Operating and Maintaining Median High Tension Cable Barrier on Highway 2 in Alberta

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ABSTRACT

Alberta Transportation has been a leader in the application of High Tension Cable Barrier (HTCB) as a median barrier. In 2010, construction of 133 km of HTCB in the median of Highway 2 was completed from North of Airdrie to Red Deer and near Leduc. The design of this HTCB was complex due to the variety of median conditions when considering variables such as median width, sideslopes, and existing hardware in the median. Recent inquiries with HTCB suppliers indicate that this project remains the largest single HTCB installation in North America to date. Previous papers in TAC proceedings by staff of EBA, A tetra Tech Company, have discussed the design, construction and safety performance of this HTCB project. This paper will present a comprehensive discussion of the various maintenance and operational issues and considerations for this HTCB installation. The maintenance and operations of the HTCB has included repairs following hits (replacement of posts and attachments, cable sections, turnbuckles, etc.), regular maintenance, and changes to mowing and snow clearing practices. Although repairs to the HTCB can be completed faster than steel beam barriers, traffic accommodation to ensure the safety of workers and the traveling public is of paramount concern on Highway 2. Another issue which has resulted in the need for repairs of the HTCB is the cutting of the cable by first responders to free vehicles caught in the HTCB. Cutting of the cable can be hazardous due to the high tension in the system and results in a need to splice the cable or replace a significant length of cable at a high cost relative to alternative methods of releasing tension in the system. To reduce the frequency of this occurrence and to minimize risk to first responders (firemen, police, and tow-truck operators), EBA provided training sessions in Leduc, Red Deer and Calgary. The content of, participation in and results of this training program will be discussed. Following the first year of operations a warranty inspection was completed and the observations and repair requirements are presented. Lessons learned from the review of these topics will be of use to road agencies that are proceeding with the use of this flexible barrier system that has proven to be effective in reducing the severity of cross median collisions in Alberta and elsewhere.

PURPOSE OF PAPER

Since May 2007 Alberta Transportation (AT) has completed several installations of high tension cable barrier (HTCB) in median and shoulder applications on provincial highways. The largest of these projects, 133 km of HTCB on 122 km of Highway 2 between Airdrie and Red Deer and in the vicinity of Leduc, was completed in July 2010, and is believed to be one of the largest HTCB projects in North America. Figure 1 shows the location of this project.

EBA, A Tetra Tech Company, provided the design and construction supervision services and Alberta Highway Services Ltd. (AHS) was the construction contractor selected through competitive bidding and many innovations were applied to increase the speed of installation and reduce the exposure of the contractors staff, described in Hassan et. al., 2011. This paper describes the maintenance and operational activities and how these activities have resulted in better, faster, and safety road maintenance of the HTCB.

OVERVIEW OF HIGH TENSION CABLE BARRIER

Advantages and Limitations of High Tension Cable Barrier

In comparison with rigid concrete and semi-rigid steel barrier systems (i.e. Concrete, W-beam, Strong post, Thrie beam, Modified Thrie beam, Box Beam etc.), the advantages of HTCB include (Hassan et. al., 2011):

- significantly reduced collision severity (fewer fatalities and injuries); high tension cable barriers deflect and thus cushion the force of the hitting vehicle and are therefore more forgiving than concrete and steel beam;
- reduced damage to vehicles; a significant proportion of vehicles which hit HTCB are able to drive away;
- cost to install is much less than concrete or steel barrier systems;
- if impacted, relatively fast and easy to repair;
- can retain much of its tension after a hit and can take additional hits until repaired;
- reduced snow drifting;
- improved sight distances in problem areas; and
- aesthetic appeal, visually non-intrusive;

Other HTCB benefits include:

- although not designed to stop semitrailers, there have been numerous instances where semitrailers were successfully restrained; and
- published research indicated HTCB is not any worse than other barrier types for motorcycles.

Limitations of HTCB include:

- HTCB has not been tested and approved for installation as a median barrier on median side slopes steeper than 4H:1V;
- HTCB is not suitable for very narrow medians (less than approximately 6 m) because the cables need space for deflection and must have sufficient distance from the nearest travel lane in both directions;
- HTCB is not suitable on small radius horizontal curves (less than about 200 m); and
- HTCB requires hand mowing around the post foundations.

A summary of the experience with cable barriers in the US, where over 5,000 km median cable barriers have been installed, is provided in Ray, et al, 2009. Churchill et al, 2011, report the results of a before-and-after analysis of the 11 km HTCB installed in 2007 on Deerfoot Trail, Calgary, Alberta. More recently, Churchill et al., 2013, reviewed the safety performance of the subject section of cable barrier and found reductions in injury and fatality collisions. Evaluations of HTCB consistently report reductions in injury and fatal median collisions and high benefit-cost ratios.

