5	1559	10.75	34,774	239.82
20N	551	3.8	1561	10.76	7,985	55.97
30N	725	5.0	1591	10.97	21,681	140.93
40N	319	2.2	1546	10.66	8,593	59.26

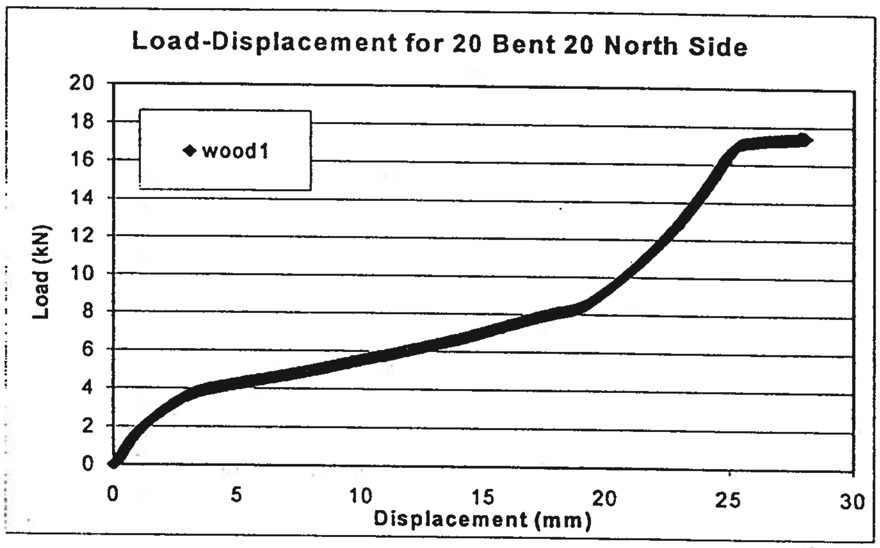
According to the Forest Products Laboratory, Wood Engineering Handbook, Second Edition, Prentice Hall, New Jersey, pages 4-12, 1990, typical values for western redcedar for compressive strength perpendicular to the grain at 0.1 inch (2.5 mm) deflection are 460 psi for dry wood and 240 psi for wet wood. Thus all the specimens still appear to have good compressive strength, and all the values reported in Table 2 are above the values for sound wood in the Wood Engineering Handbook. However, samples 20N and 40N have lower values than 20S and 30N. The modulus of elasticity is also much lower for 20N and 40N. The ultimate strength of each of the specimens is similar, however.

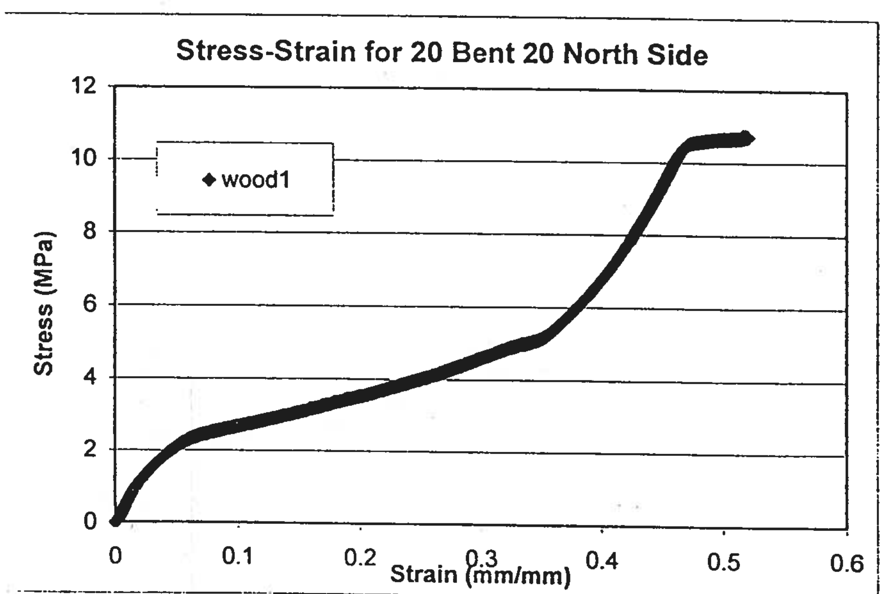
Although the surface of each specimen was softened and eroded the central portion of each core still appears to be serviceable and had good strength. It would appear that as long as the pipeline remains wet it could still be used. There is some concern about the presence of the basidiomycete decay fungus on specimen 40N, especially since this sample also had the lowest strength. These fungi, however, grow slowly under submerged conditions and would take a long time to grow into the central portion of the wood. If it is decided to keep the wood in service periodic testing might be conducted to monitor the state of the wood.

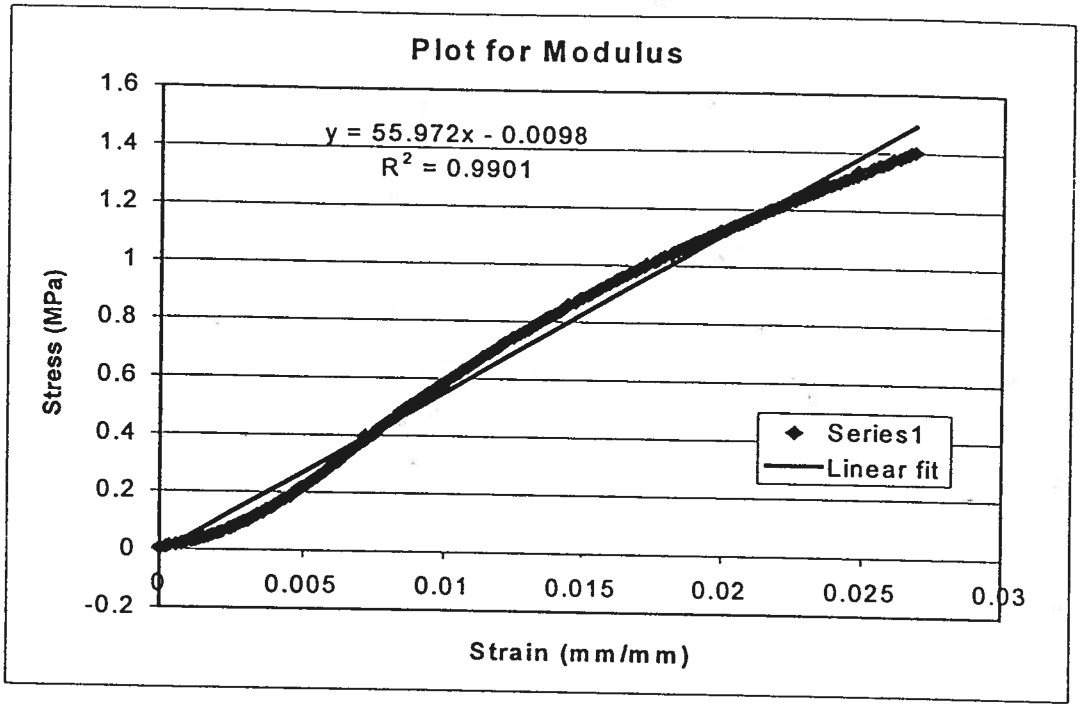
SUMMARY OF TEST RESULTS FOR WOOD SAMPLES

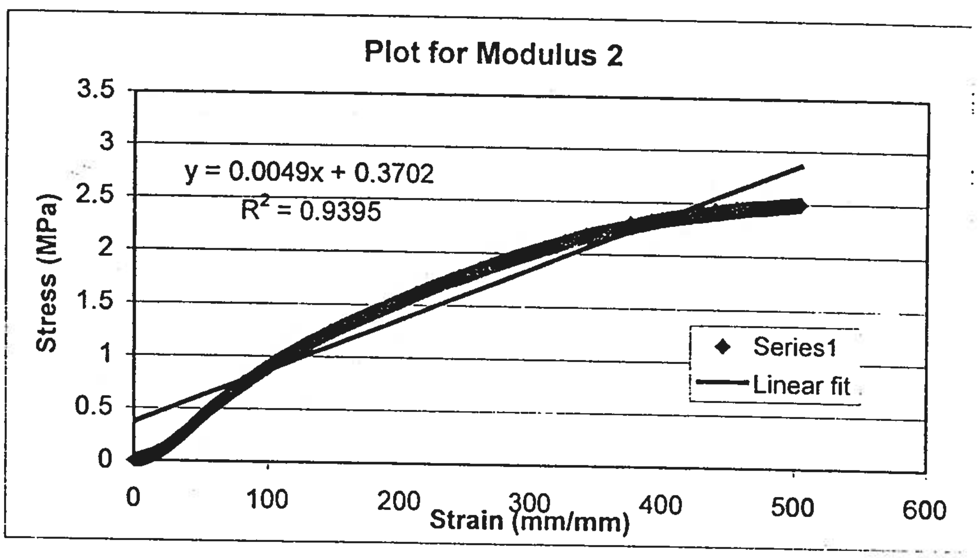
Specimen 1 - 20 Bent 20 North Side

Initial Diameter: 45.5mm Initial Area: 0.001625m^2
Initial Length: 54mm
Final Length: 42mm
Maximal Load: 17.48931 kN
Maximal Displacement: 28.06183mm
Ultimate Stress = Maximal Load/ Initial Area = 10.763MPa
Elastic Modulus (99% correlation): 55.972MPa



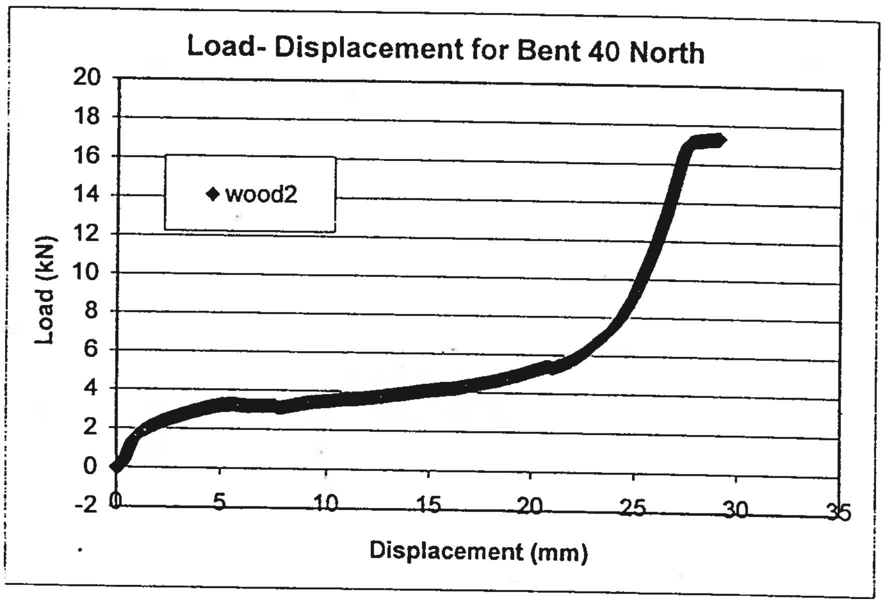


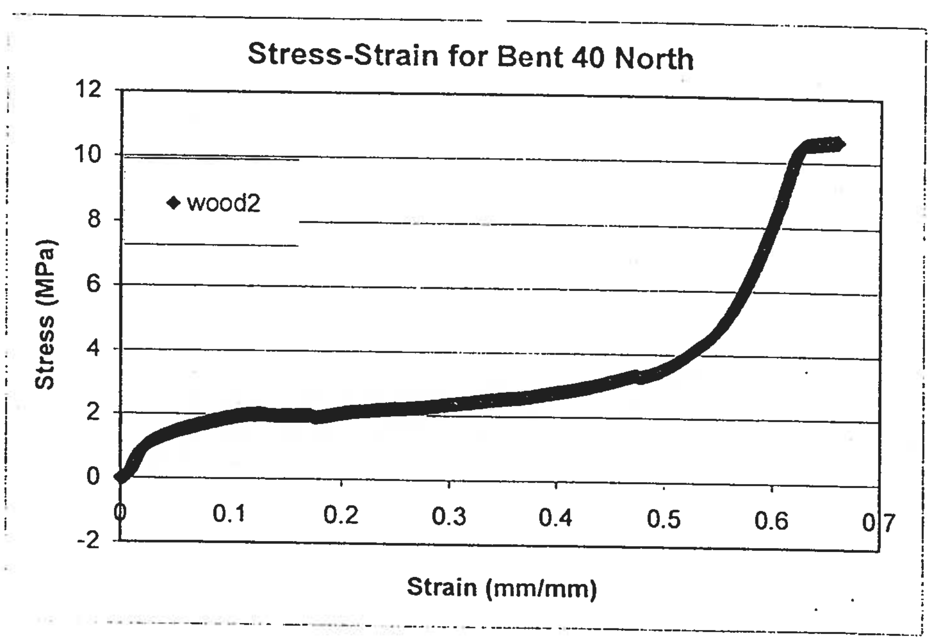

Plot for Modulus
y = 55.972x - 0.0098
R^2 = 0.9901
Stress (MPa)
Strain (mm/mm)
Series1
Linear fit
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
0.005
0.01
0.015
0.02
0.025
0.03

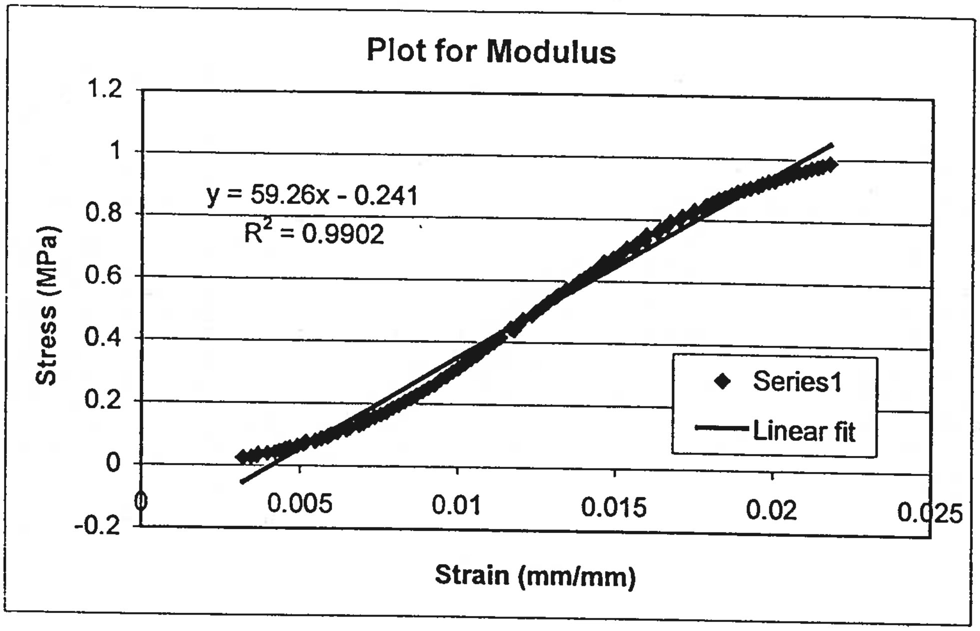

Plot for Modulus 2
y = 0.0049x + 0.3702
R^2 = 0.9395
Stress (MPa)
Strain (mm/mm)
Series1
Linear fit
3.5
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600

Specimen 2 - Bent 40 North

Initial Diameter: 45.5mm   Initial Area: 0.001625m^2
Initial Length: 44mm
Final Length: 33mm
Maximal Load: 17.32922 kN
Maximal Displacement: 29.06944mm
Ultimate Stress = Maximal Load/ Initial Area = 10.664MPa
Elastic Modulus (99% correlation): 59.26 MPa



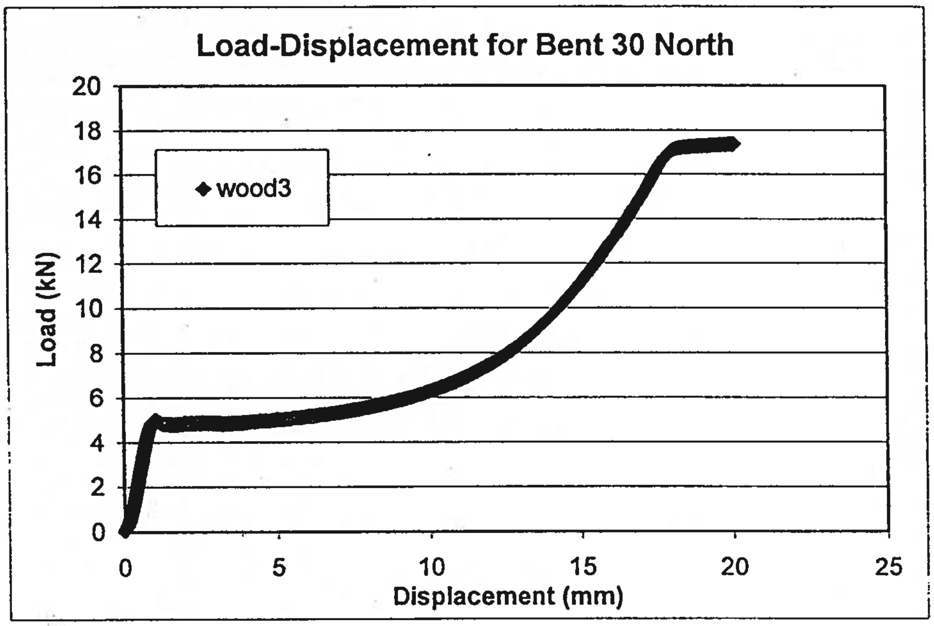


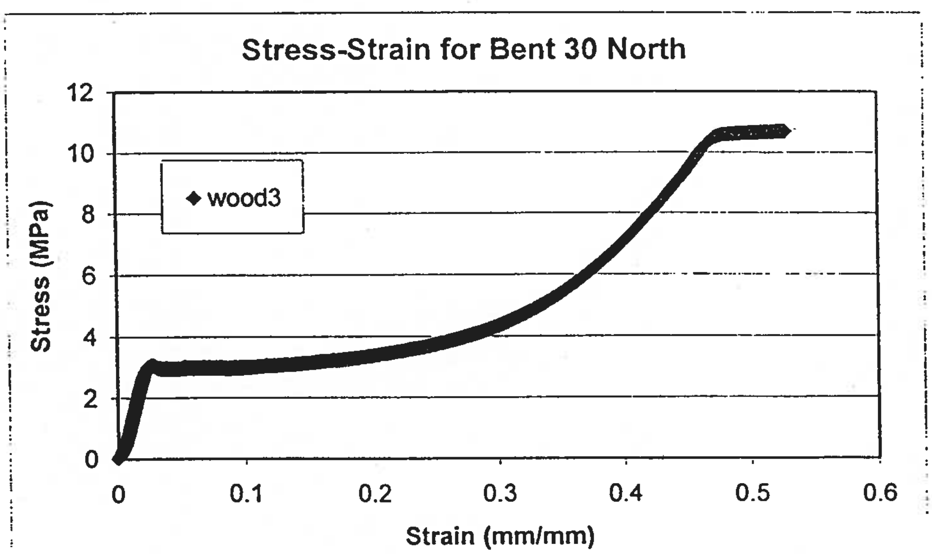


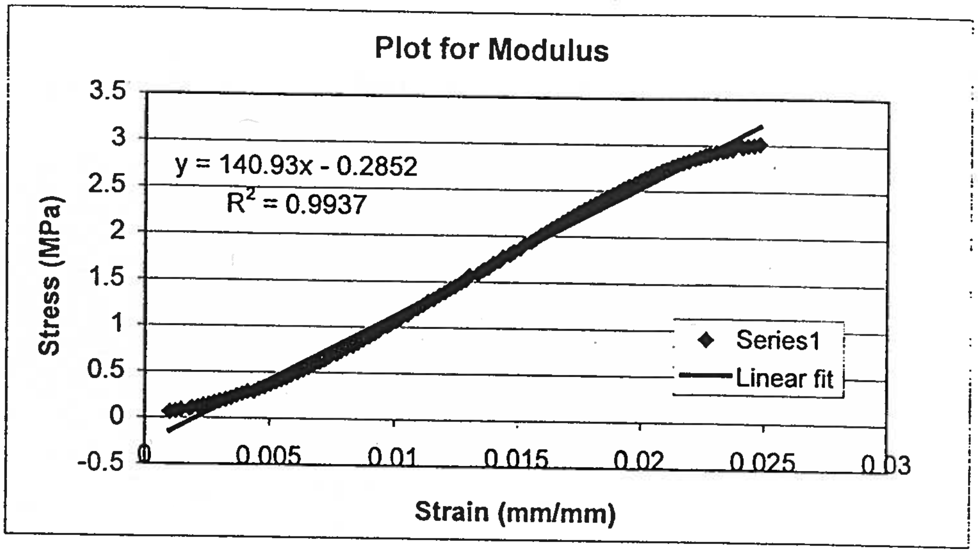
Plot for Modulus
y = 59.26x - 0.241
R2 = 0.9902
Stress (MPa)
Strain (mm/mm)
Series1
Linear fit
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
0.005
0.01
0.015
0.02
0.025

