MEDICINE HAT RIVER HAZARD STUDY

CHANNEL STABILITY INVESTIGATION

FINAL REPORT

Prepared for:

Alberta Government

25 July 2019

NHC Ref. No. 1003094

nhc
northwest hydraulic consultants
water resource specialists

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Prepared for:

Alberta Environment and Parks
Edmonton, Alberta

Prepared by:

Northwest Hydraulic Consultants Ltd.
Edmonton, Alberta

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DISCLAIMER

EXECUTIVE SUMMARY

Alberta Environment and Parks retained Northwest Hydraulic Consultants Ltd. in August 2017 to complete a river hazard study for the City of Medicine Hat and surrounding areas of Cypress County, including the Town of Redcliff and the Hamlet of Desert Blume. The river hazard study area includes 26 km of the South Saskatchewan River below Ross Creek, 19 km of the South Saskatchewan River above Ross Creek, 24 km of Ross Creek above the confluence with the South Saskatchewan River, 24 km of Seven Persons Creek above the confluence with Ross Creek, and 9.6 km of Bullshead Creek above the confluence with Ross Creek.

The study is being conducted under the provincial Flood Hazard Identification Program. The overall objectives of the study are to enhance public safety and to reduce potential future flood damages and disaster assistance costs.

The Medicine Hat River Hazard Study has been structured into eight major components. This report summarizes the work of the eighth component, *Channel Stability Investigation*. A comparison of current and historical channel banklines, cross sections, thalweg profiles, and rating curves is provided along with discussion of channel stability and evolution in the study area. The goal of the channel stability investigation was to provide qualitative insight about the general channel stability along the study reaches.

The active channel width on the South Saskatchewan River has decreased throughout the study reach since 1951. The reduction in channel width is generally the result of sediment deposition. Lateral bank migration has occurred along the reach at point bars with minimal erosion along cut banks. Deposition has also resulted in the formation of islands and infill of highwater channels, further reducing the active channel width. The thalweg elevation profile has changed little since 1986.

Seven Persons Creek is generally stable, except where constructed channel realignments have occurred to accommodate transportation infrastructure and other development. The thalweg elevation profile shows relatively short reaches of both aggradation and degradation. Aggradation was seen upstream of the Highway 1 embankment and at the confluence with Ross Creek. Degradation has occurred through the golf courses upstream of Highway 1 and downstream of the weir in Kin Coulee Park.

The stability of Ross Creek varies upstream and downstream of the confluence with Bullshead Creek. Upstream of Bullshead Creek, the planform alignment of the channel is quite stable but exhibits natural downstream migration of cut banks on sharp meander bends. Downstream of Bullshead Creek, migration of the channel has been much more significant with evidence of several cutoffs forming between 1951 and 2018. The thalweg profile comparison for Ross Creek within the City of Medicine Hat generally shows aggradation of the channel.

Bullshead Creek is generally stable throughout the study reach, but the channel planform has changed between 1951 and 2018. Over this period, the reach has evolved from a relatively straight planform pattern in 1951 towards a more pronounced meandering planform pattern in 2018.

CREDITS AND ACKNOWLEDGEMENTS

Northwest Hydraulic Consultants Ltd. would like to express appreciation to Alberta Environment and Parks for initiating this project, making extensive background information available, and providing the project team with valuable technical input throughout the project. James Choles, P.Eng., CFM managed and directed the Medicine Hat River Hazard Study on behalf of Alberta Environment and Parks.

We would also like to thank Water Survey of Canada for providing historical rating curves and discharge measurement information for relevant hydrometric stations.

The following NHC personnel were part of the study team and participated in the Channel Stability Investigation component of the River Hazard Study:

- Robyn Andrishak (Project Manager) – responsible for the overall direction of the project and survey program; senior reviewer of this report.
- Michael Brayall (Project Engineer) – co-authored of this report and was responsible for delineating the banklines.
- Hayden Kalke (Project Engineer) – was responsible for compiling the historical cross sections and thalweg profiles.
- Rebecca Himsl (GIS Analyst) – assisted with the GIS analysis of the channel banklines as well as production of the GIS report figures.

OGL Engineering were responsible for collection of the 2018 aerial imagery and orthorectification of the 1951 imagery.

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1 INTRODUCTION

1.1 Study Objectives

The overall objective of the Medicine Hat River Hazard Study is to identify and assess river and flood hazards along the South Saskatchewan River, Ross Creek, Seven Persons Creek, and Bullshead Creek within the City of Medicine Hat and surrounding areas of Cypress County, including the Town of Redcliff and the Hamlet of Desert Blume. Results from this study are designed to inform local land use planning decisions, flood mitigation projects, and emergency response planning. This study is being undertaken as part of the Flood Hazard Identification Program (FHIP) with the intent of enhancing public safety and reducing future flood damages within the Province of Alberta.

This river hazard study is comprised of the eight major study components listed below. A report and associated deliverables have been prepared for each individual study component.

1) Survey and Base Data Collection
2) Open Water Hydrology Assessment
3) Hydraulic Model Creation and Calibration
4) Open Water Flood Inundation Map Production
5) Open Water Flood Hazard Identification
6) Governing Flood Hazard Map Production
7) Flood Risk Assessment and Inventory
8) Channel Stability Investigation

This report summarizes the work of the eighth component - ***Channel Stability Investigation***. The primary task, services, and deliverables associated with this report are:

- Historical aerial photography preparation (provided as a separate memorandum).
- Channel bank delineation and comparison.
- Cross section and thalweg profile comparison.
- Rating curve comparison.

The main goal of the channel stability investigation is to provide qualitative insight and limited quantitative information about general channel stability along the study reaches. This has been achieved through a comparison of current and historic banklines, cross sections, thalweg profiles, and rating curves.

1.2 Study Area and Reach

The City of Medicine Hat is located approximately 290 km southeast of Calgary and approximately 45 km west of the Alberta-Saskatchewan border. **Figure 1** shows the location and boundaries of the river hazard study area and contributing river basins. The river hazard study area includes the following reaches: 26 km of the South Saskatchewan River below Ross Creek; 19 km of the South Saskatchewan River above Ross Creek; 24 km of Ross Creek above the confluence with the South Saskatchewan River; 24 km of Seven Persons Creek above the confluence with Ross Creek; and 9.6 km of Bullshead Creek above the confluence with Ross Creek. Municipalities along these study reaches include the City of Medicine Hat, the Town of Redcliff, the Hamlet of Desert Blume, and Cypress County.

The contributing river basins cover an area of about 61,500 km^2, extending from the headwaters in the Rocky Mountains to the downstream boundary of the river hazard study area. Major upstream rivers include the Bow and Oldman rivers, which join together approximately 100 km upstream of Medicine Hat to form the South Saskatchewan River. The gross drainage areas of the Bow River and Oldman River basins are 25,600 km^2 and 28,300 km^2, respectively. The Bow and Oldman rivers generally flow southeast and east through the Foothills and Grassland natural regions. Most of the runoff from these two sub-basins is typically derived from spring snowmelt augmented by rainfall within the Rocky Mountain and Foothills portions of the basin. The Grassland Region is the largest region within the South Saskatchewan River basin in Alberta, extending from just west of Calgary to the Saskatchewan border. It is the warmest and driest region in Alberta.

The Ross Creek sub-basin has a gross drainage area of 4,790 km^2 and includes Ross Creek, Seven Persons Creek, and Bullshead Creek. The headwaters of the sub-basin are located in the Cypress Hills, southeast of Medicine Hat. While high flows in this sub-basin more commonly occur in the spring due to snowmelt runoff with or without rainfall, intense summer rainstorm events can often result in high annual peak flows.

A number of dams and flow diversion structures have been developed throughout the South Saskatchewan River basin for various purposes including: irrigation; low-flow augmentation; water supply for industrial, municipal, and domestic users; and hydropower. These developments have altered the natural flow regime in the South Saskatchewan River basin since the beginning of the twentieth century. It is important to note, however, that the existing system was not designed to mitigate floods.

2 AVAILABLE DATA

2.1 Aerial Imagery

Two years of orthorectified aerial imagery were available for this channel stability investigation. Imagery from 1951 represents the historical channel condition, while the most recent available aerial imagery collected in 2018 represents the current channel condition.

Historical aerial imagery was obtained from Alberta Environment and Parks and processed by OGL Engineering. The 1951 images were acquired on July 3 of that year covering the portion of the study reach north of XS-37 on the South Saskatchewan River and on September 17 of that year covering the remaining southern portion south of XS-37. Complete details of the acquisition and data processing procedures are provided in **Appendix A**.

The 2018 orthophotos covering the entire study area were supplied by Alberta Environment and Parks. These 2018 orthophotos are the same as those used to produce the flood inundation and hazard mapping products for this study.

2.2 Cross Section Data

Cross section data were available from the current flood hazard study and from the flood hazard study completed in 1986 (AENV, 1986) for the channel stability investigation. The cross section locations are shown in **Figure 2**.

A total of 667 cross sections were surveyed for the current flood hazard study: 120 on the South Saskatchewan River, 157 on Ross Creek, 282 on Seven Persons Creek, and 108 on Bullshead Creek. The cross sections are numbered sequentially starting at the downstream end of the study reach on the South Saskatchewan River. The numbering continues in the upstream direction on Ross Creek, then Seven Persons Creek, and finishing on Bullshead Creek.

There are 156 historical cross sections available from the 1986 study: 74 on the South Saskatchewan River, 57 on Seven Persons Creek, and 25 on Ross Creek. These cross sections are located between:

- XS-14 and XS-119 on the South Saskatchewan River;
- From the mouth to just downstream of XS-149 on Ross Creek; and
- From the mouth to just downstream of XS-452 on Seven Persons Creek.

The 1986 study did not include data up to the confluence of Ross Creek and Bullshead Creek; therefore, no historical cross sections were available for comparison on Bullshead Creek.

2.3 Thalweg Profile Data

Thalweg profiles for the South Saskatchewan River, Ross Creek, and Seven Persons Creek were surveyed and plotted in the previous flood hazard study (AENV, 1986). Bullshead Creek was not included in the 1986 study area, so no historical thalweg data were available for comparison on this reach. Other than the 1986 data, there were no other available sources of channel geometry data for thalweg profile comparison along the South Saskatchewan River, Ross Creek, or Seven Persons Creek.

The 1986 thalweg profile for the South Saskatchewan River encompassed a reach approximately 39 km in length through the City of Medicine Hat and surrounding areas. The South Saskatchewan River thalweg profile was created from 74 surveyed river cross-sections. The upstream and downstream extent of the thalweg profile was approximately 910 and 871 km, respectively, from the confluence with the South Saskatchewan River.

The 1986 thalweg profile for Seven Persons Creek encompassed a 3.4 km reach upstream of the South Saskatchewan River. The Seven Persons Creek thalweg profile was created from 57 surveyed creek cross-sections. The 2017 survey for this study extended approximately 10 km beyond the most upstream cross-section available in the 1986 study.

The 1986 thalweg profile for Ross Creek encompassed a 3 km reach upstream of the South Saskatchewan River. The Ross Creek thalweg profile was created from 25 surveyed creek cross-sections. The 2017 survey for this study extended approximately 21 km from the most upstream cross-section available in the 1986 study.

2.4 Rating Curves

Water Survey of Canada (WSC) measures discharge (flow rate) and stage (water level) at three locations within the study area shown in **Figure 1**. WSC develops rating curves based on the observed relationship between discharge and stage for each of these sites. The historic record of rating curves is provided in **Table 1**. Site-specific conditions, floods, and channel instability may cause these relationships to change over time.

Table 1 Summary of rating tables for WSC hydrometric gauges within the study reach

Station Name and ID	Table No.	Effective Date
South Saskatchewan River at Medicine Hat 05AJ001	1	17 Dec 1957
	2	26 Jan 1959
	3	1 Dec 1959
	4	11 Jan 1961
	5	21 Jan 1964
	6	15 Nov 1967
	7	4 Jan 1972
	8	17 Oct 1984
	9	1 Jan 1995
	10	1 Jan 1997
	11	1 Jan 1999
	12	1 Jan 2001
	13	7 July 2005
Ross Creek at Highway 41 05AH052	1	1 Feb 2000
	2	1 Jan 2002
	3	1 Dec 2010
	4	7 May 2015
Seven Persons Creek at Medicine Hat 05AH005	1	12 Dec 1973
	2	19 Feb 1980
	3	4 Feb 1981
	4	1 Feb 1982
	5	9 Dec 1982
	6	10 Dec 1986
	7	16 Nov 1994
	8	6 Feb 1996
	10	19 Jun 2010
	11	1 Jan 2014

3 METHODS AND RESULTS

3.1 Channel Bank Definition

Banklines were delineated from the 1951 (**Figure 3**) and 2018 (**Figure 4**)aerial imagery throughout the study reach as digital polyline features using ArcGIS. Changes in bankline location over time is a strong indicator of the channel stability. The term "bankline" can be used to identify a number of different features. Common uses include: the wetted channel width at bankfull flow, the top of channel width, and the active channel width. The bankfull flow is the discharge required to fill a channel to bank height before flow spills on the floodplain (i.e. when the water level exceeds the top of bank), while the top of channel is the wetted channel width at either the mean annual peak flow or 2-year flow, (Baird et al. 2015). The active channel width is typically identified by the "green line" or edge of herbaceous vegetation which can be higher or lower than the top of channel width (Baird et al. 2015). The definition of bankline generally varies depending on the size of the river that is being analyzed.

The bankline on the South Saskatchewan River was defined using the active channel width. The vegetation line on the South Saskatchewan River is well above the nominal water level shown in the aerial imagery. The extent of vegetation on the South Saskatchewan generally only changes during flood events near or above bankfull and is therefore a good indicator of the channel stability.

The banklines on Ross Creek, Seven Persons Creek, and Bullshead Creek were drawn based on the water's edge in the aerial imagery. The wetted channel width on small creeks is generally consistent as flood durations are typically much shorter than on larger rivers. Vegetation generally grows right to the water's edge or to the top of vertical cut banks. The water's edge was generally clear in the aerial images except for reaches of Ross Creek and Bullshead Creek where the vegetation extended across the wetted channel width. Generally speaking, grass within the wetted width of the channel is yellow instead of green (in the 2018 aerial photograph) which helped with the delineation of the wetted width. Continuity of the bankline through the grass covered portions was achieved by maintaining a smooth shape between the reaches upstream and downstream of the grass covered portion.

The banklines identified in this channel stability investigation are not necessarily coincident with the bank stations identified in the HEC-RAS model, which were selected based on hydraulic considerations, such as channel and overbank roughness values. Inundation extents from the HEC-RAS model were not used to inform the channel delineation process, since water levels generated by the model were not applicable to the historical conditions and the above criteria were sufficient to assess the channel stability within the study reach.

3.2 Cross Section Comparison

Comparisons of cross sections from 1986 and 2017 were completed on the South Saskatchewan River, Seven Persons Creek, and Ross Creek to assess changes in the cross section shape. No historical cross sections were available for comparison on Bullshead Creek. The locations of the comparison cross

sections are shown in **Figure 2**. The cross section stationing was not georeferenced for the 1986 cross sections so the cross sections were visually aligned with the 2017 cross sections for this comparison.

Cross section comparisons on the South Saskatchewan River are provided in **Figure 5-1** to **Figure 5-7**. Sediment deposition throughout the study reach has generally changed the shape of cross sections. Sediment deposition along the bank is evident in many of the compared cross sections (XS-115, XS-106, XS-100, XS-82, XS-71, XS-63, XS-49, XS-40, XS-33, XS-28, and XS-19). Sediment deposition also resulted in the formation or expansion of several islands at XS-94, XS-56, and XS-45. The thalweg elevation of the compared cross sections has generally remained consistent between 1986 and 2017.

Cross section comparisons on Seven Persons Creek (**Figure 5-8** and **Figure 5-9**) and Ross Creek (**Figure 5-10**) show minimal change in the channel cross section profiles. The 1986 cross sections were surveyed at a coarser resolution than the 2017 cross sections with only a couple of points in the wetted portion of the channel. Therefore, it is difficult to make comparisons at a more detailed level. Generally speaking, the thalweg elevation and channel width has remained about the same for all cross sections compared.

3.3 Thalweg Profile Comparison

Thalweg comparisons were conducted between the 1986 survey and the 2017 survey to determine if the overall slope or bed profile of the South Saskatchewan River, Seven Persons Creek, and Ross Creek has changed. Recall from Section 2.3 that there were no data available to include Bullshead Creek in this assessment. The river stations from the 1986 study were adjusted to coincide with the river stations from the 2017 survey. The difference in river stationing was computed between cross sections surveyed at the same location in each study. The river stationing for cross sections surveyed in 1986 with no corresponding cross section in the 2017 survey were adjusted by linearly interpolating the station adjustment between the nearest cross sections with overlap.

A comparison of the 1986 and 2017 thalweg profiles for the South Saskatchewan River is shown in **Figure 6-1**. Thalweg elevations were compared at the 41 cross sections surveyed at the same location as cross sections from the 1986 study. Bed degradation was observed at 18 of 41 cross sections and channel aggradation was observed at 23 of 41 cross sections. The largest channel degradation was found to be 1.68 m at XS-65 (RS 27,680). The difference in thalweg was due to the development of a scour hole at the toe of the left bank between 1986 and 2017. The largest channel aggradation was found to be 1.39 m at XS-94 (RS 33,412) where a large scour hole near the right bank filled-in between 1986 and 2017. Overall, there was not a systematic change in the thalweg profile along the reach.

A comparison of the 1986 and 2017 thalweg profile for Seven Persons Creek is shown in **Figure 6-2**. The profile has experienced both aggradation and degradation throughout the study reach. Upstream of RS 9,500, there has been minimal change in the channel thalweg. Between RS 9,500 and RS 6,500, the channel has degraded by about 0.4 m. The major change through this reach was the development of several golf courses. Between RS 6,000 and RS 4,500, the channel has aggraded an average of 0.50 m upstream of the Highway 1 embankment. Downstream of the weir in Kin Coulee Park between RS 4,000

and RS 3,000, the channel has degraded an average of about 0.5 m. Potential reasons for the degradation are that sediment supply has been cut off by the Highway 1 embankment and the weir. Degradation could also be occurring in response to the channelization of the creek through Kin Coulee Park and downtown Medicine Hat. Finally, the channel has aggraded by about 0.5 m at the confluence of Ross Creek.

A comparison of the 1986 and 2017 thalweg profile for Ross Creek is shown in **Figure 6-3**. Over the 31 years between 1986 and 2017, channel aggradation was observed with an average rise in the thalweg of 0.4 m. The 1986 study reach only extended about 3000 m upstream and was only useful for a limited comparison of the thalweg.

Although there is no historical thalweg data for comparison, the surveyed thalweg profile of Bullshead Creek is provided in **Figure 6-4** to support the channel stability commentary in Section 3.5.

3.4 Rating Curve Comparison

Water Survey of Canada operates three hydrometric gauging stations within the study reach. A comparison of the current and historical rating curves at each station was done to identify any systematic adjustments that may be indicative of changes in the channel stability over time. The locations of the hydrometric gauging stations are shown in **Figure 1**.

The rating curve for the gauging station on the South Saskatchewan River (05AJ001, South Saskatchewan River at Medicine Hat) is shown in **Figure 7**. The gauging station is located on the right (south) bank of the river on the downstream side of Finlay Bridge at XS-78. The comparison of the historical rating curves suggests that the stage has increased over time. This is consistent with observations that a reduction in active channel width of about 40 m has occurred since 1951 and minimal change in thalweg elevation and cross section profile have been seen at cross sections near the gauge since 1986. The highwater marks shown on **Figure 7** also generally support the trend of an increase in stage at the gauging station over time.

The rating curve for the gauging station on Ross Creek (05AH052, Ross Creek at Highway 41) is shown in **Figure 8**. The gauging station is located on the right (north) bank of Ross Creek upstream of the bridge. This gauge has been in operation since the year 2000. Prior measurements on Ross Creek were made farther upstream outside of the study reach at Irvine. The largest measurement on record occurred in 2010 and is shown on **Figure 8**. The discharge of the 2010 event was determined to be 209 m^3/s, which was substantially higher than the previous maximum discharge in 2002 which was 44.6 m^3/s. The rating curve was extended in response to the 2010 flood. The atypical shape of the rating curve was adopted by WSC as it best matched other discharge peaks measured in the region. Over the short duration of measurement at the gauging station the stage of the rating curve has not noticeably changed.

The rating curve for the gauging station on Seven Persons Creek (05AH005, Seven Persons Creek at Medicine Hat) is shown in **Figure 9**. The gauging station is located on the left (north) bank downstream of the weir in Kin Coulee Park. This gauge has been operated periodically since 1910 with continuous

operation since 1973. The rating curve has changed substantially over time due to changes on Seven Persons Creek. Construction of the existing Trans-Canada highway and College Avenue culvert crossings and modifications to the channel in Kin Coulee Park (channel cutoff and weir) were significant changes to the local morphology resulting in changes to the rating curve. No significant floods occurred between 1973 and 2010 with all annual peak discharges being less than 30 m^3/s The 2010 flood had a peak discharge of 76.7 m^3/s and the rating curve was extended to include the peak event on record. A similar flood peak of 66.9 m^3/s occurred in 2011. The rating curve has generally increased in stage over time in a non-systematic manner, which is indicative of a river reach that has experienced significant morphologic change.

3.5 Commentary on Channel Stability

Map sheets show the delineated banklines superimposed on the 1951 (**Figure 3**) and 2018 (**Figure 4**) aerial images. Map sheets referred to in this section apply to either series. A commentary on the observed channel stability of the study reaches is provided below.

The active channel width on the South Saskatchewan River has generally decreased throughout the study reach since 1951. The reduction in channel width is generally the result of sediment deposition at point bars and islands. Erosion has occurred at several cut banks but extended less than half the distance of the depositional zone at the adjacent point bar. Several of the cut banks against the high valley slopes showed little lateral movement from 1951 to 2018. The channel stability of the South Saskatchewan River throughout the study reach is summarized in **Table 2**.

Table 2 Channel stability summary – South Saskatchewan River

Cross Section	Channel Stability Notes
XS-115	• Width of island has increased by about 70 m with the majority of increase along the west (right) channel • About 10 m of deposition along west (right) bank • Vegetated length of the island has increased by about 200 m
XS-106 and XS-105	• Old secondary channel along north (left) bank has vegetated and river is now confined to a single channel
XS-98	• About 50 m of lateral deposition on the point bar (left bank) • Cut bank (right bank) has not noticeably eroded
XS-94	• Mid-channel deposition forming vegetated island and permanent secondary channel along north bank • About 30 m of lateral deposition along north (left) bank
XS-88 to XS-84	• Around 30 m of lateral deposition along the south (right) bank which has become heavily vegetated • Similar lateral deposition (10 m) and vegetation along the north (left) bank
XS-83 to XS-81	• Around 30 m of lateral deposition along the north (left) bank which has become heavily vegetated

Table 2 Channel stability summary – South Saskatchewan River (continued)

Cross Section	Channel Stability Notes
XS-81 to XS-71	• Infrastructure development and encroachment has reduced the active channel width by about 40 m • Significant deposition and vegetation downstream of XS-71 along the north (left) bank likely due to development of Maple Avenue Bridge
XS-69 to XS-64	• Sediment deposition (between 15 m and 55 m) along the south (right) bank • Minimal deposition along the opposite bank
XS-64 to XS-55	• Lateral deposition along the point bar (left bank) from XS-64 to XS-55 with a maximum distance of about 140 m • Cut bank (right bank) erosion of about 40 m between XS-62 and XS-60; rock riprap has been installed near XS-62 in response • Vegetated island has become established at mouth of Ross Creek near XS-60 • East (right) bank is eroding between XS-58 and XS-56; spurs were installed along the bank to arrest the erosion • Vegetated island forming between XS-58 and XS-56 along the west (left) bank
XS-55 to XS-52	• Lateral deposition with a maximum distance of about 80 m along the point bar (right bank) • Opposite cut bank is stable
XS-51 to XS-42	• Lateral deposition along the point bar (left bank) from XS-51 to XS-42 with a maximum distance of about 70 m • Vegetated island has formed at XS-45 pushing the main channel towards the north (right) bank and forming a secondary channel along the south (left) bank • Formation of the island has laterally eroded the north (right) bank by a maximum distance of about 100 m between XS-46 and XS-45
XS-41 to XS-38	• Lateral deposition along the point bar (right bank) from XS-41 to XS-38 with a maximum distance of about 80 m • Opposite cut bank has experienced minimal discernable erosion
XS-38 to XS-36	• Historical island along the east (right) bank is now vegetated and no longer part of the active channel width; maximum lateral movement of active channel about 140 m
XS-35 to XS-30	• Lateral deposition along the point bar (left bank) from XS-35 to XS-30 with a maximum distance of about 40 m • Opposite cut bank has experienced minimal discernable erosion
XS-30 to XS-27	• Lateral deposition along the point bar (right bank) from XS-30 to XS-27 with a maximum distance of about 120 m • Opposite cut bank has experienced minimal discernable erosion

Table 2 Channel stability summary – South Saskatchewan River (continued)

Cross Section	Channel Stability Notes
XS-27 to XS-23	• Lateral deposition along the point bar (right bank) from XS-27 to XS-23 with a maximum distance of about 90 m • Lateral deposition along the west (left) bask from XS-27 to XS-23 with a maximum distance of about 50 m
XS-22	• Island forming mid-channel with minimal vegetation
XS-19 to XS-16	• Lateral deposition along the point bar (right bank) from XS-19 to XS-16 with a maximum distance of about 100 m • Opposite cut bank has experienced minimal discernable erosion
XS-15 to XS-13	• Vegetation has developed on along a gravel bar on the south (right) bank and the channel has narrowed in width
XS-13 to XS-8	• Lateral deposition along west (left) bank from XS-13 to XS-8 with a maximum distance of about 60 m • Opposite bank between XS-12 and XS-10 has experienced no discernable erosion
XS-9 to XS-4	• Lateral deposition along the point bar (right bank) from XS-9 to XS-4 with a maximum distance of about 90 m
XS-5 to XS-2	• Historical island along the east (left) bank in now vegetated and no longer part of the active channel width; maximum lateral movement of active channel of about 130 m

Seven Persons Creek has a generally stable channel, except for several areas where development and construction has altered the creek alignment. A summary of the channel stability of Seven Persons Creek is provided in **Table 3**.

Table 3 Channel stability summary – Seven Persons Creek

Cross Section	Channel Stability Notes
XS-551 to XS-543	• Construction of Township Road 120 resulted in the formation of 2 cutoffs
XS-343 and XS-342	• Highway 2 embankment diverted the channel through two culverts
XS-330 and XS-329	• Creek alignment adjusted through Kin Coulee Park
XS-324 to XS-320	• Construction of College Avenue crossing resulted in general straightening of the channel alignment
XS-307 to XS-303	• Banks have been stabilized downstream of the Dunmore Road crossing limiting the channel movement
XS-302 and XS-301	• Channel has shifted about 60 m towards the north
XS-289 to XS-285	• Two meander bends were cuttoff and replaced with a relatively straight channel
XS-281 to XS-125	• Meander bend was cutoff and replaced with a relatively straight channel just upstream of the confluence with Ross Creek

The stability of Ross Creek varies upstream and downstream of the confluence with Bullshead Creek (RS 8,553) due a change in channel slope. Upstream of the confluence the channel slope is 0.0011 m/m while downstream of the confluence the slope increases to 0.0050 m/m before flattening out as it approaches the South Saskatchewan River (**Figure 6-3**). Upstream of Bullshead Creek, there are a large number of oxbow relic channels with typical downstream migration of cut banks along the active channel. Downstream of Bullshead Creek, the channel migration is much more significant but is constrained by the rail line running along the left floodplain. Within Medicine Hat, development has constrained the lateral movement of the channel. A summary of the channel stability of Ross Creek is provided in **Table 4**.

Table 4 Channel stability summary – Ross Creek

Cross Section	Channel Stability Notes
XS-276 and XS-275	• Channel cutoff reducing the channel length by about 700 m immediately upstream of the Highway 41 crossing
XS-170 to XS-169	• Downstream migration of a meander bend
XS-168 to XS-167	• Downstream migration of a meander bend
XS-164 to XS-162	• Downstream migration of a meander bend
XS-160 to XS-159	• Channel cutoff formed between cross sections
XS-159 to XS-156	• Increase in sinuosity of channel
XS-135 to XS-132	• Channel cutoff formed between cross sections
XS-128 to XS-127	• Downstream migration of a meander bend
XS-125 to XS-121	• Downstream migration of meander bends

The channel shape of Bullshead Creek varies throughout the study reach. The channel slope increases from 0.0015 m/m upstream of the rail crossing at XS-611 (RS 4,283) to 0.0058 m/m downstream of the 54 Street SE crossing at XS-588 (RS 2,882) as seen in **Figure 6-4**. The channel planform through the upper reach is comprised of unconfined irregular meanders. The lower portion of the reach has a confined irregular meander pattern that has been further confined by the rail line along the left floodplain. The channel is generally stable throughout the study reach, but in the upper portion its planform has evolved from a relatively straight channel in 1951 towards the development of bi-modal meanders within the larger meanders in 2018. The reach where this change is most pronounced occurred through the upper portion of the study reach between XS #628 and XS #590 (Sheet 22 to Sheet 24). Also, a significant realignment of the channel occurred with the expansion of Highway 1 at XS #576 (Sheet 24) where a large bend in the channel was straightened to accommodate the highway.

Table 5 Channel stability summary – Bullshead Creek

Cross Section	Channel Stability Notes
XS-609 to XS-606	• Channel has been straightened by the construction Trans Canada highway embankment
XS-603 to XS-599	• Channel alignment changed to pass through the Trans Canada highway crossing
XS-584 to XS-581	• Channel alignment changed with the construction of Township Road 122

4 CONCLUSIONS

The main goal of the channel stability investigation was to provide qualitative insight and limited quantitative information about general channel stability along the study reach of the South Saskatchewan River, Ross Creek, Seven Persons Creek, and Bullshead Creek. The analysis involved assessing the change in channel stability based on aerial photography, thalweg profiles, channel cross sections, and hydrometric rating curves.

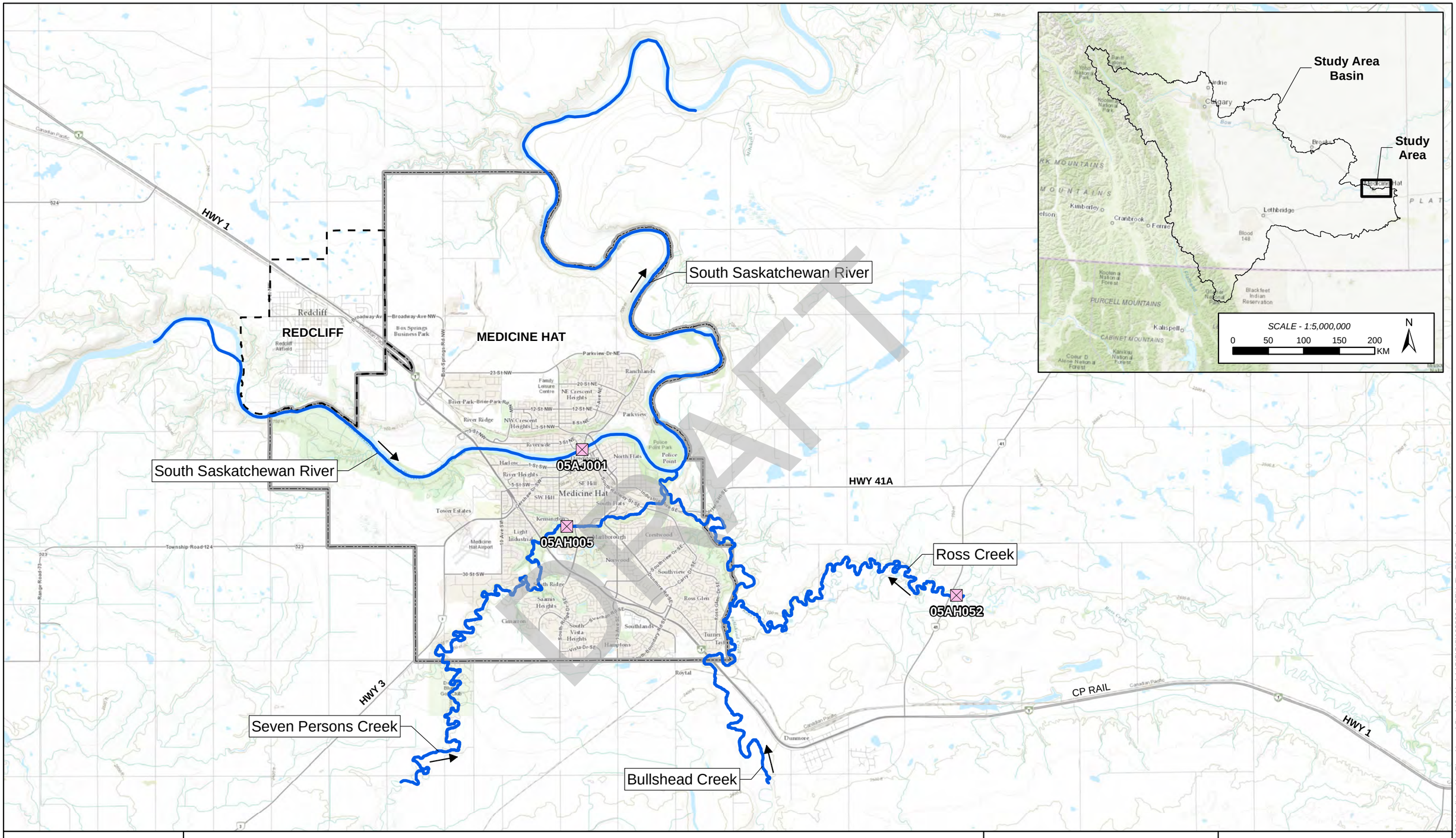
The active channel width on the South Saskatchewan River has generally decreased throughout the study reach since 1951. The reduction in channel width is the result of sediment deposition along the banks and the formation of islands, along with some encroachment associated with urban development in Medicine Hat. The reduction in channel width has resulted in a systematic increase in stage at the rating curve on the South Saskatchewan River. Seven Persons Creek is generally stable, except for several areas where significant channel realignments have occurred due to infrastructure development. The stability of Ross Creek varies upstream and downstream of the confluence with Bullshead Creek. Upstream of Bullshead Creek, the slope is lower and the alignment of the channel is quite stable exhibiting typical downstream migration of cut banks. Downstream of the confluence with Bullshead Creek, the channel slope increases resulting in significant movement of the cut banks and the formation of several cutoffs. The alignment of Bullshead Creek is generally stable throughout the study reach but the channel planform has changed between 1951 and 2018 from a relatively straight channel in 1951 towards a more meandering planform in 2018.

5 REFERENCES

AENV (1986). Medicine Hat Floodplain Study. Prepared by Water Resources Management Services, Technical Services Division, May 1986.

Baird D.C., Fotherby L., Klmup C.C., and Sculock S.M. (2015). Bank Stabilization Design Guidelines. Bureau of Reclamation, Technical Services Center, Denver, Colorado. Sedimentation and River Hydraulics Group. Report No. SRH-2015-25.

