Cold Region Pedestrian Bridge Prototype Maintenance Plan

By

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Approval of Submission

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<u>Table of Contents</u>

List of Figures

List of Tables

Page

List of Appendices

Page

Chapter 1: Introduction

In recent years there have been several failures of pedestrian bridges in the network of trails maintained by the Municipality of Anchorage (MOA), Parks and Recreation Department, causing the MOA to realize that they need to develop and maintain a bridge maintenance protocol. This project, the Cold Region Pedestrian Bridge Prototype Maintenance Plan, provides a prototype application and platform created to allow the MOA to obtain and utilize information collected by non-engineer workers to report on the condition of various pedestrian bridges ("Prototype Platform").

The Prototype Platform has three major components: the Bridge Inspection Application (BIA), a Bridge Risk Evaluation program (BRE), and the determination of Bridge Risk Categories (BRC). These three components will help the MOA to record bridge condition information, identify safety conditions that need to be addressed, classify the condition of the pedestrian bridges, group them into one of several broad risk categories, and provide the MOA with a way of accessing this information in a more organized manner.

This project will provide information about the background of the MOA pedestrian bridges, their importance to the MOA, and prior work done relating to pedestrian bridge inspection approaches. It will also provide detailed information about components of the Prototype Platform, the testing of the components, and recommendations for the future.

This project is an overall asset management tool that will help the MOA identify future potential risks on their pedestrian bridge system. The MOA intends to use this data in conjunction with more detailed reports to provide an overall condition assessment for the pedestrian bridges in Anchorage, Alaska. It is understood by all parties that the Prototype Platform is a first step in a broader effort to create a more robust pedestrian bridge maintenance management plan. The fact that the inspection data will be obtained by non-engineer field workers, and is somewhat simplistic and limited as to its content, makes the results from the field inspection data only a place to start. However, given the very real budget constraints and limited resources available to the MOA, the Prototype Platform gives the MOA a way to make meaningful progress in implementing a maintenance protocol. The BIA should be used annually as part of a routine review of pedestrian bridges. However, routine inspections conducted using the application should not replace full inspections and full structural analysis reports that can only be conducted by a professional structural engineer when needed.

Chapter 2: Background

2.1 Background Regarding MOA Pedestrian Bridges

The MOA provides the community with outlets for exercise, health, and relaxation by creating, operating, and maintaining parks and recreation centers. As part of the parks and recreation system, the MOA supports a network of over 120 miles of paved multi-use trails, many of which cross creeks, streams, and lagoons, requiring numerous pedestrian bridges. There are over 200 pedestrian bridges in the trail system, which are used by walkers, bikers, and, on occasion, MOA employees operating trail maintenance vehicles. The bridges are made from a variety of different materials and are in various states of disrepair. Some of the bridges are over 40 years old and have never been inspected or repaired (Giraldo, 2017).

An example of the compromised integrity of these bridges can be seen in Figure 1 which shows an accident that occurred due to bridge failure in the North Westchester Lagoon Park. “The North Westchester Lagoon Bridge failed on June 16, 2014, as a truck towing a wood chipper crossed the bridge” (Andrews, 2014). This 70-foot bridge was built in 1987 to connect downtown Anchorage to North Westchester Lagoon. The bridge was made from two glulam girders spanned by a wooden deck which was supported by wooden ledgers. The bridge failed when a 7,099-lb. truck towing a 7,300-lb. wood chipper attempted to cross.

Figure 1: North Westchester Lagoon Bridge

A failure investigation determined that the failure occurred due to cross-grain tension in the glulam beam stemming from water draining off the deck and penetrating the timber through lag bolts drilled into the glulam beam. The moisture caused decay which led to the failure.

This bridge failure, along with several other bridge failures, alerted the MOA to the possibility that other bridges on the Anchorage trail system might also be decaying and near failure. Since public safety is a primary concern, the MOA is motivated to fix these problems and ensure pedestrian safety.

2.2 Current Problem

The MOA does not currently have a pedestrian bridge inspection protocol or a set of established procedures to follow regarding regular maintenance of their pedestrian bridges. As a result, it is likely that most of the bridges have never been formally inspected since construction. Further, there is no procedure to ensure that action is taken when problems are identified or any effective way to know which bridges have been or need to be inspected or repaired. Given the recent bridge failures, the MOA has determined that the bridges on the Anchorage trail system should be inspected. However, any maintenance protocol would have to consider the limited budget available to the MOA, as well as the time constraints requiring that most bridges can only be inspected in the summer.

The MOA will need a cost-effective way to prioritize which bridges to fix first, based not only on engineering issues but also on budget considerations, as well as a way to keep the information about the condition of the bridges up-to-date. The MOA will need to adopt a continuous comprehensive evaluation scheme that enables the MOA to maintain the functionality of the pedestrian bridges and provide an acceptable safe environment for trail users. Over time, the MOA may also wish to communicate with the public about the condition of the bridges on the trail system and solicit input from the users of the bridges.

Figure 2 provides an example of the workflow and tasks involved in a conceptual bridge maintenance management plan. The boxes outlined in red indicate the components of the Prototype Platform. By looking that these boxes, the reader can see how the Prototype Platform could fit into the workflow relating to a bridge maintenance management plan.

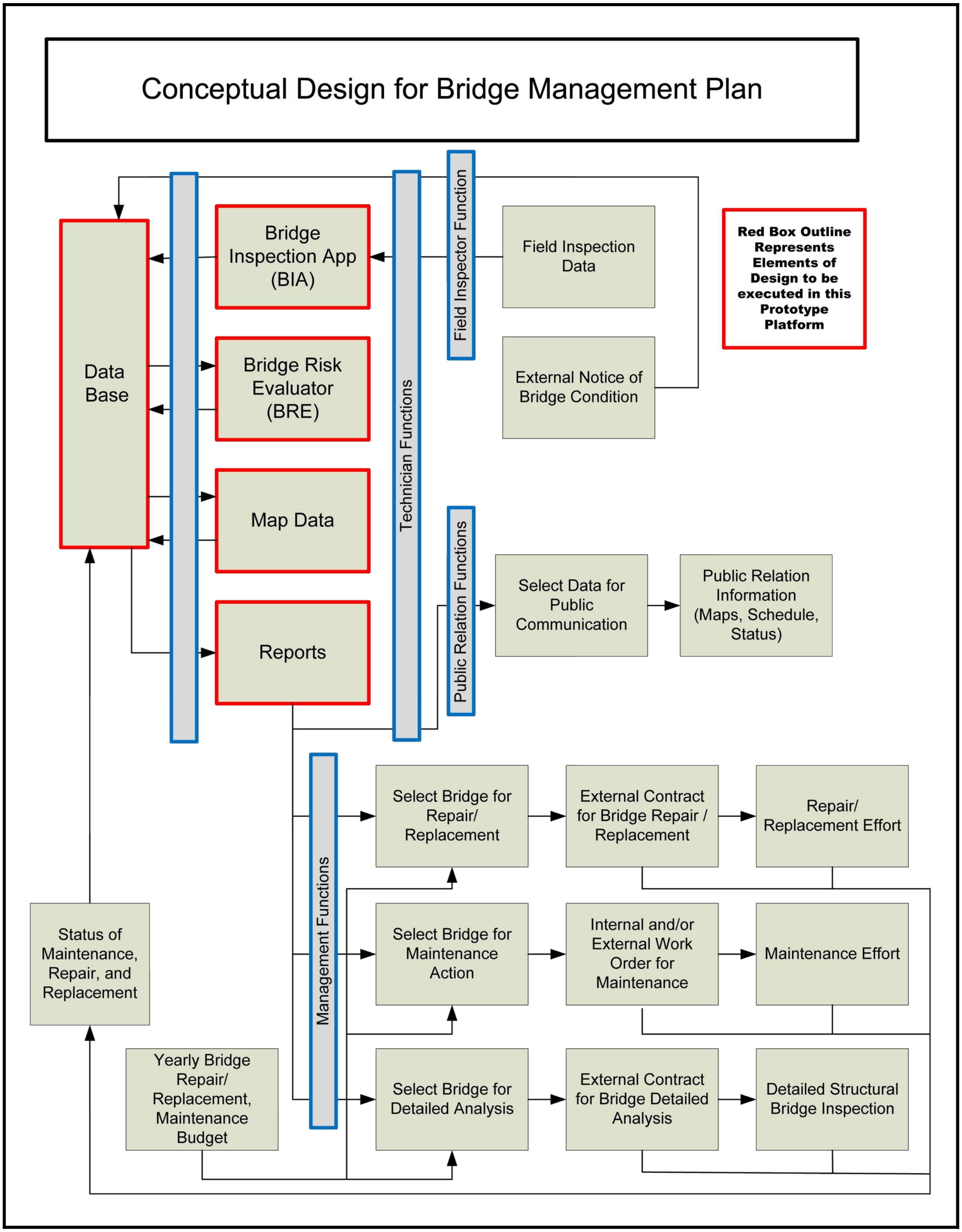

Figure 2: Conceptual Design

2.3 -Previous Work Related to Bridge Maintenance Plan

The MOA has considered multiple different approaches as it seeks to identify an affordable pedestrian bridge maintenance management solution that can give them the relevant information they need in order to prioritize the order of bridge repairs.

Miscellaneous Structural firms: The MOA has hired structural firms to inspect bridges that have failed, but only after the failure has occurred. This approach provides the MOA with information about the reasons for a particular bridge's failure, which may provide insights into potential problem areas for other similar bridges in the system. However, it does not provide them with any assessment information about the condition of other bridges.

MOA Project B, Pedestrian Bridge Inspection Guide and Inspection App ("MOA Project B"): A senior design team, consisting of four civil engineering students at the University of Alaska, Anchorage (UAA), including this author, undertook the project of identifying a possible approach to a bridge maintenance management plan for the MOA. After reviewing several structural code books and guidelines, the team decided to follow the American Association of State Highway and Transportation Officials (AASHTO) guide for pedestrian bridges. (American Association Of State Highway and Tranporation Officals, 2015) The team developed a mobile application ("app") for pedestrian bridge inspections, that followed the AASHTO guidelines and included detailed questions about all significant aspects of bridge design and condition, as well as a detailed manual to accompany the inspection app to explain the types of conditions to look for and how to evaluate the condition of the bridge for input into the app. (Giraldo, 2017)

As part of MOA Project B, the team spent time looking at various structural standards for bridges, including AASHTO and the U.S. Department of Transportation (USDOT) and Federal Highway Administration guidance for inspection of traffic bridges in the National Bridge Inspection Standards (NBIS). Since the NBIS standards are applicable for bridges carrying traffic or other moving loads with an opening of more than 20 feet between abutments under copings or arch spring lines or to culverts over 20 feet in length, the team determined they were not applicable to the pedestrian bridges in Anchorage. However, after this review, the team decided that the AASHTO Guide for the Planning, Design, and Operation of Pedestrian

Facilities, which has standards for all pedestrian facilities in their guide including numerous codes involving the length between the spacing of rails and how often a pedestrian bridge should be inspected, was an appropriate guideline to follow for evaluating pedestrian bridges. (Giraldo, 2017)

As a result of this experience, the team members became very familiar with the structural standards for pedestrian bridges. The team spent time looking at the AASHTO structural standards to determine how to include them in the app and describe them in understandable terms for inclusion in the accompanying user manual. Unfortunately, the level of detail and engineering rigor included in the MOA Project B app was considered too time consuming to complete and beyond the level of expertise and training that the available MOA personnel might have. However, it has served as a very useful base from which to develop the simpler and less specific bridge inspection app that is part of this Prototype Platform.