Specimen 3 - Bent 30 North

Initial Diameter: 45.5mm Initial Area: 0.001625m^2
Initial Length: 38mm
Final Length: 31mm
Maximal Load: 17.38258 kN
Maximal Displacement: 20.06452mm
Ultimate Stress = Maximal Load/ Initial Area = 10.97MPa
Elastic Modulus (99% correlation): 140.93MPa

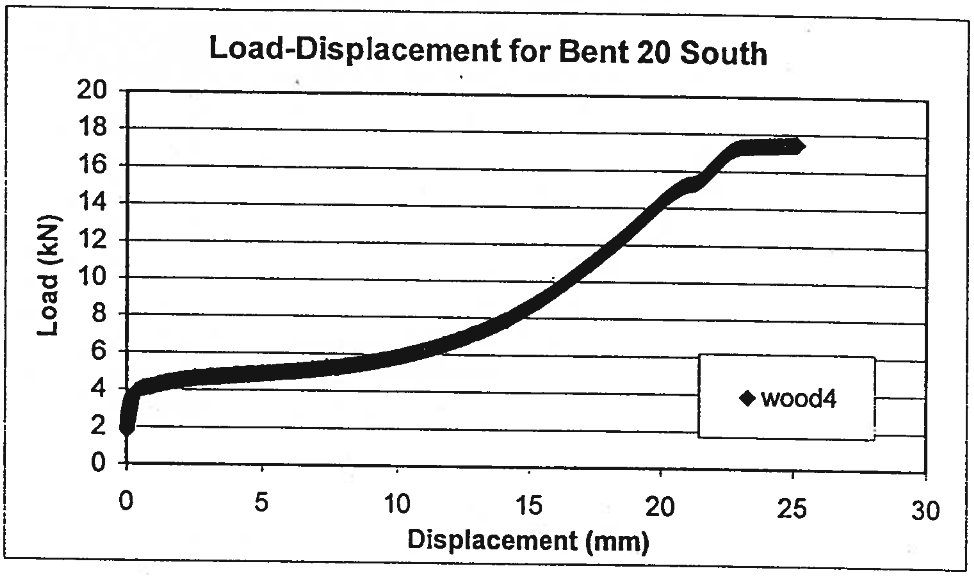


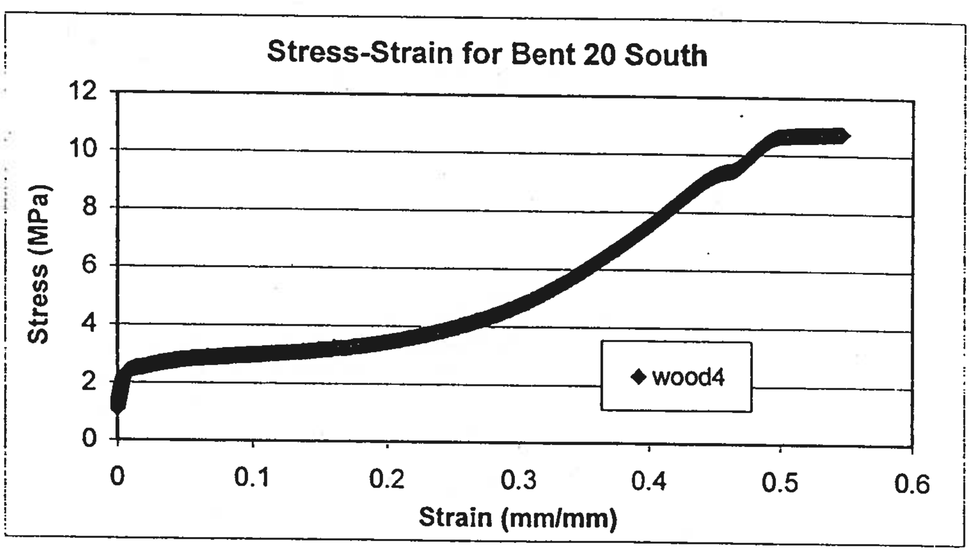


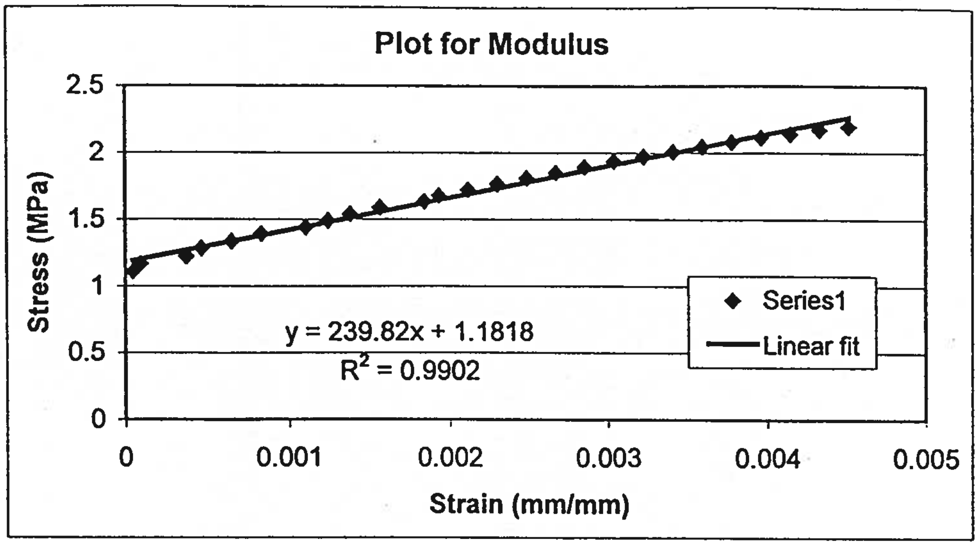

Plot for Modulus
y = 140.93x - 0.2852
R2 = 0.9937
Stress (MPa)
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
0
0.005
0.01
0.015
0.02
0.025
0.03
Strain (mm/mm)
Series1
Linear fit

Specimen 4 - Bent 20 South

Initial Diameter: 45.5mm Initial Area: $0.001625m^2$
Initial Length: 46mm
Final Length: 37mm
Maximal Load: 17.47013 kN
Maximal Displacement: 25.1332mm
Ultimate Stress = Maximal Load/ Initial Area = 10.75MPa
Elastic Modulus (99% correlation): 239.82 MPa






Plot for Modulus
2.5
2
1.5
1
0.5
0
Stress (MPa)
y = 239.82x + 1.1818
R2 = 0.9902
Series1
Linear fit
0
0.001
0.002
0.003
0.004
0.005
Strain (mm/mm)

Appendix F

APPENDIX F

MATERIAL TESTING PHOTOGRAPHS

Figure F-1. Core Bent 30 North — as received

Figure F-2. Inside pipe surface of core bent 30 north

PHOTOGRAPHS
CITY OF BELLINGHAM

PROJECT NO. 993 1668.110 DRAWING NO. 91673 DATE 2/21/00 DRAWN BY TK

Golder Associates

Figure F-3. Outside pipe surface of core bent 30 north

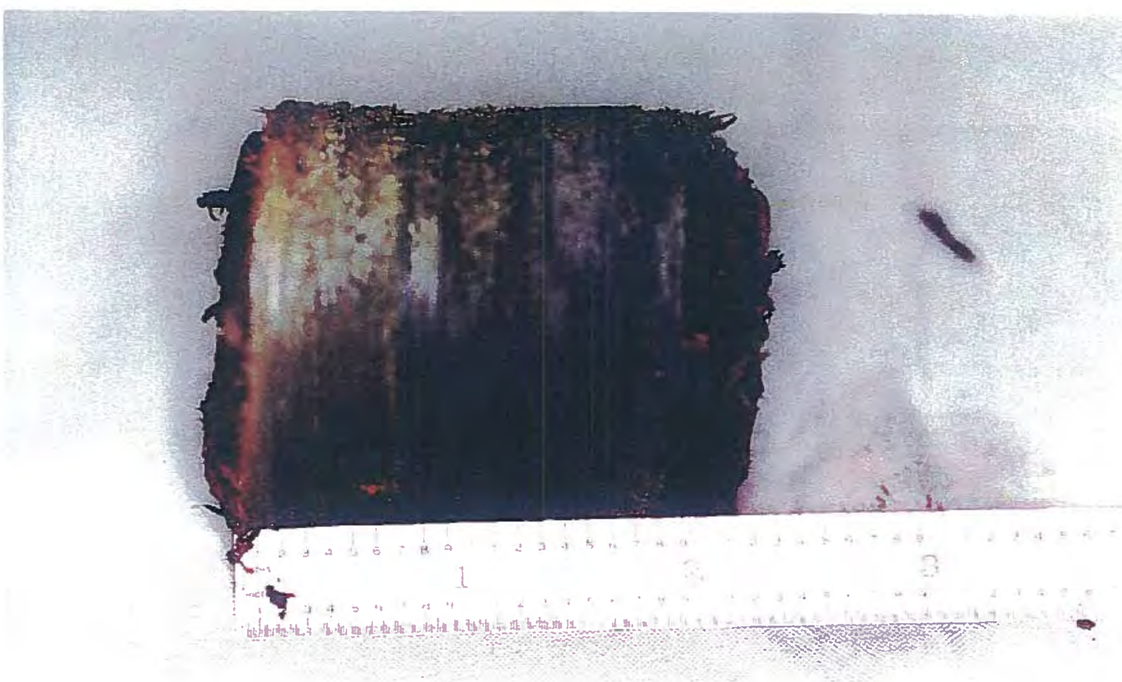


Figure F-4. View along depth of core bent 30 north

PHOTOGRAPHS
CITY OF BELLINGHAM

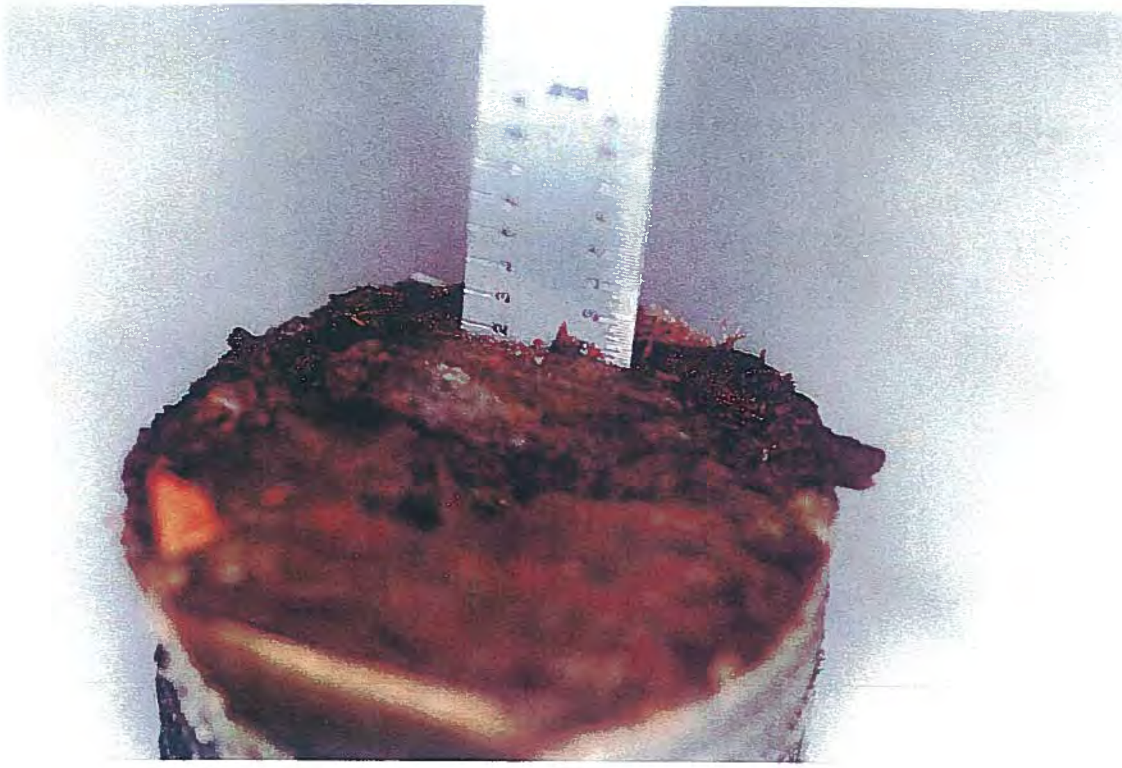


Figure F-5. Measurement of surface penetration with metal scale, 0.2" was maximum penetration measured, on pipe inside surface core samples with scale parallel to the wood grain.

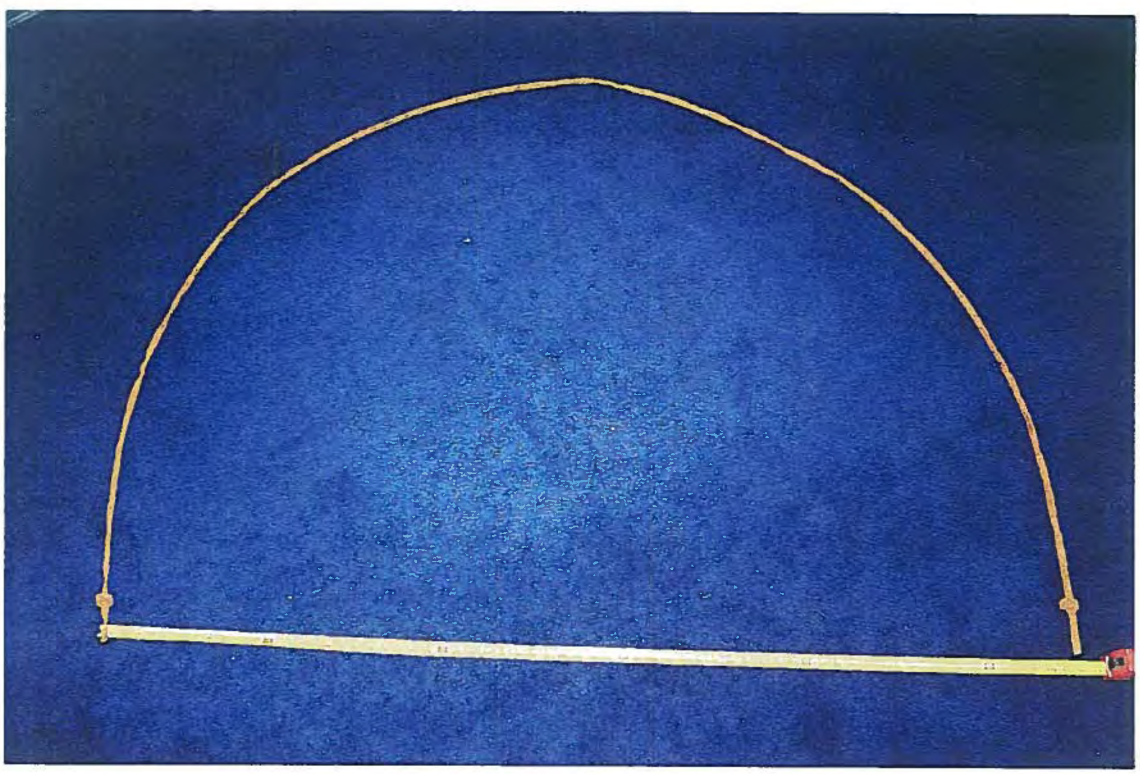


Figure F-6. As-received 180-degree section of pipe stave support hoop 1.

PHOTOGRAPHS
CITY OF BELLINGHAM

Appendix H
Compressive Strength Testing of Wood Stave Core Samples from July 20, 2014

Compression Stress Testing of Two Wood Stave Pipe Core Specimens

by:

Mark E. Tuttle, Professor
MS 2600
Dept Mechanical Engineering
University of Washington
Seattle, WA 98195-2600

submitted to:

Ms. Candice Au-Yeung
Staff Engineering
CH@M Hill
110 112th Ave NE, Ste. 500
Bellevue, WA 98004

July 20, 2014

Summary

Two wood stave pipe core specimens that had been extracted from an underwater pipeline owned by the City of Bellingham were delivered to the University of Washington campus on Monday 14 July 2014 for the purpose of compression stress testing. The two specimens will be referred to as samples 1 and 2 throughout this report.

Both samples were delivered to the UW immersed in water in a plastic bag. The overall shape of the samples as delivered was roughly tubular. Since flat and parallel ends were required to perform the compression tests, the ends of both samples were squared off using a lathe. A photo of the samples after having been squared off is shown in Figure 1.

Electronic calipers were used to measure various dimensions at four randomly selected locations on each sample. The average measured dimension was then used during subsequent calculations. These measurements and averages are summarized in Table 1.

The samples were compression tested using an Instron Model 5585H Universal Test Frame. One tests using each of the two specimens was performed. During a test the sample was placed between two platens, and the cross-head of the test frame was then positioned until initial "grazing" contact was made between the platen and the sample end. The test was then initiated by moving the cross-head downward at a constant rate of 0.050 in/min, resulting in a compressive load being applied and a corresponding shortening of the sample. The test was continued until a cross-head deflection of 1.25 inches had been imposed, i.e., until the length of the sample had been decreased by 1.25 inches.

The load-deflection curves measured for both samples are shown in Figure 2. The overall response of the two samples is considered to be remarkable consistent. Physical properties inferred from these measurements are summarized in Table 2. Some details of the data reduction process for each specimen are provided in the following subsections.

Table 1: Sample Dimensions Following Facing in a Lathe

	Outer Diameter (in)					Wall Thickness (in)					Height (in)				
Sample 1	1	2	3	4	Ave	1	2	3	4	Ave	1	2	3	4	Ave
	1.756	1.754	1.784	1.770	1.766	.656	.604	.667	.734	.665	1.856	1.848	1.840	1.854	1.850
Sample 2	1	2	3	4	Ave	1	2	3	4	Ave	1	2	3	4	Ave
	1.716	1.714	1.709	1.719	1.714	.672	.682	.678	.640	.668	1.800	1.822	1.823	1.823	1.817

Figure 1: Samples 1 and 2 (left and right, respectively) following facing in a lathe

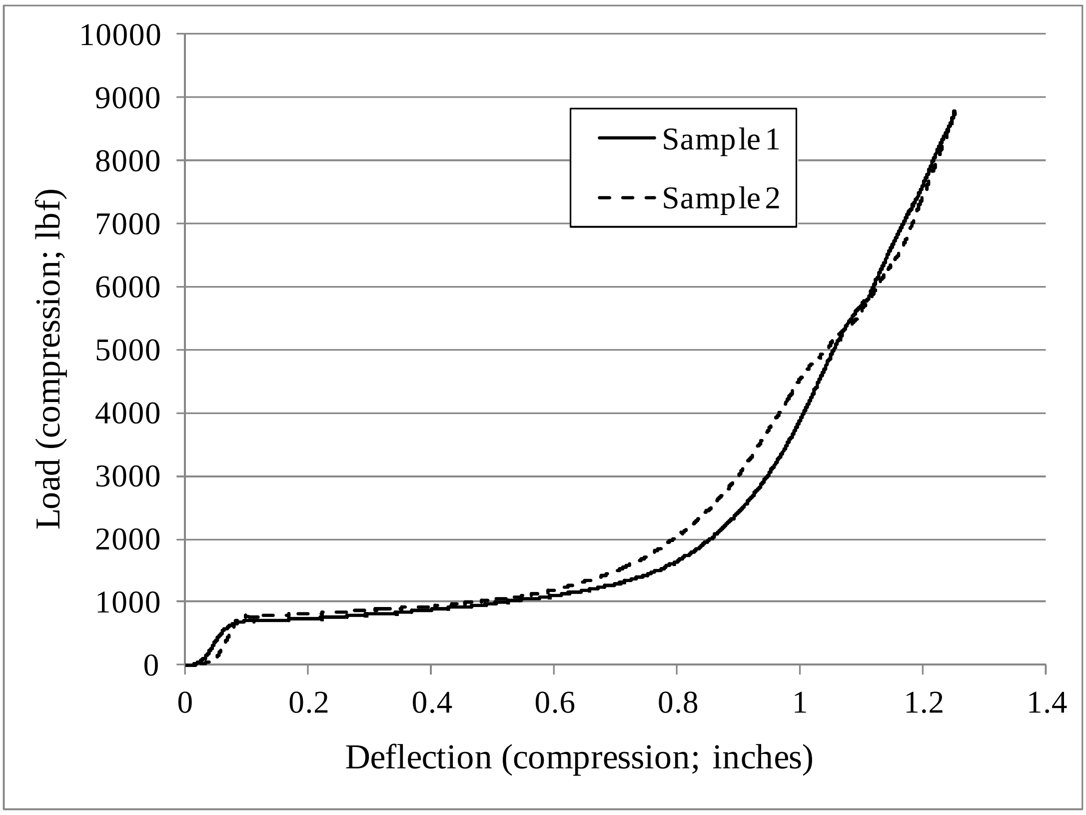


Figure 2: Load-deflection curves for samples 1 and 2

Table 2: Summary of Compressive Properties of Two Wood Pipe Core Samples

	Initial Elastic Modulus		Compressive strength perpendicular to grain at 0.1 in (2.5mm) deflection		Compressive strength perpendicular to grain at 1.25 in (32 mm) deflection	
	Msi	MPa	psi	MPa	psi	MPa
Sample 1	11.9 ksi	82.0	306	2.11	3815	26.3
Sample 2	15.2 ksi	105	366	2.52	3979	27.4

Test of Sample 1

Photos of Sample 1 (a) prior to initiation of the test and (b) at a cross-head deflection of about 0.20 inches are shown in Figures 3 and 4, respectively. Substantial amounts of water were forced from the specimen during the test, as is evident in Figure 4.