Figures



WSC Gauge Station
Model Stream Network
Redcliff Town Boundary
Medicine Hat City Boundary

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:100,000
0 1 2 3 4 KM
N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Job: 1003094 | Date: 15-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

STUDY AREA

FIGURE 1

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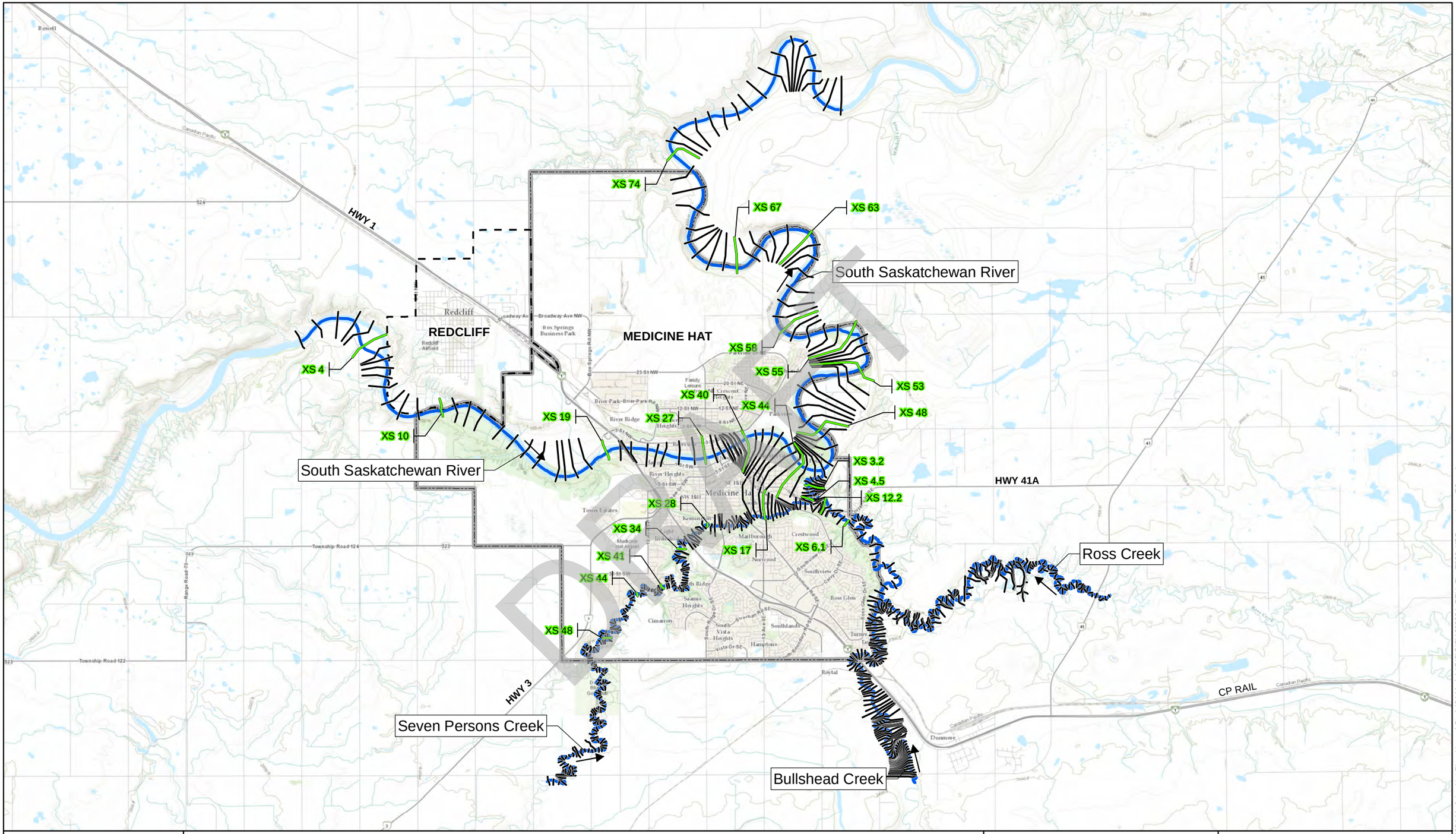
MSN, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Fig_T800_StudyArea.mxd



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- Cross Section (NHC 2017)
- Historic Section (AE 1986)
- Model Stream Network
- Redcliff Town Boundary
- Medicine Hat City Boundary

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:100,000

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

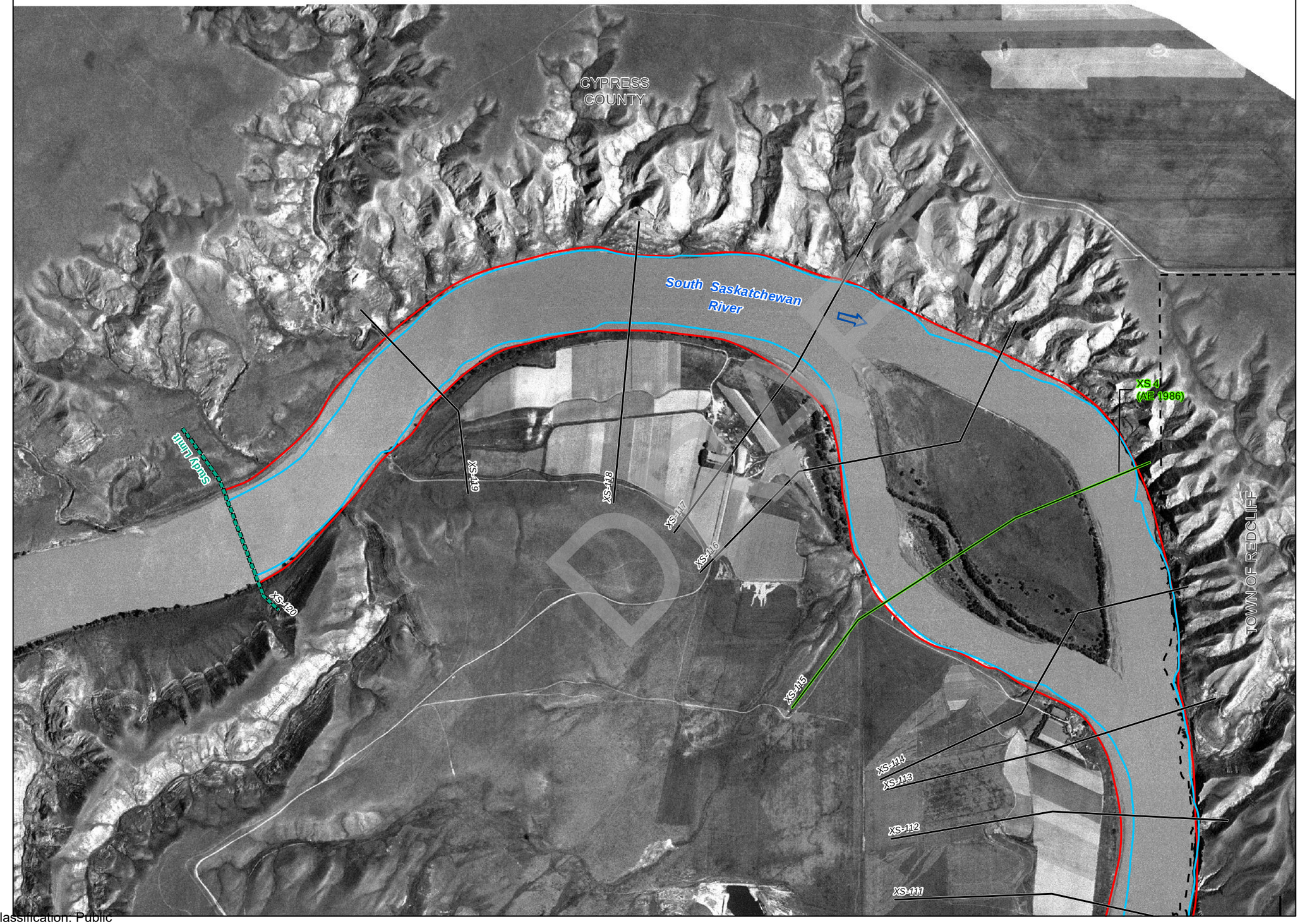
Job: 1003094 | *Date: 25-JUL-2019*

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CROSS SECTION COMPARISON LOCATIONS

FIGURE 2

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Fig_T800_XSComparison_R0.mxd



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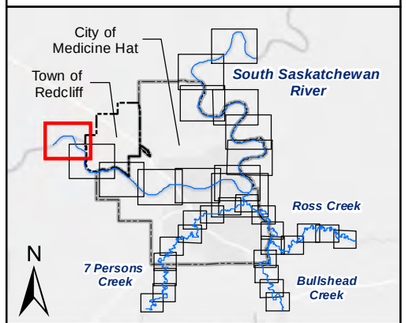

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:10,000

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N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

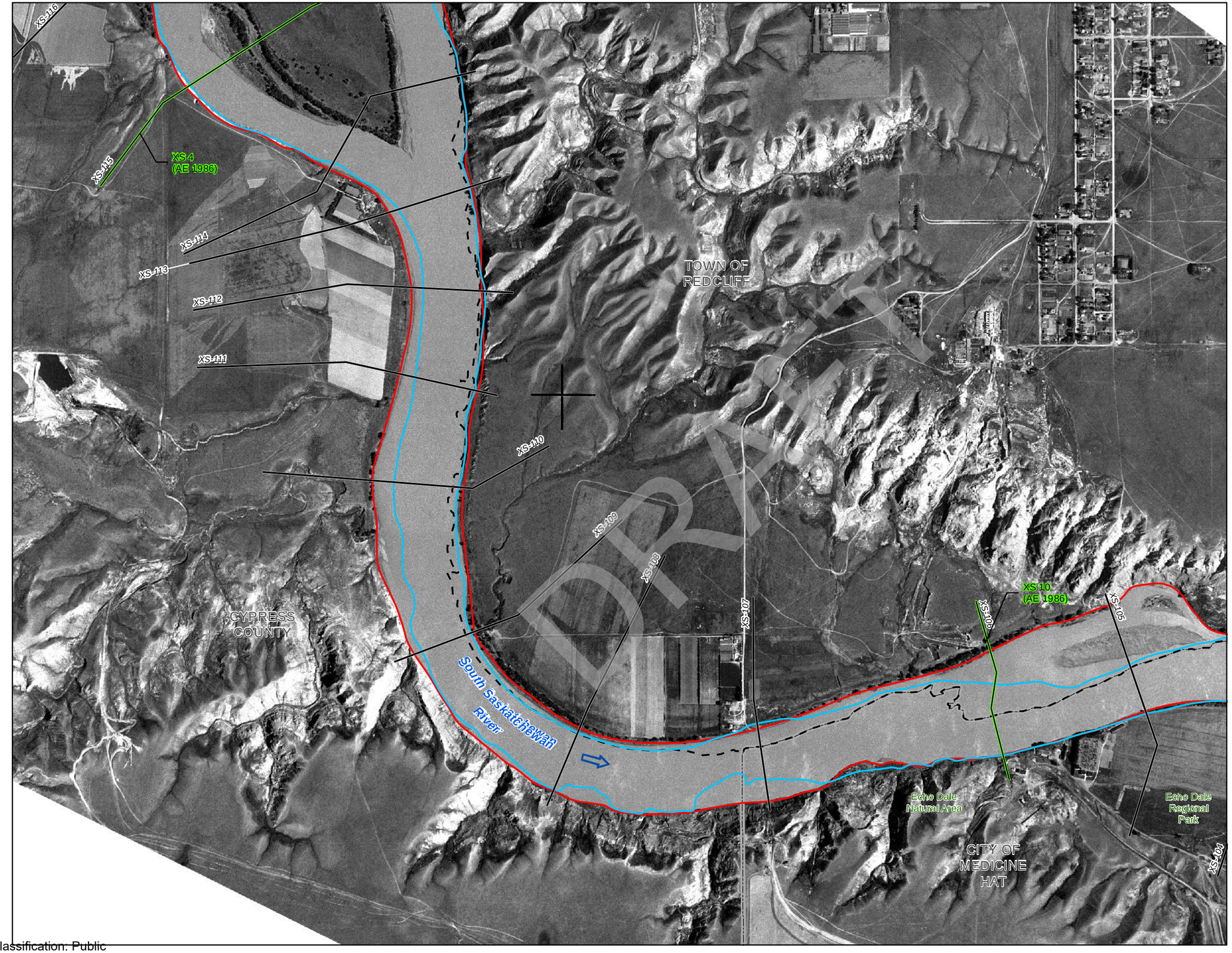
Engineer	GIS	Reviewer
MGB	REH	RBA

Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 1 OF 33



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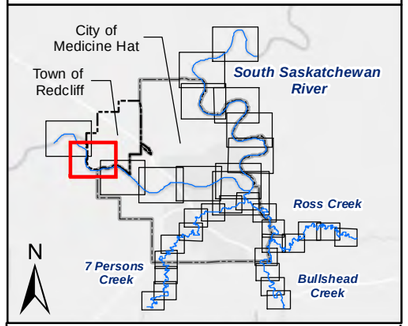

- FLOW DIRECTION
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- FLOOD CONTROL STRUCTURE
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SCALE - 1:10,000

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

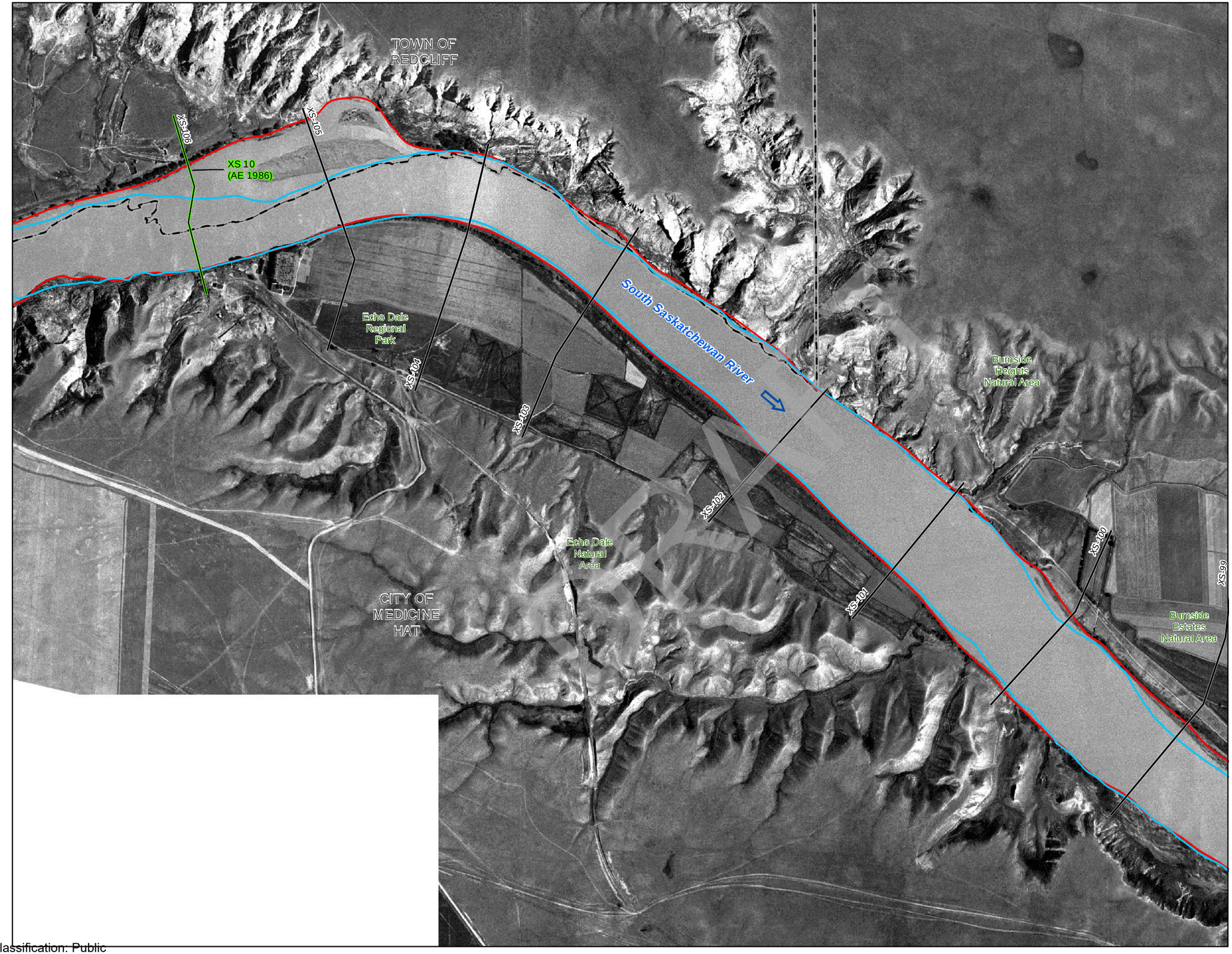
Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 2 OF 33

REH - P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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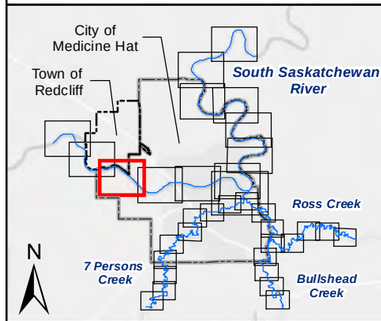

- FLOW DIRECTION
- STUDY LIMIT
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SCALE - 1:10,000

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

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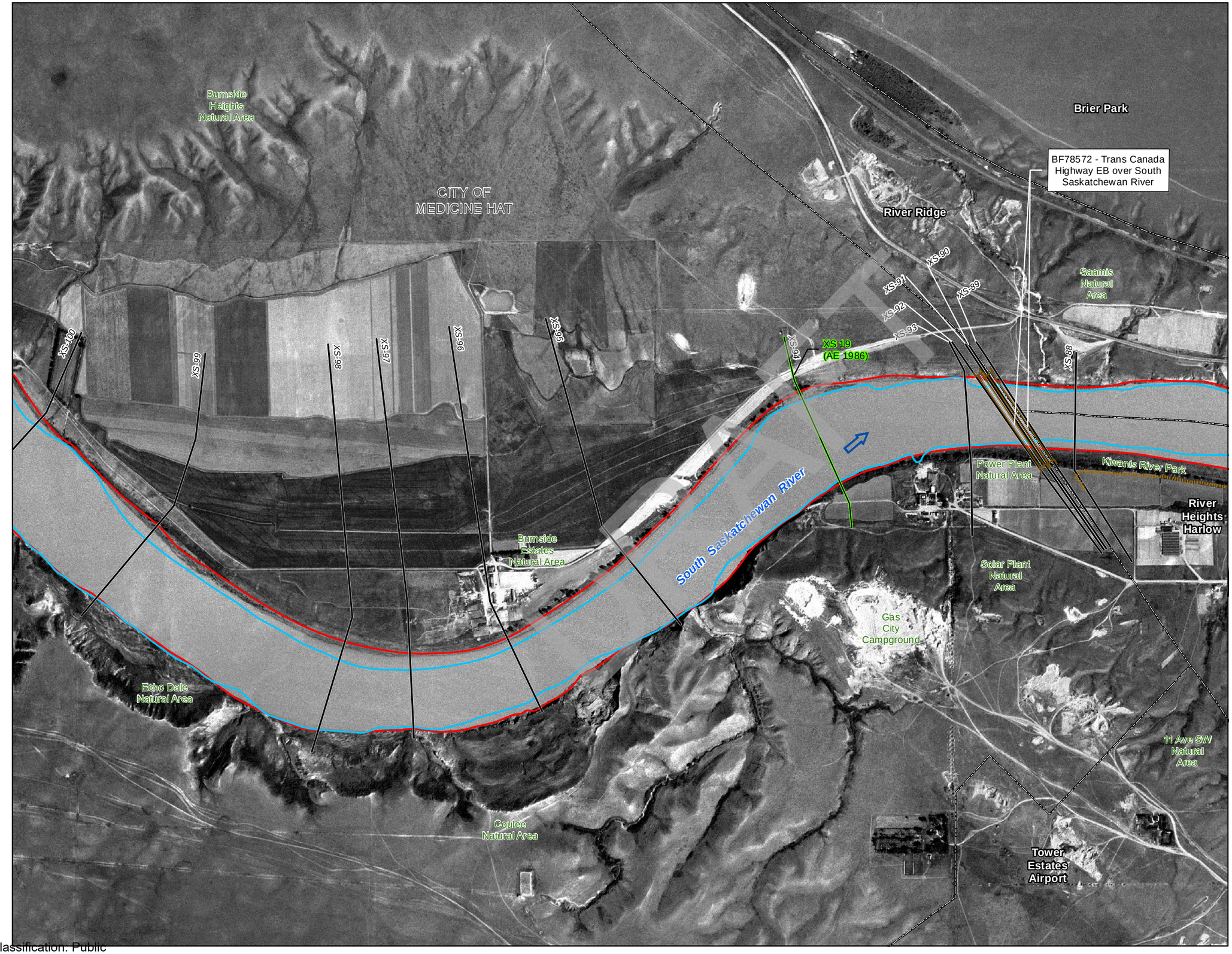
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 3 OF 33

REH_P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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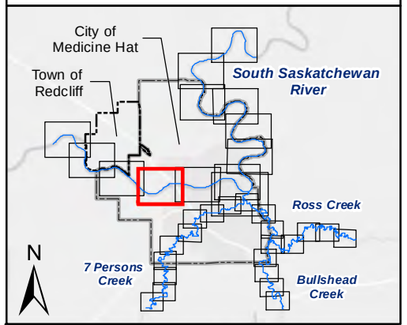

- FLOW DIRECTION
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SCALE - 1:10,000

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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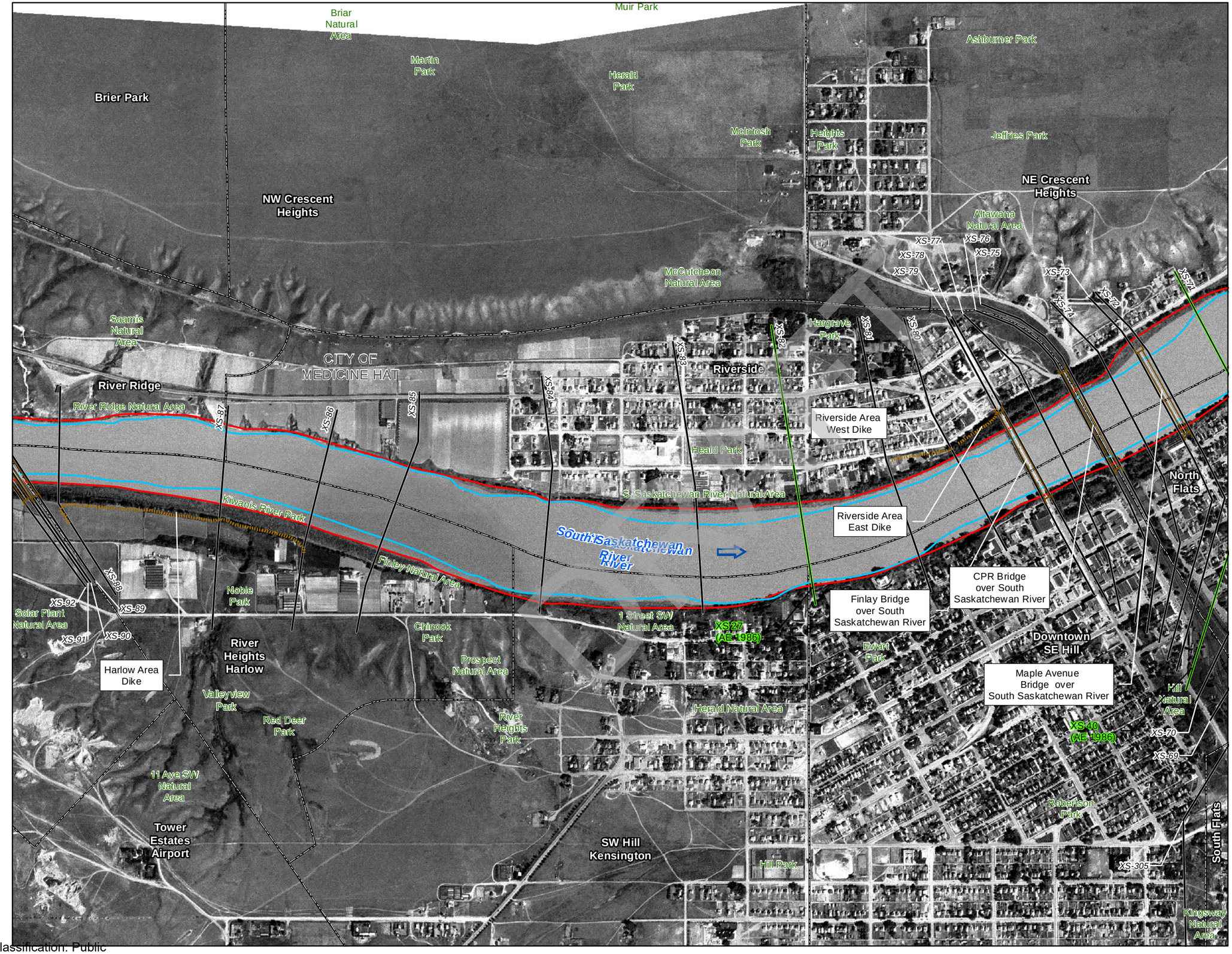
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 4 OF 33

P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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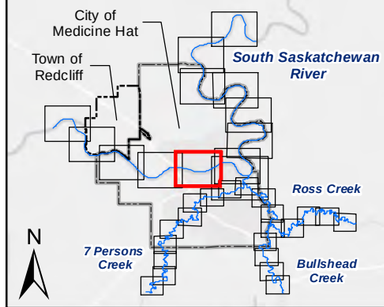

- FLOW DIRECTION
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Coordinate System: NAD 1983 CSRS 3TM 111
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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 5 OF 33

REH - P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd

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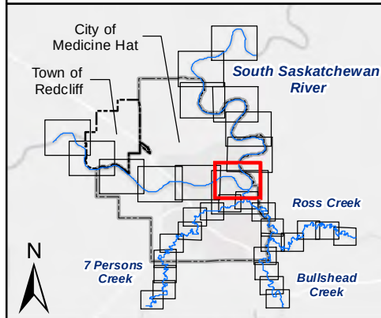

FLOW DIRECTION
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CROSS SECTION (NHC 2017)
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1951 BANKLINE

SCALE - 1:10,000

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 6 OF 33

REH - P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd

Classification: Public

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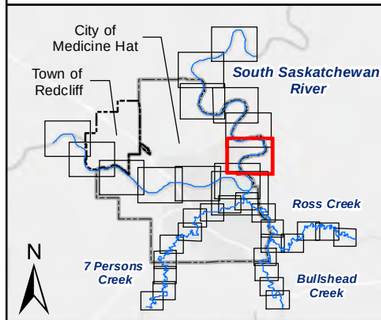

- FLOW DIRECTION
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Engineer	GIS	Reviewer
MGB	REH	RBA

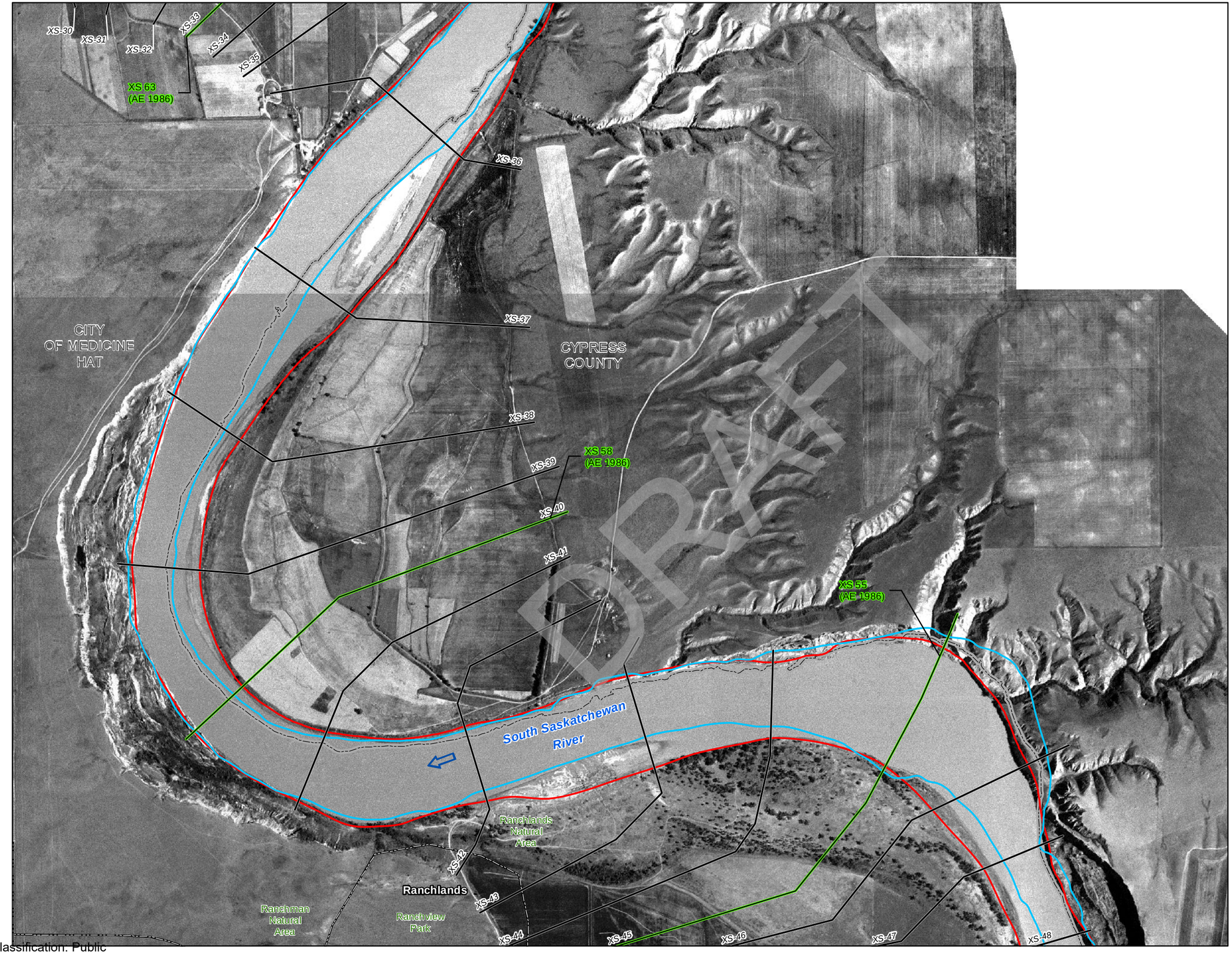
Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 7 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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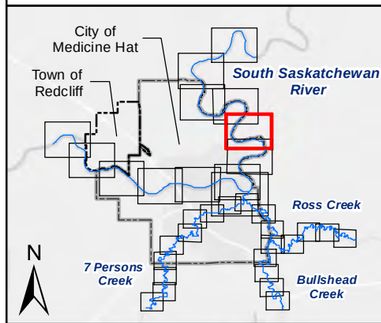

FLOW DIRECTION
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NEIGHBOURHOOD
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CROSS SECTION (NHC 2017)
2018 BANKLINE
1951 BANKLINE

SCALE - 1:10,000
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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 8 OF 33

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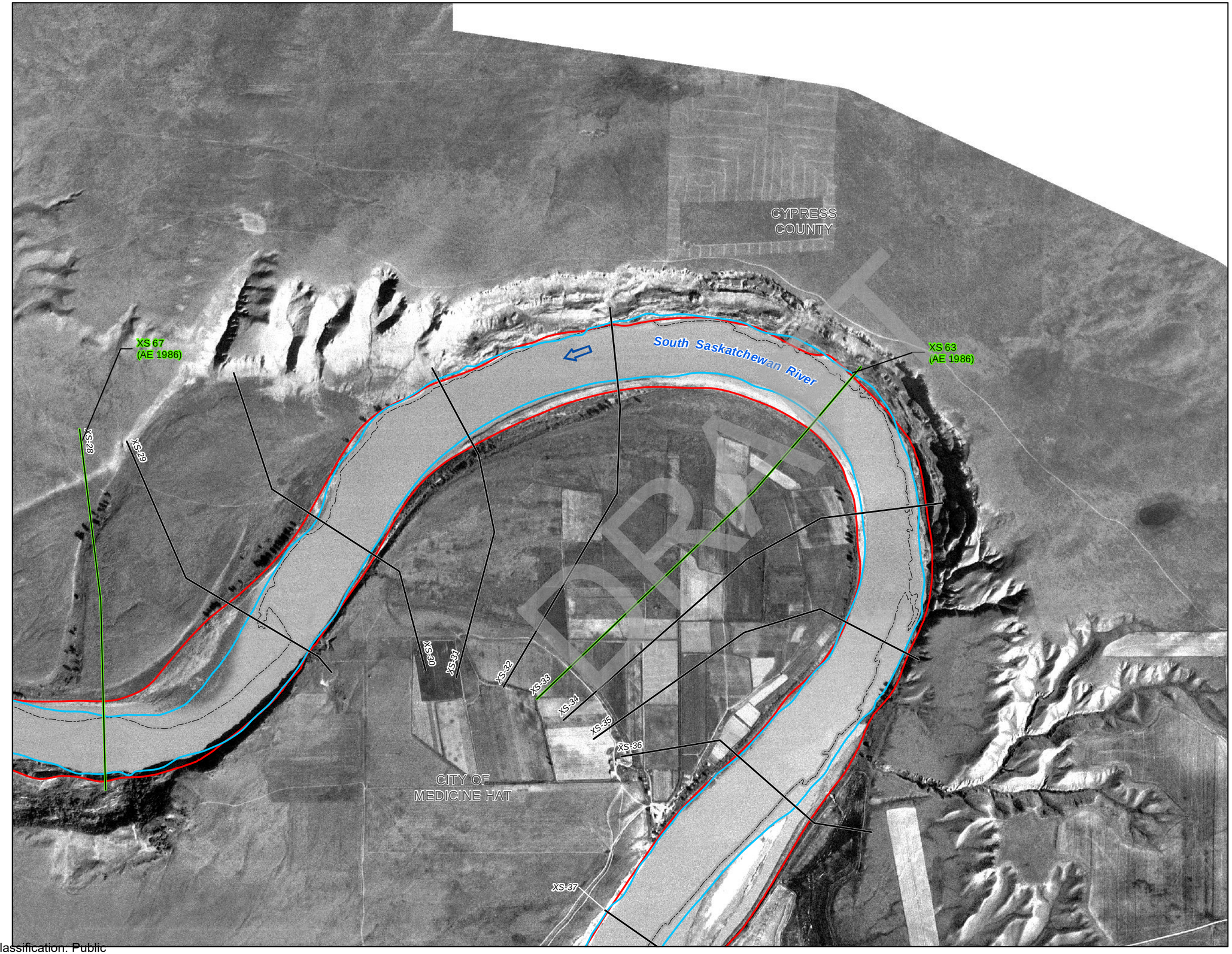

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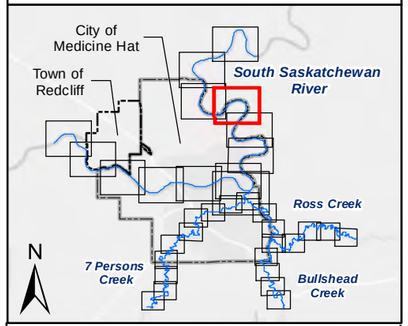

- FLOW DIRECTION
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- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:10,000

0 100 200 300 400 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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MGB	REH	RBA

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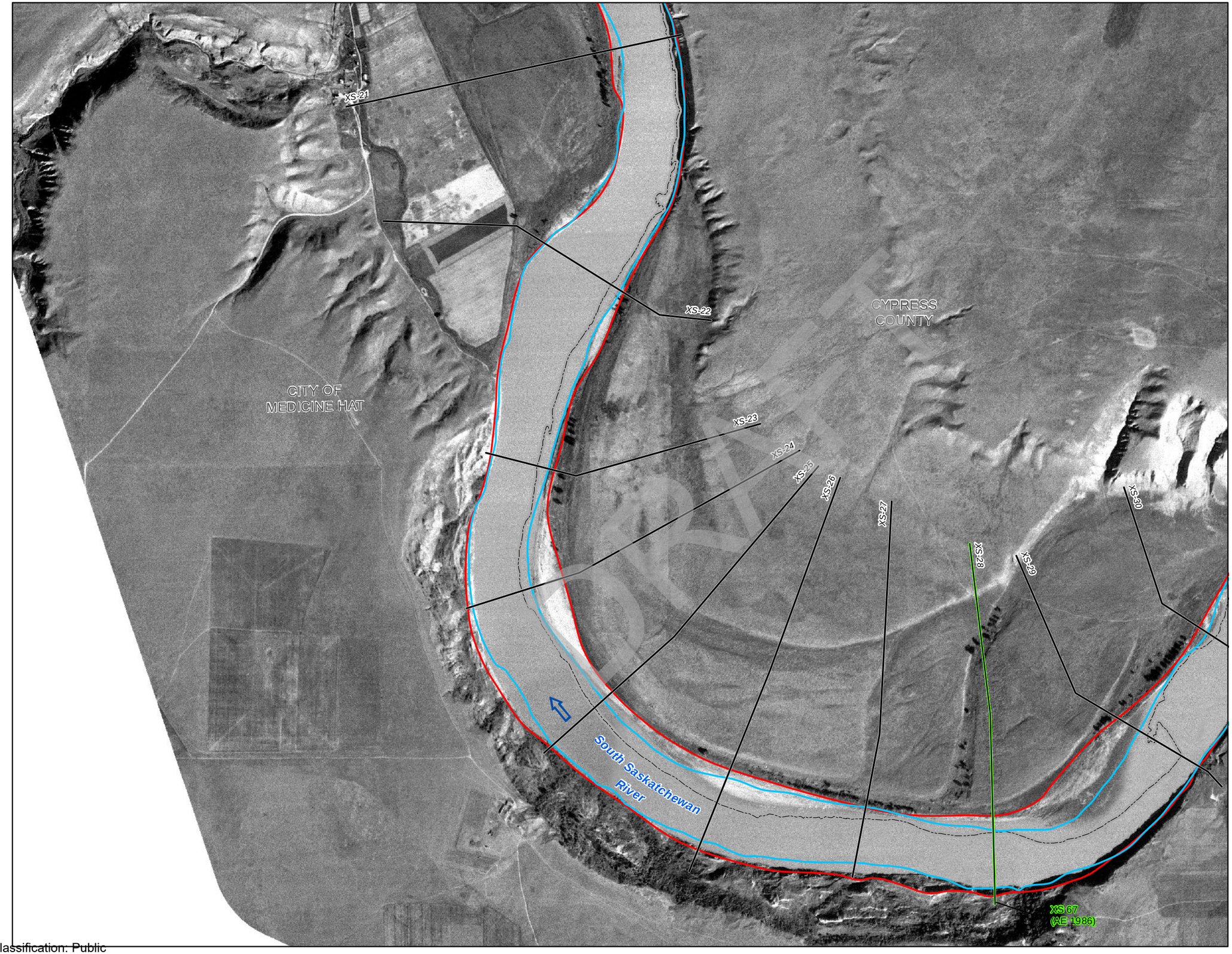
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 9 OF 33



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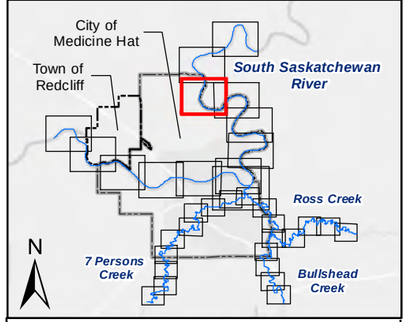

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
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SCALE - 1:10,000

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Coordinate System: NAD 1983 CSRS 3TM 111
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Engineer	GIS	Reviewer
MGB	REH	RBA

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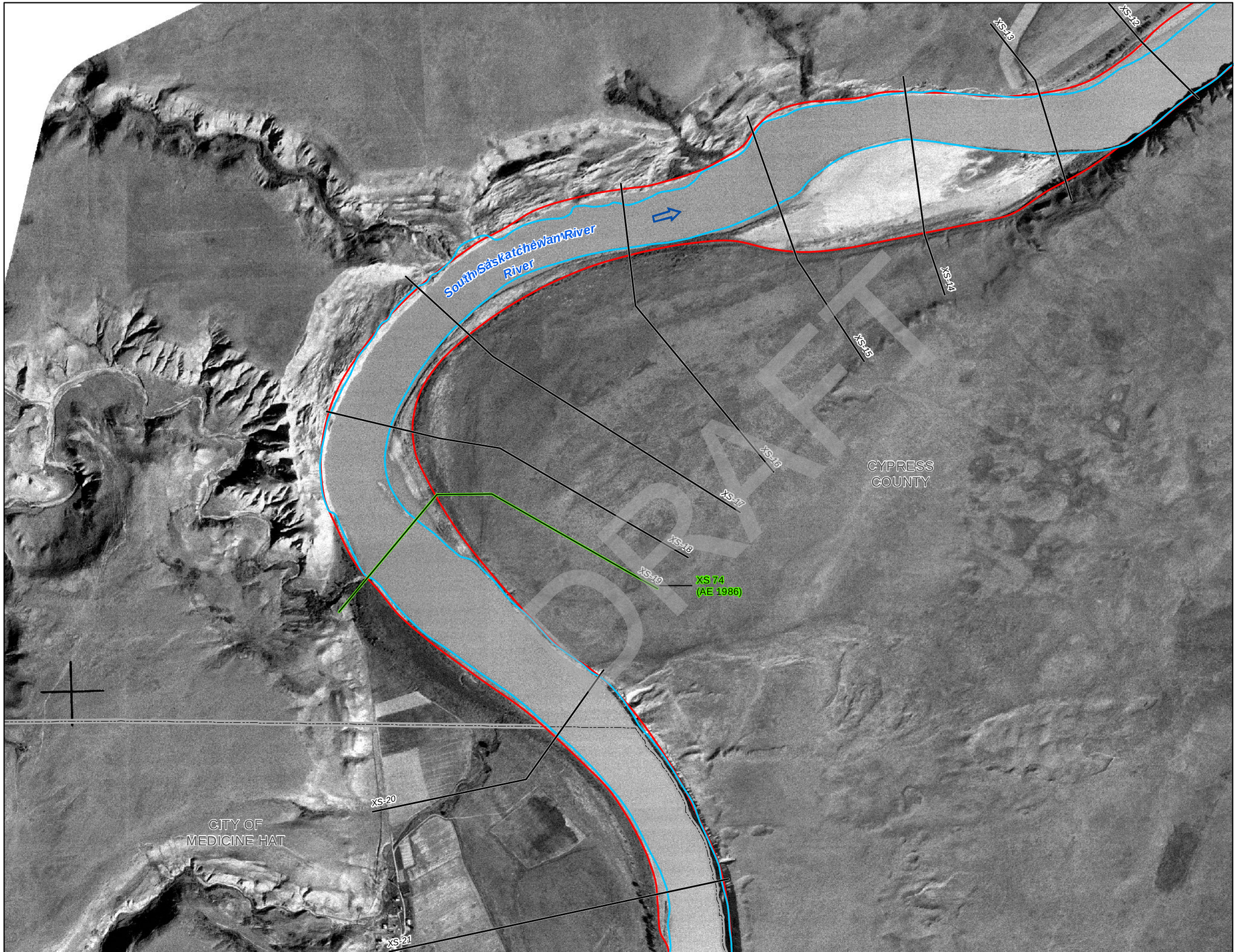
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 10 OF 33



