MAPLE CREEK EMERGENCY CULVERT REPLACEMENT

TRANSPORTATION CATEGORY

SUBMITTED TO:
CANADIAN CONSULTING ENGINEER
80 VALLEYBROOK DRIVE
TORONTO, ONT., M3B 2S9
ATTENTION: BRONWEN PARSONS

MDH ENGINEERED SOLUTIONS
Member of the SNC-LAVALIN Group

Saskatchewan Ministry of Highways and Infrastructure

Contact: Fred Antunes, P. Eng., FEC Vice President, Infrastructure; *fred.antunes@snclavalin.com*

MAPLE CREEK EMERGENCY CULVERT REPLACEMENT

TRANSPORTATION CATEGORY

The Junction Dam is located approximately eight (8) km north of the Town of Maple Creek, Saskatchewan. In 2008, the Junction Dam was reconstructed to include a free-overflow labyrinth weir structure (Labyrinth Spillway) to handle increased flood waters and reduce operating risks during run-off events. The auxiliary spillway is located approximately one (1) km east of Maple Creek.

Figure 1 – Location of Maple Creek and the Trans-Canada Highway

In 2010, increased spring runoff combined with heavy precipitation in April and May filled the water storage reservoirs in the area of the Junction Dam. Over 100 mm of rain fell on the Maple Creek drainage basin over the evening of 17 June 2010 through to 18 June 2010. The peak inflow to the Junction Reservoir occurred at 12:00 am and was categorized as a 1:3300 year event. The heavy rain fall caused the outflows from Maple Creek to exceed the capacity of the existing two (2) 3.6 m corrugated multiplate culverts under Trans-Canada Highway. The water consequently overtopped the Trans-Canada Highway (Highway No. 1) on 19 June 2010 at 1:50 am. Approximately 100 m of the westbound lanes of the Trans-Canada Highway washed out by 4:50 am, with damage also occurring to 200 m of the eastbound lanes, leaving an 11 m high crater around the culvert location (Figure 2 and Figure 3). The Trans-Canada Highway near Maple Creek generally handles approximately 4,700 vehicles per day, with approximately 33 per cent being heavy truck

traffic. Until traffic on the Trans-Canada Highway was restored, motorists and truck traffic were diverted on a five hour detour, which significantly impacted transportation efficiency for anyone using the Trans-Canada corridor in this region.

Figure 2 – Remaining eastbound lanes, looking east.

Figure 3 – Damaged roadways and culverts, looking north.

MDH personnel arrived at the washout site on 20 June 2010 at 10:30 am. The Saskatchewan Ministry of Highways and Infrastructure's (SMHI) significant initial concerns included potentially losing the remaining eastbound lanes due to a piping failure from seepage and the uncertain stability of the vertical face. Losing the remaining eastbound lanes would have forced traffic to remain on the five hour detour for several months.

Emergency repairs began immediately to stabilize and restore the eastbound lanes and construct temporary traffic transitions to allow two-way traffic on the eastbound lanes. Construction began by excavating the washout area on 21 June 2011 and hauling 41,000 tonnes of granular material to the washout site from a SMHI aggregate source using a combination of SMHI and private trucks.

The material was placed against the eastbound lanes (Figure 4). The placement of granular material was completed in three (3) days. Erosion control material was installed to protect the granular material. The

eastbound lanes and temporary transitions were paved and the two-lane facility was open to motorists on 26 June 2011, one (1) week after the flood event.

Figure 4 – Placing granular material.

SMHI's subsequent concern was to reopen the divided Trans-Canada Highway prior to winter months, so motorists would not be navigating a two lane section of highway in adverse winter weather conditions. MDH worked with AECOM to design a more permanent highway transition to safely accommodate traffic between the eastbound and westbound lanes during construction in 2010 and 2011. MDH completed and released a tender package for the permanent highway transition construction on 01 July 2010. Due to costs significantly exceeding the pre-tender estimate, the contract was not awarded. AECOM redesigned the transitions to accommodate speeds of 60 km/hr and large truck traffic. The permanent highway transition construction was completed by 13 July 2010 under day-labor agreements with several local contractors.

MDH completed a geotechnical investigation at the existing culvert location and a material borrow source investigation near the site, which included drilling several boreholes. MDH also completed as-built plans for the eastbound and westbound lane construction and a topographic survey. MDH subcontracted Northwest Hydraulic Consultants (NHC) to complete the hydraulic analysis and design.

Agriculture and Agri-Food Canada (Prairie Farm Rehabilitation Administration) provided advice on backwater levels downstream of the labyrinth spillway because they required the culverts downstream of the Junction Dam to provide a specific amount of back water for the spillway to operate safely.