The cross-sectional area of sample 1 was nominally 2.30 in^2 and the initial (unloaded) length was nominally 1.85 in. These dimensions were used to calculate the engineering stress-strain curve for sample 1 shown in Figure 5. As indicated, a compressive axial strain of 0.054 in/in (corresponding to a cross-head deflection of 0.1 in) resulted in a compressive stress of 306 psi (2.11 MPa). Similarly, a compressive axial strain of 0.676 in/in (corresponding to a cross-head deflection of 1.25 in) resulted in a compressive stress of 3815 psi (26.3 MPa). These values appear in Table 2.

The stress-strain response at relatively low strain levels is shown in Figure 6. As indicated, the slope of the stress-strain curve at low strain levels was used to infer an initial Young's modulus of 11.9 ksi (82.0 MPa).

It should be noted that a pronounced time-dependent behavior was observed during and after the test. For example, as previously described a maximum cross-head deflection of 1.25 inches was imposed during the test. Since the initial height of sample 1 was 1.85 in, during the test the length of sample 1 was reduced to (1.85 in – 1.25 in) = 0.60 in. Nevertheless, as the specimen was unloaded the specimen regained much of its original length. Immediately upon unloading the specimen length was measured as 1.47 in, but after about 10 minutes the unloaded specimen length had increased to 1.59 in. A more rigorous characterization of the time-dependent response was beyond the scope of this study.

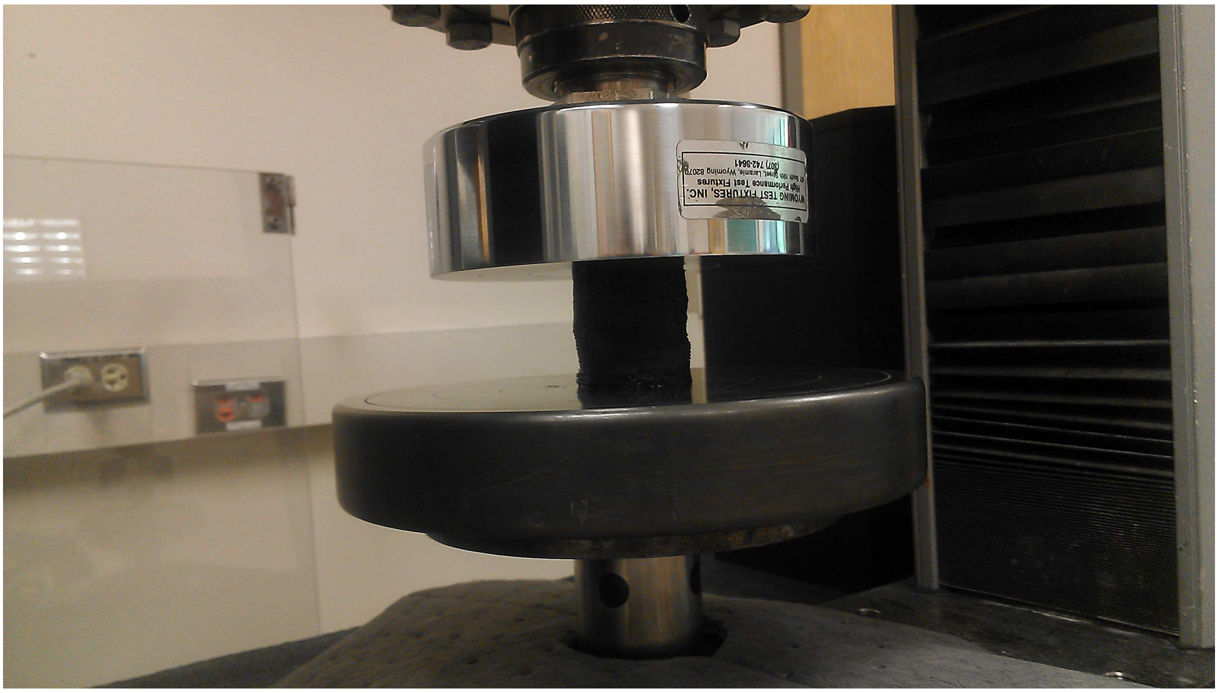


Figure 3: Sample 1 prior to initiation of the test

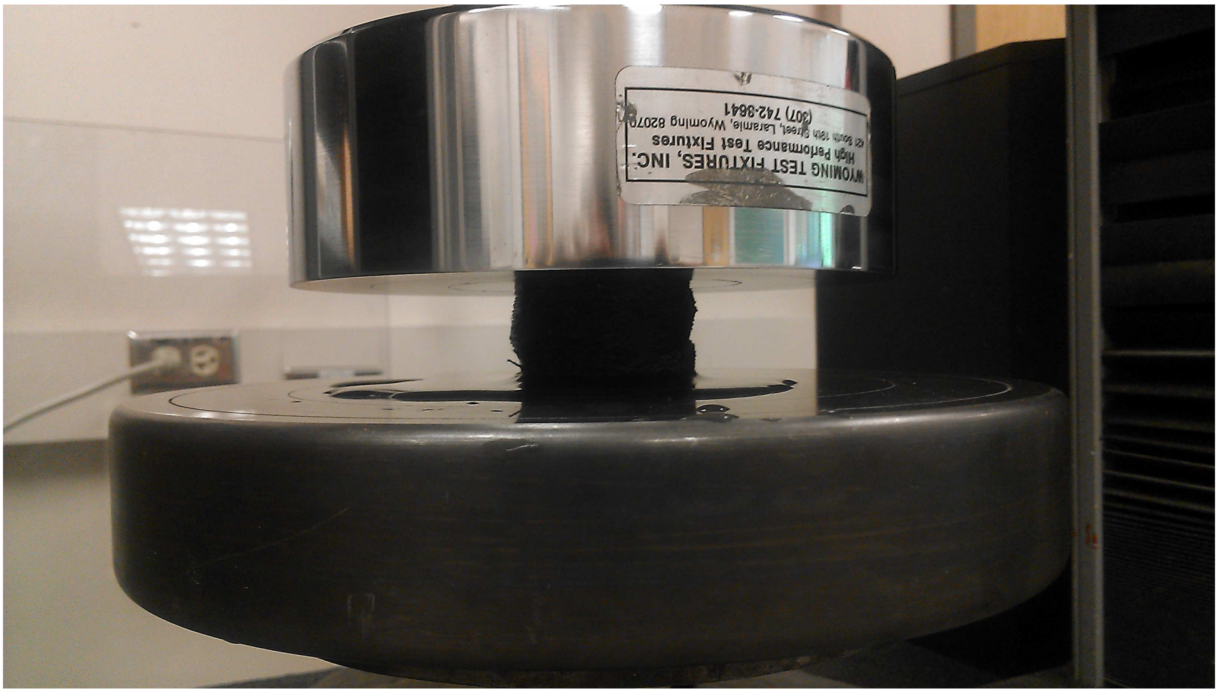


Figure 4: Sample 1 subjected to a nominal deflection of about 0.20 inches. Note the water present on the lower platen, which was forced out of the specimen during the test.

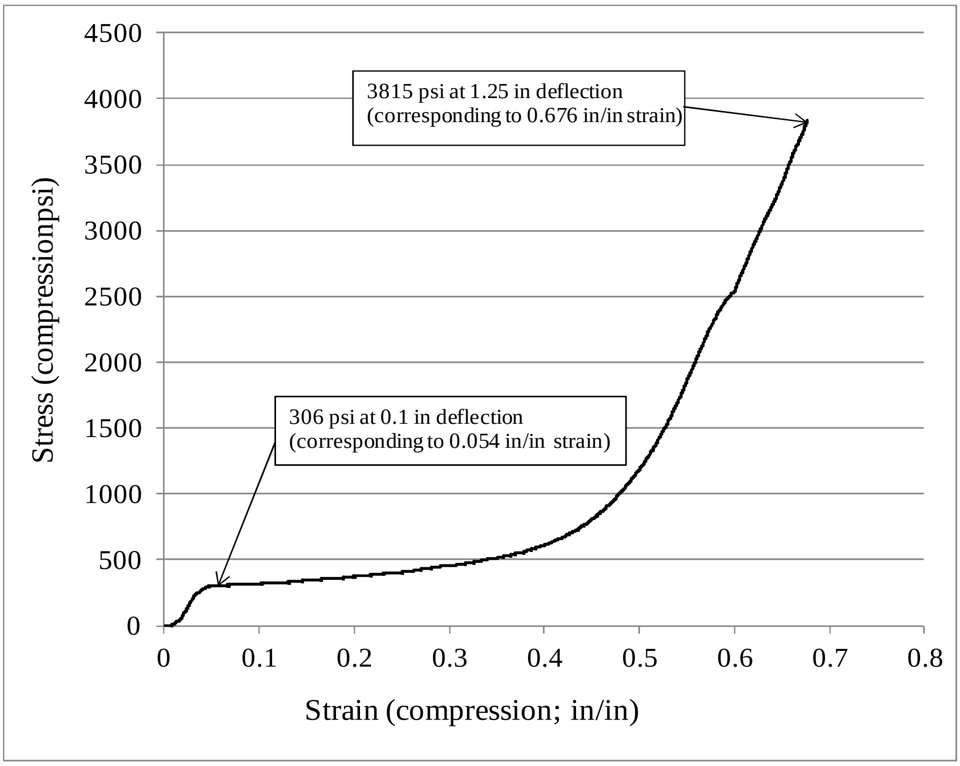


Figure 5: Stress-strain curve of Sample 1

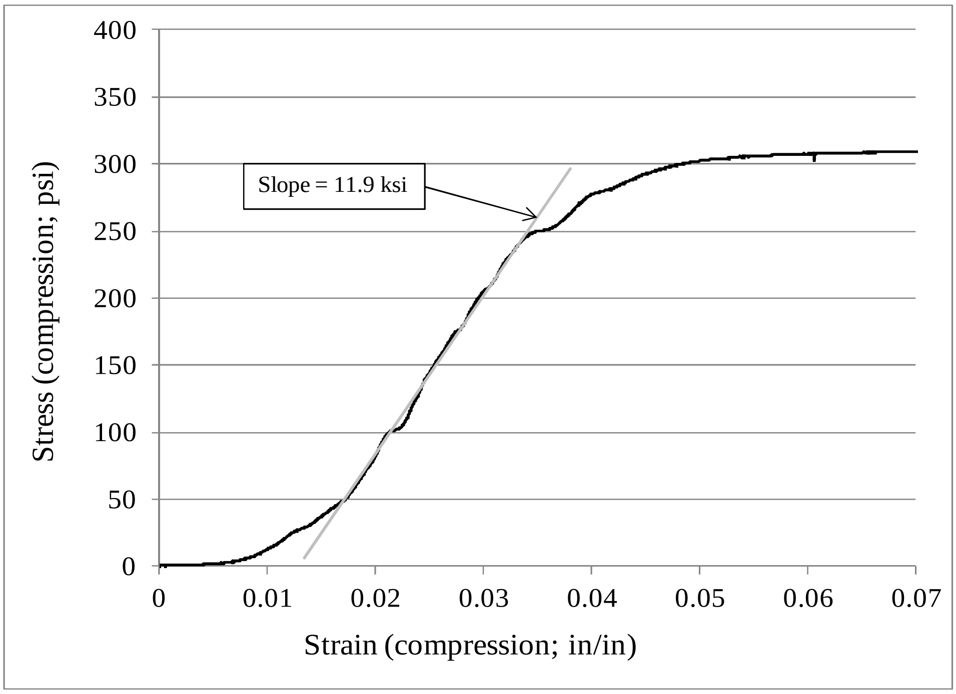


Figure 6: Stress-strain response of sample 1 at relatively low strain levels, used to calculate Young's modulus (E = 11.9 ksi)

Test of Sample 2

Photos of Sample 2 (a) prior to initiation of the test and (b) at a cross-head deflection of about 0.30 inches are shown in Figures 7 and 8, respectively. As before, substantial amounts of water were forced from the specimen during the test, as is evident in Figure 8.

The cross-section area of sample 2 was nominally 2.20 in^2 and the initial (unloaded) length was nominally 1.82 in. These dimensions were used to calculate the engineering stress-strain curve for sample 2 shown in Figure 9. As indicated, a compressive axial strain of 0.055 in/in (corresponding to a cross-head deflection of 0.1 in) resulted in a compressive stress of 366 psi (2.52 MPa). Similarly, a compressive axial strain of 0.69 in/in (corresponding to a cross-head deflection of 1.25 in) resulted in a compressive stress of 3979 psi (27.4 MPa). These values appear in Table 2.

The stress-strain response at relatively low strain levels is shown in Figure 10. As indicated, the slope of the stress-strain curve at low strain levels was used to infer an initial Young's modulus of 15.2 ksi (105 MPa).

It should be noted that a pronounced time-dependent behavior was observed during and after the test. For example, as previously described a maximum cross-head deflection of 1.25 inches was imposed during the test. Since the initial height of sample 2 was 1.82 in, during the test the length of sample 2 was reduced to (1.82 in – 1.25 in) = 0.57 in. Nevertheless, as the specimen was unloaded the specimen regained much of its original length. Immediately upon unloading the specimen length was measured as 1.47 in, but after about 10 minutes the specimen length had increased to 1.55 in. A more rigorous characterization of the time-dependent response was beyond the scope of this study.

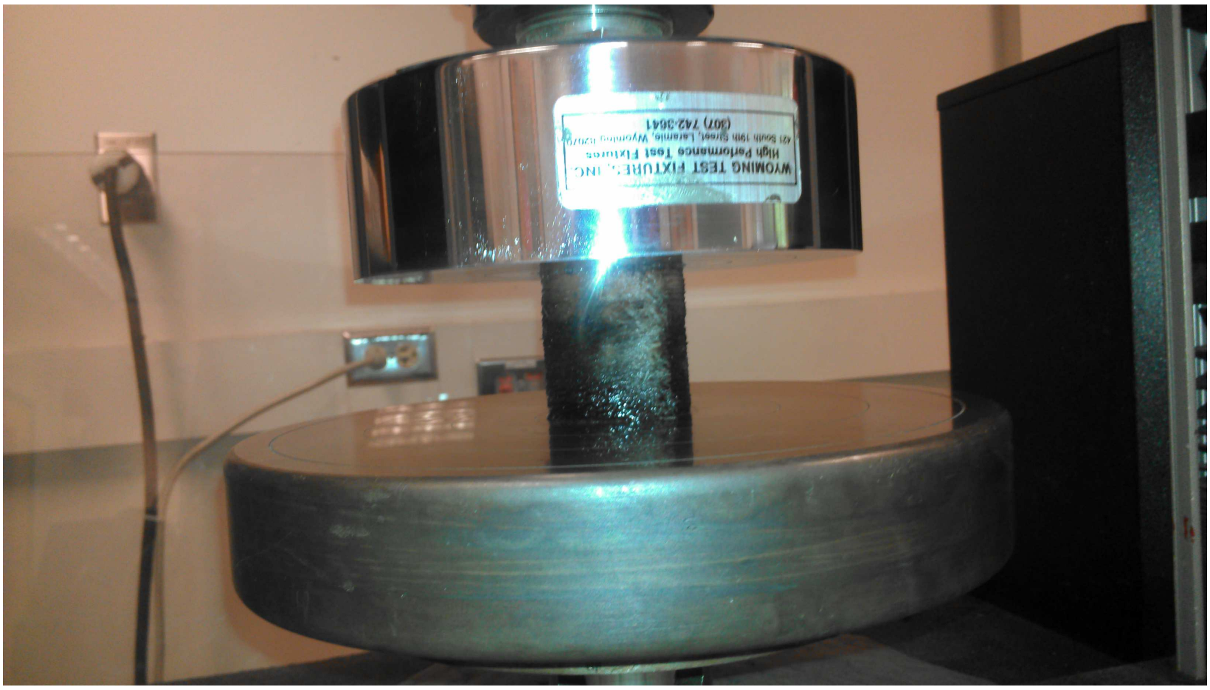


Figure 7: Sample 2 prior to initiation of the test

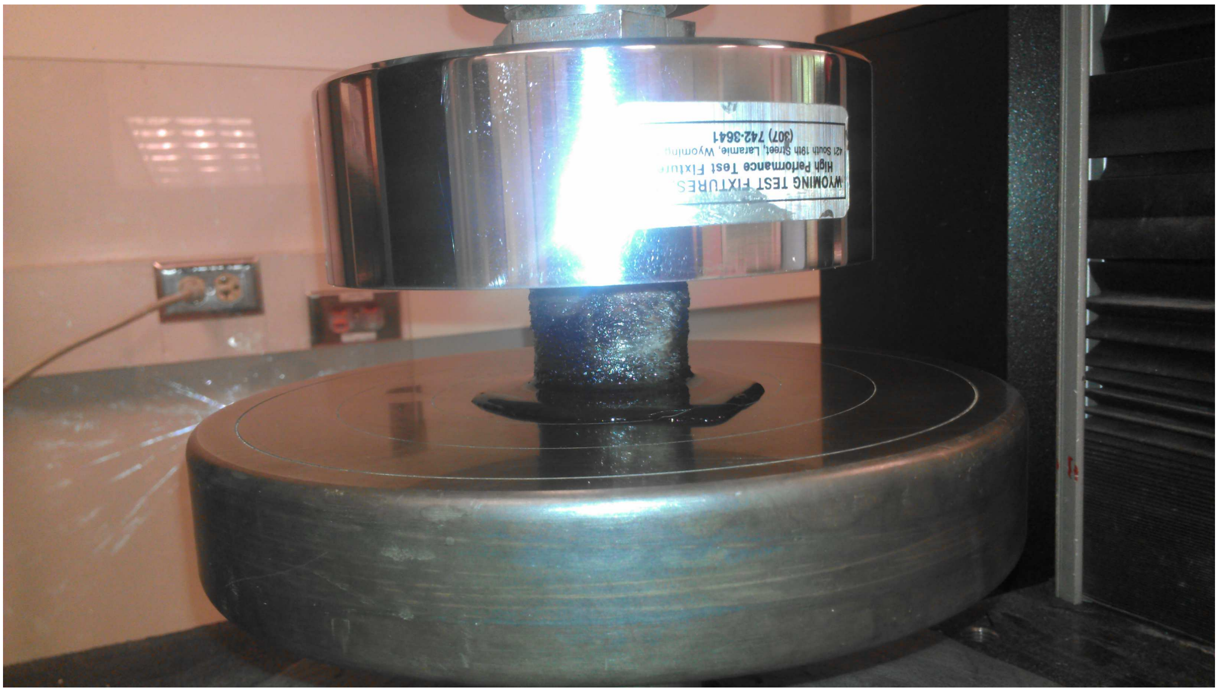


Figure 8: Sample 2 to a nominal deflection of about 0.30 inches. Note the water present on the lower platen, which was forced out of the specimen during the test