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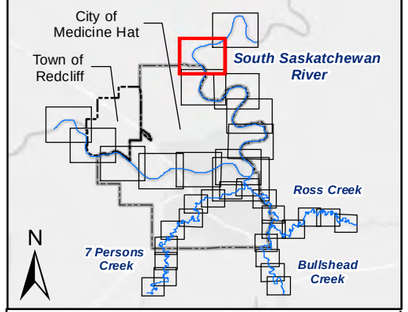

- FLOW DIRECTION
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- CULVERT
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- 1951 BANKLINE

SCALE - 1:10,000

0 100 200 300 400 M

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

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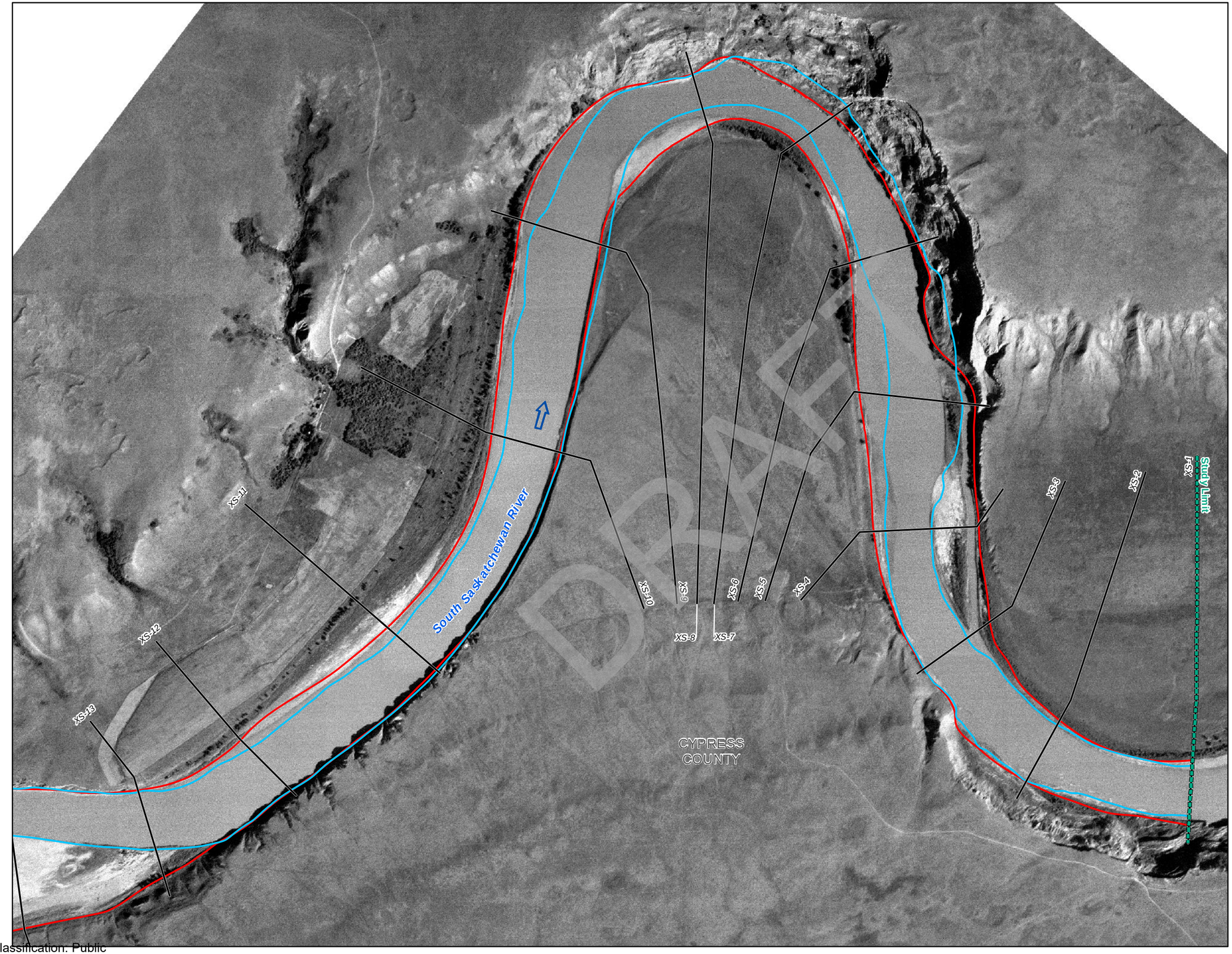
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 11 OF 33

P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd REH



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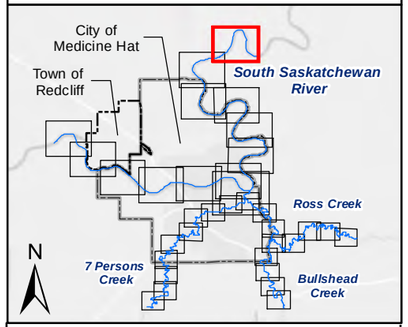

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
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SCALE - 1:10,000

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 12 OF 33

REH. P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd

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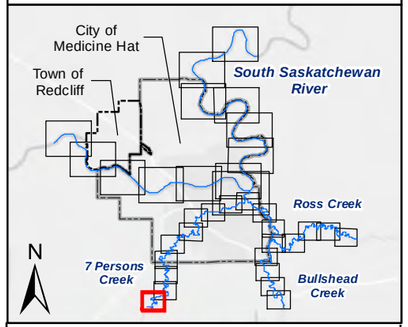

FLOW DIRECTION
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FLOOD CONTROL STRUCTURE
BRIDGE
CULVERT
WEIR
REDCLIFF TOWN
MEDICINE HAT CITY BOUNDARY
NEIGHBOURHOOD
HISTORIC SECTION (AE 1986)
CROSS SECTION (NHC 2017)
2018 BANKLINE
1951 BANKLINE

SCALE - 1:5,000
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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 13 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd

Classification: Public

Desert Blume Golf Course Bridge 1 over Seven Persons Creek

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XS-502
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XS-533

Seven Persons Creek

CYPRESS COUNTY

DRAFT

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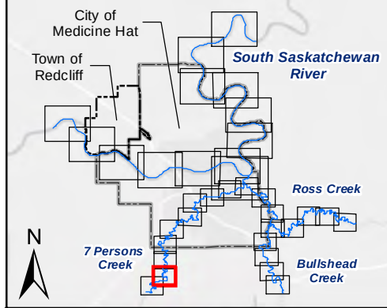


FLOW DIRECTION
STUDY LIMIT
FLOOD CONTROL STRUCTURE
BRIDGE
CULVERT
WEIR
REDCLIFF TOWN
MEDICINE HAT CITY BOUNDARY
NEIGHBOURHOOD
HISTORIC SECTION (AE 1986)
CROSS SECTION (NHC 2017)
2018 BANKLINE
1951 BANKLINE

SCALE - 1:5,000
0 50 100 150 200 M
N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

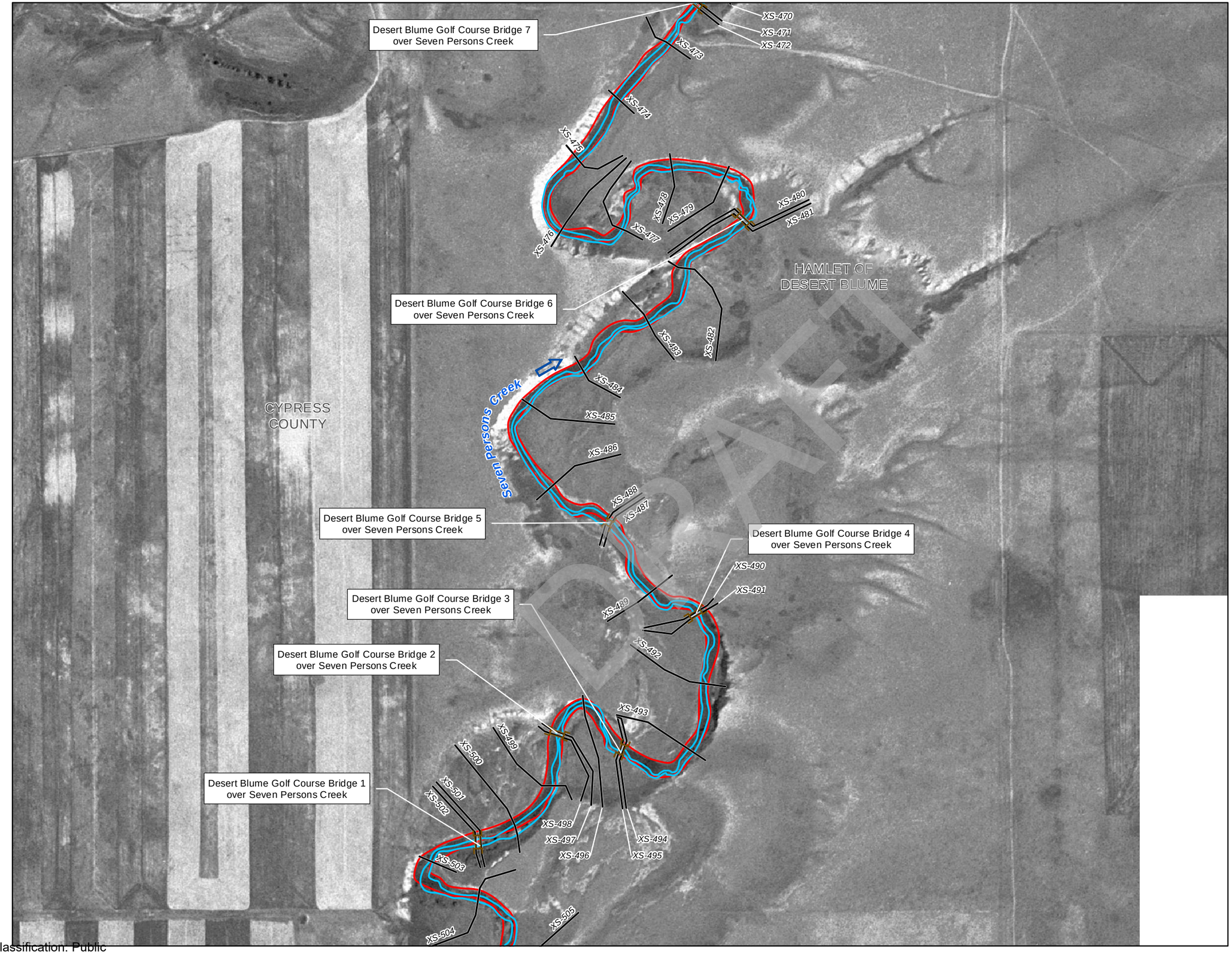
Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 14 OF 33

P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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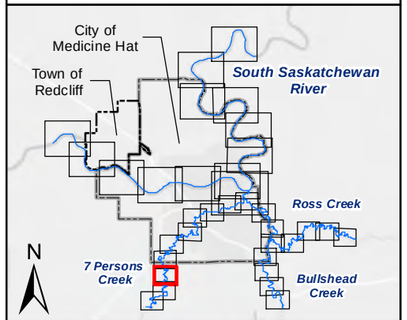

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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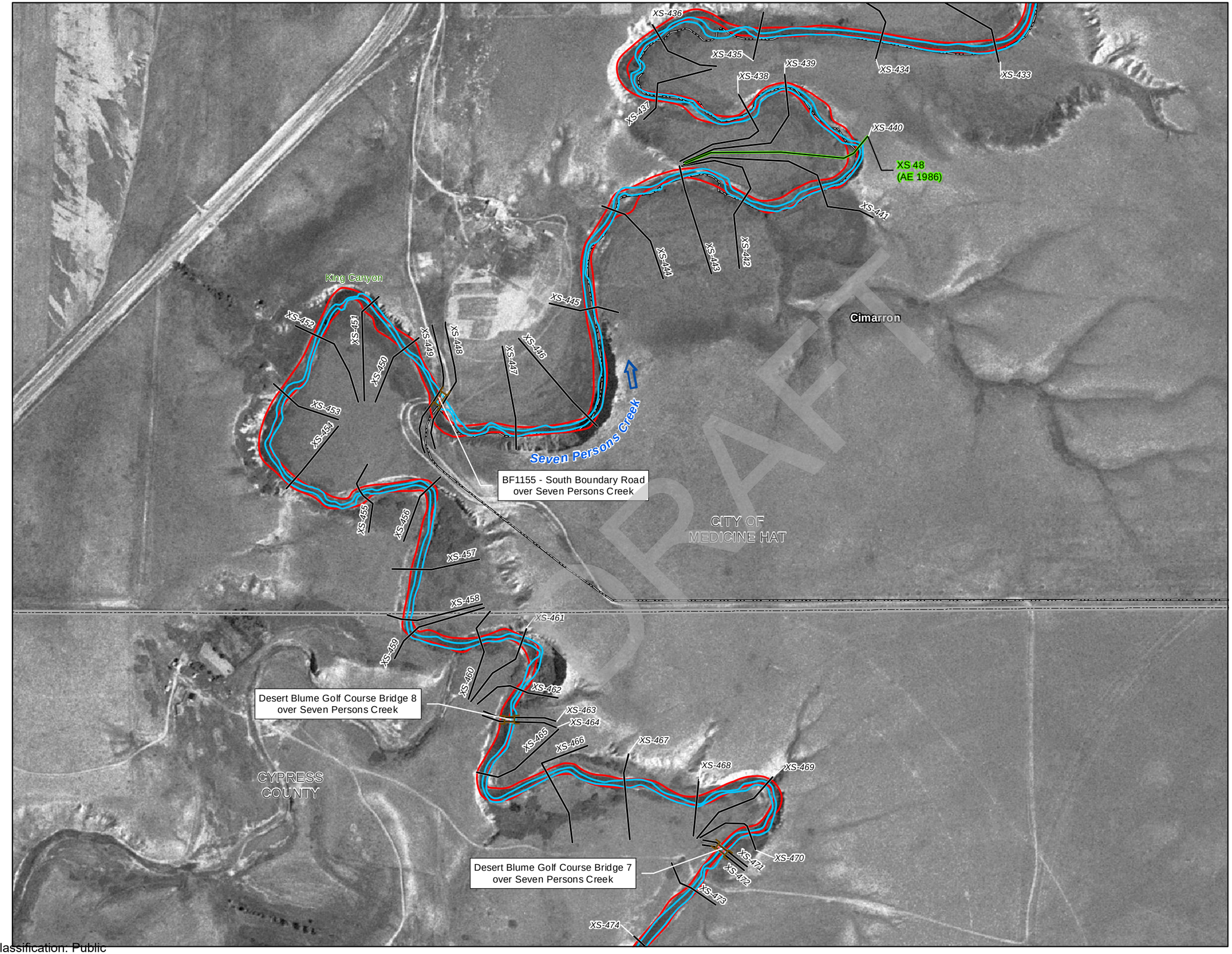
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 15 OF 33



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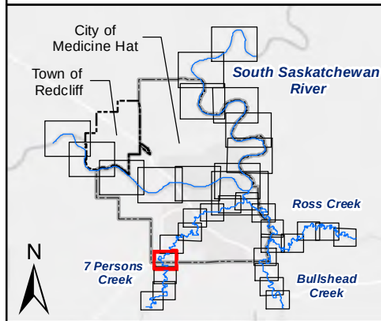

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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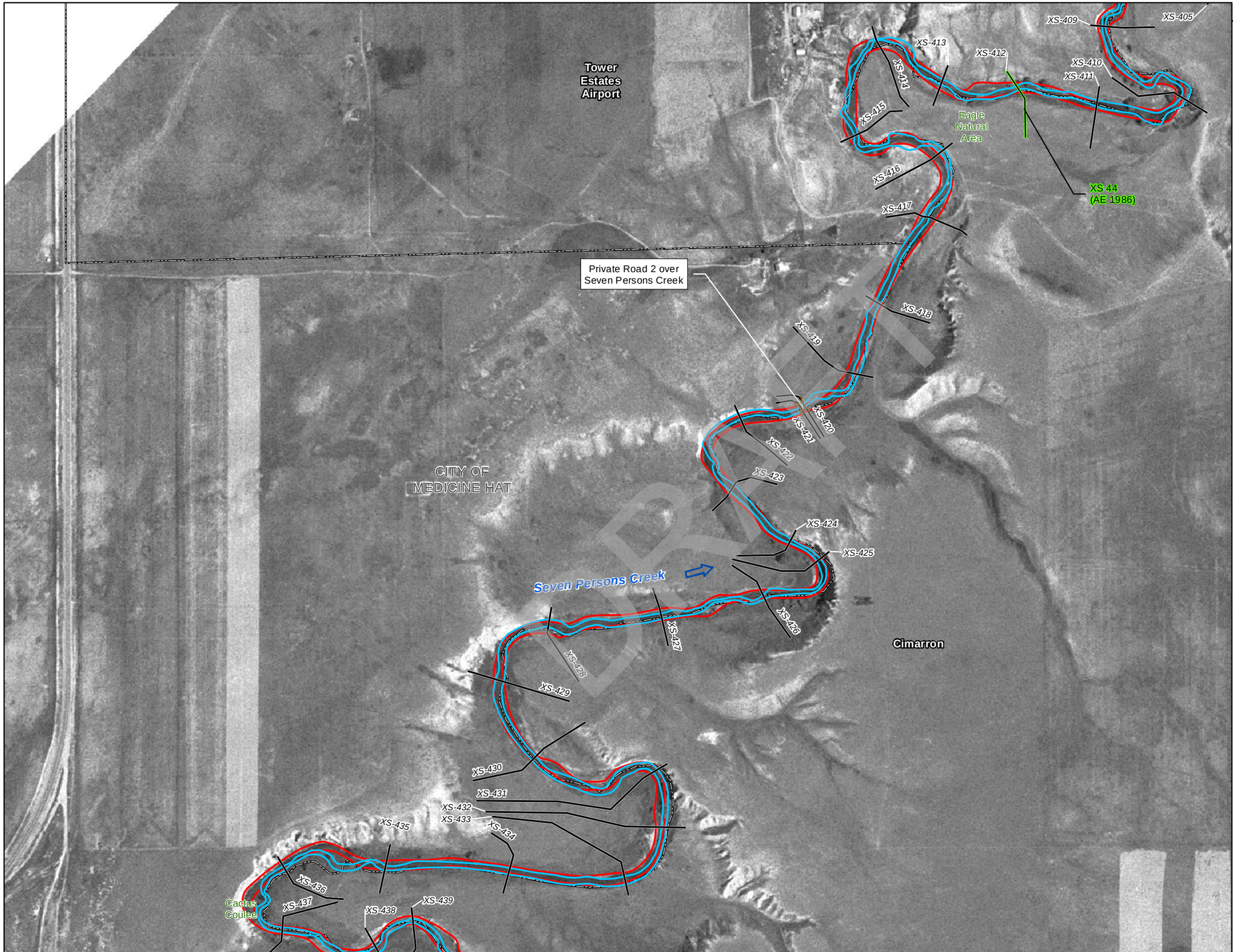
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 16 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



Classification: Public

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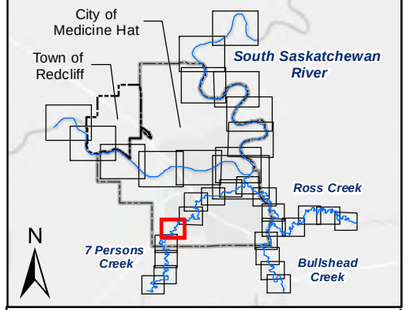

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

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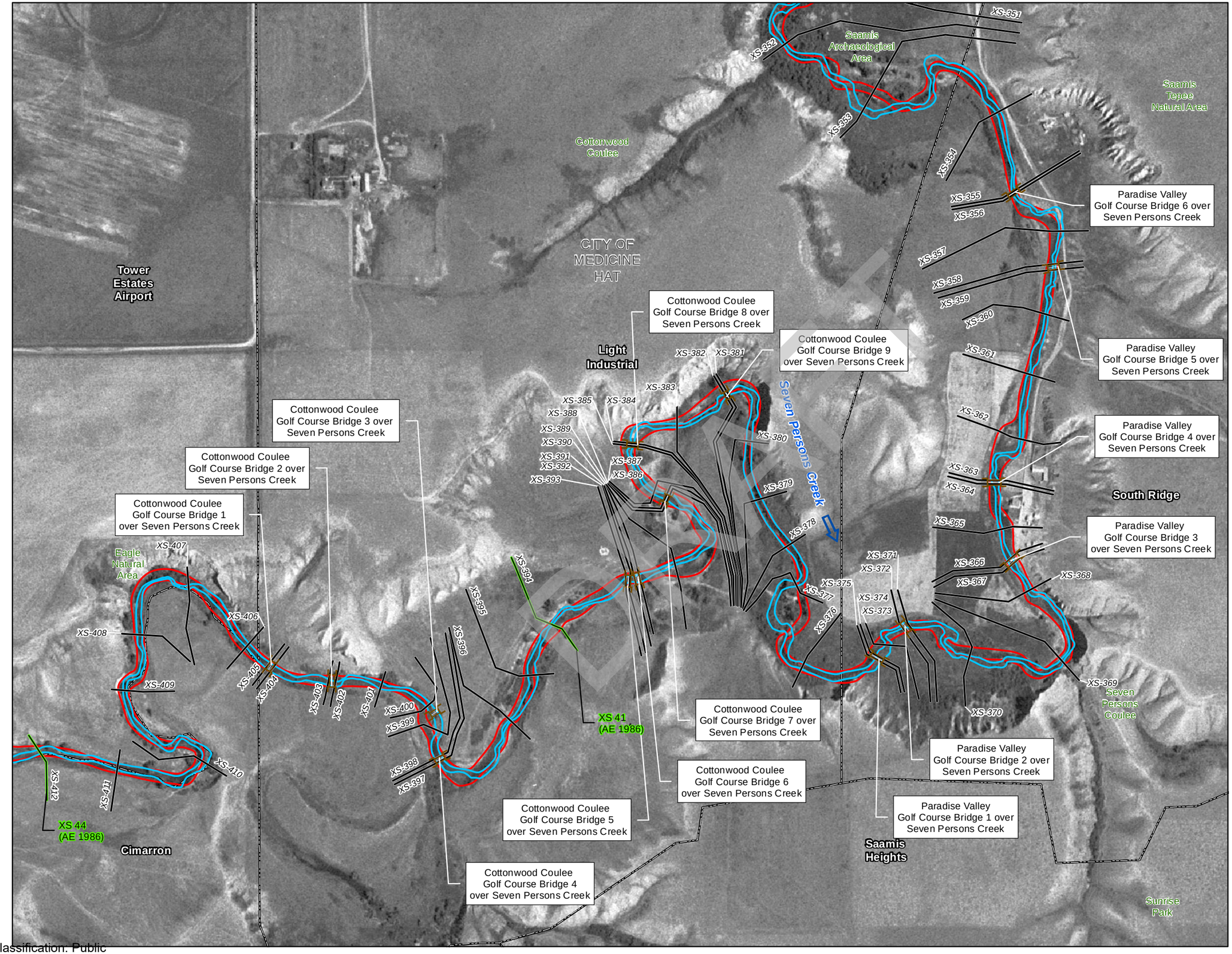
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 17 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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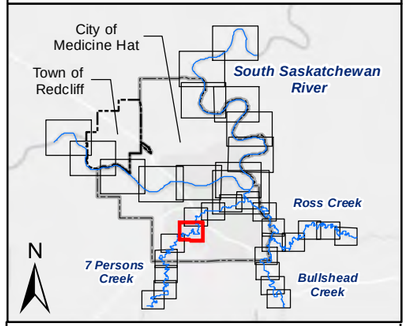

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

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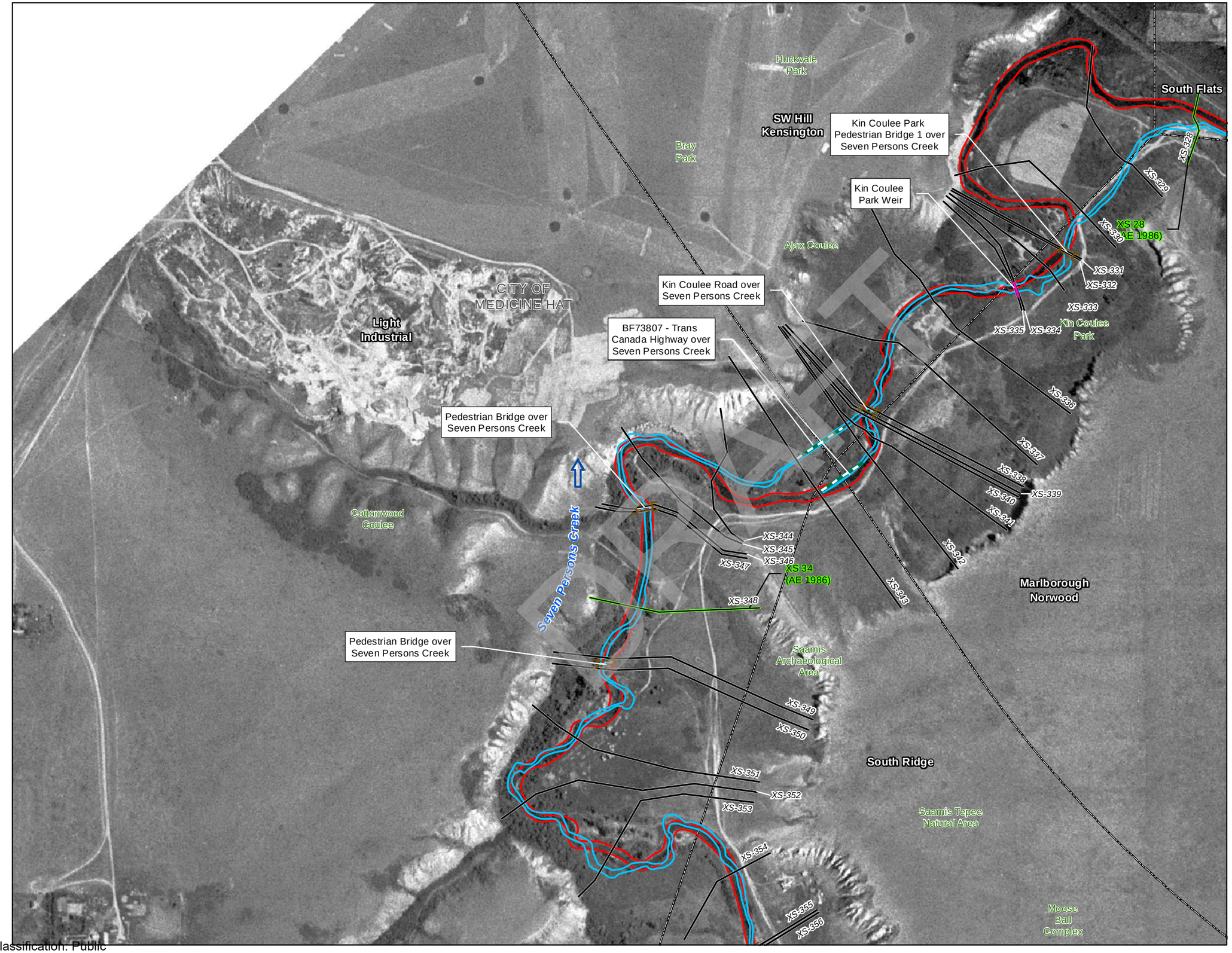
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 18 OF 33

REH - P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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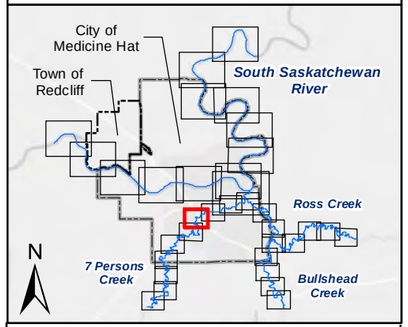

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
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SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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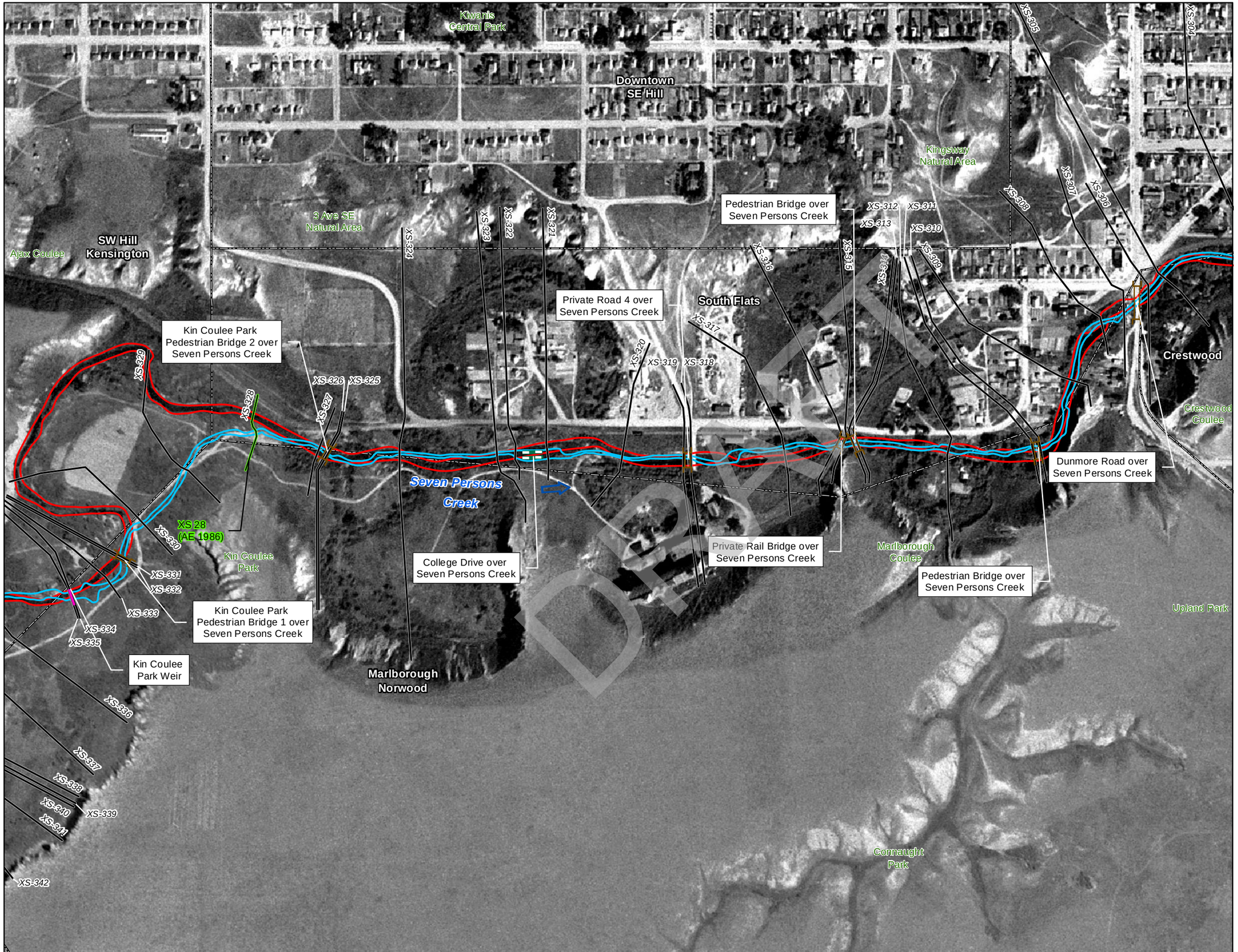
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 19 OF 33

REH - P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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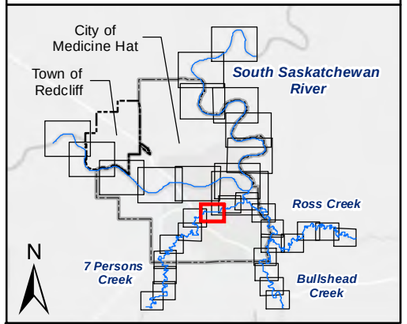

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
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SCALE - 1:5,000

0 50 100 150 200 M

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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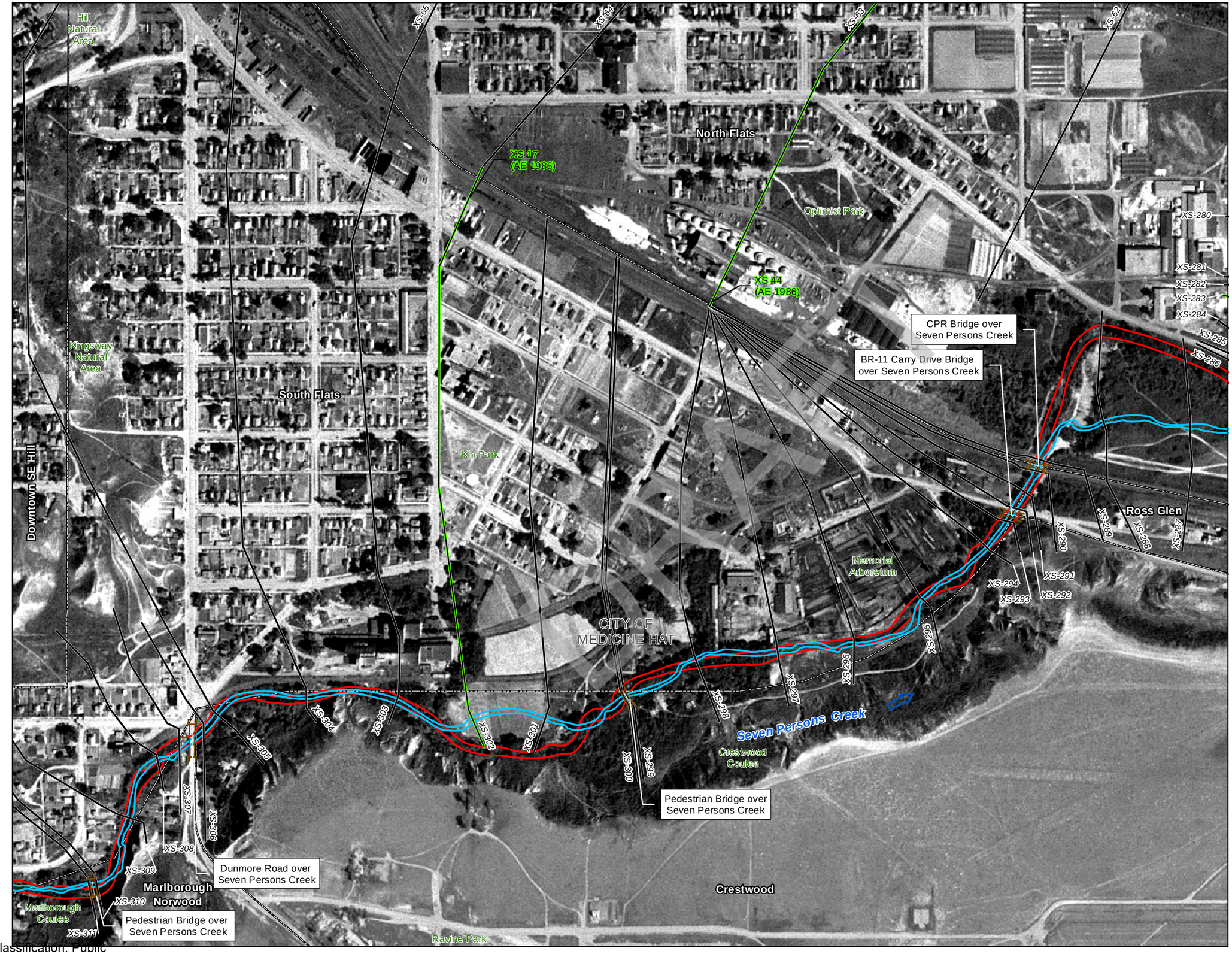
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 20 OF 33



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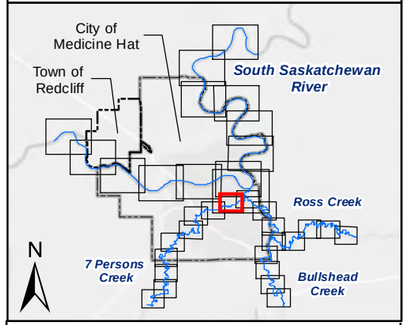

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 21 OF 33

P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd

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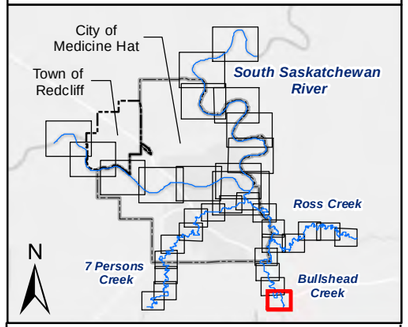