Testing and Approval of High Tension Cable Barrier Systems

The HTCBs installed on major highways in the US and Canada are generally selected from the products approved by the US Federal Highway Administration (FHWA) on the basis of tests conducted by independent laboratories. A brief description of the required testing procedures, test levels, and the FHWA approval process is provided in Hassan et al, 2007. Approved HTCBs for Test Level 3 (tested for a pickup truck) and Test Level 4 (tested for a single-unit truck) are available from five manufacturers: Brifen, Gibraltar, Nucor, Safence, and Trinity (see Photo 1). The parts are not interchangeable between various proprietary HTCB systems. Table 1 shows selective test data, including the maximum test deflection at the given post spacing, for the five cable barriers approved by FHWA for installation on 6:1 and 4:1 median side slopes. The data in the table are summarized from the FHWA acceptance letters.

New products, new tests and new FHWA guidelines may be introduced any time. It is therefore essential that thorough research be undertaken regarding available products before designing new HTCB installations.

RELEVANT DETAILS OF THE HIGHWAY 2 CABLE BARRIER PROJECT

The following selective details of the Highway 2 HTCB installation are relevant to the discussion of the maintenance and operations described in the subsequent sections of the paper.

- Since only one median HTCB is normally installed to protect both directions of traffic, sufficient deflection space consisting of the maximum specified deflection plus a safety margin must therefore be provided between the HTCB and the median side painted yellow shoulder lines in both directions; and also between the HTCB and a median hazard if the HTCB is relied upon to protect the hazard. The preferred HTCB location from a soil strength viewpoint is generally is at the top of the median side slope near the shoulder, as long as the above conditions and other FHWA guidelines can be met.
- The ditches are often uneven, with weak soil conditions and may require extra grading, compacting and review of the overall drainage patterns. HTCB was installed in the ditch only when shoulder installations were not able to meet the desirable deflection space requirements.
- As a result of competitive bidding, Highway 2 HTCB project was awarded to Alberta Highway Services (AHS) with Gibraltar as the manufacturer/supplier of the four-cable HTCB system. The project was awarded in September 2009. AHS used the time from award of contract to start of construction work in April 2010 for surveying, pre-casting foundations and other planning activities. Site work began in April 2010 and was completed in July 2010.
- Following the completion of construction, AHS continued the maintenance and operations of the HTCB as the holder of a multi-year maintenance contract with AT for portions of central Alberta, including Highway 2 between Airdrie and Red Deer.

- Some relevant statistics are:

Traffic volume	Up to 80,000 vehicles/day (AADT)
Length of Highway 2 with HTCB	122 km
Length of cable barrier installed	133 km (55 km near the shoulder on the northbound or southbound side, 56 km in the middle of the median ditch, and 11 km on both northbound and southbound side)

Number of cable barrier segments	53 (Average length = 2.5 km)
Number of end terminals	106
Number of line posts	20,000

The capital construction cost of the 133 km of HTCB installation on 122 km of Highway 2 was $7,457,800.

MAINTENANCE AND OPERATIONAL ISSUES

After every hit to the HTCB, the repairs are carried out and paid for including items such as traffic accommodation; and replacement of posts, hairpins, locks plates. Typical HTCB hits are illustrated in Photo 2 and Photo 3. The total maintenance cost for repair of the HTCB from July 2010 to December 2010 amounted to $252,260 which equates to an average yearly maintenance cost of $504,520, or $4,135/km. This cost includes the cost for supply of materials, the additional cost for traffic accommodation and inspection and the cost for mowing/trimming and snow clearing.

Since the installation of the HTCB on Highway 2, AHS has had to learn many new ways of doing maintenance. Not only the maintenance to the barrier itself, but also changes to how routine maintenance near the median is carried out. The timing of HTCB repairs has been established based on potential severity criteria with more severe hits (i.e. cables pinned to the ground or tension loss due to end terminal release as shown in Photo 5) requiring repairs sooner than typical hits where cables remain at the correct height and tension.

The location of the HTCB (near the centre of median, along the shoulder edge of the highway or offset along the highway) plays a big factor in how maintenance and operations activities are completed.

Some of the maintenance benefits of working with or repairing the cable barrier are that:

- in most cases post replacement can be completed a lot quicker than conventional W-Beam rail, bent posts are pulled out the socket and a new post inserted (Photo 4);
- crews can handle larger sections of damage in a day as opposed to W-Beam rail;
- winter post replacement poses only minor problems as opposed to summer post replacement;
- smaller crews can handle the work in relation to other types of barriers;
- smaller crews means reduced repair cost compared to W-Beam or other barriers;
- the re-tensioning process is relatively simple, once learned, and can be completed in a timely manner after repairing of damage sections. The re-tensioning must be completed after any section is hit;
- splicing of the cable if needed is a relatively simple process with the right knowledge and equipment;
- after a hit the barrier is still functional in most cases and will continue to do its job to a degree until repairs are completed (AHS finds that this holds true unless the cables are laying on the ground);

- it appears the cable can withstand many hits without compromising strength or integrity of the cable itself; and
- the authors are unaware of any instance when the cable broke from anything other than being cut by first responders or others.

