REPORT

District of Chetwynd

Flood Hazard Study

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File: 1320.0094.02

November 26, 2018

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Appendix A HEC RAS Model Results

1.0 Introduction

The District of Chetwynd is located at the junction of Highways 97 and 29, in the foothills on the eastern slope of the Rocky Mountains. Chetwynd is in the Pine River watershed, and is characterized by three creeks that flow through the community. These include Centurion, Windrem, and Widmark Creeks. These features are shown in Figure 1.

Chetwynd, as well as the surrounding region, have been significantly impacted by extreme weather events in recent years. In June 2016, as a result of prolonged heavy rainfall, runoff flowing in the creeks within the community was so great that Windrem and Widmark Creeks overtopped their banks in some locations and flooded property, and debris flowing in the runoff blocked culverts and bridges, and in other locations the high flows caused avulsion of channel banks. The impact was so great that it was necessary for the community to declare a state of emergency. Only a few years earlier, in June 2011, a comparable event caused similar impacts, and this had been preceded by a significant event in 1987. Each of these storms caused a great deal of damage to property throughout the community.

While extreme events of this sort are normally seen as rare, they can and sometimes do occur more frequently than might be expected. The fact that events with significant impact have occurred in Chetwynd twice in the past 7 years, and 3 times in the past 30 years, has increased awareness of the risks associated with natural hazards faced by Chetwynd, and has lead to this study of the hazards and risks associated with those event.

The primary purpose of the study is to provide an overview of issues associated with surface water flooding in Chetwynd, and to assess the hazards and risks that community faces now and in the future. The primary study objectives include the following:

- Document hydrologic (rainfall and surface runoff) conditions in the study area.
- Establish potential future hydrologic conditions considering climate change based on currently available understanding.
- Create hydrologic and hydraulic models of the study area and creek channels through the community.
- Identify the flood-related hazards and risks in the community, both as they exist now, and as they might exist in the future with a changed climate.
- Identify measures that can mitigate against those risks and hazards, assess their adequacy and suitability for the study area, establish an estimate of their costs, and the requirements that will go along with their implementation.

We also acknowledge that the funding of this project was provided by Emergency Management BC.

District of Chetwynd

Flood Mapping and Hazard Assessment

Location Plan

Municipal Boundary

Location within BC

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0 100 200 400 600
Metres

N

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:12,500

Data Sources:

- Imagery provided by the District of Chetwynd.
- Municipal boundary downloaded from BC Provincial Government's Land and Resource Data Warehouse.
- Streams and roads provided by Natural Resources Canada.

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FIGURE 1

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2.0 Climatic Conditions

2.1 Overview

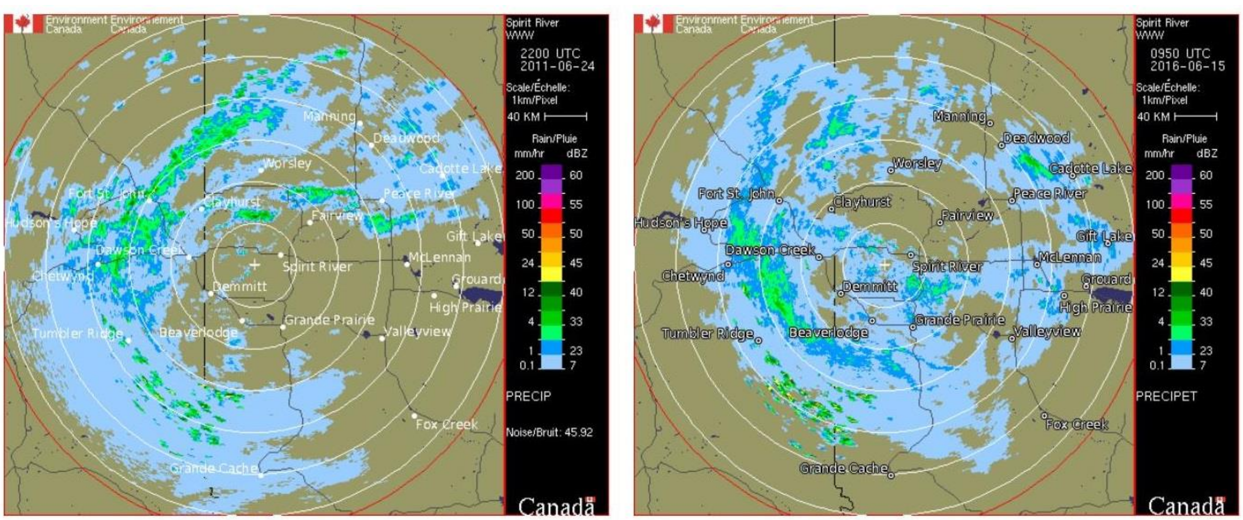
This section provides an overview of concepts related to climatic conditions, particularly rainfall and the runoff that results. One of the foundational concepts is probability.

Natural events like rainfall and runoff, especially more extreme events, are sometimes referred by their frequency of occurrence in terms of the average period between events. This is referred to as return period. For example, a 100-year return period event happens on average once in every 100 years over very long periods of time and will be more severe than an event that happens on average every 50 years.

However, from a scientific perspective, it is more appropriate to consider extreme events in terms of their probability. A 100-year event, for example, is an event of a magnitude and severity with a 1% probability that it will occur in any year. Studies of this sort are concerned mostly with events that have a relatively low probability of occurring, but also carry a high risk of impact when they do occur. These events have high return periods, and this term will be used in this report.

Another foundational concept is aerial extent, or the area covered by the storm event. Some rainfall events cover relatively small areas, often only a few square kilometers at most. Mid-summer thundershowers are example of events that cover relatively small areas. Others cover very large areas, sometimes thousands of square kilometers at the same time. Figure 2 shows the radar images of the rainfall intensity for the 2011 rainfall event on the left and the 2016 event on the right. In both cases the rain was generated by weather systems covering very broad areas, several hundreds of square kilometers in size. Rainfall from events of this type tend to have a greater impact on creeks likes those in Chetwynd.

Figure 2 – Historic Rainfall Event Radar Images From 2011 & 2016



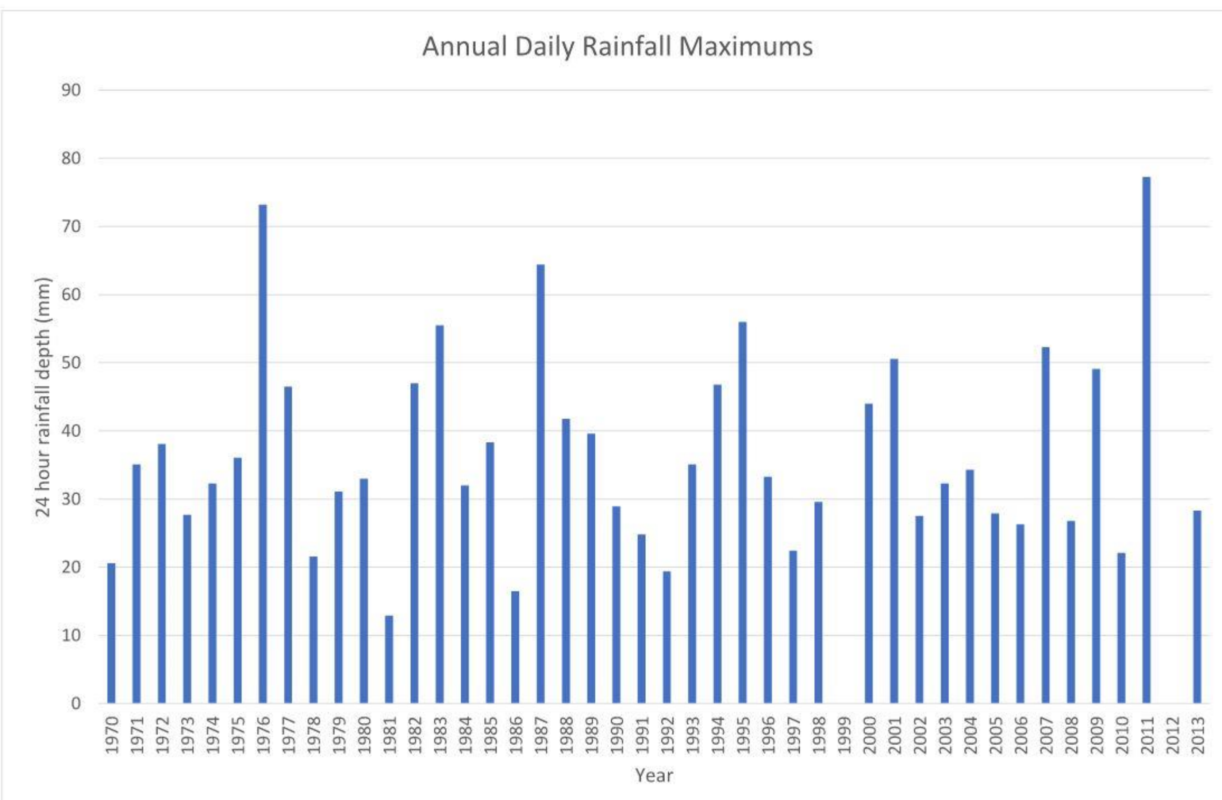
A third foundational concept associated with rainfall is event duration. Similar to aerial extent, rainfall events can be of a short duration that lasts from as little as a few minutes to a couple hours. A summer thundershower would again be an example of this sort of event. Others last for a long duration, sometimes one or two days.

Those events with significant aerial extent and long duration have the greatest potential to have an impact on the watersheds in Chetwynd. As a result, the study has focused on rainfall events with a duration in the order of 24 hours or more.

2.2 Historical Rainfall Data

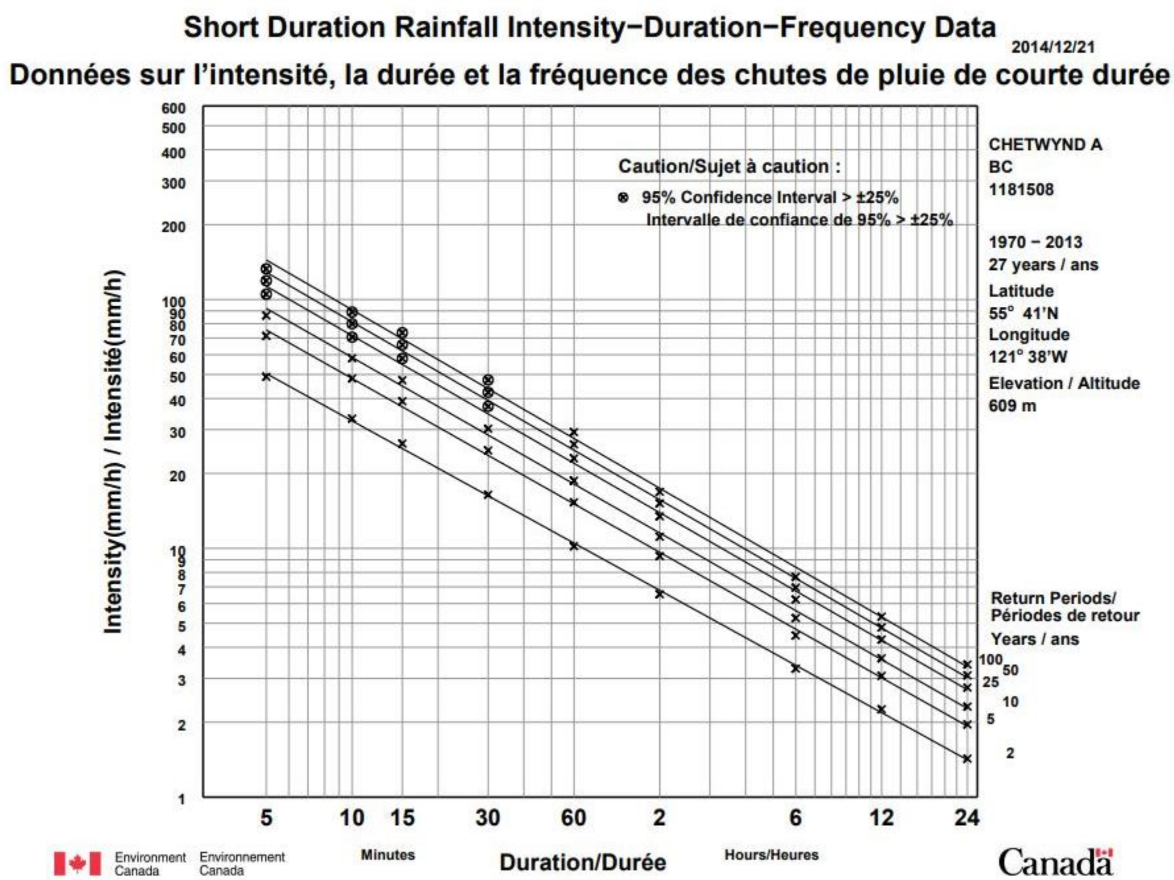
Historical rainfall data forms the basis of hydrologic analysis. It is generated from weather recording stations located throughout the country and is available from Meteorological Services Canda (MSC), which is a department of Environment Canada. One of these stations is located in Chetwynd at the airport, and is referenced as Chetwynd A, station number 1181508. This station has been used to gather daily rainfall data since 1970, but data is available from MSC only up to 2013. Figure 3 provides a graphic representation of the measured maximum rainfall depths over a 24-hour period for each year in the period of record.

Figure 3 – Annual Daily Rainfall Maximums



MSC has undertaken a statistical analysis on this data set to create estimated values for a range of return periods from 2 years to 100 years. This information is summarized in an intensity-duration-frequency (IDF) curve for each station. The IDF curve for Chetwynd A is shown on Figure 4.

Figure 4 – Chetwynd A IDF Curve



Using this data set and IDF curve, estimated values can be calculated for rainfall events of various durations and return periods. Table 1 provides estimated maximum rainfall values for 24 hour periods for a standard range of return periods from 2 year (relatively common) to 100 year (relatively infrequent).

Table 1 – 24 Hour Duration Rainfall Depths for Various Return Period Events

2 year	5 year	10 year	25 year	50 year	100 year
33.9	46.2	54.4	65.0	72.6	80.0

Although the IDF curve reports values only for events up to 24 hour duration, the raw data set is available, and has been used to determine maximum rainfall amounts on consecutive days for one, two and three days duration. Table 2 shows the rainfall depths for the one, two, and three durations for each of the rainfall events in 1987, 2011, and 2016, each of which led to significant flooding in the community.

Table 2 – Actual Rainfall Depths for Multi-Day Events for Chetwynd A

Event Dates	1 Day Depth (mm)	2 Day Depth (mm)	3 Day Depth (mm)
1987, July 30 to August 1	64.4	88.6	91.6
2011, June 23 to 25	72.0	99.5	125.3
2016, June 14 to 16	86.8	134.8	135.4

This data shows that the rainfall events that have caused the most severe flooding in Chetwynd since 1987 have had high volumes of rainfall over 24 hours, but even higher rainfall depths over consecutive days up to 3 days in a row. Furthermore, the data shows that the 1987 event had a return period of about 25 years, the 2011 event had a return period of about 50 years, and the 2016 event had a return period of about 100 years when compared to the IDF data for the Chetwynd A station.

2.3 Climate Change Impacts

Climate change is one of the more challenging aspects of hazard and risk assessment with respect to rainfall events. In the past, hazard and risk were assessed on the basis of historical data alone with the view that future climatic conditions would be similar to historic conditions. However, there is considerable evidence that our climate is not static, but rather is changing with time. As a result, the prediction of future events must take into consideration the ways in which the climate is likely to change in the future. Approaches to this issue are laid out in the Engineers and Geoscientists of BC's reference document *Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC*.

In the most general terms, future climate projections indicate that rainfall intensities and total rainfall depths are very likely to increase in this region in the future. This can be expected to manifest as an increased frequency of severe rainfall events, increased volumes of rainfall over the 1 day, 2 day, and 3 day durations, and a corresponding increased risk of more frequent and more severe flood type events in the community.

Historically, hydrologic analysis and design scenarios were based on only IDF curves available from the MSC weather data base, and these were based on only historical data sets. In order to take into consideration future hydrologic conditions based on a changed climate, future condition IDF curves are generated using a projection tool such as the IDF_CC Tool created by the University of Western Ontario. This particular tool uses results from up to twenty-four Global Circulation Models (GCMs), combined with historical data from a climate station to project future IDF values for a prescribed time period.

The IDF_CC Tool analysis results in a broad range of future climate conditions, and this is because the tool considers a number of potential future climate scenarios based on varying rates of greenhouse gas emissions. For a study of this sort, the median and 90th percentile values for future climate conditions are considered. The estimated 24 hour duration rainfall events based on the Chetwynd A station are shown in Table 3 for these two conditions. The table also shows how much each condition is an increase over the values generated by historical data.

Table 3 – Future Climate Condition 24 Hour Duration Rainfall Depths

Future Climate Condition	2 year	5 year	10 year	25 year	50 year	100 year
Median	36.0	50.9	60.6	72.1	80.5	89.0
Increase Over Historical	6%	10%	11%	11%	11%	11%
90th Percentile	40.9	59.0	71.9	87.5	99.5	111
Increase Over Historical	21%	28%	32%	35%	37%	39%

The data shows that the average projected increase due to climate change for the 100 year return period 24 hour duration rainfall depths in the region will be in the order of 11% greater than existing values based on the median future condition results, and perhaps in the order of 39% greater than historical values based on the 90th percentile future condition values.

It must also be noted that the social, economic and environmental effects of climate change represent a significant research challenge in recent times. Although analytical tools such as the IDF_CC Tool can provide valuable information on the predicted impacts of climate change, output from these tools must be carefully interpreted and used with caution. While these tools have been produced to help inform decisions associated with climate change adaptation, any major decisions should consider the significant uncertainty associated with any future climate predictions. Because of this, future rainfall conditions predicted by climate change models will be used to only to identify heightened risks and hazards, and not as a prediction of actual future conditions.

2.4 Regional Runoff Analysis

Precipitation is the driving force in runoff and stream flow. This comes in either the form of rainfall, which almost immediately produces runoff, or snow fall, which eventually melts and produces runoff in streams and rivers.

Like the system of rainfall recording stations, Water Survey of Canada (WSC), which is also a branch of Environment Canada, operates a network of flow recording stations that take measurements of flows in streams and rivers. Some of these stations are still active, but many have been discontinued and taken out of operation, although the data is still available in the WSC database. The collected data includes measurements of daily peak flows at various locations throughout the province. The resulting data set can

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be used in statistical analysis to predict flow rates for a range of probabilities or return periods, very similar to the statistical analysis used to estimate rainfall depths for various probabilities or return periods.

There are a number of both active and inactive stations in the vicinity of Chetwynd. One of the inactive stations in the database, identified as station 07FB011, was located on Windrem Creek where the creek passes under 50th Avenue. This station was used to measure peak daily flows, but was operational only for the periods of 1986 to 1998 with only ten years of records in that time period. The station was operational during the 1987 flood event on August 1, and the measured peak flow rate on that day was 21.5 m^3/s. The annual peak flows measured at this station for the entire period of record are provided in Table 4, as well as the date the peak flow occurred.

Table 4 – WSC Station 07FB011 Annual Maximums

Year	Annual Maximum Flow Rate (m^3/s)	Date of Event
1986	0641	May 27
1987	21.5	August 1
1988	1.46	June 7
1989	0.703	June 27
1990	2.99	June 12
1991	1.13	June 14
1992	No Record	
1993	0.931	July 15
1994	No Record	
1995	3.80	July 4
1996	No Record	
1997	1.25	May 14
1998	0.672	May 16

Because the station provides only 10 years of data, the confidence in the results of the statistical analysis are lower than for a station with a greater number of years of data. However, when this data set is analyzed and fit to a Log Pearson Type III probability distribution, the estimated 100 year return period flow rate is calculated as $Q_{100} = 68.0\ m^3/s$, and the 200 year rate is calculated as $Q_{200} = 133\ m^3/s$. It should be evident that these estimate values exceed the maximum recorded value of 21.5 m^3/s, which occurred in 1987, and which is known to have caused flooding in the community.

In circumstances such as this, where there is insufficient data from a single station to create reliable estimates of peak design flows, it is possible to generate estimates of peak flow rates using a greater number of stations from the broader region, which is known as a regional analysis. To do this, a number

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of stations on watersheds with similar characteristics are analyzed, and used to create a regression equation for the region which shows the relationship between peak flow and watershed drainage area.

For this case, a total of 8 flow recording stations were used. For each station, statistical analysis was performed on the station data set to estimate 100 year and 200 year return period peak flow estimates using the Log Pearson Type III distribution function. The station locations and WSC identifier are shown in Figure 5 on the following page.

Figure 5 – WSC Flow Recording Stations for Regional Analysis

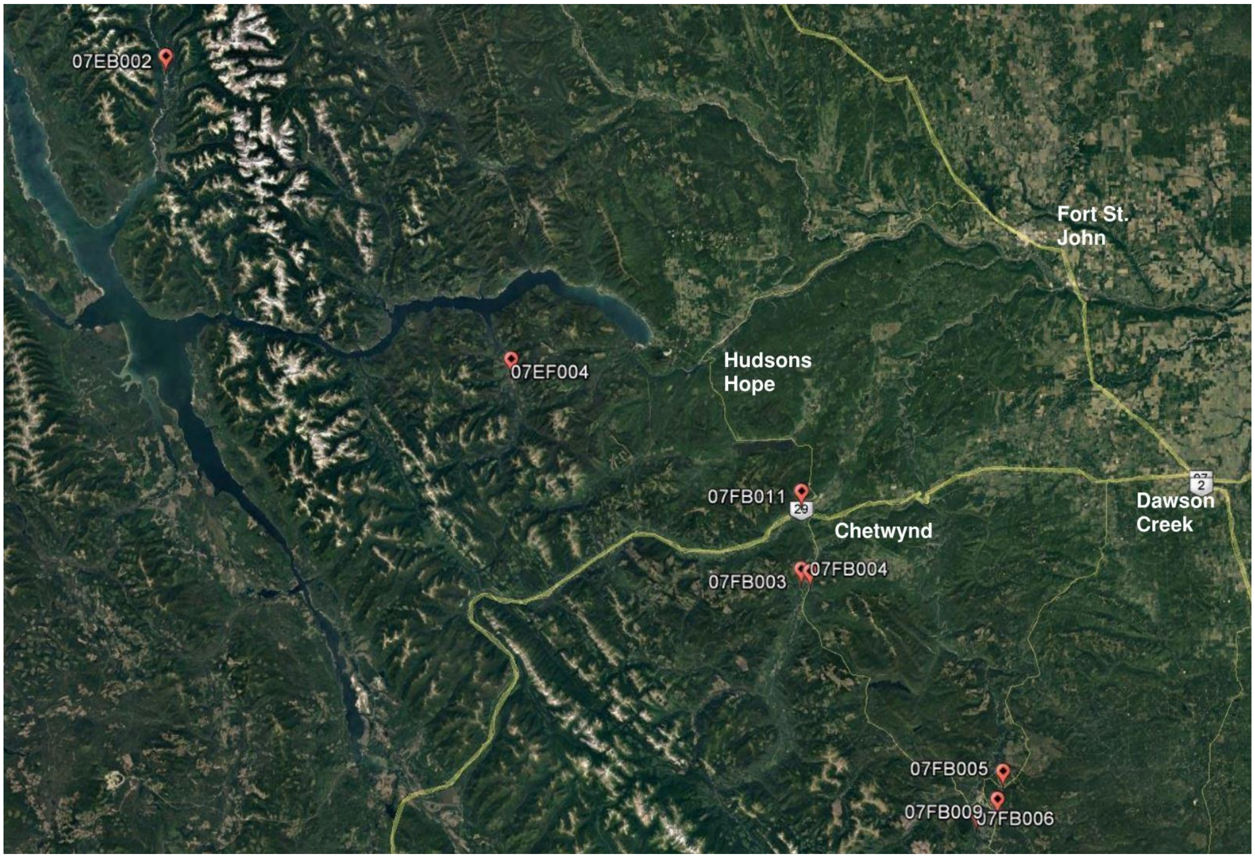


Table 5, on the following page, provides a summary of the estimated 100 year and 200 year return period flow rates for both the statistical analysis and the resulting regional regression equation. The regression curves are provided on Figure 6 for the 100 year event and Figure 7 for the 200 year event.

The regional analysis results in somewhat lower values for the estimates of the 100 and 200 year return period events for the Windrem Creek watershed when compared to the results based only on that data for that station. The resulting values are 59 m^3/s for the 100 year event, and 102 m^3/s for the 200 year event.

The regression equations will also be used to estimate peak flow rates for the Widmark Creek watershed, which has a watershed area of about 12.1 km^2, but which has no flow recording station of its own. Using these equations, the estimated peak flow rates for the Widmark Creek watershed are Q_{100} = 39 m³/s, and Q_{200} = 72 m³/s.

Table 5 – Regional Estimates

WSC Station ID Number	Watershed Area (km²)	Statistical Estimate (m³/s)		Regression Equation Estimate (m³/s)	
		100 Year	200 Year	100 Year	200 Year
07FB011	22.9	68	133	58	99
07FB005	29.5	46	66	68	114
07FB004	82.4	177	274	133	203
07FB009	486	444	599	416	547
07EF004	741	500	601	546	692
07EB002	2190	1414	1798	1098	1268
07FB006	2370	1013	1152	1155	1325
07FB003	2590	1052	1131	1223	1393

Figure 6 – Regression Equation for 100 Year Return Period Events

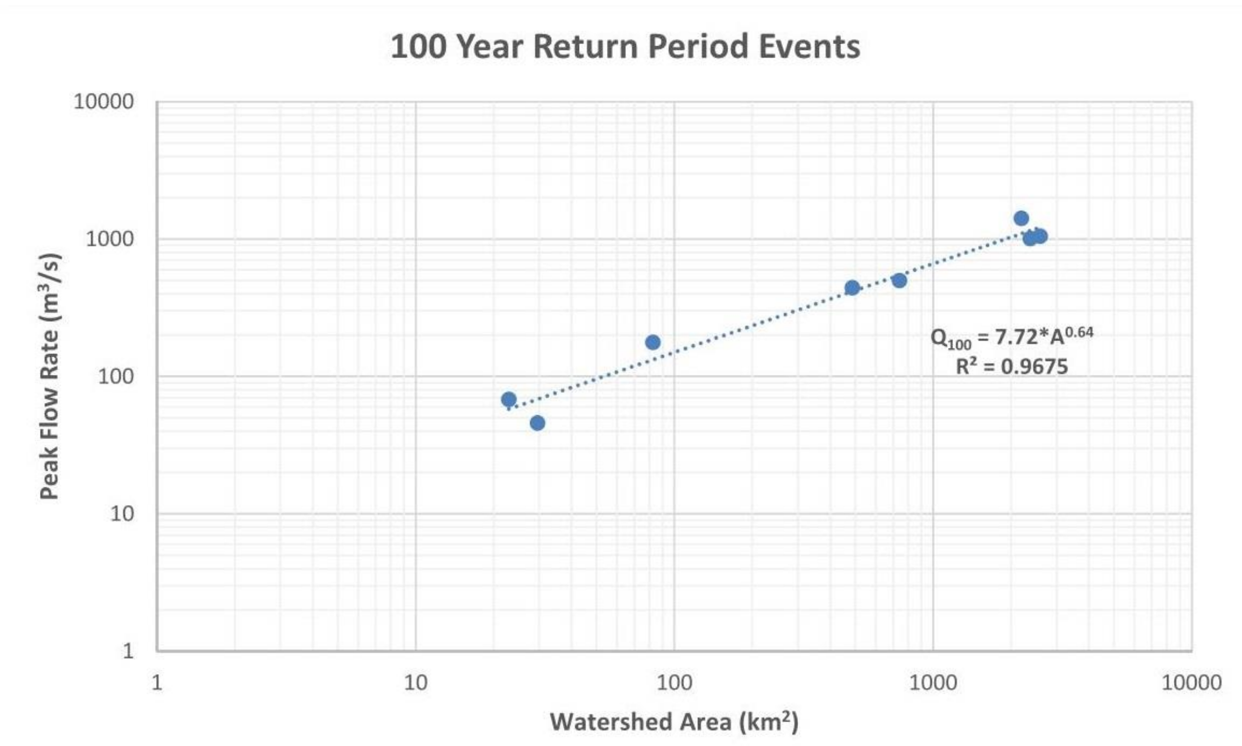
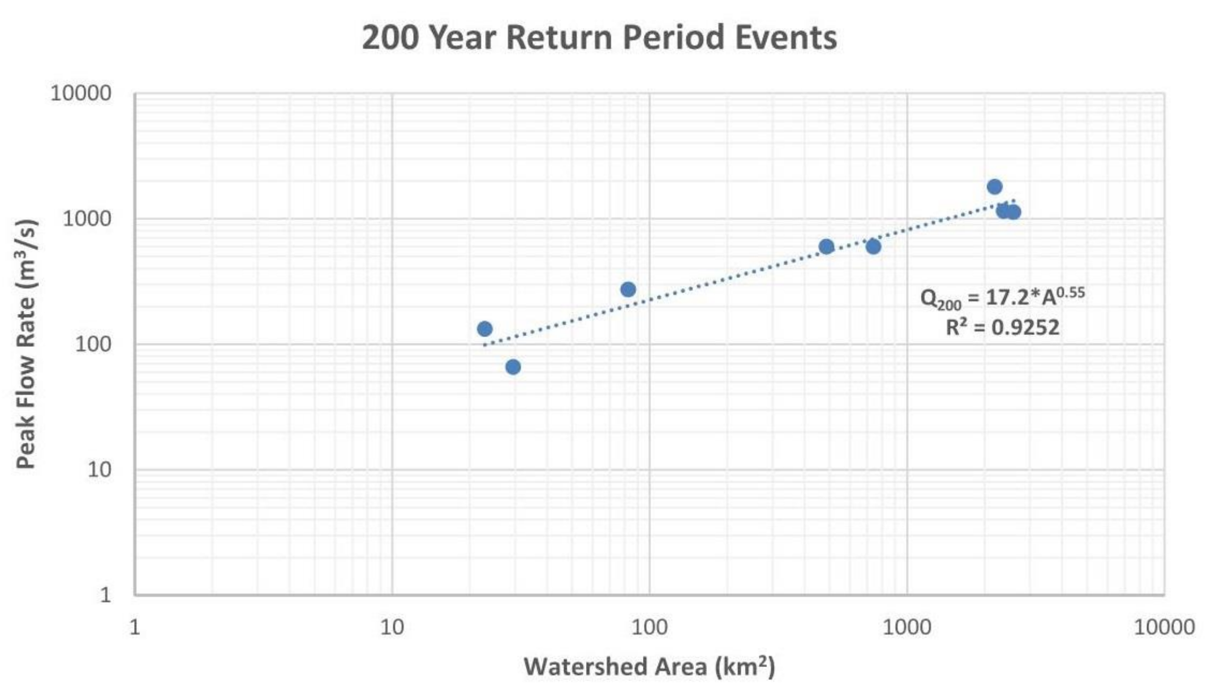


Figure 7 – Regression Equation for 200 Year Return Period Events



It is worth noting the following at this point; in table 2 of section 2.2, it was noted that the 1987 event was in response to a total rainfall of 64.4 mm over 24 hours, and that this was estimated to be approximately a 25 year return period event. Furthermore, this event produced a measured peak flow rates of 21.5 m^3/s. The regional regression equation for the stations considered results in an estimate of the peak 25 year return period flow rate of Q25 = 19.6 m^3/s. The result is an indication that rainfall return period and peak flow return period are consistent for this watershed.

2.5 Hydrologic Conditions as a Result of Climate Change

To this point, the analysis of historical rainfall and streamflow data has shown that rainfall events are the principal driver of peak flow events in the Windrem Creek watershed, and that there is a correlation between rainfall return period and runoff return period. Furthermore, the regional analysis has shown that based on historical conditions, the Windrem Creek watershed may generate peak flows during the 100 year return period event on the order 59 m^3/s, and on the order of 102 m^3/s for the 200 year event.

The same is true for the Widmark Creek watershed. Based on the regional analysis of historic records and the resulting regression equations, the flow rates for the Widmark Creek watershed are Q_{100} = 39 m^3/s, and Q_{200} = 69 m^3/s.

The assessment of hydrologic conditions under a changing climate has shown that 100 year return period 24 hour duration rainfall amounts can be expected to increase in the future, on the order of 11% based on the median condition as defined by GCMs, and as much as 39% based on the 90th percentile conditions.

Based on the evidence that there is a direct relationship between rainfall return periods and runoff return periods, estimated peak design flows for 100 year and 200 year return period runoff events under a future climate condition by increasing the historic estimates by the same percentages as rainfall depths under future climate conditions. Table 6 provides a summary of peak flow rates for historic and future flow rate conditions for both Windrem and Widmark Creeks. These values have been used in the hydraulic modelling described in the next section of the report.

Table 6 – Historic and Future Climate Condition Peak Flow Rate Estimates

Watershed	Historic Condition Peak Flow Rate (m^3/s)		Median Future Climate Condition Peak Flow Rate (m^3/s)		90th Percentile Future Climate Condition Peak Flow Rate (m^3/s)	
	100 Year	200 Year	100 Year	200 Year	100 Year	200 Year
Windrem Creek	58	99	64	109	81	138
Widmark Creek	39	69	42	76	54	96

3.0 Hydraulic Modelling

3.1 Watershed and Stream Channel Conditions

In order to assess the flood hazards and risks associated with the estimated peak flow rates, hydraulic models of the two watersheds have been created using the HEC-RAS program. The acronym HEC-RAS stands for Hydraulic Engineering Centre River Analysis System, and it is a computer program that models the hydraulics of water flow through natural streams, rivers, and other drainage channels. The program was developed by the US Army Corps of Engineers in order to manage the rivers, harbors, and other public works under their jurisdiction, and is widely used as a river analysis tool.