R&M Inspection: R&M was hired to do a full structural analysis of the pedestrian bridges across Campbell Creek and Chester Creek in Anchorage, AK, which represent about 40 pedestrian bridges. While a full structural analysis and rating of which bridges to repair first would be ideal, given the very real budget limitations facing the MOA, this approach was determined to be too costly by the MOA. In considering affordable alternatives, the MOA has decided that it will not be able to afford to hire this level of detail for all bridges and, instead, will pay qualified structural engineers to analyze only those bridges which are in a highest risk category.

Chapter 3: Project Definition and Goals

3.1 –Project Definition

Recognizing the previous work that had already been done, it seemed critical at the beginning of this project to define the outcomes that were important to the MOA, which is the client for this product. Project definition for the Prototype Platform occurred over several months as part of an interactive process with significant input and feedback from Josh Durand, Park Superintendent of the MOA Parks and Recreation Department and the client representing the MOA. In order to create the Prototype Platform, collaboration included emails, face-to-face meetings, and the submittal of documents for review. The question list and database structure were accepted after modification based on feedback in numerous meetings.

A number of clear project definitions resulted from these meetings. They were:

1. *Developmental Environment:* The selection of the template form was based on the client's preferences, current software in use at the MOA, usability, and a desire to stay current with technology. Any software solution needed to be currently licensed to the MOA or available via open source.
2. *Use of MOA employees as field inspectors:* In an effort to save money and use available resources, the MOA decided to have available maintenance workers act as the field inspectors for the pedestrian bridges. This approach will have the advantage that the existing MOA personnel are familiar with the bridge system and will be visiting the bridges in the normal course of their daily responsibilities. However, the result of this decision is that individuals with no engineering background or training will be conducting the field inspections, which means that the level of engineering detail involved in the inspections will need to be limited to non-engineering vocabulary and explanations. The inspection criteria must also be simple to understand, and the results must be quick to input, and may be subject to the non-objective observations of each individual completing the survey.
3. *Limited and simplified inspection questions:* It was agreed that 25 inspection questions would be developed and included in the BIA and that inspection data would be input using current and available technology. Since the MOA is already using

iPads for daily routine tasks, the iPad iOS was chosen. Questions were selected to provide information on potential health and safety problems as well as visible structural defects that could cause potential problems.

4. *Use of cloud-based geodatabase:* From the completed inspections, a cloud database of the inspection data will be created. The BRE determination will be completed for each bridge based on the inspection data.
5. *Group bridges into one of four risk categories:* Recognizing that the inspection data was limited in its scope, rather than develop a priority list, the BRE determinations will be grouped into four Bridge Risk Categories (BRC): (1) low apparent risk (no action needed), (2) moderate potential risk, (3) high-risk priority, and (4) health and safety. Since health and safety is a high priority for the MOA, it will be separately identified as a stand-alone BRC in addition to the categories showing the levels of risk. The BRC will be included in a report that will be reviewed by the MOA management and used by the MOA to determine which bridges need attention.

3.2 Project Goals

The goal of the Prototype Platform is that it will be the beginning of an ongoing maintenance management protocol. The BIA and the resulting BRC reports are just the start by MOA of an effort to develop and maintain an overall asset management plan for the MOA pedestrian bridges. The BIA will collect simplistic and limited information about the condition of the various pedestrian bridges. This data should be integrated with other databases containing bridge information that could be developed at a later date. It will be necessary to keep the database up-to-date and to develop a maintenance schedule to go with the inspection information. The BIA should be used annually and was designed for use as a routine pedestrian bridge condition assessment tool. Eventually, once all bridges are inspected and maintenance programs are developed, the Prototype Platform would be one part of a larger-scale bridge asset management program at the MOA.

3.3 Inspection Questions

Figure 3 provides a list of the 25 questions included in the BIA. As noted earlier, it was determined that the inspection questions would need to be simple to understand and quick to answer by a MOA employee with no engineering experience or training. These basic questions were developed based on the prior work done in MOA Project B, inspection guidelines in the AASHTO manual, hands-on inspection of numerous bridges, and input from the client. These questions were selected based on their simplicity while still being able to quantify the inspection data and provide meaningful information about potential bridge problems. They require the field inspector to look at health and safety issues, the surface condition of the bridge, the condition of the bridge structure under the bridge, and the condition of foundation, as well as provide an overall assessment. Appendix A includes the screen captures of the questions which approximate how they will appear on the iPad that will be used by the MOA field inspectors.

These 25 questions were approved by the MOA. They were also reviewed by R&M, and no modifications were suggested. It should be noted that these questions are greatly simplified from what a qualified structural engineering inspector would consider, which means that there will be limitations on the scope of the results which can be derived from this information. If a routine inspection identifies alarming bridge deficiencies, a certified engineer should perform an inspection in order to determine current bridge load ratings. Given the constraints of budget and staff, this information will provide a good starting point for creating a bridge management program that can be expanded over time. For ease of reference, the questions are numbered, and the sections are labeled.

25 Questions for Bridge Inspection App

(An answer to each question must be entered by field inspector in order to submit data)

General ***Bridge ID*** information:

1. Enter Bridge ID ______________________________________
2. Take a GPS point
3. Indicate primary material in bridge: ☐ Wood ☐ Steel ☐ Concrete
4. Does the bridge have light(s)? ☐ Yes ☐ No

Condition of the ***handrails***:

5. How many missing bolts/nuts? ☐ None ☐ 1 to 3 ☐ 4 or more
6. Are handrails loose or missing? ☐ Yes ☐ No
7. Should handrail(s) be replaced? ☐ Yes ☐ No
8. Is the spacing between any of the side railings more than 9 inches? ☐ Yes ☐ No

Condition of the ***surface of the bridge***:

9. Missing floor boards? ☐ Yes ☐ No
10. Any cracks more than 6 inches long? ☐ Yes ☐ No
11. Any holes more than 2 inches wide? ☐ Yes ☐ No
12. How irregular is the connection from the trail to the surface of the bridge?
    ☐ smooth & level ☐ 1 – 2 inch difference ☐ more than 2 inch difference

Condition of the ***bridge structure*** viewed from underneath the bridge:

13. Any cracks over 6 inches long? ☐ Yes ☐ No
14. Any visible rotting of the wood? ☐ Yes ☐ No
15. Any obvious damage or significant missing parts? ☐ Yes ☐ No
16. How many missing bolts/nuts? ☐ None ☐ 1 to 3 ☐ 4 or more

Condition of the ***main supports of the bridge***:

17. Cracks or holes bigger than 6 inches? ☐ Yes ☐ No
18. Any obvious damage, leaning, or movement of the main supports? ☐ Yes ☐ No
19. Is there excessive erosion causing undercutting around the supports of more than 12 inches? ☐ Yes ☐ No
20. Is there any erosion under the bridge or around the supports that might affect the stability of the bridge? ☐ Yes ☐ No

Overall review of the bridge:

21. Does the bridge look safe to you? ☐ Yes ☐ No
22. Would you be comfortable walking across the bridge? ☐ Yes ☐ No
23. What part of the bridge concerns you most? ☐ bridge surface ☐ handrails
    ☐ bridge structure ☐ main supports ☐ transitions from trail to bridge ☐ railings
24. Take a photo of the part of the bridge that concerns you the most. [click to upload photo]
25. Include any other observations that you think management should be aware of.

Figure 3: BIA Questions

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3.4 Selection of Software Tools

The following programs and applications were used to create the Bridge Inspection App:

1. Database program (ArcGIS)
2. Mobile device platform (iOS for use on iPhone or iPad)
3. VBA program application/Math lab (Excel/MATLAB)
4. Application Storage Program (Survey123 Application)

ArcGIS was used to prepare the database to accept data from the BIA. The BIA was created in Excel by using VBA to create a custom interface. The BRE was programmed in MATLAB using a M script. IPads were used to test the BIA.

Choice of application platforms: Three different application platforms were considered:

- Collector
- Survey123
- Bridge Inventory App

Survey123 was chosen by the MOA because it is compatible with the MOA database and is familiar to the MOA employees. The platform also has a simple and customizable interface. Survey123s platform and database can be fully integrated into the MOA security system by dragging and dropping the code into a feature class geodatabase folder on the server.

Chapter 4: Development of Components of Prototype Platform

Before the programming of the BIA and the BRE could begin, agreement needed to be reached with the MOA regarding the scope of the inspection application, the platform to be used for the inspections and the database, and the preferred level of detail in the risk assessment results. Once it was agreed that inspections would be done by field workers using iPads answering 25 basic inspection questions, the BIA was programmed for use on the iOS platform. Then, once it was agreed that the risk assessment categories would be grouped into low, moderate, or high, along with a separate identification of health and safety problems, the BRE could be programmed.

4.1 –Data Elements

The data is input into the BIA both by the operator and through a background script. The operator input includes answers to the 25 questions shown in Figure 3, and the operator's ID is captured from the device used for the inspection. The background script automatically collects data on the latitude, longitude, date, and time of the bridge inspection from the GPS data and assigns a unique Global ID based on this information. If a question is skipped, it is flagged when the field inspector tries to submit the data; the data cannot be submitted until all unanswered questions are answered.

The attribute data collected in these questions will be uploaded to the geodatabase for further analysis and are connected to the bridge ID number. Table 1 shows the data elements maintained in the database, their variable name used in the code, and the source of that data.

Changes to the Application: Changes can be made to the code by opening the VBA script in Excel, which should be done by an employee with basic programming skills. The VBA script will be located on a USB stick given to the MOA. The changes to the script will then need to be uploaded to the cloud database, which will automatically make the changes in the BIA. If changes are made to the BIA, any field worker who downloaded the app to his/her mobile device will need to upload the revised BIA before completing additional inspections.