Some of the issues that have arisen since the installation of the cable barrier are related to safety of the contractors' workers and related issues which have been introduced to the routine maintenance that needs to be performed in the median and around the HTCB.

- Escape routes for maintenance workers while working in the driving lanes along the cable barrier when it is beside the shoulder of the asphalt are now eliminated or compromised greatly. Workers can no longer just run into the ditch.
- In some cases, short duration work that only took minutes and could be performed without traffic accommodation now requires a full traffic accommodation strategy (TAS) as the contractor cannot get off of the surface to complete the work. (e.g. sign repairs, culvert steaming)
- Locations where the barrier is installed on the shoulder edge has eliminated any parking of maintenance vehicles. This is an added risk for the contractors' workers as they must now cross driving lanes, find a way into the median or, in some cases, must have traffic control.
- An activity as routine as removing a road kill from the inside lane when the barrier is installed at the edge of asphalt can no longer be done from the inside lane. Workers must either drag the animal across the outside driving lane when traffic allows, (this causes great exposure and risk to maintenance workers) or drag the animal under the barrier and find a way to get inside the median to pick it up, (this cannot be done in the winter or wet weather) or use traffic control such as signs and flag people.
- The previous issue also applies to the activity of debris removal from the median. Workers must take the debris from the surface of the inside travel lane to a vehicle that is parked on the outside shoulder. This results in increased exposure of workers to traffic and the dangers associated with the surface of any highway. This can also only be done when weather and seasonal conditions permit. AHS workers are requested not to lift objects over the barrier due to potential hazards of lifting on slopes or uneven ground. This process has added a lot of extra time to routine maintenance and operations activities.
- Narrow sections of median where the barrier is in the bottom of the median now forces mowing tractors onto the shoulder of the highway. In some cases traffic accommodation is now required.
- Some cases where the barrier transitions from the ditch bottom to the shoulder mowing tractors are forced onto the shoulder of the highway. This leads to increased risk and large delays while waiting for gaps in traffic so moving can be completed.
- Trimming of the grass along the length of the barrier exposes the contractors' workers to great risk. One such section is near the Olds overpass where the barrier is near the centre of the ditch but the median is narrow and there are very narrow paved shoulders. This results in workers being within arms-length of traffic travelling at highway speeds. Due to limited space, maintenance vehicles cannot be safely accommodated without the use of

signage and a lane closure in order for the trimming to be completed safely. This also causes delays in the traffic and increases driver frustration.

- In locations where the barrier is slightly offset from the surface we must now either expose tractors to the surface in order to mow the 1 to 2 feet or expose hand trimmers to the area. Either way a very dangerous situation.
- Snow removal where the barrier is on the edge of the shoulder has also been a concern. With the barrier on the shoulder it is no longer possible to wing the ditch to push the snow further into the median. The snow now just builds against the barrier when ploughing is unable to throw the snow past the HTCB. This can be cause for further drifting and snow build up as well as removal issues should the need arise. In the spring, melting snow can be trapped and held on the shoulder of the highway due to the snow banks that have accumulated over the winter. Removal of the snow can only get so close to the barrier should it be needed.
- In some locations AHS completes washing of the highway infrastructure at night to limit the exposure of workers to the travelling public as there is no escape route on the inside travel lanes now in some locations. This also helps to avoid delays to traffic during peak periods of travel in daylight hours.

Traffic Accommodation Strategies (TAS) that are implemented for maintenance activities on the HTCB or next to the HTCB are determined by several factors including barrier placement and traffic volumes. Traffic accommodation can vary from a very simple strategy including a truck with an arrow board to a very complex strategy involving lane closures; examples are shown in Figure 2 and Figure 3. Each location and activity is discussed prior to commencement of the work activity to ensure the proper TAS is implemented.

With the introduction of the HTCB to the median there is a need to adjust and look at every activity at every location on a daily basis to ensure the safety of AHS workers and the travelling public. AHS and AT are constantly reviewing Traffic Accommodation Strategies to ensure that both the workers and the traveling public are protected while aiming to minimize exposure by completing the work quickly.

