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SUPPLEMENTING DETAILED VISUAL INSPECTIONS WITH UAV

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Abstract: Routine visual bridge inspections are an integral aspect of maintaining a road network in a safe and serviceable condition. In Alberta, up-close visual inspections often use snooper trucks to gain access to hard to inspect places, such as deck undersides and bearings. Some bridges can be challenging to inspect due to factors such as it's configuration, and traffic usage/accommodation, and completing an up-close visual inspection can be time-consuming, expensive and sometimes hazardous.

In 2018 the City of Medicine Hat required up close visual inspections on two of their major bridges, including the Finlay Bridge (a 5-span through-truss) and Maple Avenue Bridge (a 7-span prestressed girder bridge) both spanning the South Saskatchewan River. The Finlay Bridge presented major challenges to completing the underdeck inspection by snooper truck including conflicts with the truss diagonals and a load restriction that would require full closure of the bridge. Various options were reviewed including rope access, however the decision was made to supplement the visual inspection by use of Unmanned Aerial Vehicles (UAVs).

There is significant experience in UAVs in industry for overall site photos and exploring certain defects. However, completing up close visual inspection of a bridge by use of a UAV presented unique challenges that needed to be addressed. In Alberta, UAVs have not previously been used to supplement detailed visual inspections, and there is minimal literature discussing the use of UAVs in this method across the country. As such, the methodology to complete the inspections was developed unique to these bridges.

This paper presents the case-study of the Finlay Bridge inspection. It covers the inspection methodology and the logistical challenges faced in completing the unique bridge inspection method. Items such as predetermined flight paths and identification of critical elements in advance of the inspection were key to success. This case-study discusses the technology used to complete the inspection, outcomes and benefits, and the next steps for improving inspections by UAV.

1 Introduction

The City of Medicine Hat is in southeastern Alberta, approximately 3 hours southeast from Calgary along the South Saskatchewan River (Figure 1). The River is a Class A watercourse that meanders through the middle of the City. Access is provided mainly by the historic Finlay Bridge, which was scheduled for a detailed visual inspection in 2018. The Finlay Bridge is five-span through truss structure, supported on concrete piers, carrying one-way vehicle and pedestrian traffic. It is a historic landmark for the City and is on the Alberta Register of Historic Places. Since it's construction, numerous rehabilitations and repair programs have been carried out to prolong the design life, due to its importance to the City. Figure 1 shows a map view of Medicine Hat and an elevation view of the bridge.

Figure 1: Medicine Hat Location (https://www.medicinehat.ca/) and the Finlay Bridge

Numerous constraints were immediately apparent when preparing for the inspection. The main issue being accessing the deck underside, bearing areas and truss elements. Typical options for these issues are sophisticated rope-access systems or the use of snooper trucks. In an attempt to provide a complete inspection while minimizing costs, traffic closures and overall risk to the client, the decision was made to use Unmanned Aerial Vehicles (UAV's) to supplement the visual inspection and provide all necessary details to carry out a thorough investigation.

Routine visual inspections for bridges and culverts is a critical aspect of an asset management plan for any entity (public or private) that manages these pieces of infrastructure. The inspections help to ensure public safety of the users, determine the condition and functionality of the assets through identification of defects, protect the investment for the owner and provides the necessary information used for decision making to maximize the functional life of the structure. Defects identified in the inspection must be understood in terms of relevancy, degree and urgency to confidently represent the effect on safety for the users and structural integrity of the bridge.

To perform a thorough inspection, the inspectors should have sufficient access to all components of the bridge, i.e. by getting close enough to identify any defects and their relevance. These defects are then noted and assigned action items, ranging from monitor to repair, rehabilitate or replace. Depending on the degree, location and relevancy of the defect, it will also be assigned a relative urgency to complete the work. Depending on the type of bridge, some defects are quite small and can only be identified when the element is in direct view of the inspector. If the bridge design limits access, this can pose a significant challenge to completing the inspection.

Examining the Finlay Bridge shows the challenges in completing a typical inspection. Figure 2 shows an elevation of the complete structure.