Table 1: Data Elements maintained in Database

Description of Data Element	Data code ref	Variable Name used in BRE Code	Source of data
ObjectID	1		assigned by database
GlobalID	2		GPS data (BIA Q# 2)
Enter Bridge ID:	3		BIA Q# 1
Indicate Primary Material in Bridge:	4	primaryMaterial	BIA Q# 3
Does the bridge have light(s)?	5	bridgeLights	BIA Q# 4
How many missing bolts/nuts?	6	missingBolts	BIA Q# 5
Are handrails loose or missing?	7	handrails	BIA Q# 6
Should handrail(s) be replaced?	8	handrailsReplace	BIA Q# 7
Is the spacing between any of the side railings more than 9 inches?	9	spacing	BIA Q# 8
Missing floor boards?	10	floorBoard	BIA Q# 9
Any cracks more than 6 inches long?	11	cracks	BIA Q# 10
Any holes more than 2 inches wide?	12	holes	BIA Q# 11
How irregular is the connection from the trail to the surface of the bridge?	13	connection	BIA Q# 12
Any cracks over 6 inches long?	14	cracks1	BIA Q# 13
Any visible rotting of the wood?	15	rot	BIA Q# 14
Any obvious damage or missing parts?	16	damage	BIA Q# 15
How many missing bolts/nuts?	17	missingBolts1	BIA Q# 16
Cracks or holes bigger than 6 inches?	18	cracks3	BIA Q# 17
Any obvious damage, leaning, or movement of the main supports?	19	damage1	BIA Q# 18
Is there excessive erosion causing undercutting around the supports of more than 12 inches?	20	erosion	BIA Q# 19
Is there any erosion under the bridge or around the supports that might affect the	21	erosion1	BIA Q# 20

Description of Data Element	Data code ref	Variable Name used in BRE Code	Source of data
stability of the bridge?			
Does the bridge look safe to you?	22	safe	BIA Q# 21
Would you be comfortable walking across the bridge?	23	walk	BIA Q# 22
What part of the bridge concerns you most?	24	No variable name assigned in BRE	BIA Q# 23
Photo (uploaded by field inspector)	25	No variable name assigned in BRE	BIA Q#24
Include any other observations that you think management should be aware of	26	No variable name assigned in BRE	BIA Q# 25
CreationDate	27	No variable name assigned in BRE	GPS data
Creator	28	No variable name assigned in BRE	iPad ID
EditDate	29	No variable name assigned in BRE	
Editor	30	Person making changes to data	Login ID
x	31	No variable name assigned in BRE	Longitude from GPS
y	32	No variable name assigned in BRE	Latitude from GPS
Risk Category Low Risk Moderate Risk High Risk	33	category	Determination from BRE based on answers to BIA Q# 3–22
Health & Safety If there are health and safety points, healthAndSafety = 1 If there are no health and safety points, healthAndSafety = 0	34	healthAndSafety	From the BRE based on answers to BIA Q# 4–8
Total Pts	35	Total	Sum of points from BRE based on answers to BIA Q# 3–22
H&S Pts (Health & Safety points)	36	HS	Sum of points from BRE based on answers to BIA Q# 4–8
Material Pts	37	Material	Points from BRE based on answer to BIA Q# 3

Description of Data Element	Data code ref	Variable Name used in BRE Code	Source of data
Surface Pts	38	Surface	Sum of points from BRE based on answers to BIA Q# 9–12
Under Bridge	39	underBridge	Sum of points from BRE based on answers to BIA Q# 13–16
Supports Pts	40	Supports	Sum of points from BRE based on answers to BIA Q# 17–20
Worker Pts	41	Worker	Sum of points from BRE based on answers to BIA Q# 21–22
Management Override	42	No variable name assigned in BRE	MOA manager

~~***Changes to the Application***: Changes can be made to the code by opening the VBA script in Excel, which should be done by an employee with basic programming skills. The VBA script will be located on a USB stick given to the MOA. The changes to the script will then need to be uploaded to the cloud database, which will automatically make the changes in the BIA. If changes are made to the BIA, any field worker who downloaded the app to his/her mobile device will need to upload the revised BIA before completing additional inspections.~~

4.2 -Determination of Bridge Risk Categories

Once the bridge inspection data is collected, it is reviewed and run through the Bridge Risk Evaluation (BRE) program. Each bridge will accumulate points based on the yes/no and multiple-answer questions in the app. These points are used to classify the bridge into the risk categories. Table 2 shows the number of points assigned for each answer for each of the 25 questions. These points can be modified over time as decisions are made about whether certain conditions would warrant a more severe rating. It is recommended that the points assigned to each answer be reviewed periodically to ensure that they continue to represent the best effort to identify high-risk bridges.

Table 2: Bridge Risk Evaluation (BRE) Point Assignment

Question Number	Basic Description of Question	Response	Points Assigned	Health & Safety
1	Bridge ID		n/a	
2	GPS Point		n/a	
3	Primary Material	If Steel If Concrete If Wood	0.5 1.0 1.5	
4	Bridge Lights	If no	1	X
5	Missing Bolts (on handrails)	If None If 1 to 3 If 4 or More	0 0.5 1.0	X
6	Handrails (loose/missing)	If yes	1.0	X
7	Handrails Replace	If yes	1.0	X
8	Spacing (of siderails)	If yes	1.0	X
9	Missing Floor Board	If yes	1.0	
10	Cracks (on bridge surface)	If yes	1.0	
11	Holes	If yes	1.0	
12	Connection from trail to bridge	If smooth If 1 – 2 inch difference If more than 2 inch difference	0 1 2	
13	Cracks1 (from under bridge)	If yes	1.0	
14	Rot	If yes	1.0	
15	Damage (on bridge structure)	If yes	1.0	
16	Missing Bolts1 (under bridge)	If None If 1 to 3 If 4 or More	0 0.5 1.0	
17	Cracks3 (in main support)	If yes	1.0	
18	Damage Supports	If yes	1.0	
19	Erosion (undercutting support)	If yes	1.0	
20	Erosion1 (affecting stability)	If yes	1.0	
21	Safe	If no	1.0	
22	Walk	If no	1.0	
23	Concern	If bridge surface If handrails If bridge structure	No points assigned for these	

Question Number	Basic Description of Question	Response	Points Assigned	Health & Safety
		If main supports If transitions from trail to bridge If railings	responses. Information will be available to MOA management for review.	
24	Photo			
25	Observations			

Once the points are determined, the BRE then assigns a risk category to the bridge. Because of the limited nature of the inspection data being collected, it was decided that there would only be four risk categories. The four Bridge Risk Categories (BRC) are: (1) low apparent risk (no action needed), (2) moderate potential risk, (3) high-risk priority, and (4) health and safety. It should be noted that a bridge can fall into multiple categories since it will be assigned a risk category (low, moderate, or high) and may also be assigned to the health and safety category based on answers to certain questions in the BIA. The assignment to both categories, if applicable, will be maintained in the database. Table 3 shows how the points received from the inspection data are used to place a bridge into each of these categories.

Table 3: Rules for determining Bridge Risk Category

Bridge Risk Category	Determination Rules
Low apparent risk (no action needed)	Received points less than 5
Moderate potential risk	Received points between 5 – 15
High-risk priority	Received points greater than 15
Health and safety	Received a yes from any of the questions 4 – 8

These categories can be searched to determine the levels of maintenance and repair necessary for each bridge, and which repairs are most pressing. The code for the determination of the BRC can be found in Appendix B and will be provided to the MOA on a USB drive. Again, it is advisable to review this approach after a few months to ensure that the results produced by the BRE continue to help the MOA achieve its goal of identifying high-risk bridges in need of maintenance.

~~4.3 Reports~~4.3 Reports for Management showing BRC

In order to allow management to develop a reasonable maintenance plan for the pedestrian bridges based on the data collected, reports must be generated from the data base. Figure 4 shows a sample report that has been created for MOA management to use. This report was generated from the test cases included in Appendix C. For each bridge, the report shows the BRC that was assigned based on the number of points accumulated from the inspection data, and provides a general breakdown of the sources of the points into the general inspection categories of health and safety, primary material of the bridge, surface of the bridge, bridge structure viewed from underneath the bridge, main supports of the bridge, and the overall assessment by the field inspector.

EnterBridgeID_	Risk Category	Health & Safety	Total Pts	H&S Pts	Material Pts	Surface Pts	UnderBridge Pts	Supports Pts	Worker Pts
A	Moderate Risk:	1	10.5	1	0.5	5	2	2	0
B	Low Risk:	0	4.5	0	0.5	1	2	1	0
C	Moderate Risk:	1	7.5	1	0.5	1	3	2	0
D	Moderate Risk:	1	11.5	3	0.5	3	3	2	0
E	High Risk:	1	15	3	1	3	2	4	2
F	Moderate Risk:	1	7	2	1	0	1	2	1
G	Moderate Risk:	1	8	1	1	4	1	1	0
H	Moderate Risk:	1	7.5	1	1.5	1	2	2	0
I	Low Risk:	1	4.5	1	1.5	1	0	1	0
J	High Risk:	1	15.5	4.5	1.5	4	2.5	1	2

Figure 4: Sample Report for Management showing bridge risk assessment information

As the data base is used and the needs of MOA management are clarified, IT professionals at the MOA can create other reports from the data base. Simple database queries can be used to create reports in ArcGIS. Responsible MOA management personnel will be able to override the BRC as assigned by the BRE based on their judgment and other information which may not be in the data base. The data base will include the calculation of the points determined using the BRE program, as well as the BRC assigned by the program and a separate attribute for the management override risk category.

The BIA includes a few observations from the field inspectors which are more subjective in nature. It will be important to determine how the answers to questions 23 and 25 as well as the photos included for question 24 are reported to MOA management. Those more subjective inputs cannot be included in a sample report, but they may contain very important observations that MOA management should consider. Appendix E includes screen shots of the steps that a MOA technician would follow, showing how the technician can use a simple "select by attributes" to query the database in order to create a management report.

Chapter 5: Testing of the BIA and the BRE

Once the BIA and the database format were created, along with the programming for the BRE, the testing could begin. There were two steps in testing the BIA and the BRE. The first step was to create alpha test cases. A sample of test-case inspection results for 10 bridges was created and run through the BIA and the BRE. Appendix C provides a listing of those 10 test cases, and Appendix D shows the results of the BRE determination of the BRC for those 10 test cases. The expected results were independently calculated outside of the program and used to verify that the code was correct. The database showed the expected data from the input, thus showing that the BIA read the inputs correctly from the iPad platform, and the BRC report showed the expected results based on the data input.

The next phase was the beta testing, which tested the BIA and BRE with more users. Email links were sent to 10 different people to populate the database with data of their choosing. While the inputs could not be verified (as would be the case in real life), the test showed that data from multiple users could be handled by the platform. Further, the BRC outputs from the beta sample data showed the results as expected for the data entered via the BIA.

