Acoustic Imaging System

SP&R Part II, 775 Project# RB24-014

January 2020

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Bridges and Structures Bureau

TECHNICAL REPORT DOCUMENTATION PAGE

<table>
<tr><td>1. Report No.
RB24-014</td><td>2. Government Accession No.</td><td>3. Recipient’s Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
Acoustic Imaging System</td><td>5. Report Date
January 2020</td></tr>
<tr><td>6. Performing Organization Code:</td></tr>
<tr><td colspan="2">7. Author(s)
Michael Todsen</td><td>8. Performing Organization Report No.</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
Iowa Department of Transportation
800 Lincoln Way
Ames, IA 50010</td><td>10. Work Unit No.</td></tr>
<tr><td>11. Contract or Grant No.</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
Iowa Department of Transportation
Research and Analytics Bureau
800 Lincoln Way
Ames, IA 50010

Federal Highway Administration
U.S. Department of Transportation
1200 New Jersey Avenue SE
Washington, DC 20590</td><td>13. Type of Report and Period</td></tr>
<tr><td>14. Sponsoring Agency Code
RB24-014</td></tr>
<tr><td colspan="3">15. Supplementary Notes</td></tr>
</table>

16. Abstract

The inspection of bridges is an important component in maintaining a safe and efficient highway system. Portions of bridges underwater can be difficult to inspect due to lack of visibility and accessibility. Traditionally underwater inspections are performed using commercial diving operations. This requires specially trained individuals and the appropriate equipment. Additionally, poor visibility, accumulated debris and currents can adversely affect the quality of the inspection as well as pose safety hazards for the diver. Recent advances in the capabilities of sonar equipment have presented the possibility for alternatives to using divers. To better understand the capabilities of the sonar systems, a Kongsberg high resolution scanning sonar was evaluated for practicality and effectiveness in inspecting bridges.

The goal of this evaluation was to determine if state bridge inspection personnel, with appropriate training, could utilize this equipment to provide information that is beneficial in the evaluation of underwater portions of bridges. To achieve this, staff were trained in the equipment operation and bridges were selected for inspection. The inspection findings were evaluated for their ability to assist in the overall bridge inspection.

The system will provide insight to the underwater conditions that are not always possible with divers. It provides information that makes understanding the underwater conditions easier to explain, understand and document. The images can be collected in conditions that would make diving difficult due to low visibility or hazardous conditions. In addition, it can help in planning dive operations and identify location where divers need to concentrate efforts.

<table>
<tr><td colspan="2">17. Key Words
Bridges, Inspection equipment, Sonar</td><td colspan="2">18. Distribution Statement
No restrictions.</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified</td><td>20. Security Classif. (of this page) Unclassified</td><td>21. No. of Pages
11</td><td>22. Price</td></tr>
</table>

Background

The inspection of bridges is an important component in maintaining a safe and efficient highway system. Portions of bridges underwater can be difficult to inspect due to lack of visibility and accessibility. Traditionally underwater inspections are performed using commercial diving operations. This requires specially trained individuals and the appropriate equipment. Additionally, poor visibility, accumulated debris and currents can adversely affect the quality of the inspection as well as pose safety hazards for the diver. Recent advances in the capabilities of sonar equipment have presented the possibility for alternatives to using divers. To better understand the capabilities of the sonar systems, a Kongsberg high resolution scanning sonar was evaluated for practicality and effectiveness in inspecting bridges.

Equipment

After reviewing the available sonar systems, the Kongsberg system was selected based on capabilities and cost. The system evaluated included the following components:

- Kongsberg MS1000 sonar processor software with 3D profiling option and remote keypad
- Kongsberg 1171 series high resolution scanning sonar head with variable frequency fan and cone transducers and interface unit
- Kongsberg sonar head rotator and interface unit
- Kongsberg sonar tripod and pole mounts
- Kongsberg system cables and transport cases
- Ruggedized laptop
- 1000w generator

Evaluation Procedure

The goal of this evaluation was to determine if state bridge inspection personnel, with appropriate training, could utilize this equipment to provide information that is beneficial in the evaluation of underwater portions of bridges. To achieve this, staff were trained in the equipment operation and bridges were selected for inspection. The inspection findings were evaluated for their ability to assist in the overall bridge inspection.