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

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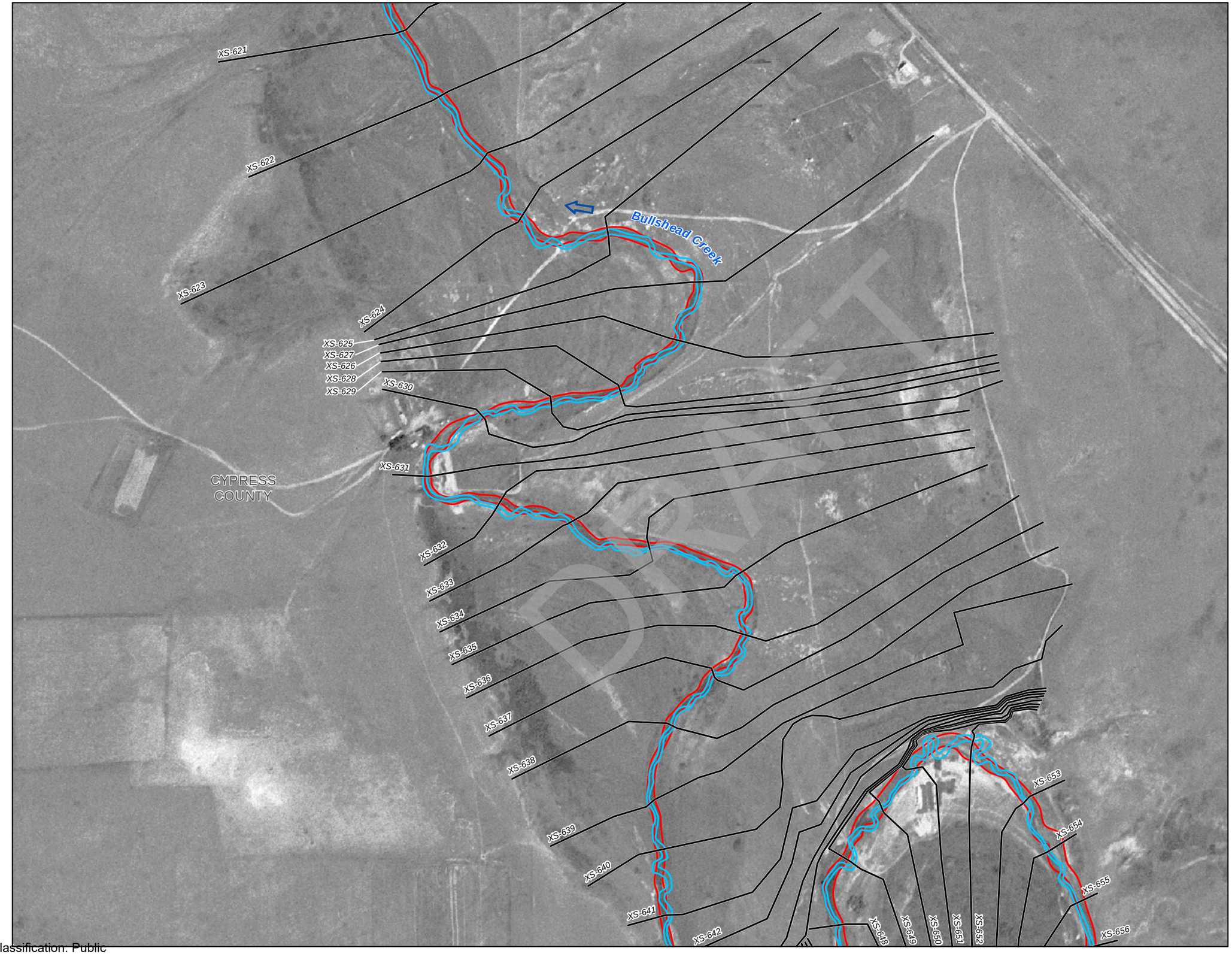
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 22 OF 33

REH_P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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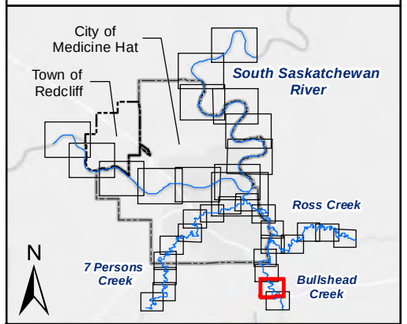

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 23 OF 33

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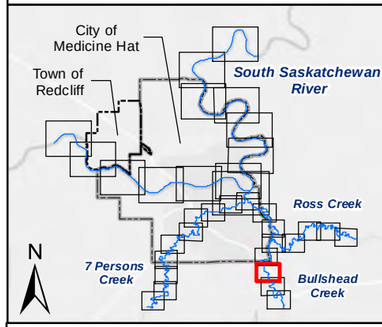

- FLOW DIRECTION
- STUDY LIMIT
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- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
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SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 24 OF 33

REH. P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd

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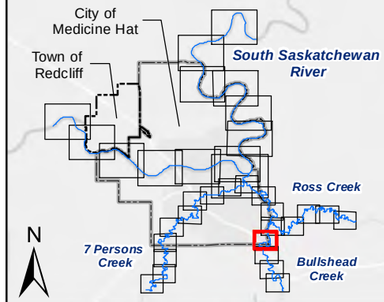

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
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SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

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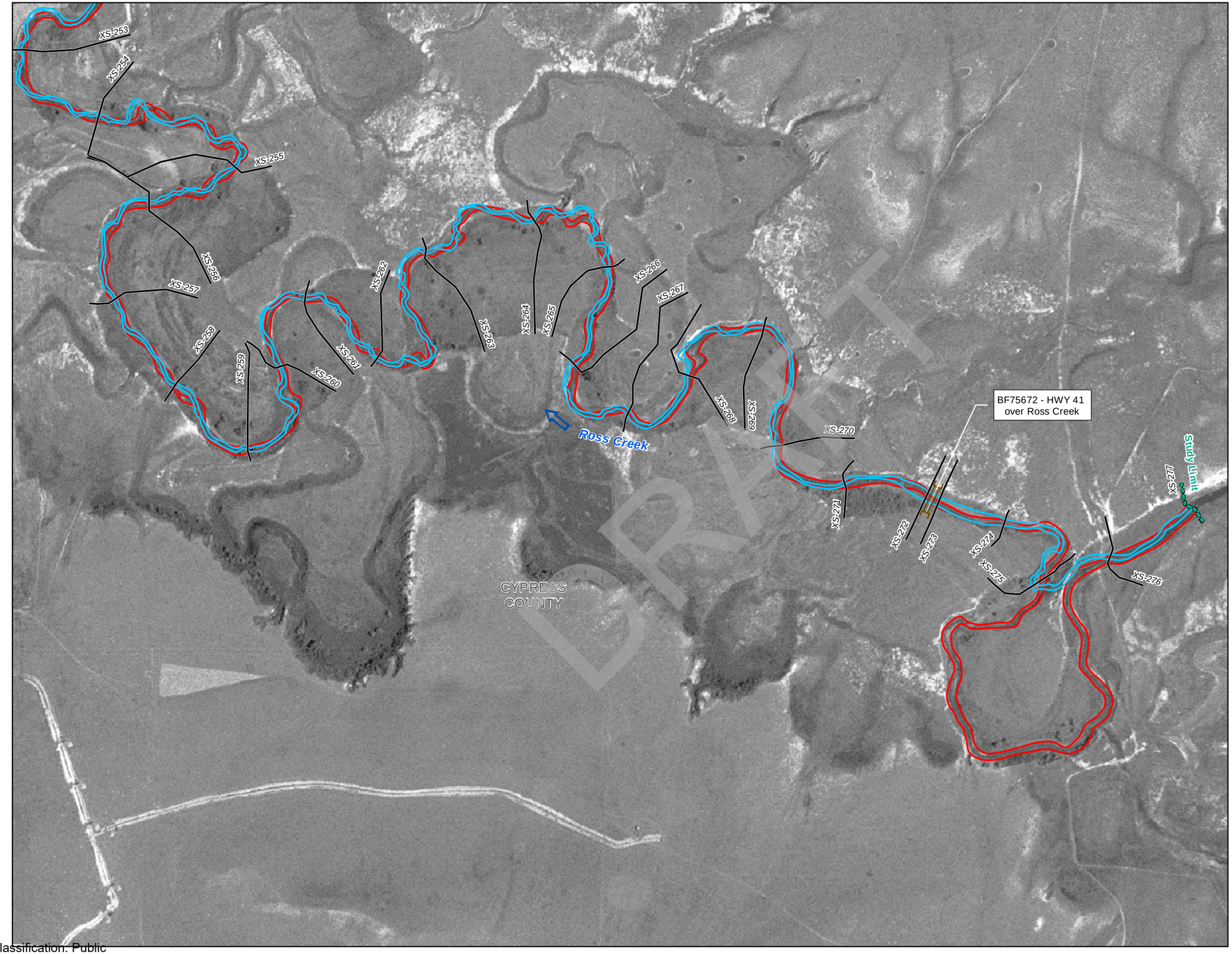
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 25 OF 33

REH_P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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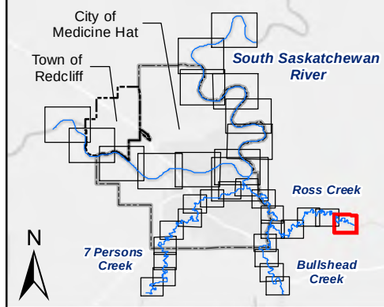

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
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SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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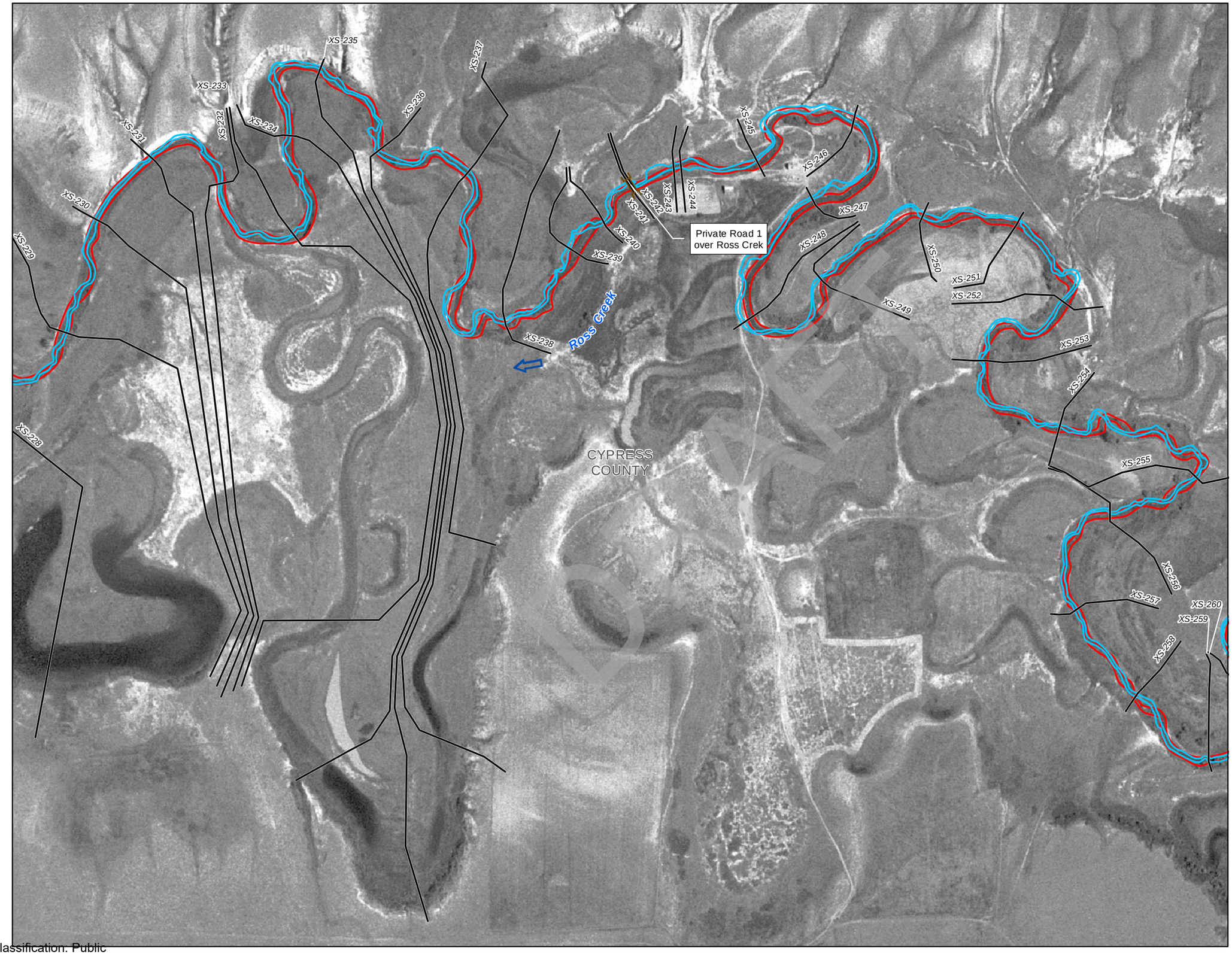
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 26 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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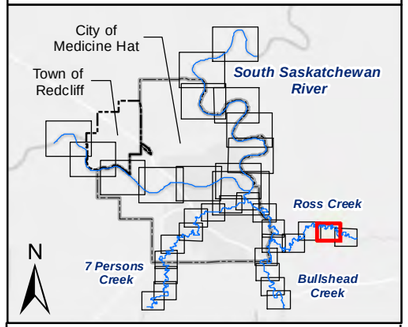

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
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SCALE - 1:5,000

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Coordinate System: NAD 1983 CSRS 3TM 111
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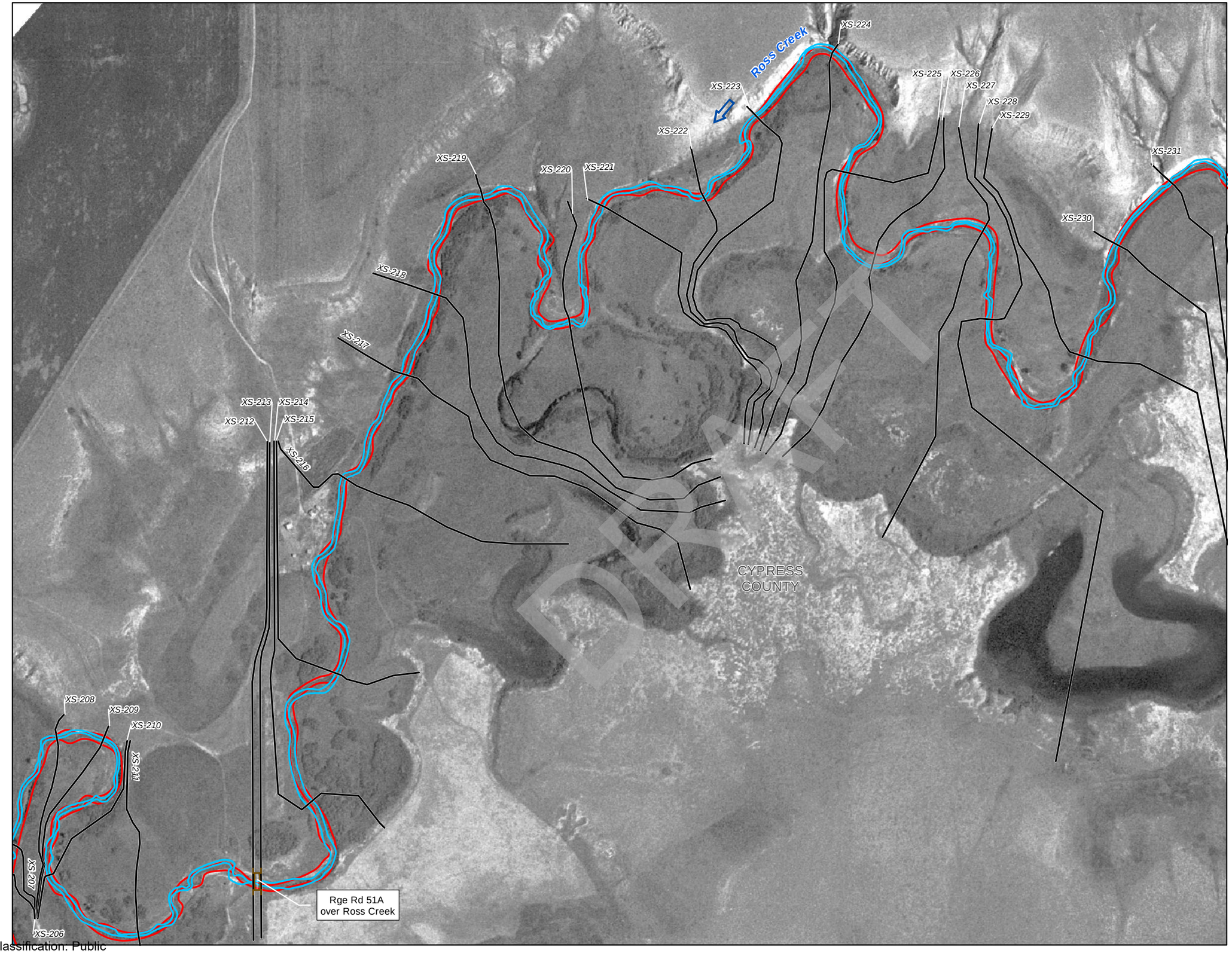
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 27 OF 33



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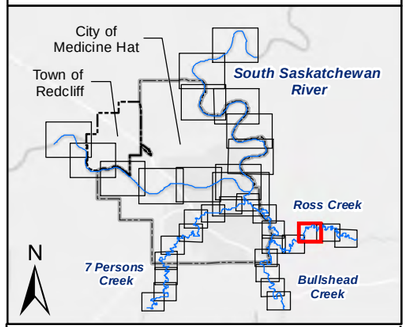
northwest hydraulic consultants



- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
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SCALE - 1:5,000

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Coordinate System: NAD 1983 CSRS 3TM 111
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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 28 OF 33

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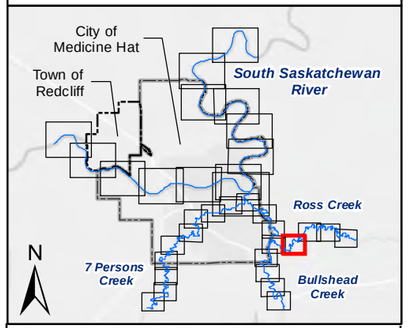

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
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SCALE - 1:5,000

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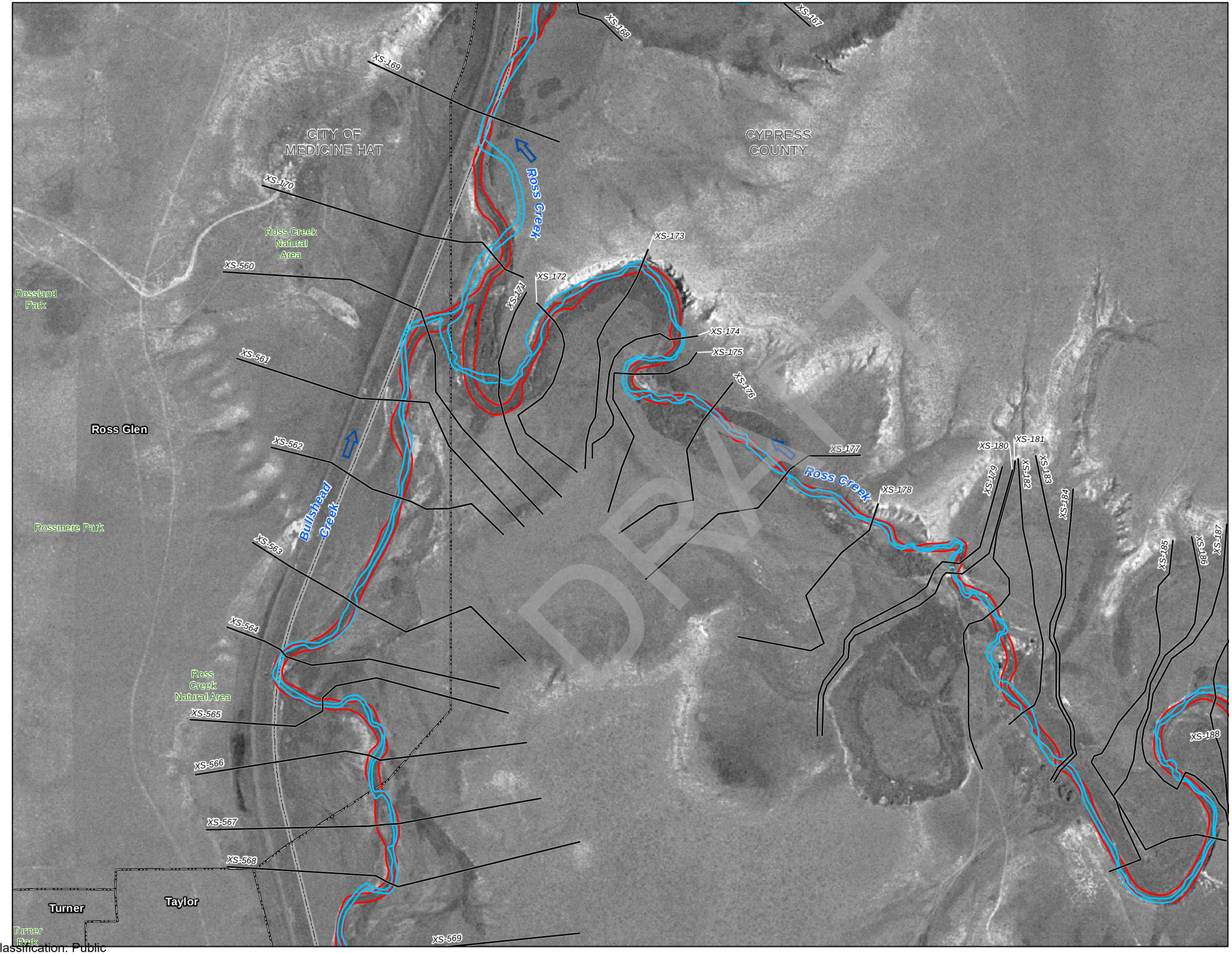
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 29 OF 33

REH - P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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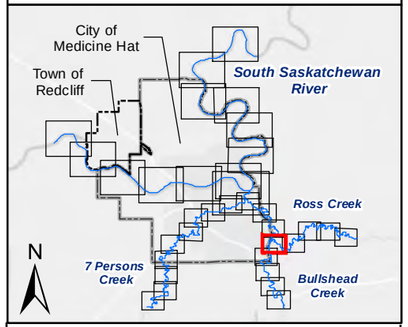


- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

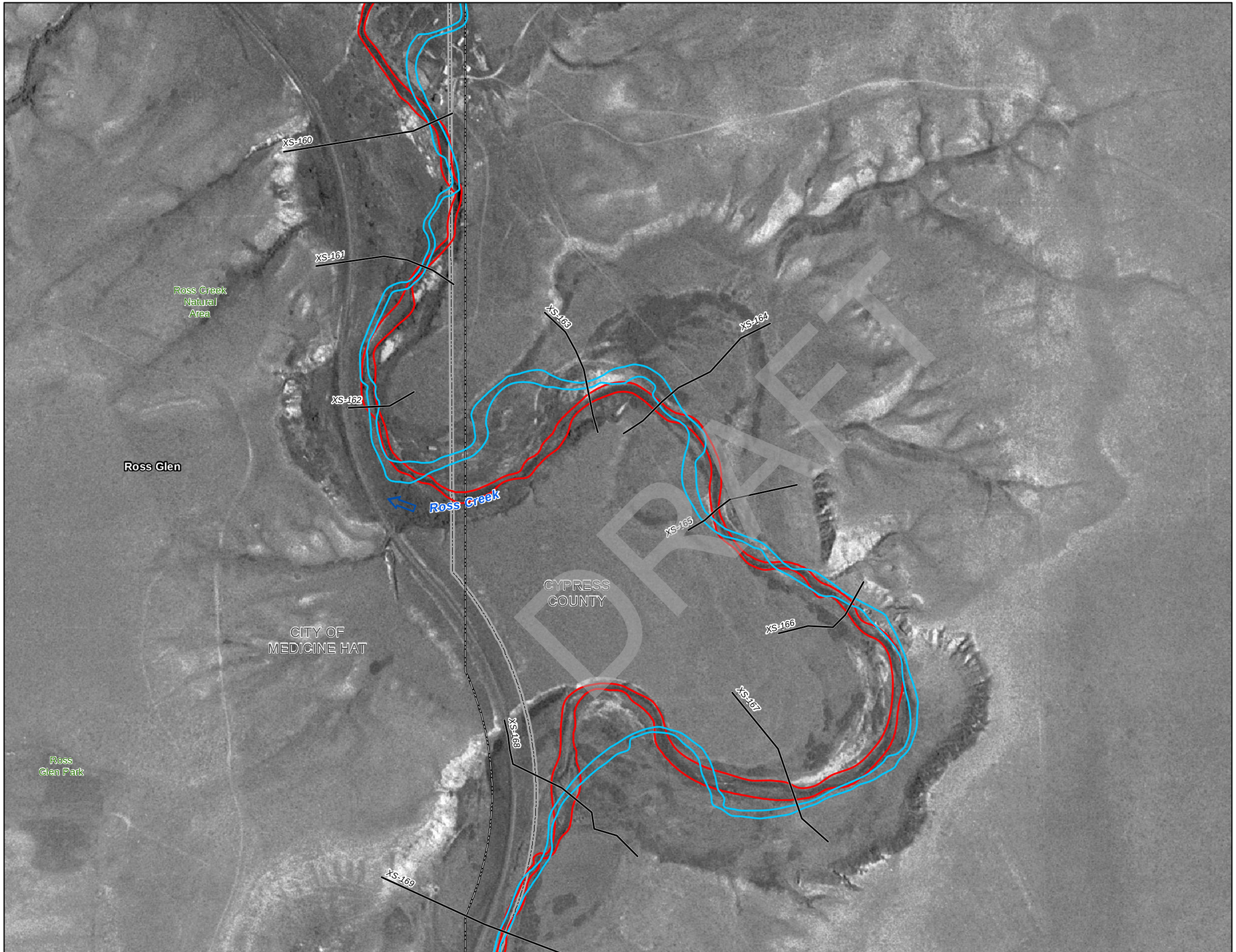
Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 30 OF 33

P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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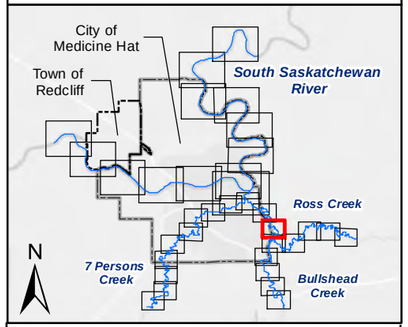

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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MGB	REH	RBA

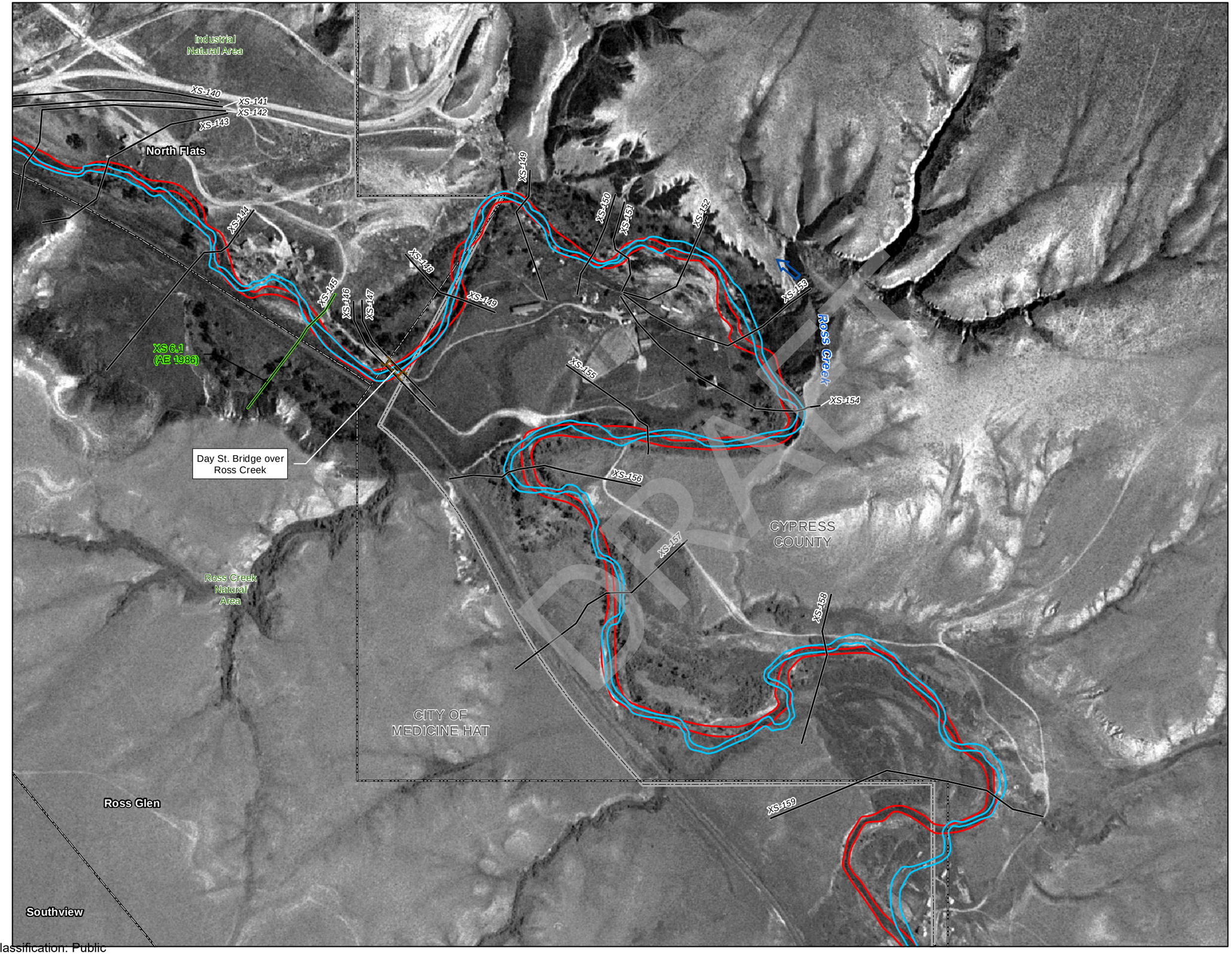
Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 31 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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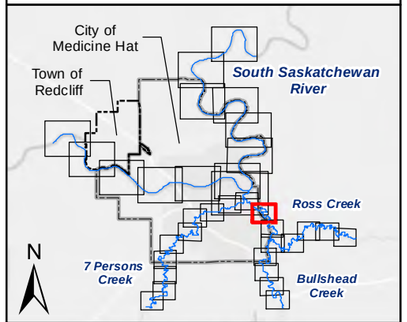

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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MGB	REH	RBA

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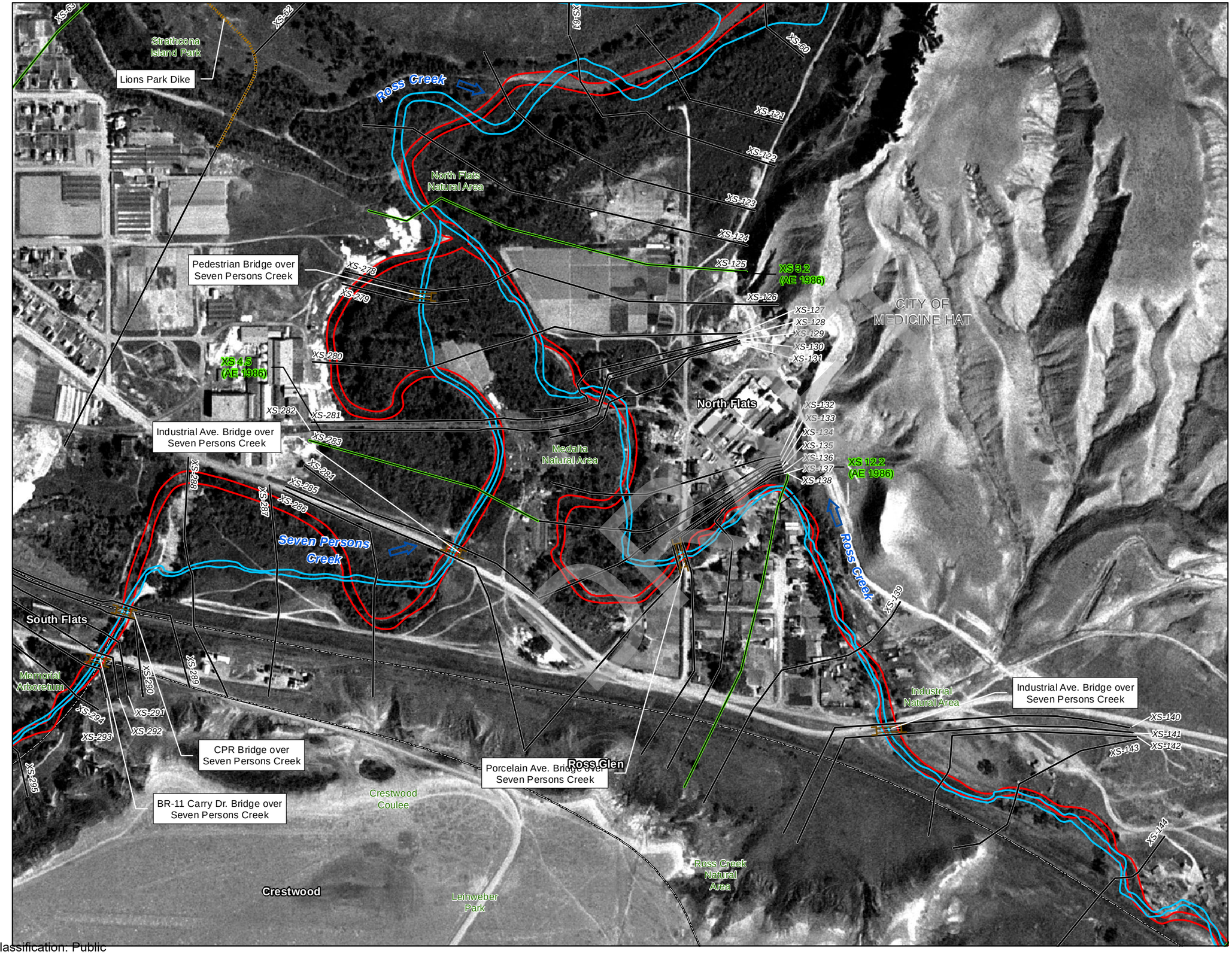
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 32 OF 33



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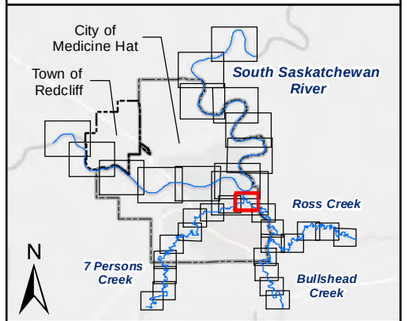


- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

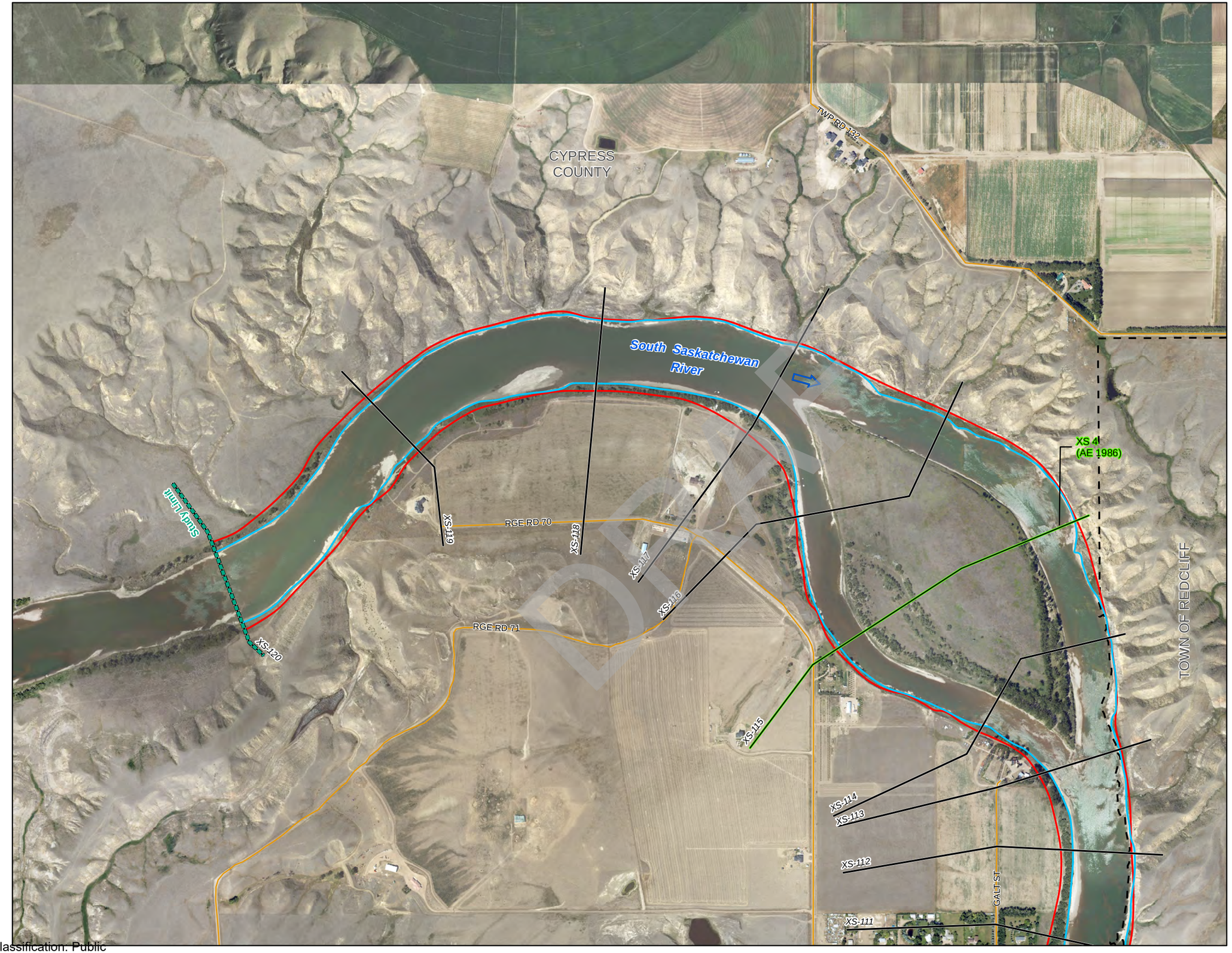
Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 1951 IMAGERY

FIGURE 3 | SHEET 33 OF 33

REH_P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability1951.mxd



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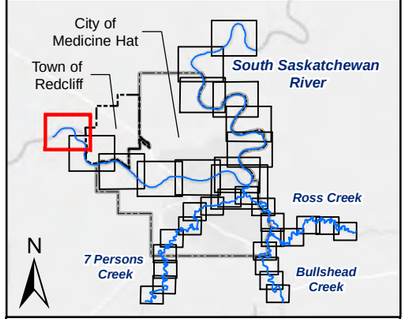

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:10,000
0 100 200 300 400 M
N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