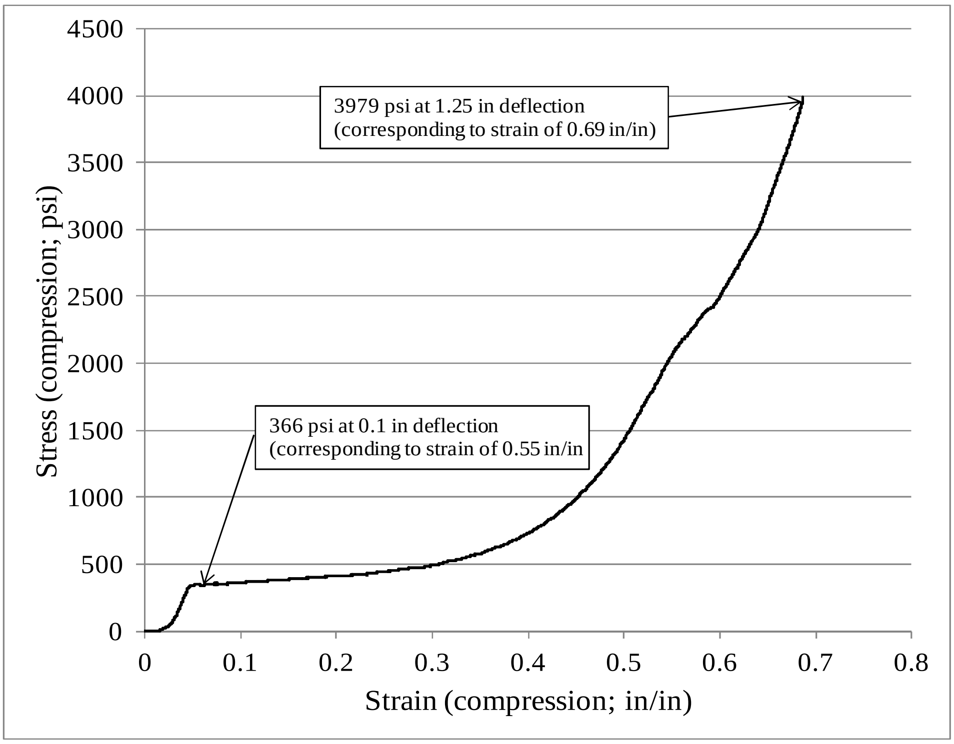


Figure 9: Stress-strain curve of Sample 2

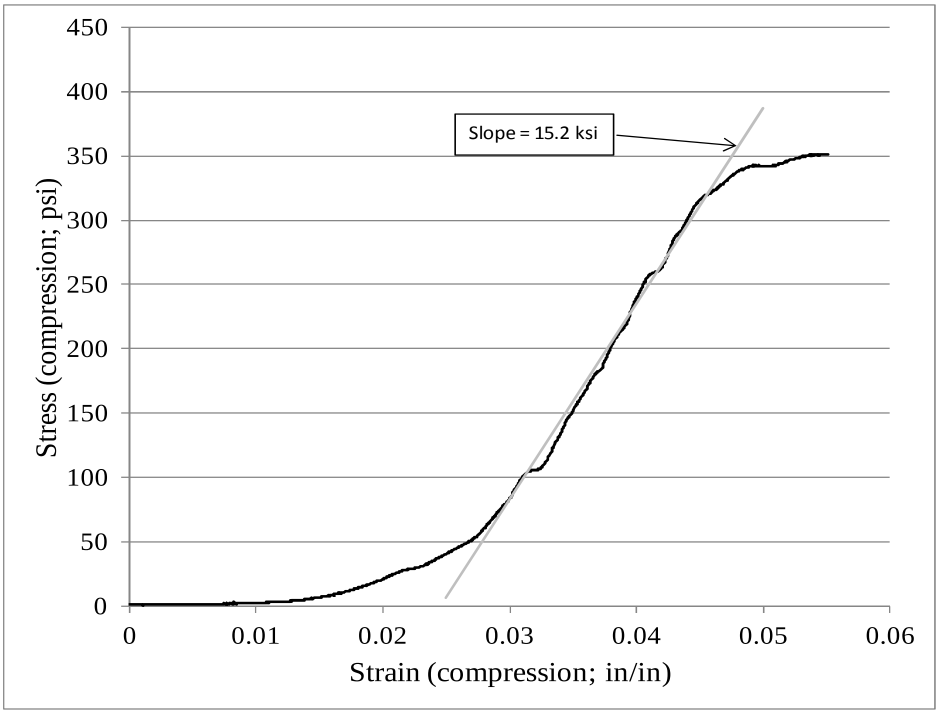


Figure 10: Stress-strain response of sample 2 at relatively low strain levels, used to calculate Young's modulus (E = 15.2 ksi)

Appendix I
AMTEST Laboratory Results of "Unknown" Material

Am Test Inc.
13600 NE 126TH PL
Suite C
Kirkland, WA 98034
(425) 885-1664
www.amtestlab.com

Professional Analytical Services

ANALYSIS REPORT

CH2M Hill
1100 112th Ave NE
Bellevue, WA 98009-2050
Attention: Candine Au-Yeung
Project Name: City of Bellingham Water intake pip
All results reported on a dry weight basis.

Date Received: 08/05/14
Date Reported: 8/21/14

AMTEST Identification Number **14-A011835**
Client Identification **Unknown Hard Material brown**
Sampling Date **06/26/14, 13:00**

Conventionals dry weight

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANALYST	DATE
Microscope	Mineral						

Conventionals

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANALYST	DATE
Total Solids	49.9	%		0.1	SM 2540G	AB	08/12/14
Total Volatile Solids	3.96	%		0.1	SM 2540-G	AB	08/12/14

Minerals

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANALYST	DATE
Calcium	140000	ug/g		2.98	SW-846 6010B	EB	08/14/14
Potassium	55.1	ug/g		5.97	SW-846 6010B	EB	08/14/14
Magnesium	7400	ug/g		0.597	SW-846 6010B	EB	08/14/14
Sodium	109.0	ug/g		2.98	SW-846 6010B	EB	08/14/14

Total Metals

PARAMETER	RESULT	UNITS	Q	D.L.	METHOD	ANALYST	DATE
Acid Digestion	Y				SW-846 3050B	EB	08/13/14
Silver	< 0.299	ug/g		0.298	SW-846 6010B	EB	08/14/14
Aluminum	2750	ug/g		0.597	SW-846 6010B	EB	08/14/14
Arsenic	1.54	ug/g		0.597	SW-846 6010B	EB	08/14/14
Boron	0.98	ug/g		0.597	SW-846 6010B	EB	08/14/14
Barium	202.	ug/g		0.030	SW-846 6010B	EB	08/14/14
Beryllium	< 0.0299	ug/g		0.030	SW-846 6010B	EB	08/14/14
Cadmium	< 0.1492	ug/g		0.149	SW-846 6010B	EB	08/14/14
Cobalt	0.381	ug/g		0.060	SW-846 6010B	EB	08/14/14
Chromium	2.02	ug/g		0.298	SW-846 6010B	EB	08/14/14
Copper	< 0.06	ug/g		0.060	SW-846 6010B	EB	08/14/14
Iron	731.	ug/g		0.597	SW-846 6010B	EB	08/14/14
Mercury	0.98	ug/g		0.597	SW-846 6010B	EB	08/14/14
Lithium	3.81	ug/g		0.298	SW-846 6010B	EB	08/14/14
Manganese	137.	ug/g		0.060	SW-846 6010B	EB	08/14/14
Molybdenum	< 0.299	ug/g		0.298	SW-846 6010B	EB	08/14/14
Nickel	2.16	ug/g		0.298	SW-846 6010B	EB	08/14/14
Phosphorus	112.	ug/g		2.98	SW-846 6010B	EB	08/14/14
Lead	< 0.6	ug/g		0.597	SW-846 6010B	EB	08/14/14
Sulfur	244.	ug/g		2.98	SW-846 6010B	EB	08/14/14
Antimony	< 1.78	ug/g		1.79	SW-846 6010B	EB	08/14/14
Selenium	1.50	ug/g		1.19	SW-846 6010B	EB	08/14/14
Silicon	637.	ug/g		2.98	SW-846 6010B	EB	08/14/14
Tin	8.30	ug/g		0.597	SW-846 6010B	EB	08/14/14
Strontium	251.	ug/g		0.060	SW-846 6010B	EB	08/14/14
Titanium	6.75	ug/g		0.298	SW-846 6010B	EB	08/14/14
Thallium	< 1.2	ug/g		1.19	SW-846 6010B	EB	08/14/14
Vanadium	0.741	ug/g		0.597	SW-846 6010B	EB	08/14/14
Yttrium	0.341	ug/g		0.149	SW-846 6010B	EB	08/14/14
Zinc	220.	ug/g		0.060	SW-846 6010B	EB	08/14/14

Microscopic exam. Two distinct materials were found in the mass. The majority is a brown colored mineral. The clear brown crytals appear black in the photos (#6,7,8,9) The four pictures are of the same material just different exposures. Chemial composition suggests the mass is calcium carbonate and silica.

The second material appears brown/gray on the mass. This is pictured in photo #10. There are no internal cell structures. The organic carbon content is 35%.

Kathy Fugiel
President

Photo 6: Clear Brown Crystals in Mass of Unknown Material

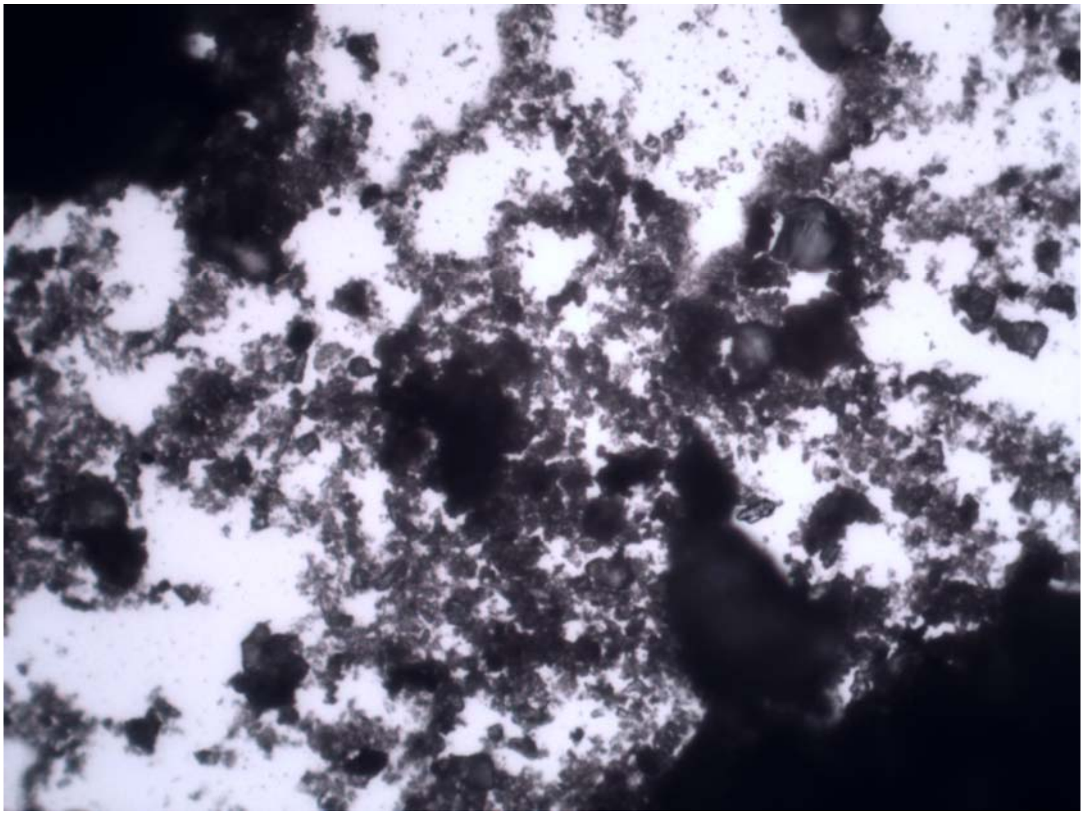


Photo 7: Clear Brown Crystals in Mass of Unknown Material

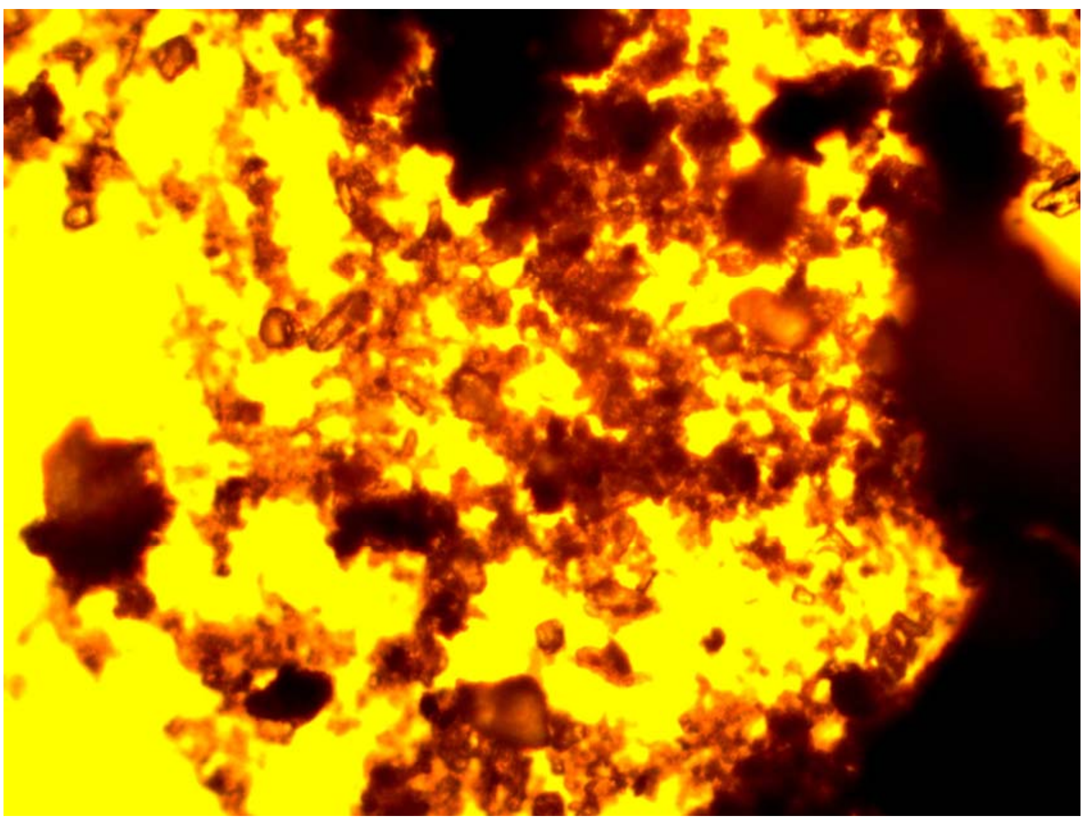


Photo 8: Clear Brown Crystals in Mass of Unknown Material

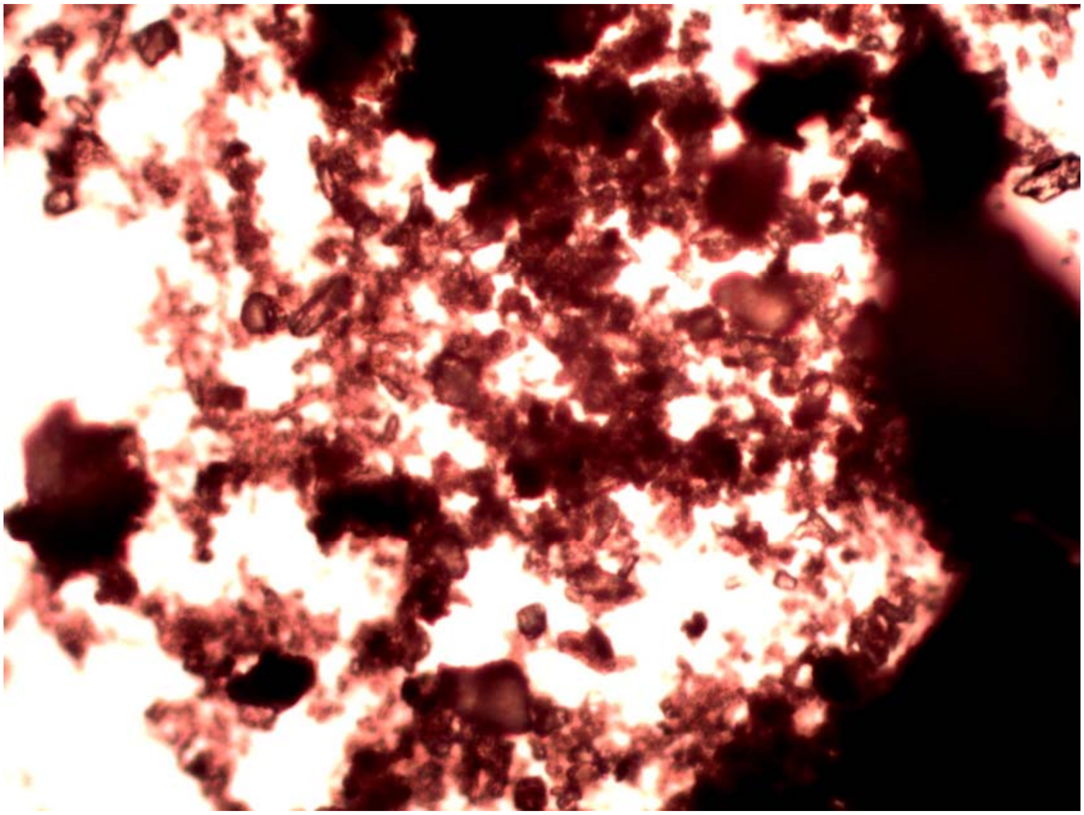


Photo 9: Clear Brown Crystals in Mass of Unknown Material

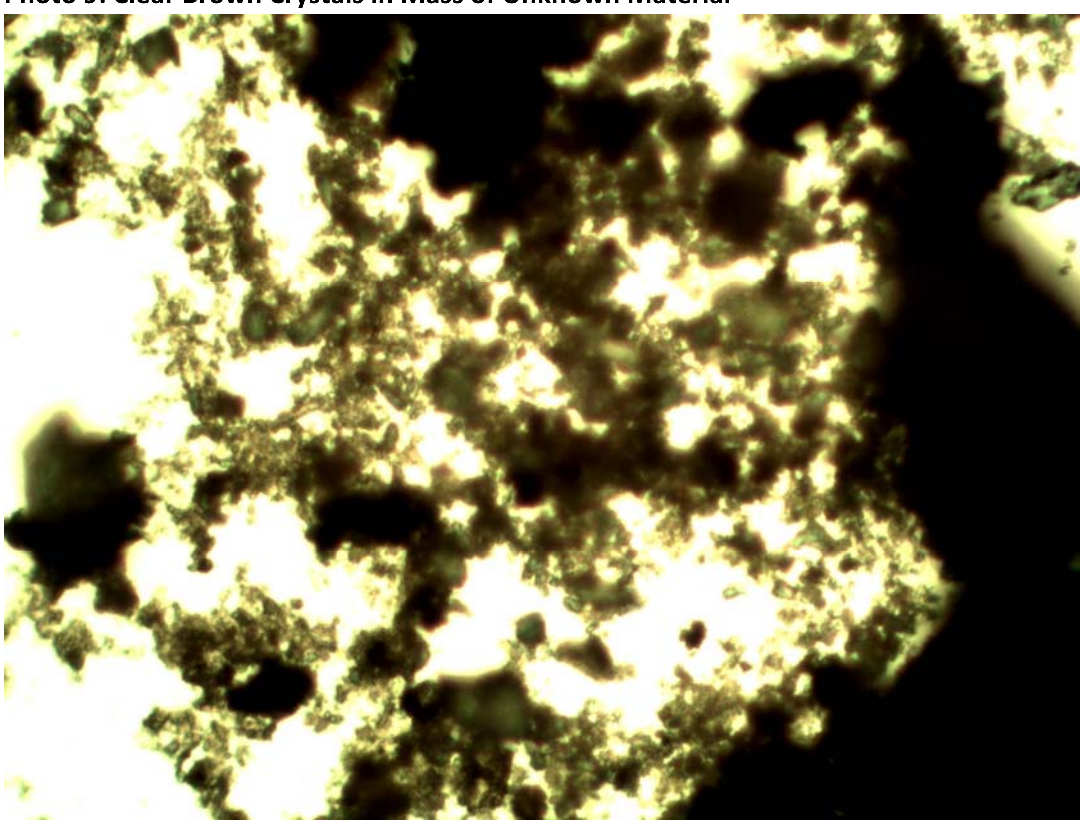
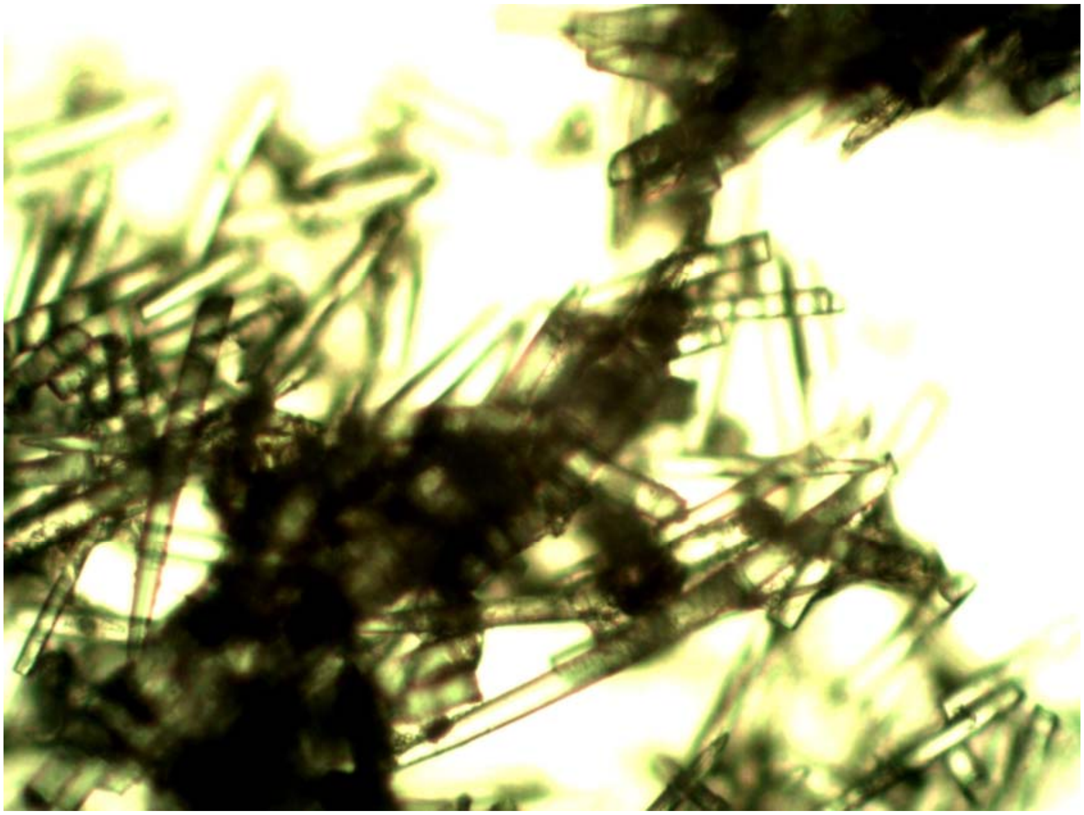