Chapter 6: Overview of Work Flows for the BIA and the BRC

Figure 5 shows the expected workflows within the MOA for using and running the BIA and for producing the BRC reports for management. This chart shows the MOA employees responsible for certain tasks and the actions that are completed by the application and programs.

Box 1, Inspect Bridge: The first step in the bridge inspection process is the inspection of the pedestrian bridges using the BIA. The BIA was designed keeping in mind that a non-engineer worker would be collecting the data for the pedestrian bridges. The field inspectors will collect data from a basic and simplistic manual inspection of the bridge conditions. Once the field inspector has completed all 25 of the inspection questions, the raw data can be submitted to an online cloud-based geodatabase. If any of the 25 questions are not completed on the BIA, the data cannot be submitted. The inspection data can only be uploaded to the cloud-based database when the iPad is connected to a cell system.

If field inspectors are going to be in an area without a cellular connection, they should download the BIA onto their iPad before going into the field. However, if the BIA is resident on their iPad, they will need to remember to update the BIA periodically in order to ensure they are using the most recent version.

Box 2, Download Data: Periodically (recommended at least monthly), a MOA technician will download the inspection data from the online cloud-based geodatabase. The structure for this database will be given to the MOA to be uploaded to their server. The geodatabase stores the data as a local cache and a visual representation of the current data that has been collected. As a part of the download process, a unique file name is given to the data to be downloaded.

Box 3, Inspect Data and Quality Control: After the data is downloaded into the MOA geodatabase, a MOA technician should review the data looking for inconsistencies or errors in the data. During this step, manual corrections can be entered by the technician. It is critical that bad data not be uploaded into the official bridge database.

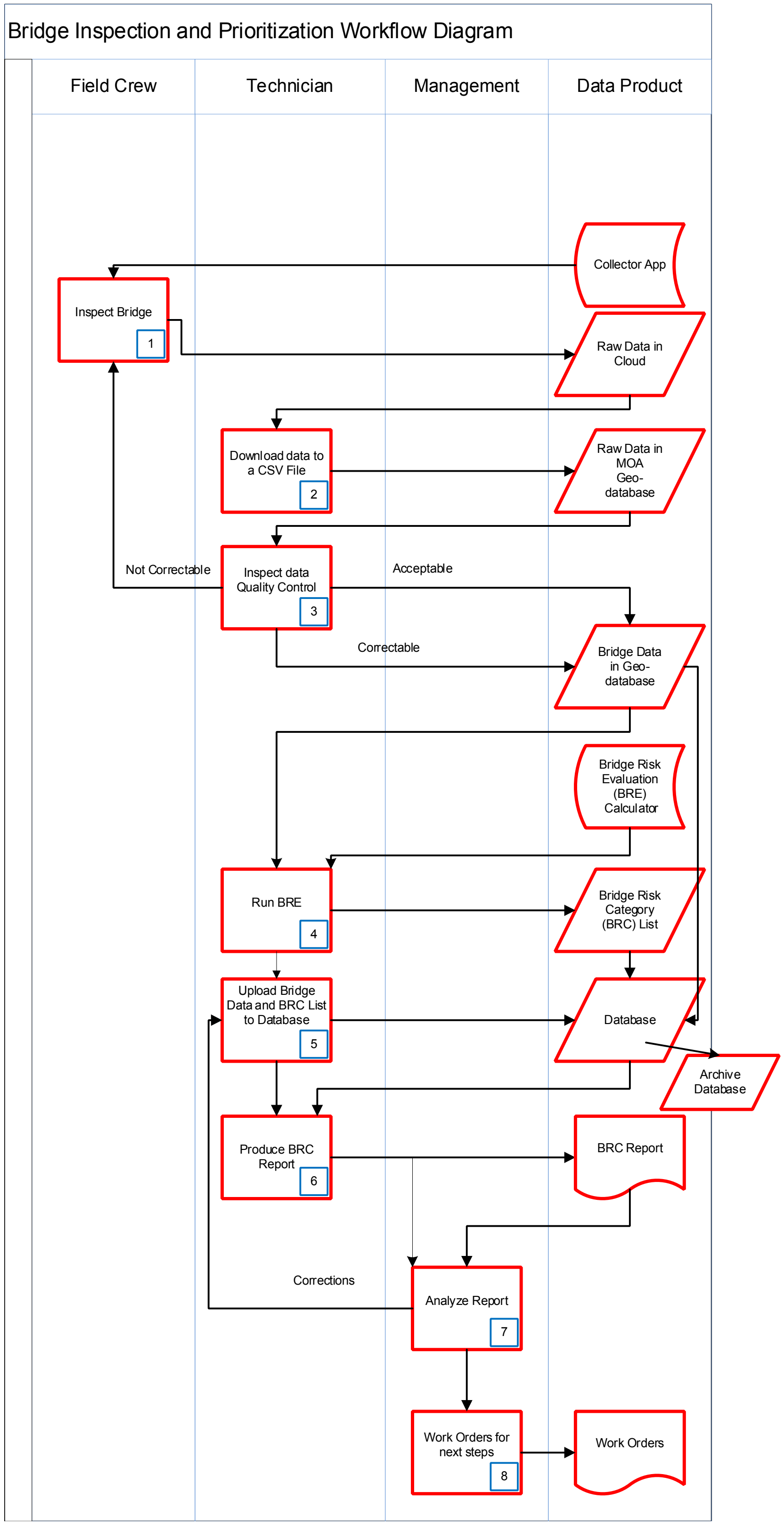


Figure 5: Overall Flow

~~the raw data can be submitted to an online cloud-based geodatabase. If any of the 25 questions are not completed on the BIA, the data cannot be submitted. The inspection data can only be uploaded to the cloud-based database when the iPad is connected to a cell system.~~

~~If field inspectors are going to be in an area without a cellular connection, they should download the BIA onto their iPad before going into the field. However, if the BIA is resident on their iPad, they will need to remember to update the BIA periodically in order to ensure they are using the most recent version.~~

~~*Box 2, Download Data:* Periodically (recommended at least monthly), a MOA technician will download the inspection data from the online cloud-based geodatabase. The structure for this database will be given to the MOA to be uploaded to their server. The geodatabase stores the data as a local cache and a visual representation of the current data that has been collected. As a part of the download process, a unique file name is given to the data to be downloaded.~~

~~*Box 3, Inspect Data and Quality Control:* After the data is downloaded into the MOA geodatabase, a MOA technician should review the data looking for inconsistencies or errors in the data. During this step, manual corrections can be entered by the technician. It is critical that bad data not be uploaded into the official bridge database.~~

Box 4, Run the BRE: Once the reviewed data is uploaded into the official bridge database, a MOA technician will run the BRE program. The BRE program is a custom FME/M file which groups the bridges into four risk categories based on the number of "points" they received as a result of the answers to the inspection questions: (1) low apparent risk (no action needed), (2) moderate potential risk, (3) high-risk priority, and (4) health and safety. It should be noted that a bridge can fall into multiple categories since it will be assigned a risk category (low, moderate, or high) and may also be assigned to the health and safety category based on answers to certain questions in the BIA. The assignment to both categories, if applicable, will be maintained in the database.

After running the BRE on the recently uploaded inspection data, the BRE will create a new file with the prefix "BRE_" appended to the initial file name for the downloaded data (e.g., BRE_filename.csv). In addition, the BRC report shown in Appendix D will be generated. It is recommended that the technician provide this BRC report to management as a snapshot of the risk assessment information on the recently uploaded inspection data.

Box 5, Upload Bridge Data: After the BRE program has been run, the bridge database and the BRC determination and other data calculated by the BRE will be uploaded into the database on the MOA server. During this step any prior data regarding a previously-inspected bridge are archived.

Box 6, Produce BRC Reports: Once the BRE program has been run and the BRC have been determined, a MOA technician produces a BRC report for MOA management for consideration and determination of any required bridge maintenance action. The creation of BRC reports can be done easily using the tools in ArcGIS.

Box 7, Analyze Bridge Reports: MOA management will review and evaluate the BRC report and make a decision regarding any bridge maintenance priorities, based on available funding and other constraints. The manager responsible for reviewing the BRC and making decisions about maintenance actions can override the BRC assigned by the program to any particular bridge. That information is input into the database so that it can be available for inclusion in future reports.

Box 8, Create Work Orders: The final step in the bridge maintenance protocol is producing the work orders to complete any necessary bridge maintenance or repairs.

~~Chapter 7: Conclusion and Recommendations~~

7.1 Conclusion

The development of the Prototype Platform was the result of a collaboration between UAA and the MOA which was intended to provide a useful bridge maintenance prototype platform based on the current budget constraints and limited resources available to the MOA. It is understood by all parties that the Prototype Platform is the beginning of the development of a more robust bridge condition database and a bridge management maintenance program. The implementation of the Prototype Platform gives the MOA a way to make meaningful progress in developing a maintenance protocol.

The Prototype Platform provides the MOA with a tool that is immediately usable and user-friendly and which can be easily modified to meet future needs. The program and platform have been designed to be dynamic and can be modified by most IT professionals. It is expected that there will be changes to the Prototype Platform as it is used and as the needs of the MOA are more clearly defined. Because the inspections are basic and are being conducted by non-engineers, routine inspections conducted using the application should not replace full inspections and full structural analysis reports that can only be conducted by a professional structural engineer when needed. While using the components of the Prototype Platform will help the MOA to identify potential risks in their pedestrian bridge system, it should be noted that the Prototype Platform would not have identified the structural defects that caused some of the recent bridge failures.

7.2 Recommendations

It is important to determine whether the app is able to provide repeatable and representative information about the condition of the bridges that meets the need of the MOA. Therefore, once the MOA begins to use the app and implement the components of the Prototype Platform, the following recommendations are made:

- *Get feedback from field inspectors:* Even though the BIA was reviewed by several non-engineers to get feedback on the wording of the questions, as the MOA starts to use this application, it is recommended that management request feedback from the field workers who have used the app to determine whether there are changes that should be made to the questions or to the app.
- *Review initial inspection data:* After the first real results are input into the database, it is recommended that the data and the risk assessment determination should be reviewed carefully to make sure that the results are as expected. At this point, some issues to consider might be: (1) whether the field inspectors are answering the questions in a manner that is consistent with expectations; (2) whether bridges are being placed into a risk category that is not expected based on an independent review of the bridge condition;

(3) whether the BRC appropriately identifies the health and safety conditions of the inspected bridges.