FIRST RESPONDER TRAINING

Information, in text and video format, regarding best practices from the US was presented by EBA to first responders (fire, ambulance, and police departments in Calgary, Leduc County, City of Leduc, and in Counties and Towns serving Highway 2 between Calgary and Red Deer, as well as tow trucking companies operating in the area) in three information sessions:

RED DEER: Monday, November 22, 2010; 10:00 a.m. - 12:00 noon (Attendance: 34)
LEDUC: Wednesday, November 24, 2010; 10:00 a.m. - 12:00 noon (Attendance: 20)
CALGARY: Thursday, November 25, 2010; 2:00 p.m. – 4:00 p.m. (Attendance: 22)

At the request of the RCMP Airdrie Integrated Traffic Unit, a presentation was also made at the "Highway 2 winter planning session" on October 26, 2010 in Airdrie.

Information for First Responders

Following an overview of the characteristics of HTCB, a generic summary of vehicle handling, tension release and cable cutting procedures was provided for first responders. However, it was strongly recommended that first responders have a copy of the particular supplier's guidelines available at all times, and follow them in the light of their professional judgment. It was also recommended that all first responders, particularly the fire rescue and tow truck personnel, be trained in working near the barrier and aware of the preference for not cutting the cable, but if required how to do so safely as a last resort.

Releasing Tension and Extraction of Vehicles from High Tension Cable Barrier

The following summary guidelines regarding releasing cable tension to facilitate extraction of vehicles entangled in HTCB were communicated to first responders. Various ways to release cable tension are:

- Remove hairpins & lock plates up and downstream of the crash site
- Loosen the nearest turnbuckle(s); there should be a turnbuckle about every 300 m. Note that the turnbuckle designs may vary, but simple tools like wrenches or crowbars is all that is required to loosen the turnbuckles. Turnbuckles should not be loosened beyond a certain point; otherwise there is risk of the cable slipping out of the turnbuckle.
- Remove posts, or cut posts at grade (near the ground), on either side of the vehicle.
- Knock down/pushover with a mallet or crowbar the cable-release terminal at the end of the cable run. However, cable runs can be long (up to 5 km on Highway 2), and there may not be an end terminal in vicinity of the crash site. It should be remembered that this action, and cutting the cable discussed in the next section, should be taken as a last resort because it will remove all tension from the entire cable run, and could allow a vehicle to cross the median which may result in a higher severity collision.

To extract the vehicle from the cable barrier, pull the vehicle out the same way it went in. In some cases, the part of vehicle entangled in the cables may need to be cut off, which is much preferred to cutting the cable. If the vehicle is lying on top of the cables, it may need to be lifted.

In all cases, new posts should be installed and cable tension checked as soon as possible per AT's HTCB maintenance specifications or special provisions.

Cutting of High Tension Cables When Absolutely Necessary

As discussed in the previous section, the cable should be cut only as a last resort. In this vein, it is interesting to note that the Michigan Department of Transportation requires the first responders to obtain the Department's permission before cutting the cables.

Guidelines for cable cutting were provided to first responders, and videos were used to demonstrate safe methods of cable cutting. In summary, if the cable must be cut, it should preferably be cut at a turnbuckle between two upright posts; there should be a turnbuckle about every 300 m. The repair of cut cables takes longer and is more expensive than replacing turnbuckles. A clear message was communicated to participants that cutting the cables will disable the entire cable run, and it is important that repairs be performed as soon as possible, and that the HTCB be re-tensioned.

WARRANTY INSPECTION

Prior to the warranty inspection of June 20th, 2011 EBA, performed a detailed inspection of the median cable barrier system, which detailed the type of end anchor at each median cable barrier segment, movement out-of-plum at each location, and any additional deficiencies noted at the time of inspection. The warranty inspection was completed by EBA, AHS and AT.

The following is a summary of the observations made during the detailed and warranty inspections of the median cable barrier system made the week of June 13th, 2011 and June 20th, 2011 respectively.

- A majority of the end anchors and terminals, both concrete and driven, were out-of-plum. The distance out-of-plum varied from site to site, and is dependent on soil conditions and construction methods.
- No movement of the cast in place anchors at the control section of Hwy 2:18, km 11.935 and km 11.978 was observed during inspection. (Photo 6)
- The precast concrete anchors in the northbound and southbound lanes of the Red Deer section (approx. km 26.350 to km 36.440) were showing significant (30-50cm) of movement out-of-plum. In addition, the material used to backfill around the anchors, has been eroded away leaving holes 40-50 cm in depth. (Photo 7)
- Driven anchors, along with the attached angle iron, are observed to be lifting out of the ground at various locations. Movement of the anchors and terminals was observed to be 10-20cm out-of-plum.
- At the Olds overpass (Control Section at Hwy 2:20/:22) the line posts at these short sections were tilting at an angle in the tapered transition between anchor and terminal and the line posts in the centerline of the median ditch.
- Several sections of barrier that were repaired by the maintenance contractor were missing the reflective stickers required on the line posts. When replacing portions of the cable barrier that have been damaged by vehicle impacts, the placement of the reflective stickers should be required as they are part of the cable barrier system.
- It was mentioned during the inspection that the threading of any type of turnbuckle should extend a minimum of ¾" to 1" into the turnbuckle to prevent the bolt threads from pulling out during tensioning. (Photo 9)

A table of the compiled end anchor and terminal information, detailing the amount of movement and any additional observations was prepared to assist in the development of a repair procedure. In consultation with Gibraltar, AHS developed a repair procedure to address all of the identified issues.