Evaluation

The sonar head is designed for deep water use and is well sealed. The head must be handled with some care though as it is relatively sensitive to physical damage. The transducers themselves are fully exposed to produce the clearest signal. This leaves them susceptible to physical damage and appropriate care must be taken while using the equipment. The sonar head is connected to an interface unit that in turn is connected to the computer with the operating software through a USB cable. The interface unit is intended for a rack mount and is not water resistant. Care must be taken to keep the interface unit dry as it is most often used on or near the water.

The sonar head has two transducers, a linear transducer that produces a fan shaped beam and a circular transducer that produces a narrow cone shaped beam. These transducers are mounted in a rotating head, controlled by a servo. When multiple reflections are collected, the linear transducer produces image like results. This is accomplished by holding the sonar head still while the transducers pivots.

The system included a second rotator and interface unit. This allows the creation of a 3-D point cloud by rotating the entire sonar head on a second axis. While this capability can be very desirable in the inspection of bridges and the evaluation of the streambed, the time required to perform the scan needs to be considered when planning work. A complete detailed scan can take several hours to collect dependent on the density of the scan pattern. If a low point cloud density scan is acceptable, the collection time is significantly reduced.

The sonar system does not have an internal GPS (global position system) unit or similar positioning ability. Location information can be input from an external source as a text string following NEMA (National Marine Electronics Association) format. This allows for location information to be stored with the sonar data and use of the system for bathometric survey. During the evaluation, data strings from GPS unit built into the laptop computer used with the system and from a Topcon GR-3 GPS receiver were successfully used. The Topcon system provided a higher degree of accuracy but requires additional equipment and configuration.

The key to collecting good images is holding the sonar head still. This can also be the biggest challenge. Initial attempts were made collecting images with the system mounted on a 16’ jon boat. This allowed for the transducer to be placed such that it makes a scan of the face of a pier. The motion of the boat from waves and wind made it difficult to collect quality images. Ongoing work will use a larger boat which should provide improved stability and imagery.