Photo 10: Brown/Gray Material in Mass of Unknown Material



Am Test Inc.
13600 NE 126th PL
Suite C
Kirkland, WA, 98034
(425) 885-1664
www.amtestlab.com

AMTEST LABORATORIES

Professional Analytical Services

QC Summary for sample number: 14-A011835

DUPLICATES

SAMPLE #	ANALYTE	UNITS	SAMPLE VALUE	DUP VALUE	RPD
14-A011980	Total Solids	%	72.0	69.2	4.0

MATRIX SPIKES

SAMPLE #	ANALYTE	UNITS	SAMPLE VALUE	SMPL+ SPK	SPK AMT	RECOVERY
14-A012294	Silver	ug/g	< 4.5	95.6	96.6	98.96 %
14-A012294	Silver	ug/g	< 4.5	93.7	96.6	97.00 %
14-A012294	Aluminum	ug/g	3950	5070	1060	105.66 %
14-A012294	Aluminum	ug/g	3950	5010	1060	100.00 %
14-A012294	Arsenic	ug/g	< 9	86.0	96.6	89.03 %
14-A012294	Arsenic	ug/g	< 9	88.7	96.6	91.82 %
14-A012294	Barium	ug/g	136.	231.	96.6	98.34 %
14-A012294	Barium	ug/g	136.	225.	96.6	92.13 %
14-A012294	Beryllium	ug/g	< 0.45	95.0	96.6	98.34 %
14-A012294	Beryllium	ug/g	< 0.45	94.4	96.6	97.72 %
14-A012294	Calcium	ug/g	27000	30000	2500	120.00 %
14-A012294	Calcium	ug/g	27000	29000	2500	80.00 %
14-A012294	Cadmium	ug/g	< 2.25	85.00	96.60	87.99 %
14-A012294	Cadmium	ug/g	< 2.25	84.90	96.60	87.89 %
14-A012294	Chromium	ug/g	39.9	127.	96.6	90.17 %
14-A012294	Chromium	ug/g	39.9	129.	96.6	92.24 %
14-A012294	Copper	ug/g	427.	528.	96.6	104.56 %
14-A012294	Copper	ug/g	427.	520.	96.6	96.27 %
14-A012294	Iron	ug/g	3640	4940	1060	122.64 %
14-A012294	Iron	ug/g	3640	4850	1060	114.15 %
14-A012294	Potassium	ug/g	2160	3100	966.	97.31 %
14-A012294	Potassium	ug/g	2160	3080	966.	95.24 %
14-A012294	Magnesium	ug/g	11000	13000	2500	80.00 %
14-A012294	Magnesium	ug/g	11000	13000	2500	80.00 %
14-A012294	Manganese	ug/g	110.	202.	96.6	95.24 %
14-A012294	Manganese	ug/g	110.	199.	96.6	92.13 %
14-A012294	Molybdenum	ug/g	13.2	99.1	96.6	88.92 %
14-A012294	Molybdenum	ug/g	13.2	102.	96.6	91.93 %
14-A012294	Sodium	ug/g	467.0	2850.	2512.	94.86 %
14-A012294	Sodium	ug/g	467.0	2830.	2512.	94.07 %
14-A012294	Nickel	ug/g	9.81	97.6	96.6	90.88 %
14-A012294	Nickel	ug/g	9.81	97.6	96.6	90.88 %
14-A012294	Lead	ug/g	< 9	105.	96.6	108.70 %
14-A012294	Lead	ug/g	< 9	106.	96.6	109.73 %
14-A012294	Antimony	ug/g	< 27	86.4	96.6	89.44 %
14-A012294	Antimony	ug/g	< 27	90.0	96.6	93.17 %

MATRIX SPIKES continued....

SAMPLE #	ANALYTE	UNITS	SAMPLE VALUE	SMPL+ SPK	SPK AMT	RECOVERY
14-A012294	Selenium	ug/g	< 18	80.6	96.6	83.44 %
14-A012294	Selenium	ug/g	< 18	89.4	96.6	92.55 %
14-A012294	Thallium	ug/g	< 18	65.6	96.6	67.91 %
14-A012294	Thallium	ug/g	< 18	72.1	96.6	74.64 %
14-A012294	Zinc	ug/g	815.	887.	96.6	74.53 %
14-A012294	Zinc	ug/g	815.	872.	96.6	59.01 %
14-A012373	Zinc	ug/g	24.2	52.5	32.7	86.54 %
14-A012373	Zinc	ug/g	24.2	52.5	32.7	86.54 %

MATRIX SPIKE DUPLICATES

SAMPLE #	ANALYTE	UNITS	SAMPLE + SPK	MSD VALUE	RPD
Spike	Silver	ug/g	95.6	93.7	2.0
Spike	Aluminum	ug/g	5070	5010	1.2
Spike	Arsenic	ug/g	86.0	88.7	3.1
Spike	Barium	ug/g	231.	225.	2.6
Spike	Beryllium	ug/g	95.0	94.4	0.63
Spike	Calcium	ug/g	30000	29000	3.4
Spike	Cadmium	ug/g	85.00	84.90	0.12
Spike	Chromium	ug/g	127.	129.	1.6
Spike	Copper	ug/g	528.	520.	1.5
Spike	Iron	ug/g	4940	4850	1.8
Spike	Potassium	ug/g	3100	3080	0.65
Spike	Magnesium	ug/g	13000	13000	0.00
Spike	Manganese	ug/g	202.	199.	1.5
Spike	Molybdenum	ug/g	99.1	102.	2.9
Spike	Sodium	ug/g	2850.	2830.	0.70
Spike	Nickel	ug/g	97.6	97.6	0.00
Spike	Lead	ug/g	105.	106.	0.95
Spike	Antimony	ug/g	86.4	90.0	4.1
Spike	Selenium	ug/g	80.6	89.4	10.
Spike	Thallium	ug/g	65.6	72.1	9.4
Spike	Zinc	ug/g	887.	872.	1.7
Spike	Zinc	ug/g	52.5	52.5	0.00

STANDARD REFERENCE MATERIALS

ANALYTE	UNITS	TRUE VALUE	MEASURED VALUE	RECOVERY
Silver	ug/g	55.1	48.3	87.7 %
Silver	ug/g	55.1	49.7	90.2 %
Aluminum	ug/g	1550	1500	96.8 %
Aluminum	ug/g	1550	1560	101. %
Arsenic	ug/g	109.	97.7	89.6 %
Arsenic	ug/g	109.	97.3	89.3 %
Boron	ug/g	780.	654.	83.8 %
Boron	ug/g	780.	669.	85.8 %
Barium	ug/g	608.	528.	86.8 %
Barium	ug/g	608.	540.	88.8 %
Beryllium	ug/g	376.	315.	83.8 %
Beryllium	ug/g	376.	317.	84.3 %
Calcium	ug/g	14000	14000	100. %
Calcium	ug/g	14000	14000	100. %

STANDARD REFERENCE MATERIALS continued....

ANALYTE	UNITS	TRUE VALUE	MEASURED VALUE	RECOVERY
Cadmium	ug/g	326.0	251.0	77.0 %
Cadmium	ug/g	326.0	255.0	78.2 %
Cobalt	ug/g	390.	300.	76.9 %
Cobalt	ug/g	390.	303.	77.7 %
Chromium	ug/g	320.	273.	85.3 %
Chromium	ug/g	320.	278.	86.9 %
Copper	ug/g	390.	349.	89.5 %
Copper	ug/g	390.	352.	90.3 %
Iron	ug/g	2780	2020	72.7 %
Iron	ug/g	2780	2000	71.9 %
Mercury	ug/g	4.32	3.34	77.3 %
Mercury	ug/g	4.32	3.32	76.9 %
Potassium	ug/g	11600	10100	87.1 %
Potassium	ug/g	11600	10200	87.9 %
Magnesium	ug/g	2400	2000	83.3 %
Magnesium	ug/g	2400	2000	83.3 %
Manganese	ug/g	1250	916.	73.3 %
Manganese	ug/g	1250	924.	73.9 %
Molybdenum	ug/g	50.8	37.6	74.0 %
Molybdenum	ug/g	50.8	37.1	73.0 %
Sodium	ug/g	2880.	2810.	97.6 %
Sodium	ug/g	2880.	2830.	98.3 %
Nickel	ug/g	190.	139.	73.2 %
Nickel	ug/g	190.	140.	73.7 %
Lead	ug/g	118.	98.4	83.4 %
Lead	ug/g	118.	97.1	82.3 %
Antimony	ug/g	177.	125.	70.6 %
Antimony	ug/g	177.	126.	71.2 %
Selenium	ug/g	218.	143.	65.6 %
Selenium	ug/g	218.	147.	67.4 %
Tin	ug/g	102.	76.9	75.4 %
Tin	ug/g	102.	77.4	75.9 %
Strontium	ug/g	316.	256.	81.0 %
Strontium	ug/g	316.	261.	82.6 %
Thallium	ug/g	390.	309.	79.2 %
Thallium	ug/g	390.	312.	80.0 %
Vanadium	ug/g	364.	308.	84.6 %
Vanadium	ug/g	364.	314.	86.3 %
Zinc	ug/g	566.	451.	79.7 %
Zinc	ug/g	566.	456.	80.6 %

QC Summary for sample number: 14-A011835...

BLANKS

ANALYTE	UNITS	RESULT
Silver	ug/g	< 0.005
Aluminum	ug/g	< 0.01
Arsenic	ug/g	< 0.01
Boron	ug/g	< 0.01
Barium	ug/g	< 0.0005
Beryllium	ug/g	< 0.0005
Calcium	ug/g	0.41
Cadmium	ug/g	< 0.0025
Cobalt	ug/g	< 0.001
Chromium	ug/g	< 0.005
Copper	ug/g	< 0.001
Iron	ug/g	0.027
Mercury	ug/g	< 0.01
Potassium	ug/g	< 0.1
Lithium	ug/g	< 0.005
Magnesium	ug/g	< 0.01
Manganese	ug/g	< 0.001
Molybdenum	ug/g	< 0.005
Sodium	ug/g	< 0.05
Nickel	ug/g	< 0.005
Phosphorus	ug/g	< 0.05
Lead	ug/g	< 0.01
Lead	ug/g	< 0.01
Sulfur	ug/g	< 0.05
Antimony	ug/g	< 0.03
Selenium	ug/g	< 0.02
Silicon	ug/g	0.06
Tin	ug/g	< 0.01
Strontium	ug/g	< 0.001
Titanium	ug/g	< 0.005
Thallium	ug/g	< 0.02
Vanadium	ug/g	< 0.01
Yttrium	ug/g	< 0.0025
Zinc	ug/g	< 0.001
Zinc	ug/g	< 0.001

Appendix J – 1998 Harza Engineering Intake Report

INTAKE PIPE REVIEW BASED ON VIDEO'S & DESIGN DRAWINGS

HARZA Consulting Engineers and Scientists

Sears Tower
233 South Wacker Drive
Chicago, Illinois 60606-6392 U.S.A.

WATER AND ENVIRONMENT

Tel: 312-831-3000
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FAX COVER SHEET

Date: March 22, 1999

To: William P. McCourt
Company: Bellingham Department of Public Works
Subject: Report on Intake Inspection
Total pages including this cover sheet: 22

From: Leonard L. Holt, PE, DEE
Phone: 312-831-3813
Fax: 312-831-3976
e-mail: lholt@harza.com

Dear Mr. McCourt;

Attached is our report concerning our review of the video tapes and plans provided by you.

A hard copy is in the mail to you.

Please contact me with any comments.

Very truly yours,

Leonard L Holt

Harza Engineering Company
Leonard L. Holt

City: Bellingham
State: WA
Nation: USA
Project: H00-05-HB
Transmit to Fax Number: 360-676-7799
Transmitted by Harza Water and Environment Fax Operator , telephone: 312-831-3426

Elvia

BELLINGHAM, WASHINGTON

REPORT ON

INTAKE INSPECTION

OCTOBER – 1998

BY

HARZA ENGINEERING COMPANY

CHICAGO, ILLINOIS

At the request of Mr. William P. McCourt, Public Works Superintendent/Operations of Bellingham, WA we have reviewed the video tapes and drawings provided by him. The following notes were made to help form an opinion as to the structural integrity of the 72-inch wood intake pipeline in Lake Whatcom. They were taken from , 1998 and historic videos. We also reviewed drawings dated 1938, 1939, and 1940.

After review of the above videos and drawings, we combined the notes made in this review in an attempt to determine details of the original construction and changes that may have occurred over the years.

The pipeline was constructed in 1939/40 on the shore of Lake Whatcom, much like you would construct a ship, on a set of Ways, utilizing templates and methods similar to the construction of a ship's hull. As the pipe on the Ways was completed, it was then slid off into the water until just the uncompleted end of the pipeline was resting on the Ways, with the wood in different lengths extending out to form staggered joints as construction of the pipe continued. From the video, the construction of the pipeline appeared to be along the path of the final resting place of the pipeline, or close to it. Some of the video scenes indicated that the pipe might have been submerged as it was pulled off the Ways by Tugboats and nudged along side wood piling to place it on line. The pipe was constructed in several undetermined lengths and connected with steel flanges, welded on steel pipe spool pieces and inserted into the wood pipe ends. These were then bolted together to seal the pipeline.

The pipeline is 72-inchs in diameter, made of wood stave construction and approximately 1225 feet out into Lake Whatcom, starting onshore at the Tunnel Gate House. It is buried 350 to 400 feet from the Gate House out into the Lake. We had no information whether the buried pipe was being inspected externally or internally so we were unable to include any findings regarding that section of pipeline in this review except to recommend an internal inspection of this section be made under conditions which will be included in our final summary. After the pipeline is no longer buried where it exits the slope of the shore and lake bottom, it is supported on wood pile bents out to the inlet and wood crib structure. A total of 44 pile bents were inspected and numbered in the inspection and video taping.

Our comments concerning this combined inspection and review start at the Intake Crib and proceed west along the pipeline towards shore. The wood pile bents are numbered with tags with number 1 being the bent just west of the crib and increasing in numerical order toward shore.

The wood crib at the inlet end of the pipeline deviates from the planned intake tower rising above the waters of the lake. An alternate submerged intake crib cross section is shown on the Baar and Cunningham drawing WA-46 and the 11991984 video shows the existing structure is similar to that drawing. We assume this structure was constructed from that drawing. The video gave some good looks at the crib and at that time it appeared to be in very good condition. The 1998 video was not as extensive in showing the crib structure, but no structural damage was noted by the diver or on the video. The pipeline ends just inside the crib structure and appears to be about 3 to 3 ½ feet inside the west wall. the video demonstrated, and the narrator of this video mentioned that there was a flared bell piece on the end of the pipe. The 1998 video did not provide a clear picture regarding what was on the end of the pipe. We believe we saw a flange, but the view was inconclusive regarding this inconsistency. The pipe seems to be drawing well and the 1998 video reported they were drawing 7200 gpm at the time of the inspection.

Neither video provided detailed viewing or commentary regarding the wood stave wall of the pipe and its condition. There was silt and algae growth on the exterior of the pipe and as the camera swept past, it was hard to determine the condition of the wall of the pipe. However no damage or deterioration of the wood was noticed. In the 1998 video tape several bands that hold the wood staves in place it appeared to be broken and there was a recommendation that more stainless steel bands be placed around the pipe, especially in the areas where these bands were broken and in areas where excess corrosion was noted.

The 1998 diver examined several bands, and reported that none seemed to be badly corroded. However the 1984 video did mention some as being corroded and noted that the bands farther offshore seemed to be worse then the ones inshore. Both videos noted that there seemed to be more replacement stainless steel bands on the inshore half of the pipeline, which were evidently installed in the 1970's. We have no record of their installation. It was also evident that stainless steel bands had been installed on most of the concrete saddles used for weight to prevent flotation of the pipe. In the 1984 video, some concrete saddles were noted on the lake bottom which were not fastened or holding the pipe down. While no concrete saddles were noted in the 1998 video, the segment of this video dealing with the passage along the pipeline covered the top of the pipe between pile bents and at the bents, showed both sides of the bents. By contrast, the 1984 video moved along the lake bottom on the North side of the pipeline, concentrating on that side of the pipe and the pile bents, giving a different look and perspective to the inspections.

Detailed notes have been prepared evaluating each identified pipeline bent with comments on the condition of each. These are included as an appendix.

The final position of the pipe as installed, was buried in the lake bottom, until it was offshore approximately 350 feet or so from its connection to the Tunnel Gate House structure. From this point out to the lake end of the pipeline, the pipe is supported on wood pile bents driven into the lake bottom at intervals of about 25 foot or so along the pipeline, for a distance of approximately 1225 feet out to the inlet end, which appears to be slightly belled and is inside a wood crib structure.

The typical pile bent used appears to be a 10 or 12 inch diameter wood pile driven on each side of the pipe and outside of its overall diameter. Next, A 6x12x36 inch foot block is bolted on each side of each pile running parallel to the pipe and a wood cross brace is then placed across under, but not up bottom of pipe. These rest on the foot blocks fasten to the pile and in turn are bolted to each pile. A wood spreader is placed

This condition of buried intake pipe cannot be determined as it is inaccessible without excavation to the pipe or by internal pipe inspection and testing.

Some pipeline support bents are either damaged or out of alignment and strapping securing the pipe to some of the supports is also damaged or missing.

Condition of the wood piles supporting the pipe is not known.

The previous inspections did not cover all portions of the intake and supports.

Additional inspection and study is recommended to determine the extent of any remedial work required to stabilize this pipeline. While there does not seem to be any immediate danger of failure of the inspected portion of the pipeline, some maintenance work will be required to secure and stabilize the line against further movement.

Some of the work is minor, requiring only the services of a diver, stainless steel strapping with clamping tools, wood wedges, assorted wood blocking, underwater hand tools, above water vessels and support system. While this work is being carried out, inspection of the wood walls of the pipe, the steel bands, the flange connections and the intake crib in more details could be accomplished.

We do have concern regarding the buried portion of the pipeline from the lake to the Gate House. We recommend an internal inspection be made of this section which could also include the lake portion. For safety reasons, this inspection should not be done by diver penetration, but by a Remotely Operated Submersible Vehicle (ROV). This ROV should be inserted into the pipeline and should capable of moving through the pipeline on its own power. It should be equipped with maneuverable video cameras, capable of scanning and pinpointing specific areas that need to be monitored.

Recommendations

1. Additional inspection and testing is recommended to determine the condition of the wood pipe wall. Where the pipe is supported on pile bents above the bottom of the lake, a diver may remove wood cores from the pipe for analysis. The holes created would be plugged with wooden pegs of stainless steel lug bolts. Where the pipe is buried, a core could be removed by divers working from the inside of the intake if safe entry can be made. Otherwise, a ROV capable of extracting a wood core and plugging the pipe wall might be used. Dewatering of the intake is not advised.

2. We are not sure whether or not the City of Bellingham has another water supply source. If an alternate supply is not available, we think that the suggested measures should be undertaken in the near future. The possibility of obtaining an alternate water supply source could also be considered.

between and in the center of the cross braces. These are not shown on any of the plans. However, in the video they appear to be about four feet long, and approximately four to six inches thick, and wide enough to fit snugly between the cross braces. These spreaders were not noted at all of bents in the video tapes.