- *Have multiple field inspectors complete the BIA for the same bridge:* By having different field inspectors complete the BIA for the same bridge, management can evaluate whether the Prototype Platform is able to provide enough differentiation among the bridges based on the input data, or whether there is more variation among the responses by the various inspectors thus making the outputs less reliable.
- *Consider changes to the weighting given to various answers:* If the results of the risk assessment is not as expected, consideration should be given to expanding the level of detail requested or changing the weighting of various answers. For example, if there are bridges with significant undercut, perhaps BIA Question 19 should be changed to a multiple-answer question, or perhaps a yes answer to that question should be changed from 1 point to 4 points.
- *Download and review inspection data monthly:* As field inspectors review the condition of the bridges, the data collected should be reviewed for quality control and downloaded to the data base at least monthly. In addition, BRC reports should be generated monthly to enable MOA management to make current decisions about future maintenance plans. In this way, if an inspection identifies alarming or extreme bridge deficiencies, it could be identified sooner and a professional engineer could conduct a more extensive inspection to determine the safety of the bridge.
- *Develop bridge condition reports:* While a sample bridge condition report is provided as part of this project, since the data will be used to make decisions about needed repairs and maintenance, it is recommended that the MOA management consider appropriate changes to the report format after a period of using the reports.
- *Determine frequency of inspections:* It is expected that inspections will be performed annually on each of the bridges in the system. However, if that schedule is considered too burdensome and unnecessary, inspections might only be conducted annually on the higher-risk bridges.

After testing the BIA and BRE for one summer, a review and evaluation of the questions and answers should be conducted to determine whether the Prototype Platform is meeting the ongoing needs of the MOA.

~~7.3 Possible~~7.3 Possible Future Enhancements

It is expected that as the MOA begins to use the Prototype Platform, changes may be made so that it meets the needs of the MOA. The following are some possible enhancements to make to the platform:

- *Assign a single ID number to each bridge*: Assign a single ID number to each bridge which would be used for all reports relating to that bridge, and have that number included in a drop-down menu on the BIA. Provisions should be made for how to identify bridges which have been replaced.
- *Keep a record of bridge inspections:* Given the number of bridges in the MOA trail system and the fact that, realistically, the bridges can only be inspected in the summer months, it may be that not all the bridges will be able to be inspected every year. Once a list of all the bridges is created, a report should be created showing which bridges have *not* been inspected, so that MOA management can take action to have those bridges inspected if needed.
- *Create separate maintenance status tables*: Once a maintenance protocol is established, create maintenance tables in the database to keep track of the status of ongoing and completed maintenance.
- *Obtain and record additional information about the bridges*: Additional bridge information such as age of the bridge, prior and ongoing repairs, and length, width, and load capacity of the bridge, might be useful when making decisions about bridge maintenance and could be recorded in the data base. Further, if such a table were created, data requested in the BIA for the initial inspections, such as the material of the bridge and whether there are lights on the bridge, could be included on such a table and removed from the BIA in the future.
- *Determine how to use the photos and the comments and concerns of the field inspectors*: Questions 23, 24, and 25 of the BIA were included to provide a way for the field inspectors to record concerns they saw that were not included sufficiently in the other questions. The MOA needs to determine how best to use this input.

- *Consider using multi-spectral imaging*: The MOA could consider using multi-spectral images as a way to find the types of damage that cannot be seen by visual inspection of a bridge.

References

American Association Of State Highway and Tranporation Officals. (2015). *LFRD Guide Specification for the Design of Pedestrians Bridges.* AASHTO.

Andrews, L. (2014, June 16). *Anchorage Daily News*. Retrieved from https://www.adn.com/anchorage/article/bridge-collapses-anchorages-westchester-lagoon/2014/06/16/

Giraldo, K. W. (2017). *MOA ProjectB Group.* Anchorage: unpublished.

Appendices

Appendix A: BIA screen captures

Appendix A contains screen captures of each screen in the BIA. These screen captures approximate what the field inspector will see using the iPad app.