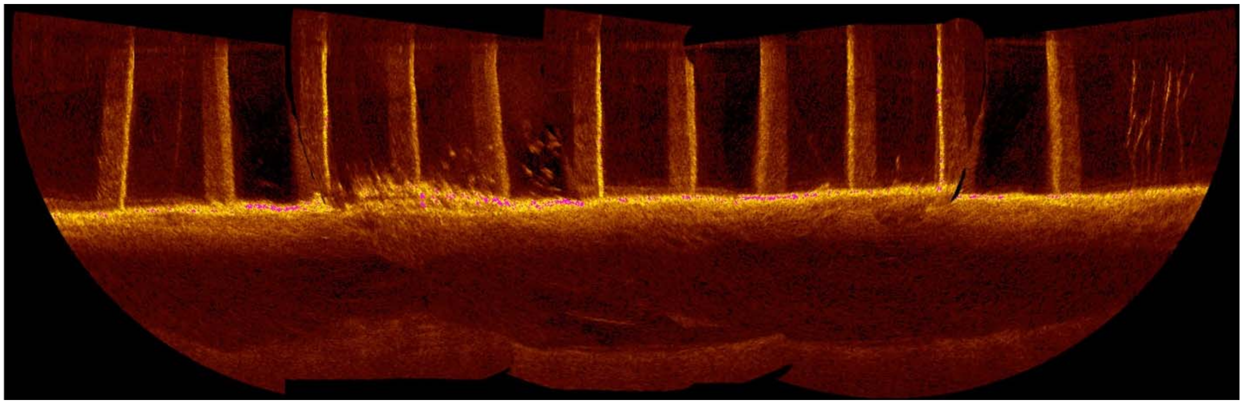

Figure 1

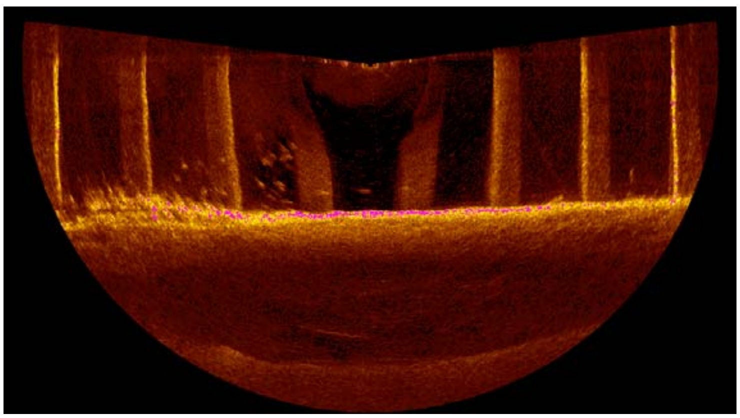

Figure 2

Figures 1 and 2 were collected at Bridge 8838.4S025. The scans were made for the purpose of reviewing the pile bent condition. Figure 1 is a mosaic of three scans. Figure 2 is the center scan of the three. Note the distortion near sonar head. This is typical of all scans and must be considered when planning the work. Four scans of this location would have provided for increased overlap and an improved mosaic image. When combining scans into one mosaic, it is important to have adequate reference points in the individual scans to provide for accurate placement in the mosaic. This location would have benefited from the inclusion of artificial reference points.

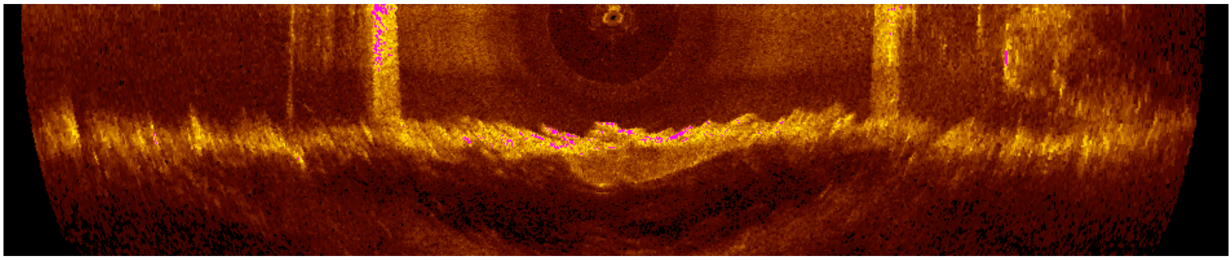

Figure 3

Figure 3 was collected at Bridge 0342.5S076. The scan shows the face of a wall pier. Flood debris is on right.