POSITIVE RESULTS OF MAINTAINING AND OPERATING THE HTCB

With each new innovation or improvement comes adaptation and issues. Many of the issues and solutions described in this paper will be directly applicable to other sites. However, as more HTCB systems are placed on the highway network different issues will arise regarding maintenance and operations unique to those proprietary systems. Contractors will need to continue the development of practices to address these issues to ensure that the HTCB systems perform in the manner intended.

This type of maintenance work was new to AHS but, in collaboration with AT, meeting the challenge to provide better, faster, safer maintenance of the HTCB has contributed to success in terms of collision severity reductions on Highway 2.

REFERENCES

Churchill, T., Barua, U., Hassan, M., Imran, M., and Kenny, B. (2011). Evaluation of safety and operational performance of high tension median cable barrier on Deerfoot Trail, Calgary, Alberta. Paper prepared for presentation at the "Canadian Applications of the AASHTO Highway Safety Manual" Session of the 2011 Annual Conference of the Transportation Association of Canada, Edmonton, Alberta. 2011.

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Hassan, M., McGregor, R., and Lahey, O. (2007). Design of a TL-4 median cable barrier For Deerfoot Trail, Calgary. Proceedings of the Transportation Association of Canada Annual Conference, Saskatoon, Saskatchewan, 2007.

Ray, M., Silvestri, C., Conron, C. and Mongiardini, M. (2009). Experience with cable median barriers in the United States: design standards, policies and performance. Journal of Transportation Engineering, v 135, n 10, 711-720, October 2009.

TABLES

TABLE 1. Selective characteristics of the five FHWA-approved high tension cable systems*

<table>
<tr><th rowspan="2">Item</th><th>Brifen</th><th colspan="2">Gibraltar</th><th>Nucor</th><th colspan="2">Safence</th><th colspan="2">Trinity</th></tr>
<tr><th>4-cable only</th><th>3-cable</th><th>4-cable</th><th>4-cable only</th><th>3-cable</th><th>4-cable</th><th>3-cable</th><th>4-cable</th></tr>
<tr><td>6:1 OR FLATTER SIDE SLOPE, (FHWA-approved as TL-4)</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Test deflection, m</td><td>2.4</td><td>2.4</td><td rowspan="2">Assume same as 3-cable</td><td>2.55</td><td>3.7</td><td>2.1</td><td>2.3</td><td>2.3</td></tr>
<tr><td>Test Post Spacing, m</td><td>3.2</td><td>6.1</td><td>6.1</td><td>10.0</td><td>4.0</td><td>6.1</td><td>6.1</td></tr>
<tr><td>Selective FHWA guidelines for installation on 6:1 or flatter side slope</td><td colspan="8">May be placed in the median ditch; when placed on the median side slope the cable barrier should not be between 1 ft and 8 ft (0.3 m and 2.4 m) from the ditch bottom.</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4:1 SIDE SLOPE, (FHWA-approved as TL-3)</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td><td>?</td><td>Yes</td></tr>
<tr><td>Test deflection, m</td><td>2.7</td><td>2.6</td><td rowspan="2">Assume same as 3-cable</td><td>2.93</td><td>5.0</td><td rowspan="2">FHWA letter pending</td><td>?</td><td>2.28</td></tr>
<tr><td>Test Post Spacing, m</td><td>3.2</td><td>6.1</td><td>6.1</td><td>4.9</td><td>?</td><td>6.4</td></tr>
<tr><td>Selective FHWA guidelines for installation on 4:1 side slope</td><td colspan="8">May be placed in or near (+/- one foot or +/- 0.3 m) the centre of a 4:1/4:1 median ditch; when placed on the median sideslope the cable barrier should be no more than 4 ft (1.2 m) down a 4:1 slope and no closer than 8 ft (2.4 m) from the ditch bottom.</td></tr>
<tr><td>FHWA-approved End Anchors</td><td>TL-3, TL-4</td><td>TL-3</td><td>TL-3</td><td>TL-3</td><td>TL-3, TL-4</td><td>TL-3, TL-4</td><td>TL-3</td><td>TL-3</td></tr>
</table>

(Source: FHWA approval letters)

* Rather than relying on this summary table, designers should consult the original FHWA approval letters for these products and search for the latest versions of the products. Note that new products or new tests on existing products may be introduced any time, e.g. as of March 2011 Safence had FHWA approval letters pending based on new tests.