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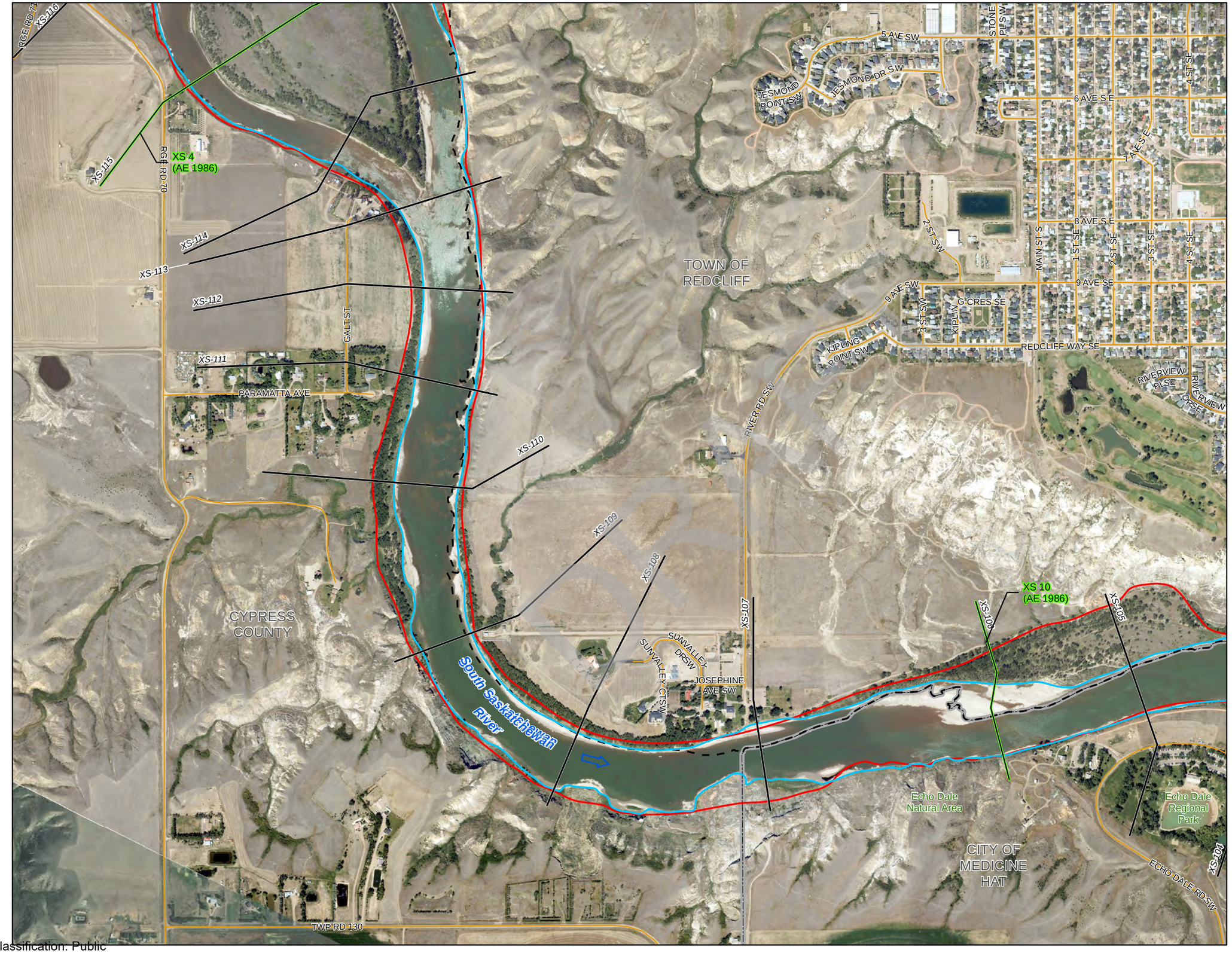
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 1 OF 33



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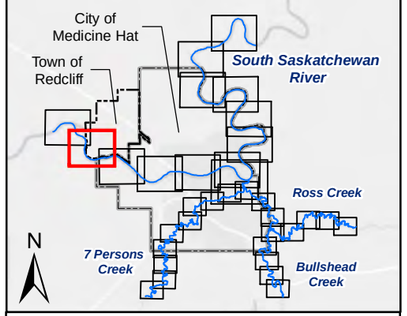

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:10,000

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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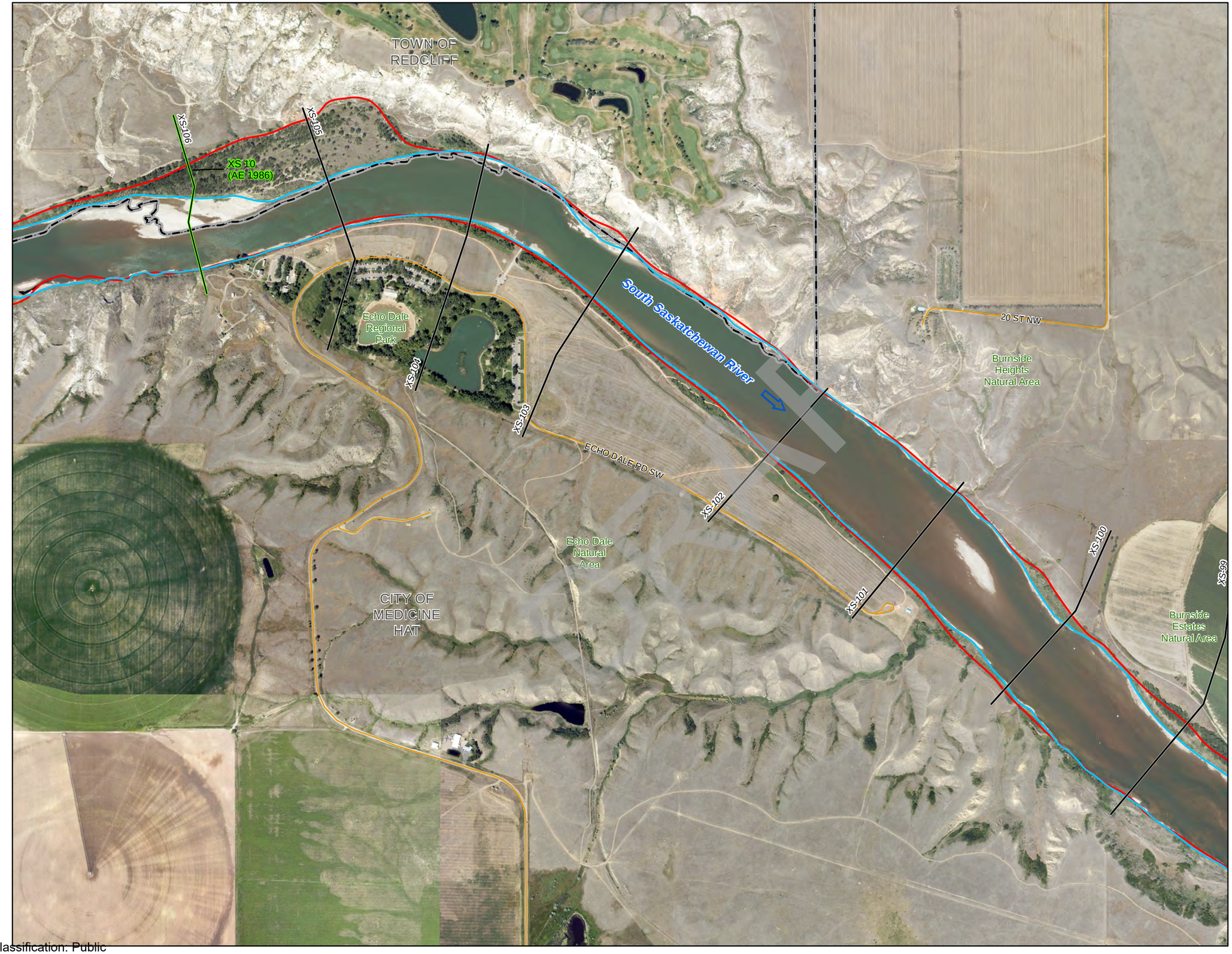
Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 2 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd



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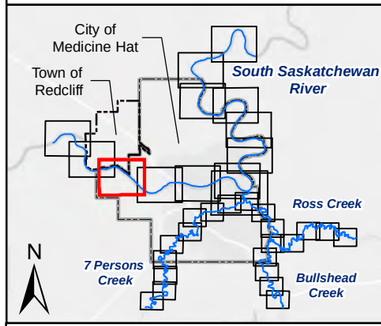

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
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- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:10,000

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 3 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd

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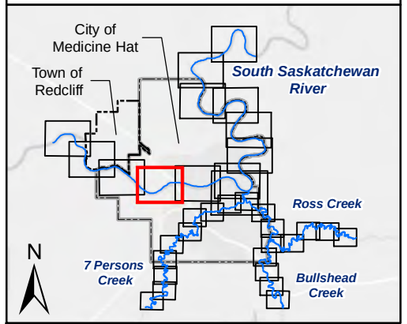

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
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- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
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SCALE - 1:10,000

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 4 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd

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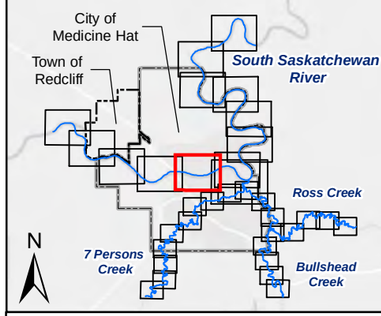

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
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SCALE - 1:10,000

0 100 200 300 400 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

Job: 1003094 | *Date: 25-JUL-2019*

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | *SHEET 5 OF 33*

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS1003094_REH_Map_T800_ChannelStability2018.mxd

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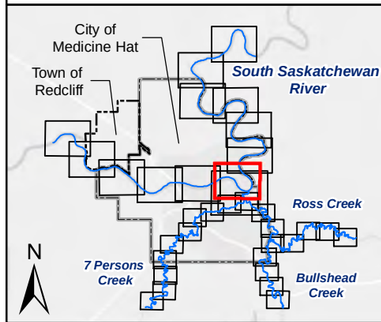


- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:10,000

0 100 200 300 400 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

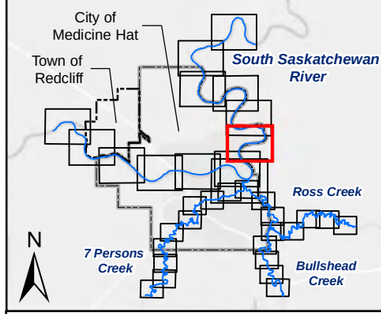
Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 6 OF 33

REH. P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd



- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
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- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:10,000

0 100 200 300 400 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 7 OF 33

P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS1003094_REH_Map_T800_ChannelStability2018.mxd REH

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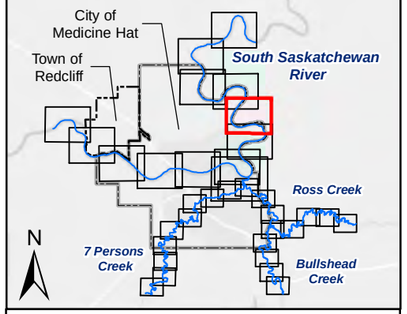

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
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- 1951 BANKLINE

SCALE - 1:10,000

0 100 200 300 400 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 8 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd

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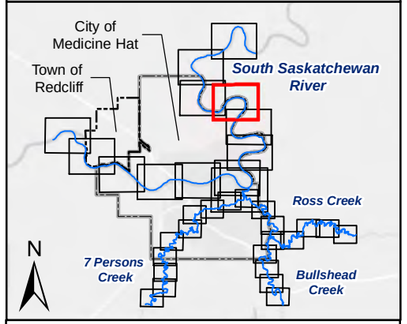

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
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- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
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SCALE - 1:10,000

0 100 200 300 400 M

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

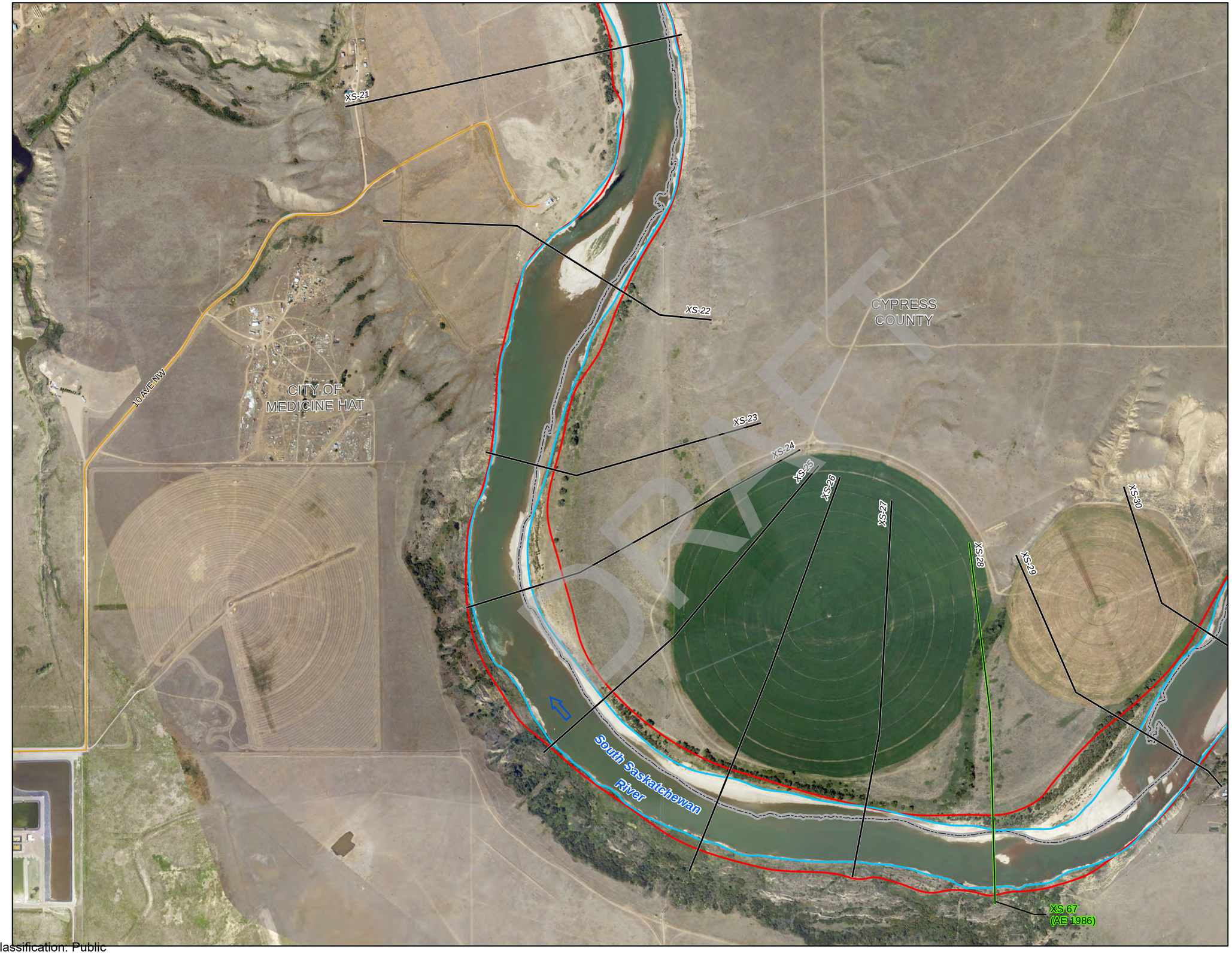
Engineer	GIS	Reviewer
MGB	REH	RBA

Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 9 OF 33



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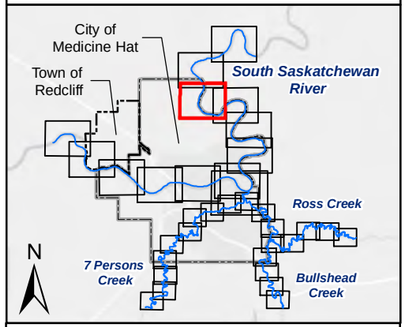

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
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- REDCLIFF TOWN BOUNDARY
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- 2018 BANKLINE
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SCALE - 1:10,000

0 100 200 300 400 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

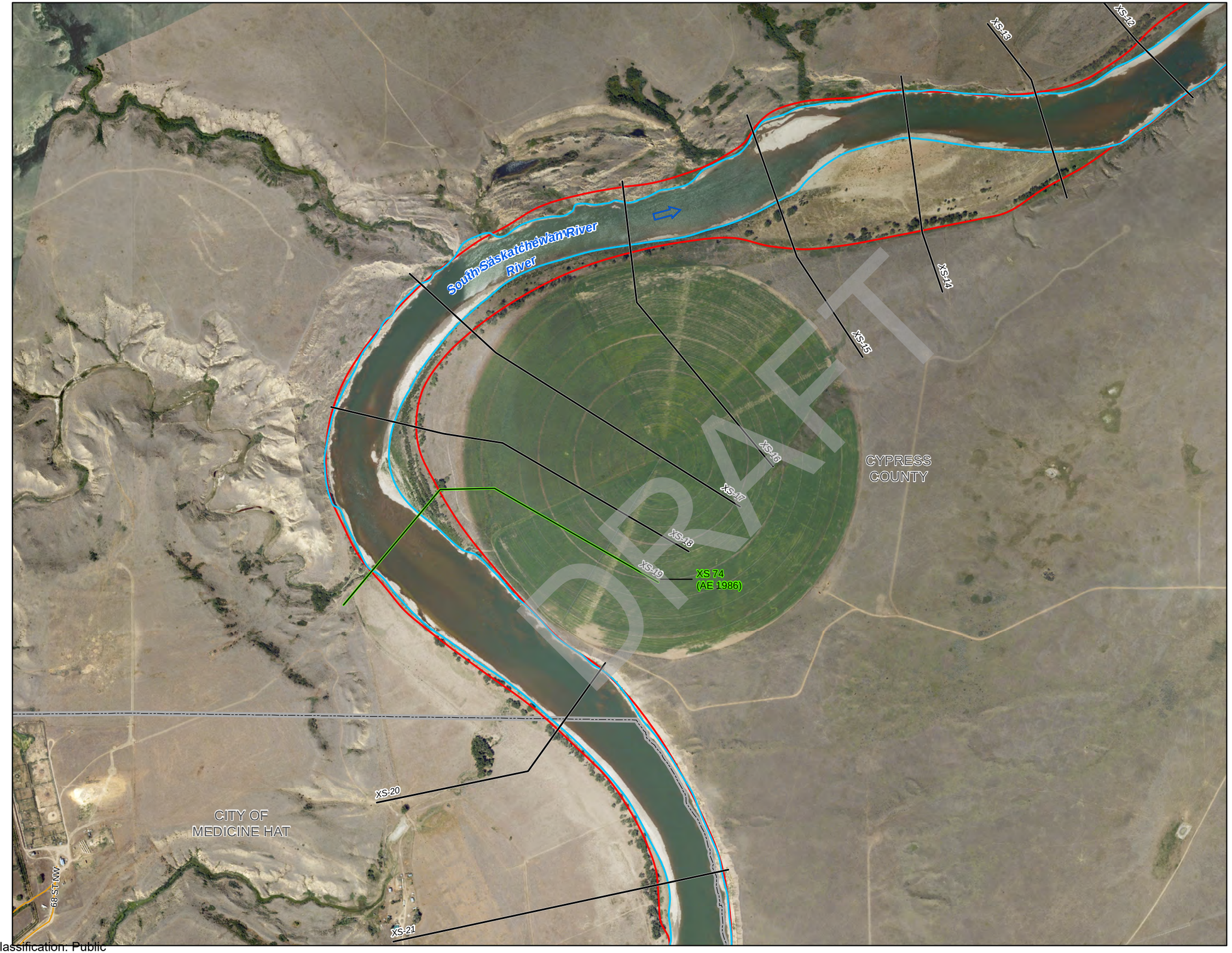
Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 10 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd



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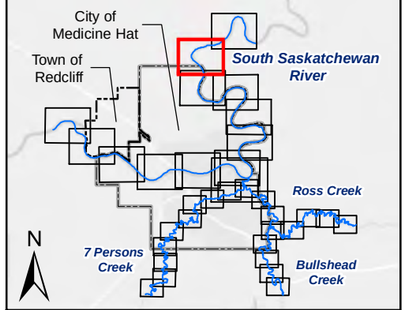

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
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- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:10,000

0 100 200 300 400 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 11 OF 33

REH: P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd

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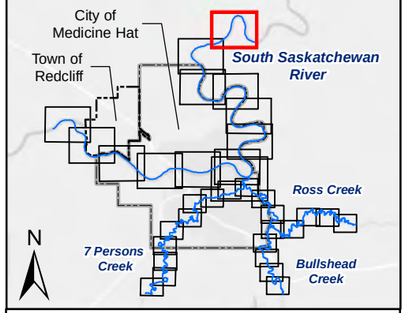

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
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SCALE - 1:10,000

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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 12 OF 33

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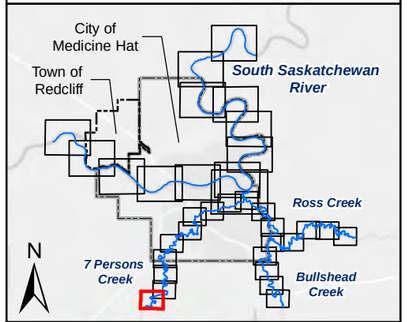

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 13 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd

Desert Blume Golf Course Bridge 1 over Seven Persons Creek

XS-500
XS-501
XS-502
XS-503
XS-504
XS-505
XS-506
XS-507
XS-508
XS-509
XS-510
XS-511
XS-512
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XS-523
XS-524
XS-525
XS-526
XS-527
XS-528
XS-529
XS-530
XS-531
XS-532
XS-533

Seven Persons Creek

CYPRESS COUNTY

RGE RD 61A

RGE RD 62

DRAFT

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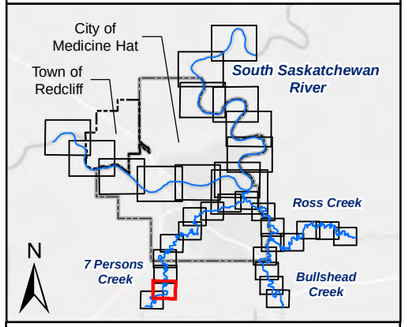

FLOW DIRECTION
STUDY LIMIT
FLOOD CONTROL STRUCTURE
BRIDGE
CULVERT
WEIR
REDCLIFF TOWN BOUNDARY
MEDICINE HAT CITY BOUNDARY
NEIGHBOURHOOD
HISTORIC SECTION (AE 1986)
CROSS SECTION (NHC 2017)
2018 BANKLINE
1951 BANKLINE

SCALE - 1:5,000
0 50 100 150 200 M
N

Coordinate System: NAD 1983 CSRS 3TM 111
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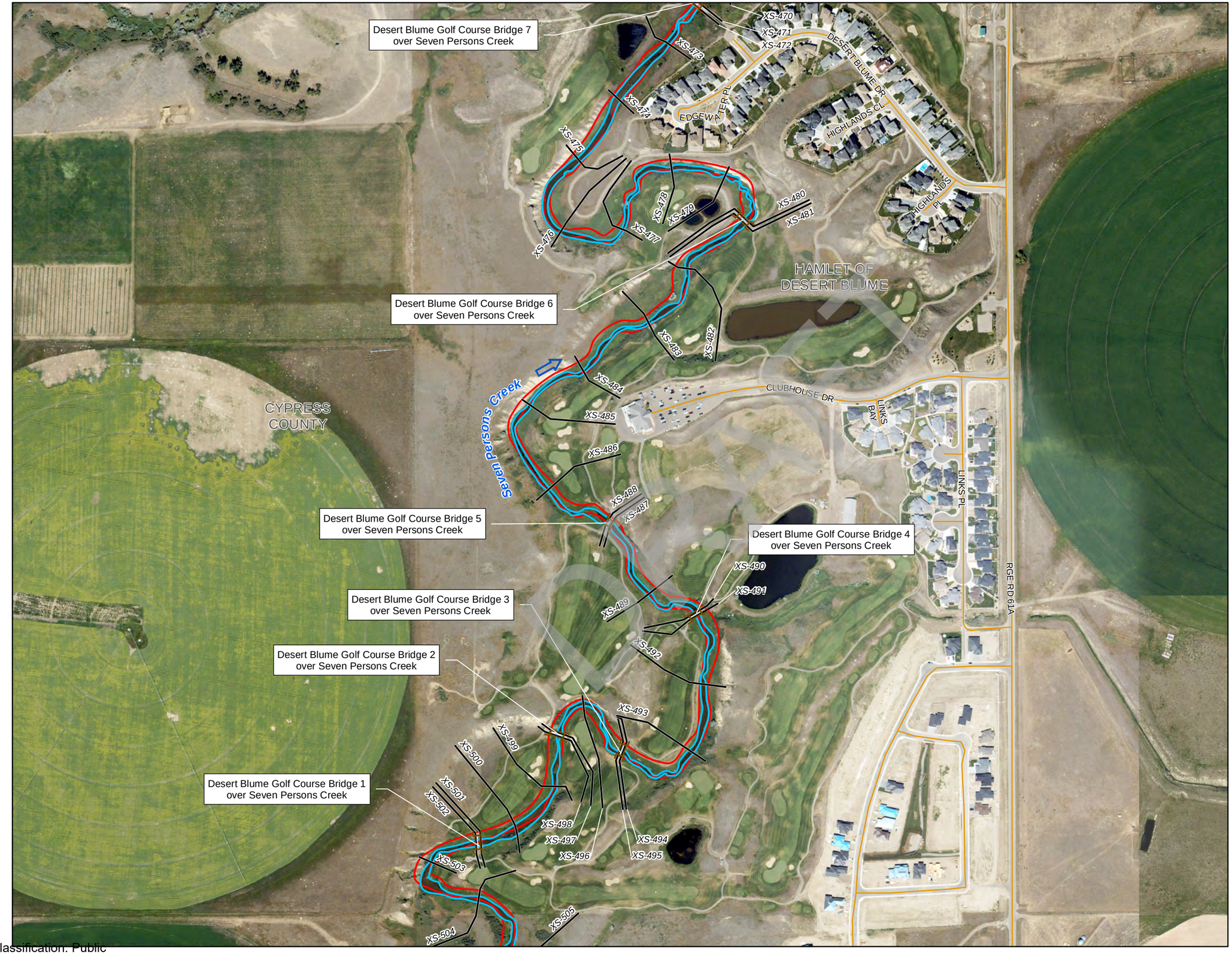
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 14 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd



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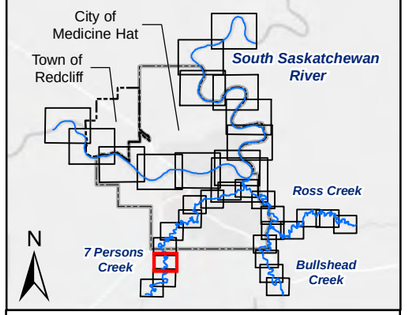

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
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- MEDICINE HAT CITY BOUNDARY
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SCALE - 1:5,000

0 50 100 150 200 M

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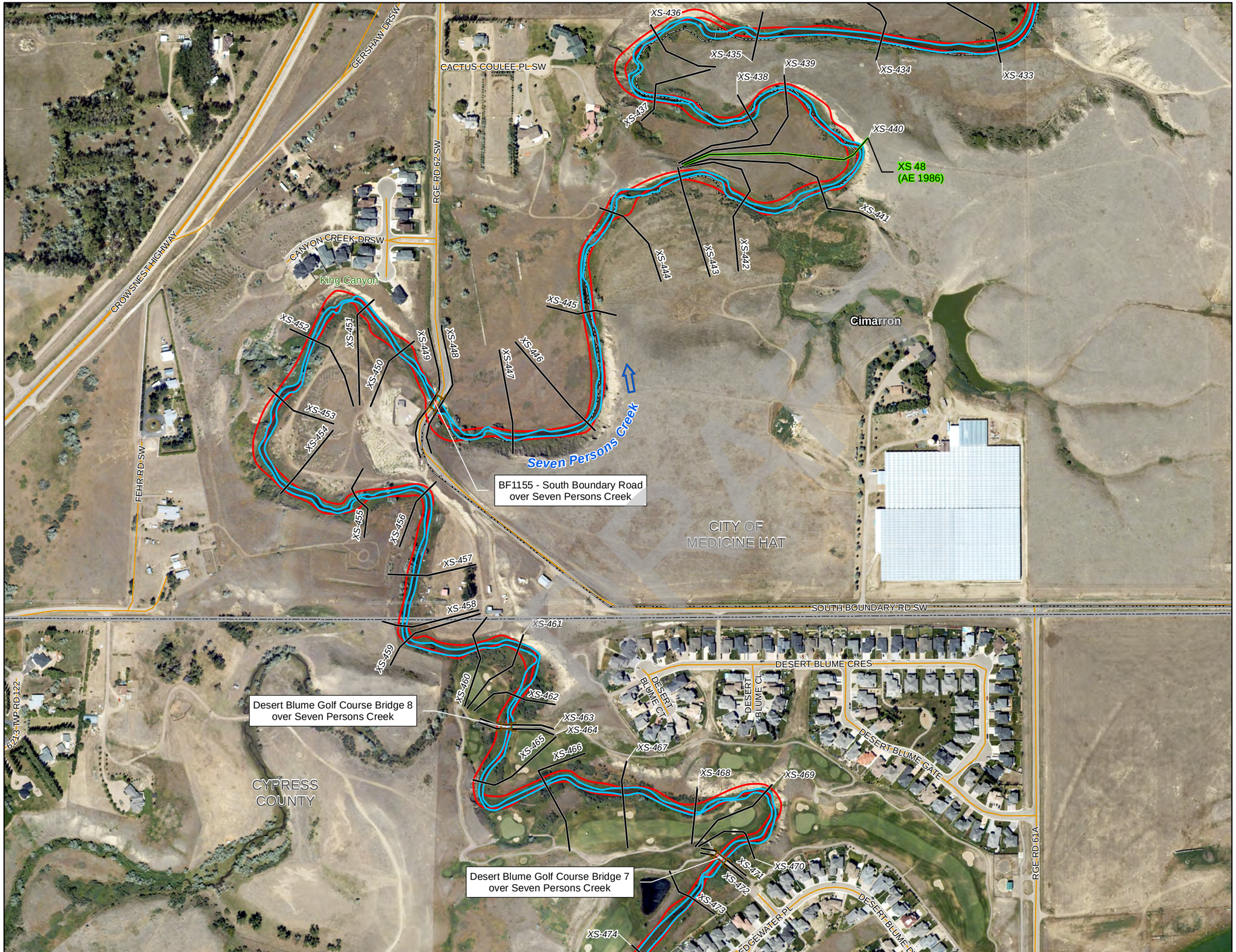
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 15 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd



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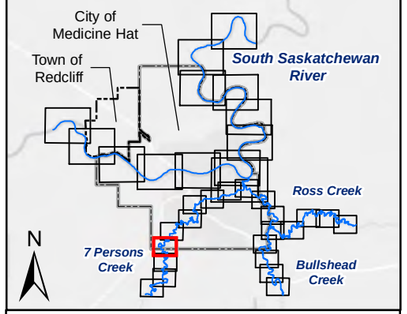

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 16 OF 33

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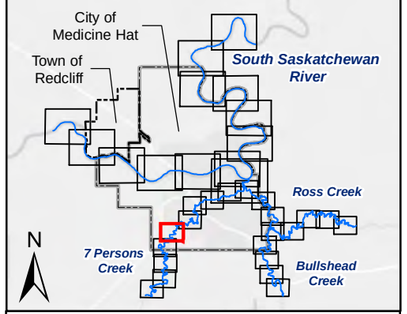

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
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SCALE - 1:5,000

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Coordinate System: NAD 1983 CSRS 3TM 111
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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 17 OF 33

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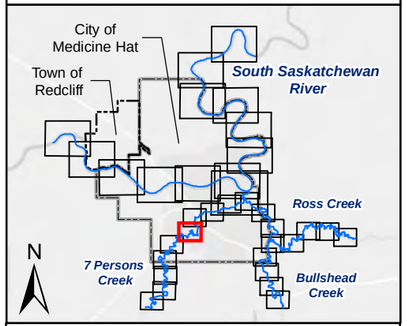

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
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Coordinate System: NAD 1983 CSRS 3TM 111
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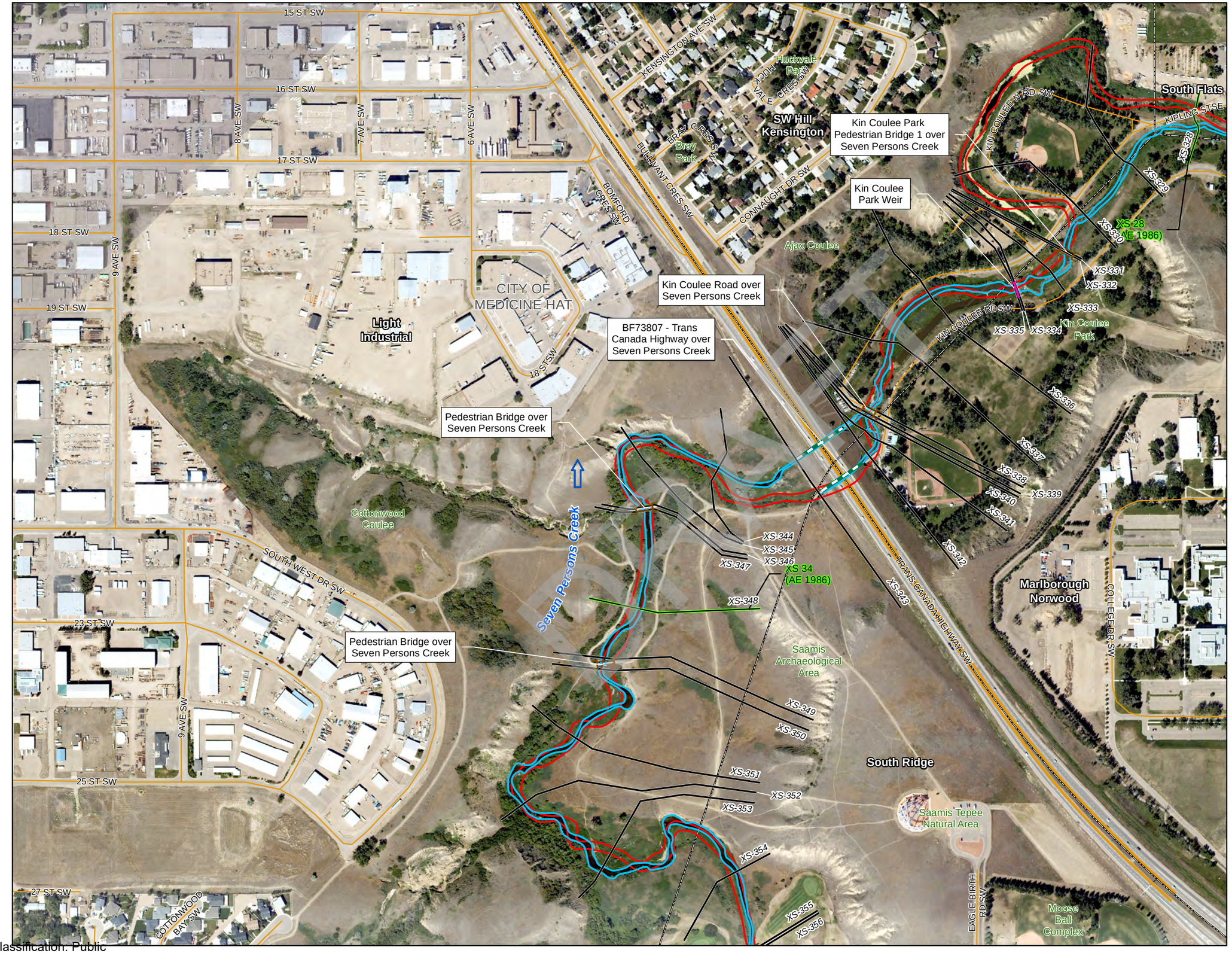
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 18 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd



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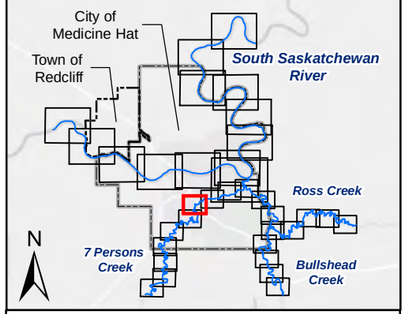

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
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SCALE - 1:5,000

0 50 100 150 200 M

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 19 OF 33

REH. P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd

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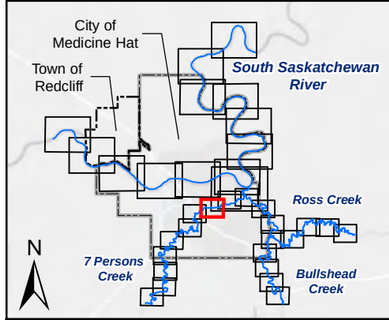

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
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SCALE - 1:5,000

0 50 100 150 200 M

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 20 OF 33

REH. P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd

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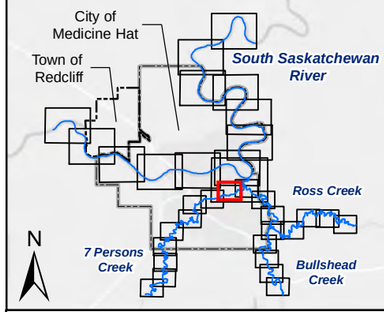

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
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SCALE - 1:5,000