Inputs to the program include data about watershed conditions, stream channel geometry, bridge and culvert structures, and flow rates. The model produces water surface elevations and estimates of erosion potential due to shear stress during design flows. This information is discussed in the following sections.

The assessment of watershed conditions began with a review of historic air photos, which were available for the years of 1945, 1956, 1964, 1969, 1981, 1990, 1997, 2006, and 2016. The air photos are shown on Figure 8, and clearly show the growth and development of Chetwynd since its founding. More importantly, the air photos show that the creek channels are relatively stable over this time period, and have not moved due to flood events. It should be noted, however, that Widmark Creek was intentionally realigned at some point between 1956 and 1964 in conjunction with land development.

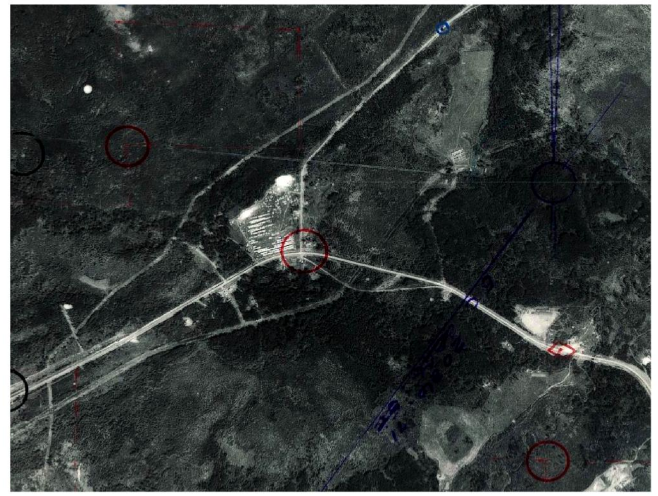
The review if the air photos also revealed that the watershed have experienced some changes in tree cover over time due to both logging and beetle kill. The loss of trees can affect the hydrology of the watershed by increasing the amount of runoff during a rainfall event.

One of the more striking characteristics about the watersheds is revealed by the contour map shown on Figure 9. The contours show the characteristics of alluvial fans for both watersheds. This means that both watersheds have been and continue to be significant sources of gravel and other eroded material, and Chetwynd is located at the mouth of the canyons, which is the primary location where the material is deposited.

The HEC-RAS model requires survey data that defines the channel geometry, and which is used to establish the cross-sectional and profile elements of the model. This information was gathered by a field survey. Figure 10 shows locations of the survey cross sections used in HEC-RAS model

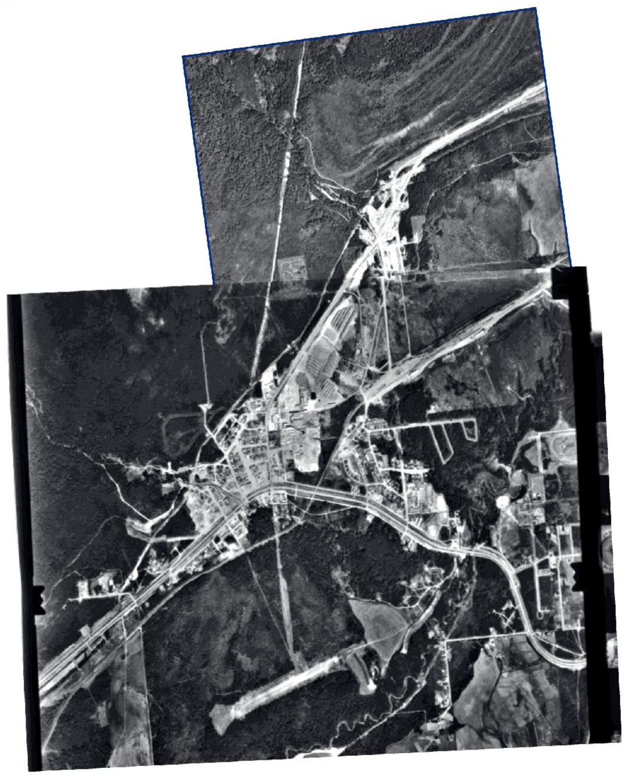
At the same time the field survey was carried out, information about each of the structures that crosses the creek channels was gathered. These structures included all vehicle and pedestrian bridges, as well as culverts on the creeks. Information gathered included the width, height and length of structures, as well as channel geometry in the vicinity of the structure.

1945

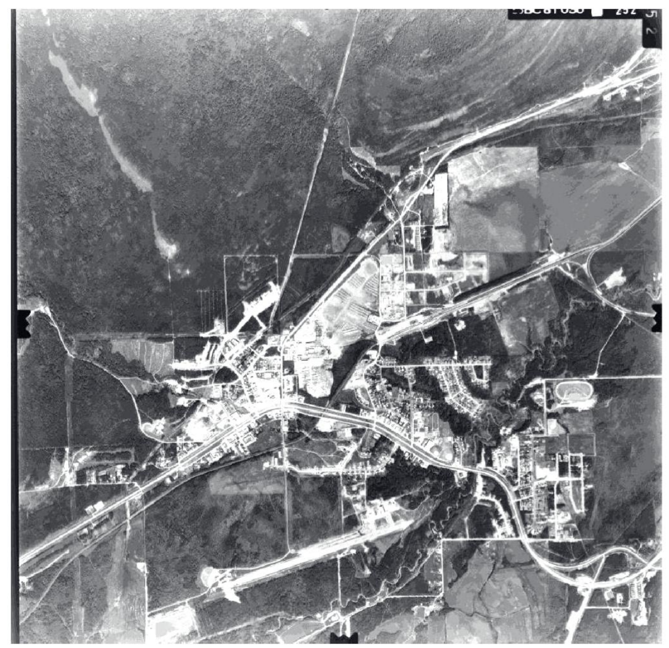


1956

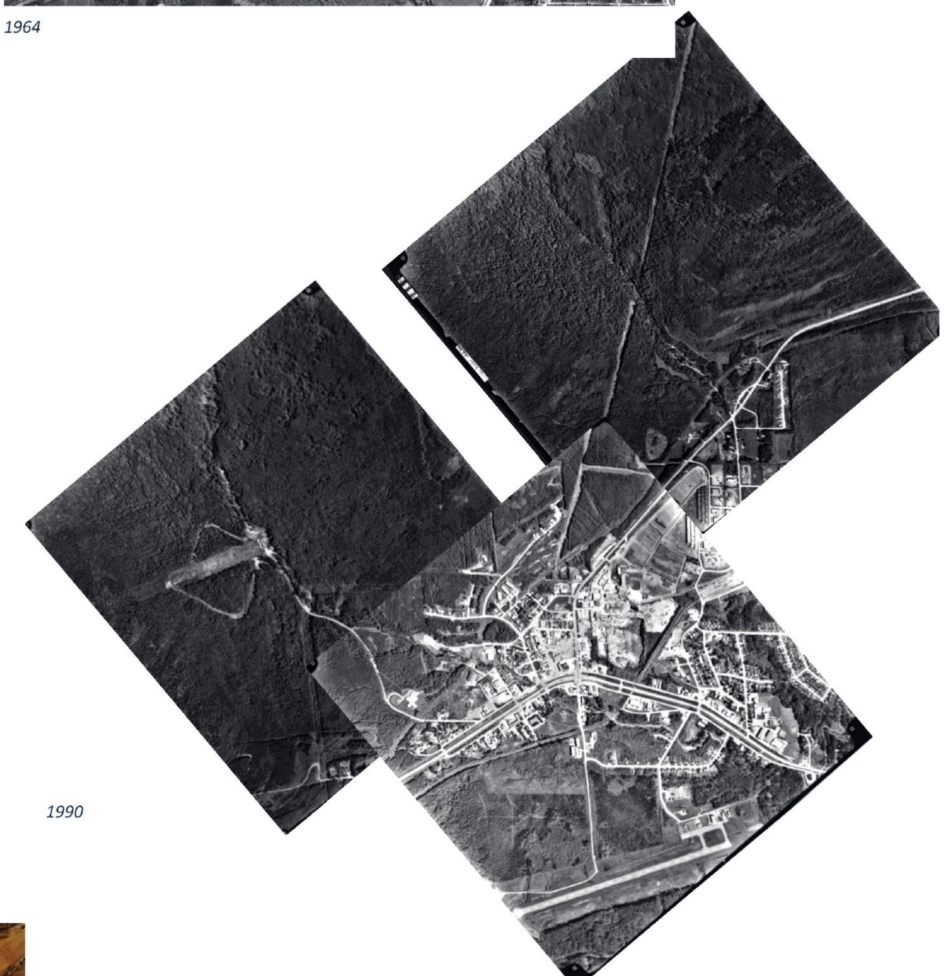
1964



1969



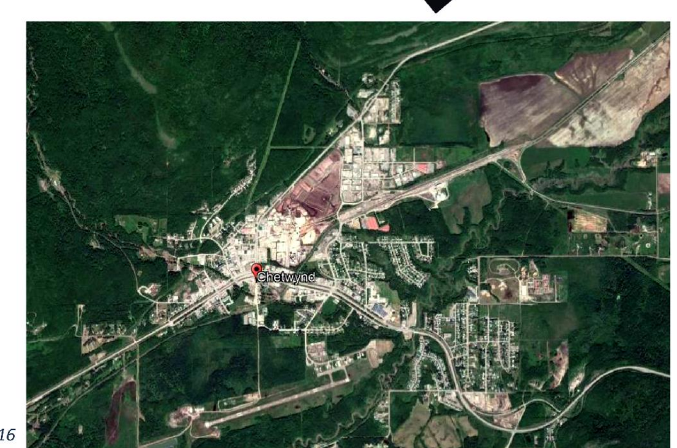
1981



1990

1997

2006



2016

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Flood Mapping and Hazard Assessment

Historic Airphotos

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Coordinate System: N/A

Scale: NOT TO SCALE

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Date:	2018 / 2 / 16

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FIGURE 8

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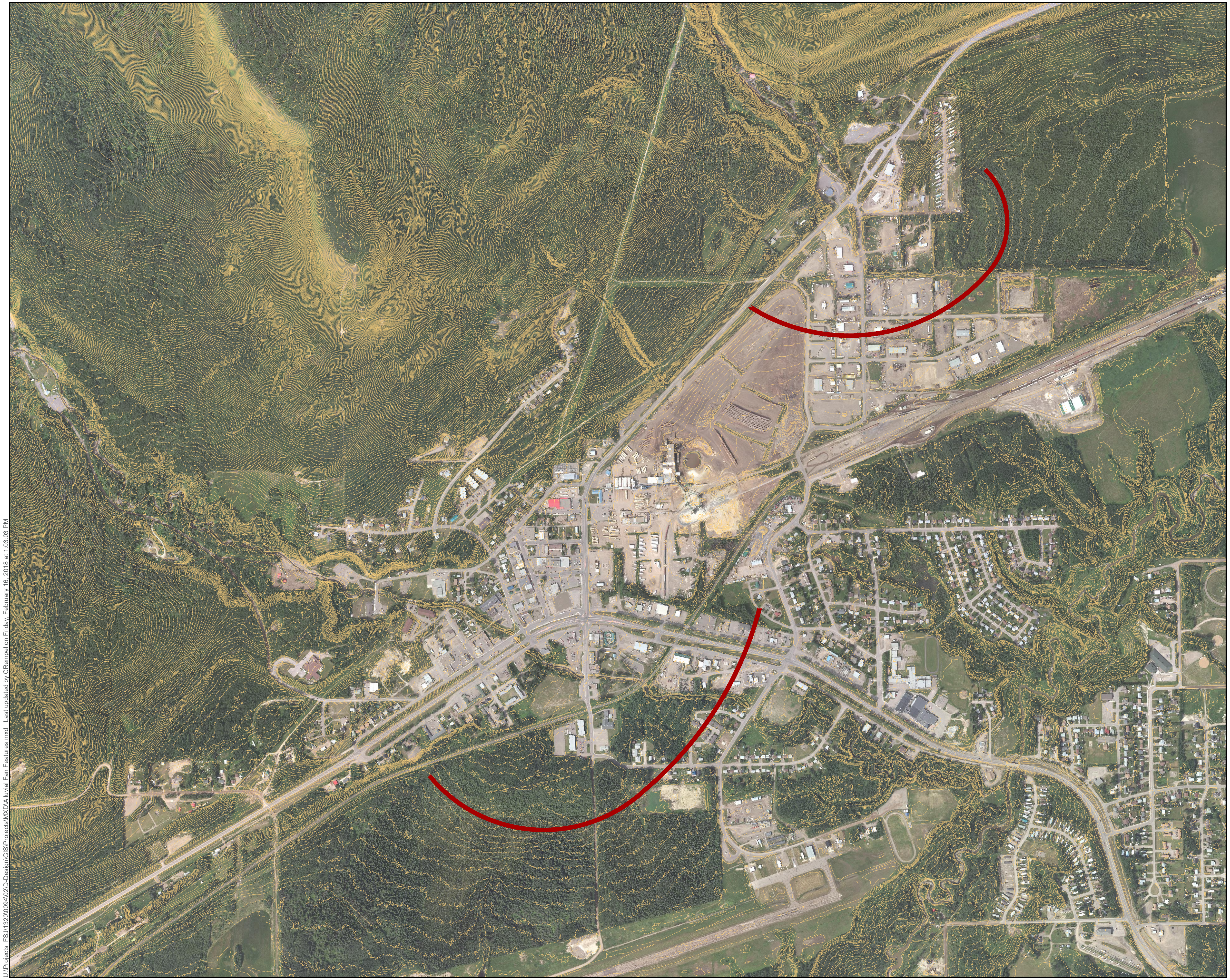

District of Chetwynd

Flood Mapping and Hazard Assessment

Alluvial Fan Features

Municipal Boundary
Alluvial Fan Features
Contours (1m)

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0 100 200 400 600
Metres

N

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:12,500

Data Sources:

- Base data provided by the District of Chetwynd.

Project #: 1320.0094.02
Author: CR
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Status: ~ DRAFT ~
Revision: A
Date: 2018 / 2 / 16

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FIGURE 9

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District of Chetwynd

District of Chetwynd

Flood Mapping and Hazard Assessment

HECRAS Cross-Sections

Municipal Boundary

HECRAS Cross-Section

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0 50 100 200 300
Metres

N

Coordinate System:
NAD 1983 UTM Zone 10N

Scale:
1:10,000

Data Sources:
- Imagery provided by the District of Chetwynd.
- Municipal boundary downloaded from BC Provincial Government's Land and Resource Data Warehouse.
- Streams and roads provided by Natural Resources Canada.

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FIGURE 10

3.2 Review of Video and Photographs

A great deal of video and photographic evidence was also readily available from local news media. This information was reviewed prior to the preparation of the hydraulic models of the creek channels. The following significant observations were revealed during the review.

The most significant observation is that both Windrem Creek and Widmark Creek mobilize significant quantities of woody debris and gravel during flood events. Figure 11 shows gravel, rocks, boulders and woody debris being removed from the channel immediately upstream of the 50th Street bridge crossing during the 2016 flood event.

Figure 11 – Woody Debris and Gravel

The mobilized material has two significant adverse impacts. One impact is that the gravel and boulders temporarily accumulate in the channel at various locations as it moves downstream, which reduces the capacity of the main channel, and increases the likelihood that the creeks will overtop their banks and flood adjacent properties. The second impact is that both the gravel and the debris have the potential to partially or completely block cross structures, such as bridges and culverts.

It is known that during the 2016 flood event gravel and debris blocked the CN Rail crossing, which caused flood waters to flow onto the South Access Road along the route shown in Figure 12. Similarly, debris blocked Widmark Creek at the Highway 22 culvert, causing flood waters to overtop the highway and flow onto adjacent properties as shown on Figure 13. The blockage at the CN Rail was so severe during the 2016 flood event that a decision was taken by the District of Chetwynd emergency responders to breach the railway and relieve the flooding and overflow.

Figure 12 – Flow Path Following Blockage of CN Rail Culverts

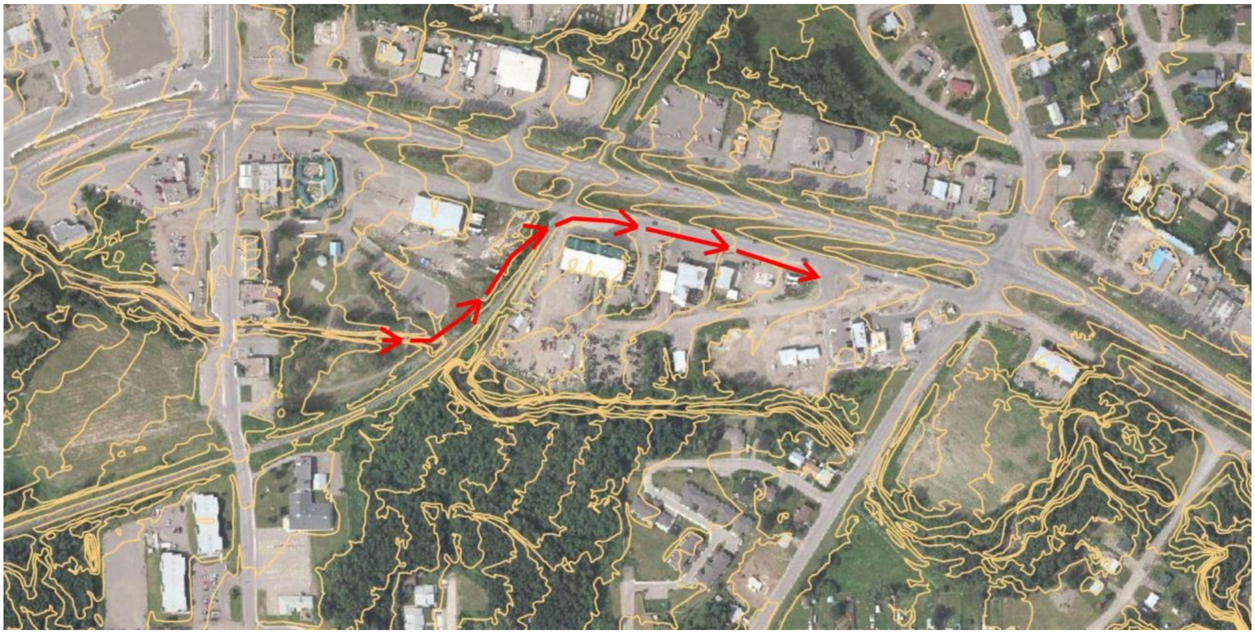
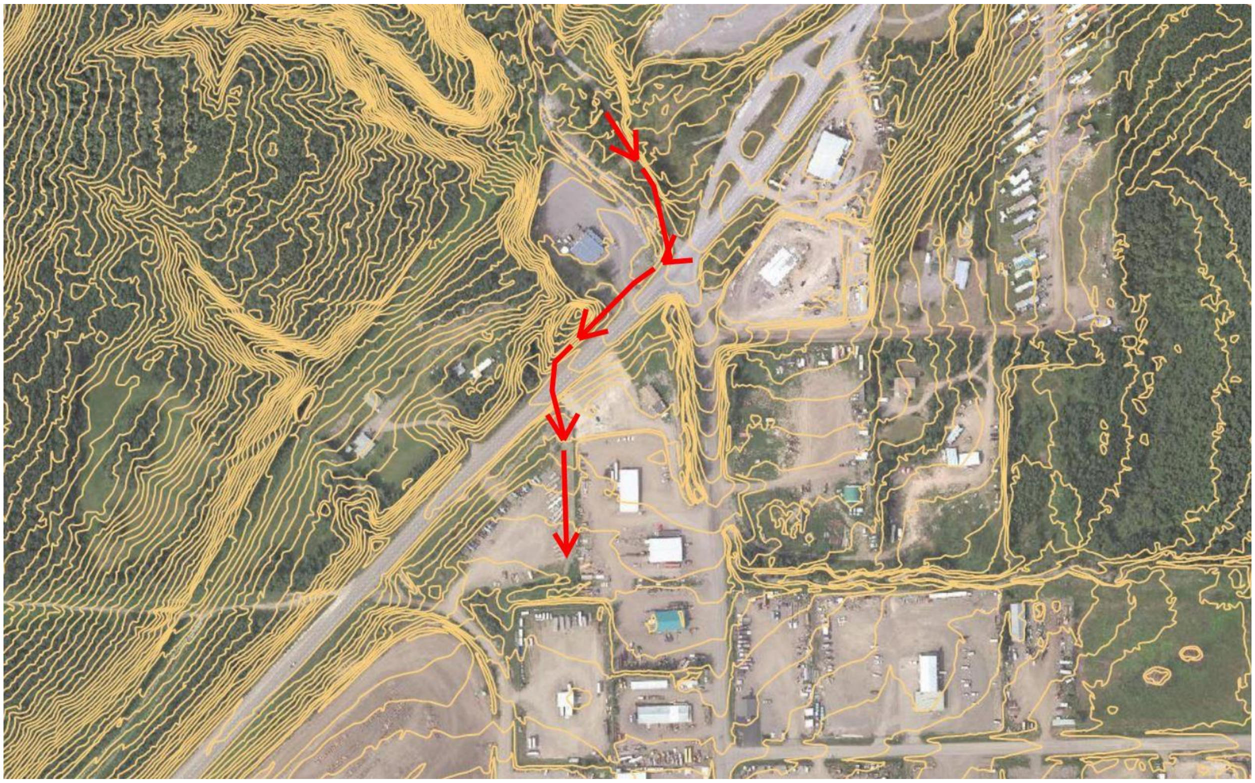


Figure 13 – Flow Path Following Blockage of Highway 22 Culverts



In a similar fashion, the culvert at Nicholson Road became overwhelmed by the flow rate, and blocked by debris, which resulted in the road being overtopped and the culvert being washed out during the 2016 flood. The culvert was replaced with a bridge structure in 2017.

The videos revealed that both creek channels are particularly susceptible to he impacts of debris and sediment, and that these are a primary cause of flood related damage in the community during extreme events.

3.3 Hydraulic Modelling Results

HEC-RAS models were created for each of the Windrem Creek and Widmark Creek channels for the historic condition, median future climate change condition, and 90th percentile future climate change condition for both the 100 year and 200 year return period events. The key outputs of the models are calculated water surface elevations at each modelled cross section, along with flow velocities and channel shear stresses. The water surface elevations are used to identify areas where overbank flooding is likely to occur during the various design events, while flow velocities and shear stresses show segments of channel that are susceptible to erosion. These areas are shown graphically in Appendix A.

The modelling results also show that several of the channel crossing structures, that is bridges and culverts, have inadequate capacity to pass the estimated flow rates for the specified conditions. Furthermore, when some of these structures are overwhelmed by flood flows, ground conditions are such that the flow path can be altered in unexpected ways, such as was observed during the 2016 event.

The modelling also shows that some areas adjacent to Windrem Creek are prone to flooding due to high water, although most of these areas are currently undeveloped, and likely to remain undeveloped. There are both existing and future development areas adjacent to Widmark Creek that are also prone to flooding, particularly in the event that the flows leave the normal channel. Future development in this area should include filling of land above designated flood protection level to protect the development.

4.0 Hazards and Risks

4.1 Background

The assessment of historic hydrologic and hydraulic conditions in Chetwynd, and the determination of potential future hydrologic and hydraulic conditions, has led to the conclusion that the community faces a number of hazards and risks. For studies of this sort, hazards are defined as the likelihood that an event will occur, while risk is the consequence of the event. The consequence may be further defined in terms of economic loss, or impacts on people, including the potential for loss of life.

The hydrologic and hydraulic analysis, and assessment of historic conditions, has shown that the community faces considerable hazard associated with flooding in the community. In the 31 years since the 1987 flood event, there have been several flood events of significant impact, including those in 2011 and 2016, as well as another less reported event in 2001 that caused some damage in the community. Based on these recorded events, the frequency of significant events is on the order of once in every eight years. The risks associated with these events have included economic loss associated with the following:

- overtopping of roadways and washout of culverts and other drainage structures because of insufficient capacity to pass the extreme event flow rates,
- flooding of buildings in the community due to either high water adjacent to creek channels, or unexpected flood flows when flood waters leave the normal channel,
- emergency response costs, such as hiring of equipment to remove accumulations of gravel in creek channels and clean up following flood events,
- loss of property due to avulsion,
- losses to natural assets, such as creek side trees, and
- high groundwater resulting in basement flooding.

The following sections provide greater detail about each of these hazards and the associated risks.

4.2 Culverts and Bridges Blocked by Debris and Gravel

There are a number of drainage structures that do not have sufficient capacity to convey the estimated extreme event flows under historic flow conditions. In the future, under the effects of climate change, the frequency of potential overtopping will increase. There structures include the following:

- 50th Street SW bridge – accumulation of gravel under this bridge has reduced its capacity considerably.
- Windrem CN Rail culverts – these culverts do not have sufficient capacity to pass the extreme event flows, furthermore, they are particularly prone to plugging by gravel and debris as they are the first small diameter opening in the flow path on the channel.

- Wabi Crescent – this single culvert does not have sufficient capacity to pass the extreme event flow rate. This single culvert is also likely prone to plugging with gravel and debris, but may not have experienced much debris to this point because CN Rail and Nicholson Road South culverts prevented debris from reaching that far downstream.
- Highway 29 culvert – insufficient capacity to pass extreme event flow, and prone to blockage with debris. If this culvert's capacity to pass debris is improved, the debris accumulation problem will likely move downstream to the 46th Drive NE Culvert.
- Widmark railway culverts – insufficient capacity to pass extreme event flows.

To complicate matters, when some of these structures are overtopped, the flows do not return to the main channel, but follow an unexpected path. This is true of John Hart Highway, 50th Street, the CN Rail, and Highway 29. The flow paths are shown on Figure 14 for WIndrem Creek, and Figure 15 for Widmark Creek.

4.3 Insufficient Hydraulic Capacity

There are only a few locations where the creek channels have insufficient capacity to pass the extreme event flows which makes the adjacent land flood prone. The most significant of these is on Widmark Creek downstream of the 46th Street culvert crossing. As noted during the review of historic air photos, the natural path of this creek channel was diverted at some point between the 1956 air photo and the 1965 air photo. The channel that was created does not have sufficient capacity to convey the estimated extreme event flows that are likely to happen based on historic data, and will be further compromised under a changed climate condition.

There are also locations on Windrem Creek where lower lying land adjacent to the creek is prone to high water in the main channel. However, these areas are limited to largely undeveloped lands.

Flood prone areas for Windrem Creek and Widmark Creek are shown on Figure 16 through Figure 19 for both the 100 year and 200 year return periods.

4.4 Erosion and Avulsion

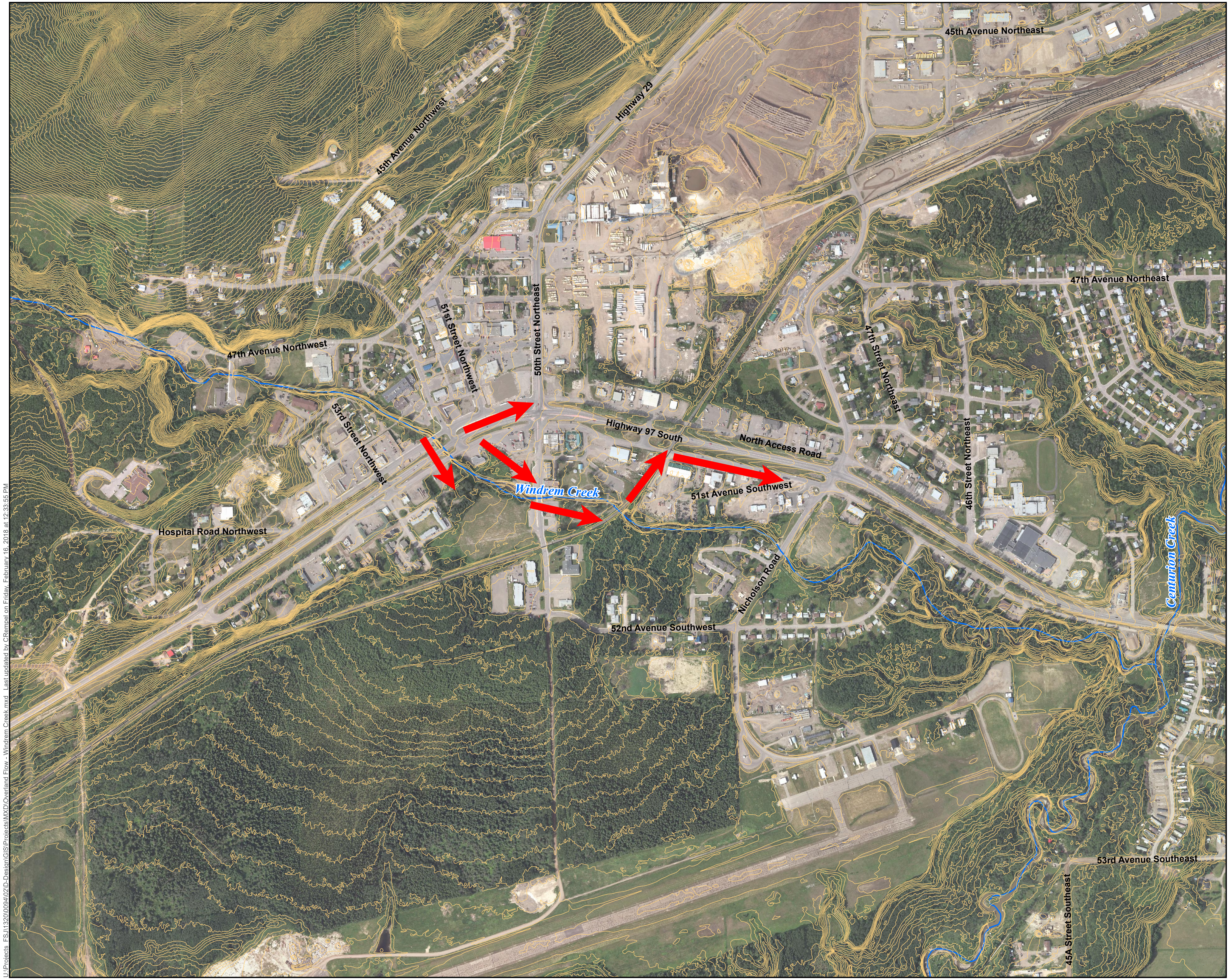
Historic evidence, as well as hydraulic analysis, have shown that extreme event flows create shear stresses in the channel that exceed the capacity of the natural materials to resist erosion. In typical circumstances, this results in the mobilization and movement of bed load from steeper sections of channel, and subsequent deposition in channel segments that have a flatter channel slope. Furthermore, in more extreme circumstances, this results in avulsion of significant areas of land. This occurred during the 2016 flood event upstream of the bridge located at the west end of 47th Avenue.

It should be noted that the loss of channel and bank material can also result in the complete loss of creek side trees. This adds to the amount of floating woody debris in the flood flow, and increases the potential for blockage of culverts and other crossing structure. Very large debris, and large amounts of it, can also result in the blockage of bridge sized structures.

In order to protect against avulsion, the creek channels should be protected with riprap armour, or some similar channel lining, such are articulated concrete mats, or gabion baskets.

4.5 Flood Wave Due to Crossing Failure

As noted earlier, some crossing structures are prone to plugging with large floating woody debris, and overtopping of the associated embankment as a result. In some cases, this has the potential to lead to catastrophic loss of the embankment through overtopping and erosion, and the creation of a flood water several times greater than the peak flow of the extreme event. CN Rail and Highway 29 are the clearest examples of this hazard.



DISTRICT OF CHETWYND

District of Chetwynd

Flood Mapping and Hazard Assessment

Overland Flow Paths Windrem Creek

Contours (1m)

Overland Flow Path

Railway

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 50 100 200 300

Metres

N

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:8,500

Data Sources:

- Imagery provided by the District of Chetwynd.
- Municipal boundary downloaded from BC Provincial Government's Land and Resource Data Warehouse.
- Streams, railway and roads provided by Natural Resources Canada.