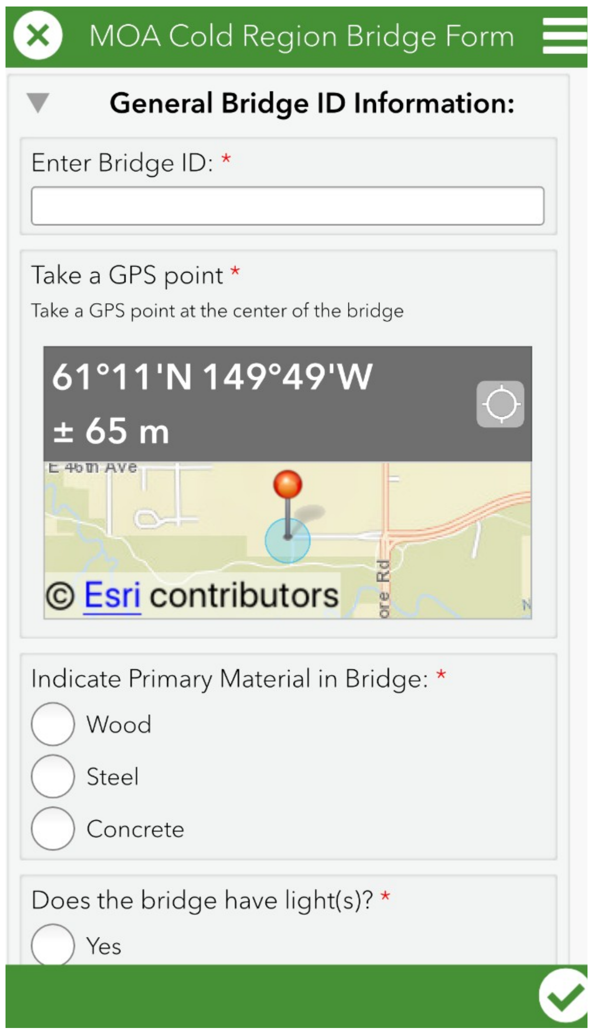


Figure 6: BIA Page 1

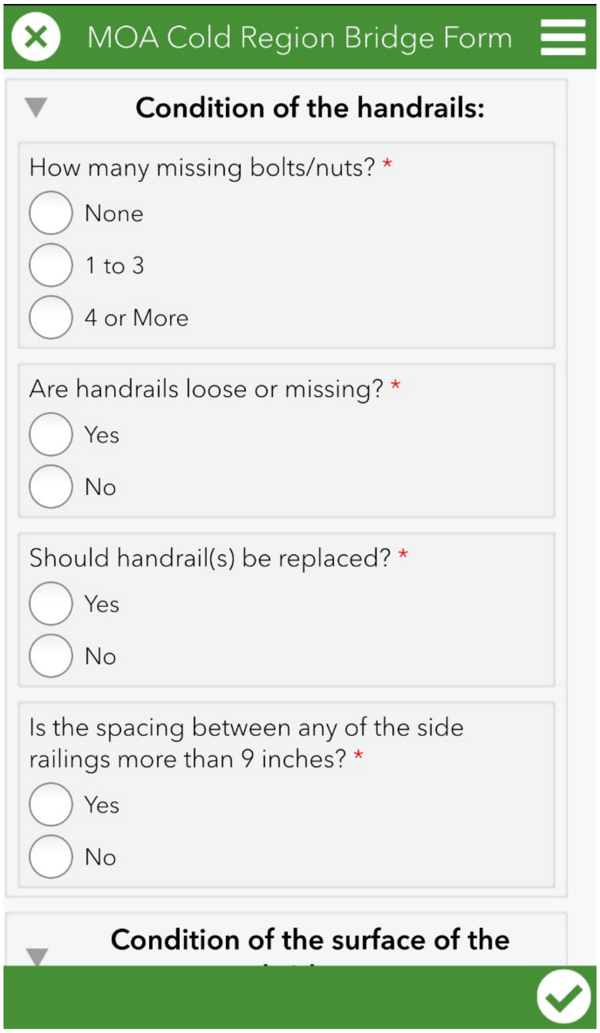


Figure 7: BIA Page 2

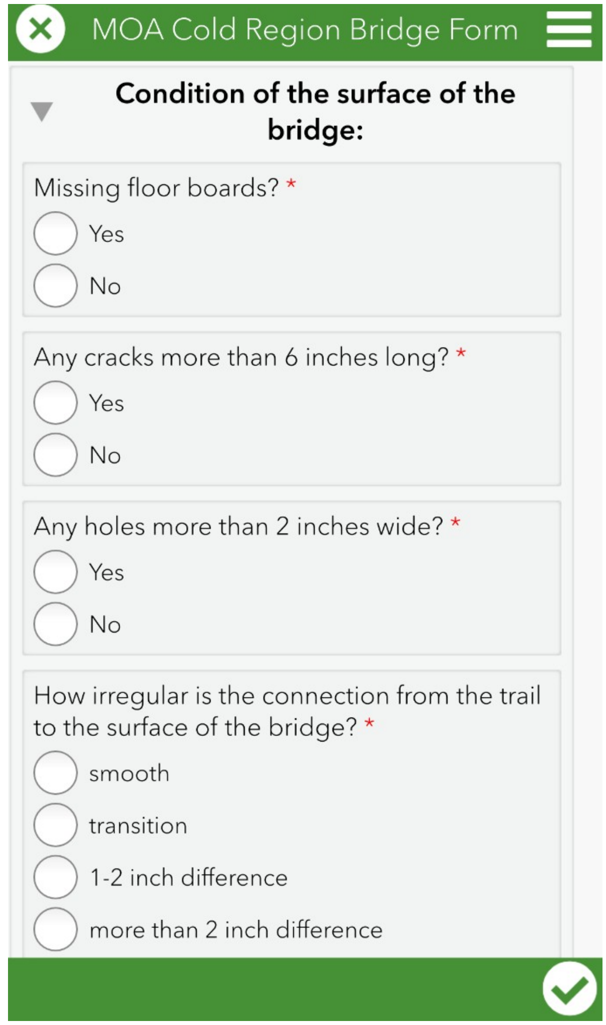


Figure 8: BIA Page 3

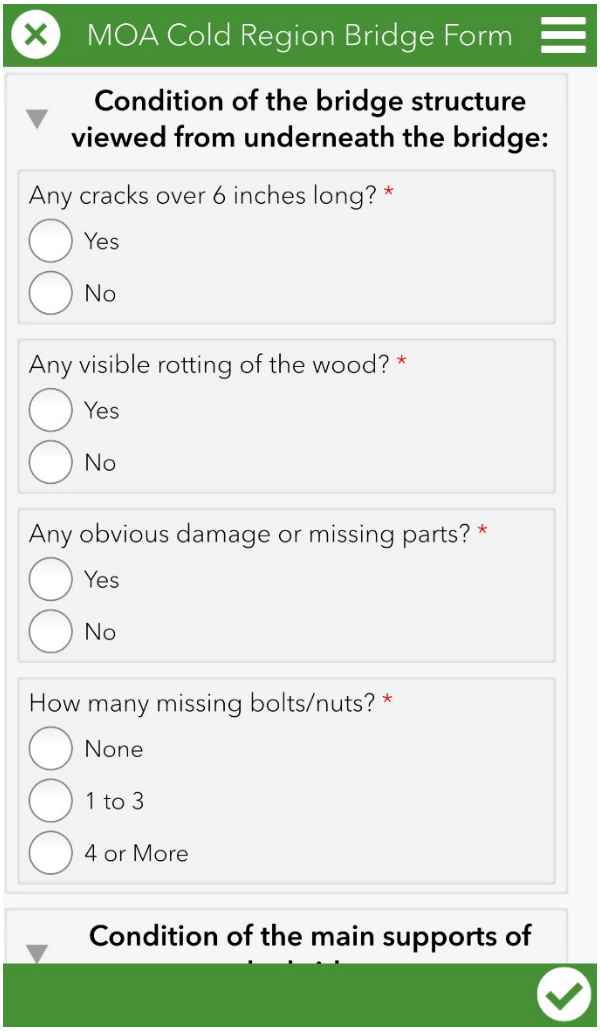


Figure 9: BIA Page 4

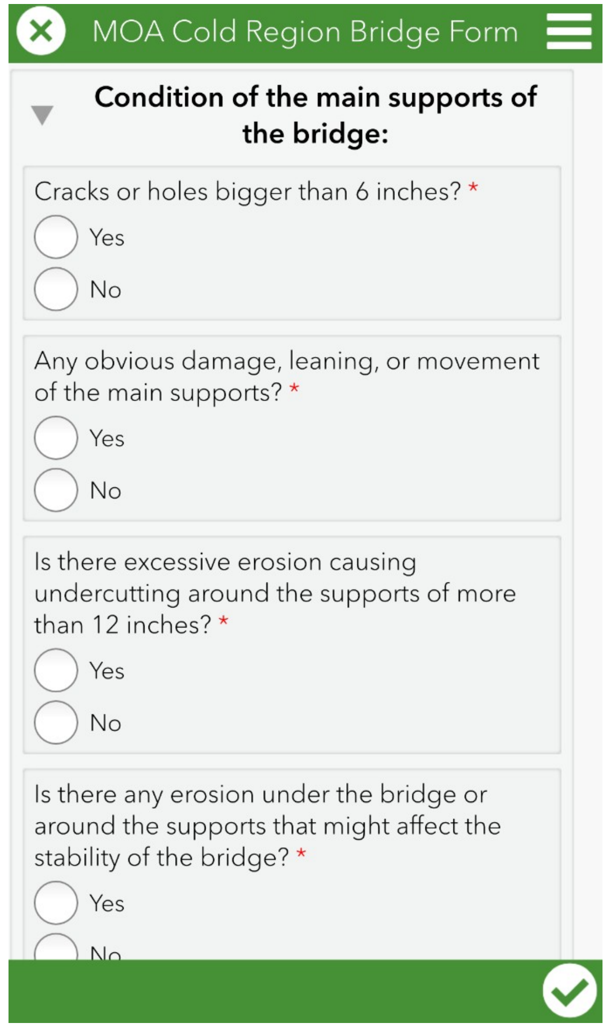


Figure 10: BIA Page 5

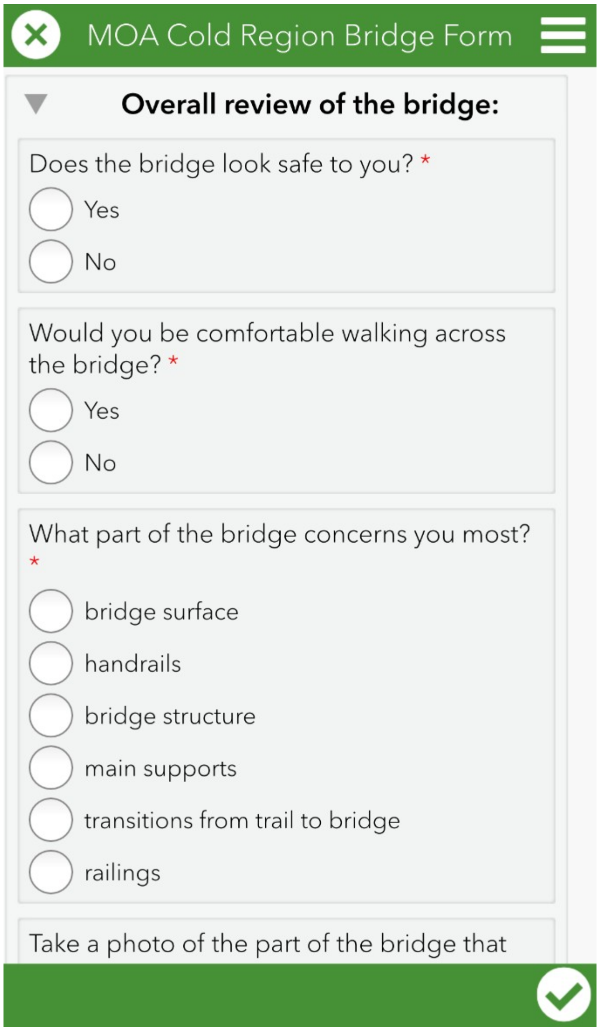


Figure 11: BIA Page 6

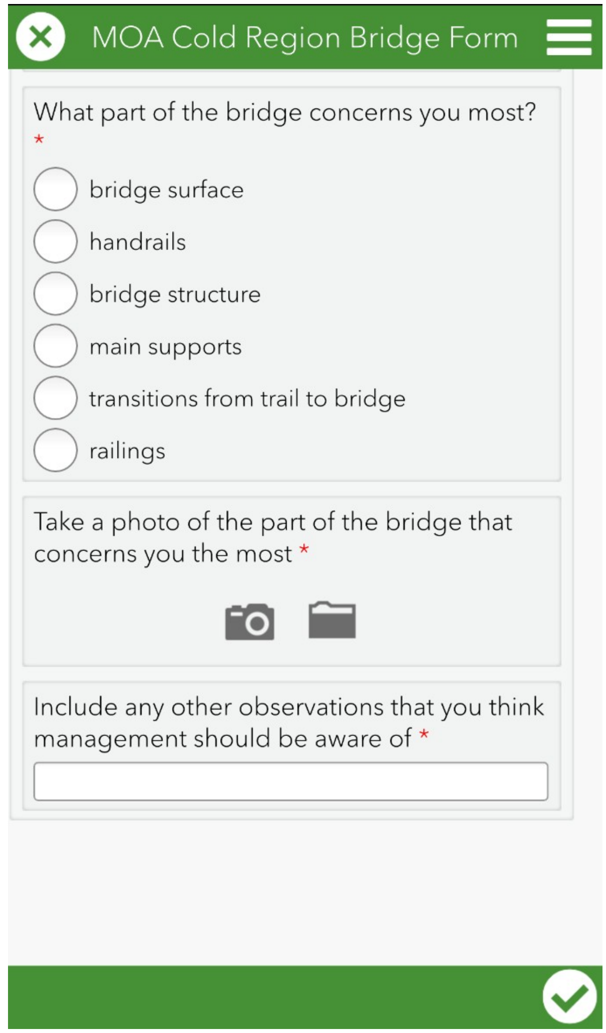


Figure 12: BIA Page 7

Appendix B: Programming code for the BRE determination

Appendix B contains the code of the BRE. By looking at each figure, the reader can see the coding used to determine the BRC based on the answers from the BIA. The wording in green is text intended to make the code easier to read.

```
 1 close all
 2 clear
 3 clc
 4
 5 %% Read in Bridge Data from Table
 6 [filepath,name,ext] = fileparts(uigetfile('.csv'));
 7 data = table2cell(readtable(strcat(filepath,name,ext)));
 8 % objectID = cell2mat(data(:,1));
 9 globalID = data(:,2);
10 bridgeID = data(:,3);
11
12 % Indicate Primary Material in Bridge:
13 primaryMaterial = zeros(size(data,1),1);
14 primaryMaterial(ismember(data(:,4),'Steel')) = 0.5;
15 primaryMaterial(ismember(data(:,4),'Concrete')) = 1;
16 primaryMaterial(ismember(data(:,4),'Wood')) = 1.5;
17
18 % Does the bridge have  light(s)?
19 bridgeLights = zeros(size(data,1),1);
20 bridgeLights(ismember(data(:,5), 'no')) = 1;
21
22 % How many missing bolts/nuts? (Handrails)
23 missingBolts = zeros(size(data,1),1);
24 missingBolts(ismember(data(:,6),'None')) = 0;
25 missingBolts(ismember(data(:,6),'1 to 3')) = 0.5;
26 missingBolts(ismember(data(:,6),'4 or More')) = 1;
27
28 % Are handrails loose or missing?
29 handrails = zeros(size(data,1),1);
30 handrails(ismember(data(:,7), 'yes')) = 1;
31
32 % Should handrail(s) be replaced?
33 handrailsReplace = zeros(size(data,1),1);
34 handrailsReplace(ismember(data(:,8), 'yes')) = 1;
35
36 % Is the spacing between any of the side railings more than 9 inches?
37 spacing = zeros(size(data,1),1);
38 spacing(ismember(data(:,9), 'yes')) = 1;
39
40 % Missing floor boards?
41 floorBoard = zeros(size(data,1),1);
42 floorBoard(ismember(data(:,10), 'yes')) = 1;
43
44 % Any cracks more than 6 inches long?
45 cracks = zeros(size(data,1),1);
46 cracks(ismember(data(:,11), 'yes')) = 1;
47
```

Figure 13: BRE Code (lines 1 – 47)

```
48 % Any holes more than 2 inches wide? (Surface of Bridge)
49 holes = zeros(size(data,1),1);
50 holes(ismember(data(:,12), 'yes')) = 1;
51
52 % Connection from the trail to bridge?
53 connection = zeros(size(data,1),1);
54 connection(ismember(data(:,13),'smooth')) = 0;
55 connection(ismember(data(:,13),'1-2 inch difference')) = 1;
56 connection(ismember(data(:,13),'more than 2 inch difference')) = 2;
57
58 % Any cracks over 6 inches long? (Under the Bridge)
59 cracks1 = zeros(size(data,1),1);
60 cracks1(ismember(data(:,14), 'yes')) = 1;
61
62 % Any visible rotting of the wood?
63 rot = zeros(size(data,1),1);
64 rot(ismember(data(:,15), 'yes')) = 1;
65
66 % Any obvious damage or missing parts?
67 damage = zeros(size(data,1),1);
68 damage(ismember(data(:,16), 'yes')) = 1;
69
70 % How many missing bolts/nuts? (Under the Bridge)
71 missingBolts1 = zeros(size(data,1),1);
72 missingBolts1(ismember(data(:,17),'None')) = 0;
73 missingBolts1(ismember(data(:,17),'1 to 3')) = 0.5;
74 missingBolts1(ismember(data(:,17),'4 or More')) = 1;
75
76 % Cracks or holes bigger than 6 inches? (Main Support)
77 cracks3 = zeros(size(data,1),1);
78 cracks3(ismember(data(:,18), 'yes')) = 1;
79
80 % Any obvious damage, leaning, or movement of the main supports?
81 damage1 = zeros(size(data,1),1);
82 damage1(ismember(data(:,19), 'yes')) = 1;
83
84 %  erosion causing undercutting supports
85 erosion = zeros(size(data,1),1);
86 erosion(ismember(data(:,20), 'yes')) = 1;
87
88 % erosion affect the stability
89 erosion1 = zeros(size(data,1),1);
90 erosion1(ismember(data(:,21), 'yes')) = 1;
91
92 % Does the bridge look safe to you?
93 safe = zeros(size(data,1),1);
94 safe(ismember(data(:,22), 'no')) = 1;
95
96 % Would you be comfortable walking across the bridge?
97 walk = zeros(size(data,1),1);
98 walk(ismember(data(:,23), 'no')) = 1;
```