0 50 100 150 200 M

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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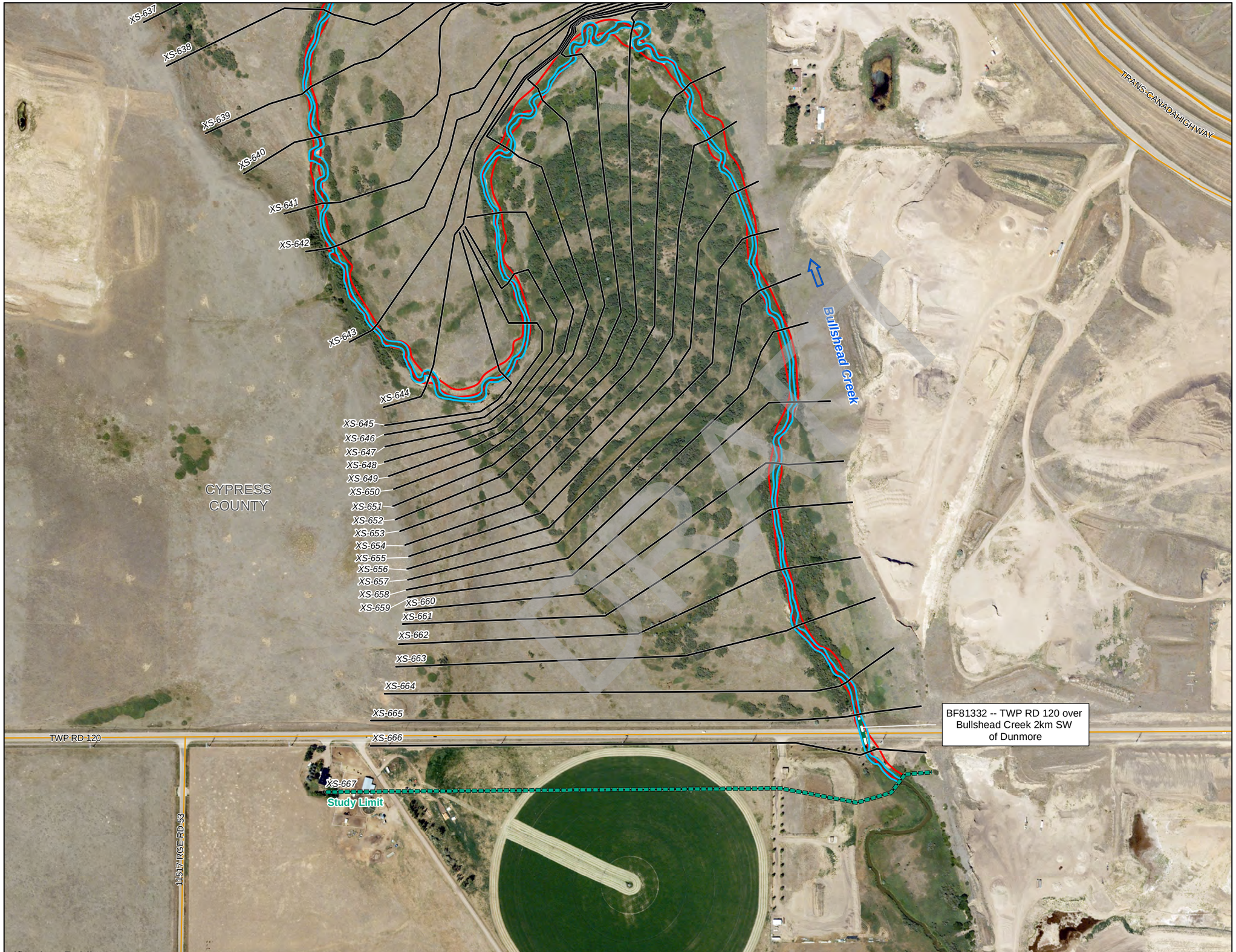
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 21 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd



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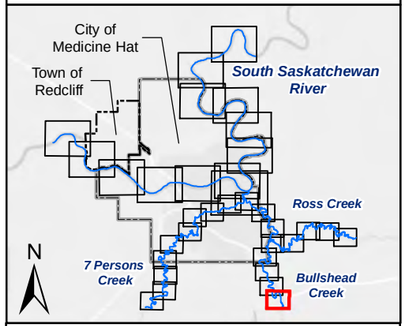

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
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- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 22 OF 33

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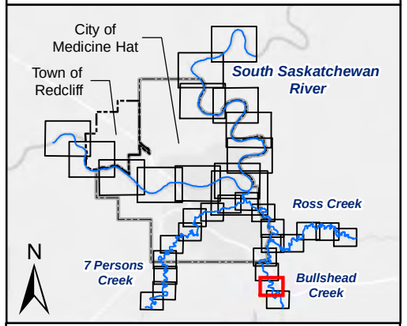

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
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SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 23 OF 33

P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd

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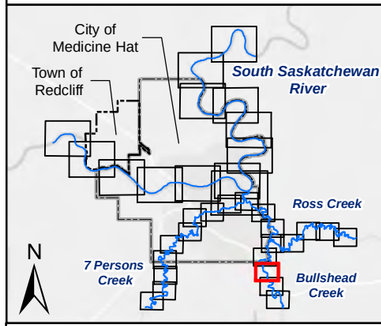

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
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SCALE - 1:5,000

0 50 100 150 200 M

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

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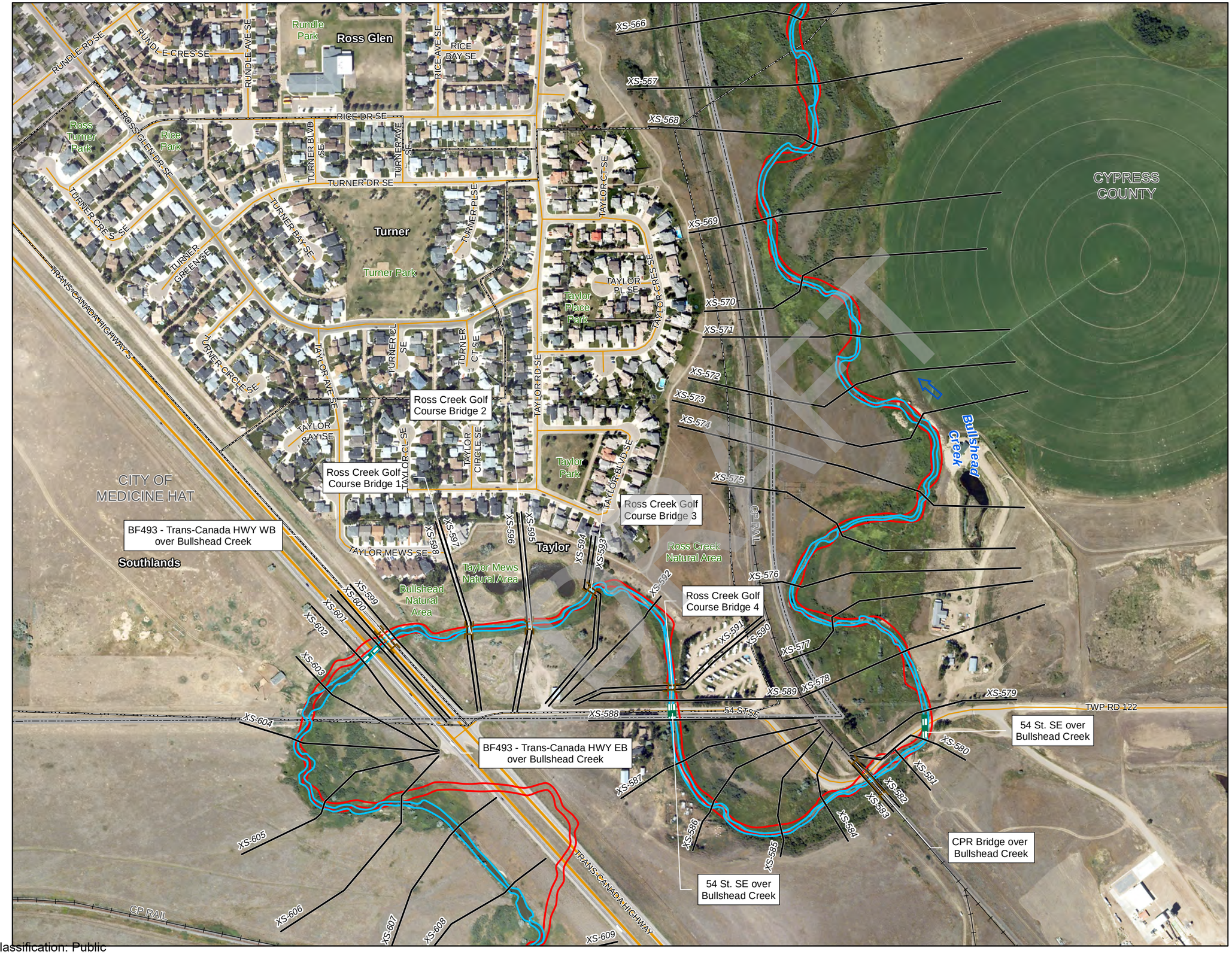
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 24 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd



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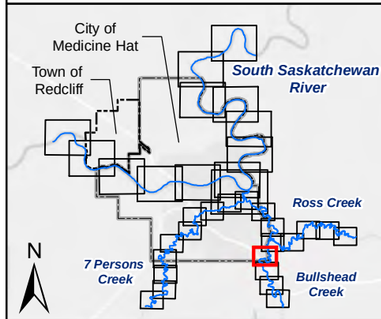

- FLOW DIRECTION
- STUDY LIMIT
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SCALE - 1:5,000

0 50 100 150 200 M

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Coordinate System: NAD 1983 CSRS 3TM 111
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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 25 OF 33

P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd

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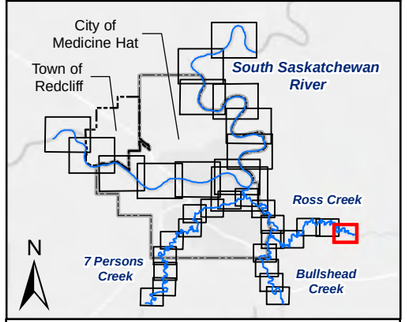

- FLOW DIRECTION
- STUDY LIMIT
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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 26 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd

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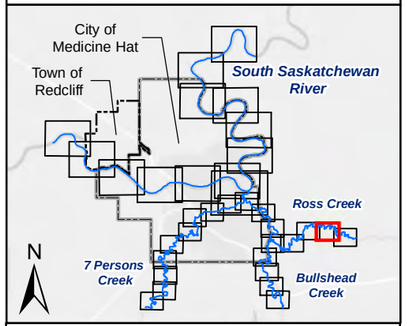

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
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MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 27 OF 33

P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd

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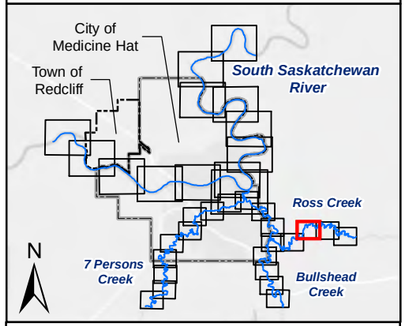

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
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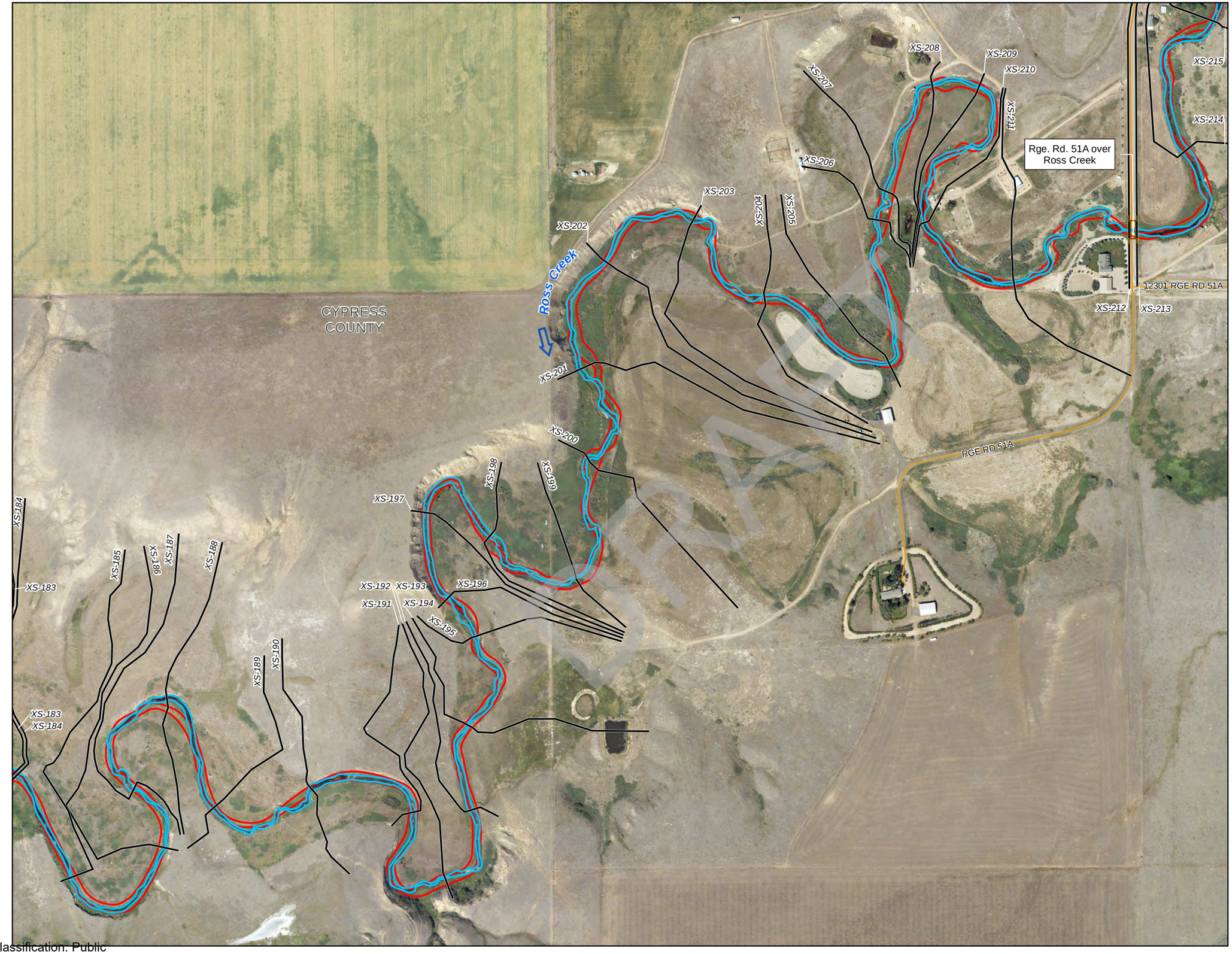
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 28 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd



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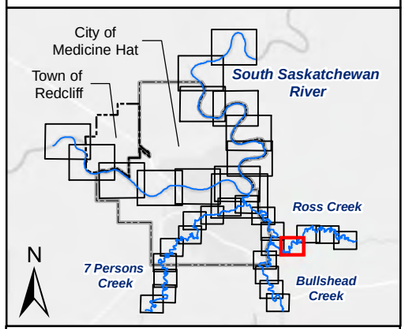


- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

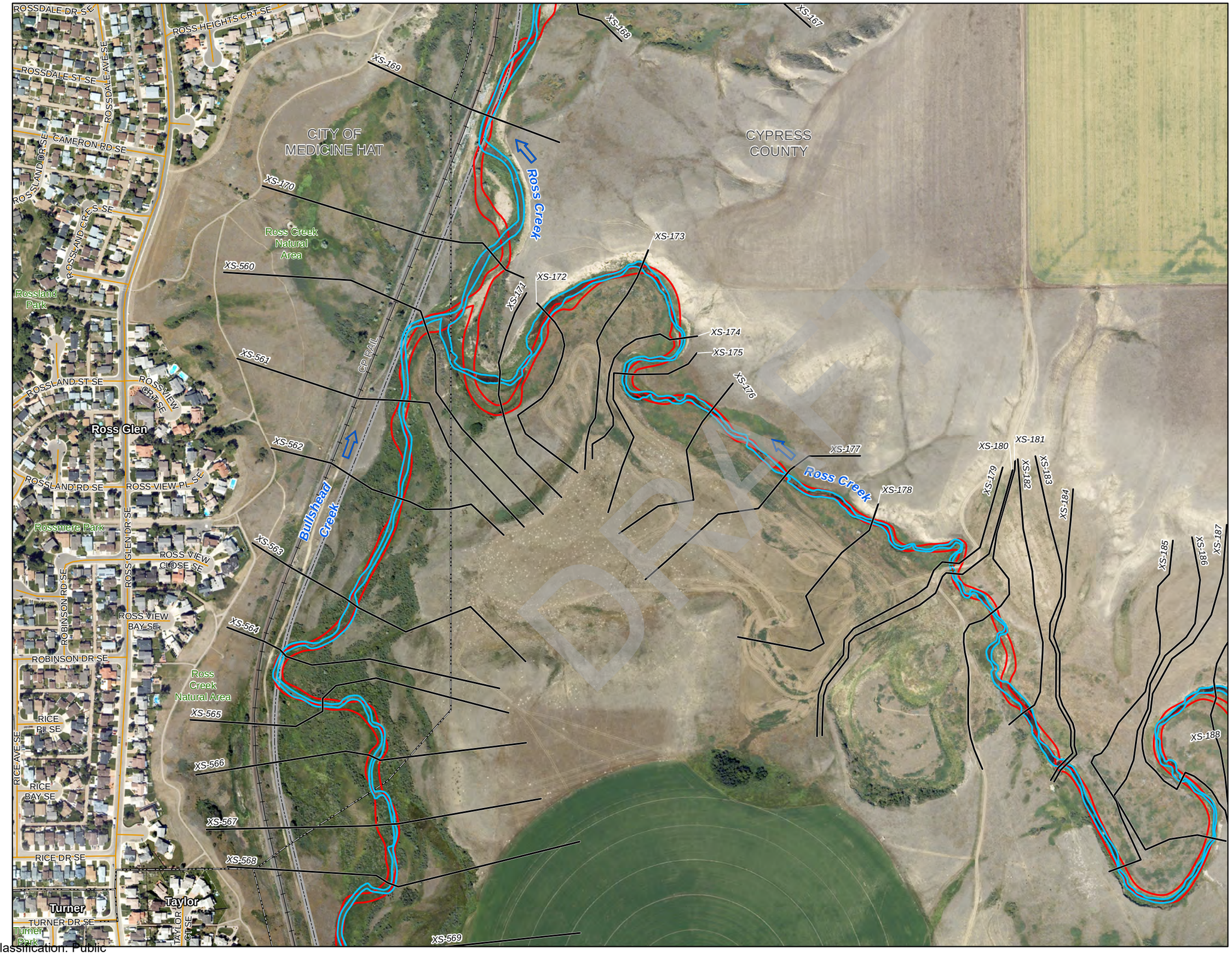
Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 29 OF 33

REH, P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd



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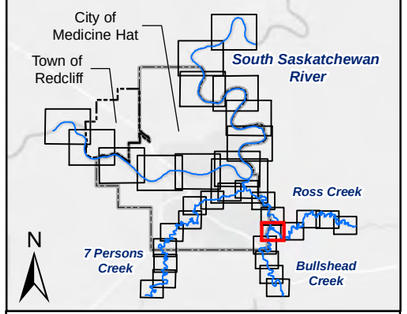

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
MGB	REH	RBA

Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 30 OF 33

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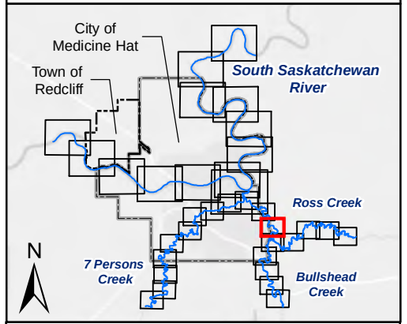

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

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Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
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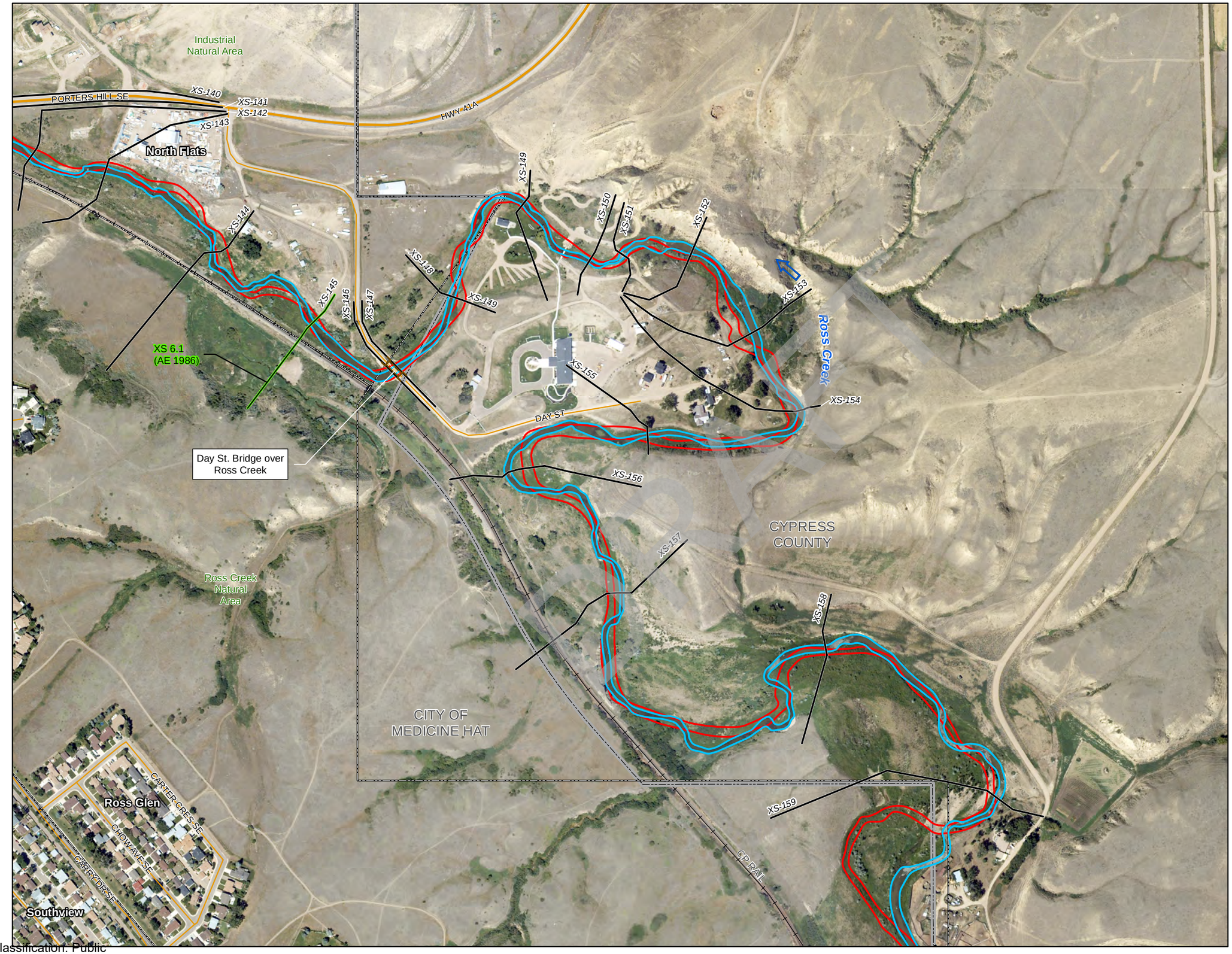
Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 31 OF 33

P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd



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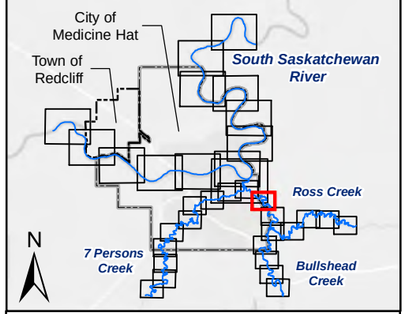

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

Coordinate System: NAD 1983 CSRS 3TM 111
Units: METRES; Vertical Datum: CGVD28 HTv2.0

Engineer	GIS	Reviewer
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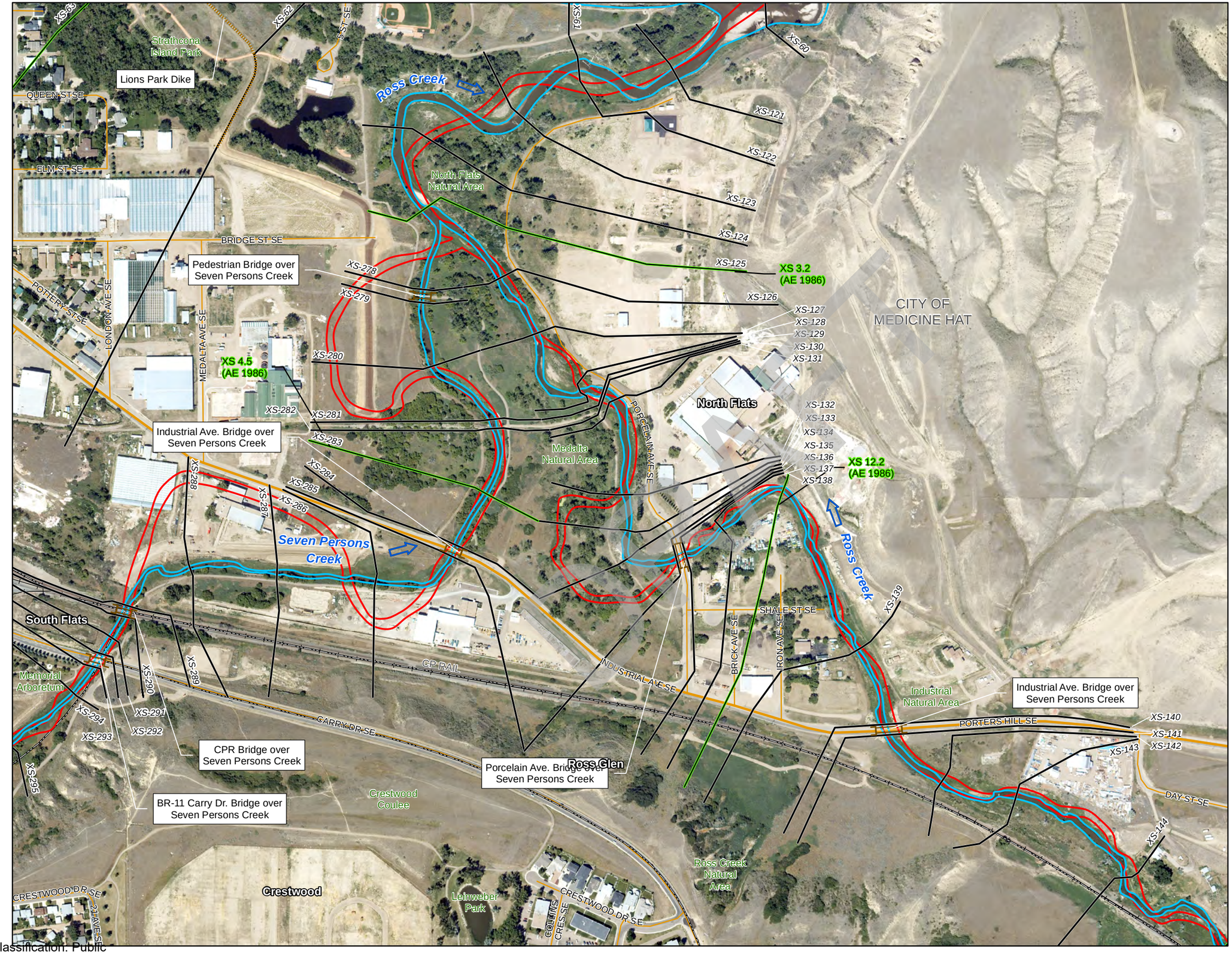
Job: 1003094 | Date: 25-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 32 OF 33

P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd



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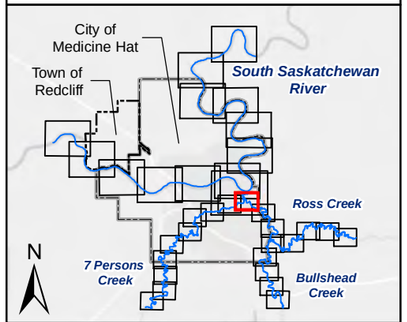

- FLOW DIRECTION
- STUDY LIMIT
- FLOOD CONTROL STRUCTURE
- BRIDGE
- CULVERT
- WEIR
- REDCLIFF TOWN BOUNDARY
- MEDICINE HAT CITY BOUNDARY
- NEIGHBOURHOOD
- HISTORIC SECTION (AE 1986)
- CROSS SECTION (NHC 2017)
- 2018 BANKLINE
- 1951 BANKLINE

SCALE - 1:5,000

0 50 100 150 200 M

N

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Engineer	GIS	Reviewer
MGB	REH	RBA

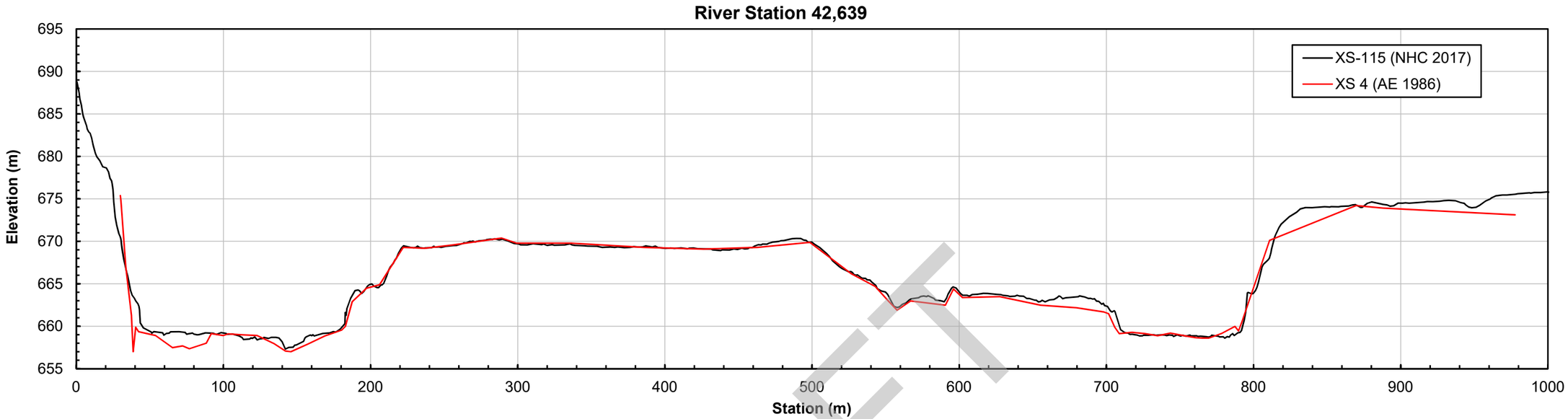
Job: 1003094 | Date: 25-JUL-2019

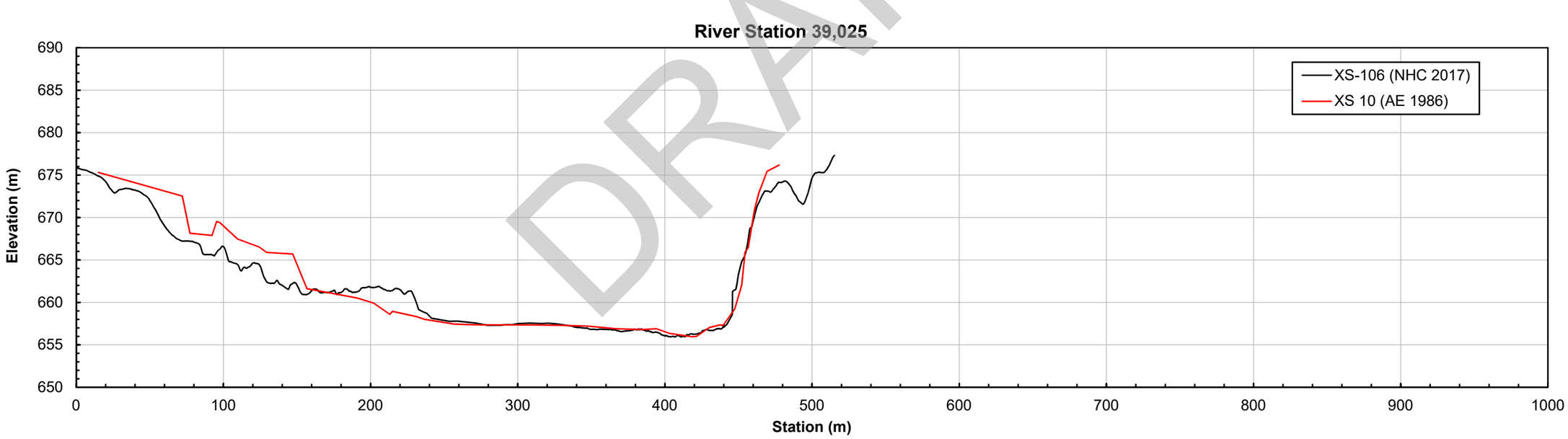
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CHANNEL BANKLINE COMPARISON - 2018 IMAGERY

FIGURE 4 | SHEET 33 OF 33

REH. P:_Projects (Active)\1003094 Medicine Hat River Hazard Study\04 Models\GIS\GIS\1003094_REH_Map_T800_ChannelStability2018.mxd





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SCALE – AS SHOWN

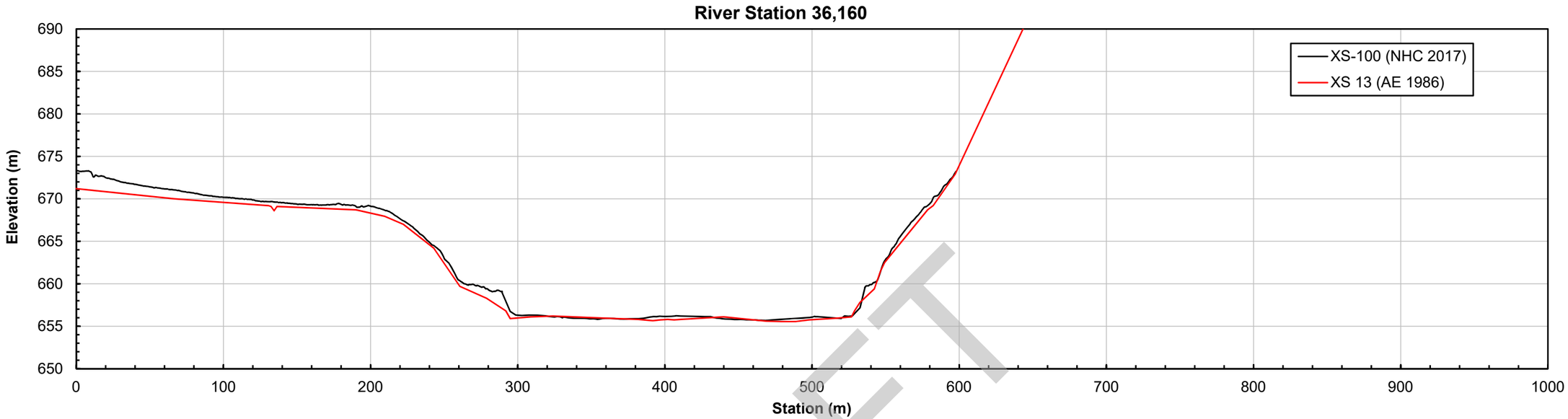
Coordinate System:
Units: As Shown

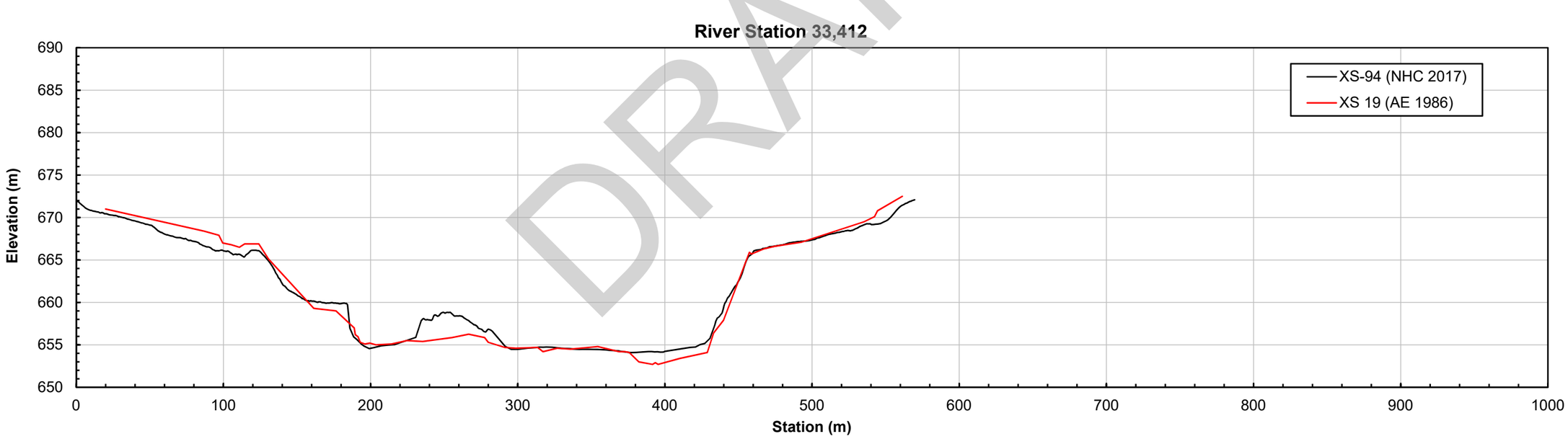
Job: 1003094 | Date: 27-JUN-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CROSS SECTION COMPARISON
SOUTH SASKATCHEWAN RIVER