According to various design criteria requirements, NHC evaluated the following six (6) options:

- Option 1: 9.6 m span and 3.7 m rise single arch culvert;
- Option 2: 11.8 m span and 4.8 m rise single arch culvert;
- Option 3: Two (2) 3.6 m circular pipes;
- Option 4: Two (2) 3.6 m circular pipes and one (1) 4.6 m circular pipe;
- Option 5: Minimum 42 m long standard Saskatchewan Ministry of Highways and Infrastructure bridge designed to utilize the standard pre-cast units and standard bridge girders; and
- Option 6: Minimum 16 m long custom bridge design with vertical abutments.

All culvert design options (options 1 through 4) met the backwater criteria for the Junction Dam labyrinth spillway. The bridge design options required an additional control structure to create the desired backwater levels. NHC and MDH recommended installing one (1) 11.8 m span and 4.8 m rise single arch culvert. This recommendation allowed for a high-flow capacity that would accommodate a 1000 year flood event without overtopping the roadway. This design also controlled impacts to upstream and downstream channels and allowed for greater flexibility during the design and construction processes. The original design parameters for the single arch culvert are shown in Table 1.

Table 1 – Summary of Hydraulic Parameters for arch culvert option.

Shape	Low Profile Arch Culvert
Size (m)	11.78 (maximum span), 11.68 (bottom span), 4.80 (total rise)
Manning's n	0.040 (bottom); 0.035 (top/side)
U/S Invert (m)	743.7
D/S Invert (m)	741.5
Design Discharge (m^3/s)	232
U/S Water Level (m)	751.15
Maximum Velocity (m/s)	6

MDH sub-contracted NHC to complete the culvert design. NHC evaluated alternative culvert/bridge structures, and recommended a proposed structure and location. In addition, NHC completed a configuration of the roadway embankment relative to the proposed structure, and determined the riprap size and layer thickness to prevent erosion of the underlying till material downstream and on the roadway embankments. MDH worked with SMHI to develop the construction sequencing to maintain flow capacity

in Maple Creek during construction. The design was modified in as construction was starting in September 2010 to adjust the invert and outlet elevations in order to accommodate fish passage requirements, upstream water ponding, and the stand up walls proposed for the arch culvert by the Contractor.

MDH produced the following four (4) separate tender packages through 16 August 2011 to 30 September 2011:

- Arch Culvert Tender Package released 16 August 2010 and awarded to SaskCon Repair Services Ltd. on 24 August 2010;
- Roadway Construction and Granular Backfill Tender Package released 28 August 2010 and was not awarded due to high estimates;
- Aggregate Production Tender Package released on 14 September 2010 and awarded to Rock Hound Crushing Ltd. on 16 September 2010; and
- Westbound Lanes Roadway Construction Tender Package released on 23 September 2010 and awarded to Cee Gee Southern Inc. on 30 September 2010.

The last two tender packages were developed because there was only one bidder and high costs for the 28 August 2010 tender package. As a result, the scope was changed and two additional tender packages were developed. The Westbound Lanes Roadway Construction Tender Package was released on an hourly rate basis to alleviate the Contractor's risk and allow MDH staff to direct the repairs in anticipated poor weather conditions.

Environmental approval and permits were obtained from the Department of Fisheries and Oceans Canada (DFO), Saskatchewan Ministry of Environment and Transport Canada Navigable Waters. Environmental permits for the borrow source were also required to complete drilling investigations on land owned by the Ministry of Agriculture and protected under the Wildlife Habitat Protection Act. A heritage evaluation, habitat assessment and rare plant assessment were all completed prior to receiving approval from the Ministry of Environment to use earth borrow material from the protected land. Permits were requested on 24 August 2010 and permission was received from all departments by 14 September 2011, just as construction was starting.

Construction began on 13 September 2010 with isolation of the channel and a fish salvage, which collected over 80,000 fish. Construction of the arch culvert included the following: removal of a section of the west culvert, excavation for the raft slab under the culvert, forming and placement of reinforcing steel for the raft slab and tail wall areas, three separate pours of concrete totaling 1,350 m^3 (Figure 5), constructing concrete

arch culvert upstand walls, moving the existing west pipe culvert onto the raft slab, pre-assembly of the arch culvert, sheet pile installation around the tail wall footing to prevent scour, and installation of the arch culvert sections on the upstand walls.

Figure 5 – Concrete pour for raft slab foundation.

The arch culvert was not completed until late October 2010, so the granular backfill around the culvert was completed primarily in freezing conditions. The contractor hoarded the arch culvert and used heaters to keep the granular material from freezing (Figure 6 and Figure 7). As it got colder, insulated tarps and heaters were used to cover the granular material in the stockpile and around the culvert.