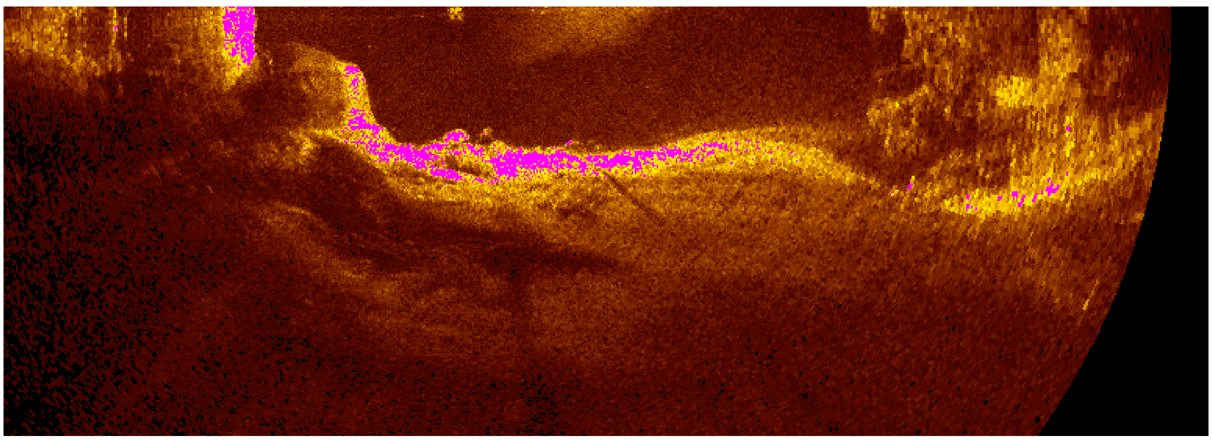

Figure 4

Figure 4 was collected at Bridge 0308.8S026. The image is parallel to bridge. Pier shown on left, flood debris shown on right. The scan was used to verify streambed profile. Stream bed depths were measured utilizing tools included in the scanning software.

The system also includes a tripod mount for scanning stream bottoms. In areas with low current, this provided a good scan of the bottom. For most locations, several scans must be collected and combined to form a mosaic image. Examples of these scans are shown below.