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Author:	CR
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Revision:	A
Date:	2018 / 2 / 16

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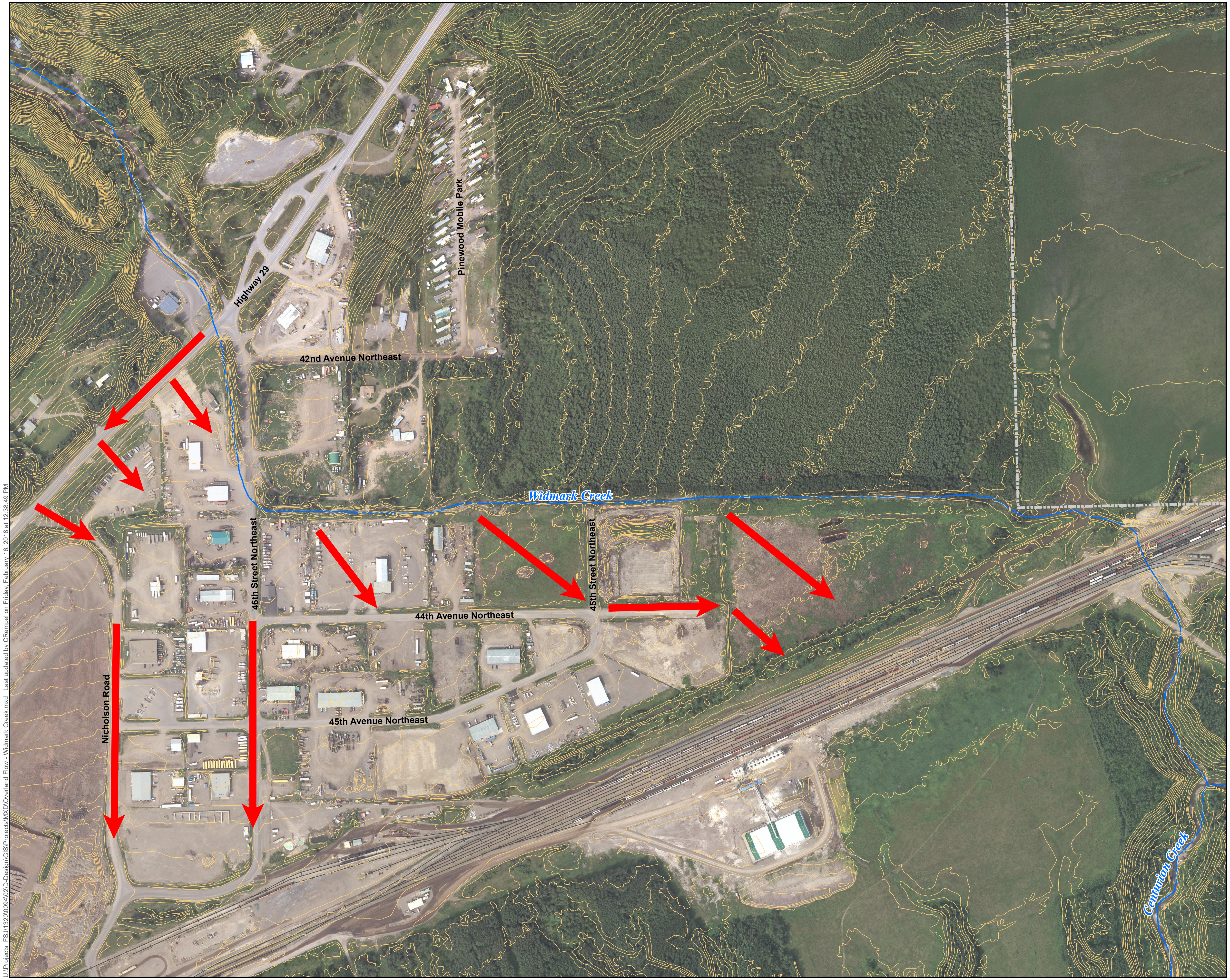
FIGURE 14



DISTRICT OF CHETWYND

District of Chetwynd

Flood Mapping and Hazard Assessment

Overland Flow Paths
Widmark Creek

Municipal Boundary
Contours (1m)
Overland Flow Path
Railway

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 25 50 100 150
Metres

N

Coordinate System:
NAD 1983 UTM Zone 10N

Scale:
1:5,000

Data Sources:
- Imagery provided by the District of Chetwynd.
- Municipal boundary downloaded from BC Provincial Government's Land and Resource Data Warehouse.
- Streams, railways and roads provided by Natural Resources Canada.

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Status: ~ DRAFT ~
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FIGURE 15

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District of Chetwynd

Flood Mapping and Hazard Assessment

Windrem Creek 100 Year Flood Hazard Area

Windrem Creek 100 Year Flood Hazard Area

Railway

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 50 100 200 300

Metres

N

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:7,500

Data Sources:

- Imagery provided by the District of Chetwynd. Government's Land and Resource Data Warehouse.
- Streams, railway and roads provided by Natural Resources Canada.

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FIGURE 16

DISTRICT OF CHETWYND

District of Chetwynd

Flood Mapping and Hazard Assessment

Windrem Creek 200 Year Flood Hazard Area

Windrem Creek 200 Year Flood Hazard Area

Railway

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 50 100 200 300

Metres

N

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:7,500

Data Sources:

- Imagery provided by the District of Chetwynd.
Government's Land and Resource Data Warehouse.
- Streams, railway and roads provided by Natural Resources Canada.

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Status: ~ DRAFT ~
Revision: A
Date: 2018 / 2 / 16

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FIGURE 17

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District of Chetwynd

Flood Mapping and Hazard Assessment

Widmark Creek 100 Year Flood Hazard Area

- Municipal Boundary
- Widmark Creek 100 Year Flood Hazard Area
- Railway

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 25 50 100 150
Metres

N

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:5,000

Data Sources:

- Imagery provided by the District of Chetwynd.
- Municipal boundary downloaded from BC Provincial Government's Land and Resource Data Warehouse.
- Streams, railways and roads provided by Natural Resources Canada.

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FIGURE 18

U:\Projects_FSJ\1320\0094\02\D-Design\GIS\Projects\MXD\Widmark Creek - 200 Year Flood.mxd Last updated by CRempel on Friday, February 16, 2018 at 12:35:00 PM

DISTRICT OF CHETWYND

District of Chetwynd

Flood Mapping and Hazard Assessment

Widmark Creek 200 Year Flood Hazard Area

Municipal Boundary

Widmark Creek 200 Year Flood Hazard Area

Railway

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 25 50 100 150

Metres

N

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:5,000

Data Sources:

- Imagery provided by the District of Chetwynd.
- Municipal boundary downloaded from BC Provincial Government's Land and Resource Data Warehouse.
- Streams, railways and roads provided by Natural Resources Canada.

Project #:	1320.0094.02
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FIGURE 19

5.0 Mitigation Options

Mitigation is one of four components of emergency management. The other three being preparedness, response, and recovery. Of these, mitigation is the most effective means to reduce or eliminate the costs and impacts of disasters. Furthermore, investment in mitigation can result in significant savings when compared to the cost of response and recovery, although these can be difficult to predict with certainty.

5.1 Enhanced Preparedness

One aspect of community protection preparedness in advance of extreme events. The study has shown that the creeks that affect Chetwynd are particularly prone to relatively long duration rainfall events which produce significant volumes of rainfall over periods of 1 or more days. Preparedness would include weather monitoring to identify potential long duration rainfall events, combined with advanced warning to ensure that the types of equipment needed for gravel and debris control are at the ready.

5.2 Debris Management

The study has shown that debris is a primary cause of flood hazards and risks in the community. The two watersheds have considerable capacity to generate large quantities of floating woody debris, which can block some of the crossing structures, and cause both localized flooding, and overflows to parts of the community that would not normally experience flood flows.

Debris management can be achieved through the use of debris barriers, such as those manufactured by Geobrugg. An example of a debris net installed in Cougar Creek near Canmore, AB is shown in Figure 20. The barrier is manufactured of high tensile strength flexible rings designed to withstand the dynamic and static loads associated with mobilized debris. The barrier is supported on mid-channel structural supports and anchored in place with spiral rope anchors. They are suitable for channel widths up to 25 m and barrier heights of 6 m.

In order to protect the community, a debris barrier could be located in each of the Windrem Creek and Widmark Creek channels near the location where the channels make the transition from gulley to fan. Possible locations are shown on Figure 21 for Windrem Creek, and Figure 22 for Widmark Creek.

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Figure 20 – Debris Net, Canmore Alberta (courtesy of Geobrugg)

Figure 21 – Windrem Creek Debris Location Options

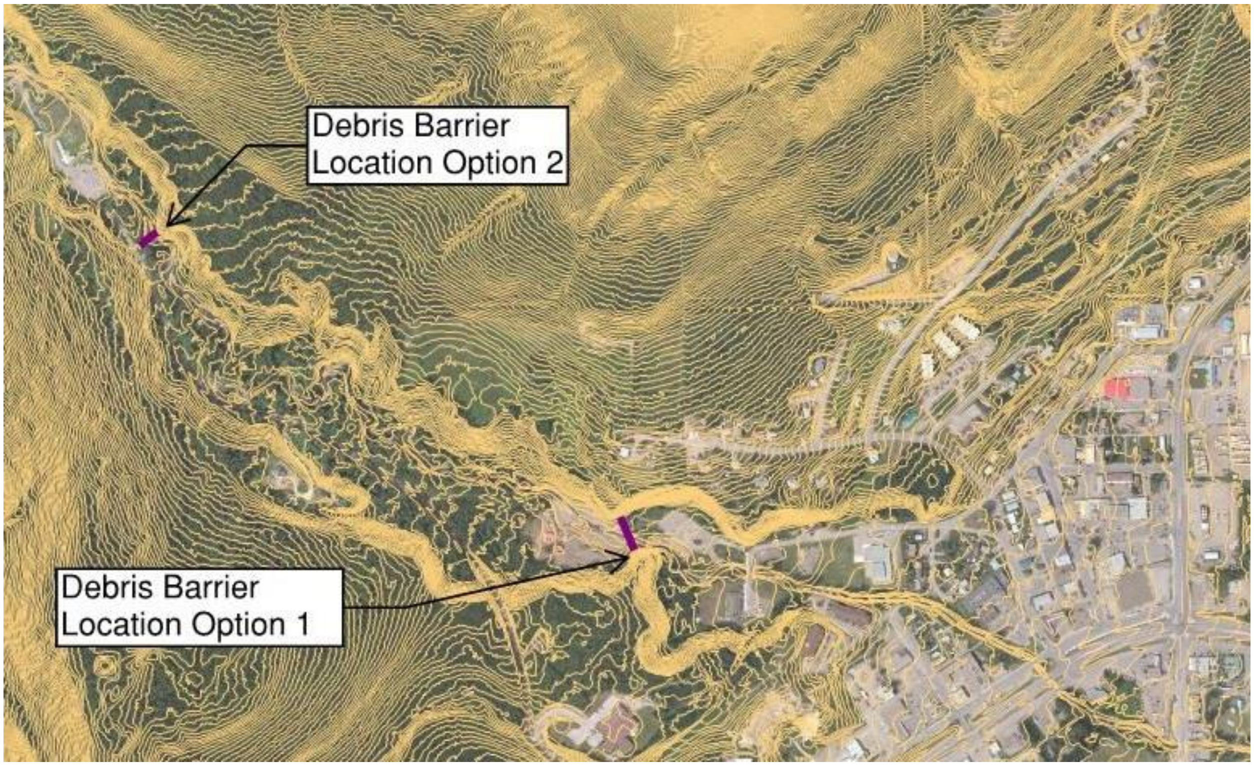


Figure 22 – Widmark Creek Debris Location

5.3 Gravel and Sediment Management

The accumulation of gravel and sediment in an active creek bed as a result of natural sediment transport and deposition is known as aggradation. This can increase flood hazards on alluvial fans by filling the channel and causing localized overtopping of the channel banks. Aggradation is known to be an ongoing issue in both Windrem Creek and Widmark Creek, and recent flood events have required the removal of considerable quantities of gravel during the flood event.

The modelling has also shown that channel capacity is insufficient in some locations, and that gravel removal is the most effective way of restoring channel capacity. Environmentally appropriate in-stream sediment management program should be an important part of Chetwynd's flood hazard mitigation program, and should begin with a program to monitor sediment accumulation in the creek channels to track when deposition has resulted in reduced discharge capacity. This should be seen as the beginning of a program aimed at understanding the sediment balance, and will require ongoing gravel surveys, sediment budget reviews, and flood profile re-modelling.

Sediment transport is a natural process, and interference in the process through the artificial removal of gravel can result in unexpected and unintended consequences, such as erosion or sediment deposition in other places in the channel that might create problems, and harm to valuable aquatic habitat. As a result, careful consideration needs to be given to the scale of intended actions. The ongoing removal of gravel in small amounts that are comparable to the amount of incoming bed material can be used as an approach to maintain a creek's water surface profile at an acceptable level. However, removing significant quantities of sediment to immediately lower the water surface profile will entail much larger excavations with greater environmental impact and more potential for unintended consequences.

There is one location on Windrem Creek where immediate action should be taken, and this is immediately upstream of the 50th Street bridge. This location is particularly prone to gravel accumulation because the channel slope becomes flatter at this location, and the channel also becomes wider, which reduces the shear stress on the creek gravels. There is evidence that the hydraulic capacity of the bridge has been compromised over time through the accumulation of gravel under the bridge itself as shown on Figure 23.

Figure 23 – Gravel Accumulation Under 50th Street Bridge

In addition to the removal of accumulated gravel in specific problem locations, the management of sediment through the use of in-channel sediment traps should be considered on both Windrem and Widmark Creek. Sediment traps are essentially enlargements in the channel, which capture sediments being transported by the creek before it can reach other areas that are prone to deposition. Sediment traps could be constructed in conjunction with the debris barriers described earlier.

Because gravel removal operations have the potential to impact riparian habitat, instream habitat, and fisheries resources, these operations must be conducted in accordance with provincial and federal requirements. In order to acquire the required approvals for the works, the following should be completed:

- Description of proposed works.
- Assessment of ecosystem components/habitat types and potential for impacts to species at risk and fisheries resources in the project area.
- Identification of appropriate timing windows for the protection of migratory birds, wildlife protected under the provincial wildlife act and fisheries resources protected under the provincial Fish Protection Act and federal Fisheries Act.
- Identification of mitigation measures to protect valued ecosystem components including measure to avoid serious harm to fish.

Consideration should also be given to the potential for known and recorded archaeological resources that may be located with proximity to the project area. Any known and recorded archaeological sites can be determined through a search of the BC Integrated Land and Resource Registry.

These items are normally incorporated into an Environmental Management Plan, which is to support applications to the BC Ministry of Forests, Lands and Natural Resource Operations under Section 11 of the Water Sustainability Act/Water Sustainability Regulation, and referrals to Fisheries and Oceans Canada for a Request for Review.

Section 39(1)(h) of the Water Sustainability Regulation allows for “the restoration or maintenance of a stream channel by a municipality or regional district” provided a notification is submitted to a habitat officer at least 45 days before beginning the authorized change and obtain from the habitat officer a statement of terms and conditions under which the authorized change can proceed. It is important to note that the habitat officer can make a determination that the proposed works can only proceed under an “approval” which would require First Nations consultation and a longer review period (up to 140 days or more). For work of this sort, it is prudent to allow for the longer review period.

If, after a project review, Fisheries and Oceans Canada determines that the project will cause serious harm to fish, an application must be made for an Authorization from the Minister of Fisheries and Oceans to ensure compliance with the Fisheries Act. The timeframe for a response to an Authorization application is up to 90 days. The Authorization will result in the need to prepare and implement an “off-setting plan” including an irrevocable letter of credit to guarantee the implementation of the plan.

Where sediment traps will be used to manage the location of gravel deposition, the same applications will be required to be submitted, including engineered drawings. There will also be an additional application in these circumstances for a license under the Water Sustainability Act to divert water.

It is worth noting that any instream work, that is, work that happens within the wetted portion of the channel, will need to be isolated from the flow in the creek at the time of the work. With a small stream such as Windrem Creek and Widmark Creek this can be relatively simple using sandbags and pumps or even a flume or pipe through the work area. Furthermore, the fisheries resources of the creeks are minimal according to the provincial database of fisheries info but it is assumed that rainbow trout and bull trout could be present due to the proximity and connectivity to the Pine River, which is known to contain both species. As a result, it should be assumed that those two species are present in the stream. This means that any instream work will have to be done during the fisheries window, which is July 15th to August 15th. To further complicate matters, it is typically necessary to remove any riparian vegetation that needs to be removed for site access prior to April 15th so that delays do not occur due to nesting birds. The removal of the vegetation prior to the nesting period prevents nesting bird from being present during the work window.

5.4 Improve Hydraulic Conditions at Crossings

There are five locations where the existing creek crossing structures have insufficient capacity to convey the estimated peaks flows as calculated based on historic data. The following is a summary of the conditions that cause the insufficient capacity.

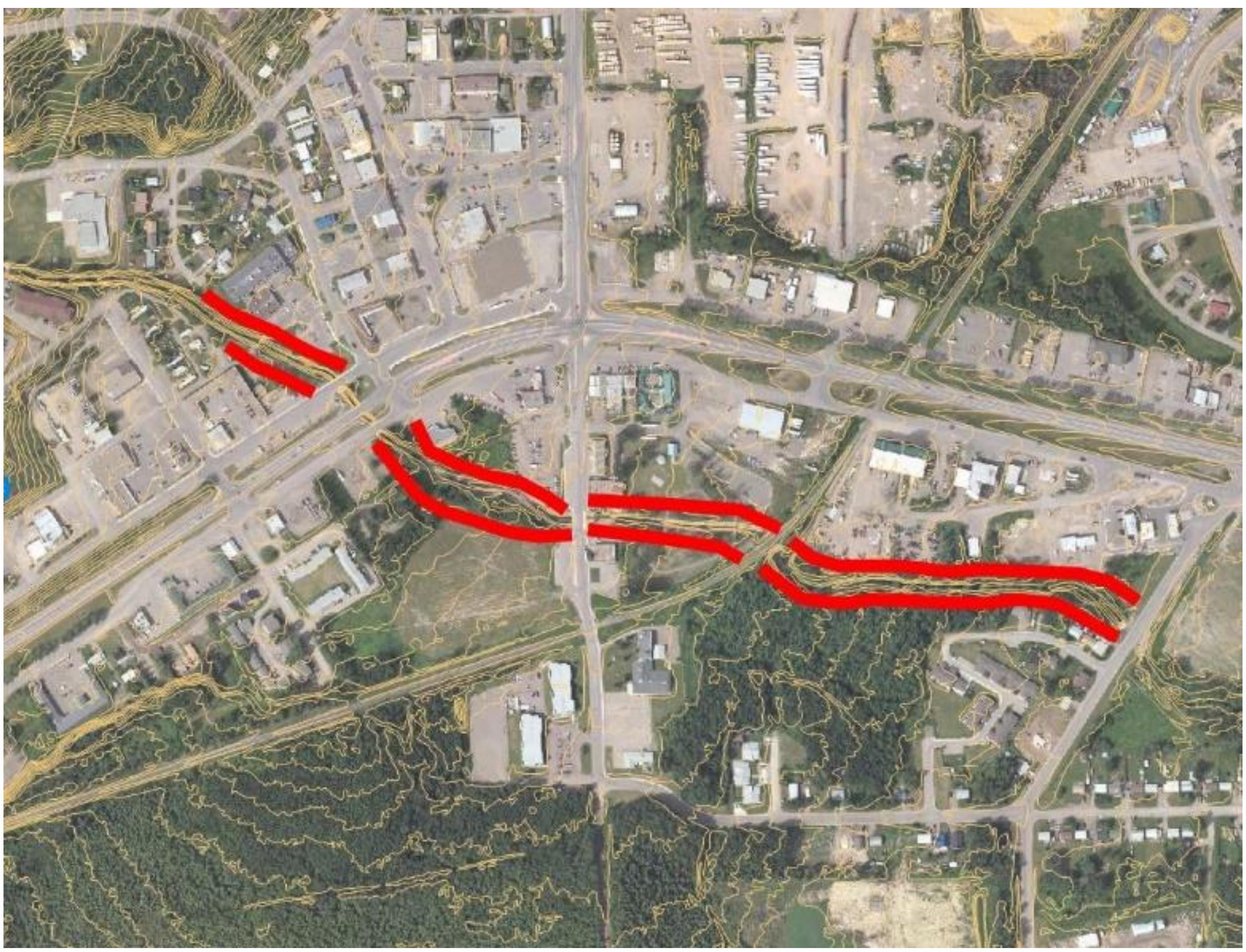
- Highway 29 culvert – the culvert is undersized for the estimated peak extreme event flows. Even without the risk of blockage by floating debris, this culvert will be overwhelmed during the extreme flows, and will cause flood waters to flow to the southwest, and overtop Highway 29 approximately 100 m from the crossing location. This will cause uncontrolled flooding of properties immediately south of Highway 29 as is known to have occurred during the 2016 flood.
- CN Rail culverts in Spirit Park – even though there are multiple culverts, the crossing is undersized for the estimated peak extreme event flows. Even without the risk of blockage by floating debris, these culverts will be overwhelmed during the extreme flows, and will cause flood waters to flow to the southeast, and overtop the railway where it crosses the South Access Road. This will cause uncontrolled flooding of properties immediately south of the John Hart Highway as is known to have occurred during the 2016 flood.
- Wabi Crescent culvert – the culvert is undersized and will not pass the extreme event flow. At this location, the culvert is located at a sag in the road and could be allowed to overtop as long as the upstream and downstream faces of the crossing were protected to prevent the overflow from eroding the embankment.
- 50th Street bridge – the bridge opening is insufficient to pass the extreme event flows, but could be remedied by removing accumulated gravel and enlarging the waterway under the bridge.

5.5 Flood Protection Berms

There are some areas that would benefit from the construction of flood protection berms. These would be designed and constructed in accordance with provincial dike design guidelines, and would become flood protection works under the provincial dike and drainage act. The District of Chetwynd would become the diking authority, and would be responsible for the construction and ongoing operation and maintenance of the berms.

For Windrem Creek, that areas that would benefit from the construction of flood protection berms in order to contain the extreme event flows are located in the core of the community. Flood protection berms would contain the flows in the main channel in these areas where water surface elevations are impacted by the road crossings at the John Hart Highway, North and South Access Roads, 50th Street, and Nicholson Road, as well as the CN Railway crossing. Those estimated extent of the flood protection berms are shown in Figure 24.

Figure 24 – Windrem Creek Flood Protection Berms



With respect to Widmark Creek, the area of concern is the future development area on the north side of 44th Avenue NE. The estimated extent of the flood protection berm for this area is shown on Figure 25.

Figure 25 – Widmark Creek Flood Protection Berms

5.6 Restrictions on Further Development in Hazard Areas

The flood hazard maps show the areas most prone to surface flooding and overland flooding. Where possible and practical, development should not be allowed to occur in the flood prone area, for example, low lying areas near Windrem Creek between Nicholson Road and Wabi Crescent. It is unlikely, however, that attempts would be made to develop these areas to begin with.

The development area along Widmark Creek north of 44th Avenue will see further development in the future. In order to protect those properties from flood hazard and risk, developers of parcels in this area should be required to raise their proposed buildings and other valuable assets above the flood hazard level or protect their properties with flood protection berms. It is critical to ensure that the flood protection works of one developer do not impact an adjacent property.

6.0 Cost Estimates

Some of the proposed mitigation measures presented in the previous section have capital costs associated with them, while some have ongoing operation and maintenance (O&M) costs. Those mitigation measures with capital costs include items such as the debris traps, the flood protection berms, and the improvements to hydraulic conditions at affected crossings. Those mitigation measures with ongoing O&M costs include items such as ongoing gravel and debris management.

Order of magnitude capital cost estimates have been prepared for proposed flood protection works, and these have been prepared for future planning purposes.

6.1 Debris Management

This capital project involves the construction of two gravel traps and debris barriers, one on each of Windrem and Widmark Creeks. The estimate of probable costs, including allowances for project contingencies, engineering services and regulatory approvals, is provided in the following table.

Windrem and Widmark Creek Gravel Traps and Debris Barriers Estimate of Probable Project Costs					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Amount**
1	Gravel Trap Excavation	Cubic Meters	4,000	$40.00	$160,000
2	Maintenance Access Roads	Lineal Meters	100	$1,000.00	$100,000
3	Geobrugg Barriers	Each	2	$100,000.00	$200,000
				Subtotal (rounded)	**$460,000**
				Project Contingencies @ 30% (rounded)	**$138,000**
				Engineering Services and Regulatory Approvals @ 20% (rounded)	**$120,000**
				TOTAL	**$718,000**

6.2 Improve Hydraulic Conditions at Crossings

There are four locations where hydraulic conditions require improvement to pass the design flow rates. These include Highway 29, the CN Rail culverts in Spirit Park, the Wabi Crescent culvert, and the 50th Street bridge. In the case of Highway 29 and the CN Rail culverts, the only practical solution is to increase the size of the structures at these locations. However, neither of these is owned by the District, and are instead owned by the BC Ministry of Transportation and CN Railway, respectively. Because the infrastructure at these two locations are owned by other parties, the costs of improving the works have not been estimated. However, both of these parties should be engaged so that they can incorporate the planning for future improvements to their infrastructure.

In the case of Wabi Crescent, the configuration of the crossing is such that the flows during extreme events can be passed over the roadway and does not require the complete removal and replacement of the existing culvert. However, in order to project the roadway during an extreme event, the upstream and downstream faces of the roadway embankment should be protected with riprap armour, or some other comparable erosion control product, in order to prevent erosion during an overtopping event. The estimate of probable project costs for these improvements is provided in the following table.

Wabi Crescent Erosion Protection Measures Estimate of Probable Project Costs					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Amount**
1	Clearing and Grubbing	Square Meters	400	$10.00	$4,000
2	Filter Fabric and Riprap Filter	Square Meters	400	$150.00	$60,000
3	Riprap	Square Meters	400	$200.00	$80,000
				Subtotal (rounded)	**$144,000**
				Project Contingencies @ 30% (rounded)	**$43,000**
				Engineering Services and Regulatory Approvals @ 20% (rounded)	**$37,000**
				TOTAL	**$224,000**

In the case of the 50th Street bridge crossing, the hydraulic conditions can be improved by removing accumulated gravel and sediment in the vicinity of the bridge. In addition to the gravel removal, it will be necessary to remove and restore the riprap in the area of the work so that it is properly keyed into the creek channel. The estimated cost of this work if provided in the following table.

50th Street Bridge Gravel Removal Estimate of Probable Project Costs					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Amount**
1	Gravel Removal	Cubic Meters	2,000	$40.00	$80,000
2	Riprap Restoration	Cubic Meters	2,000	$100.00	$200,000
				Subtotal (rounded)	**$280,000**
				Project Contingencies @ 30% (rounded)	**$84,000**
				Engineering Services and Regulatory Approvals @ 20% (rounded)	**$73,000**
				TOTAL	**$437,000**

6.3 Flood Protection Berms

The risks of flooding associated with both Windrem and Widmark Creeks can be mitigated by constructing flood protection berms in certain locations. In the case of Windrem Creek, flood protection berms would be provided for a portion of the creek from 150 m upstream of the North Access Road to Nicholson Road. This

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is a total length of about 1,000, and berms would be required on both sides of the creek channel. The estimate of probable costs for this work is provided in the following table.

Windrem Creek Flood Protection Berms Estimate of Probable Project Costs					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Amount**
1	Site Clearing	Square Meters	30,000	$5.00	$150,000
2	Base Preparation	Square Meters	20,000	$2.00	$40,000
3	Berm Fill	Cubic Meters	1,600	$80.00	$128,000
4	Riprap Armor	Cubic Meters	6,000	$100.00	$600,000
5	Geotextile and Filter	Square Meters	6,000	$50.00	$300,000
6	Site Restoration	Square Meters	16,000	$40.00	$640,000
				Subtotal (rounded)	**$1,858,000**
				Project Contingencies @ 30% (rounded)	**$557,000**
				Engineering Services and Regulatory Approvals @ 20% (rounded)	**$483,000**
				TOTAL	**$2,898,000**

In the case of Widmark Creek, the flood protection berm would be required only on the south side of the creek since the land on the north side of the creek is not at risk of flooding. The area to be protected would extend from 46th Drive NE to the west limit of the development area. This is a length of about 1,000 m, and the estimate of probable costs is provided in the following table.

Widmark Creek Flood Protection Berms Estimate of Probable Project Costs					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Amount**
1	Site Clearing	Square Meters	15,000	$5.00	$75,000
2	Base Preparation	Square Meters	10,000	$2.00	$20,000
3	Berm Fill	Cubic Meters	800	$80.00	$64,000
4	Riprap Armor	Cubic Meters	3,000	$100.00	$300,000
5	Geotextile and Filter	Square Meters	3,000	$50.00	$150,000
6	Site Restoration	Square Meters	8,000	$40.00	$320,000
				Subtotal (rounded)	**$929,000**
				Project Contingencies @ 30% (rounded)	**$279,000**
				Engineering Services and Regulatory Approvals @ 20% (rounded)	**$242,000**
				TOTAL	**$1,450,000**

6.4 Ongoing Gravel and Debris Management

Because Windrem and Widmark Creeks create alluvial fans in the developed area of Chetwynd, they will continue to move significant quantities of gravel and debris over time. With the implementation of a gravel trap and a debris barrier on each creek, as described in section 6.1, most of the debris and gravel management can be carried out at a single location. However, there will almost certainly continue to be some movement of gravel throughout the creek systems, and this will require annual inspections and removal from time to time.

We recommend that an annual allowance of between $20,000 and $50,000 be set aside for annual maintenance of debris and gavel accumulations.

7.0 Conclusions and Recommendations

7.1 Conclusions

Through this flood hazard study, the following conclusions have been reached:

1. Chetwynd has experienced a number of extreme weather events in recent years that have caused considerable damage within the community.
2. Climate change is expected to result in an increase in the frequency of extreme events, which is expected to create greater hazards and risks to the community than in the past.
3. The two study creeks, Windrem Creek and Widmark Creek, are characterised as alluvial fans, and are prone to mobilization of gravel and debris during some runoff events, and especially during extreme events.
4. Crossing structures on the two creek channels, specifically bridges and culverts, are prone to blockage with debris and gravel, which can result in the flows overtopping the creek banks and flooding adjacent properties.
5. Some crossing structures, such as the Highway 29 culvert, the CN Rail culvert, Wabi Crescent Culvert and 50th Street Bridge, have inadequate hydraulic capacity, even without blockage with floating debris and gravel.
6. The creeks are prone to avulsion during extreme events, and would benefit from riprap armour throughout most of the developed area.
7. There are some locations where there is a risk that a flood wave could result from the overtopping of an embankment that becomes overwhelmed by extreme events flows, such as the CN Rail crossing downstream of 50th Street, and the Highway 29 crossing.

7.2 Recommendations

There are a number of mitigation measures that are recommended in order to protect the community against the risks and hazards associated with flooding due to extreme weather events.

1. Enhance community preparedness through the development of an extreme event weather monitoring program.
2. Manage debris generated by the watersheds using debris barriers upstream of the community.
3. Remove accumulated gravel and sediment at specific locations to restore creek channel capacity. Create an ongoing program of gravel and sediment management to prevent future channel capacity inadequacies.
4. Improve hydraulic conditions at some crossings, including Highway 29, 50th Street, CN Rail culverts, and Wabi Crescent.
5. Create flood protection berms at select locations.
6. Restrict future development in flood prone area or require flood proofing in conjunction with development.

8.0 Closure

This report was prepared by Urban Systems Ltd. for the District of Chetwynd. The material in this report reflects the best judgement of Urban Systems Ltd. based on the information available at the time of preparation. Any use by parties not authorized by Urban Systems Ltd., or reliance on or decisions made based on it, are the responsibility of these parties. Urban Systems Ltd. accepts no responsibility for damages, if any, suffered by parties not authorized by Urban Systems Ltd. as a result of decisions made or actions taken as a result of a reliance on the information contained in this report.

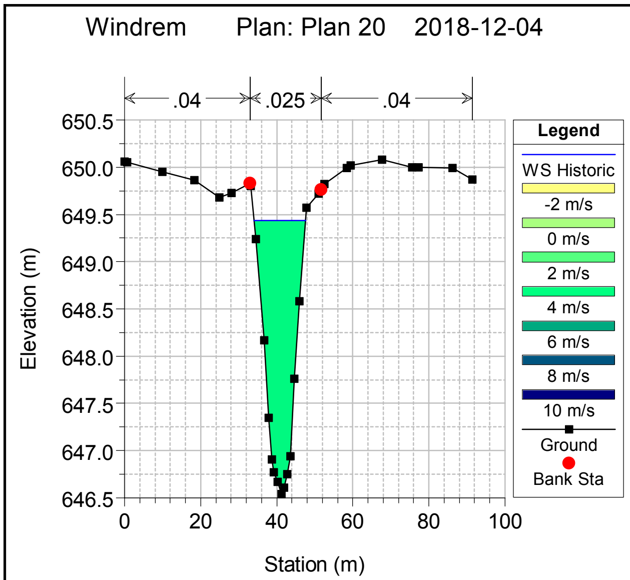
Dec. 4 2018

Cameron Gatey, P.Eng.