Figure 14: BRE Code (lines 48 – 98)

```
 99
100 example = primaryMaterial+bridgeLights+missingBolts↙
+...
101↙
handrails+handrailsReplace+spacing+floorBoard+cracks+...
102↙
+holes+connection+cracks1+rot+damage+missingBolts1+cracks3↙
...
103↙
+damage1+erosion+erosion1+safe+walk;
104
105 output = [num2cell(example) bridgeID];
106 output1 = output((example) < 5,:);
107 output2 = output((example) >= 5 & (example) < 15,:);
108 output3 = output((example) >= 15,:);
109 output4 = output↙
(bridgeLights==1|missingBolts~=0|handrails==1|...
110                     handrailsReplace==1|spacing==1,:);
111 output5 = output(bridgeLights==1,:);
112 output6 = output(spacing==1,:);
113 output7 = output(handrailsReplace==1,:);
114
115 disp('Low Risk:')
116 disp(sortrows(output1,1))
117 disp('Moderate Risk:')
118 disp(sortrows(output2,1))
119 disp('High Risk:')
120 disp(sortrows(output3,1))
121 disp('Health & Safety:')
122 disp(sortrows(output4,1))
123
124
125 [M,~] = size(data);
126
127 category = cell(M,1);
128 healthAndSafety = cell(M,1);
129 for i=1:M
130     if example(i) < 5
131         category{i} = 'Low Risk:';
132     elseif example(i) >= 5 & example(i) < 15
133         category{i} = 'Moderate Risk:';
134     else
135         category{i} = 'High Risk:';
136     end
137
138     if bridgeLights(i)==1|missingBolts(i)~=0|handrails↙
(i)==1|handrailsReplace(i)==1|spacing(i)==1
139         healthAndSafety{i} = 1;
140     else
141         healthAndSafety{i} = 0;
142     end
143 end
144
145 output = [data category healthAndSafety];
146 cell2csv(strcat('BRE_',name,ext),output);
147
148
```

Figure 15: BRE Code (Line 99 – 148)

Appendix C: Test Cases

Figure 16 shows a chart of the inspection data for the 10 test bridges that were entered into the BIA and used to analyze outputs from the BRE. Further, it was confirmed that the data from questions 23 – 25 were passed through the BRE into the database, but were not part of the BRE calculations.

Enter Bridge ID:	A	B	C	D	E	F	G	H	I	J
Indicate Primary Material in Bridge:	Steel	Steel	Steel	Steel	Concrete	Concrete	Concrete	Wood	Wood	Wood
Does the bridge have working light(s)?	yes	yes	yes	yes	yes	yes	yes	yes	yes	no
How many missing bolts/nuts?	None	None	None	4 or More	None	4 or More	None	None	None	1 to 3
Are handrails loose or missing?	no	no	no	no	yes	no	no	no	no	yes
Should handrail(s) be replaced?	yes	no	yes	yes	yes	yes	yes	no	no	yes
Is the spacing between any of the side railings more than 9 inches?	no	no	no	yes	yes	no	no	yes	yes	yes
Missing floor boards?	yes	no	no	no	yes	no	no	yes	yes	yes
Any cracks more than 6 inches long?	yes	no	no	yes	no	no	yes	no	no	no
Any holes more than 2 inches wide?	yes	no	yes	yes	yes	no	yes	no	no	yes
How irregular is the connection from the trail to the surface of the bridge?	more than 2 inch difference	1-2 inch difference	smooth	1-2 inch difference	1-2 inch difference	smooth	more than 2 inch difference	smooth	smooth	more than 2 inch difference
Any cracks over 6 inches long?	yes	yes	yes	yes	yes	yes	yes	yes	no	yes
Any visible rotting of the wood?	no	no	yes	yes	no	no	no	no	no	yes
Any obvious damage or missing parts?	yes	yes	yes	yes	yes	no	no	no	no	no
How many missing bolts/nuts?2	None	None	None	None	None	None	None	4 or More	None	1 to 3
Cracks or holes bigger than 6 inches?	yes	yes	yes	yes	yes	yes	yes	no	no	no
Any obvious damage, leaning, or movement of the main supports?	yes	no	yes	yes	yes	no	no	yes	no	no
Is there excessive erosion causing undercutting around the supports of more than 12 inches?	no	no	no	no	yes	yes	no	yes	no	no
Is there any erosion under the bridge or around the supports that might affect the stability of the bridge?	no	no	no	no	yes	no	no	no	yes	yes
Does the bridge look safe to you?	yes	yes	yes	yes	no	no	yes	yes	yes	no
Would you be comfortable walking across the bridge?	yes	yes	yes	yes	no	yes	yes	yes	yes	no

Figure 16: Test cases

Appendix D: Determination of BRC

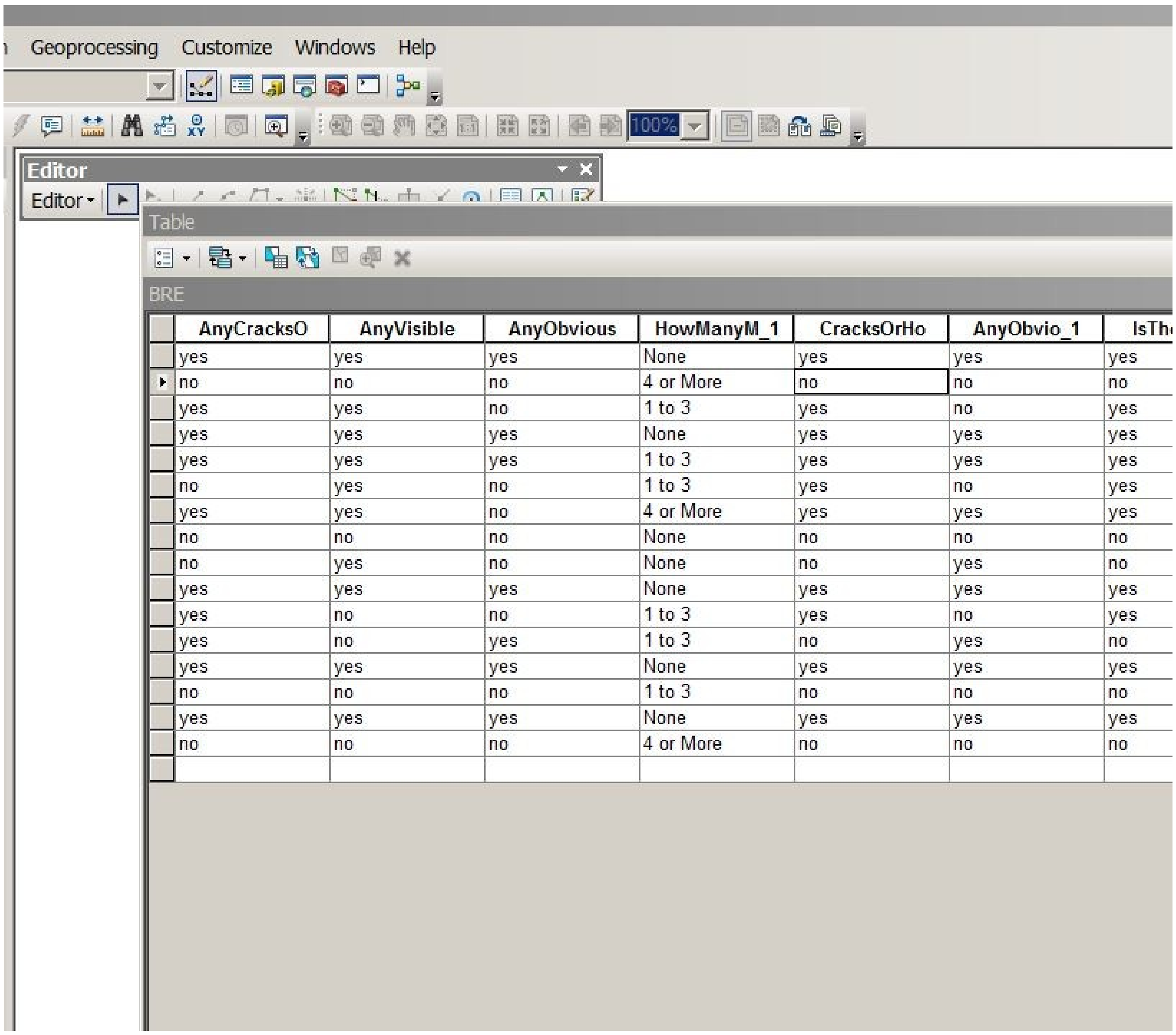
Figure 17 is a screen capture of the BRC results determined by the BRE based on the answers from the BIA for the 10 sample test cases set forth in Figure 16. This report should be produced for MOA management after each set of bridge inspections are uploaded to the database so that management has a snapshot of the results of recent inspections.

```
Low Risk:
    [4.5000]    'B'
    [4.5000]    'I'

Moderate Risk:
    [      7]    'F'
    [ 7.5000]    'C '
    [ 7.5000]    'H'
    [      8]    'G'
    [10.5000]    'A'
    [11.5000]    'D'

High Risk:
    [     15]    'E'
    [15.5000]    'J'

Health & Safety:
    [ 4.5000]    'I'
    [      7]    'F'
    [ 7.5000]    'C '
    [ 7.5000]    'H'
    [      8]    'G'
    [10.5000]    'A'
    [11.5000]    'D'
    [     15]    'E'
    [15.5000]    'J'

Health & Safety:bridgeLights
    [15.5000]    'J'

Health & Safety:missingBolts
    [      7]    'F'
    [11.5000]    'D'
    [15.5000]    'J'

Health & Safety:handrails
    [     15]    'E'
    [15.5000]    'J'

Health & Safety:handrailsReplace
    [      7]    'F'
    [ 7.5000]    'C '
    [      8]    'G'
    [10.5000]    'A'
    [11.5000]    'D'
    [     15]    'E'
    [15.5000]    'J'

Health & Safety:spacing
    [ 4.5000]    'I'
    [ 7.5000]    'H'
    [11.5000]    'D'
    [     15]    'E'
    [15.5000]    'J'
```

Figure 17: BRC Results from Test Cases

Appendix E: Sample Queries

Figures 18, 19, 20 and 21 show the steps that a MOA technician would follow in creating a query of the database in order to produce a report to management with specific requested information.