Support of the pipe varied from wood cradles on one cross brace, concrete saddles resting on another cross brace or center spreader to wood timber or planks and wood wedges. There were other wood spreaders, braces or fillers on some bents but the above. were the general rule the main support for the pipe. Some of the bents appeared to be out of alignment with the pipeline and some piling was not in line with its opposite pile. This puts some of the cross braces at an angle other than a right angle to the pipe and not horizontal under the pipe.

There are differences between the actual construction of the pipeline and as shown on the proposed construction, but the finished pipeline appears to be completed with the general lines and intent of the design.

Summary

The intake pipe appears to be structurally intact where the pipe is not buried. However, the condition of the wood in the pipe wall is not known.

Bellingham, Washington

Water Intake

Appendix No. 1.

Notes On Pipeline Condition

Notes were developed based on review of video tapes and plans. These start with Wood Pile Bent No. 1 located at the inlet crib and proceed inward to Pile Bent No 44., located near the shore.

Bent No. 1: The pipe rests on a concrete saddle which in turn rests on the center support between the cross braces, which run between the wood pile on each side of the pipe. This is true in both videos and seems to be secure except that there did not seem to be a band around the pipe to hold it to the pipe.

Bent No. 2: Pile bent is on an angle to the pipeline causing the concrete saddle to support the pipe at an angle on pile bent support. Steel band around pipe is broken, just East of pile bent. This was noted on both videos. The 1984 video also noted other bands badly corroded, and the presence of concrete cylinders lying on the lake bottom along the pipeline. This finding was also noted at several other locations along the pipeline.

Bent No. 3: The pipe is supported on a concrete saddle, which in turn rests only on the West cross brace. The saddle appears to be in an adequately stable position in the 1984 video. However, a gap under the south end of the saddle and a broken band around the pipe at this bent were observed in the 1998 video.

Also, concrete saddles were typically observed to be located at or close to each pile bent, and half way between each bent. In most cases, these saddles were secured to the pipe by stainless steel banding. However, the saddle between bent No. 3 and No. 4 did not appear to be secured to the pipe in any way.

Bent No. 4: The 1984 video showed the pipe resting on a concrete saddle, balanced on the East cross timber. However the 1998 video clearly shows the pipe resting on the center support between the cross timbers, clearly indicating movement of the pipe in this location.

Bent No. 5: The 1984 video depicted the pipe resting on a wood cradle on the West cross timber. A concrete saddle rested over (the pipe?) but not on the East cross timber. In the 1998 video, we could not confirm the support on the East cross timber, but did confirm a wood cradle supporting the pipe on the West cross timber.

Bent No. 6: The 1984 video showed the Pipe resting on a concrete saddle, which in turn appeared to be resting on the East cross brace and the center support. In the 1998 video, the concrete saddle may appeared to be resting only on the center support, suggesting that some longitudinal movement may have occurred.

Bent No. 7: The 1984 video showed the Pipe resting directly on the wood cross bracing and center support, with two broken bands down on the cross timbers. In the 1998 video, a broken band was observed between the pipe and the center support.

Bent No. 8: In both videos , the Pipe Seems to be well supported. It is viewed resting on concrete saddle, at an angle to the pile bents cross timbers, resting on the East cross brace and the center support.

Bent No. 9: In both 1984 and 1998 videos the Pipe appears to be well supported. The concrete saddle is placed under the pipe which is in turn resting on the cross timbers and center support.

Bent No. 10: In both the 1984 video, the Pipe is resting on a concrete saddle which is in turn resting firmly on the West cross brace. The 1998 video shows the Pipe resting on the West cross brace. However, the later video also shows the Pipe touching only the North end of the saddle, with a gap of about 1 ½ -inches between the saddle and the cross brace on the South end of the saddle. There was a broken band showing in both videos.

Bent No. 11: Both videos seem to provide similar information. The pile bent is at an angle from the pipeline. The East cross timber is out about six inches from North pile. The Pipe rests on a concrete saddle which in turn rests on the timber cross pieces. The North end of the saddle is on the West cross brace. The South end of the saddle is much more precariously placed n the East cross brace. It was not possible to determine how much of the saddle was resting on the center support. At the time the second video was made, the situation at this bent was described as sufficiently stable.

Bent No. 12: Pipe is resting firmly on concrete saddle, which in turn rests on the cross bracing. The Pipe appears to be well supported in both videos with no apparent changes.

Bent No. 13: The pile bent is on an angle to pipeline. As such, the pipe rests on a saddle. Due to the angle of the pile bent, the saddle also rests on an angle to the cross bracing. However, from the perspective provided by both videos, the pipe appears to be well supported at this point.

Bent No. 14: Pipe is supported as on pile bent No. 13. The 1984 video showed concrete cylinders on the lake bottom, a few on top of the pipe and on the timber cross bracing also, none were noted in the 1998 video.

Bent No. 15: Pipe in both videos show the pipe with a concrete saddle under it, which is on an angle to the cross bracing, touching on the north end of the saddle, but with a gap of about 1 ½ to 2 inches on the South end of the saddle.

Bent No. 16: Pipe has a concrete saddle under it, again at an angle to the cross bracing but appears to be resting firmly on the cross bracing and well supported.

Bent No. 17: Pipe has a concrete saddle under it, as above at an angle to the cross bracing. It appears to be resting firmly on the cross bracing and well supported. There was a broken band from around the pipe noted in the 1998 video that was not noted in the 1984 video.

Bent No. 18: Pipe is resting on a wood cradle on East cross timber, a concrete saddle is over the West cross brace but about 4-inches above the brace. This was similar in both videos.

Bent No. 19: The 1984 video passed by this bent with out any detail shown. The 1998 video showed the pipe resting on 2 wood cradles, one on each cross brace, the West cradle on the West brace. The East cradle only partly on the East cross brace as it went across the brace. A broken band around the pipe was observed in the 1998 video.

Bent No. 20: The 1984 Video provided only a quick shot of this bent. We determined that the pipe was supported on a concrete saddle which was resting on the West cross brace. The 1998 video showed the pipe down resting directly on the cross braces. We noted no saddle, cradles or wedges under the pipe. This indicates movement in the pipe here.

Bent No. 21: The 1984 video provided only a quick passing shot. The concrete saddle seemed to be under pipe and resting on cross bracing. The 1998 video confirmed that the saddle was under pipe and resting squarely on cross bracing.

A cable was found draped over the pipeline between bent No. 21 and No. 22. The narrator for the 1984 video thought it might have been a cable used to position the pipe while it was being laid. The cable appeared to be about 2 ½ to 3 inches in diameter and lead covered. We agree with the 1998 diver who thought it was a power cable or it might be a telephone cable. This was just to the East of pile bent No. 22.

Bent No. 22: The pipe was resting on a wood cradle supported on West cross brace. There was a cradle on East cross brace under pipe, a little askew of that brace, not fully resting on cross brace. The concrete saddle is shown a feet to the West of the bent. Only the saddle was evident in the 1984 video.

Bent No. 23: The 1998 video showed the pile bent and support system at this bent to be in good shape and giving support. The 1984 video did not show support system under pipe, as the diver was on top of pipe. This video showed another cable over the pipe just East of bent No. 24 and what a appeared as a broken band right by the band.

Bent No. 24: The 1998 video again showed the pile bent with a concrete saddle under pipe and it was satisfactorily resting on the cross bracing. The 1984 video only showed the top of the pipe, with no problems evident in the first view, but the second view was consistent with the 1998 view.

Bent No. 25: The 1998 video showed the pile bent and cross bracing to be in good shape, with the pipe resting firmly on the cross brace supports. The 1984 video also showed a concrete saddle hanging from the pipe just to the West of the bent.

Bent No. 26: The pipe is resting on the wood cradle on the East cross brace and is well positioned, the wood cradle on the west cross brace is not quite centered to give stable support to pipe. Another cable was noted over the pipeline midway between bent No. 26 and 27.

Bent No. 27: The 1984 video had two different views of this bent. The first one was the top of the pipe and showed a flanged connection in the pipeline. The second was a view of the support system, including a shot of the flange and a concrete saddle West of the bent. Both the 1984 and 1998 videos showed the pipe resting on a wood cradle on the West cross brace which appeared to be in good shape and supporting the pipe.

The flanged connection in the pipeline mentioned above between bent 27 and 28,connect the pipes of undetermined lengths. The steel flanges are on a steel spool piece that is inserted into the pipe, views of these pieces in the movies made at the time of the construction, (now on video) show them to be approximately 30-inches to 36-inches long and they appear to be inserted into the pipe except for 4 to 6 inches close to the flange. The wood ends at the flange look to be slightly irregular in length making the difference. Without a close inspection, the flange and bolts appeared to be secure. No measurements were taken on either video.

Bent No. 28: The Pipe is resting on wood cradles, that in turn rest on the cross braces. The angle of the pile bents to the pipeline is slightly off, but East cradle rests firmly on East cross brace, the West cradle is about half supported along its length on the cross brace. The south pile on this bent seemed to be split. This is consistent in both videos, although the 1984 video also shows a concrete saddle off to the West of the cross bracing about 3-inches. A large log lies just to the North of the North pile, and is several feet long, extending partially under the pipeline. while we did not view it, this log was mentioned by the diver in the 1998 inspection. This video also showed a lot of concrete cylinders lying on the lake bottom here.

Bent No. 29: One steel band around pipe appears to be missing at this bent, the pipe is supported on what appears to be 4X4 timbers on each side of the pipe, running longitudinal to the pipeline and resting at each end on the cross braces. It appears to be properly supporting pipe. Conditions seem to be similar in both the 1984 and 1998 videos, the lake bottom did appear closer to the bottom of the pipe in the 1998 video.

Bent No. 30: The pipe is resting on a wood cradle, which in turn is supported on the East cross brace, with no support under pipe to the West cross brace, The concrete saddle is hanging a few inches to the West of the West cross brace. Both videos are similar.

Bent No. 31: Pipe is resting on a wood cradle, which is supported by the East cross brace. In the 1984 video, the concrete saddle was over the West cross brace, on an angle about 1-inch above it on the North and almost touching o the South. The concrete saddle position was undetermined in the 1998 video.

Bent No. 32: In the 1984 video the wood cradle supporting the pipe on the East cross brace was tilted some and partially off the cross brace on North side of pipeline, with full contact on South side. The concrete saddle was off to the side of the West cross brace and just touching the brace on South end. In the 1998 it was similar but the concrete saddle was not touching the cross brace. This may indicate some minor movement.

Bent No. 33: The 1984 video did not provide a good shot of the support system. It was noted that the pipe was farther from the lake bottom, which seems to be fairly level, which may indicate pipe is rising or sloping up. The 1998 video showed a wood cradle under the pipe, resting at an angle on the East cross brace. There is partial support on the North end of cradle but it is fully supported on the South end. There is a wood cradle under the North side of the pipe on the center section of the cross brace, but there is none opposite it on the South side.

Bent No. 34: Both videos showed similar conditions, with the pipe resting on a cradle, supported by the East cross brace. There was nothing supporting pipe on West cross brace. The concrete saddle was just off the side of the West cross brace.

Bent No. 35: The Pipe is supported by a wood cradle resting fully on the East cross brace, with what appears to be good support. The concrete saddle is off to side of West cross brace, almost touching it. This presentation is similar in both videos. However, the 1998 video shows the concrete saddle at an angle over the West cross brace, not quite over it on the North with a gap between it and the brace. On the South end it was just touching and half way across the width of the brace. The 1998 diver noted the wood pile on the South side of this bent was broke off at the bolt supporting the cross braces, leaving the bolt intact, but exposed on the broken pile top to support the cross bracing.

Bent No. 36: The diver was able to move from side to side under the pipe here, Supporting the probability of the upward slope of the pipe noted at pile bent No. 29. The pipe is on a wood cradle, supported on the East cross brace. Concrete saddle just off to the side of the West cross brace is almost touching in 1984 video, but is resting on its South end on the West cross brace, in the 1998 video. This indicates possible movement here also.

Bent No. 37: The Pipe in both videos is supported by the concrete saddle which is on the center section of the cross bracing. The Pipe appears to be closer to the lake bottom again, the 1998 diver noted the pile on the South side of the bent was split off above cross timbers.

Bent No. 38: The Videos shows the pipe supported on the concrete saddle, resting on wood 4X4 blocks and the center section of the cross bracing, which is on an angle to the pipeline, causing the 4X4 on the North side to just be under the corner of the saddle. This should be wedged up. It Looked better in the 1998 than in 1984 video.

Bent No. 39: Both of the cross brace timbers running under the pipe are on the East side of the North pile, but they are resting on the foot block fasten to the North pile. It was noted in the 1984 inspection that these cross braces and timber seemed to be of smaller dimensions than the bents to the East of these. There were wood cradles under the pipe at both the East and West cross braces, but only the West cradle and brace were giving support to the pipe. The Bottom of cross braces in 1998 video, were a foot or more above lake bottom. From this point inward to were pipeline is buried, there was a significant amount of silting in and filling of the lake bottom since the 1984 video was made.

Bent No. 40: The cross timbers in this bent were smaller dimension also, similar to bent No. 39 and were cut to form a cradle. They also were at different elevations to each other and extended from one side to the other side of the bent. In the 1984 video the braces were just above lake bottom. In the 1998 video, they were partly buried in lake bottom. We did not get a good view of this bent in the1998 video because silt stirred up. However, the diver did say the braces were touching pipe.

Between bents No. 40 and No. 41 there is a flanged connection in the pipeline, it is similar to the flange connection previous noted in this review and appeared to be in good condition.

Bent No. 41: This was the first bent offshore inspected in the 1998 inspection, it was of similar construction to bent No. 40, but the cross braces have failed since the 1984 inspection. They have flipped over up side down and are giving no support to the pipeline. The East cross brace is pulled off the pile. Some remedial work is needed here. The 1984 inspection showed this bent supporting the pipe and in good condition.

Bent No. 42: This bent in the 1984 video showed the pipe resting on a concrete saddle, resting on the East cross brace, and no band or strap holding the saddle to the pipe. The saddle was just off center on the brace. If it is still in this position, it should be banded to the pipe. There are stainless steel bands around the pipe, to reinforce the original strapping around the pipe along this inshore section of the pipeline. In the 1984 video several concrete saddles were noted along this section of the line sitting on the lake bottom below the pipe and unattached to the pipe. In the 1998 video these appeared to be covered by the silt and lake bottom mud.

There have been concrete saddles in between most of the bents from the East end of the pipeline into this point, There may be some missing, but we could not see due to the video camera passing above them in the 1998 inspection. They were more noticeable in the 1984 inspection as the diver moved along the lake bottom along side the pipeline.

Bent No. 43: In the 1984 inspection the pipe was resting on the East cross brace, we are not sure if it is touching on the West brace as it was covered in the mud of the lake bottom which sloped up quickly, west of the bent. In the 1998 inspection, the cross bracing is covered by the bottom mud. A concrete saddle under the pipe just a short way to the East of the bent was partly buried in the silt of the lake bottom. It was not clear if it if it was strapped to the pipe or providing any support.

Bent No. 44: This is the last bent before the pipeline becomes completely buried in the lake bottom. In the 1984 inspection the cross members were covered and the mud line was just below the springline of the pipeline. In the 1998 inspection the mud line is well above the springline.

This completes our notes made from all the videos and drawing submitted for our review and evaluation.