Senior Water Resources Engineer

Appendix A

HEC RAS Model Results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.025
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Station (m)
Legend
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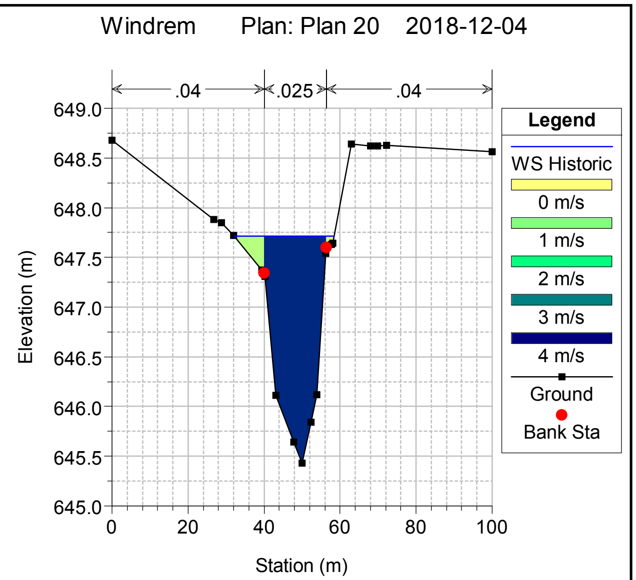
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta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Station (m)
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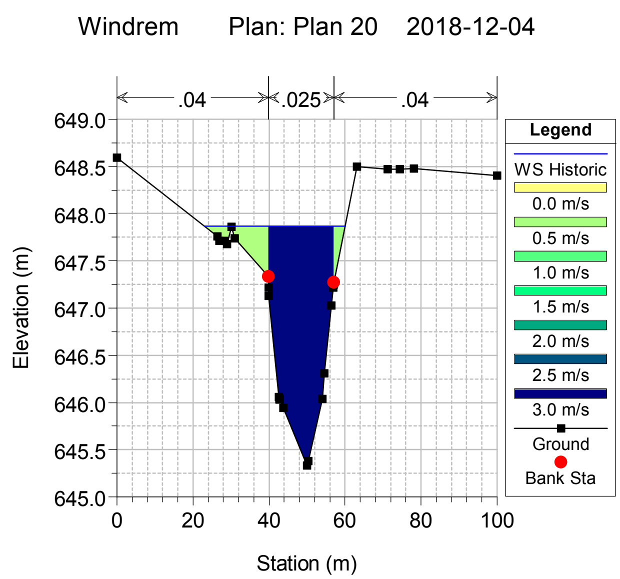
4 m/s
Ground
Bank Sta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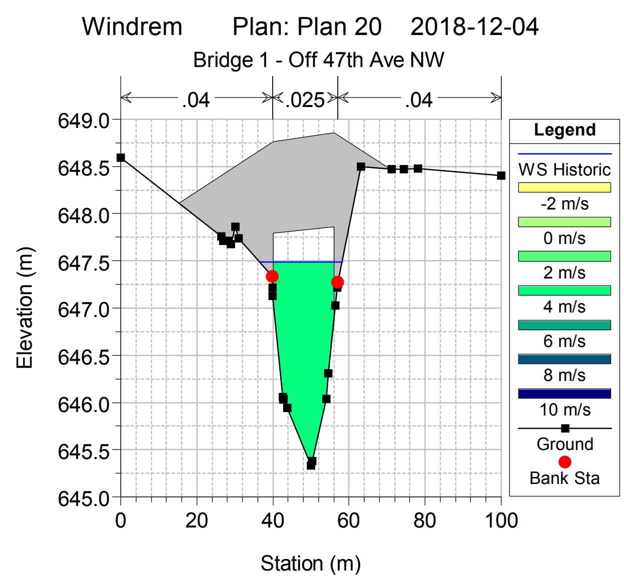
Ground
Bank Sta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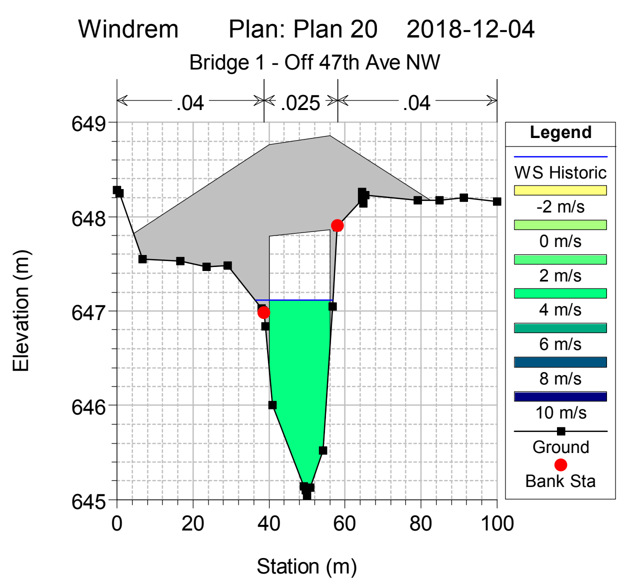
Ground
Bank Sta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Station (m)
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Ground
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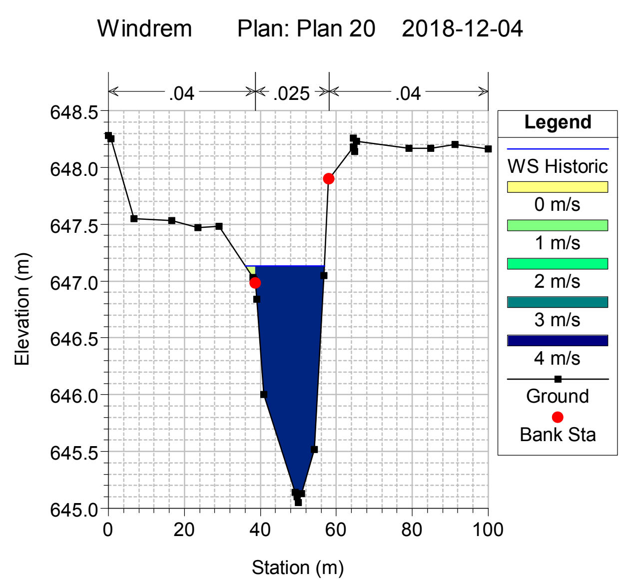
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Ground
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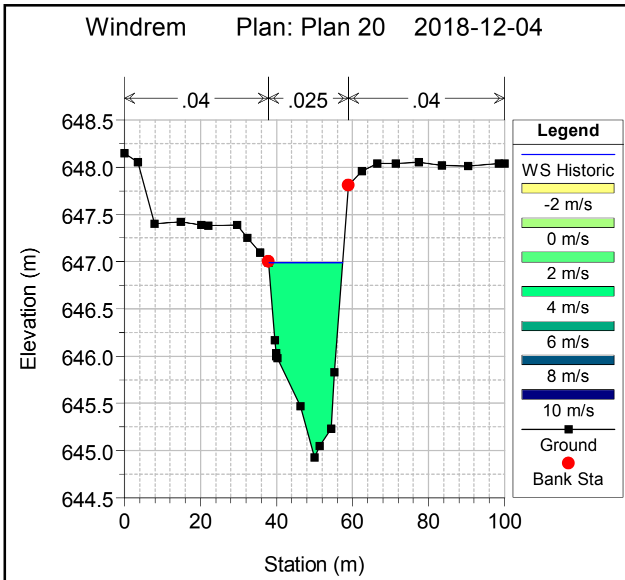
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Station (m)
Legend
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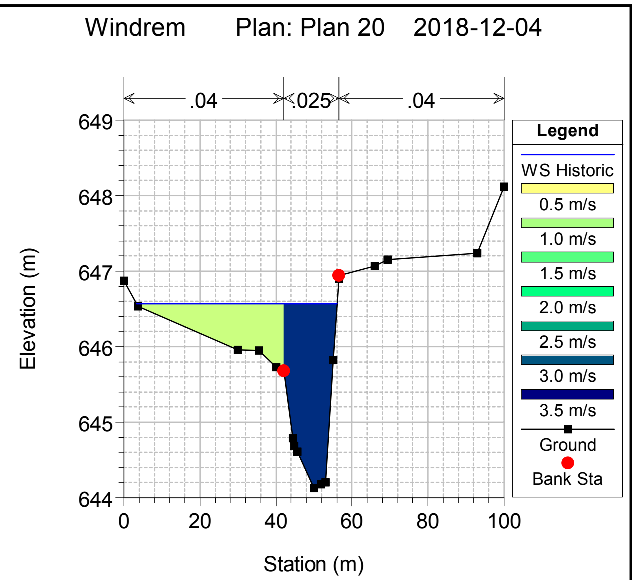
Ground
Bank Sta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Station (m)
Legend
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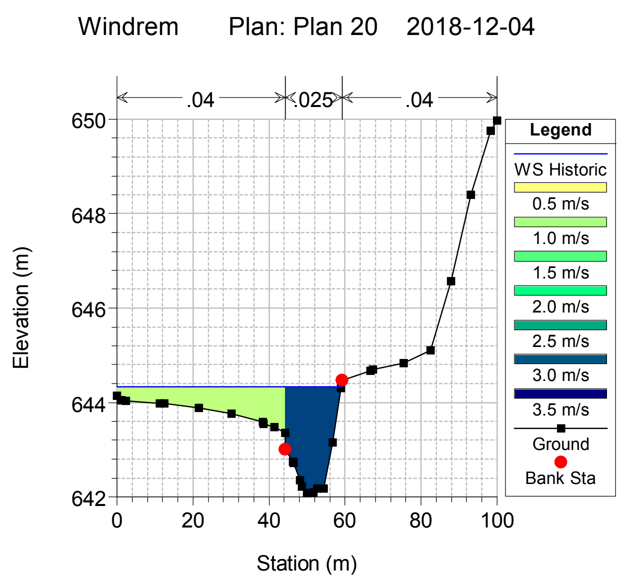
3.5 m/s
Ground
Bank Sta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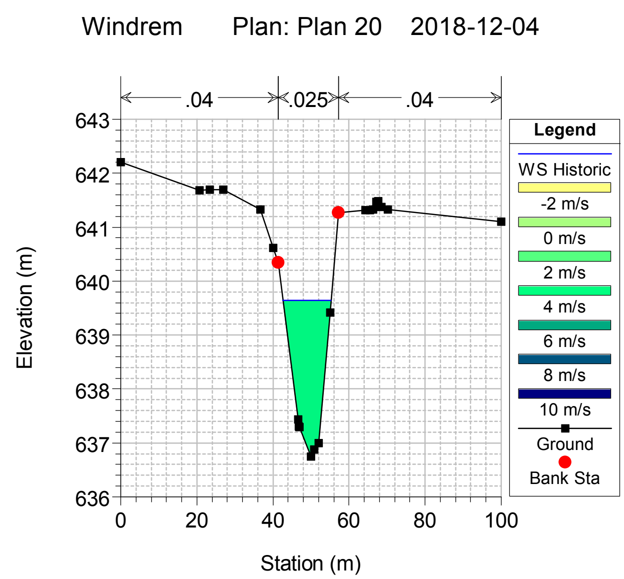
3.0 m/s
3.5 m/s
Ground
Bank Sta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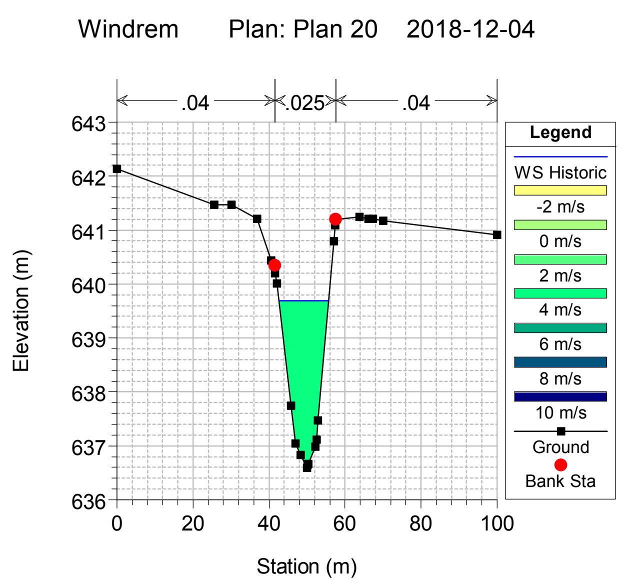
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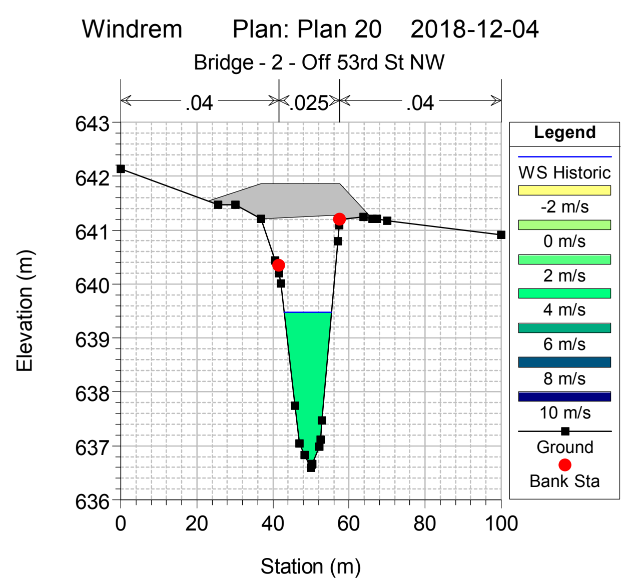
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Station (m)
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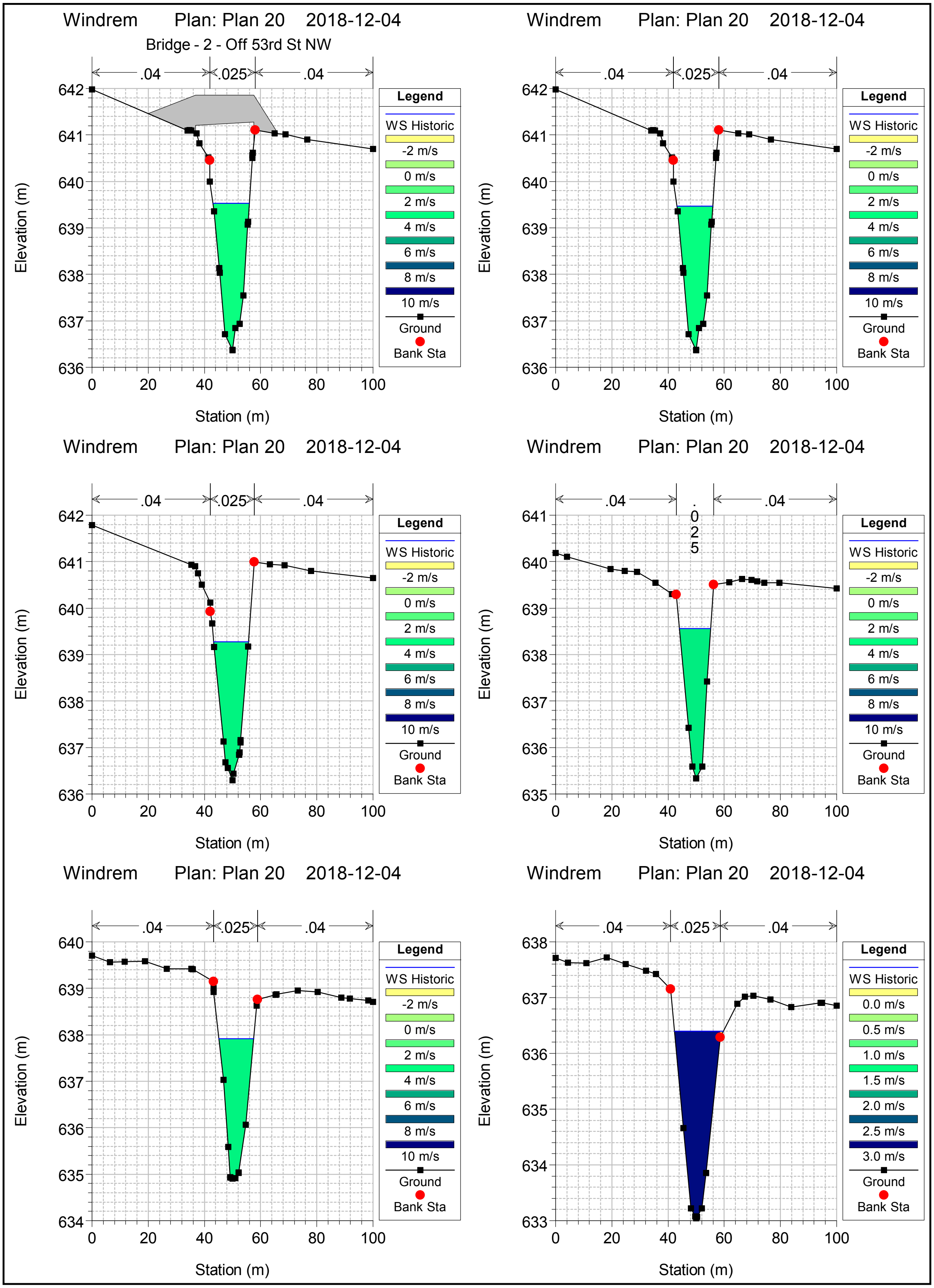
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta



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Bridge - 2 - Off 53rd St NW
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Legend
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4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta
Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
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Legend
WS Historic
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Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
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Elevation (m)
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Windrem Plan: Plan 20 2018-12-04
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Windrem Plan: Plan 20 2018-12-04
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Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
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Legend
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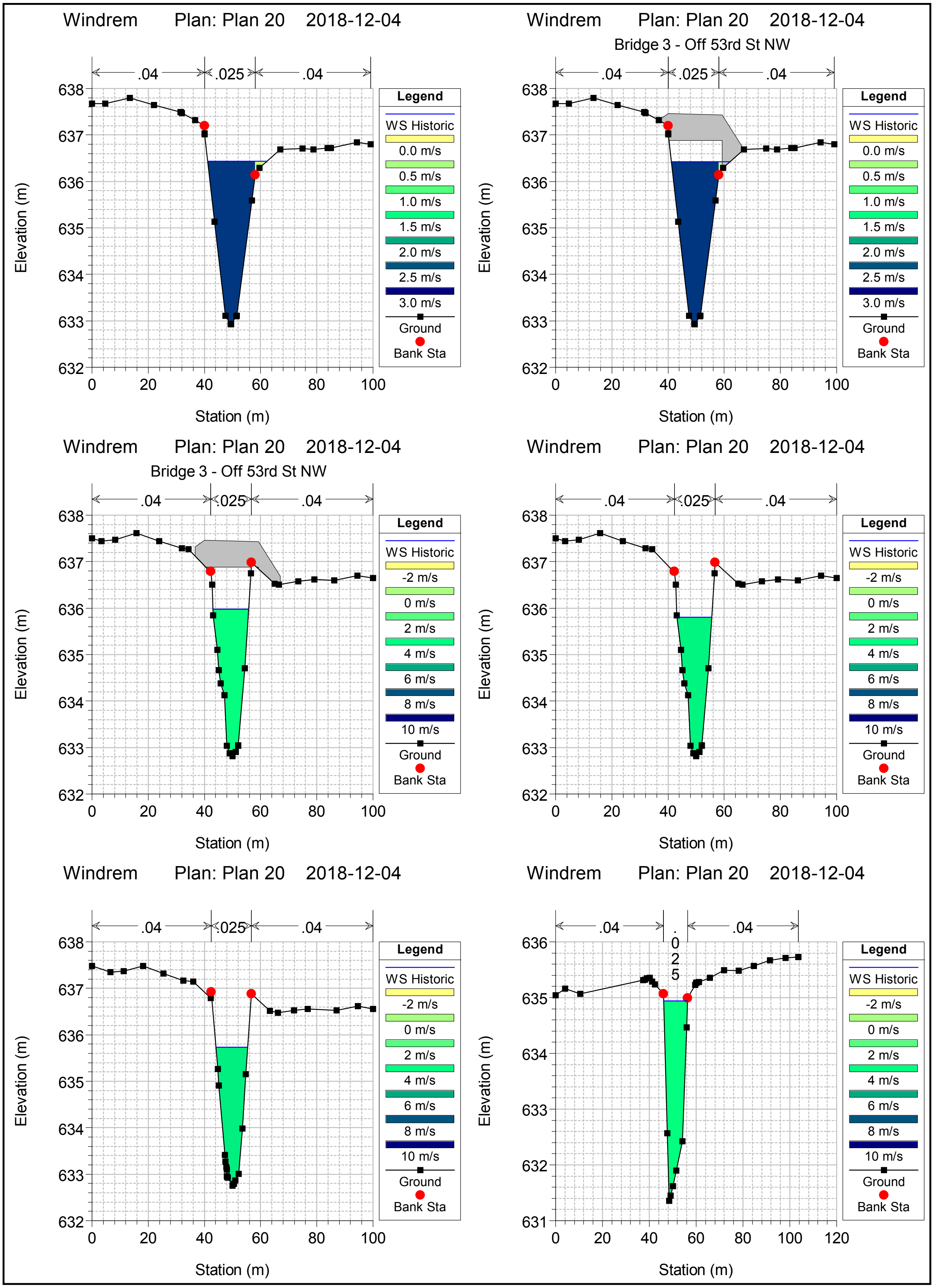
Ground
Bank Sta
Elevation (m)
Station (m)



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2.0 m/s
2.5 m/s
3.0 m/s
Ground
Bank Sta
Windrem Plan: Plan 20 2018-12-04
Bridge 3 - Off 53rd St NW
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.025
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Elevation (m)
Station (m)
Legend
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2.5 m/s
3.0 m/s
Ground
Bank Sta
Windrem Plan: Plan 20 2018-12-04
Bridge 3 - Off 53rd St NW
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Station (m)
Legend
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10 m/s
Ground
Bank Sta
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Station (m)
Legend
WS Historic
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4 m/s
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Bank Sta
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Station (m)
Legend
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4 m/s
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8 m/s
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Ground
Bank Sta
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Elevation (m)
Station (m)
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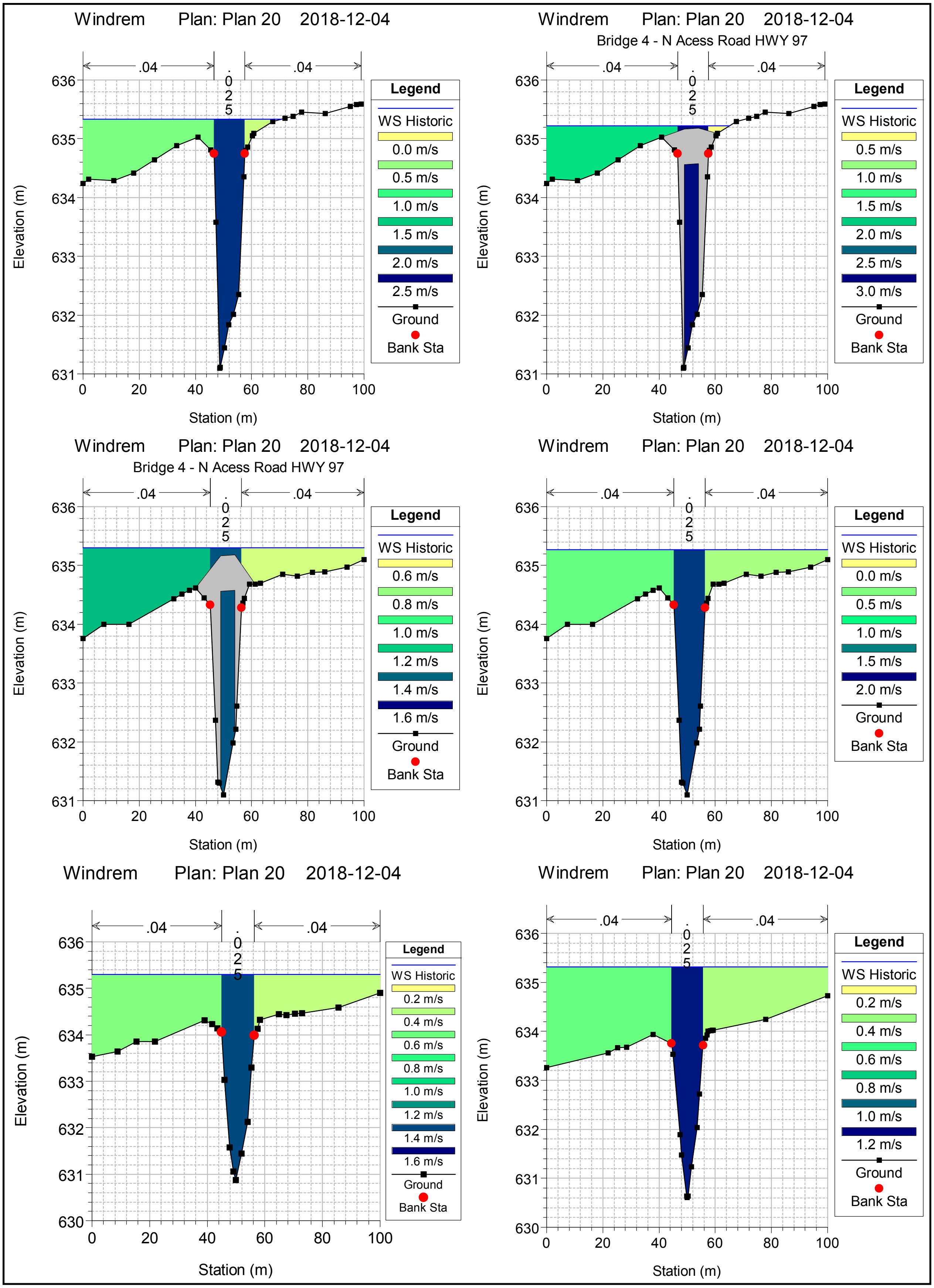

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Ground
Bank Sta
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Legend
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2.5 m/s
3.0 m/s
Ground
Bank Sta
Windrem Plan: Plan 20 2018-12-04
Bridge 4 - N Acess Road HWY 97
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1.2 m/s
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Ground
Bank Sta
Windrem Plan: Plan 20 2018-12-04
Legend
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Ground
Bank Sta
Windrem Plan: Plan 20 2018-12-04
Legend
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Ground
Bank Sta
Windrem Plan: Plan 20 2018-12-04
Legend
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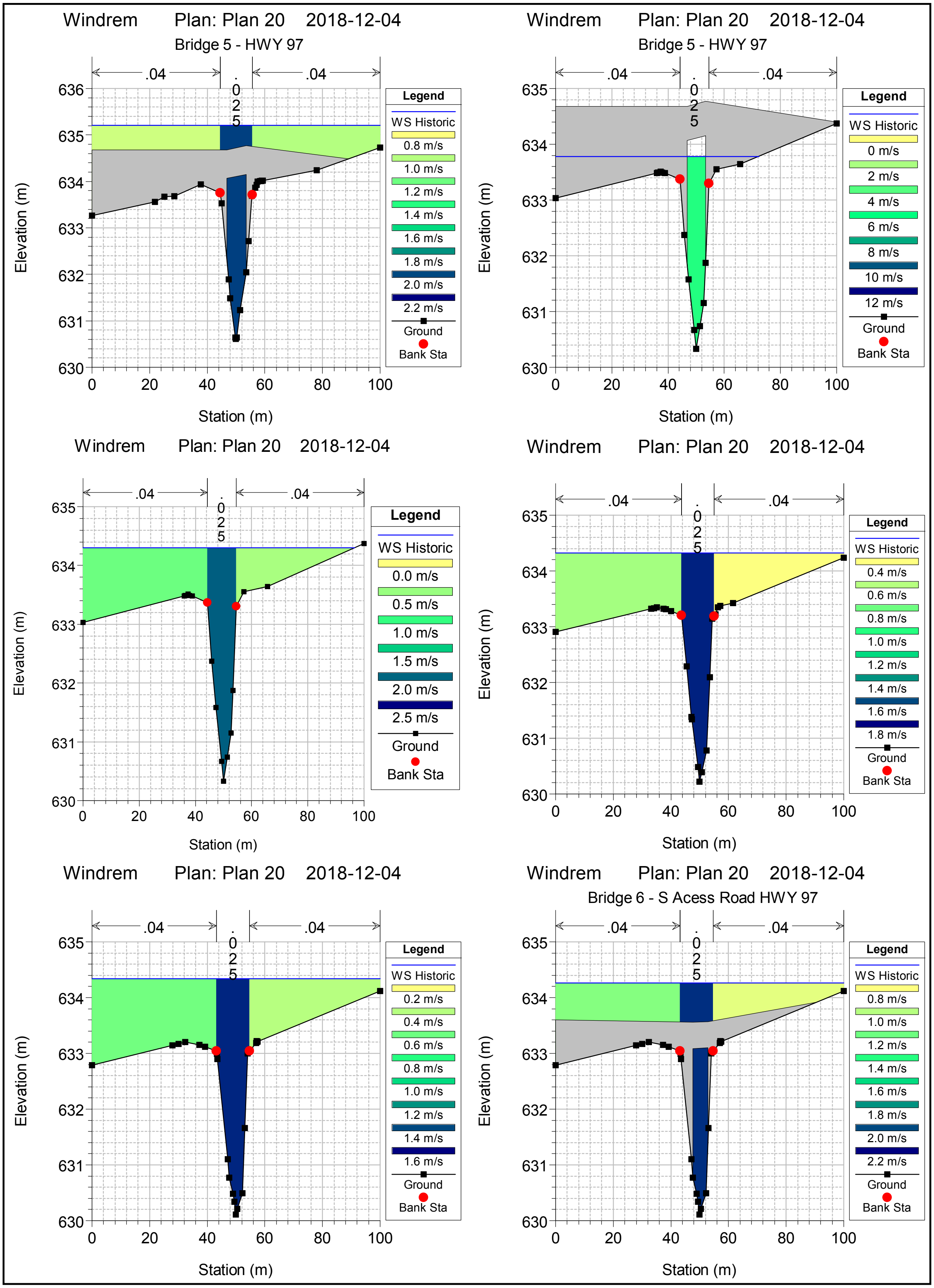

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2.2 m/s
Ground
Bank Sta
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.04
.025
.04
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Station (m)
Legend
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10 m/s
12 m/s
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Bank Sta
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.04
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.04
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Station (m)
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1.5 m/s
2.0 m/s
2.5 m/s
Ground
Bank Sta
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Station (m)
Legend
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1.2 m/s
1.4 m/s
1.6 m/s
1.8 m/s
Ground
Bank Sta
Windrem Plan: Plan 20 2018-12-04
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Station (m)
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Bank Sta
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Station (m)
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Ground
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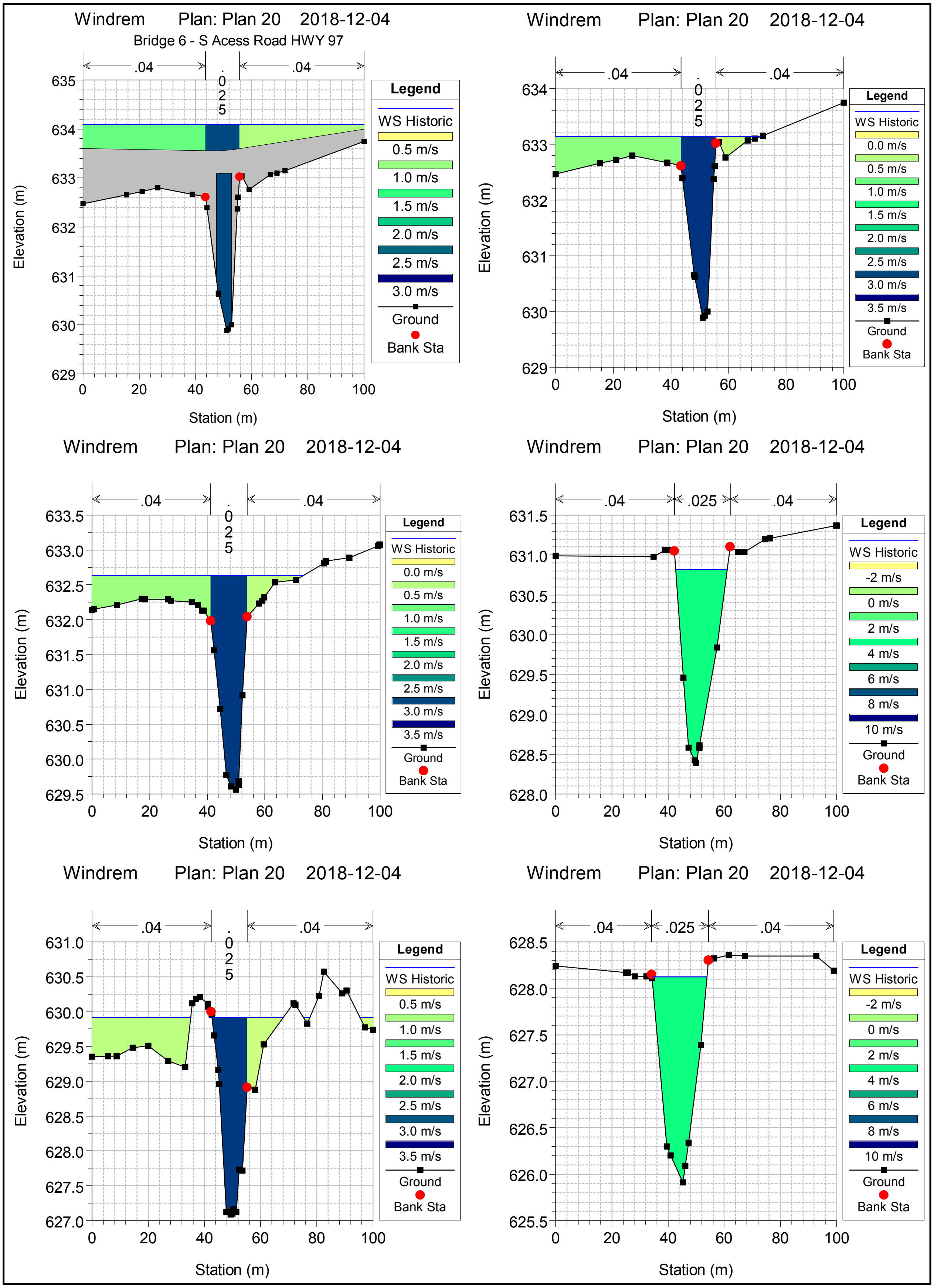