FIGURES

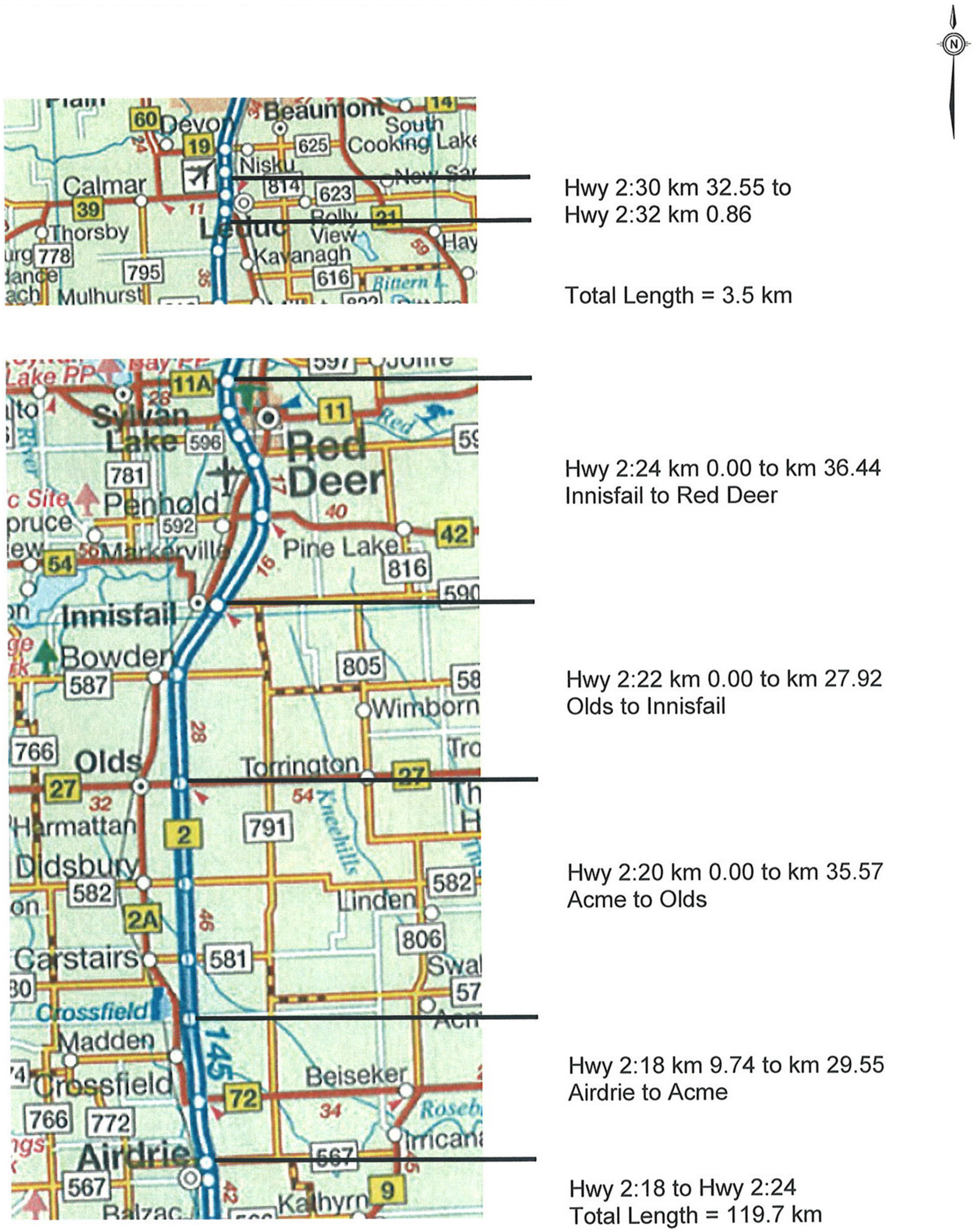


FIGURE 1. Location of Alberta Highway 2 High Tension Cable Barrier project.