Appendix K – Photographs from 1998 Video Inspection of Intake Pipeline


OVERSIZE LOAD

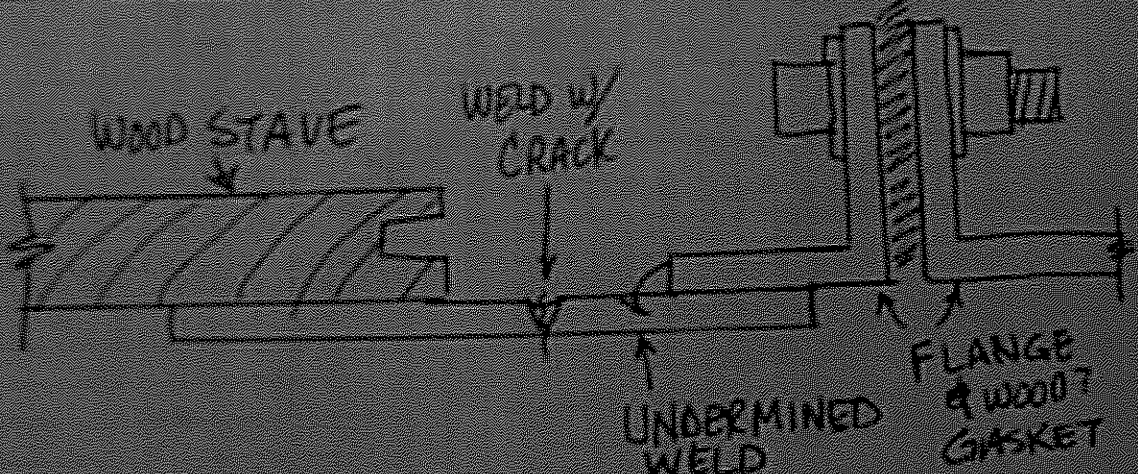

BIRCH

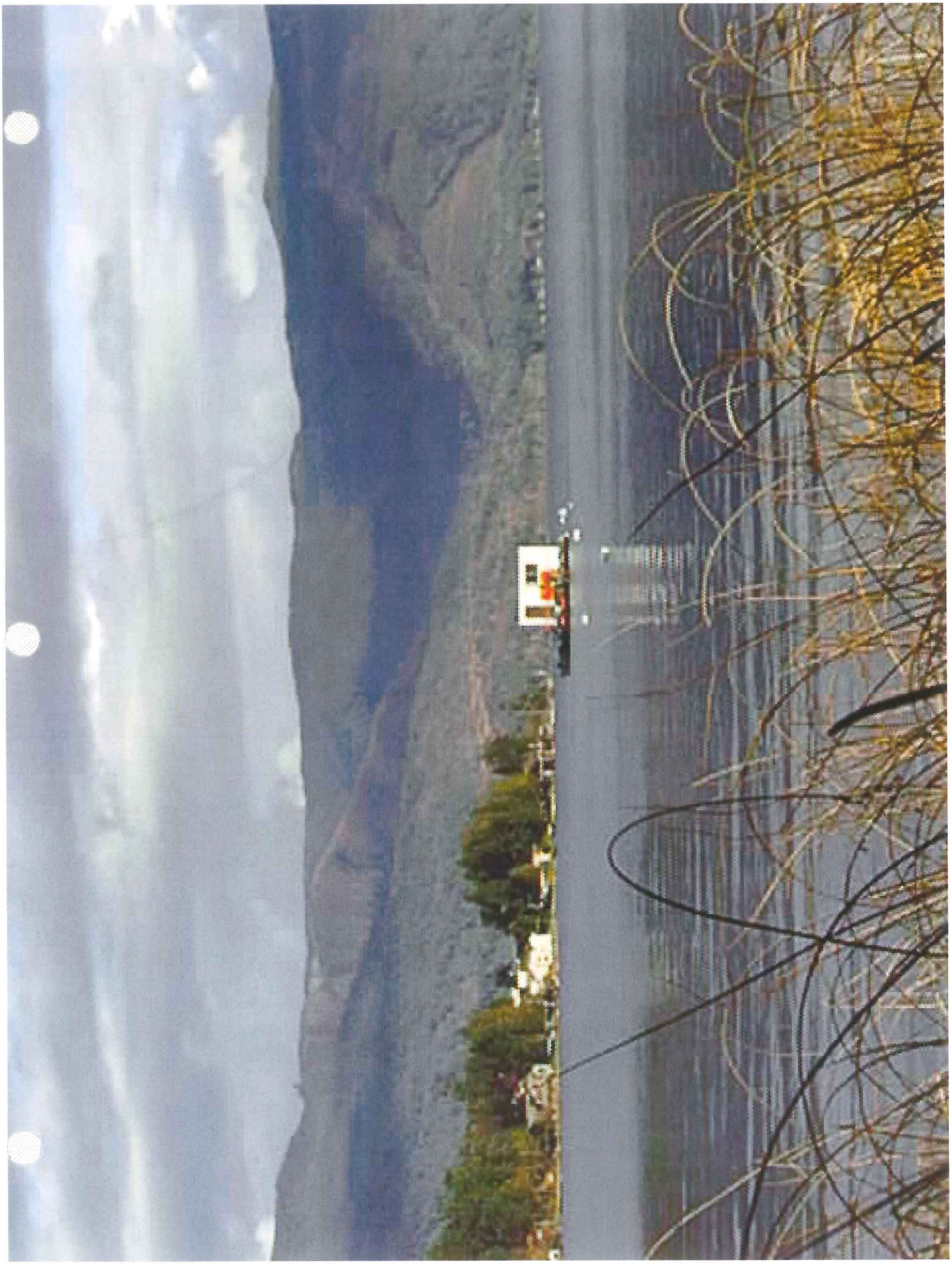
CALCULATION SHEET

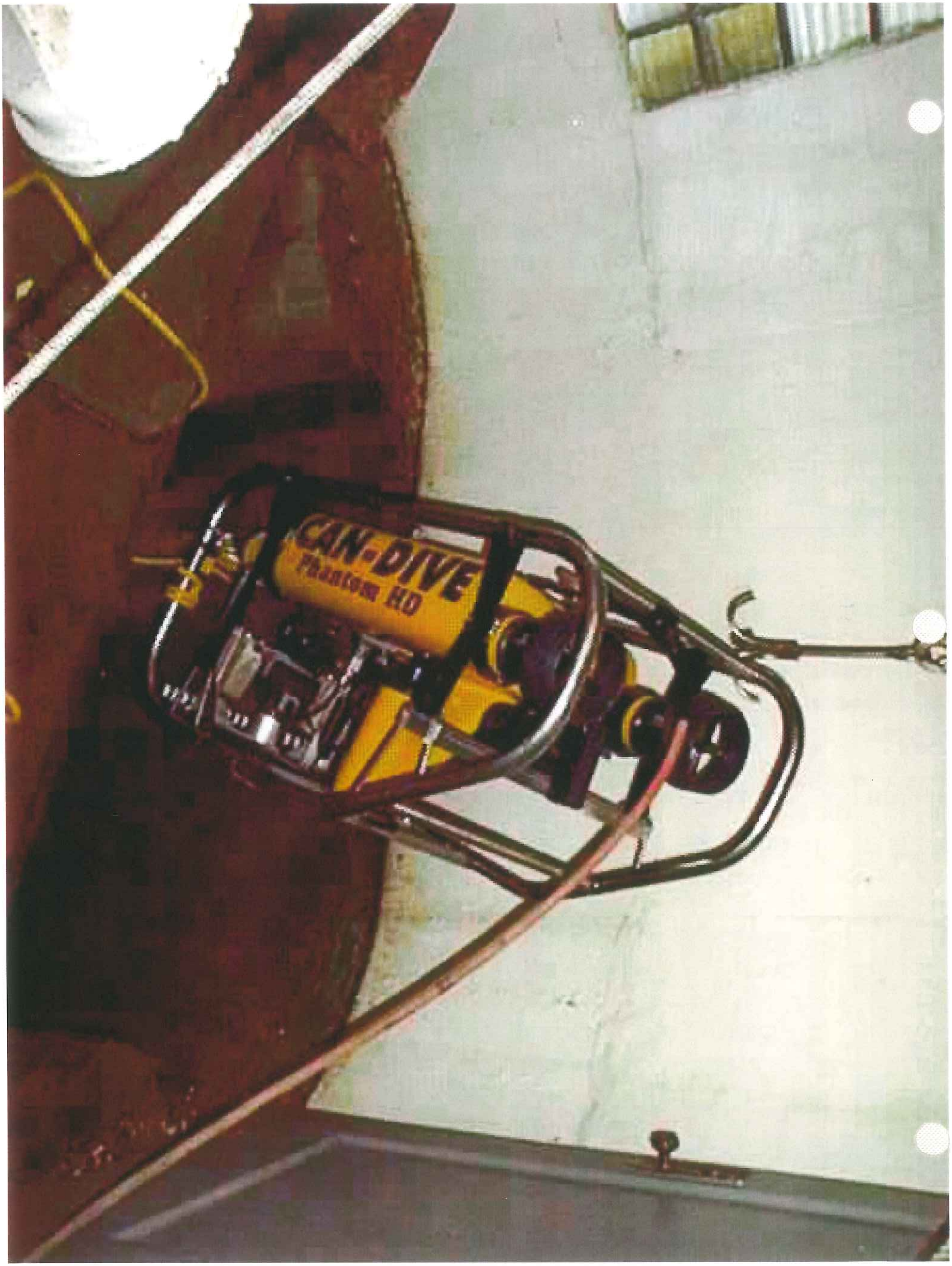
PROJECT ______________________ PROJ. NO. __________

DESCRIPTION __________________ DATE __________

CALCS. BY __________ CHECKED BY __________ PAGE _____ OF _____



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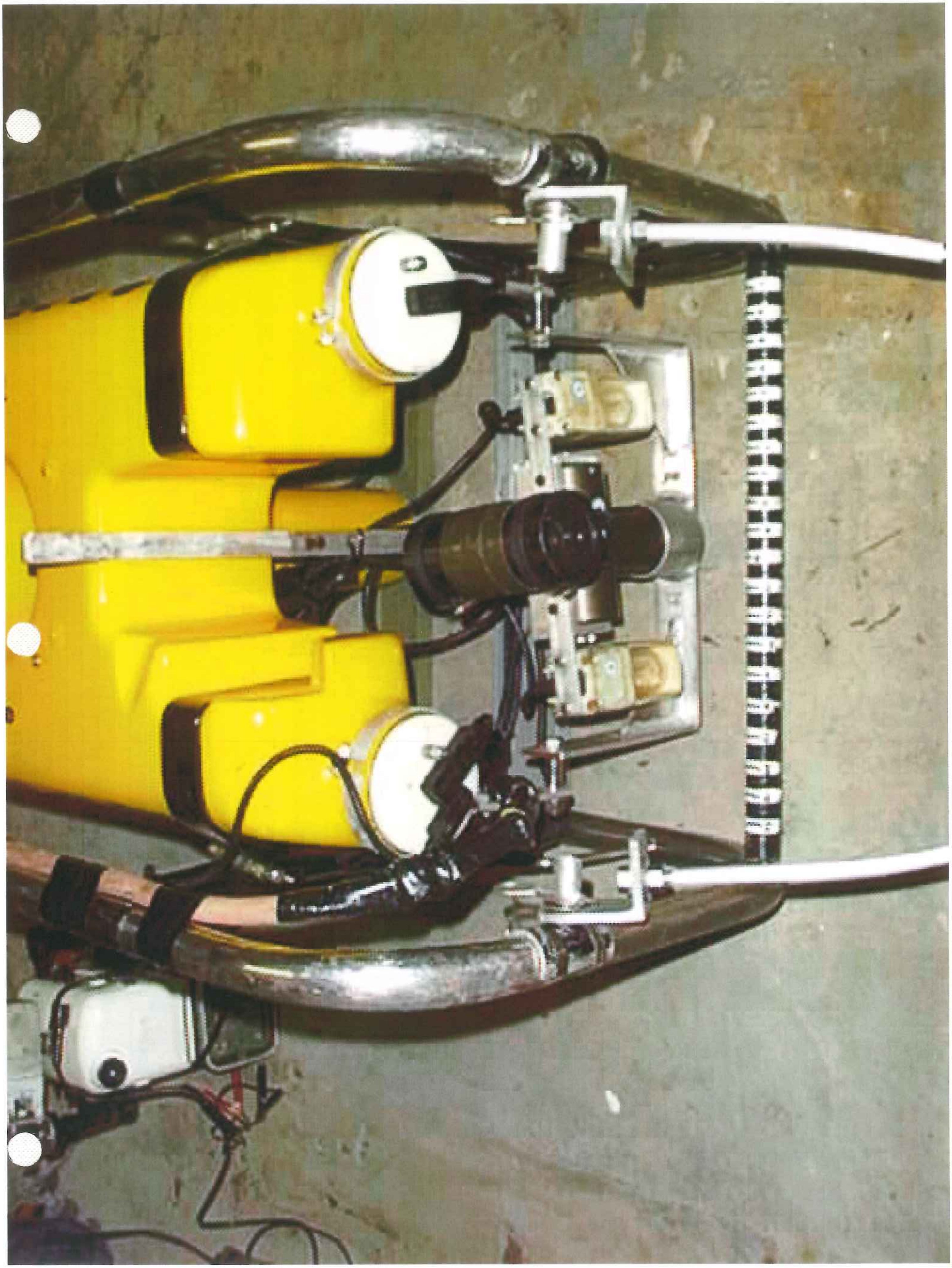
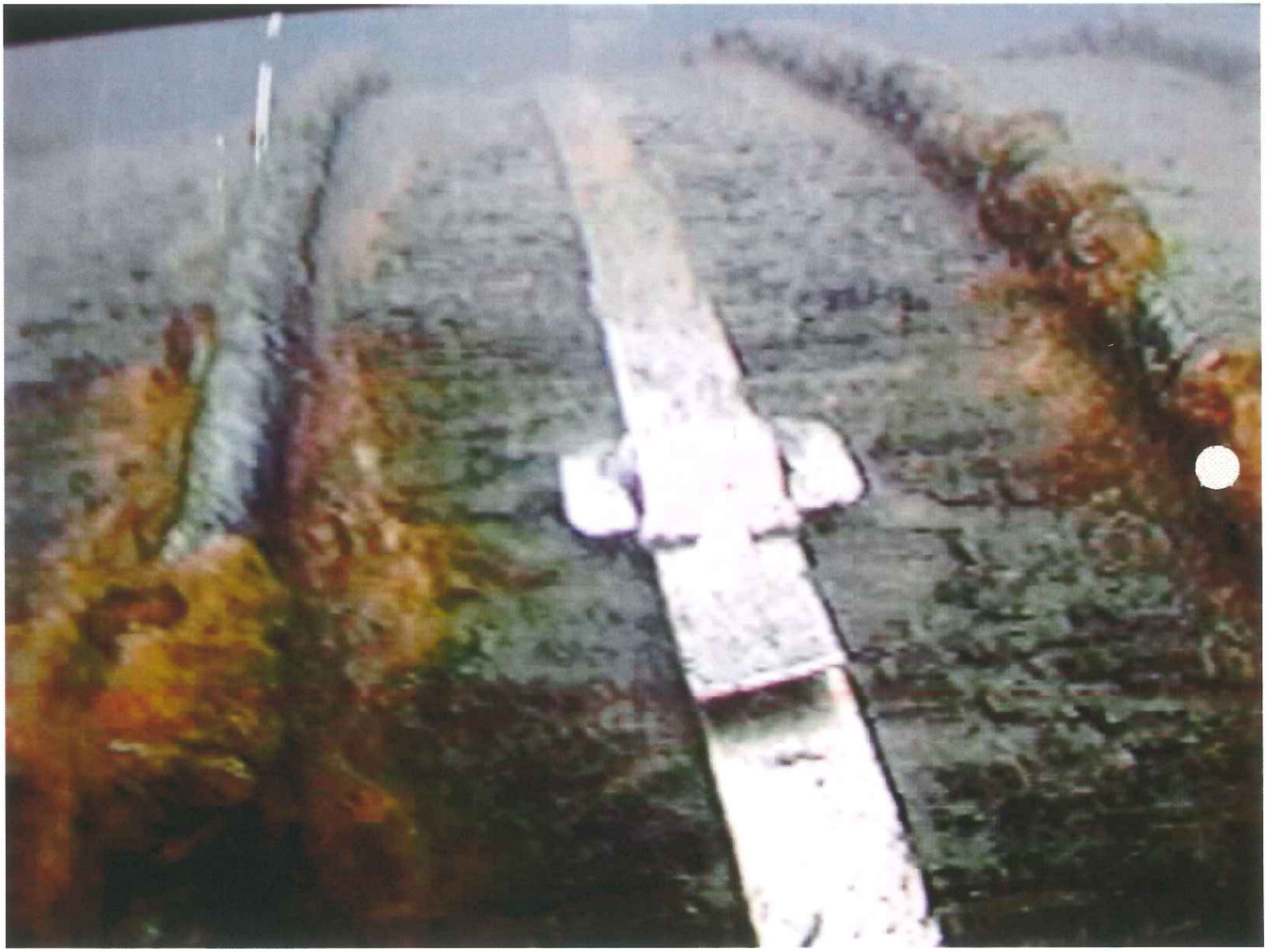
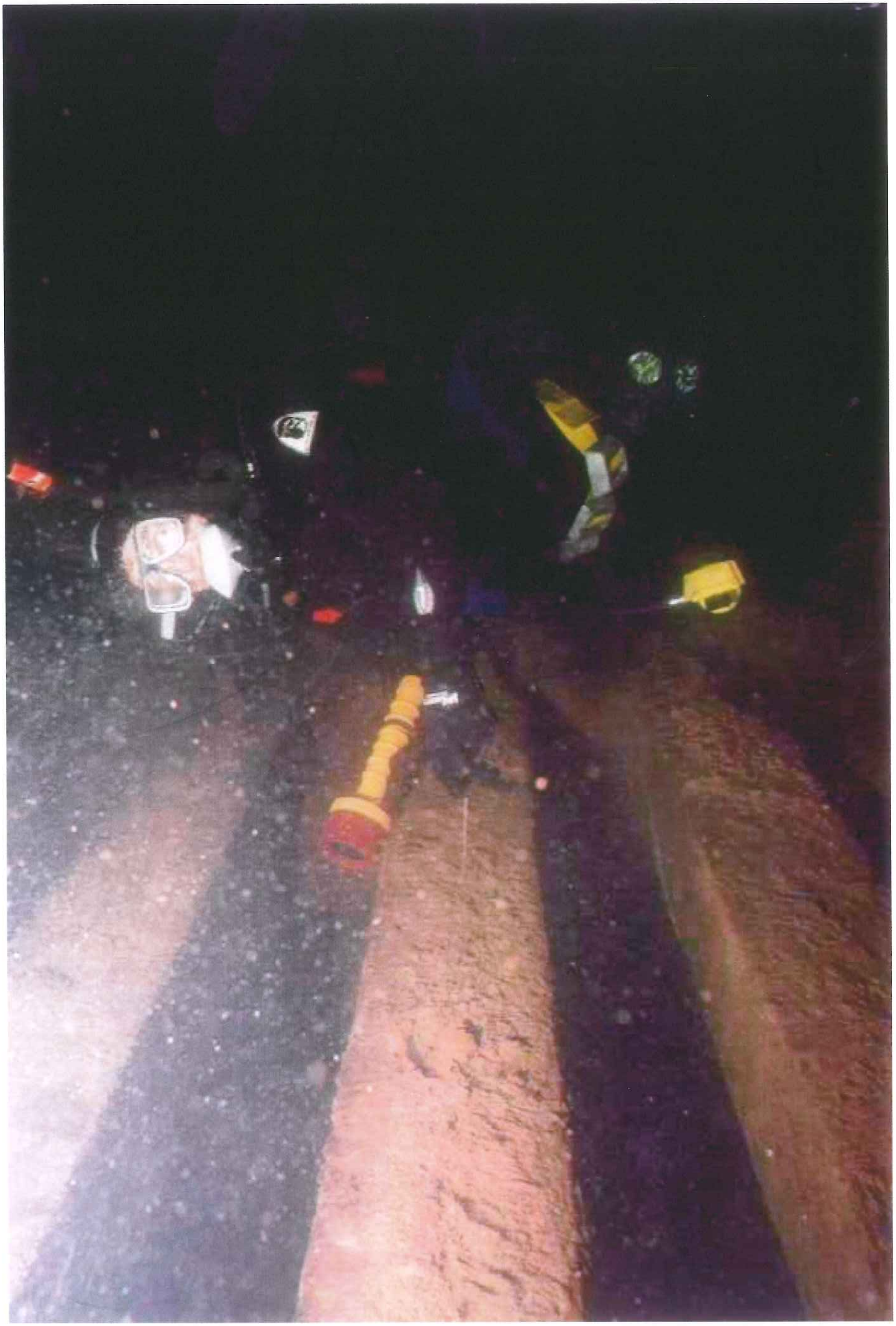
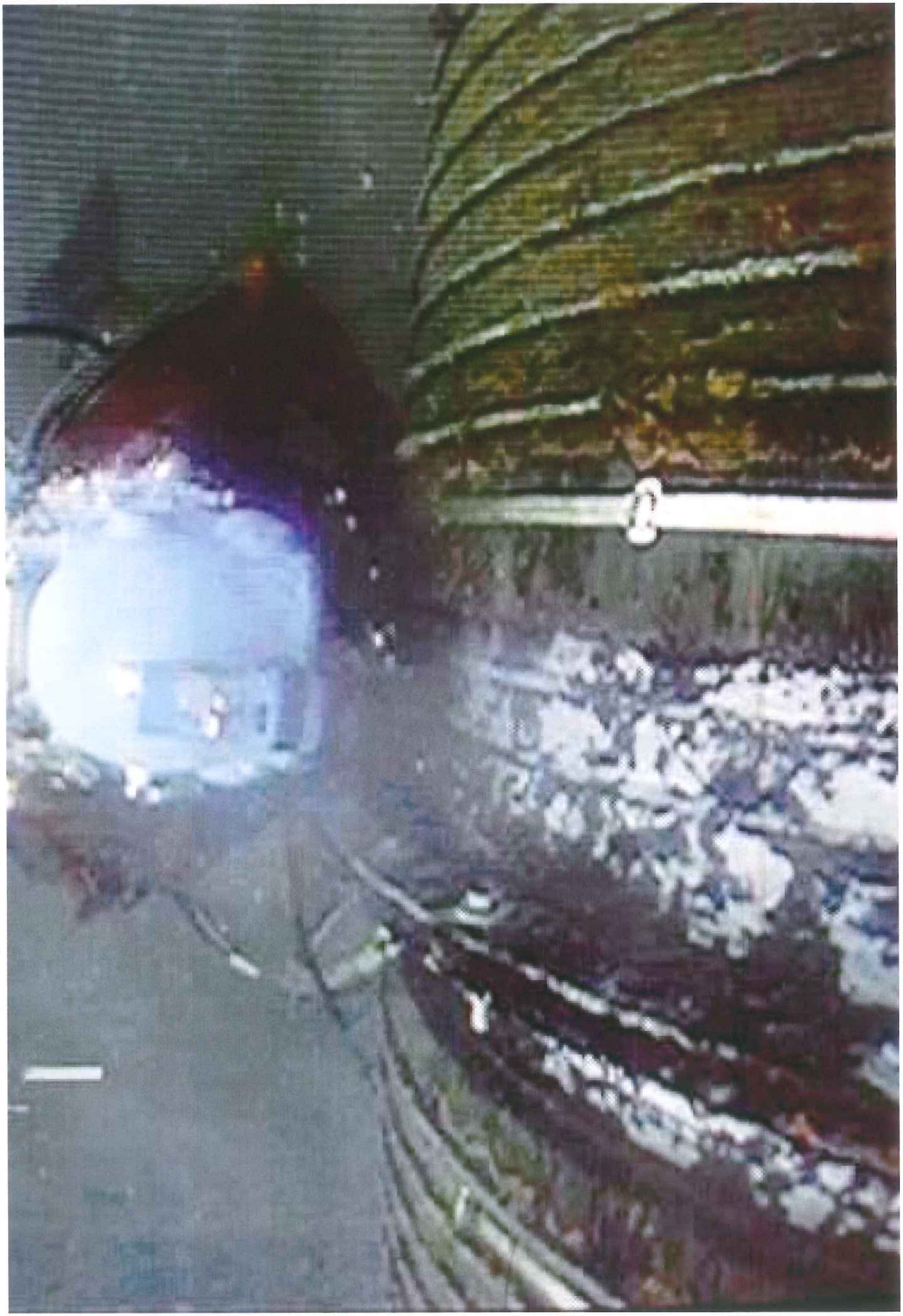
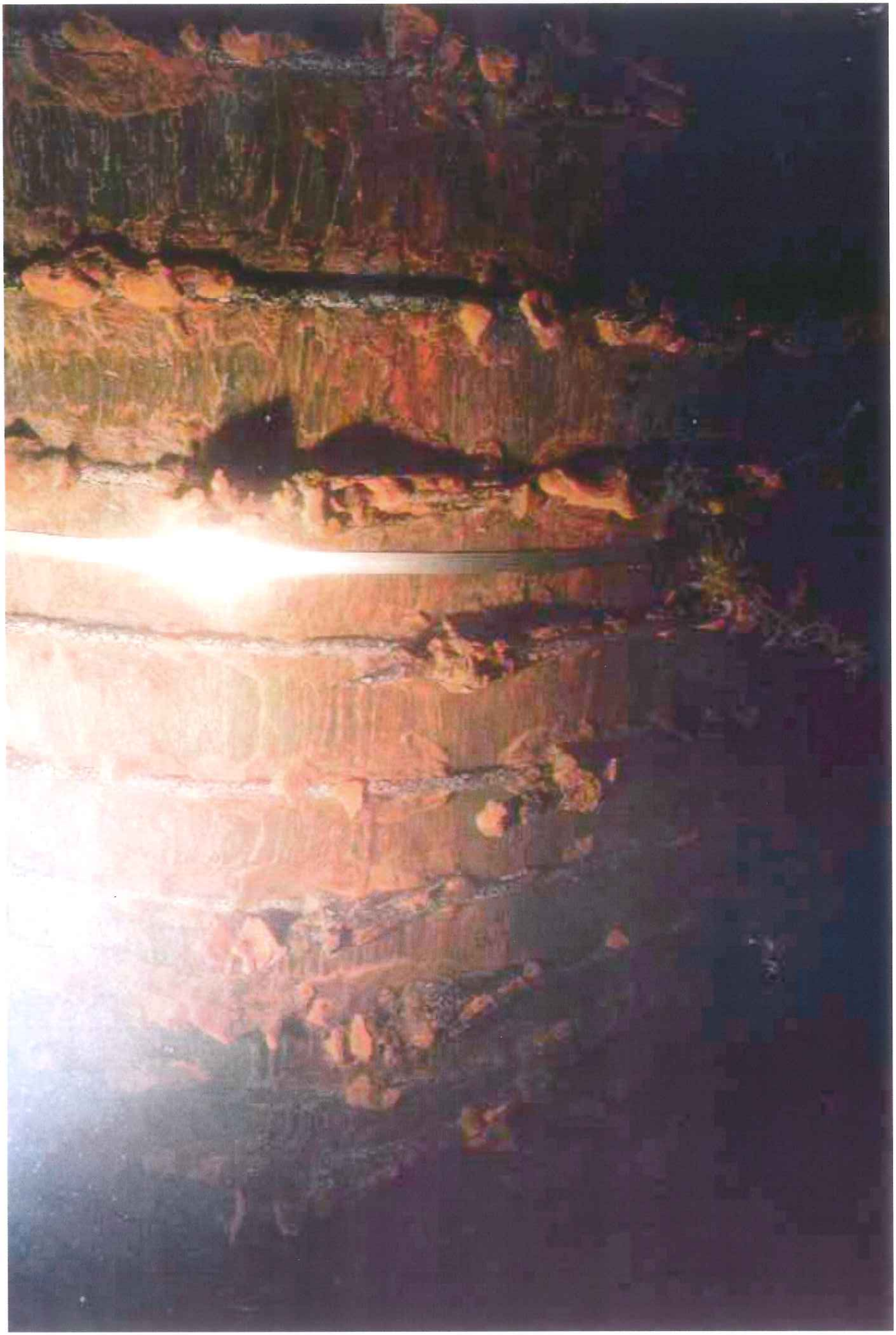
Phantom HD