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2.5 m/s
3.0 m/s
Ground
Bank Sta
Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
Legend
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3.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
Elevation (m)
Station (m)
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Legend
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6 m/s
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10 m/s
Ground
Bank Sta
Elevation (m)
Station (m)
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Elevation (m)
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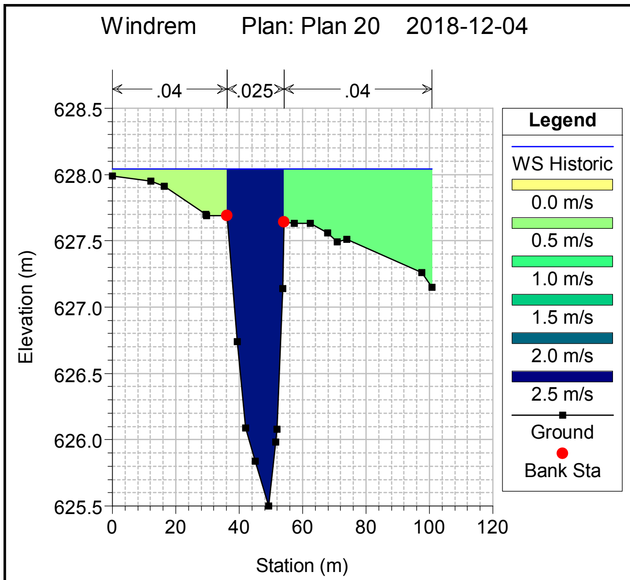
Elevation (m)
Station (m)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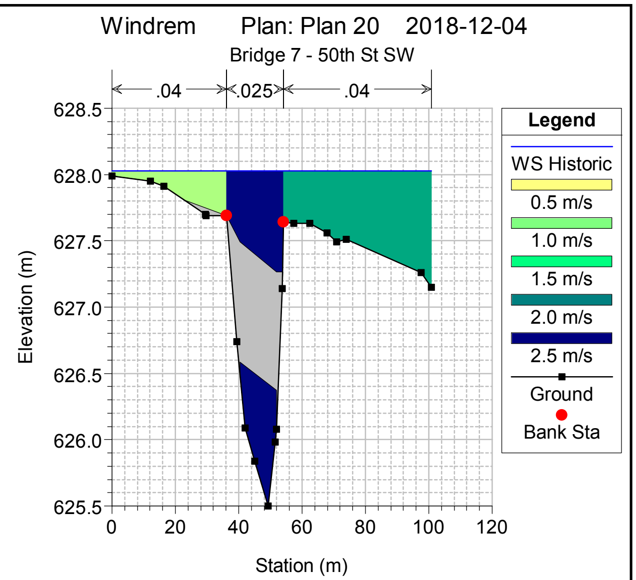
Ground
Bank Sta
Elevation (m)
Station (m)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Ground
Bank Sta
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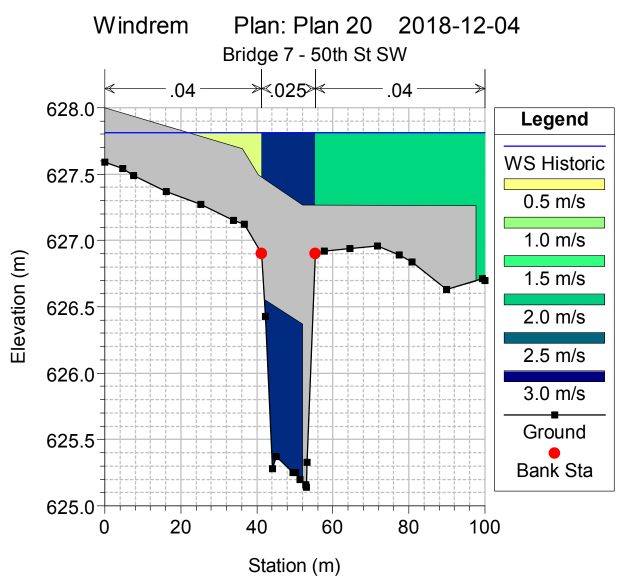
Station (m)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Bridge 7 - 50th St SW
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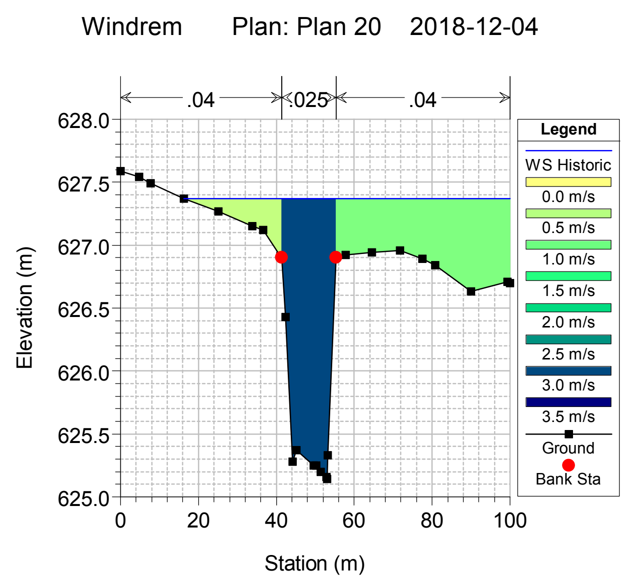
Ground
Bank Sta
Elevation (m)
Station (m)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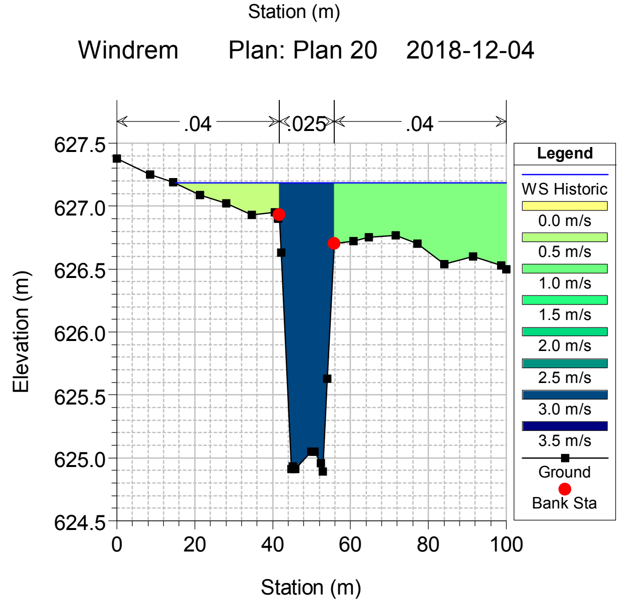
Ground
Bank Sta
Elevation (m)
Station (m)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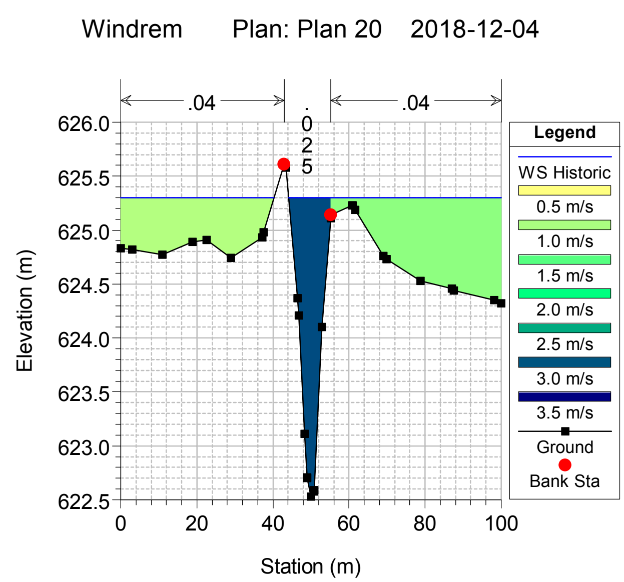
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Windrem Plan: Plan 20 2018-12-04
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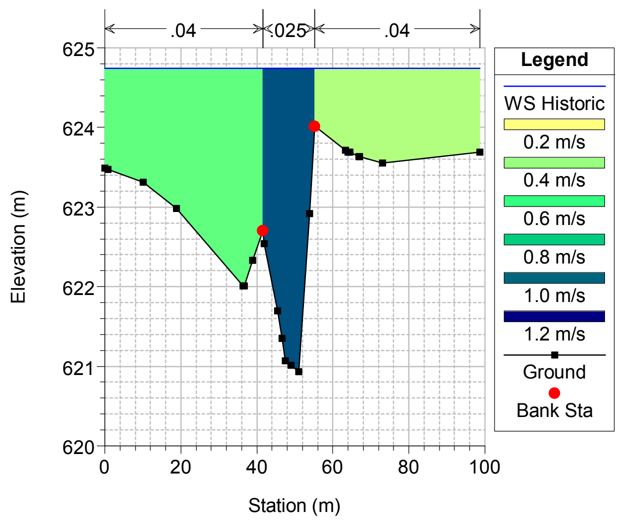
Legend
WS Historic
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)

Windrem Plan: Plan 20 2018-12-04



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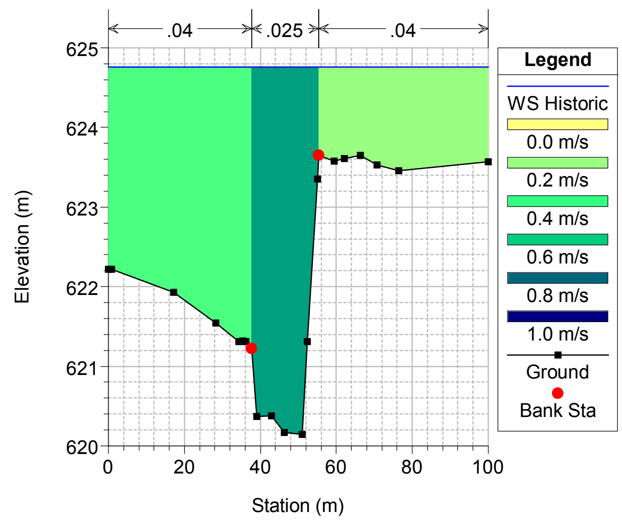
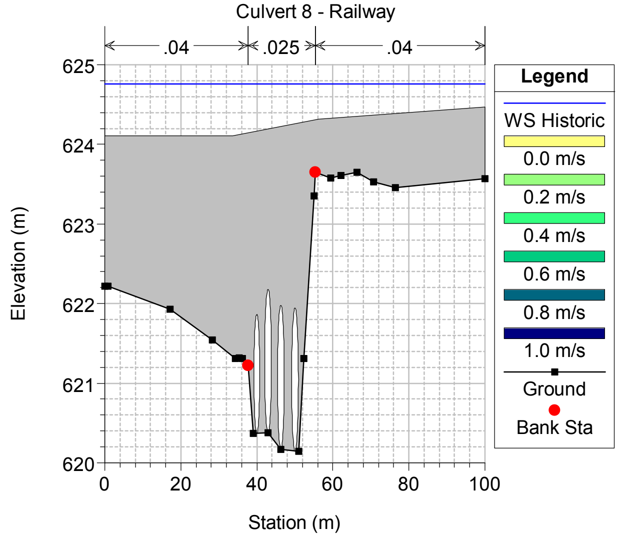


Windrem Plan: Plan 20 2018-12-04

Culvert 8 - Railway



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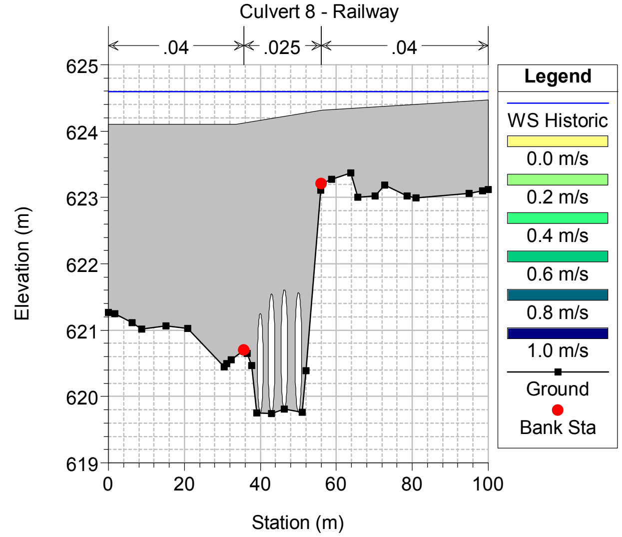
Culvert 8 - Railway



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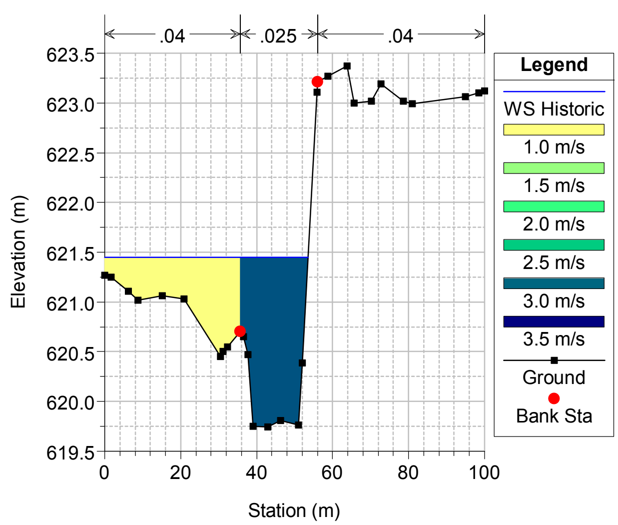

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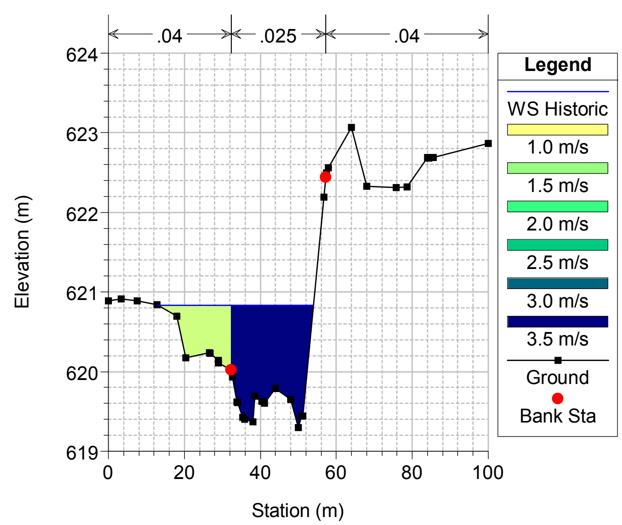

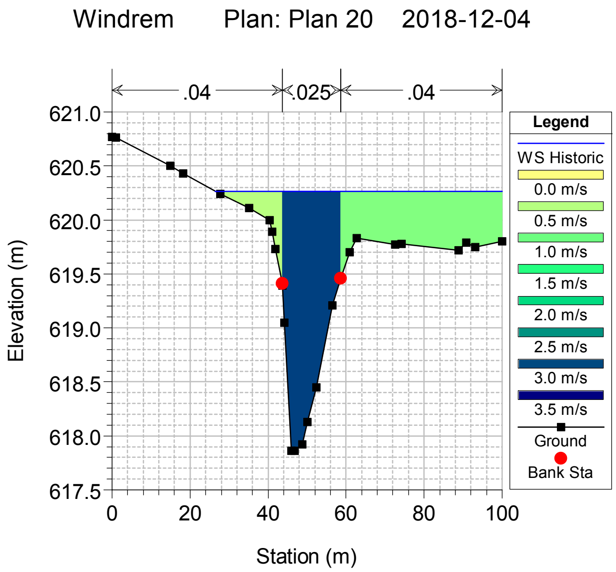
Windrem Plan: Plan 20 2018-12-04
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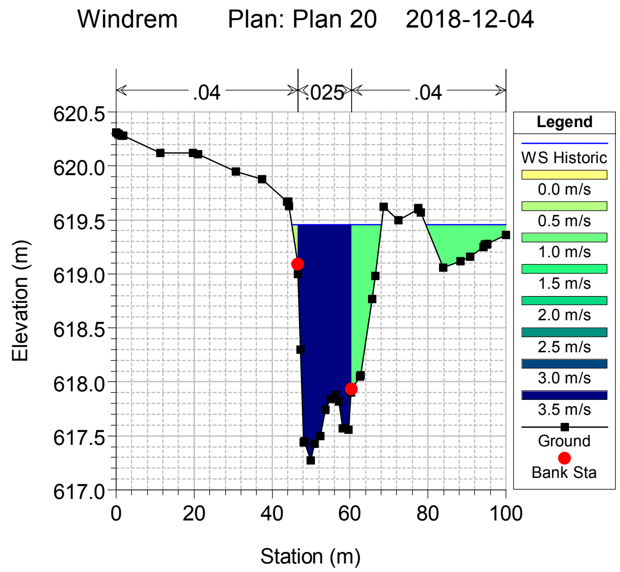
Elevation (m)
Station (m)
Legend
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
WS Historic
0.0 m/s
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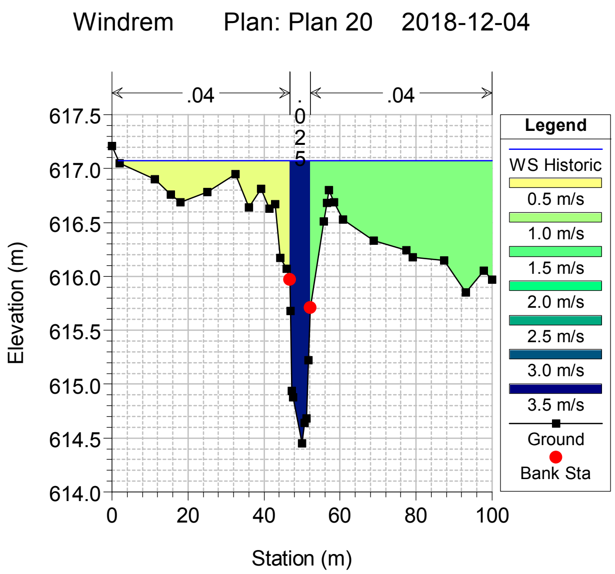
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
WS Historic
0.5 m/s
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1.5 m/s
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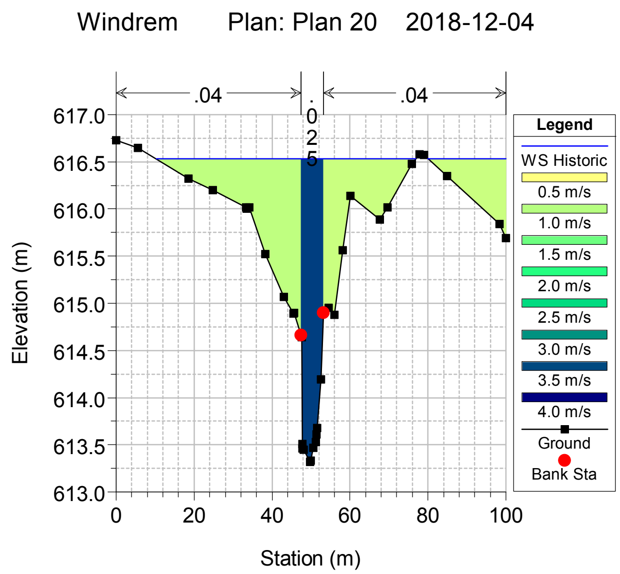
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta


Windrem Plan: Plan 20 2018-12-04
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Elevation (m)
Station (m)
Legend
WS Historic
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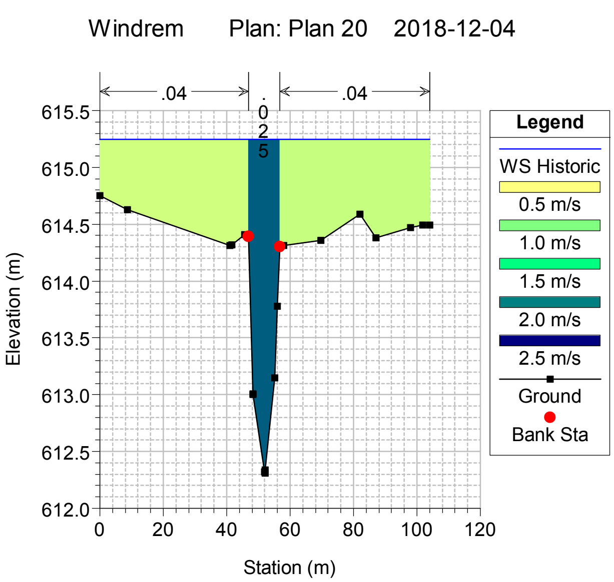
3.0 m/s
3.5 m/s
4.0 m/s
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
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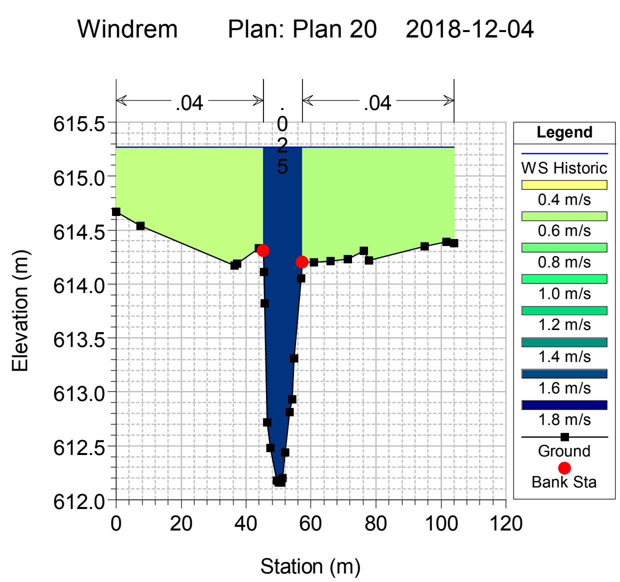
2.0 m/s
2.5 m/s
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
WS Historic
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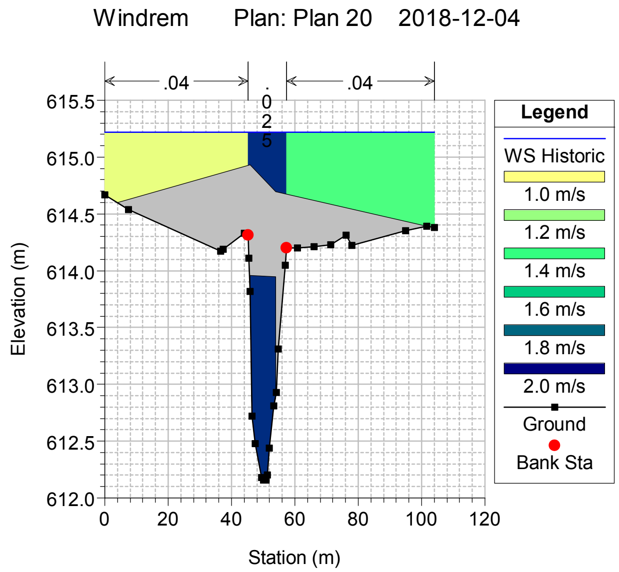
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
1.4 m/s
1.6 m/s
1.8 m/s
Ground
Bank Sta


Windrem Plan: Plan 20 2018-12-04
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Elevation (m)
Station (m)
615.5
615.0
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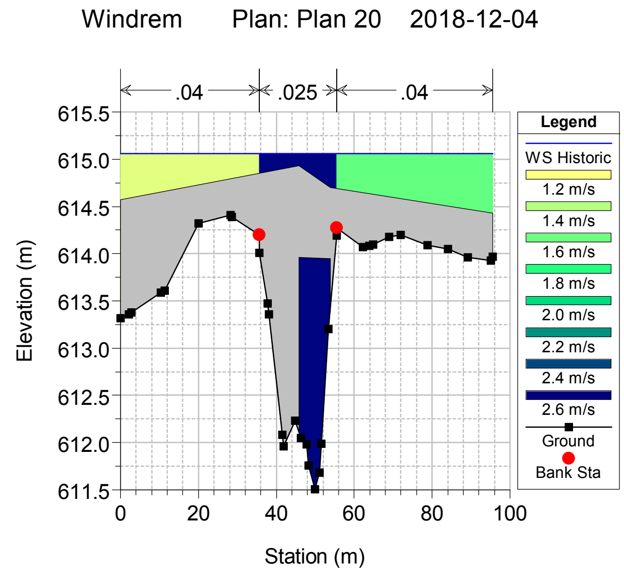
612.5
612.0
0 20 40 60 80 100 120
Legend
WS Historic
1.0 m/s
1.2 m/s
1.4 m/s
1.6 m/s
1.8 m/s
2.0 m/s
Ground
Bank Sta