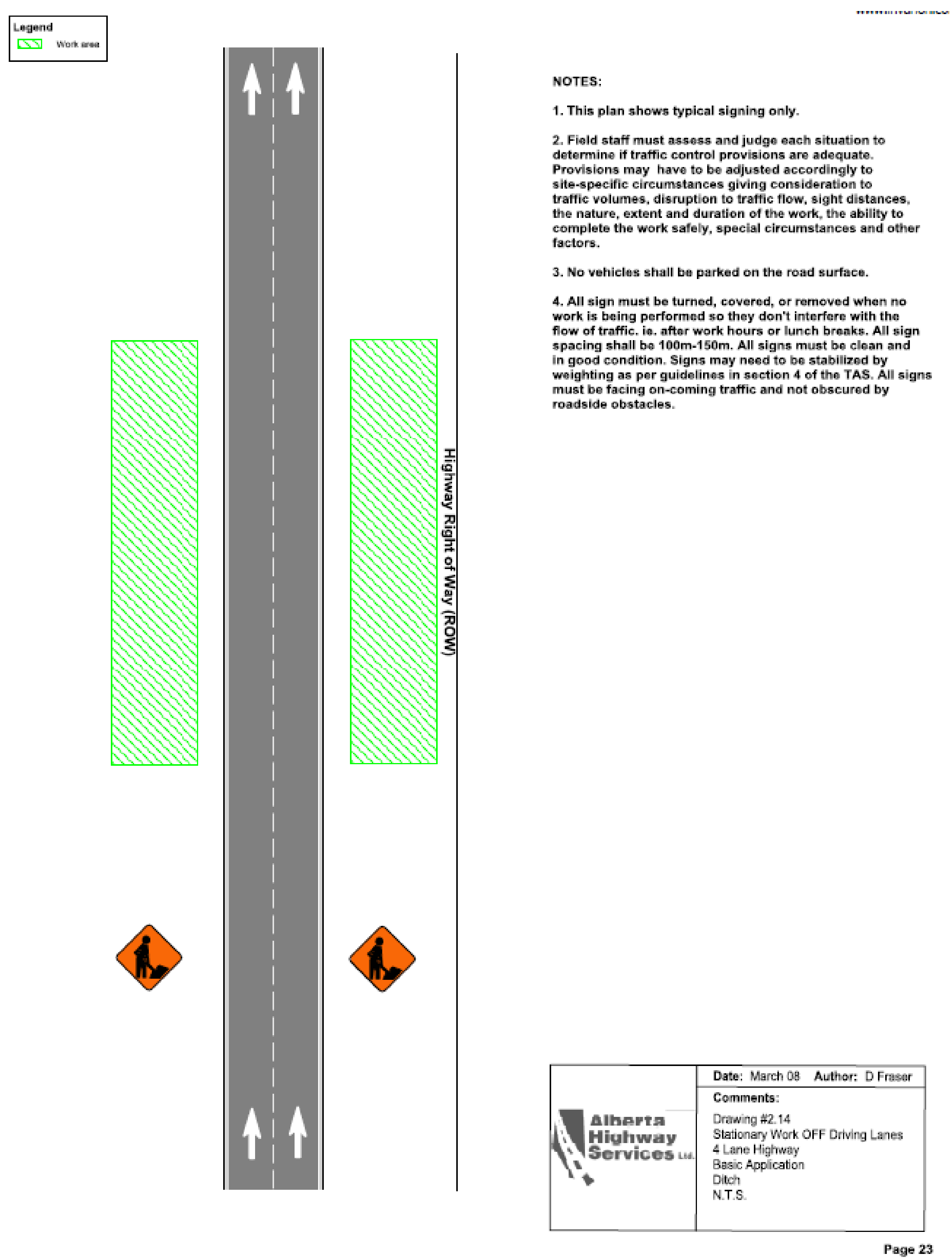
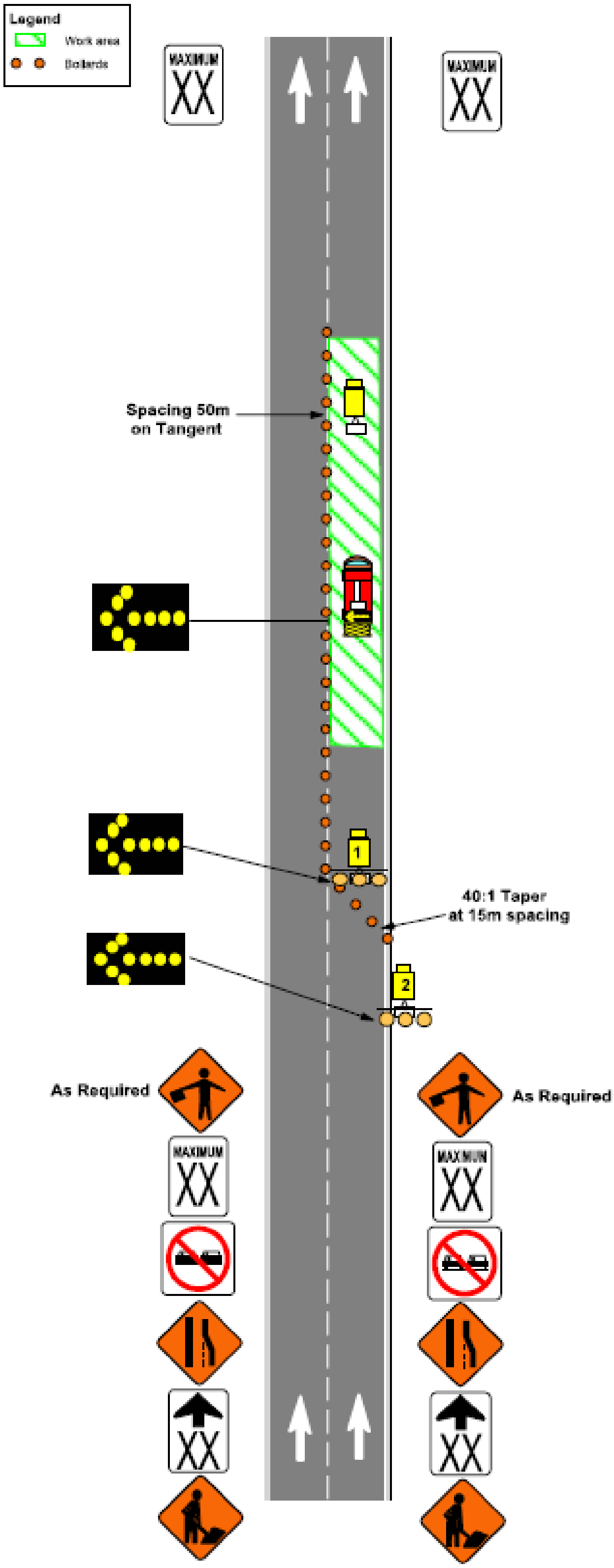