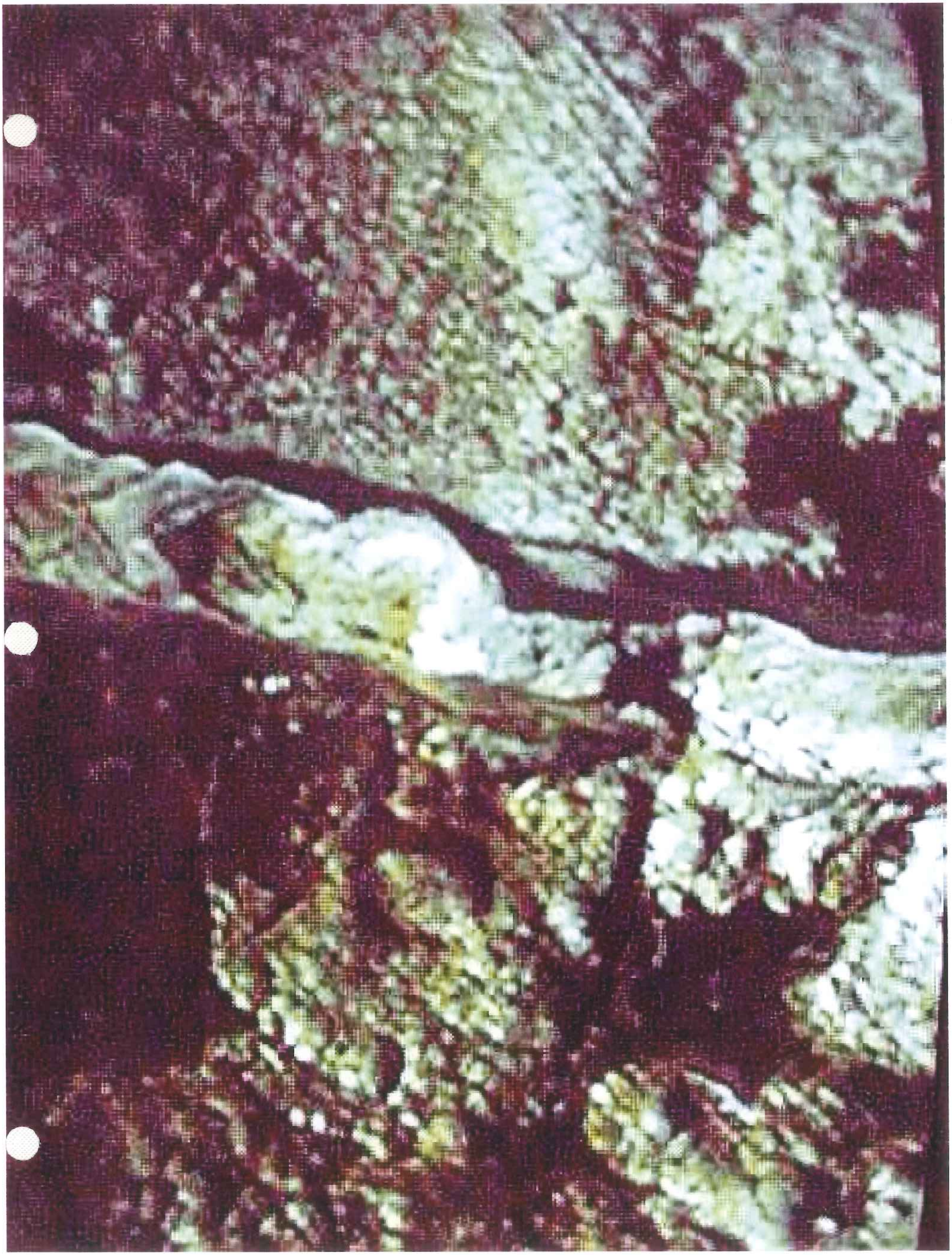


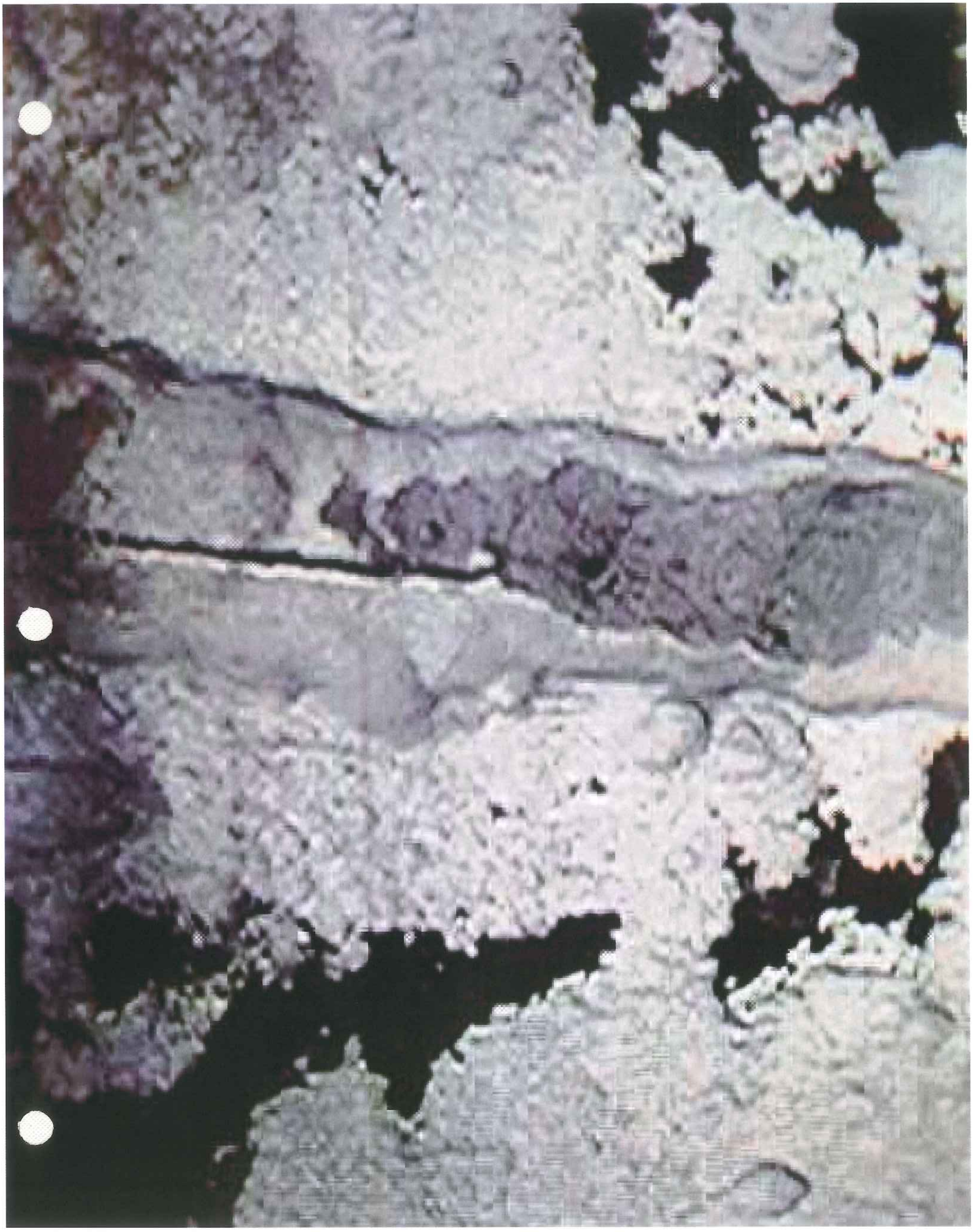


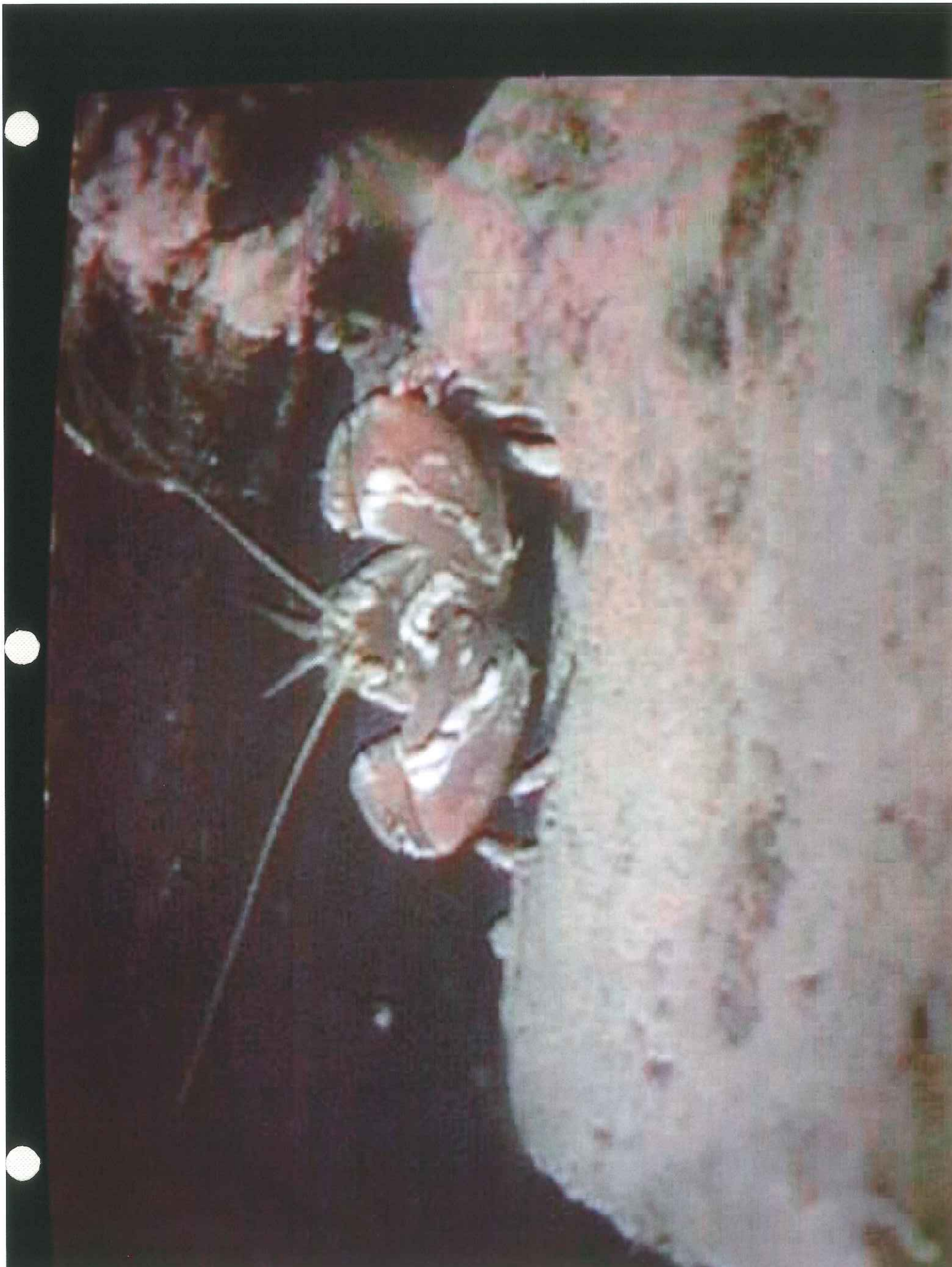


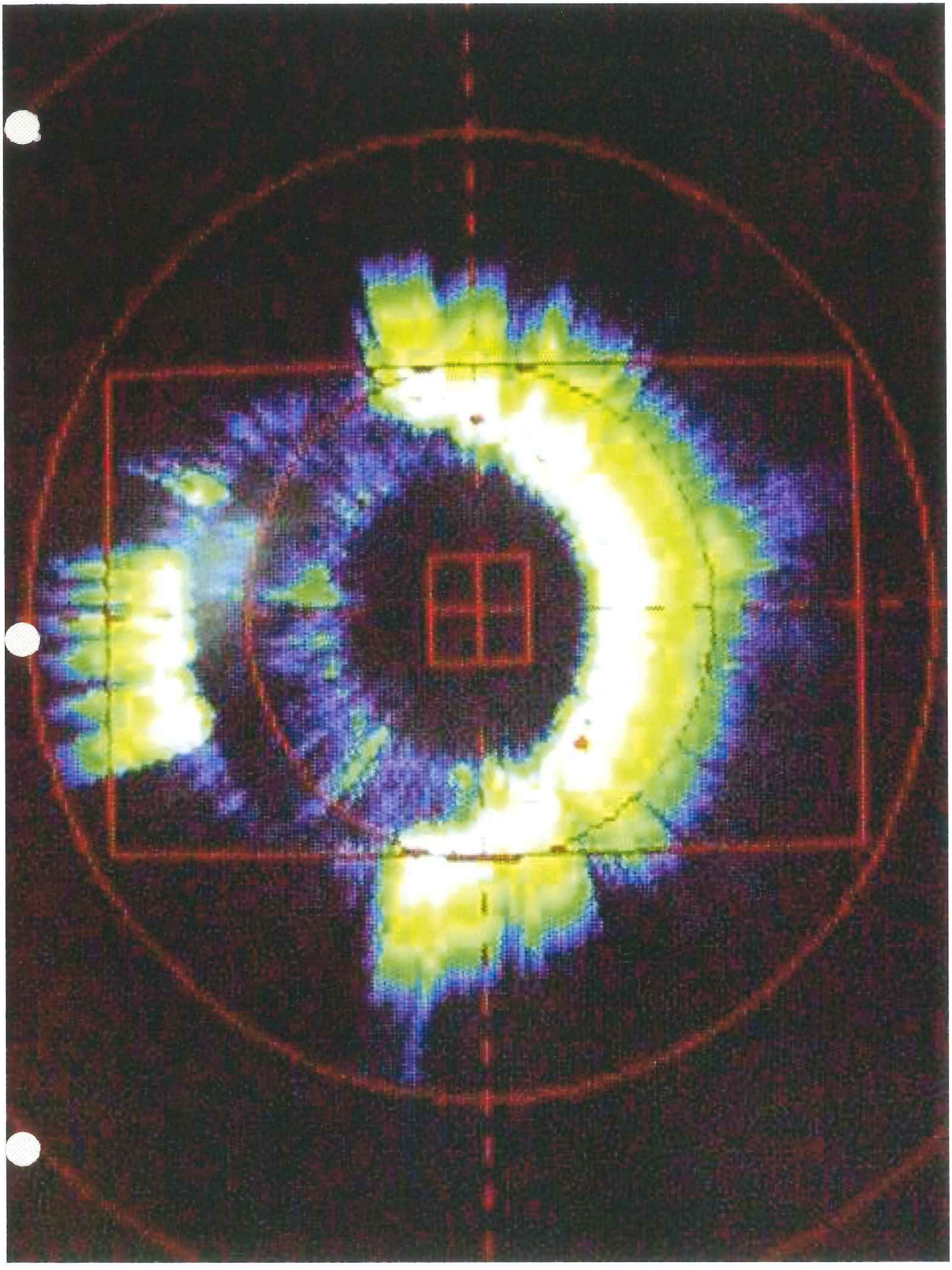


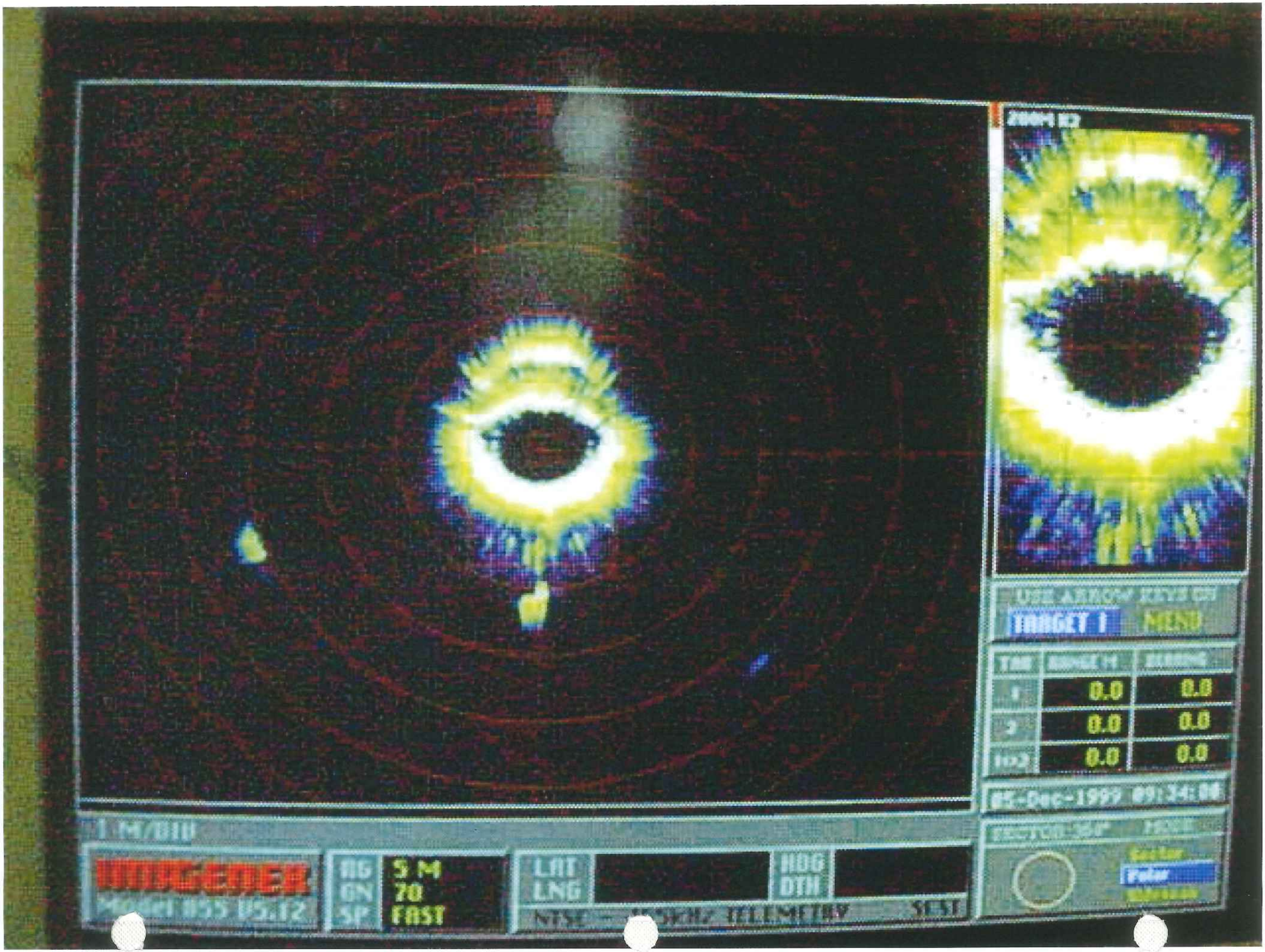








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SP
FAST
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HDG
DTH
TELEMETRY
SEST