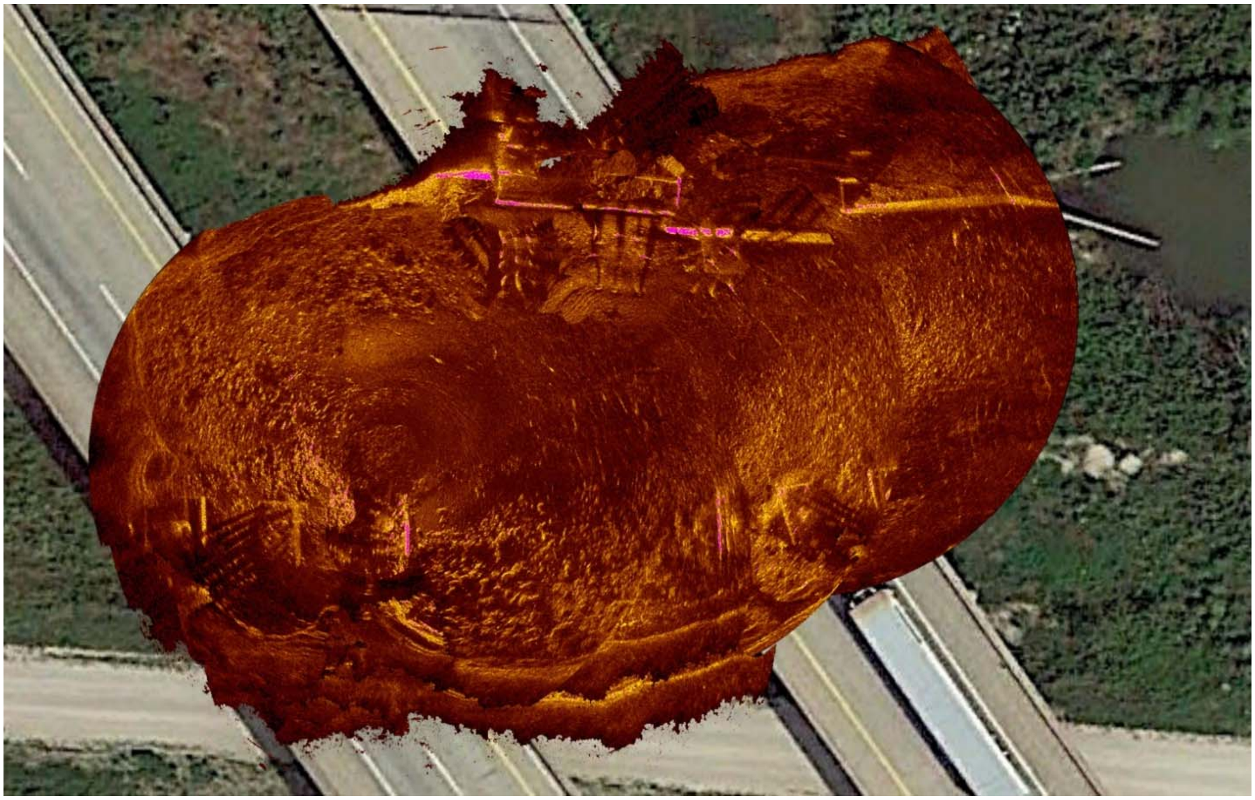

Figure 5

Figure 5 shows scour conditions at bridges 3608.5L/R029. The scan was made during flooding of the area to identify scour damage. Exposed pier pile caps with shadows from exposed piling are visible on the lower end of both bridges. Exposed piling below the pile caps are visible on the upper end of the right bridge. A box culvert that was exposed and shifted as a result of the scour is visible below the upper end of the right bridge. Overlapping of the images allowed for covering the small blind areas directly beneath the sonar head.

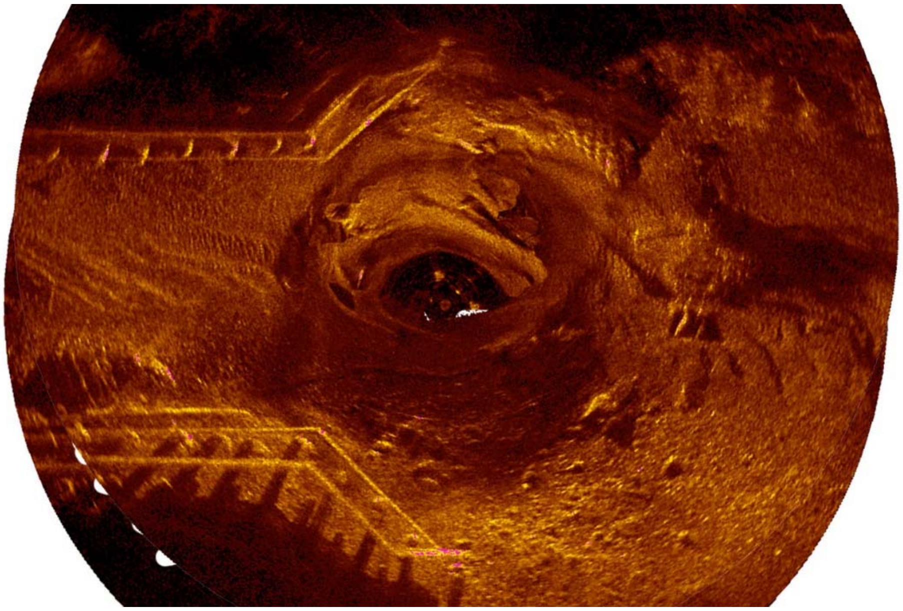

Figure 6

Figure 6 shows scour conditions at bridge 5722.3S151. The scan was made following a flash flood. Exposed piling at both abutments are visible. Scour extending behind the lower abutment is also visible.