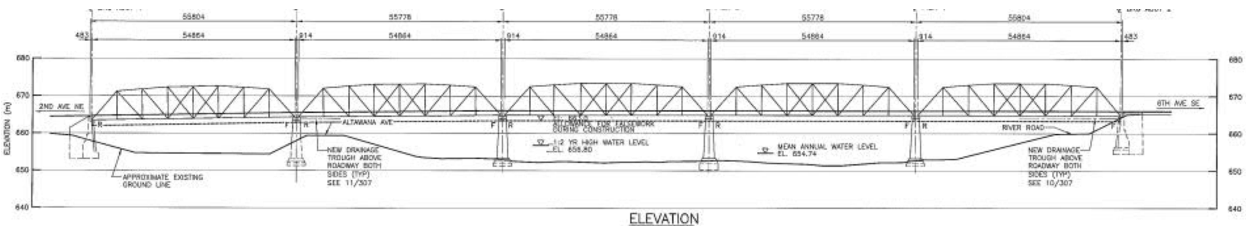

Figure 2: Finlay Bridge Elevation

The bridge was built in 1908, as part of the original Trans-Canada Highway. It has undergone many rehabilitations since that time, including the addition of sidewalks on both sides, numerous deck replacements, pier upgrading and recoating of the steel trusses. It spans a total of 270 m, with 5.8 m of clear roadway and 1.5 m wide sidewalks. It carries two lanes of southbound traffic only, with an approximate 11 m drop from roadway to top of water. Due to its historic and cultural value, the City stressed the importance of identifying all defects and preparing accurate repair plans. Based on the age and existing condition, the bridge has a posted loading of 15 tonnes for all vehicle configurations. It also has a vertical clearance posting of 4.4 m at both ends.

2 Site Specific Challenges

The configuration and location of the Finlay Bridge created a unique set of challenges associated with typical visual inspection techniques. When assessing the most appropriate strategy for the inspection, we evaluated our options with the following criteria.

Table 1: Finlay Bridge Inspection Criteria

Criteria	Challenge
Access	• Access to piers and bearings viewed as critical. • Numerous truss elements along the superstructure needed to be maneuvered around to gain access below.

Criteria	Challenge
Traffic Accommodation	• Bridge carries a high amount of vehicle and pedestrian traffic on a regular basis. • Significant logistical challenge as all traffic would be diverted to other crossing.
Safety	• Eliminating fall risks to inspectors. • Limiting lane closures reduce risk to travelling public.
Cost	• Cost-effective approach highly desired by the City. • Limiting labour and specialized equipment required.
Load Restriction	• Working within the load restrictions of the bridge.

We then assessed different inspection methodologies considering the above criteria. The most conventional method of deck underside inspections is the use of a snooper truck. This is a useful approach for simple bridges. The structure in the Figure 3 is a concrete girder vehicle bridge in Edmonton, AB.

The snooper truck was not a suitable choice in respect to the assessment criteria. Based on the configuration of the truss elements, the snooper could not physically manipulate the boom to provide access to the underside. The relatively narrow roadway width of the bridge meant that the snooper would require a full bridge closure to be used. Working out of the snooper requires safety certifications and has the inherent risk of working over water. The truck itself is unique and was not immediately available in the Medicine Hat area. It would have had to be driven from Calgary, approximately 2 hours away, thus increasing costs. Finally, and the most critical issue, based on the posted loading it was unclear if the truck could pass on the bridge.

The other approach that was investigated was using rope access. This is done by hiring a third-party rope contractor who arrives on site and rigs up the underside to allow the inspectors full access, as seen in Figure 3 below. Work is required to determine the feasibility of using rope access, as the effectiveness of the method is highly bridge dependent. The rope access contractor would require site photos and potentially a site visit to determine if it's possible. It's also likely to require at least one lane closure to facilitate the inspectors getting on and off the system. Overall, this approach was deemed impractical given the truss configuration and time needed to carry out the inspection. Because it is a time-consuming process and requires full mobilization, set up and tear down, the costs tend to be higher.

Figure 3: Recent Inspections completed using Snooper Truck and Rope Access

Another alternative included inspection from boat, which was ruled out early based on navigability requirements and logistical complications including an inability to get complete up-close visual observations of the key elements. Additionally, the South Saskatchewan River has a relatively high stream velocity and has many users in the summertime, including canoers, kayakers and rafters.

After considering all possible alternatives, the use of UAV's became a viable option with multiple benefits. They allow for visual observation of the complete underside of the structure, thus ensuring that each individual element is documented and examined. This provided the additional benefit of tracking each element over time and comparing them inspection to inspection. No lane closures or traffic accommodation was required, as the UAV operators only require a small take-off area that can be set up along the shore or bank, away from traffic. From a safety perspective, it eliminates all major hazards as it requires no work at heights, over water or around traffic. This approach only requires two additional people on site, one person operating the UAV and the other operating the mounted camera.