Windrem Plan: Plan 20 2018-12-04
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Elevation (m)
Station (m)
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0 20 40 60 80 100
Legend
WS Historic
1.2 m/s
1.4 m/s
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2.0 m/s
2.2 m/s
2.4 m/s
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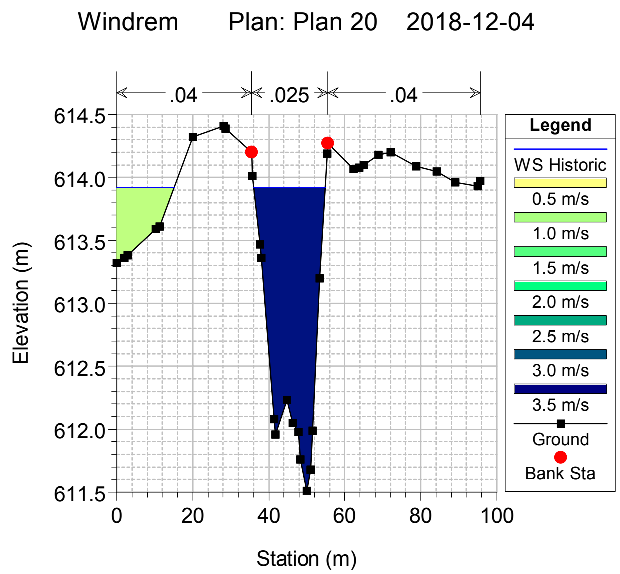
Ground
Bank Sta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Elevation (m)
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Legend
WS Historic
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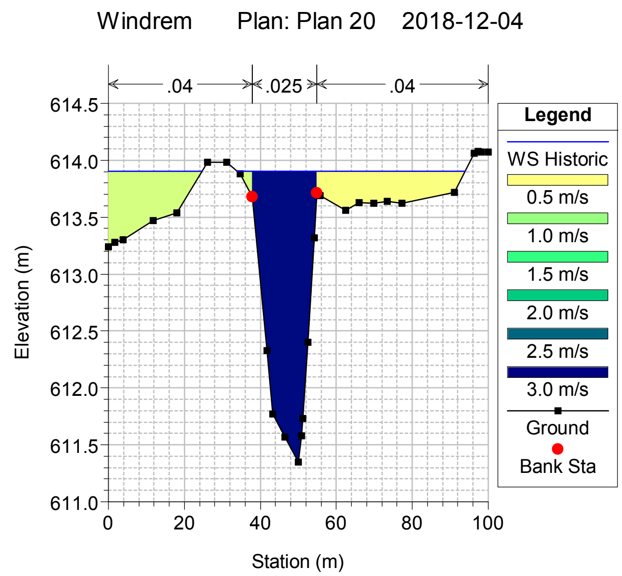
Ground
Bank Sta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Elevation (m)
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Legend
WS Historic
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Ground
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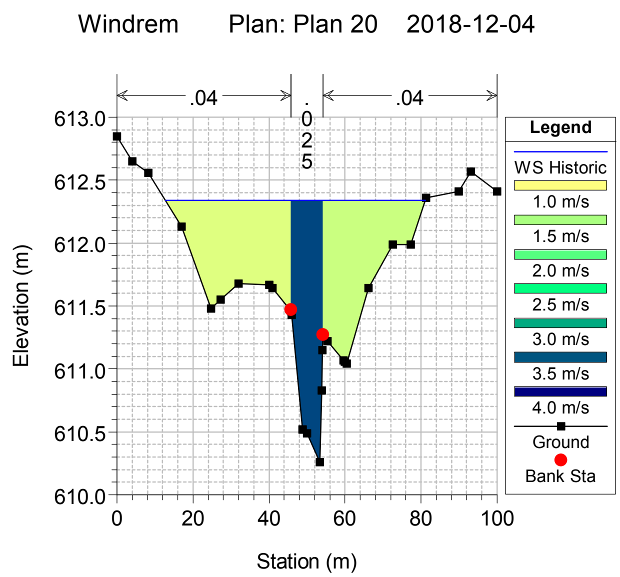
Windrem Plan: Plan 20 2018-12-04
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Elevation (m)
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0 20 40 60 80 100
Legend
WS Historic
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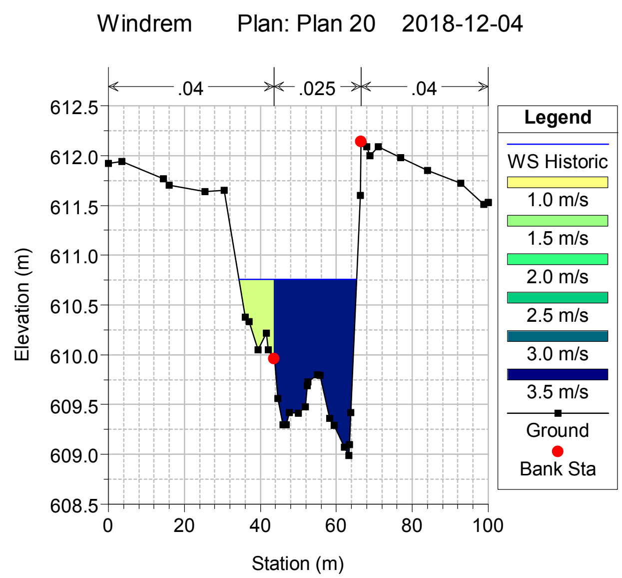
Ground
Bank Sta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Elevation (m)
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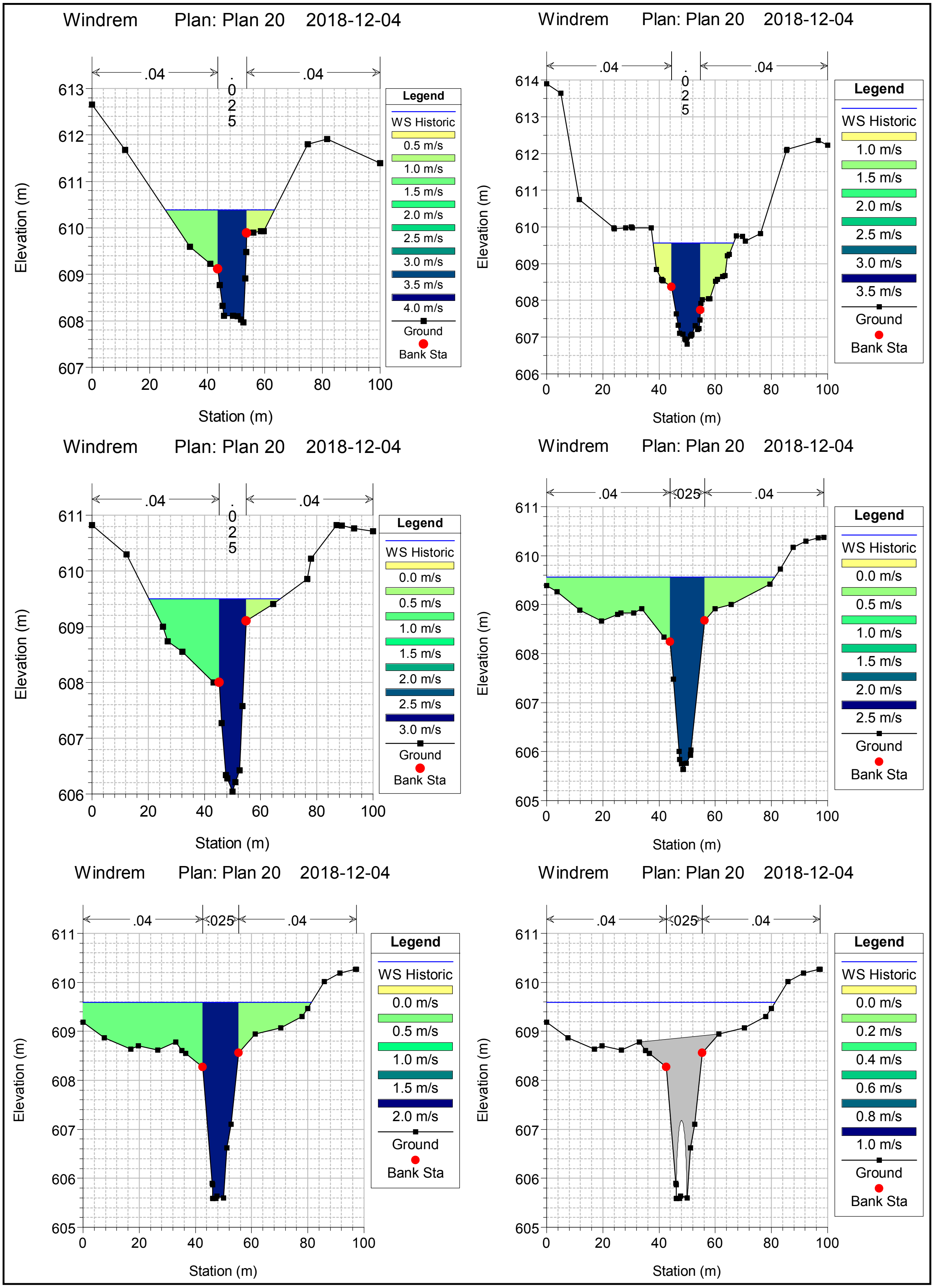
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Windrem Plan: Plan 20 2018-12-04
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Legend
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Windrem Plan: Plan 20 2018-12-04
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Windrem Plan: Plan 20 2018-12-04
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Windrem Plan: Plan 20 2018-12-04
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WS Historic
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Station (m)
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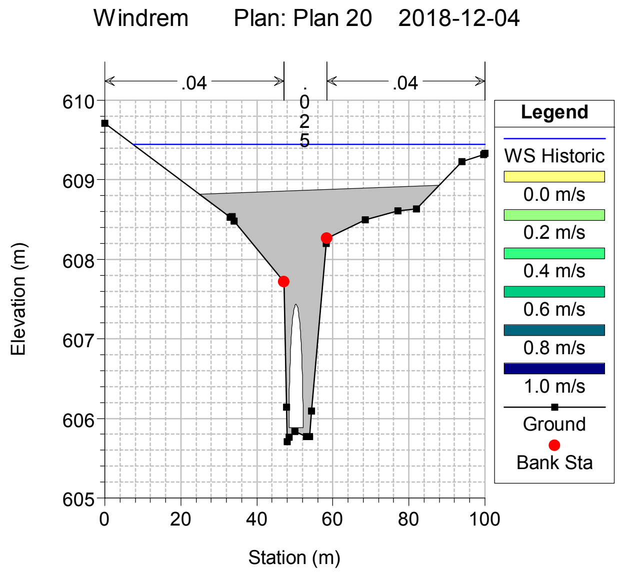
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Elevation (m)
Station (m)
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Ground
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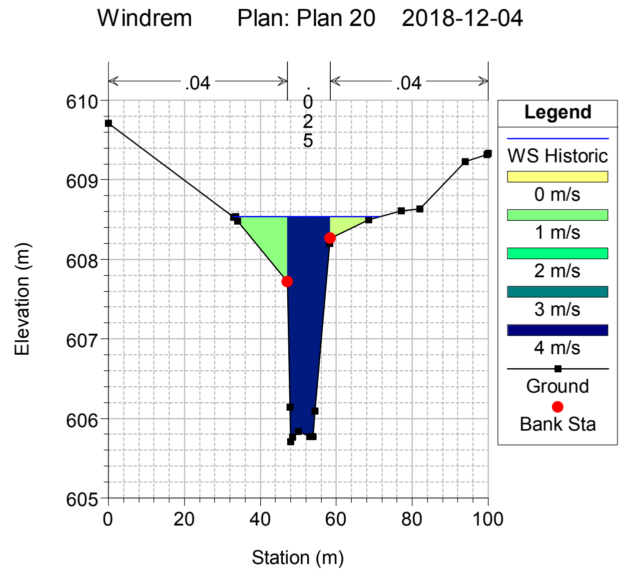
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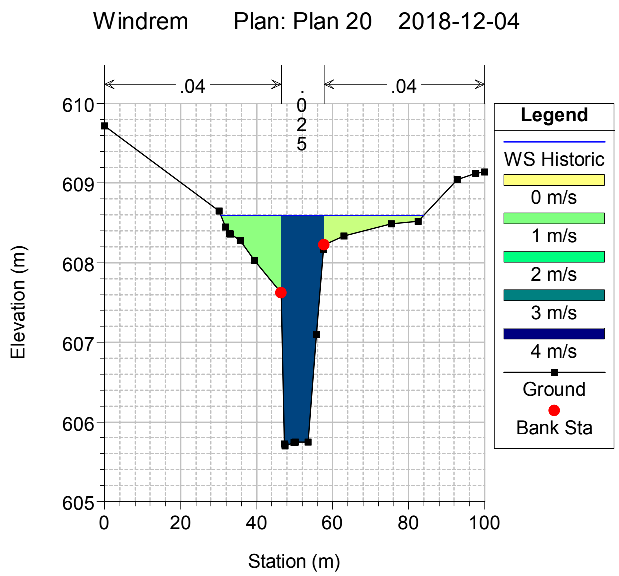
Ground
Bank Sta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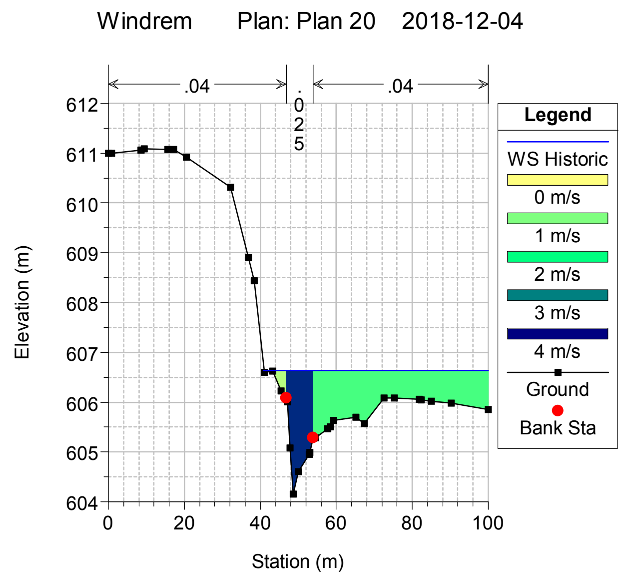
Bank Sta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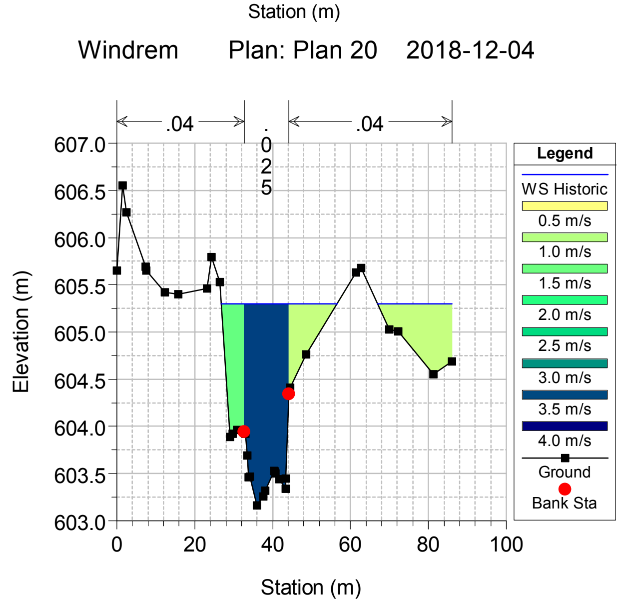
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
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Ground
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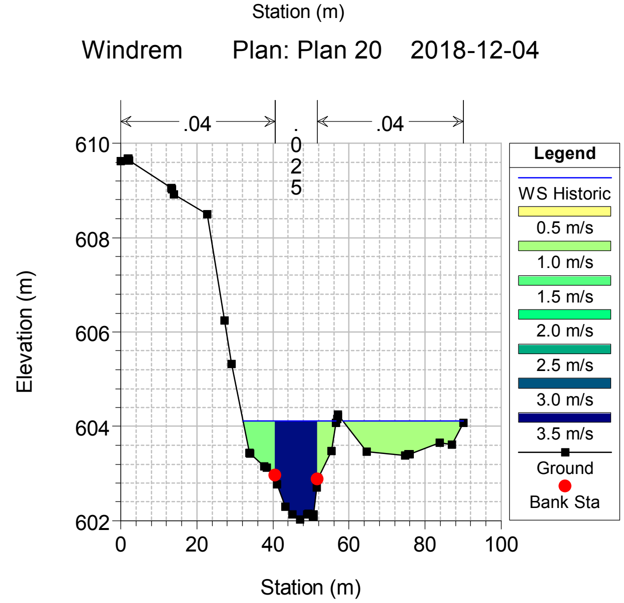
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Station (m)
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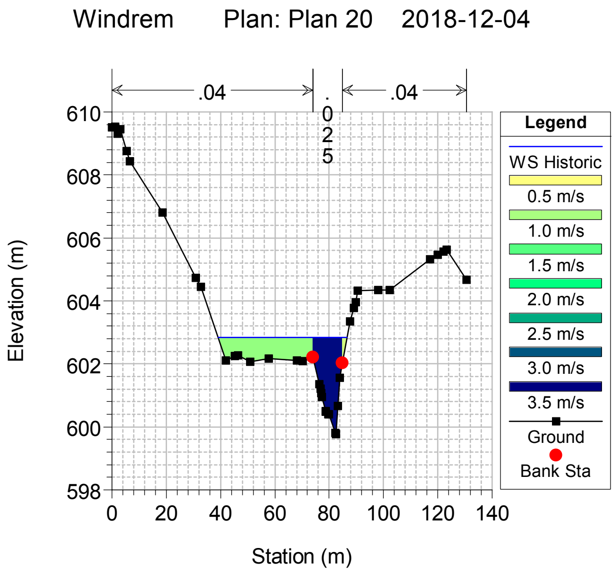
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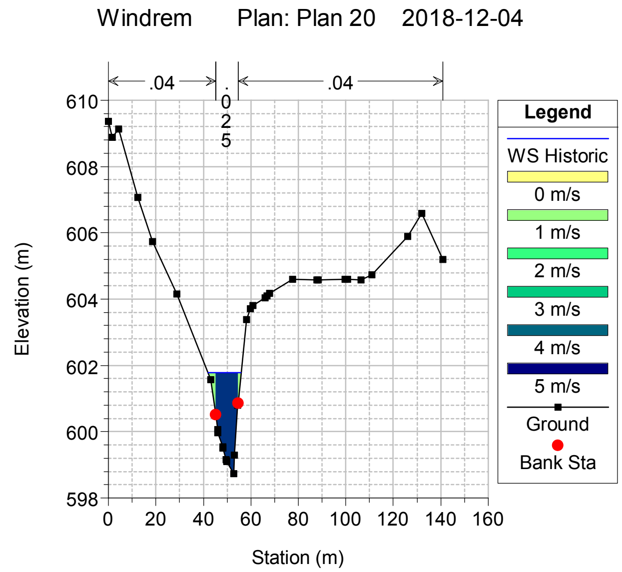
Ground
Bank Sta
Elevation (m)
Station (m)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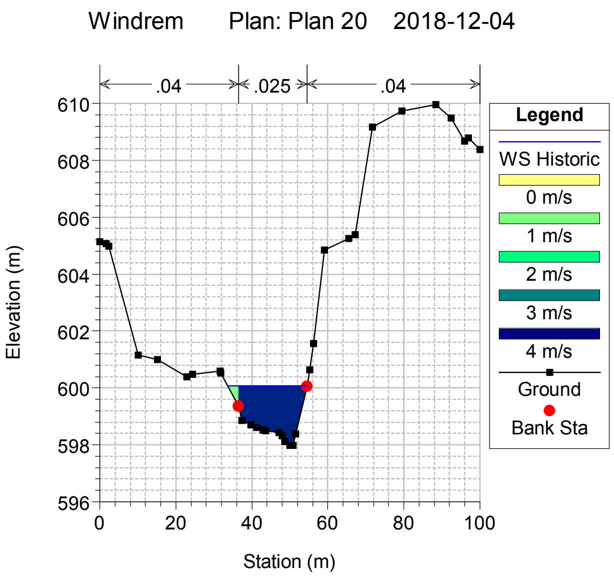
Ground
Bank Sta
Elevation (m)
Station (m)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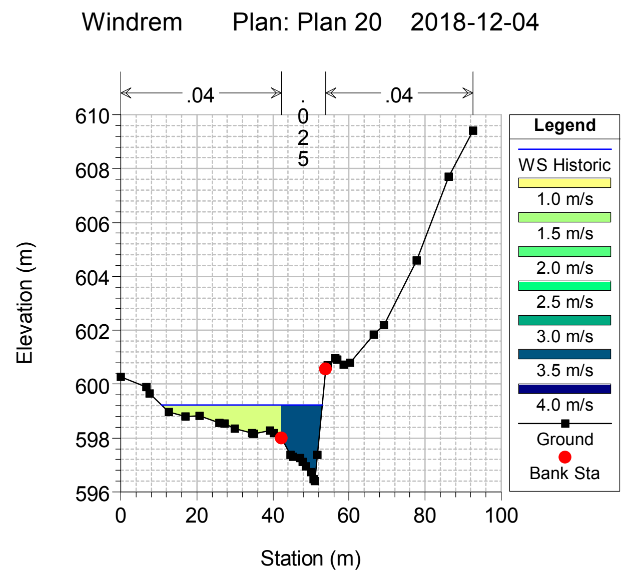
Ground
Bank Sta
Elevation (m)
Station (m)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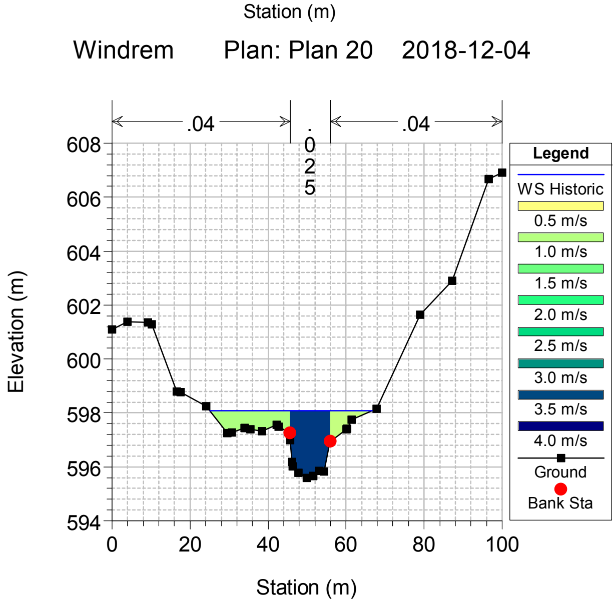
Ground
Bank Sta
Elevation (m)
Station (m)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Bank Sta
Elevation (m)
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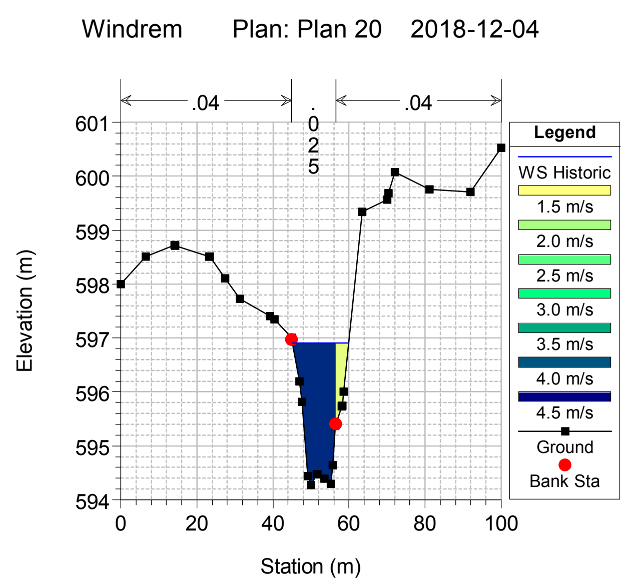
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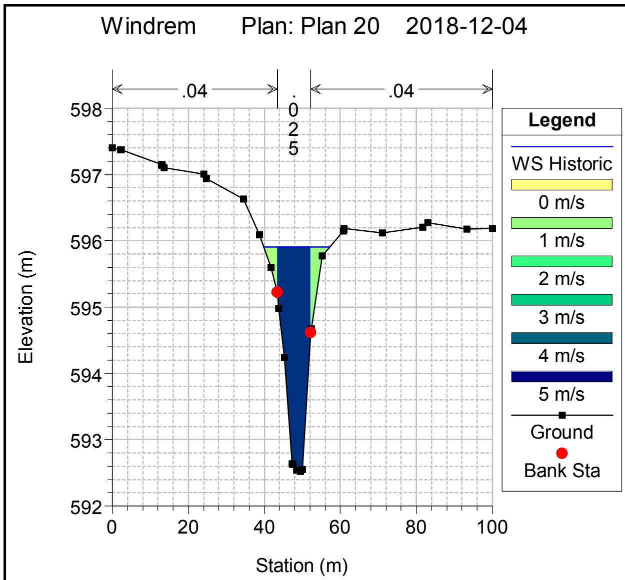
Ground
Bank Sta
Elevation (m)
Station (m)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Elevation (m)
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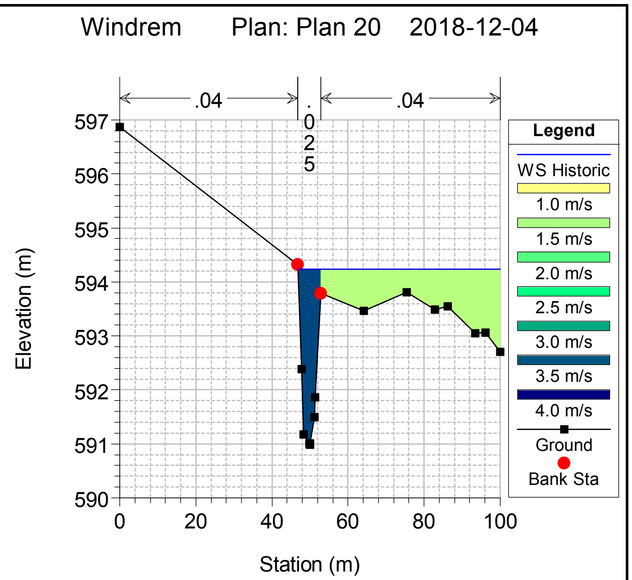
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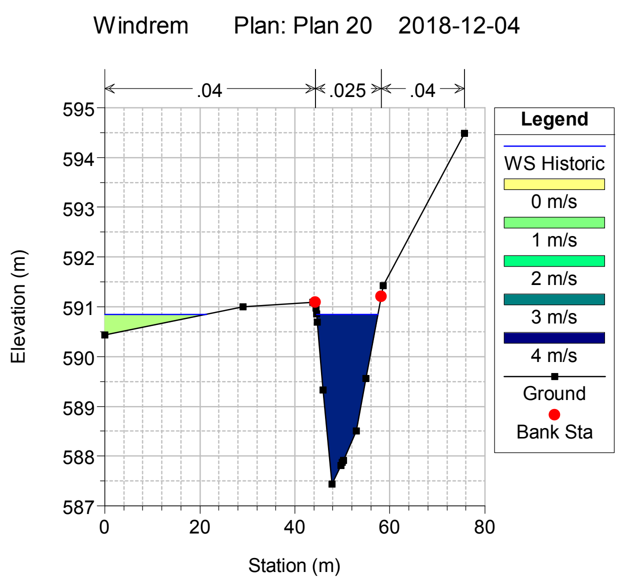
Ground
Bank Sta
Elevation (m)
Station (m)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Ground
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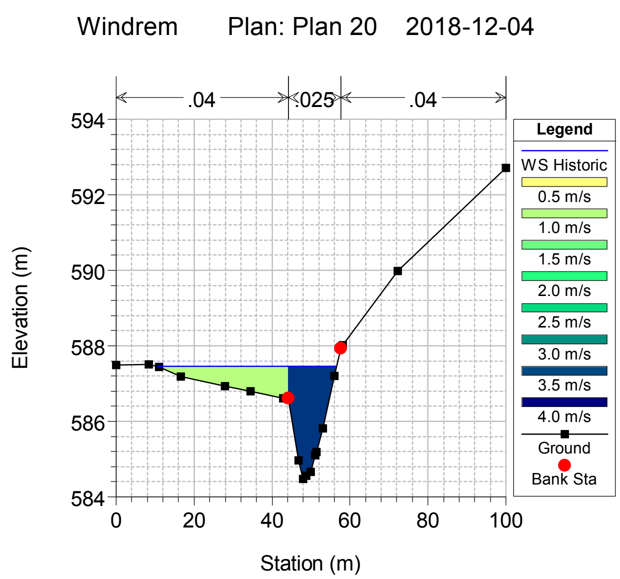
Elevation (m)
Station (m)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Ground
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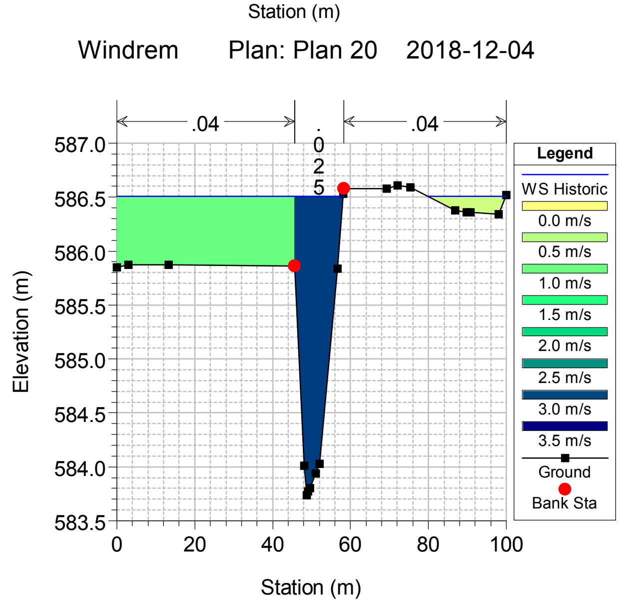
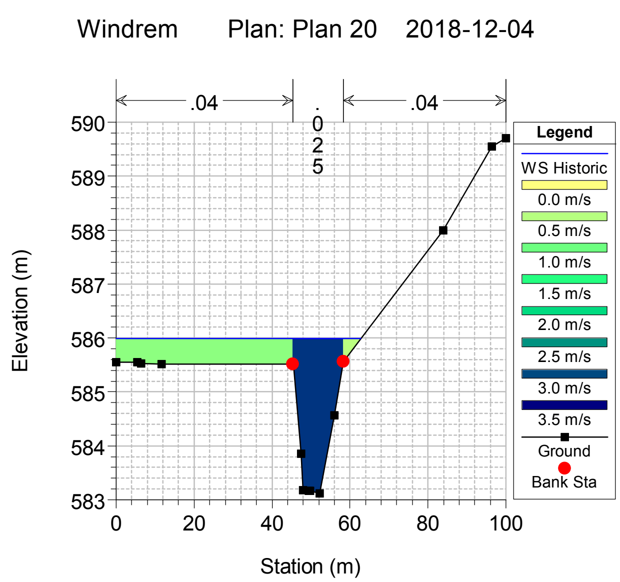
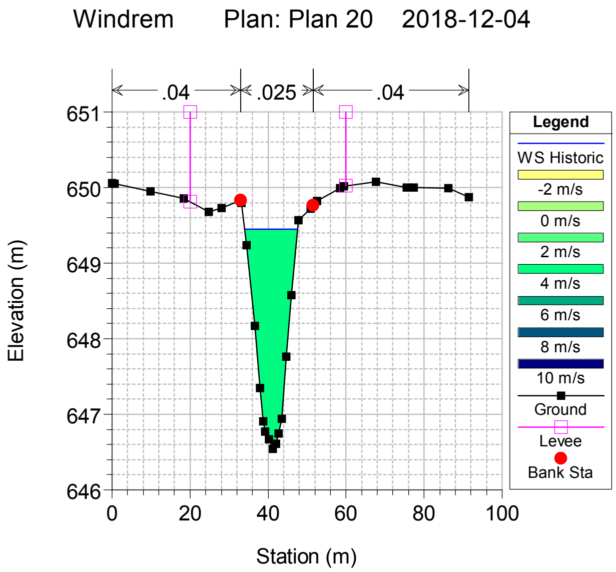
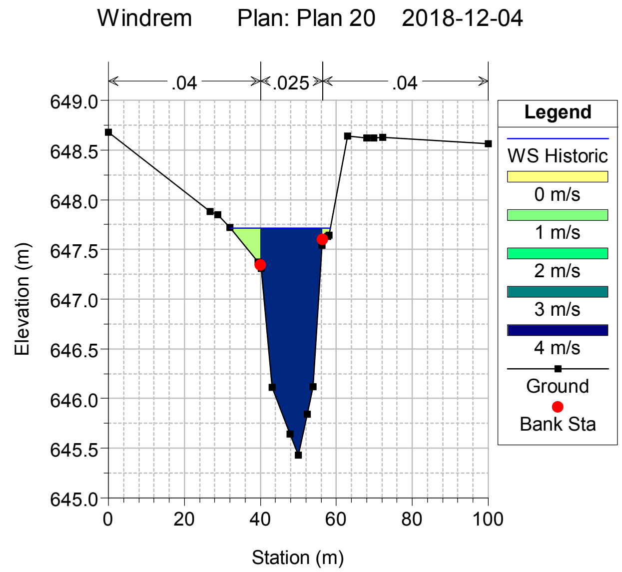
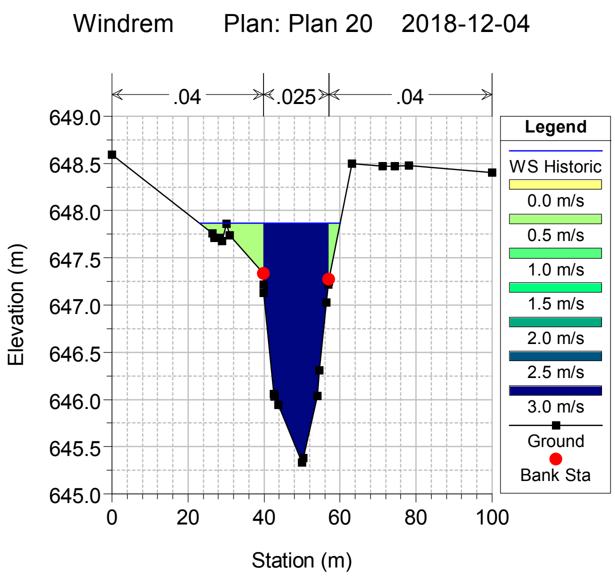
Elevation (m)
Station (m)

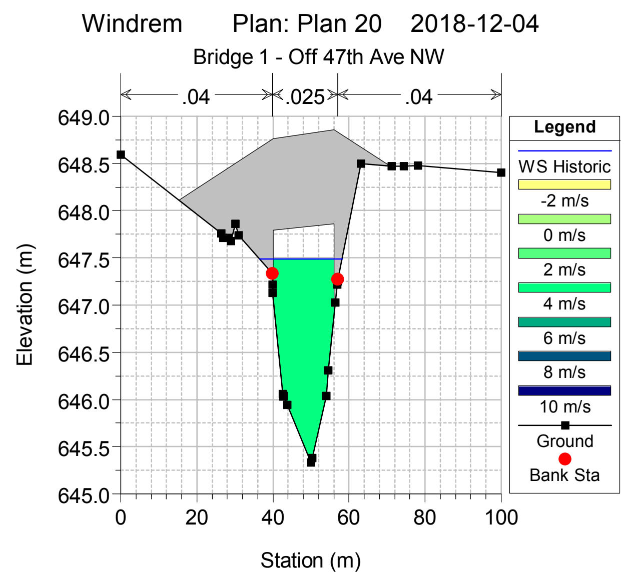

Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)

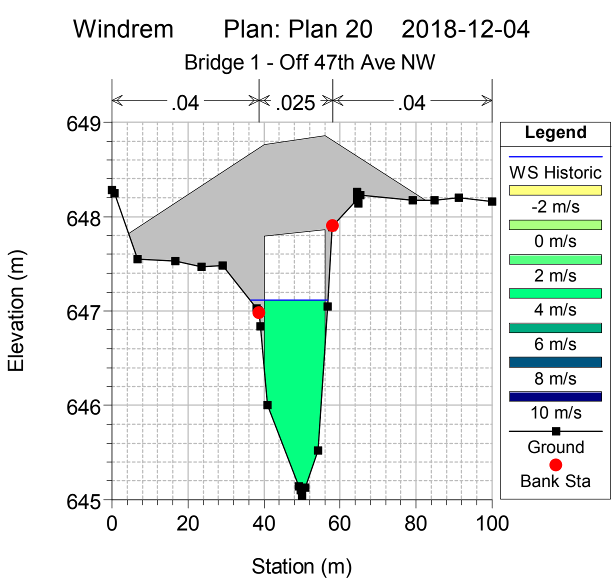

Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)

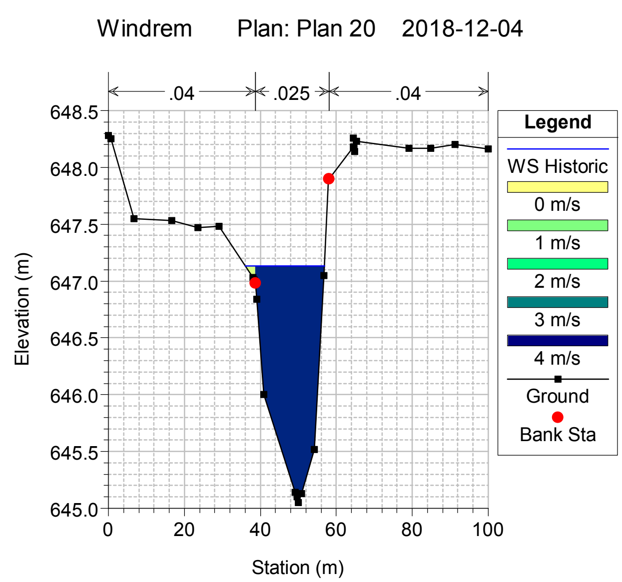

Windrem Plan: Plan 20 2018-12-04
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Levee
Bank Sta


Windrem Plan: Plan 20 2018-12-04
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Bank Sta

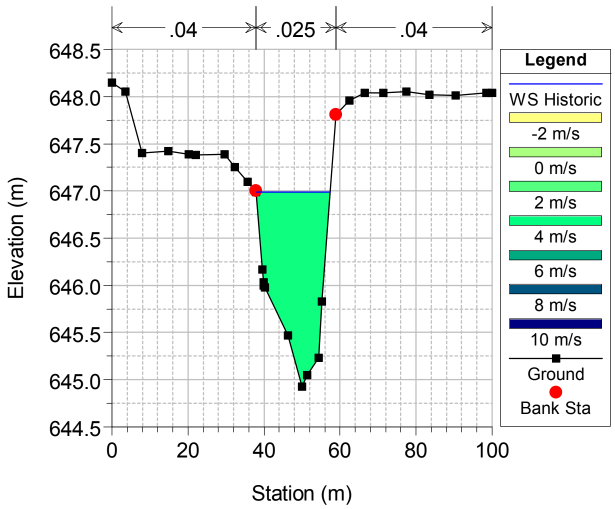

Windrem Plan: Plan 20 2018-12-04
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
Ground
Bank Sta


Windrem Plan: Plan 20 2018-12-04
Bridge 1 - Off 47th Ave NW
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta

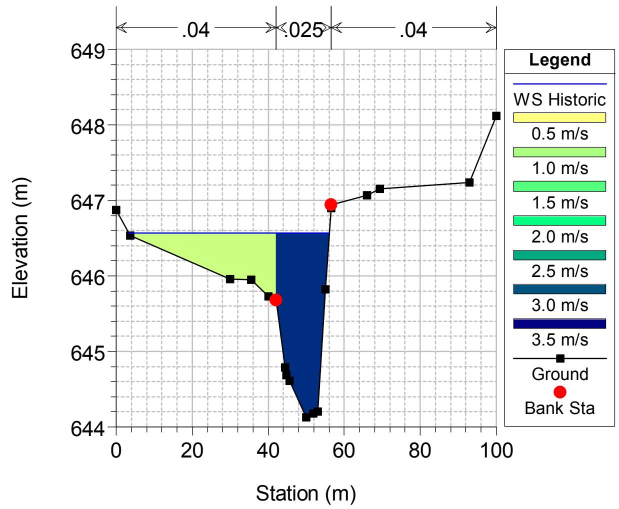

Windrem Plan: Plan 20 2018-12-04
Bridge 1 - Off 47th Ave NW
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta


Windrem Plan: Plan 20 2018-12-04
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Bank Sta