Figure 6 – Hoarding the culvert to prepare for granular backfill placement in winter conditions.

Figure 7 – Backfilling granular material in winter conditions.

When it appeared that the downstream wingwalls would not be constructed in time to contain the granular backfill around the culvert, MDH designed a geosynthetically reinforced soil wall at the north end of the granular backfill, so that the embankment could be built at the same time as the wingwalls (Figure 8). This was necessary as the roadway embankment was on the critical path for opening the four lane facility in December 2010.

Figure 8 – Geosynthetically confined soil wall behind wingwall.

Construction continued into November 2010 with the formation of tail walls, placing fill against the raft slab foundation, placing reinforcing steel for tail walls, excavating the west slope to facilitate granular material placement and embankment construction, placing concrete in tail walls, and placing rip rap downstream of the culvert. The Trans-Canada Highway westbound lanes were paved and open to the public on 09 December 2010, within six (6) months of the initial flood event.

As part of the 2010 construction, DFO required excavating restoring a 6 m deep scour hole at the culvert outlets that had been filled with sediment during the flood. In November 2010, the scour hole was constructed to provide a safe winter habitat for the fish in Maple Creek. Due to consistent freezing temperatures, an aeration system was installed to provide oxygen and prevent ice from forming in the temporary habitat (Figure 9) until salvaged fish could be relocated to a permanent winter habitat downstream of the construction zone. Riparian works opened upstream of the arch culvert in December 2010 to flood the construction area and the scour hole before removing the coffer dam and allowing the salvaged fish to swim to their permanent winter habitat.

Figure 9 – Aeration system to prevent ice forming in temporary fish habitat.

In March 2011, MDH released a second complete tender package for constructing the eastbound lanes of the Trans-Canada Highway after the arch culvert was installed. Construction of the eastbound lanes began on 15 June 2011 with the diversion of the channel through one of the existing culverts and a fish salvage followed by draining the work area. Construction required the removal of a concrete headwall, excavation for the raft slab, forming and placement of reinforcing steel for the raft slab and tail wall areas, three separate pours of concrete totaling 1,350 m^3, constructing concrete arch culvert upstand walls, erecting arch culvert on the upstand walls, pre-assembly of arch culvert forming and pouring head walls and cut off

wall, decommissioning the existing pipe culverts, placing riprap on the upstream embankment, and removing the upstream dam.

As a result of the flood event, the downstream channel was redirected and the bank of the existing riffle system was eroded. DFO required redesigning and restoring the riffle system to prevent erosion.

MDH encountered various unanticipated construction complications in 2011. During removal of the concrete headwall, located under the eastbound lane, an existing culvert, which was used to divert the stream when the original culverts were installed, suddenly burst due to corrosion. The de-watered work area was filled with water and fish. MDH was required to conduct a fish salvage and de-water the work area again. The culvert was decommissioned by filling it with concrete and installing sheet piling along the length of the culvert.

Additional complications arose in 2011 when the Contractor was unable to connect the arch culvert to the section built in 2010 because three of the arch culvert panels on the east side were deformed. This was caused by differential loading against an unsupported edge when the culvert was back filled in 2010. The only way to align the culverts was to unload the panels, so they could be removed and replaced. Unloading the panels carried a unique level of complexity and risk because an 11 m high almost vertical face already existed immediately adjacent to traffic. Additional excavation of this face was required to unload the arch culvert panels, so that they could be repaired. In order to carry out work in a manner that ensured safety for the workers and motoring public, air launched soil nails were installed to increase the geotechnical factor of safety and mitigate the risk of catastrophic slope failure (Figure 10). The contractor also placed granular back fill around the rest of the south half of the culvert to provide more stability. The arch culvert repair and granular back fill was completed as quickly as possible to mitigate the potential risk.

Figure 10 – Installing soil nails to strengthen westbound lanes for excavation around 2010 arch culvert construction.

The construction of the Trans-Canada Highway Maple Creek Arch Culvert (Figure 11), highway construction and the channel/riffle system was completed on 27 October 2011 with four lane traffic opening to the public later that day.

This complex project was completed in a tight timeframe in adverse weather conditions, with the cooperation from a team of very committed and dedicated contractors, (CeeGee Southern Inc., H J R Asphalt Ltd., Saskcon Repair Service Ltd., South Rock Ltd, Rock Hound Crushing Ltd., Armtec, Langenburg Redi Mix Ltd., and Koncrete Construction Group), subconsultants (AECOM, NHC, Western Heritage Services Inc.), and regulators (SMHI, Saskatchewan Ministry of Environment, Saskatchewan Ministry of Agriculture, Fisheries and Oceans Canada, Agriculture and Agri-Food Canada).

Figure 11 – Completed culvert and riprap December 2010.