3 Inspection Approach

All elements that were accessible on land were visually inspected by the team. This included some truss elements, the deck surface, sidewalk and abutments. The typical visual inspection was carried out according to the Alberta Transportation (AT) Bridge Inspection & Maintenance (BIM) System, wherein every element receives a condition rating and maintenance recommendations are made for serious defects.

By inspecting the abutment bearing locations and approach spans, the team was able to build a baseline of expectations for general condition of the bridge and defects to recognize when reviewing UAV photos. This approach provided the bridge inspector with a reasonable level of confidence that defects would be identifiable in the images obtained by the UAV and give the team confidence in the results of the bridge inspections. By combining the up-close visual inspections with the UAV inspections for the areas that were inspectable by both methods, and getting thorough and reliable results, this was felt to provide the confidence necessary to proceed with UAV supplemented visual inspections.

Although successfully used in other areas of inspection, such as in the oil and gas industry for industrial flare tip and stack inspections, the authors were unable to find much published work in completing detailed visual inspections with UAVs. As such, significant time went into planning the inspections and coordinating with the many aspects of inspection and logistics with UAV contractor. From our experience, it is recommended that the UAV operators be fully accredited, experienced flyers and should be professional photographers. There are regulatory guidelines that must be followed and permits applied for ahead of time, including:

- A Special Flights Operations Certificate (SFOC)
- Permission from Governmental Bodies (City, Town, County)
- Nav Canada flight registration
- Notice To Airmen (NOTAM) if required

UAV use is subject to favourable weather. Prior to arriving on site, weather forecasts and high winds should be analyzed.

Once on site, the bridge inspectors and UAV operators would have a meeting to discuss the flight plan. The inspectors inform the operators of the critical elements/areas that require special attention. Based on this, the operators then choose a setup area and to place their gear and landing pad.

The cameras used for this purpose should be of high quality with optimal zoom capabilities. The benefit of having proper equipment is the ability to zoom (in our case up to 30x optical zoom) in on specific elements, including a specific bolt, screw, or element. Once in the air, one operator controls the UAV and the other takes the inspection photos. Based on the configuration of the bridge, the UAV may not be able to physically access every viewpoint, thus manipulating the camera (having full 360º capability) is highly beneficial.

A top-mounted camera gimbal allows for an unobstructed view of the bridge underside. The vehicle should be equipped with Obstacle Avoidance and the shooting capability of the camera capable to handle highlights, shadows and high contrast situations. The vehicle is also equipped with a D-RTK GPS system, which provides more accurate position when flying close-proximity to the structure. Figure 4 shows some pictures of the UAV being used at the Finlay Bridge.

Figure 4: Using the UAV at the Finlay Bridge

The footprint needed to setup the equipment is small. The operators can set up on rocky, uneven or sloped terrain, as they just need to ensure that the UAV has a flat surface to land on, typically through use of a tripod-like table system. From here, the UAV is flown to the various bridge elements, and photos are taken of the specific areas that were flagged by the inspectors.

One common misconception is that the bridge inspector will be able to actively dictate inspection, however this is not practical in most situations. When operating, the pilot remains focussed on the flight plan and is in communication with the photographer. At the Finlay Bridge, the UAV team used a portable office to download images for review with the inspection team to determine if areas required reinspection or images from other angles.

The inspection post-processing includes cataloging the images to a predetermined file-naming convention that matches the inspection methodology and aids in the bridge inspectors review, easily identifying what elements observed images correspond to. Additionally, as the UAV is equipped with a GPS system, each photo can be geotagged, to ensure that the inspectors can confirm with certainty exactly which element is being shown in each photo. Other processing activities include opening shadowed details, increasing highlight detail if needed. Figure 5 shows an example of the geotags being used to confirm the contents of a photo.