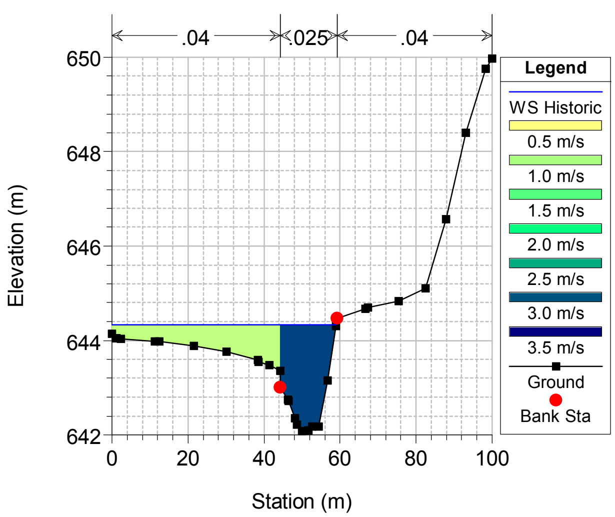
Windrem Plan: Plan 20 2018-12-04



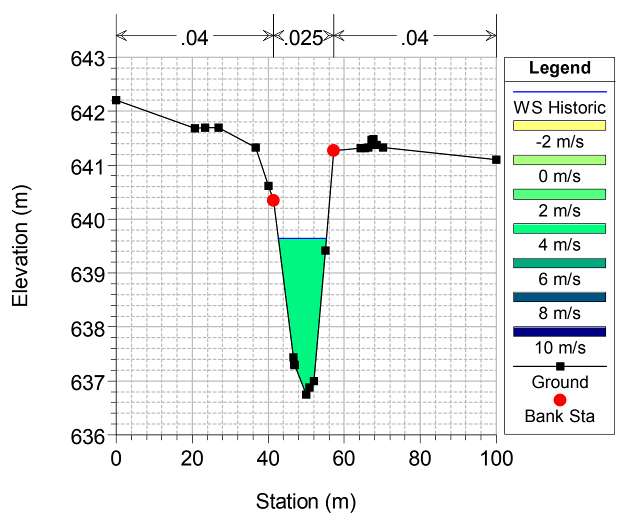
Windrem Plan: Plan 20 2018-12-04



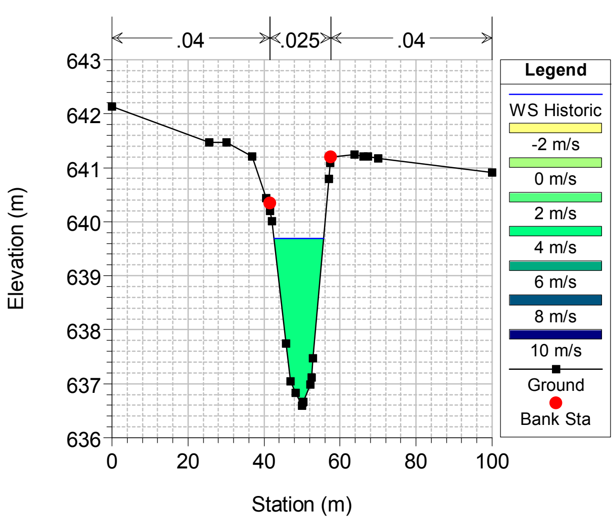
Windrem Plan: Plan 20 2018-12-04



Windrem Plan: Plan 20 2018-12-04

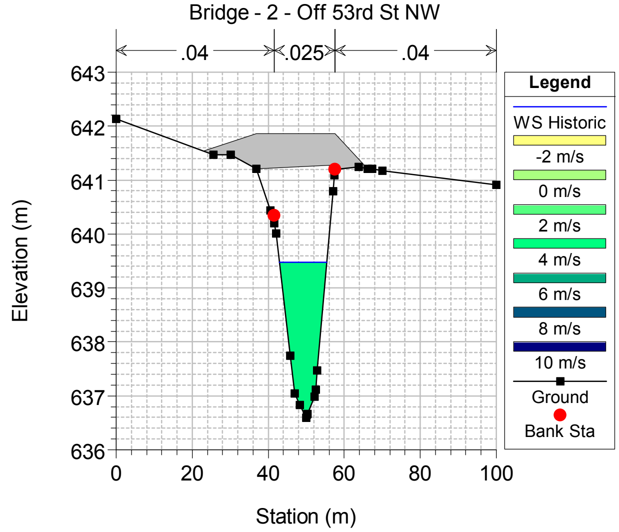


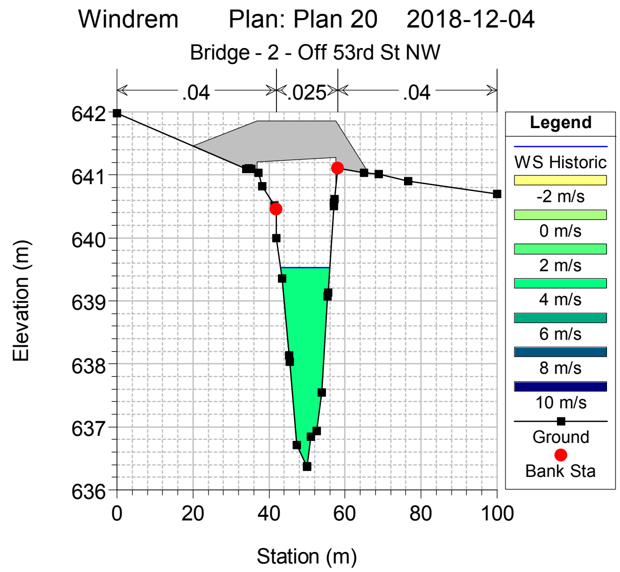
Windrem Plan: Plan 20 2018-12-04



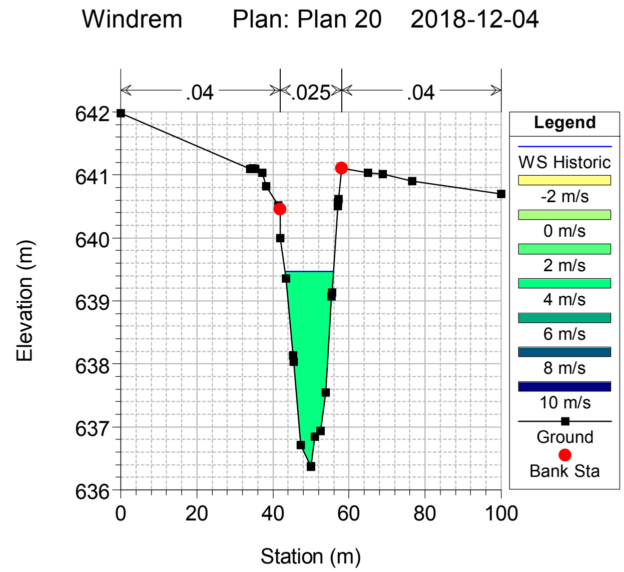
Windrem Plan: Plan 20 2018-12-04

Bridge - 2 - Off 53rd St NW

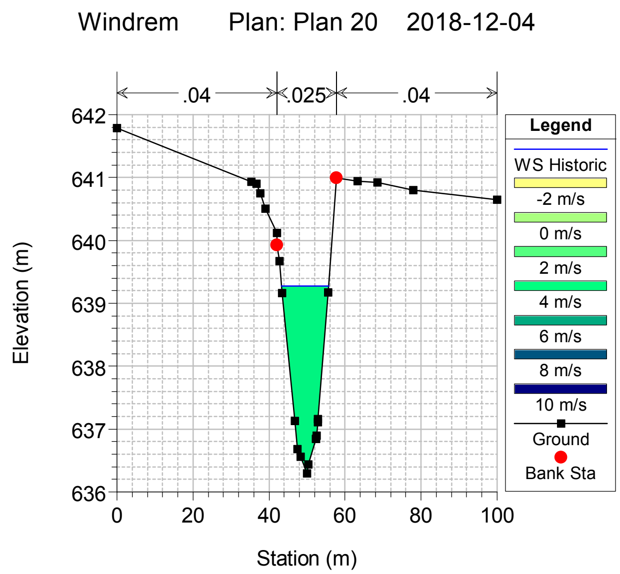




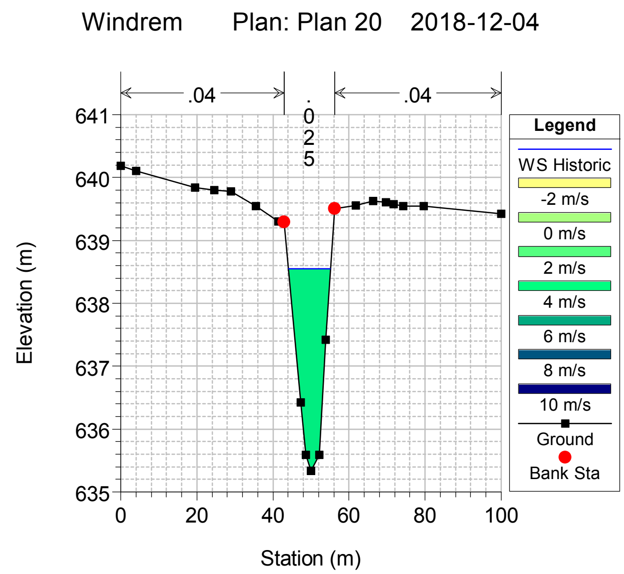
Windrem Plan: Plan 20 2018-12-04
Bridge - 2 - Off 53rd St NW
.04
.025
.04
Legend
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta
Elevation (m)
Station (m)



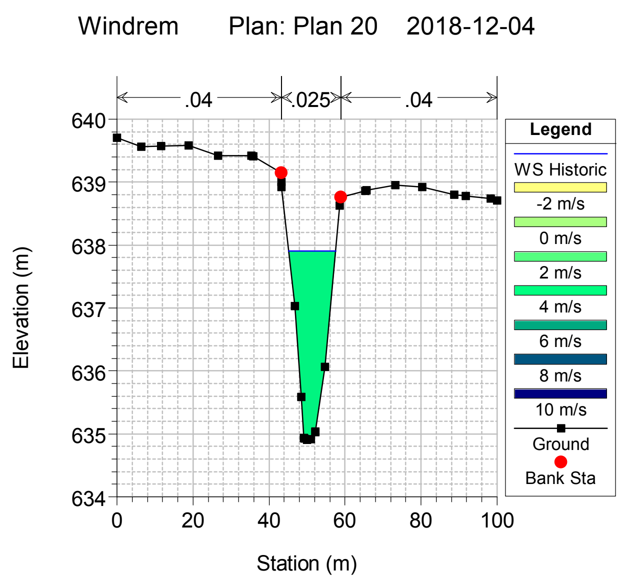
Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta
Elevation (m)
Station (m)



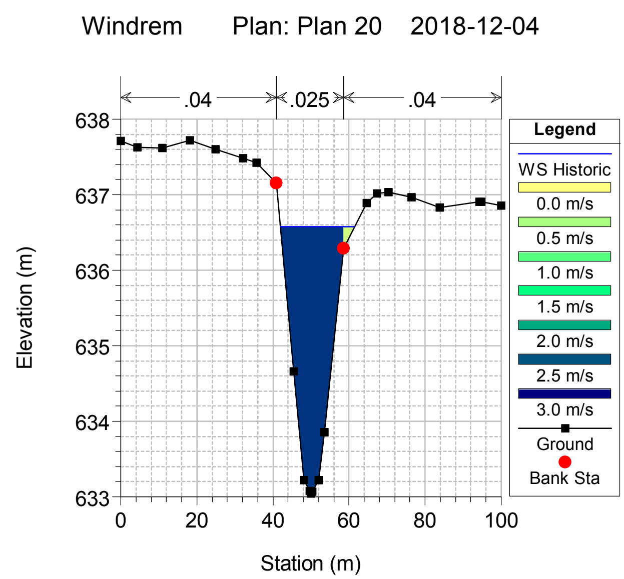
Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta
Elevation (m)
Station (m)



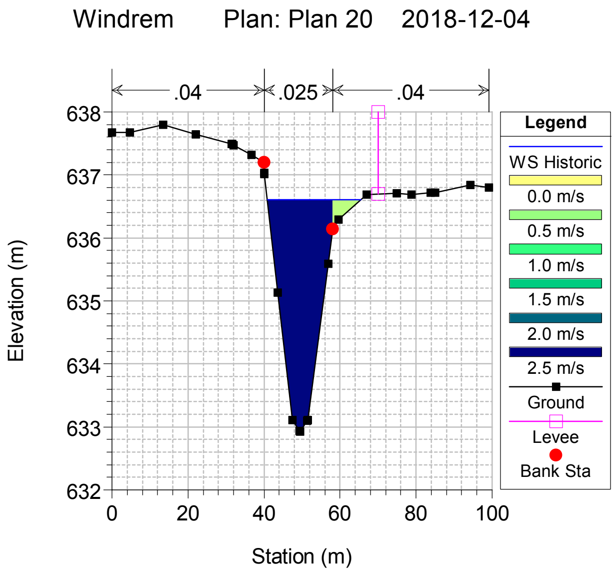
Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta
Elevation (m)
Station (m)

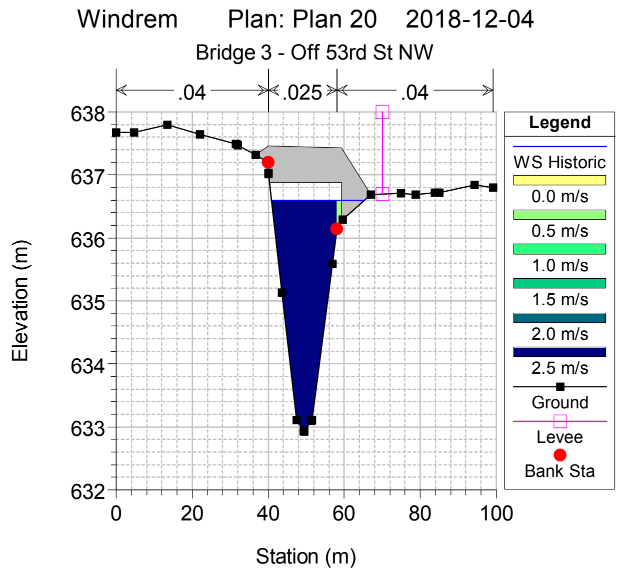


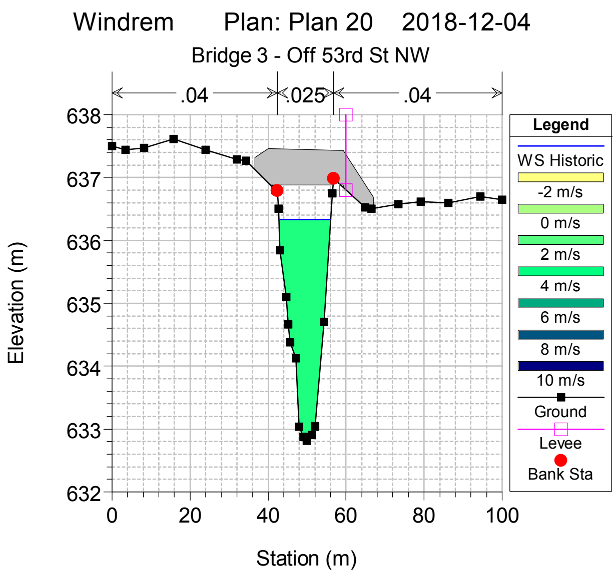
Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta
Elevation (m)
Station (m)

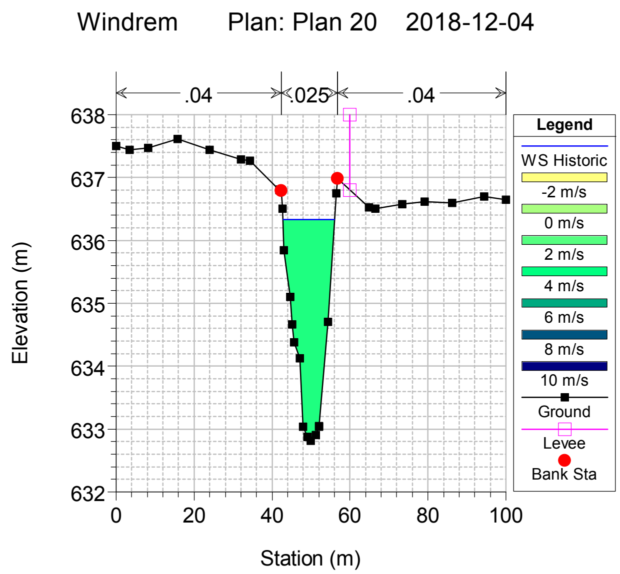


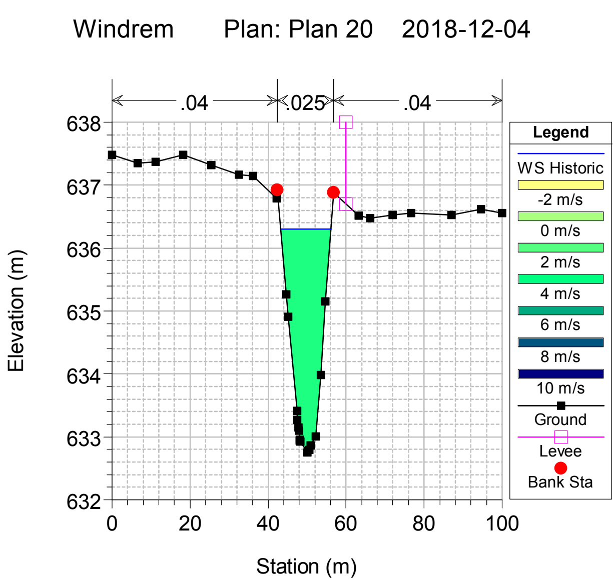
Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
Ground
Bank Sta
Elevation (m)
Station (m)

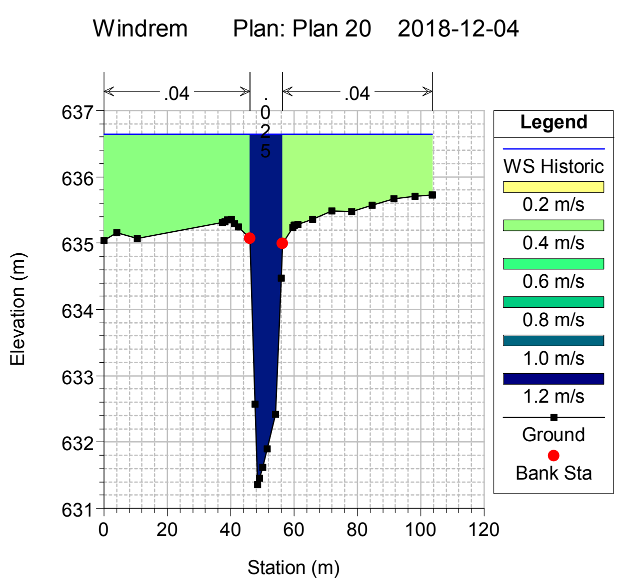

Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
Ground
Levee
Bank Sta

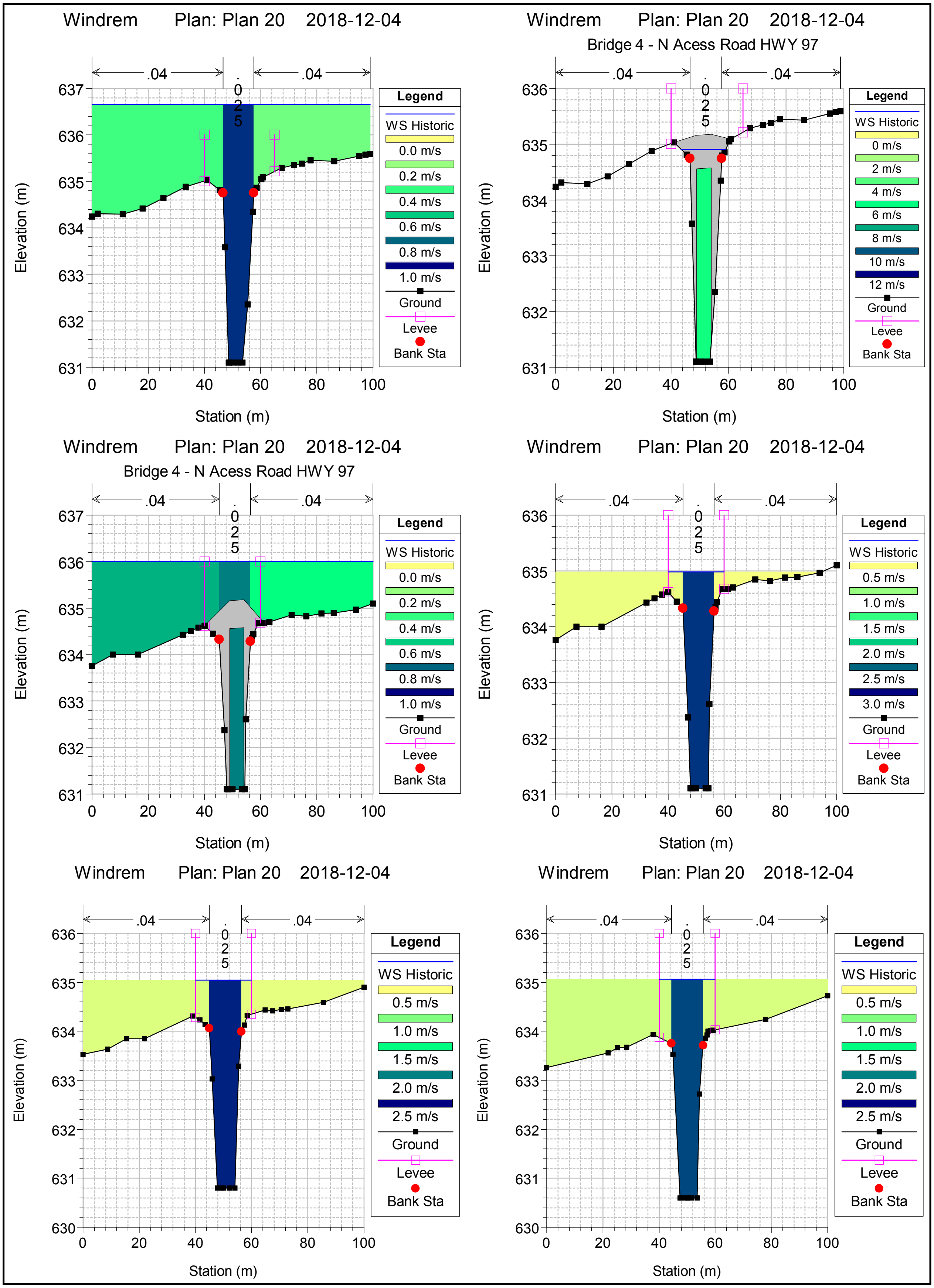

Windrem Plan: Plan 20 2018-12-04
Bridge 3 - Off 53rd St NW
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
Ground
Levee
Bank Sta


Windrem Plan: Plan 20 2018-12-04
Bridge 3 - Off 53rd St NW
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Levee
Bank Sta

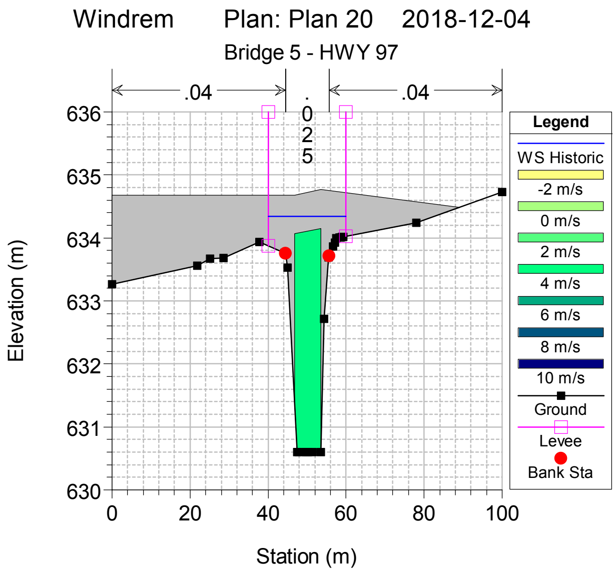

Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Levee
Bank Sta

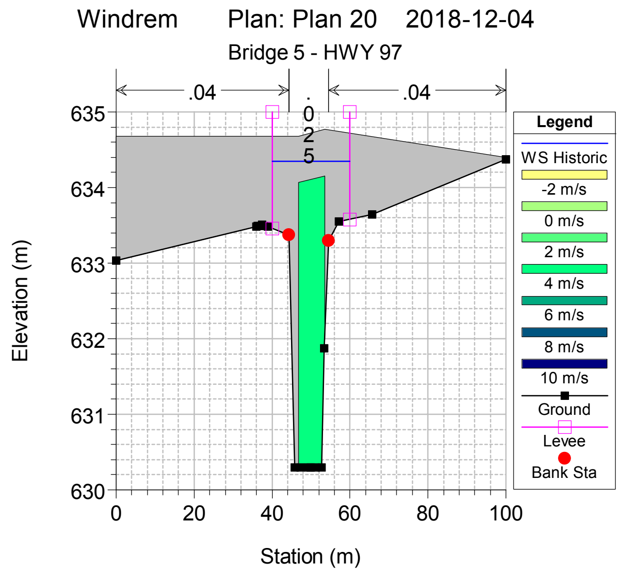

Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Levee
Bank Sta

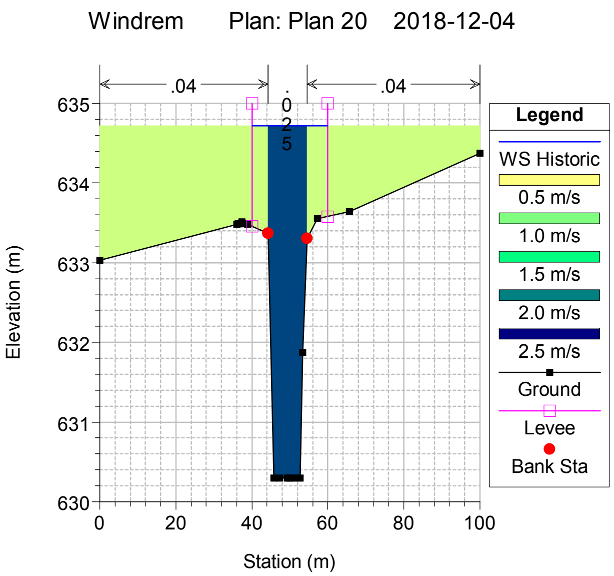

Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
Ground
Bank Sta

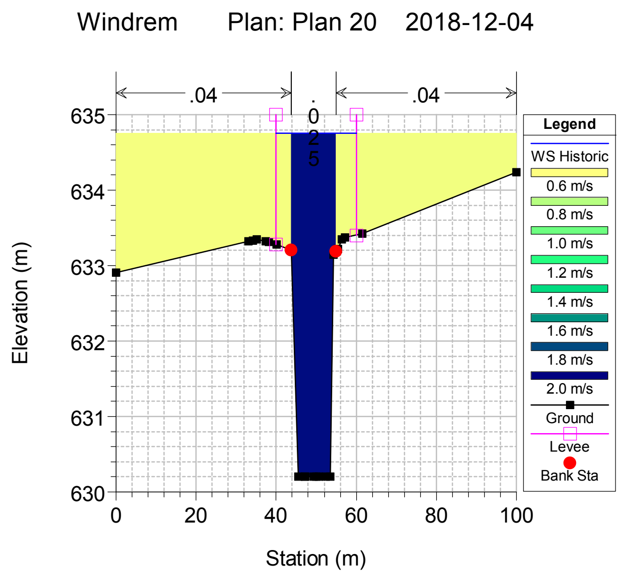


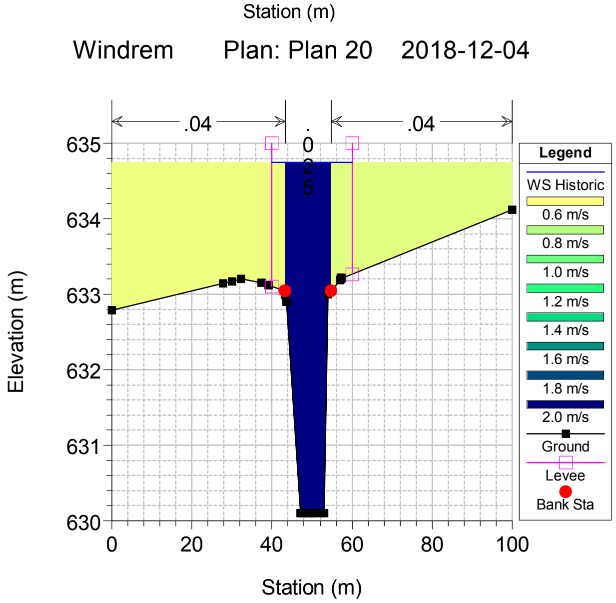
Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
Bridge 4 - N Acess Road HWY 97
.04
.025
.04
Legend
WS Historic
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
12 m/s
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
Bridge 4 - N Acess Road HWY 97
.04
.025
.04
Legend
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
Ground
Levee
Bank Sta
Elevation (m)
Station (m)

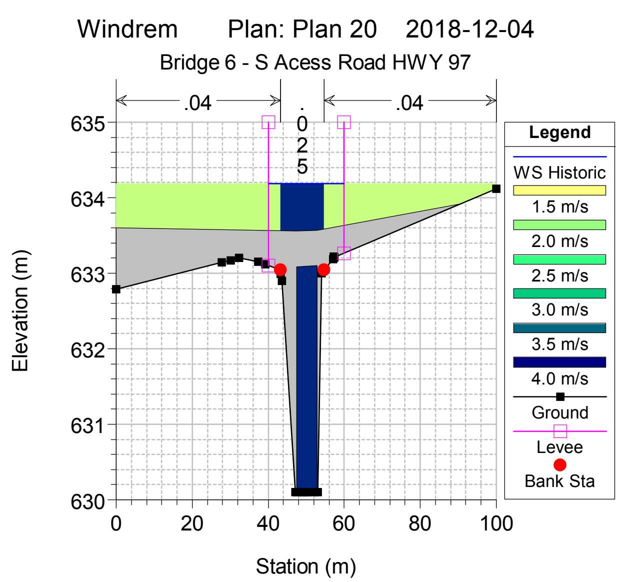

Windrem Plan: Plan 20 2018-12-04
Bridge 5 - HWY 97
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Levee
Bank Sta

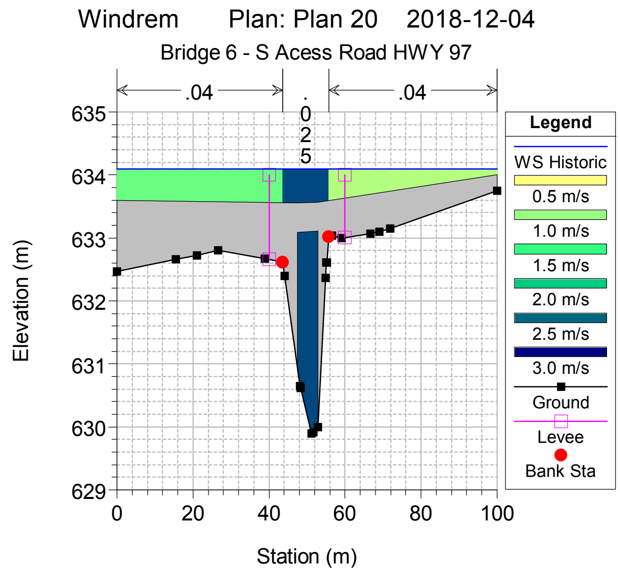

Windrem Plan: Plan 20 2018-12-04
Bridge 5 - HWY 97
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Levee
Bank Sta

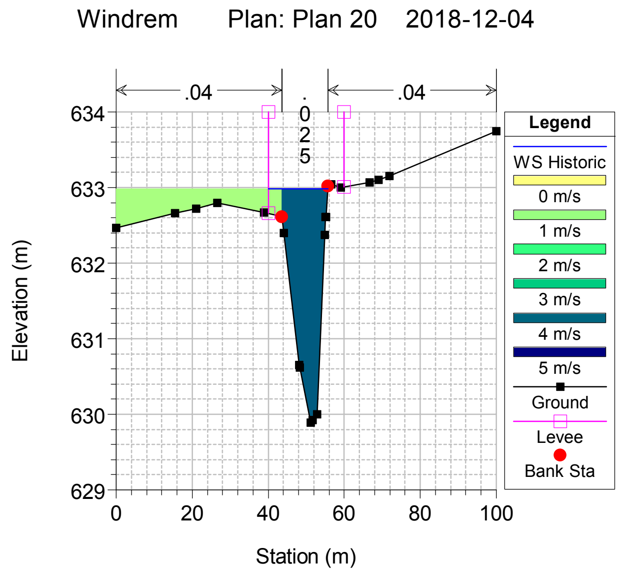

Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
Ground
Levee
Bank Sta

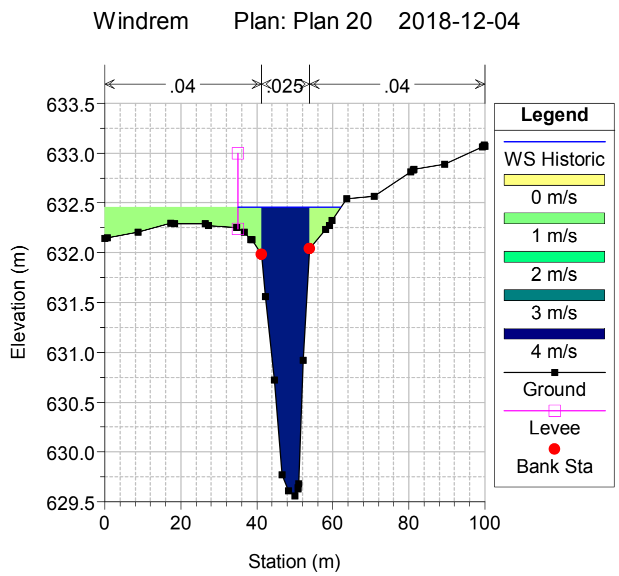

Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
1.4 m/s
1.6 m/s
1.8 m/s
2.0 m/s
Ground
Levee
Bank Sta