FIGURE 5-1





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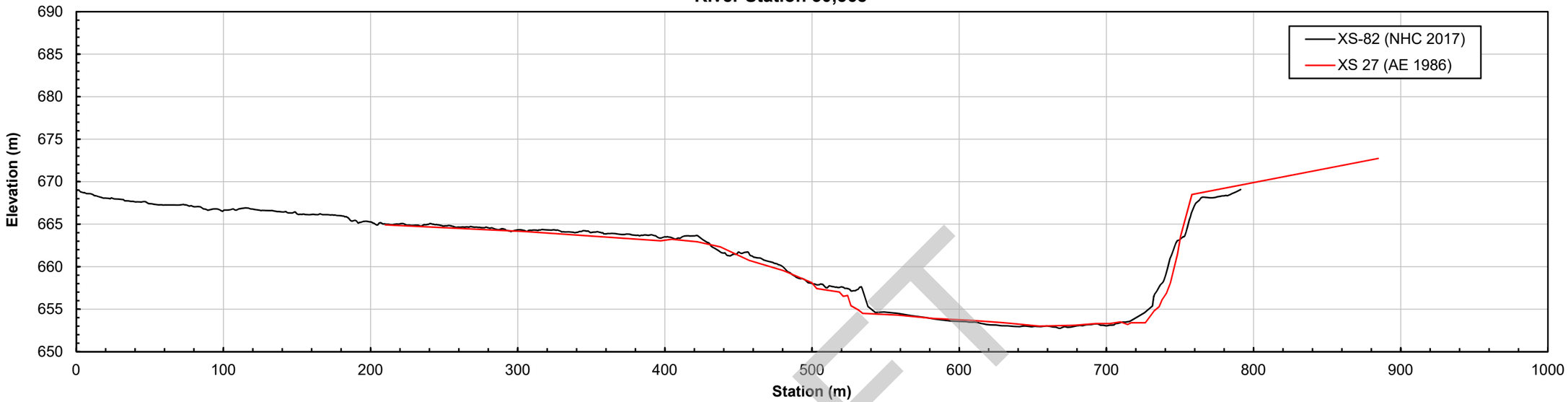
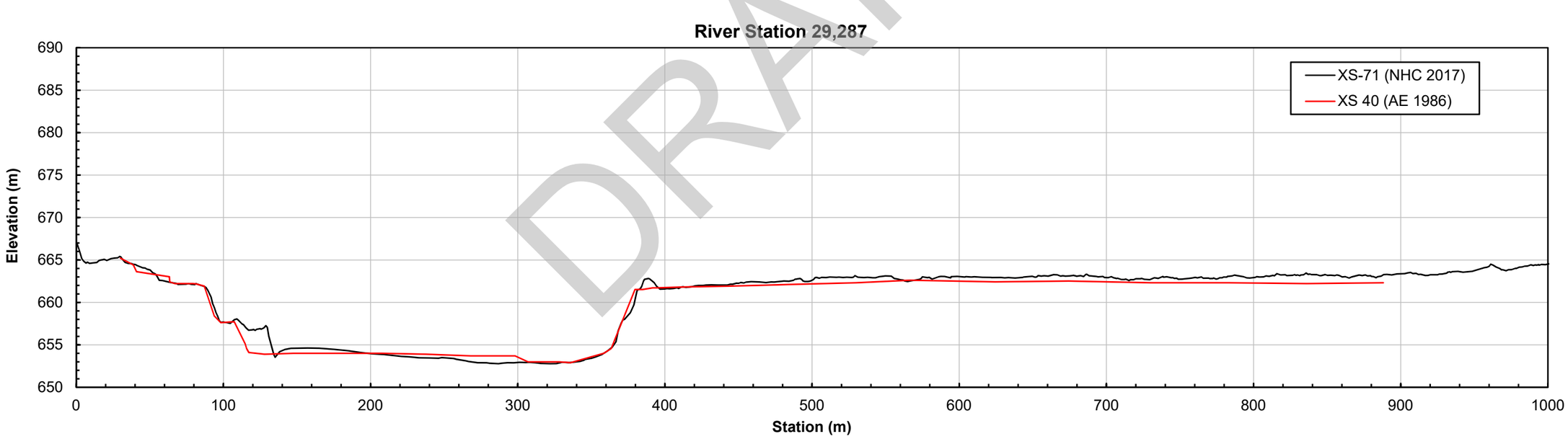
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CROSS SECTION COMPARISON
SOUTH SASKATCHEWAN RIVER

FIGURE 5-2





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Units: As Shown

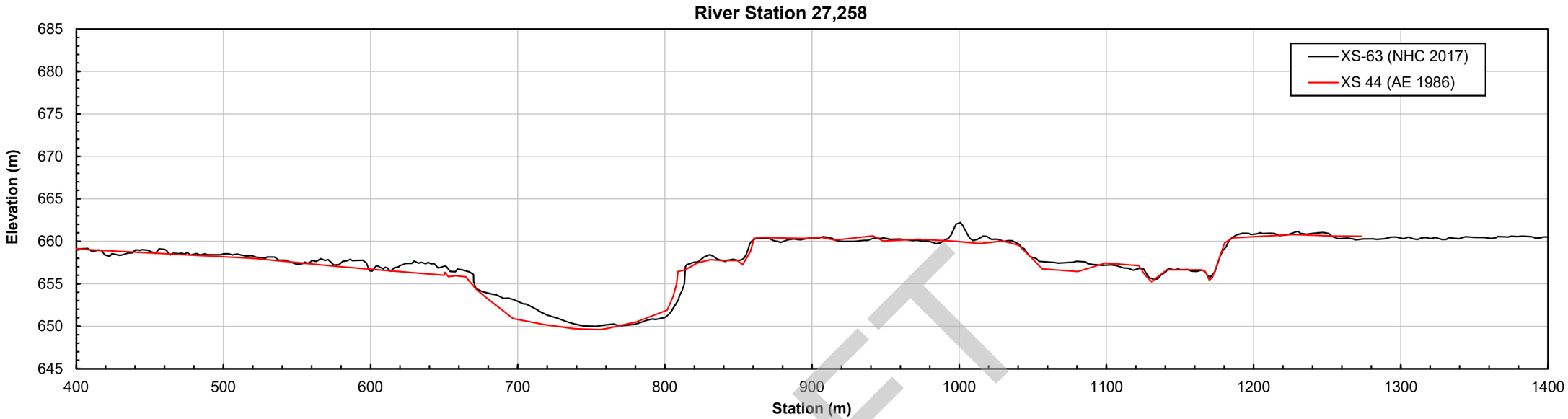
Job: 1003094

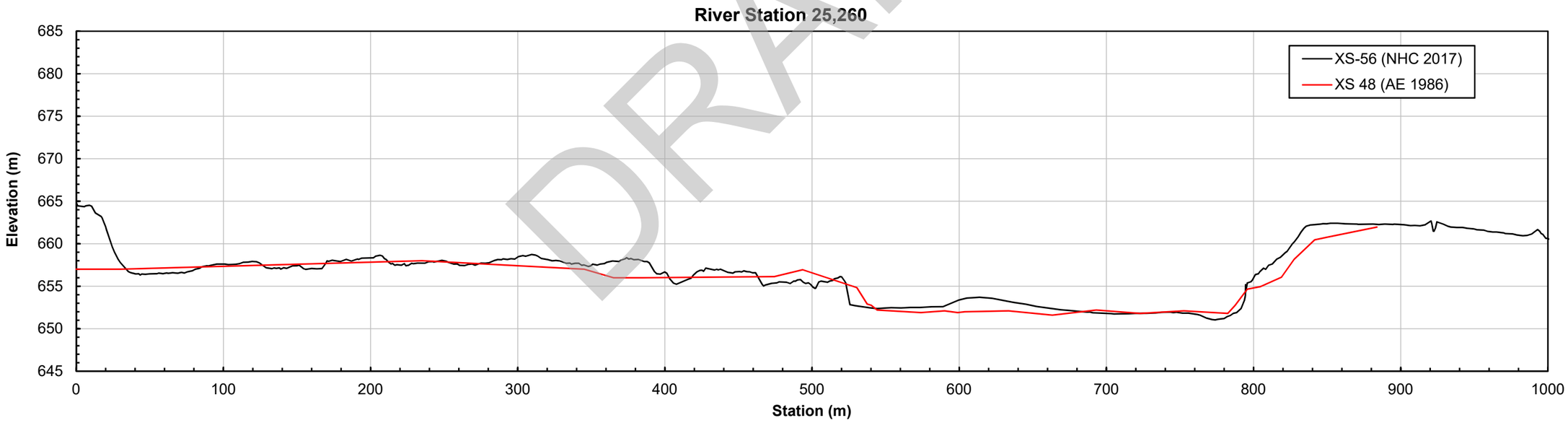
Date: 27-JUN-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CROSS SECTION COMPARISON
SOUTH SASKATCHEWAN RIVER

FIGURE 5-3





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Job: 1003094

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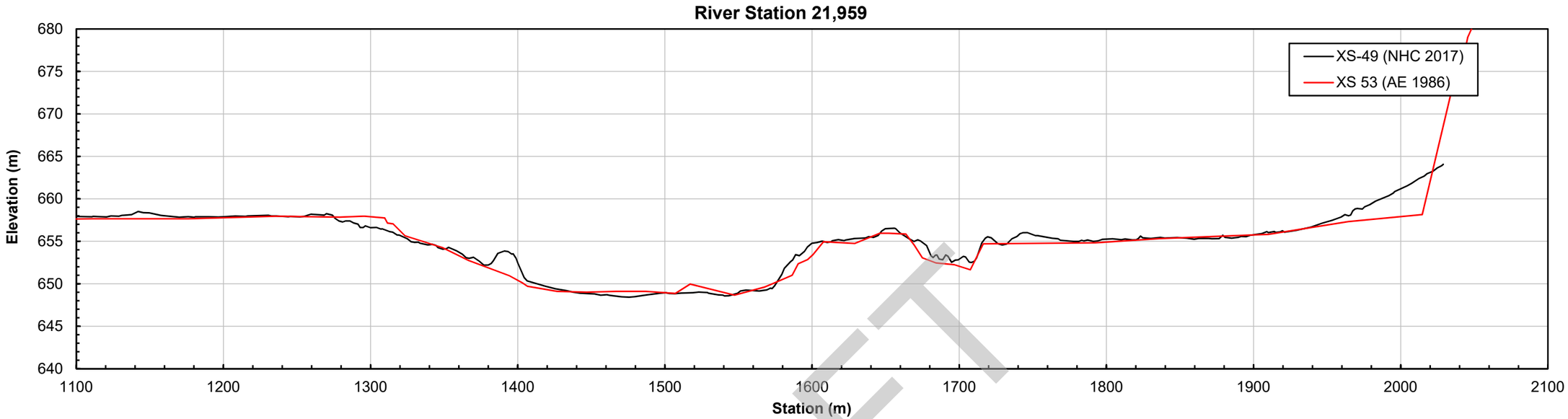
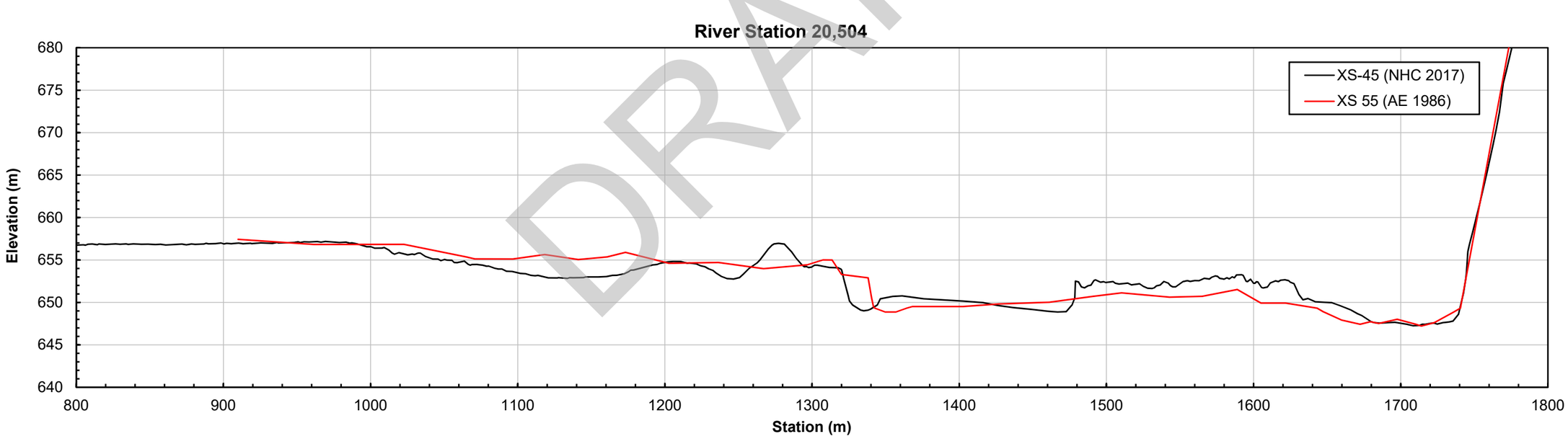
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CROSS SECTION COMPARISON
SOUTH SASKATCHEWAN RIVER

FIGURE 5-4





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Coordinate System:
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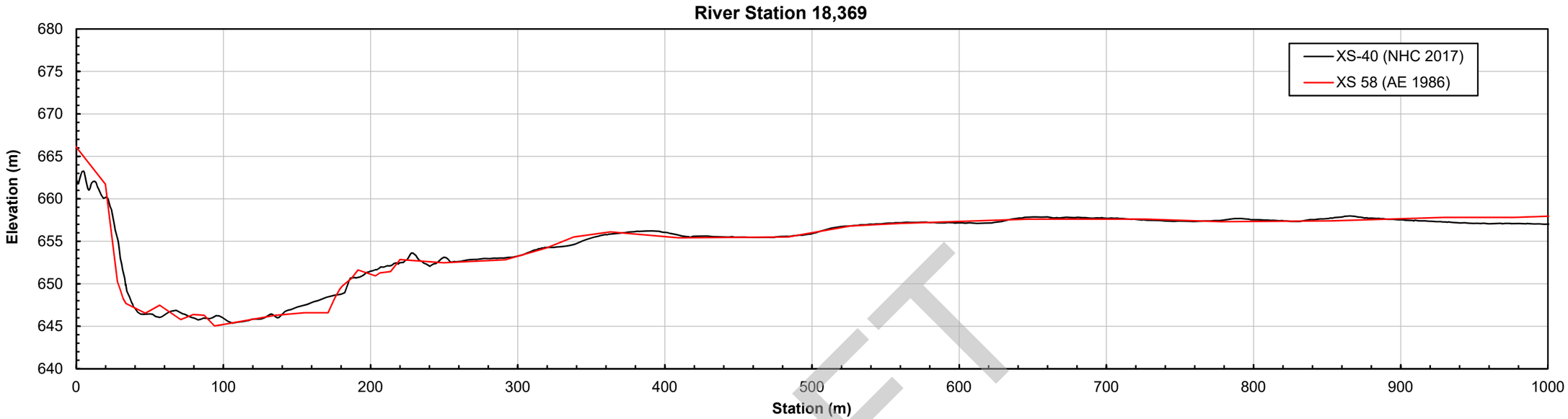
Job: 1003094

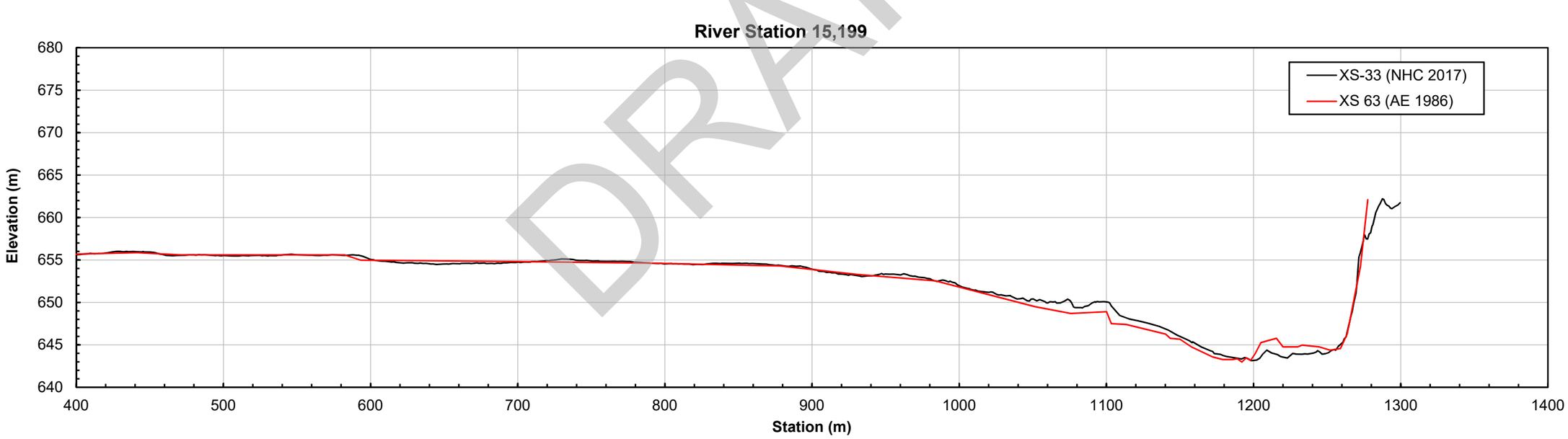
Date: 27-JUN-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CROSS SECTION COMPARISON
SOUTH SASKATCHEWAN RIVER

FIGURE 5-5





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Units: As Shown

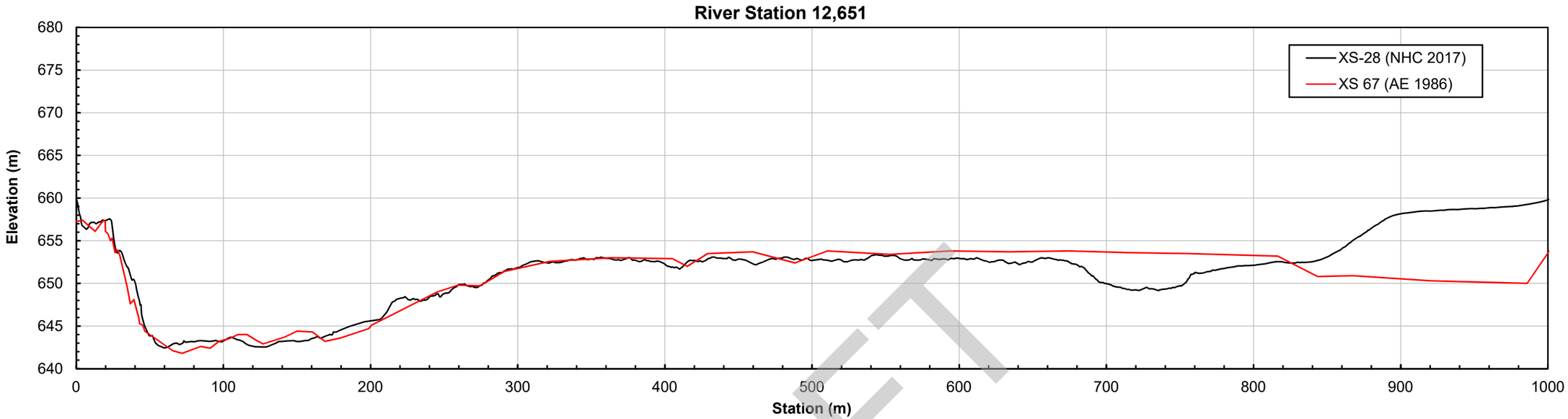
Job: 1003094

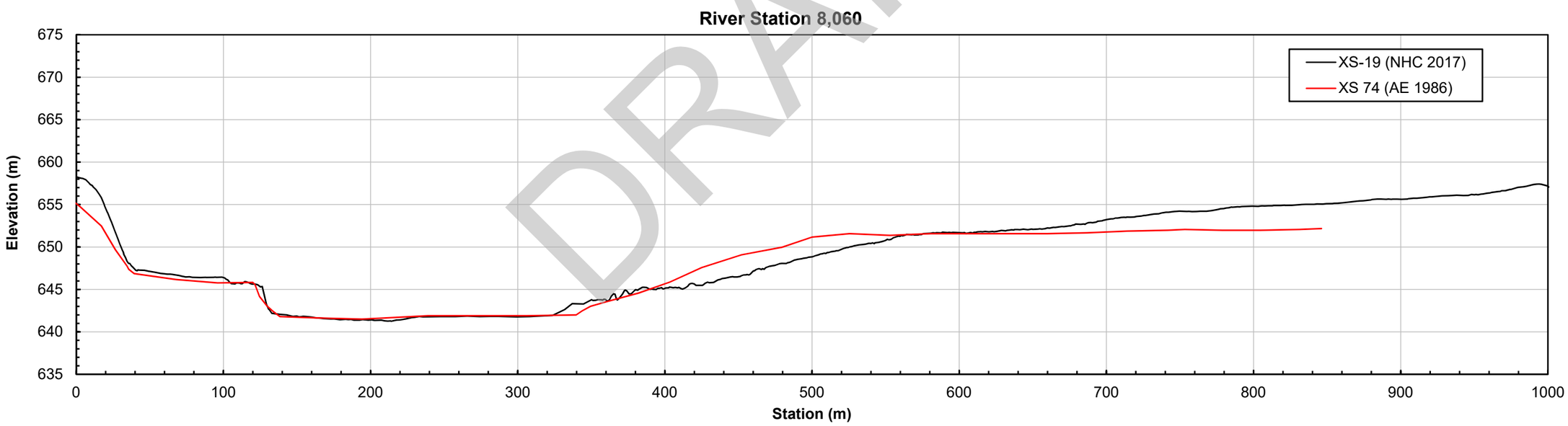
Date: 27-JUN-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CROSS SECTION COMPARISON
SOUTH SASKATCHEWAN RIVER

FIGURE 5-6





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Coordinate System:
Units: As Shown

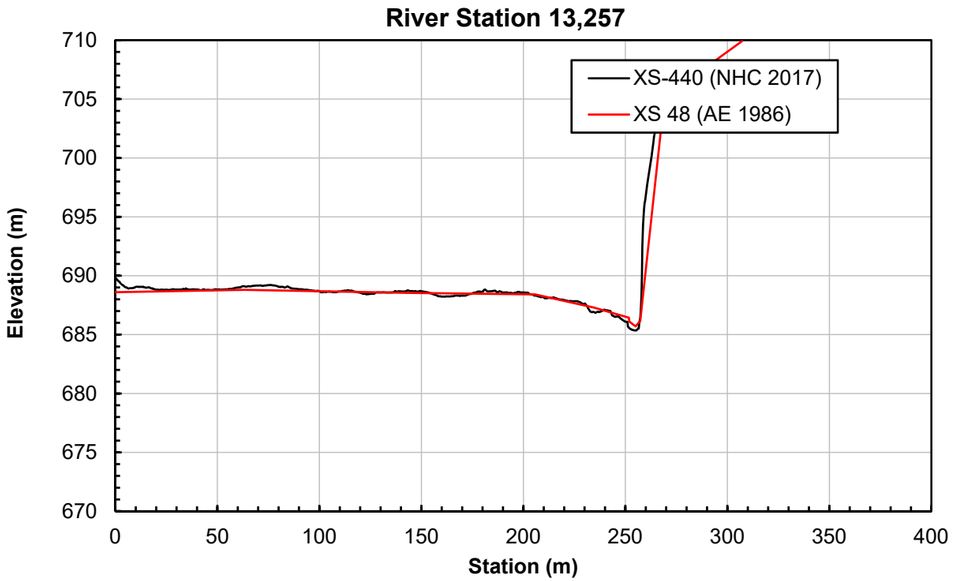
Job: 1003094

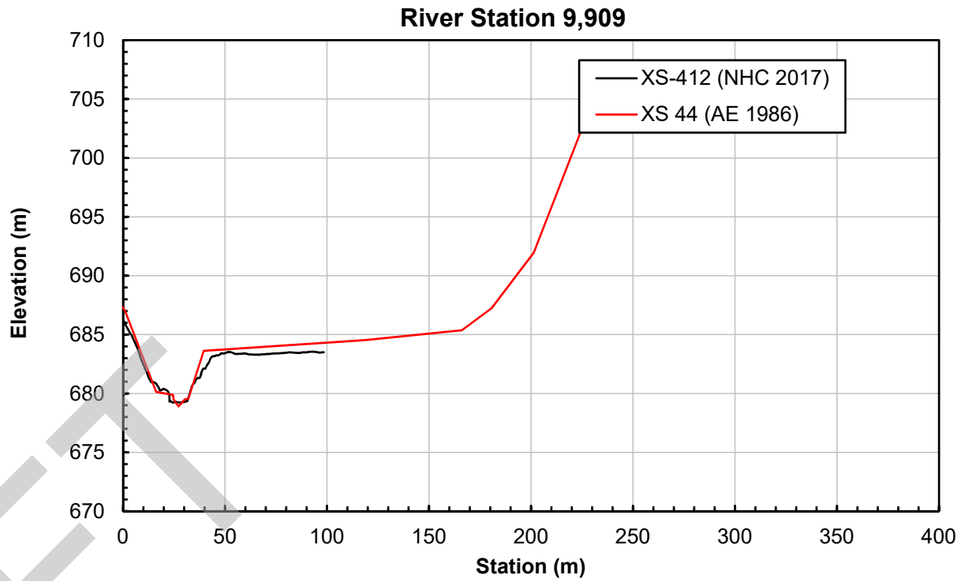
Date: 27-JUN-2019

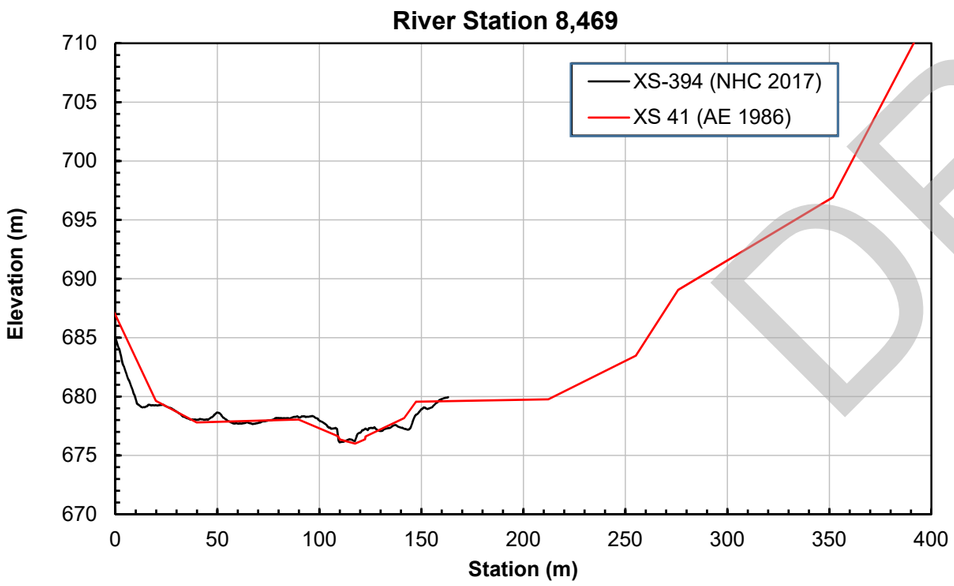
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

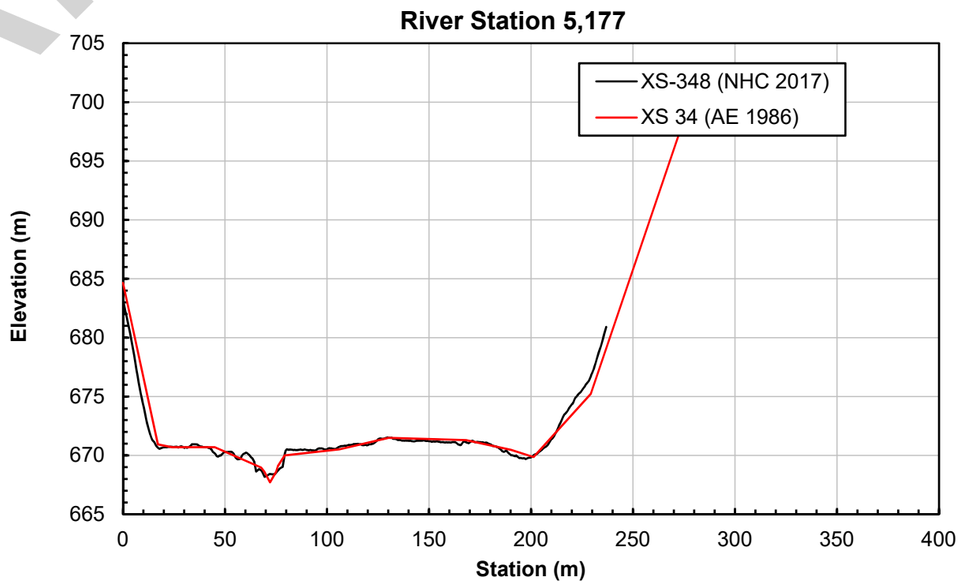
CROSS SECTION COMPARISON
SOUTH SASKATCHEWAN RIVER

FIGURE 5-7









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Units: As Shown

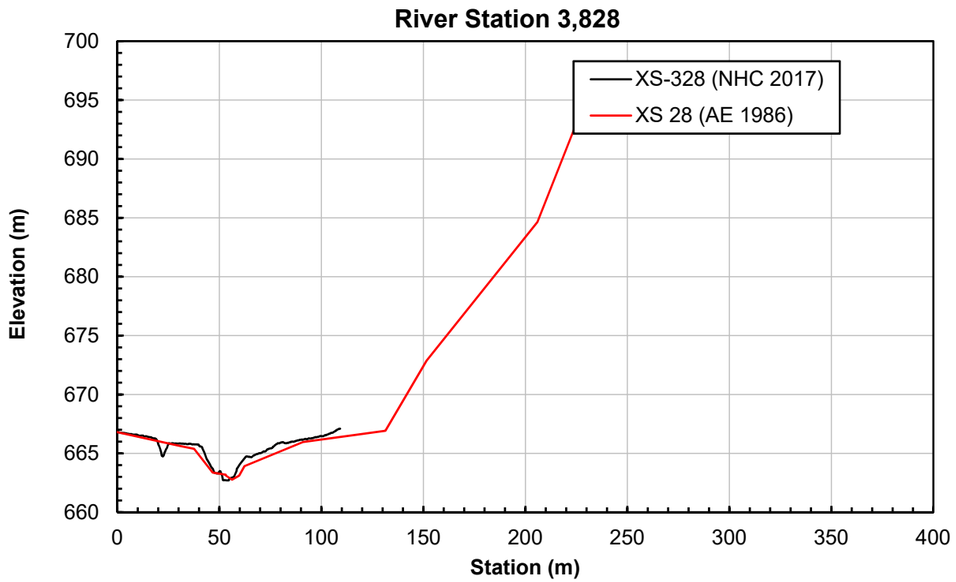
Job: 1003094

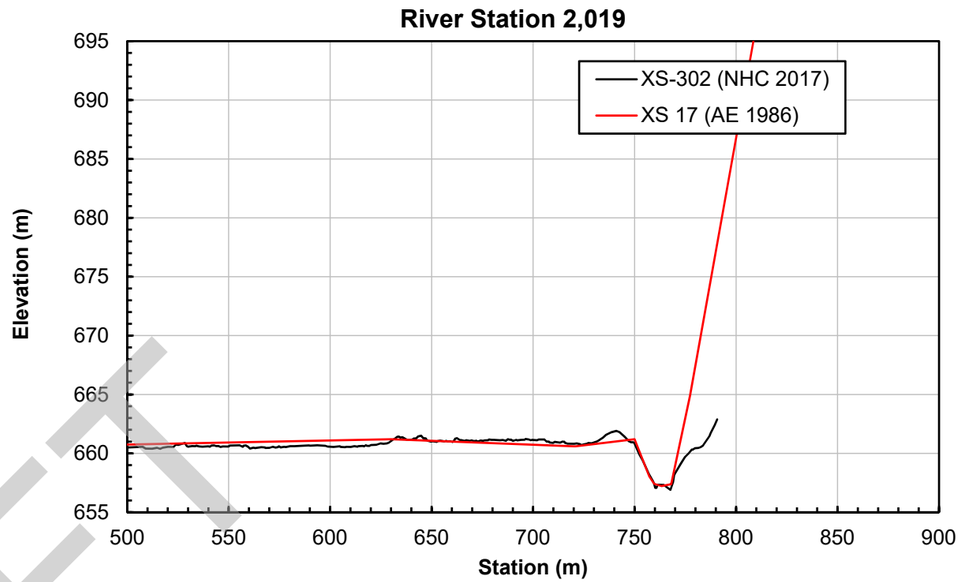
Date: 27-JUN-2019

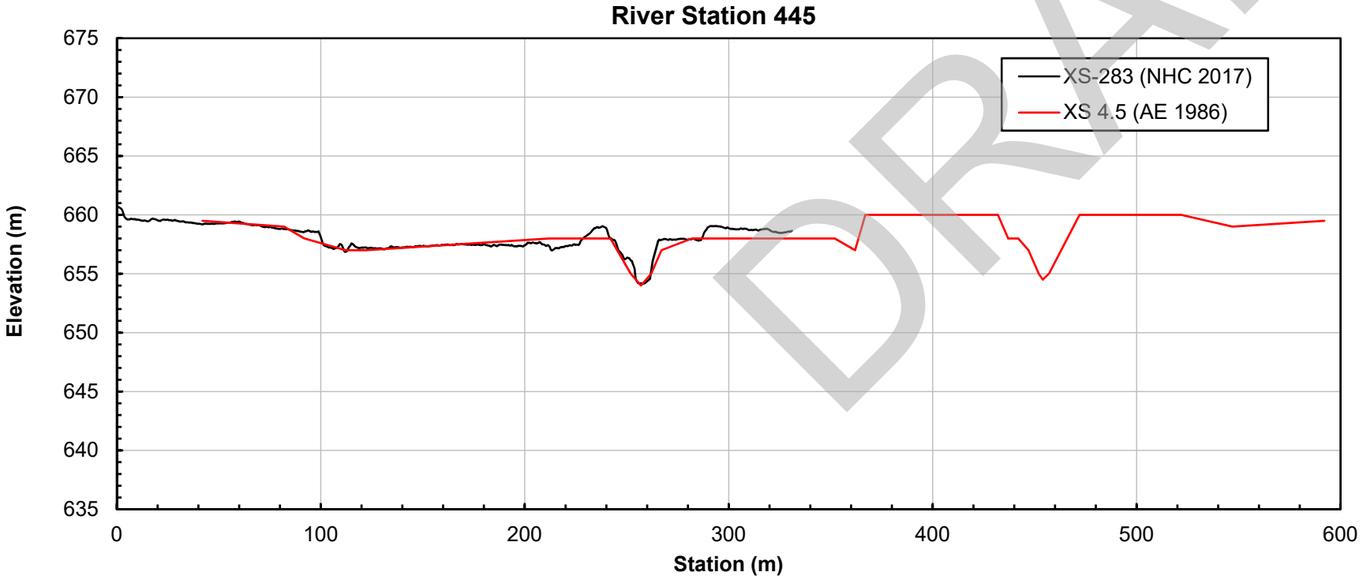
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CROSS SECTION COMPARISON
SEVEN PERSONS CREEK

FIGURE 5-8







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Coordinate System:
Units: As Shown

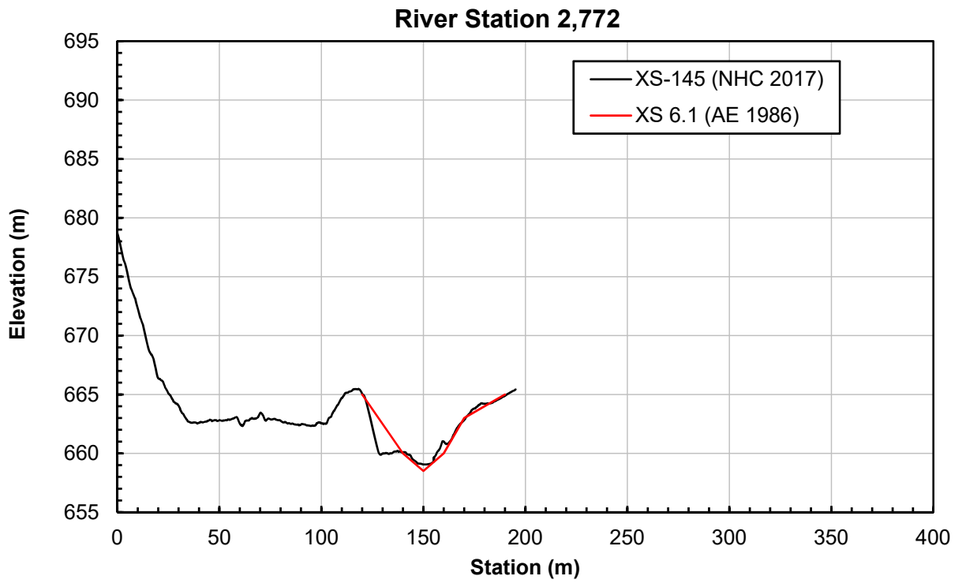
Job: 1003094

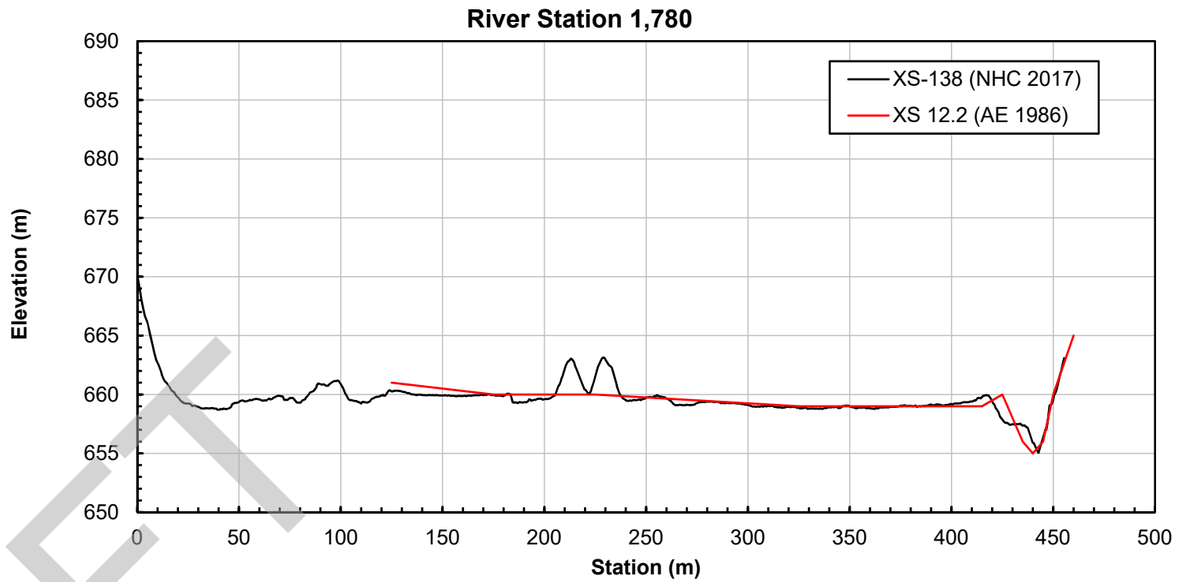
Date: 27-JUN-2019

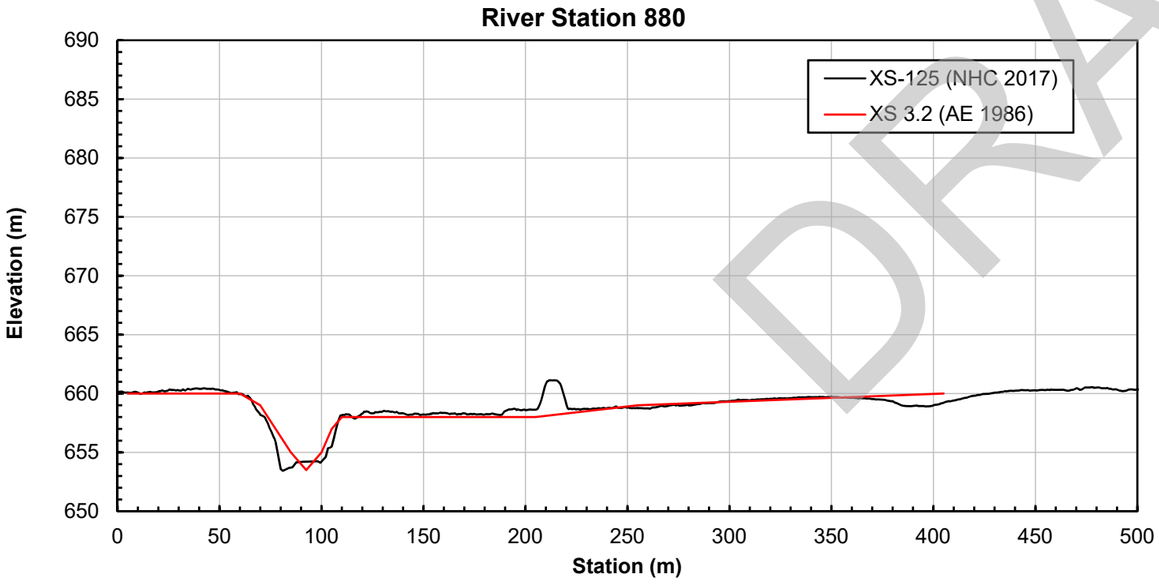
MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CROSS SECTION COMPARISON
SEVEN PERSONS CREEK