FIGURE 2. Simple Traffic Accommodation Strategy when space allows.



NOTES:

1. This plan shows typical signing only.

2. Field staff must assess and judge each situation to determine if traffic control provisions are adequate. Provisions may have to be adjusted accordingly to site-specific circumstances giving consideration to traffic volumes, disruption to traffic flow, sight distances, the nature, extent and duration of the work, the ability to complete the work safely, special circumstances and other factors.

3. Sequential Arrowboard #1 shall be located in the center of the closed lane within the transitional area. Sequential Arrowboard #2 is placed as an advanced warning device on the shoulder 100m to 300m in advance of the taper. An additional Sequential Arrowboard may be required in situations identified from the above assessment where sight distance is restricted or other special circumstances arise. These situations may be such things like curves, hills, or intersections. It's positioning is dependant on the site-specific situation.

4. Cones must be set on a 40:1 transitional taper with 15m spacing of cones and 50m on tangent. Cones must be a minimum of 70cm in height. Cones on tangent may be placed off the centerline allowing extra room for work activity and enhanced available worker safety. A minimum open lane width of 3.5m must be applicable at all times. Wide loads may need to have special consideration.

5. A Crash Attenuator with an arrowboard is used as a Companion vehicle. The unit is positioned to create an additional work zone buffer (space between Crash Attenuator and crew) in the 50-200m range. The optimum distance is determined from the assessment completed in point #2.

6. Flagpersons must be equiped as per specifications and follow procedures outlined by ACSA.

7. All sign must be turned, covered, or removed when no work is being perfomed so they don't interfere with the flow of traffic. Ie. after work hours or lunch breaks. All sign spacing shall be 100m-150m. All signs must be clean and in good condition. Signs may need to be stabilized by weighting as per guidelies in section 4 of the TAS. All signs must be facing on-coming traffic and not obscured by roadside obstacles.

8. Space between the last advance warning sign and the flagperson sign must be at a minimum of 100m. Buffer Space between flagperson and workspace shall be a minimum of 100m. For special circumstances where a speed reduction exists (ie. Intersections, urban areas) above distances may be reduced.

9. In CMA 17&19 80 Ahead and Maximum 80 to be used. All other CMA's 70 Ahead and 70 Maximum.

Alberta Highway Services Ltd.

Date: March 08 **Author:** D Fraser

Comments:

Drawing #2.08
Moblie Work IN Driving Lanes
4 Lane Highway
Basic Application
Typical Circumstances
N.T.S.

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FIGURE 3. Traffic Accommodation Strategy when lane closure required.

PHOTOS

PHOTO 1. Photos of the five FHWA-approved high tension cable barrier systems.

PHOTO 2. Typical HTCB hit in the median of Highway 2 looking downstream (vehicle travelling in direction of photo). Note wheel path in grass.

PHOTO 3. Typical HTCB hit in the median of Highway 2 looking upstream (vehicle was traveling toward photo on left side of the median). Note direction of posts.

PHOTO 4. Bent post with un-damaged socket can be extracted and a new post fitted.

PHOTO 5. Sagging cables due to release of end terminal.

PHOTO 6. Bent line post, hairpin, and lockplate.

PHOTO 7. Cast in place concrete end terminal anchor with no movement.

PHOTO 8. Pre-cast concrete end terminal anchor out of plumb and erosion.

PHOTO 9. Turnbuckles connecting cables with insufficient thread following tension release.

PHOTO 10. Clip on Quick Check Tension Meter (DILLON) to measure tension in the cable.