AnyCracksO	AnyVisible	AnyObvious	HowManyM_1	CracksOrHo	AnyObvio_1	IsTh
yes	yes	yes	None	yes	yes	yes
no	no	no	4 or More	no	no	no
yes	yes	no	1 to 3	yes	no	yes
yes	yes	yes	None	yes	yes	yes
yes	yes	yes	1 to 3	yes	yes	yes
no	yes	no	1 to 3	yes	no	yes
yes	yes	no	4 or More	yes	yes	yes
no	no	no	None	no	no	no
no	yes	no	None	no	yes	no
yes	yes	yes	None	yes	yes	yes
yes	no	no	1 to 3	yes	no	yes
yes	no	yes	1 to 3	no	yes	no
yes	yes	yes	None	yes	yes	yes
no	no	no	1 to 3	no	no	no
yes	yes	yes	None	yes	yes	yes
no	no	no	4 or More	no	no	no

Figure 18: Step 1: Identify the data elements to be queried

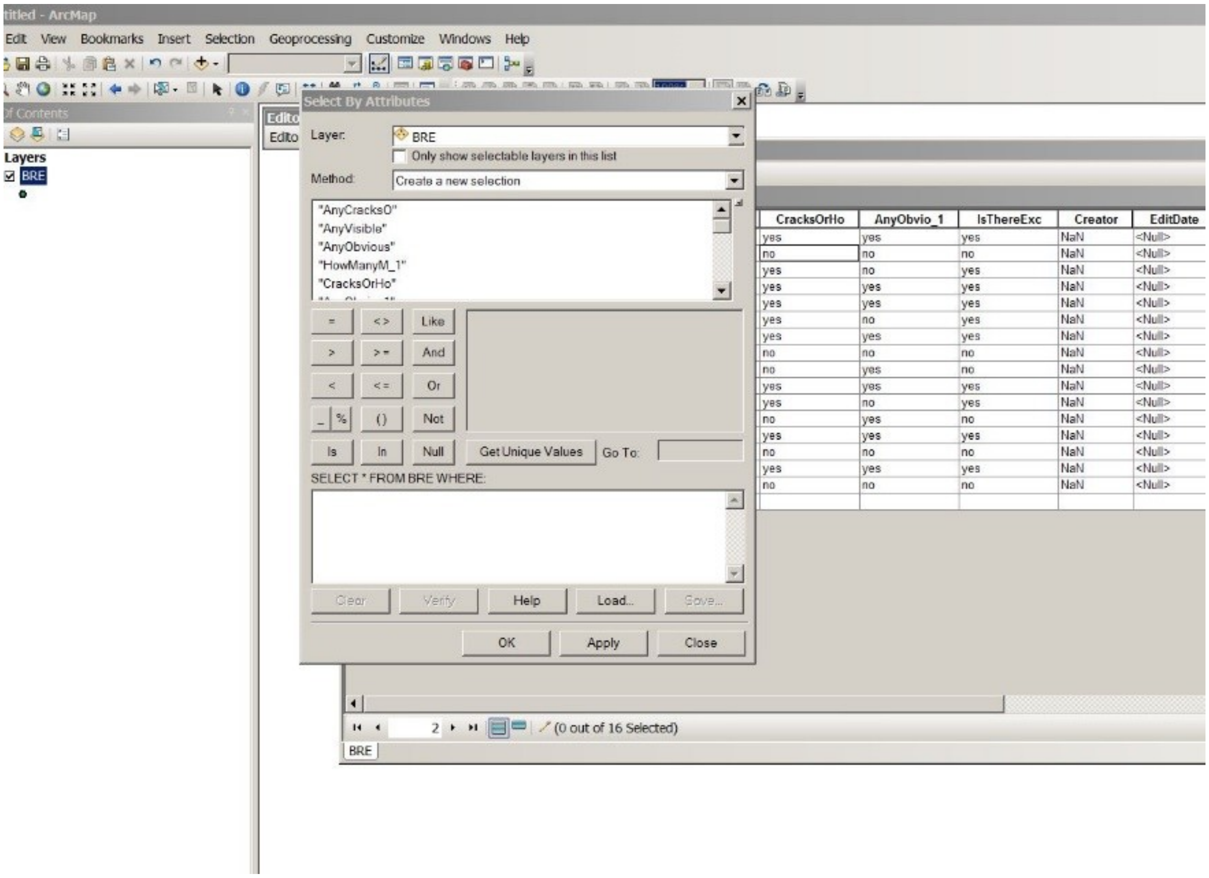


Figure 19: Step 2: Open "Select by Attributes" window

By opening the "Select by Attributes" window, the technician can select the desired data elements for the query.

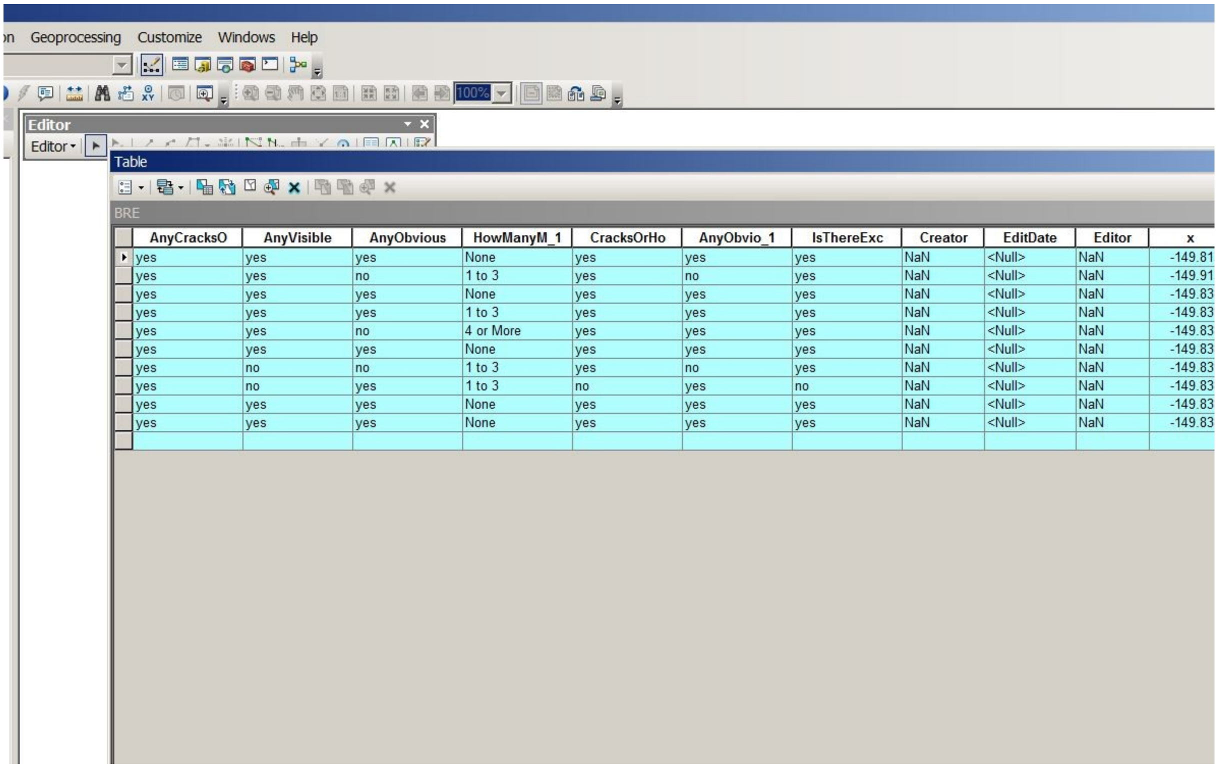


Figure 20: Step 3: Select the data elements desired

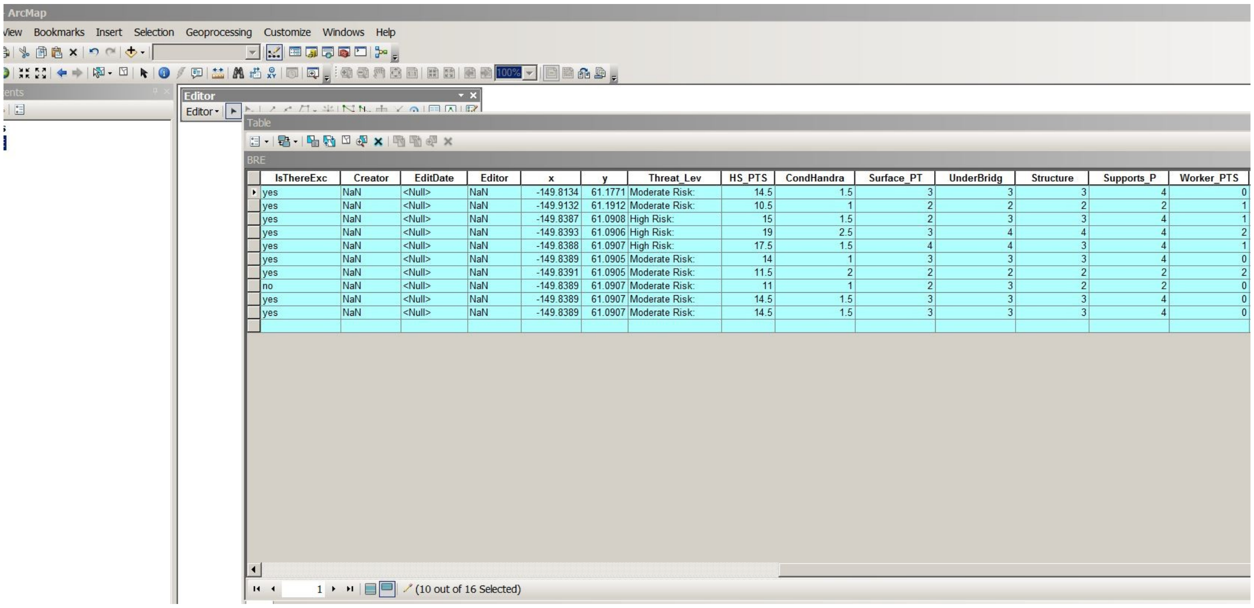


Figure 21: Step 4: Copy the data elements desired to a new spreadsheet