FIGURE 5-9







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SCALE – AS SHOWN

Coordinate System:
Units: As Shown

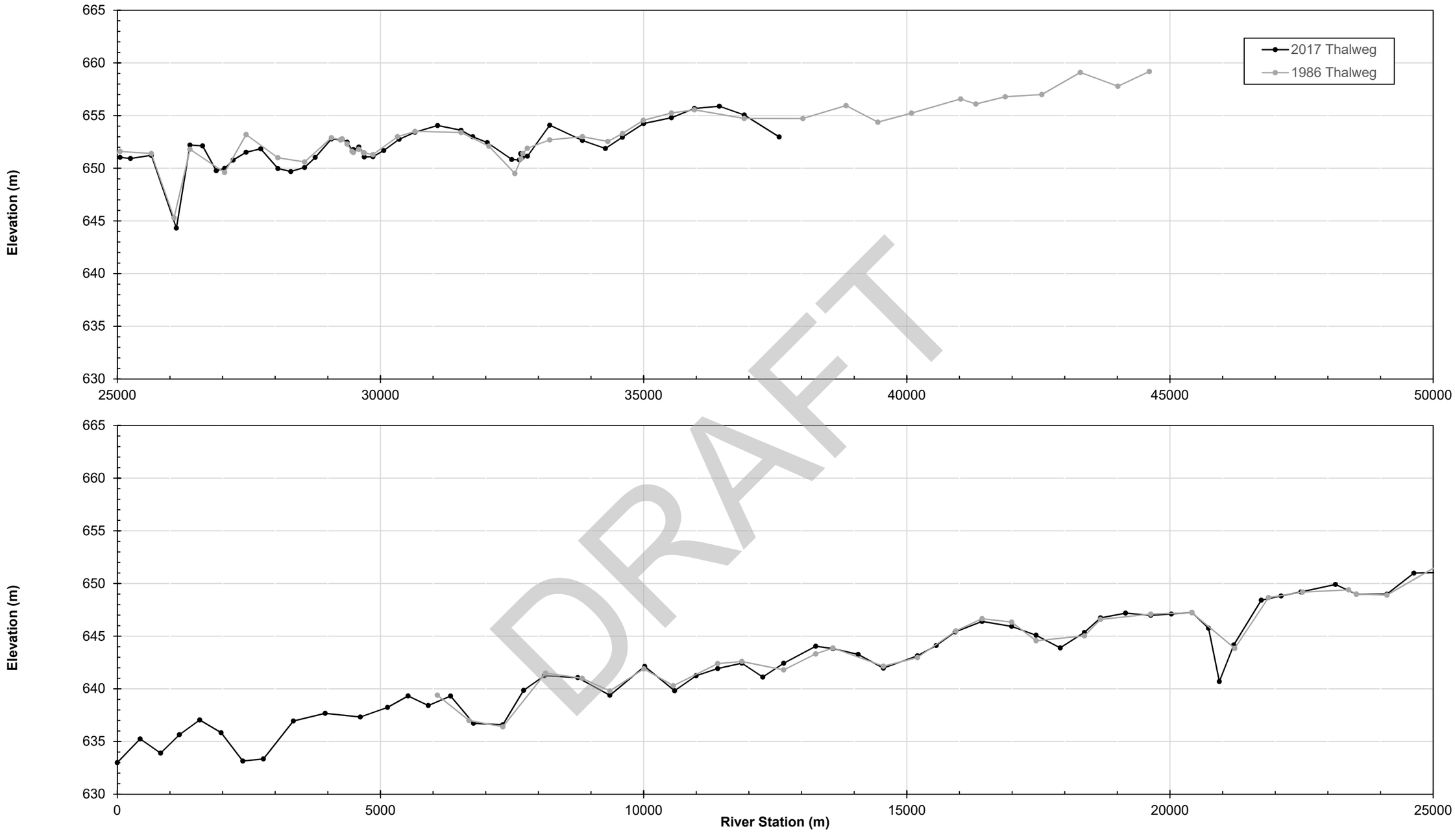
Job: 1003094

Date: 27-JUN-2019

MEDICINE HAT RIVER HAZARD STUDY
CHANNEL STABILITY INVESTIGATION

CROSS SECTION COMPARISON
ROSS CREEK

FIGURE 5-10



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SCALE – AS SHOWN

Coordinate System:
Units: As Shown

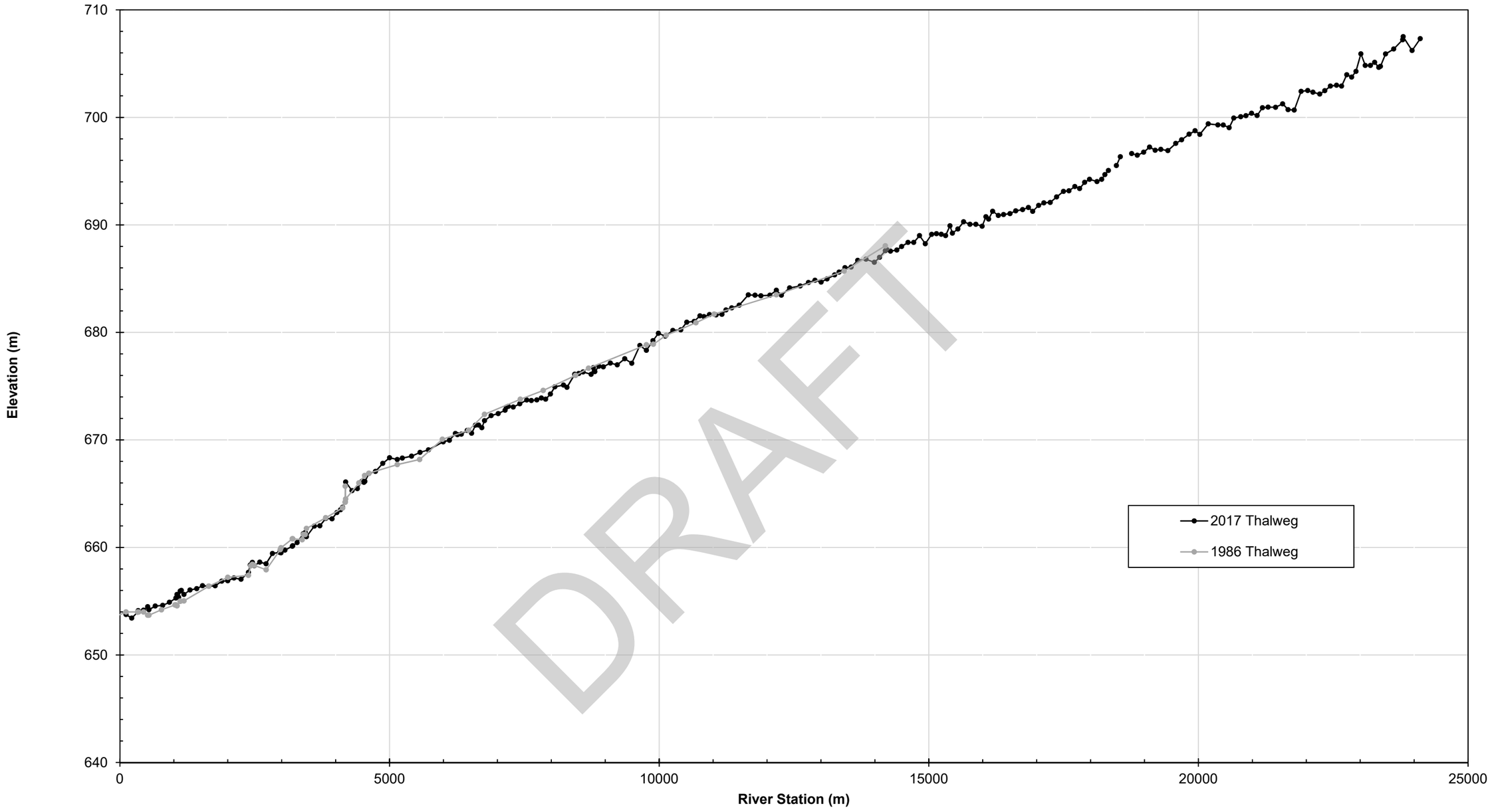
Job: 1003094

Date: 09-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

SOUTH SASKATCHEWAN RIVER THALWEG COMPARISON

FIGURE 6-1



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Coordinate System:
Units: As Shown

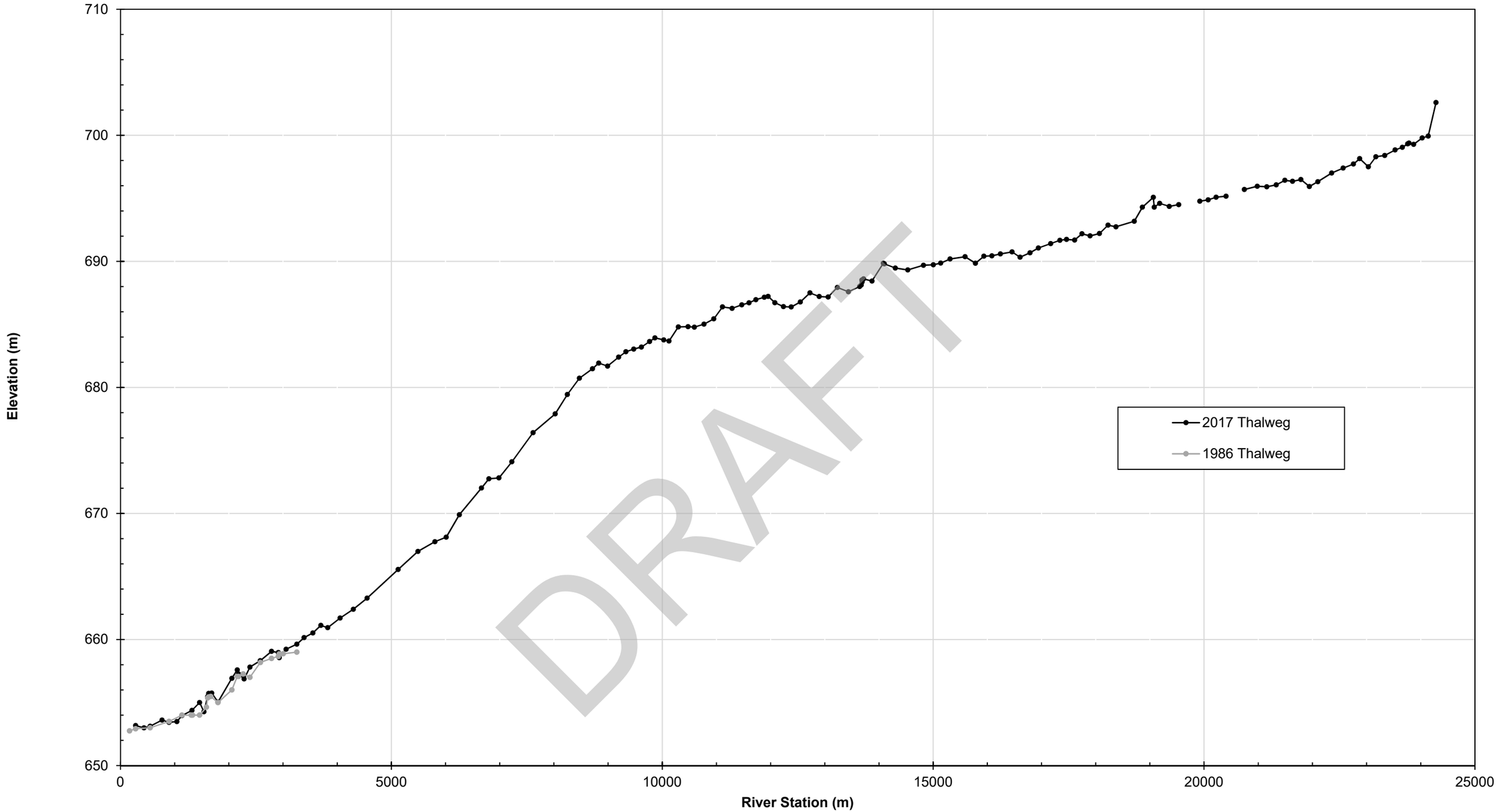
Job: 1003094

Date: 09-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

SEVEN PERSONS CREEK
THALWEG COMPARISON

FIGURE 6-2



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SCALE – AS SHOWN

Coordinate System:
Units: As Shown

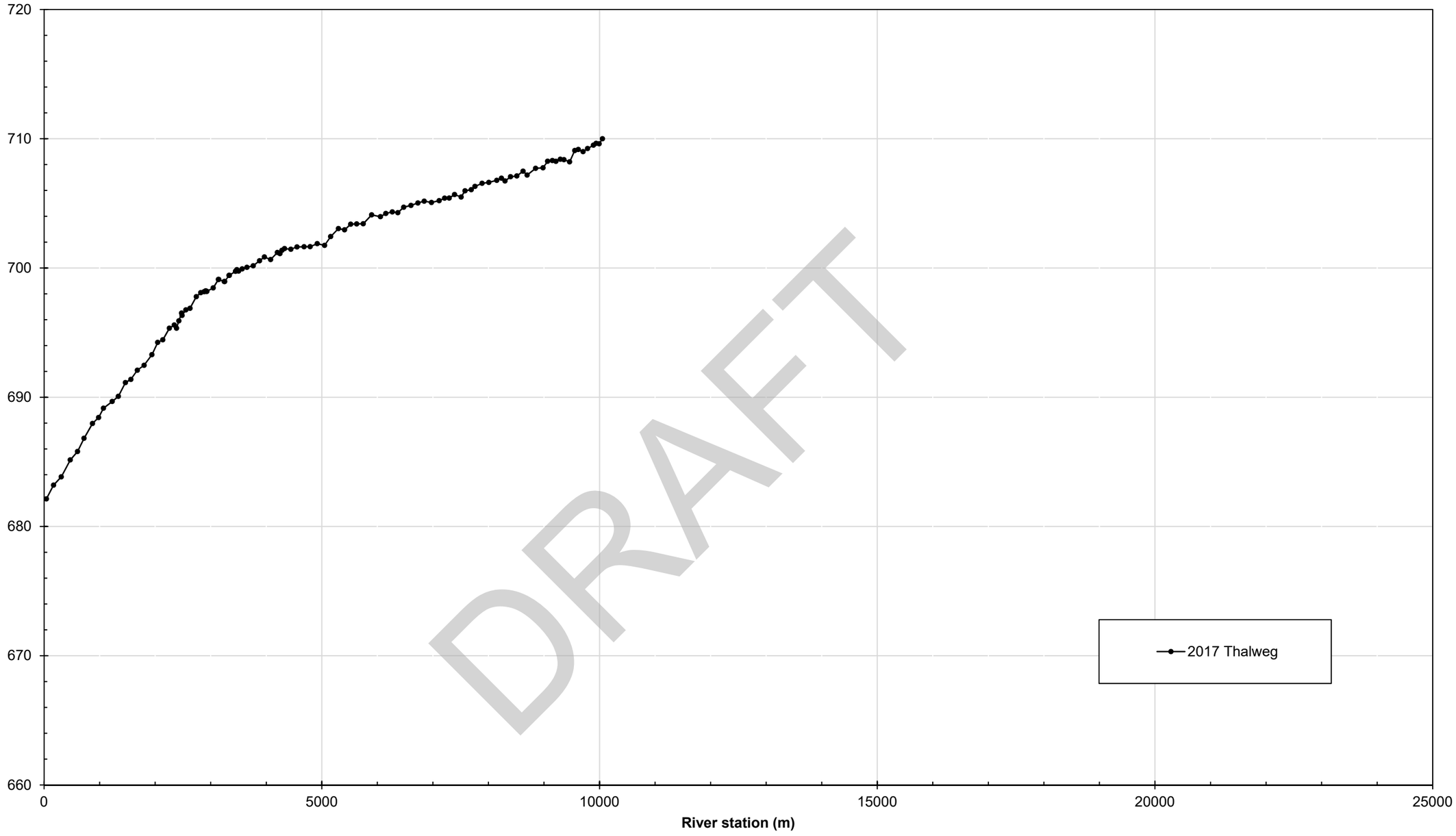
Job: 1003094

Date: 09-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY SURVEY AND BASE DATA COLLECTION

ROSS CREEK THALWEG COMPARISON

FIGURE 6-3



Alberta Government

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SCALE – AS SHOWN

Coordinate System:
Units: As Shown

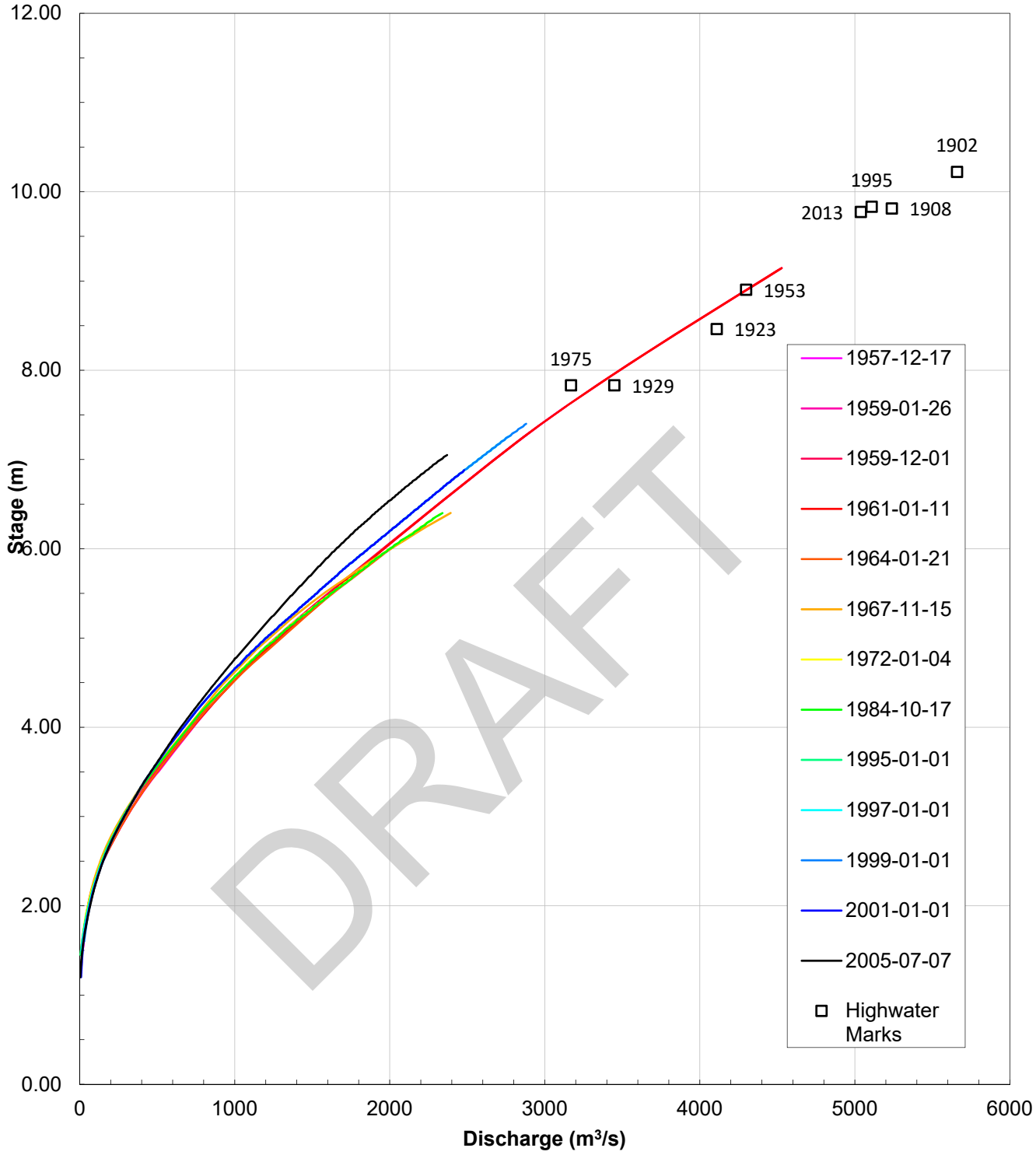
Job: 1003094

Date: 09-JUL-2019

MEDICINE HAT RIVER HAZARD STUDY SURVEY AND BASE DATA COLLECTION

BULLSHEAD CREEK THALWEG PROFILE

FIGURE 6-4



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SCALE – AS SHOWN

Coordinate System:
Units: As Shown

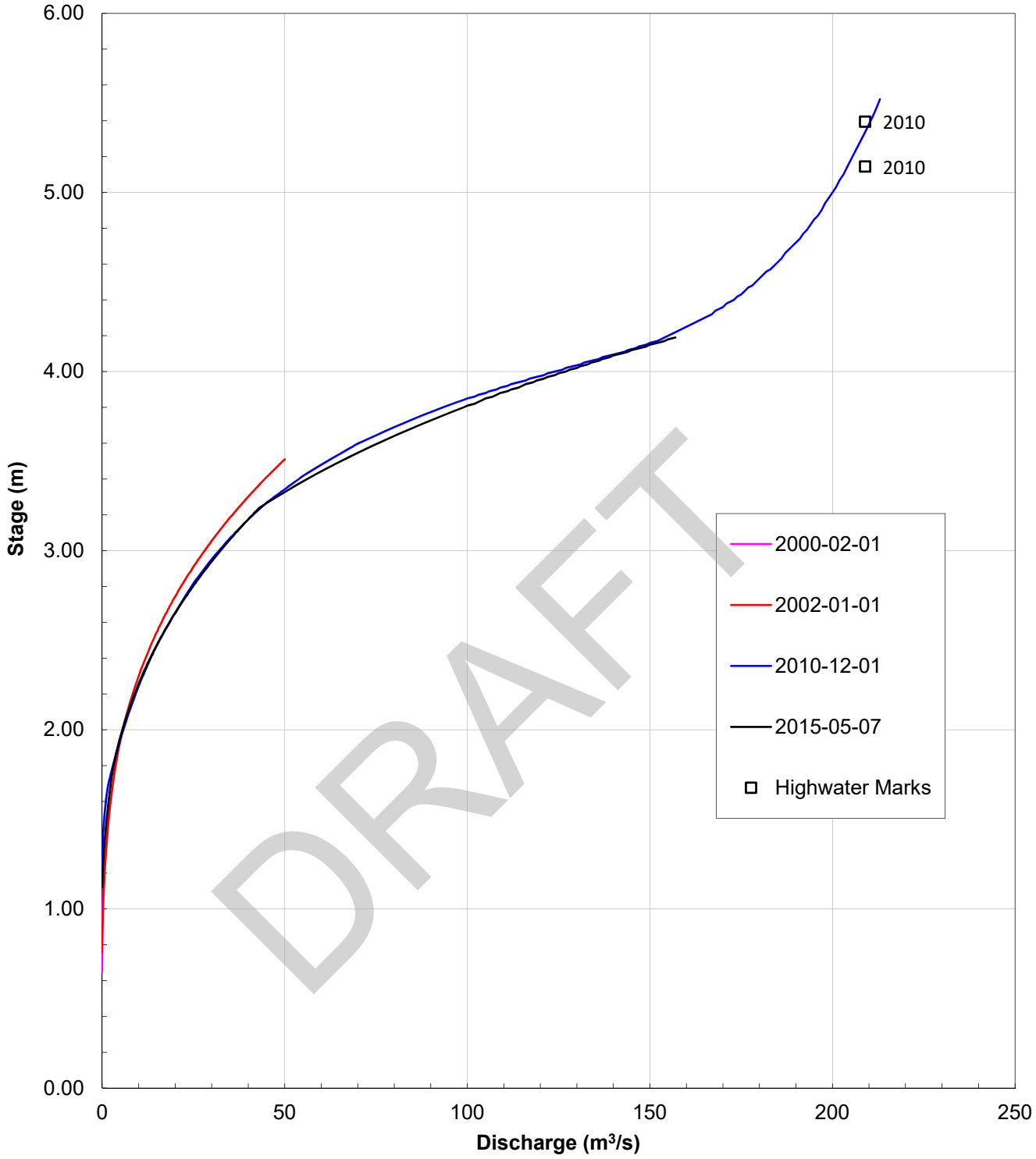
Job: 1003094

Date: 09-JUL-2019

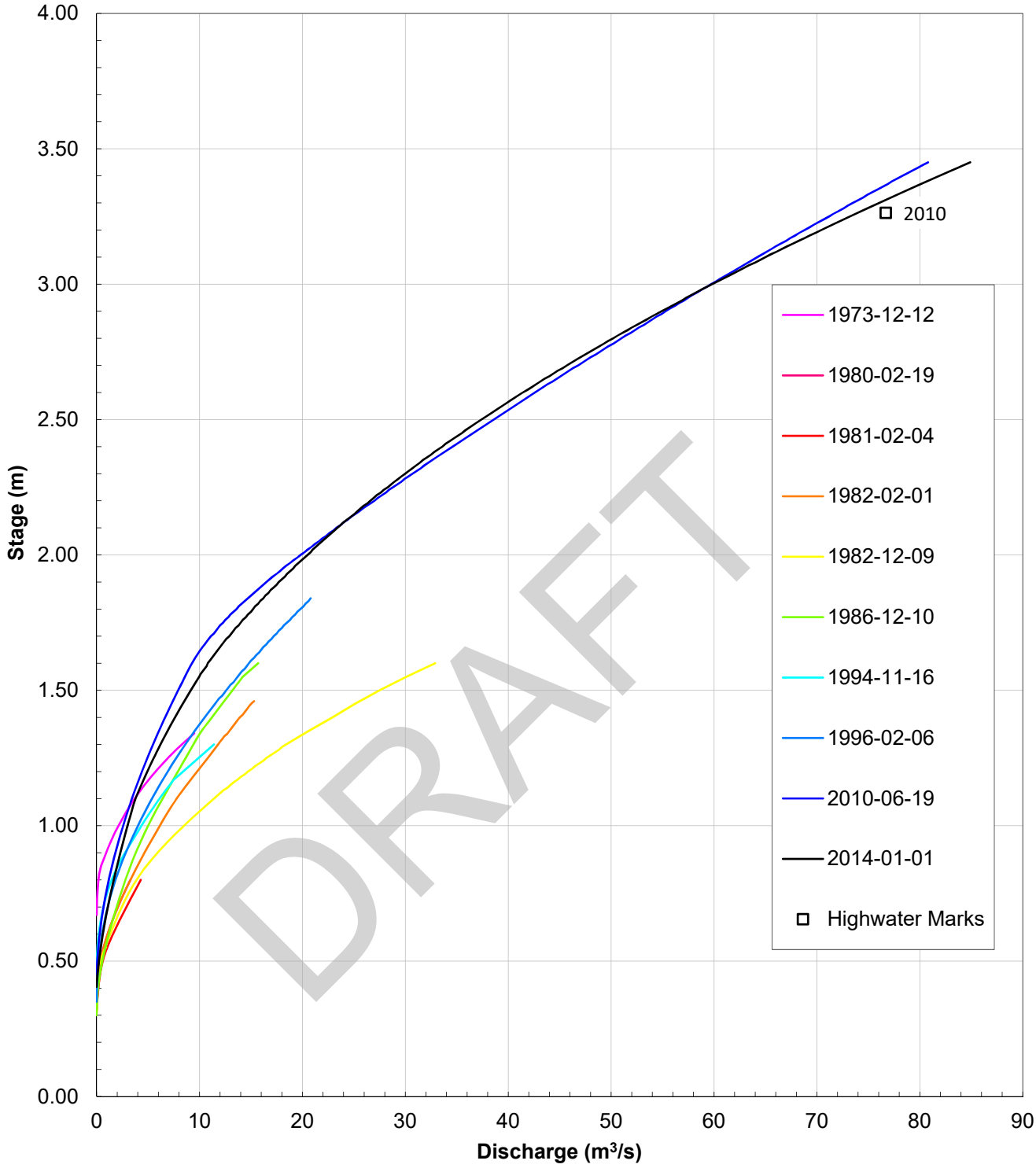
MEDICINE HAT RIVER HAZARD STUDY
SURVEY AND BASE DATA COLLECTION

RATING CURVE – 05AJ001
SOUTH SASKATCHEWAN RIVER AT MEDICINE HAT

FIGURE 7



Alberta Government	SCALE – AS SHOWN	*MEDICINE HAT RIVER HAZARD STUDY* *SURVEY AND BASE DATA COLLECTION*
nhc northwest hydraulic consultants	Coordinate System: Units: As Shown	*RATING CURVE – 05AH052* *ROSS CREEK AT HIGHWAY 41*
	Job: 1003094 / *Date: 09-JUL-2019*	*FIGURE 8*



Notes: 1. Highwater mark from 2010 was measured at College Avenue located about 170 m downstream of the WSC gauge.

Alberta Government	SCALE – AS SHOWN	*MEDICINE HAT RIVER HAZARD STUDY SURVEY AND BASE DATA COLLECTION*
nhc northwest hydraulic consultants	Coordinate System: Units: As Shown	*RATING CURVE – 05AH005 SEVEN PERSONS CREEK AT MEDICINE HAT*
	Job: 1003094 / *Date: 09-JUL-2019*	*FIGURE 9*

Appendix A
Historical Aerial Imagery Preparation Memorandum

Project Information

OGL Work Order No.	10995
Client	Northwest Hydraulic Consulting Ltd. (NHC)
AEP Contract No.	18STR805
AEP Project Name	Historical Medicine Hat Flood Hazard Study

Mapping Projection

Projection	Horizontal Datum	Vertical Datum	Geoid Model
3TM CM111W	NAD83 (CSRS)	CGVD28	HT v2.0

Acquisition Parameters

Dates (YYYY-MM-DD)	Average Flying Height AGL (m)	Estimated Camera Focal Length (mm)	Pixel Size (m)
1951-07-03 1951-09-17	7012	152.4	1.0

Aerial Survey Equipment

Component	Description
Camera	Eagle IX – Kenting Aviation

Data Processing Procedures

Source: All historical imagery was obtained from the Air Photo Distribution and Repository database at the recommendation of OGL Engineering. The original imagery was flown by an Eagle IX film camera by Kenting Aviation. The scanned images had damage such as rips in the film, scratches and various particles & blemishes. Additionally, there was overexposure, and vignetting. No specific camera identification or camera calibration could be found for this 1951 imagery.

Stereo Imagery QA/QC: The original imagery was checked for damage, overexposure and vignetting. Overexposure and vignetting were corrected by applying tonal corrections & matching, grain reduction, and variable frequency dodging using AGFA AperTune. This step also helps to create an even tone, contrast and saturation throughout the project.

Camera Calibration: With no camera calibration information available, interior orientation parameters (IOPs) had to be calculated; using the fiducial mark coordinates, principal point and camera focal length. Erdas Imagine Photogrammetry Suite was used to measure the image fiducial mark coordinates from the imagery. The fiducial mark measurements had an acceptable RMSE of 2.35 pixels.

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Triangulation: Initial approximation of the exterior orientation parameters (EOPs) for the imagery were determined from the Air Photo Distribution geodatabase. The final EOPs of the images were determined by performing an indirect georeferencing triangulation in Erdas Imagine Photogrammetry Suite. Ground control points were collected from 30cm resolution 2018 orthophoto mosaics. 54 control points were found in both the 1951 and 2018 imagery, where 47 were inside the project boundary, and 7 were outside. The X, Y coordinates were obtained from the 2018 orthophoto and the Z coordinate from the corresponding location in the Alberta Government 1980s DEM which had 20m resolution. These points were spread across the entire project area to provide control in urban and remote areas and for redundancy.

Manual tie points were collected to find the approximate orientation between images. Using the approximate orientation, tie points were generated using the automated tie point process in Photogrammetry Suite, and were checked manually to remove or correct any blunders.

Orthophoto Generation: The imagery was orthorectified with a 1m pixel resolution using Erdas Imagine Photogrammetry Suite. Orthorectification was performed using the Alberta Government DEM from the 1980s which had 20m resolution. This older DEM was used instead of the current 2017 DEM for three main reasons:

1. The older DEM is a closer representation of the ground conditions at the time that the historic imagery was taken, by about 40 years. It is important for orthophoto creation that the ground in the imagery matches the DEM as closely as possible.
2. The resolution of the historic imagery is comparably low and so the spatial uncertainty in the older DEM should not affect the orthophoto creation in a significant way.
3. The horizontal accuracy is still controlled by the 2017 data.

Mosaic Creation: The raw orthophotos are mosaicked using Orthovista v.8.0.6. The mosaics were then edited, checked and patched to ensure that seamlines were reduced, and no mis-ties were present. Areas with damaged portions from scanning were avoided, so the best available orthophotos were used and clipped to be consistent with the National Topographic System 1:20 000 series. Positional accuracy was verified (where possible) by using the 2018 orthophoto mosaics. Finally, in Adobe Photoshop, larger artifacts in the mosaic imagery were removed when possible and image contrast and saturation were corrected to provide overall consistency across the project.

Mosaic QA/QC: The 1951 orthophoto mosaics were checked for overall quality and the orthophoto mosaics were used to verify the positional accuracy. Specifically, the 47 identifiable ground control points were used as check points to determine the horizontal accuracy of the triangulation.

Accuracy Summary

Horizontal Accuracy Check (Orthophoto Mosaic): The accuracy of the orthophoto mosaic was checked by measuring the locations of ground control points in the 1951 imagery and comparing these with the 2018 imagery. Table 1 shows the coordinates and image checks for 47 unique points inside the area of interest. According to these residuals, the horizontal accuracy of the 1951 orthophoto mosaics relative to the 2018 orthophoto mosaics is approximately 2.355 m RMSE (2.355 pixels).

Vertical Accuracy Check (Stereo Imagery Model): The vertical accuracy of the 1951 orthophoto mosaics relative to the 20m resolution Alberta Government 1980s DEM was 1.315 m RMSE.

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Table 1: Ground Check Points – Orthophoto Mosaic					
	Control Point from 2018		Image Meas. from 1951		
Point Name	Easting (m)	Northing (m)	Easting (m)	Northing (m)	Dx (m)
90001	35349.604	5538316.701	N\A	N\A	N\A
90002	9654.613	5549194.597	9655.357	5549195.686	-0.744
90003	19151.842	5540795.921	19150.437	5540797.253	1.405
90004	17593.265	5535837.359	17592.681	5535840.000	0.584
90005	15404.699	5548950.959	N\A*	N\A*	N\A*
90006	32166.468	5545716.729	N\A*	N\A*	N\A*
90007	30519.168	5548942.606	N\A*	N\A*	N\A*
90008	22235.078	5544253.752	22233.419	5544254.145	1.659
90009	22064.803	5544253.365	22063.562	5544253.352	1.241
90010	17561.043	5535936.083	17558.668	5535939.452	2.375
90011	12416.351	5546897.692	12414.967	5546899.787	1.384
90012	28704.268	5534047.036	N\A*	N\A*	N\A*
90013	28078.772	5534900.406	28079.324	5534902.636	-0.552
90014	28614.284	5534304.090	N\A*	N\A*	N\A*
90015	15388.936	5549411.524	N\A*	N\A*	N\A*
90016	21425.330	5552034.231	21425.324	5552033.203	0.006
90017	21330.913	5552026.860	21329.775	5552029.121	1.138
90018	21470.999	5554244.794	21471.423	5554243.897	-0.424
90019	20840.737	5554672.913	20842.143	5554670.493	-1.406
90020	25899.149	5555995.972	25901.199	5555998.325	-2.050
90021	25779.300	5550626.771	25779.548	5550628.633	-0.248
90022	32750.192	5542169.492	32753.588	5542170.838	-3.396
90023	10108.718	5548780.632	10109.137	5548782.015	-0.419
90024	12341.957	5546721.539	12341.069	5546723.739	0.888
90025	15195.755	5547574.524	15192.325	5547573.584	3.430
90026	17392.067	5544748.935	17389.596	5544750.355	2.471
90027	22081.959	5545258.198	22078.622	5545256.420	3.337
90028	21925.410	5543542.668	21922.595	5543542.596	2.815
90029	23314.474	5543849.047	23314.133	5543850.414	0.341
90030	26622.211	5545324.683	26623.459	5545324.486	-1.248
90031	26391.687	5544068.197	26391.866	5544070.728	-0.179
90032	27251.500	5547580.379	27252.445	5547577.580	-0.945
90033	24383.267	5551500.840	24381.611	5551500.359	1.656
90034	23520.365	5549949.007	23519.396	5549947.823	0.969

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90035	20400.407	5553586.150	20402.011	5553586.356	-1.604
90036	21245.898	5552605.756	21245.831	5552605.555	0.067
90037	22485.950	5552111.111	22485.202	5552112.892	0.748
90038	25658.086	5555578.717	25660.356	5555578.486	-2.270
90039	19468.741	5537541.510	19469.322	5537542.502	-0.581
90040	21264.598	5541770.454	21264.342	5541771.261	0.256
90041	23461.156	5542640.884	23461.308	5542638.484	-0.152
90042	27361.376	5541362.896	27361.167	5541361.861	0.209
90043	27450.729	5541028.105	27451.467	5541026.492	-0.738
90044	27320.744	5542278.802	27322.503	5542276.524	-1.759
90045	27334.120	5539093.759	27333.627	5539095.732	0.493
90046	26988.744	5537340.298	26987.138	5537342.618	1.606
90047	28668.690	5535011.118	28669.823	5535015.598	-1.133
90048	30903.299	5541448.407	30904.474	5541446.314	-1.175
90049	32689.394	5542207.424	32688.195	5542207.999	1.199
90050	33080.299	5540525.623	33081.572	5540526.602	-1.273
90051	34275.740	5540913.037	34276.044	5540912.815	-0.304
90052	33849.789	5541009.854	33850.819	5541007.545	-1.030
90053	34414.393	5540268.410	34414.287	5540268.515	0.106
90054	18359.327	5536742.411	18358.388	5536746.178	0.939
				STDEV	1.460
				RMSE	1.469
				Circular RMSE	2.355
				At 95%	4.076

*N\A indicates control points used in the triangulations that were not within the AOI boundaries, but are covered by stereo imagery collected for the project by OGL.

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