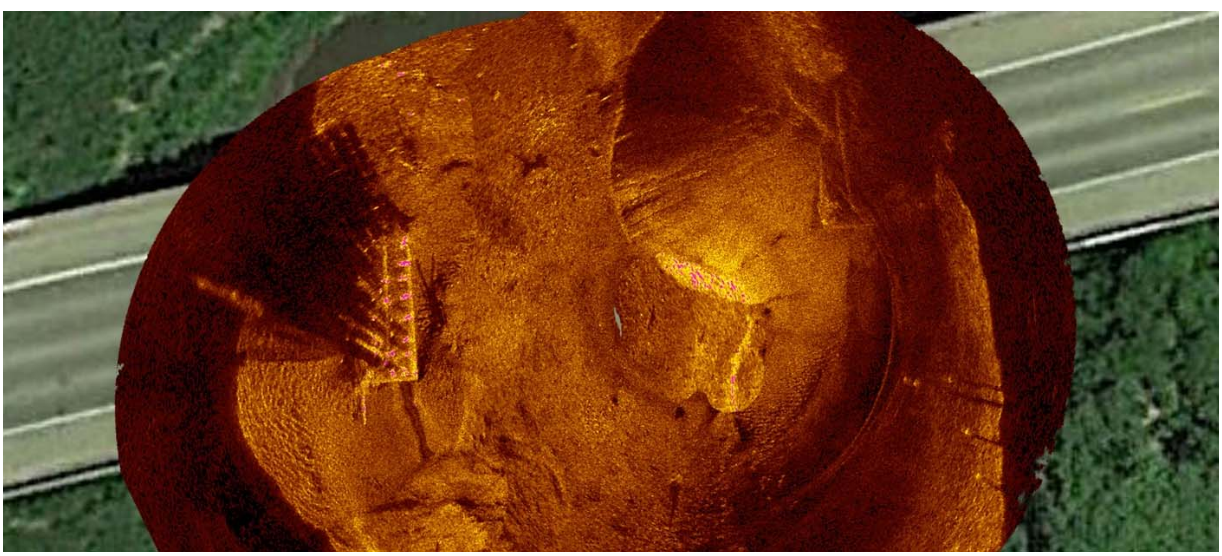

Figure 7

Figure 7 shows scour conditions at bridge 7058.9S022. Scanning was used to identify scour damage following flooding. An exposed pile cap and underlying pile are visible on the left. An exposed pile cap is visible on the right. Exposed abandoned piling from a previous bridge are visible in the lower right.

The system controls allow for adjustment of the frequency, range, scan speed, gain and beam type. The combination of these can be adjusted to provide the optimum output for a given situation. For the scans shown a high frequency, medium range and slow scan speed were used to produce a high-resolution image. The gain is adjusted to provide the greatest detail without excessive signal clipping. The pink areas on the scans identify locations where the signal was clipped. Several color pallets are available for the images. Selection of the color pallet is primarily a matter of user preference.

Conclusions

Overall the system works well for the intended purpose, collecting images of underwater conditions. The water clarity has a minor effect on the image quality, allowing for image collections where water conditions make visual imagery impossible. The system interface allows for considerable adjustment to maximize the quality of the images. While this is necessary to achieve the best quality images and provide for flexibility in application it does result in a significant learning curve for proper operation. In order to maximize the potential of the system and achieve the best results, the operator must have a comprehension of theory behind the technology and successful deployment methods. The book Echoes and Images by Mark W. Atherton provides a good basis for understanding the system and should be included in operator training.

Output from the system can be saved as bitmap images. A separate image editing program is necessary to combine or otherwise manipulate the imagery. Additional training may be necessary to utilize the image editing software. The addition of a background image can be beneficial by placing the underwater image in context and provide for an improved viewer understanding.

Understanding the imagery can take a little getting used to. With a good understanding of how the system works the understanding of the imagery is straightforward. For those without this understanding it may be necessary to provide additional explanation.

The system will provide insight to the underwater conditions that are not always possible with divers. It provides information that makes understanding the underwater conditions easier to explain, understand and document. The images can be collected in conditions that would make diving difficult due to low visibility or hazardous conditions. In addition, it can help in planning dive operations and identify location where divers need to concentrate efforts.

Future Work

A larger boat is now available for use when operating the system. Work will be done to develop a deployment system to use in the larger boat. This will improve our ability to utilize the system on bridges crossing larger bodies of water.

References

Echoes and Images, Mark W. Atherton, 2011