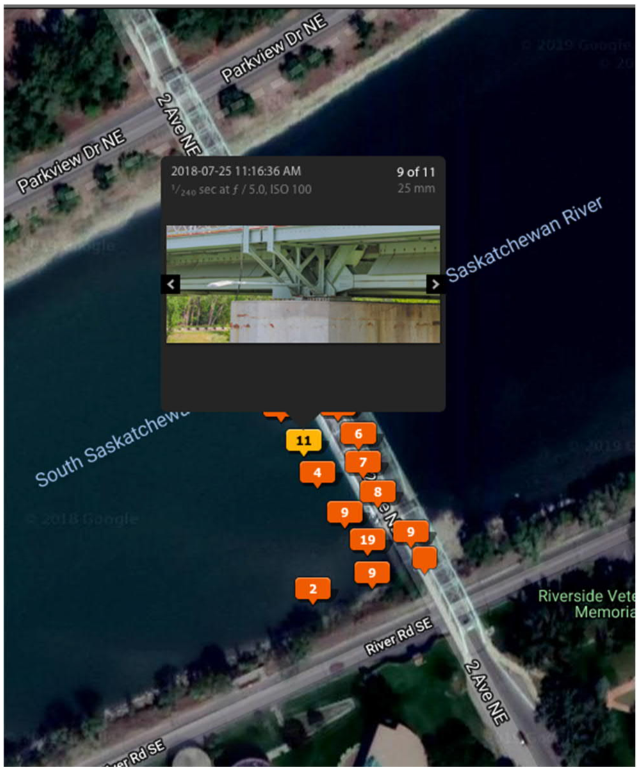

Figure 5: Geotagged Photos

4 Findings/Results

Figure 6 shows sample photos taken by the UAV during the inspection and the benefit of optical zoom.

Figure 6: Optical Zoom Capabilities

The photos on the left and right are at approximate 10% and 100% zoom, respectively. The original photos are typically in the order of 8 - 10 MB which can then be zoomed in considerably to identify any indication of deterioration. The colour quality of the photos is important as well in order to identify any discoloration in the elements (rusting, rotting, water leakage). Each photo is tagged with the element and direction.

These photos are highly effective when combined with the findings of the standard visual inspection at either abutment/approach span. With the baseline in mind, the inspector can look through and examine the photos for similar patterns of deterioration and ensure that these elements are included in any recommended rehabilitation program. It helps to strengthen the quantity estimates, which can be difficult to estimate for large bridges.

5 Conclusions/Lessons Learned

As far as the authors could determine, this was the first routine visual inspection of a major bridge in Canada, that was supplemented with UAV to replace up-close visual inspection. The use was highly successful, with many opportunities for future use. As this was a first application of this technology for the team, several lessons learned that have been documented that we hope will improve future bridge inspections supplemented with UAV.

Bridge Education: A significant aspect to consider is the operators knowledge base of bridge structures themselves. The inspectors will describe the areas they want photos of, but it’s crucial that the operators understand exactly what they are asking for. Thus, a strong emphasis should be placed on establishing the flightplan and going through existing drawings as a team beforehand. Ensuring consistent numbering of the elements simplifies the photo review process and record keeping. As the use of this technology increases, UAV operators will grow in their understanding of the bridge terminology and communication with the lead bridge inspector will improve.

Hardware Limitations: Understanding the limitations of the hardware helps to find efficiencies within the process and helps develop a realistic understanding of timelines and required effort. Flight times of the UAV are limited due to battery life. During the Finlay inspection, each flight lasted between 15 – 20 minutes. This requires the operators to recharge their batteries throughout the day, resulting in some downtime. The UAV has built-in GPS functionality, therefore if it ever loses sight of the landing pad, it will automatically return. This is important to remember as many bridges have various substructure configurations. Maneuverability is a potential issue depending on the substructure configuration but can often be compensated for in the manipulation of the camera.

Pedestrian Traffic: One risk that should be planned for is the presence of pedestrian traffic. At multiple times during the Finlay inspection, pedestrians would stop and try to query the operators. Depending on the volume of pedestrian traffic around the bridge it may be of value to have an additional team member handling pedestrian accommodation through the area, or even to close pedestrian traffic during flights. This also includes kayakers and rafters who were often using the South Saskatchewan River. When this occurred, the operators would need to fly back to the landing pad, as they could not fly over live traffic. The UAV cannot be used over vehicle traffic.

Wind Hazard: In terms of environmental hazards, the main source of potential conflict is wind. Based on the wind velocities in the area, the operators may decide not to fly that day, as it may result in damage to the equipment and increased risk to the surrounding public.

Methodology: The case-studies provide good results, as well as important lessons learned. Developing a standard methodology in supplementing visual inspections with UAVs will be an important next step. While positive results were obtained in this case-study, a standard methodology will provide the necessary confidence that thorough and complete inspections are being undertaken, and that inspectors recognize the limitations in UAV use when planning and completing inspections.

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References

Alberta Transportation. 2008. *Bridge Inspection And Maintenance System Manual, Version 3.1.* AB, Canada.