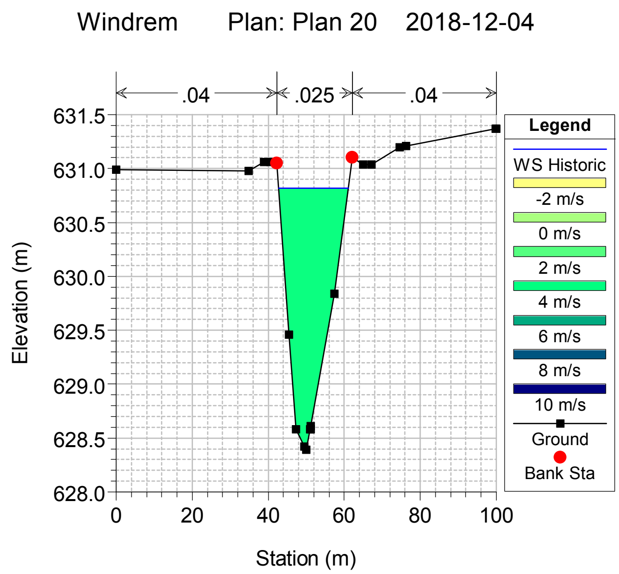

Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
1.4 m/s
1.6 m/s
1.8 m/s
2.0 m/s
Ground
Levee
Bank Sta

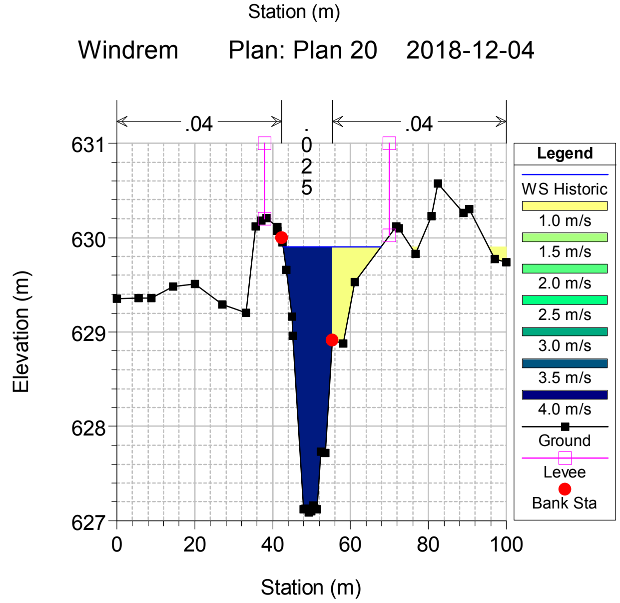

Windrem Plan: Plan 20 2018-12-04
Bridge 6 - S Acess Road HWY 97
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
4.0 m/s
Ground
Levee
Bank Sta

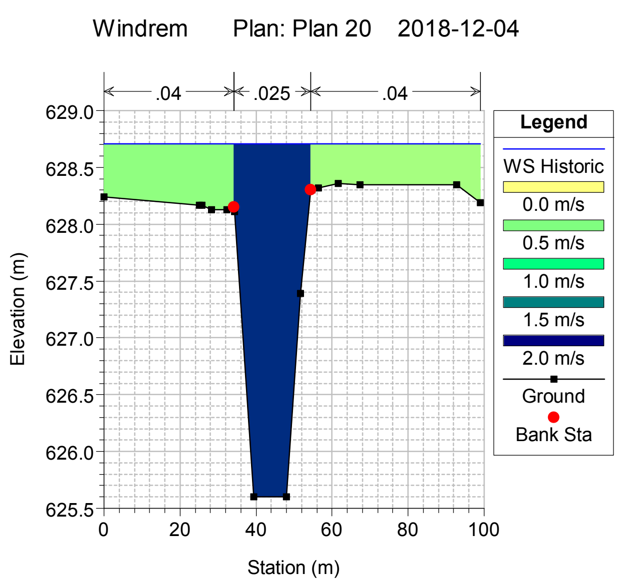

Windrem Plan: Plan 20 2018-12-04
Bridge 6 - S Acess Road HWY 97
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
Ground
Levee
Bank Sta

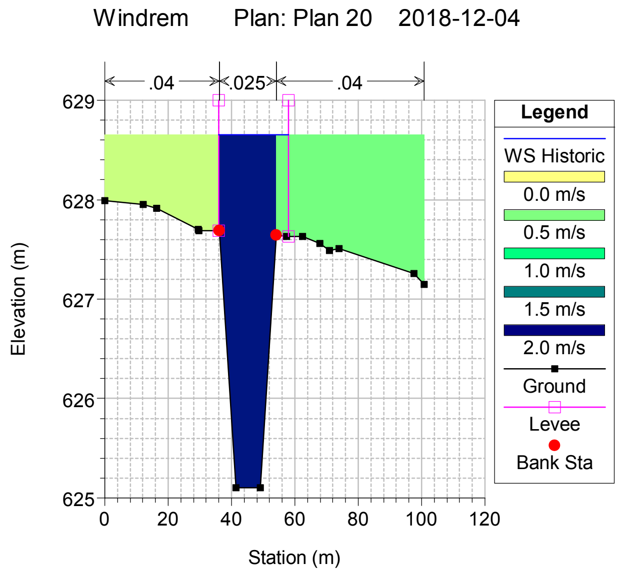

Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Levee
Bank Sta

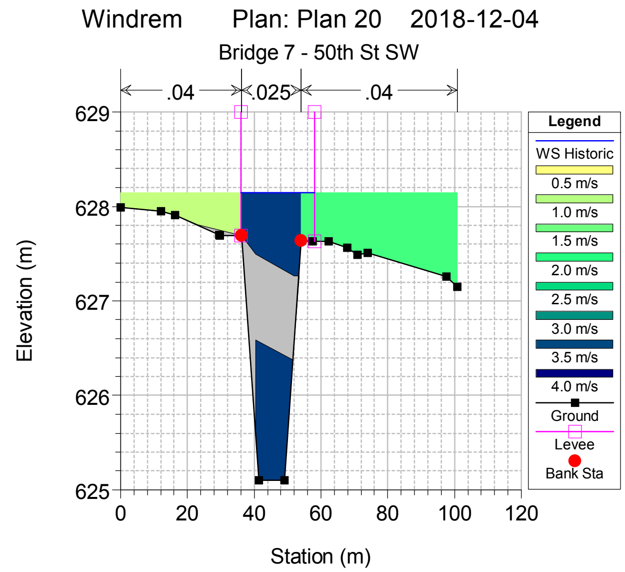

Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Levee
Bank Sta

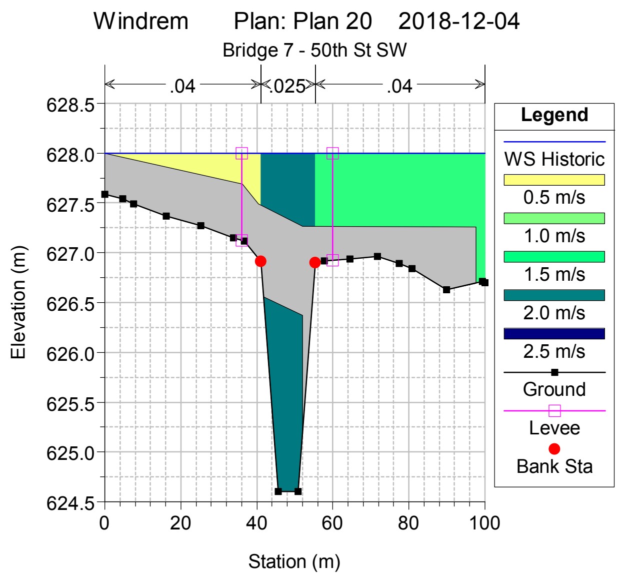

Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta

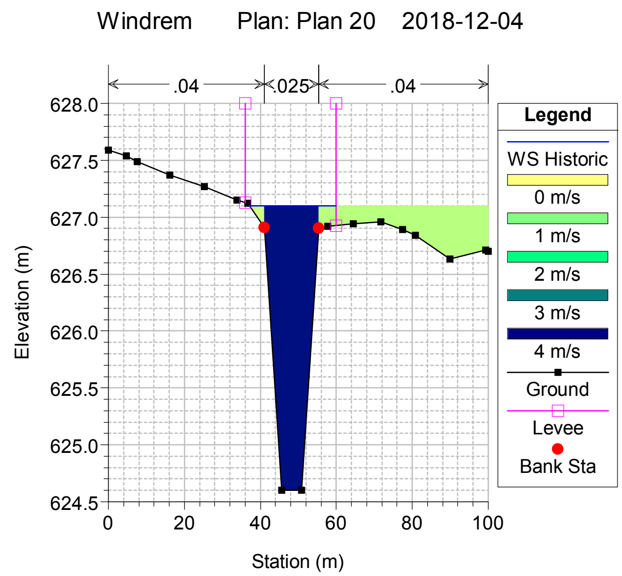

Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
4.0 m/s
Ground
Levee
Bank Sta

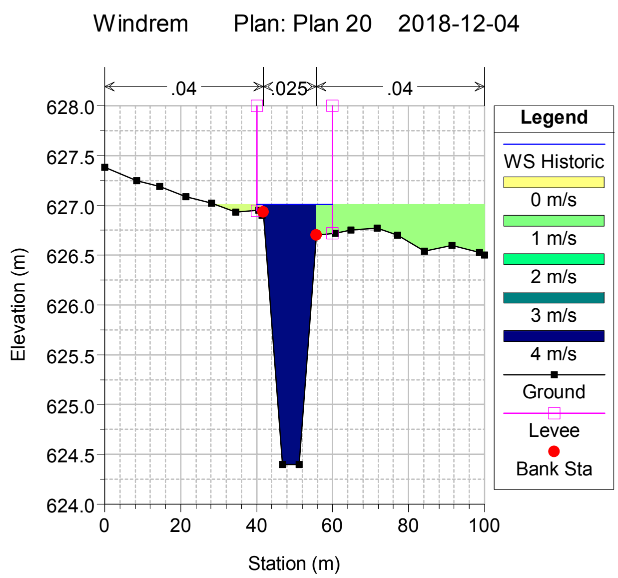

Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
Ground
Bank Sta


Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
Ground
Levee
Bank Sta


Windrem Plan: Plan 20 2018-12-04
Bridge 7 - 50th St SW
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
4.0 m/s
Ground
Levee
Bank Sta


Windrem Plan: Plan 20 2018-12-04
Bridge 7 - 50th St SW
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
Ground
Levee
Bank Sta


Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Levee
Bank Sta


Windrem Plan: Plan 20 2018-12-04
.04
.025
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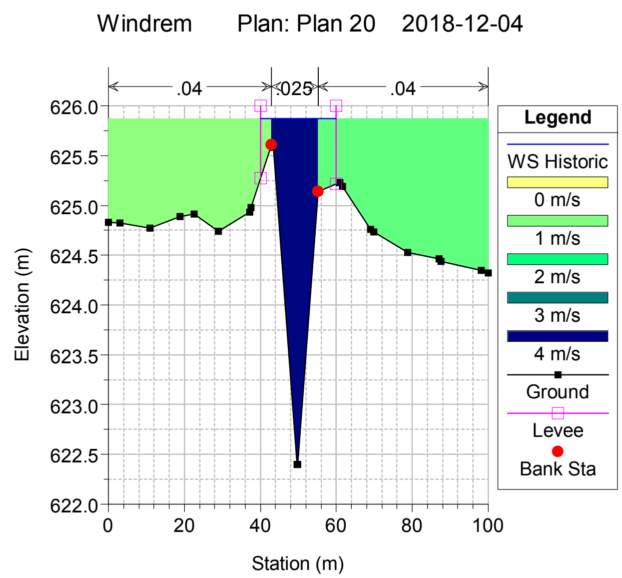
Elevation (m)
Station (m)
Legend
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Levee
Bank Sta


Windrem Plan: Plan 20 2018-12-04
.04
.025
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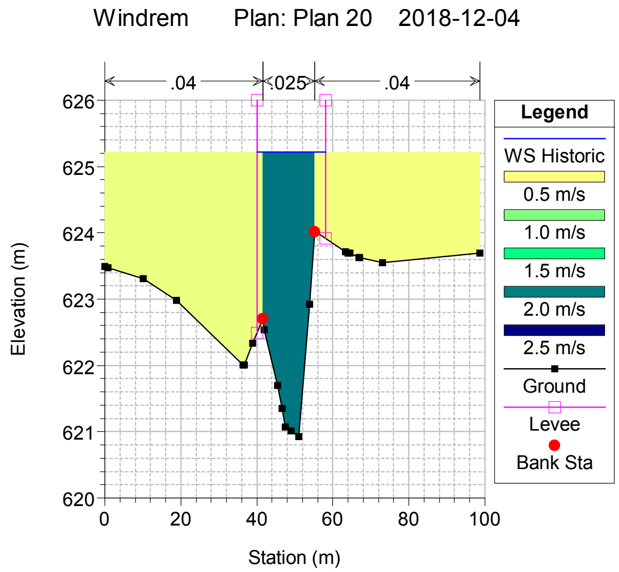
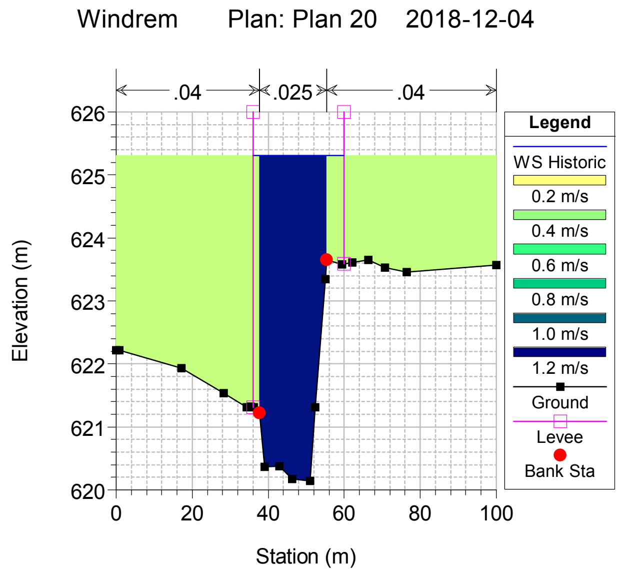
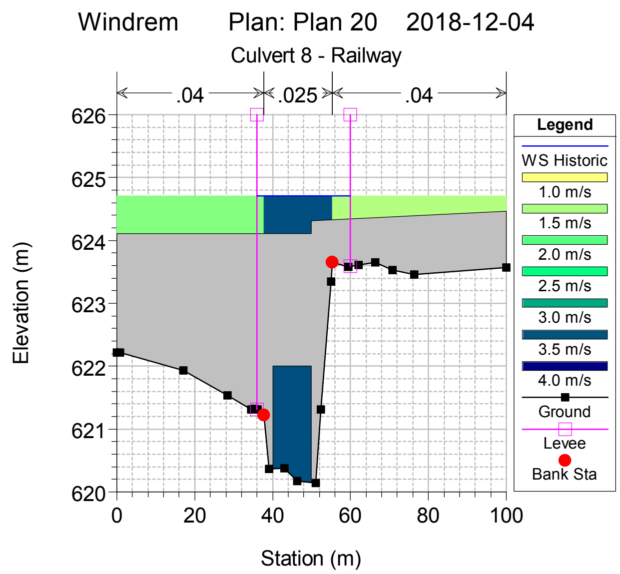
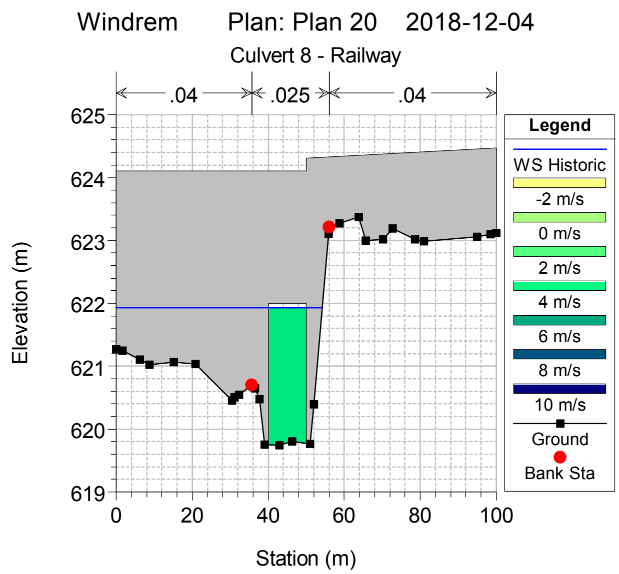
Elevation (m)
Station (m)
Legend
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Levee
Bank Sta


Windrem Plan: Plan 20 2018-12-04
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS Historic
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
Ground
Levee
Bank Sta


Windrem Plan: Plan 20 2018-12-04
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS Historic
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
Ground
Levee
Bank Sta


Windrem Plan: Plan 20 2018-12-04
Culvert 8 - Railway
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS Historic
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
4.0 m/s
Ground
Levee
Bank Sta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Culvert 8 - Railway
.04 .025 .04
Elevation (m)
Station (m)
Legend
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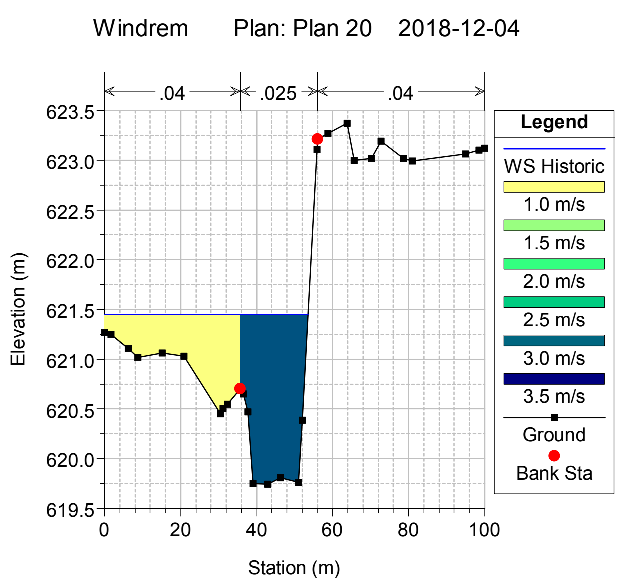
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta


Windrem Plan: Plan 20 2018-12-04
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS Historic
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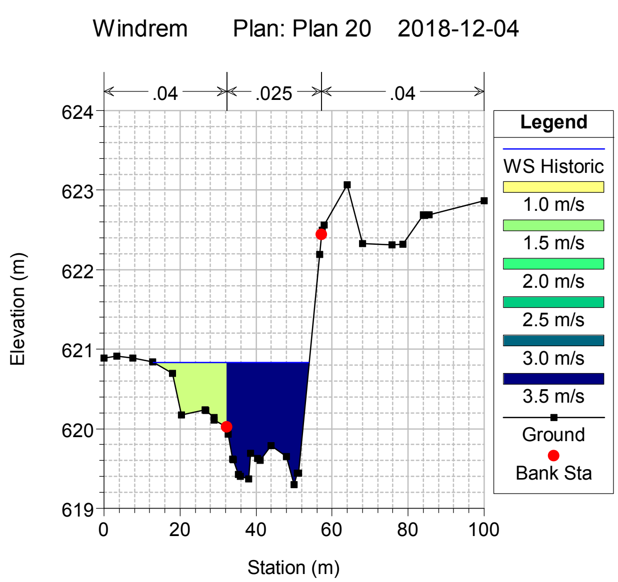
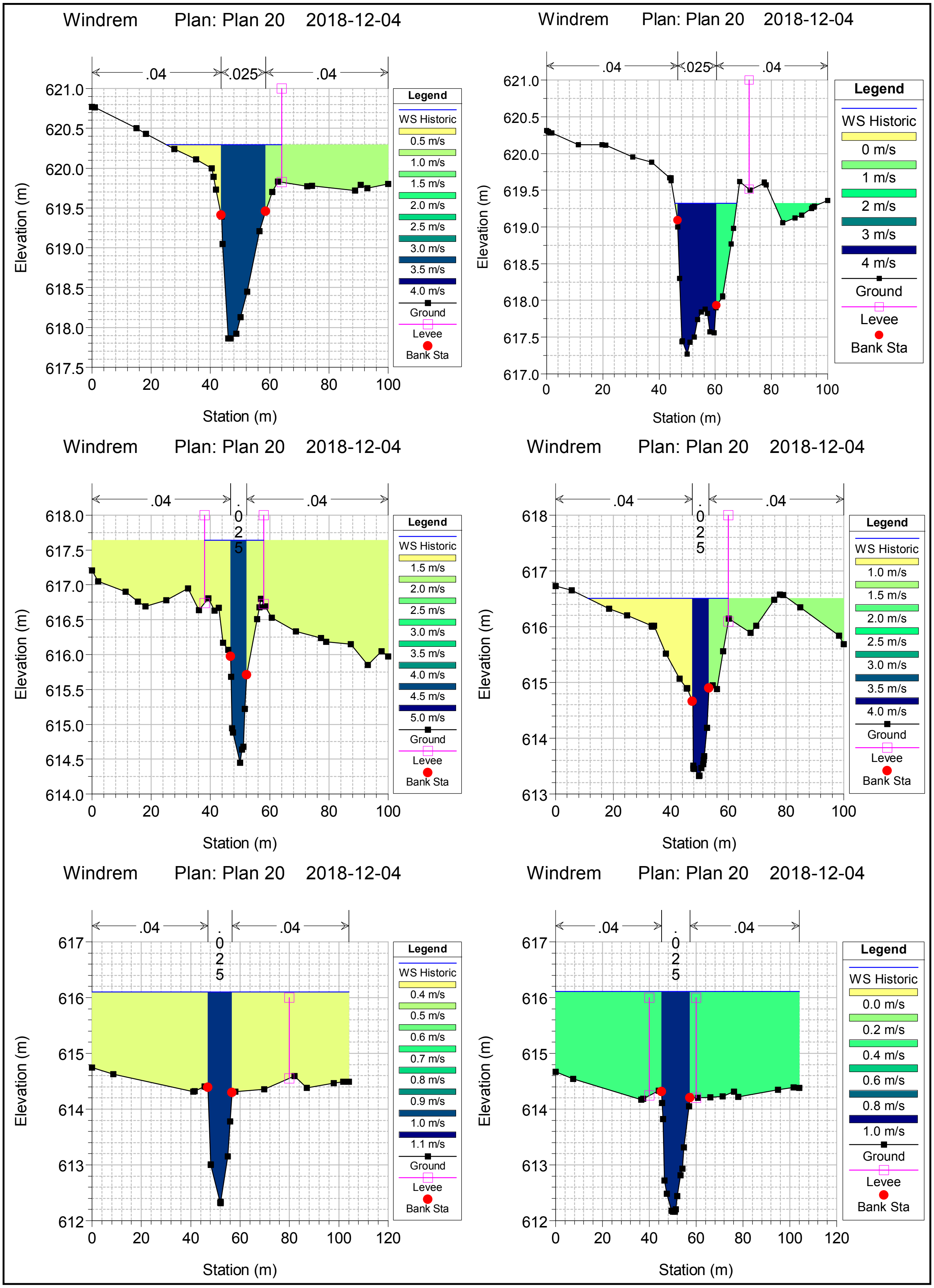
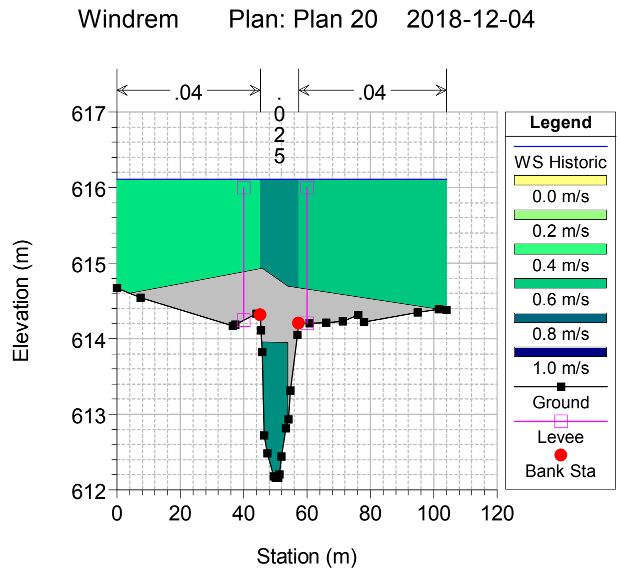
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta


Windrem Plan: Plan 20 2018-12-04
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS Historic
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta


Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
4.0 m/s
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
4.0 m/s
4.5 m/s
5.0 m/s
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
4.0 m/s
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
0.4 m/s
0.5 m/s
0.6 m/s
0.7 m/s
0.8 m/s
0.9 m/s
1.0 m/s
1.1 m/s
Ground
Levee
Bank Sta
Elevation (m)
Station (m)
Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Levee
Bank Sta
Elevation (m)
Station (m)


Windrem Plan: Plan 20 2018-12-04
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Elevation (m)
Station (m)
Legend
WS Historic
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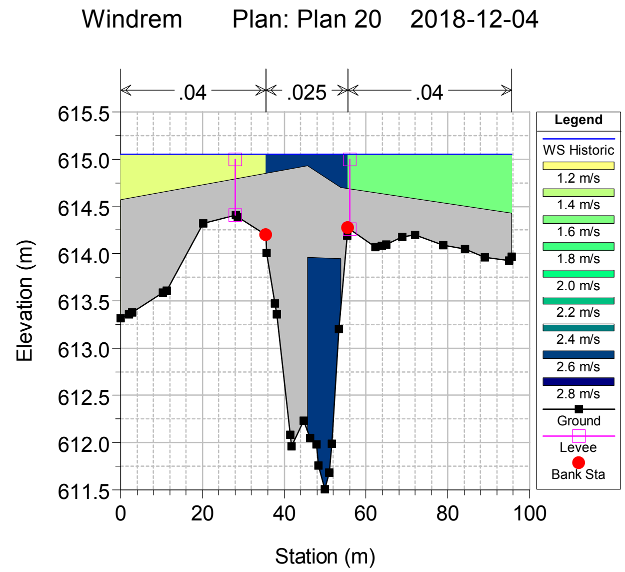
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Levee
Bank Sta


Windrem Plan: Plan 20 2018-12-04
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.025
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Elevation (m)
Station (m)
Legend
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1.4 m/s
1.6 m/s
1.8 m/s
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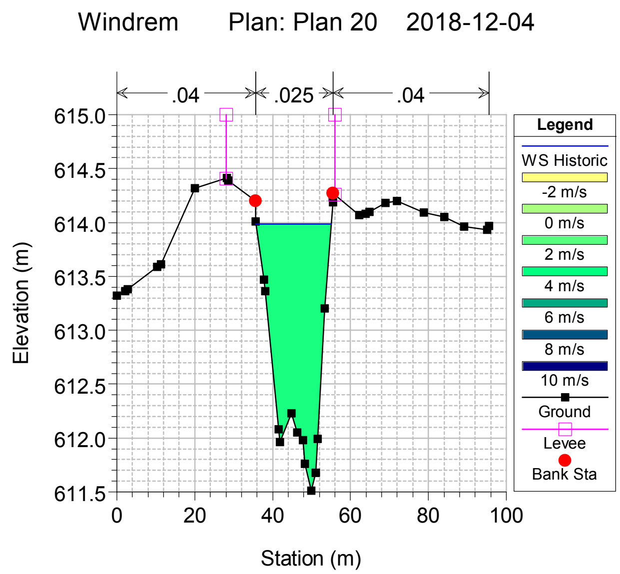
2.2 m/s
2.4 m/s
2.6 m/s
2.8 m/s
Ground
Levee
Bank Sta


Windrem Plan: Plan 20 2018-12-04
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Elevation (m)
Station (m)
Legend
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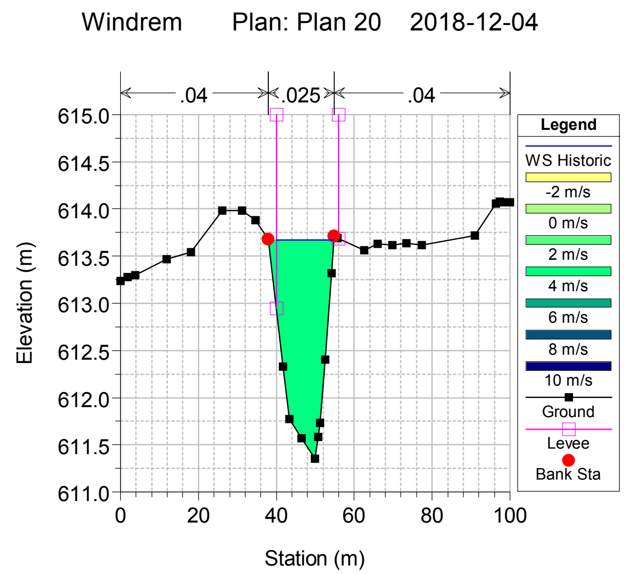
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Levee
Bank Sta


Windrem Plan: Plan 20 2018-12-04
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Elevation (m)
Station (m)
Legend
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0 m/s
2 m/s
4 m/s
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8 m/s
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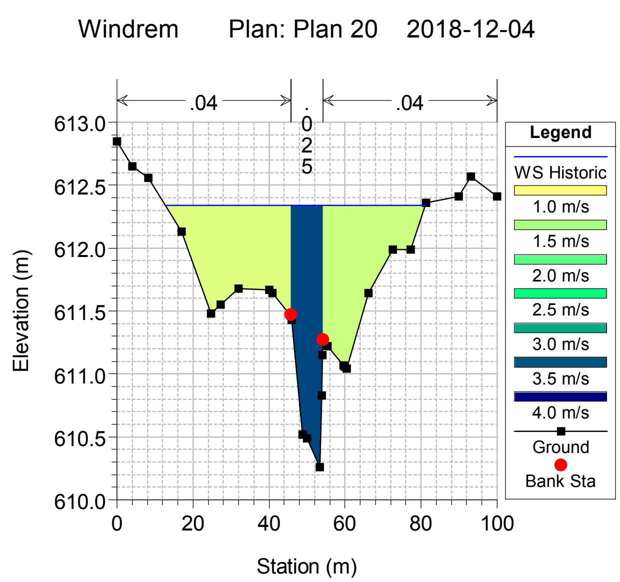
Ground
Levee
Bank Sta


Windrem Plan: Plan 20 2018-12-04
.04
.025
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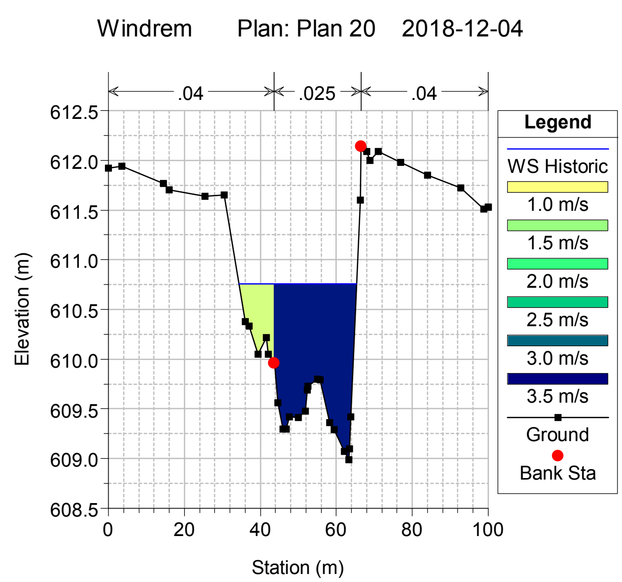
Elevation (m)
Station (m)
Legend
WS Historic
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
4.0 m/s
Ground
Bank Sta


Windrem Plan: Plan 20 2018-12-04
.04
.025
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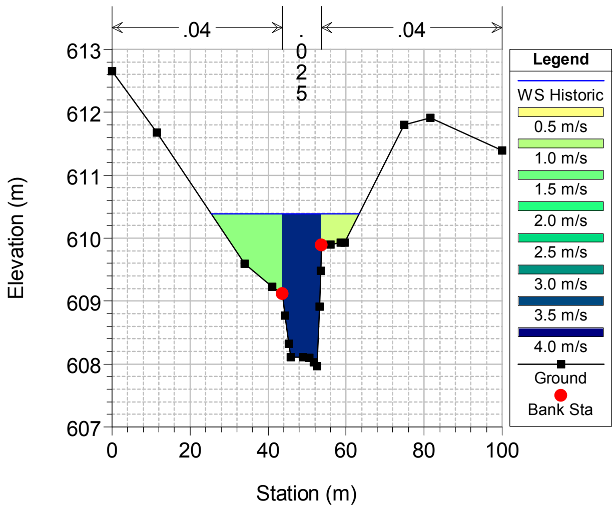
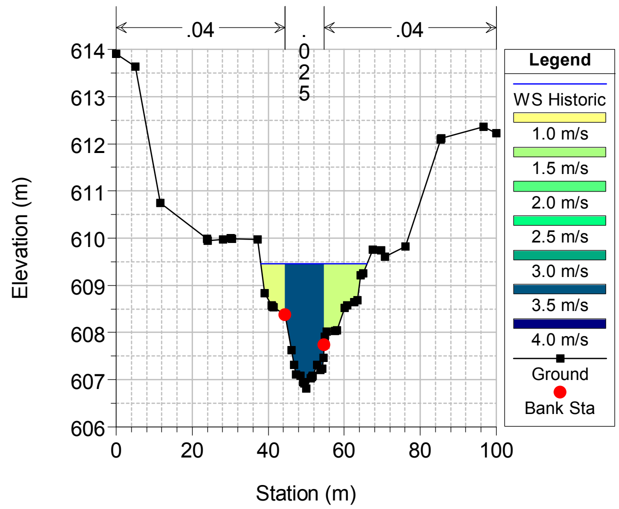
Elevation (m)
Station (m)
Legend
WS Historic
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta

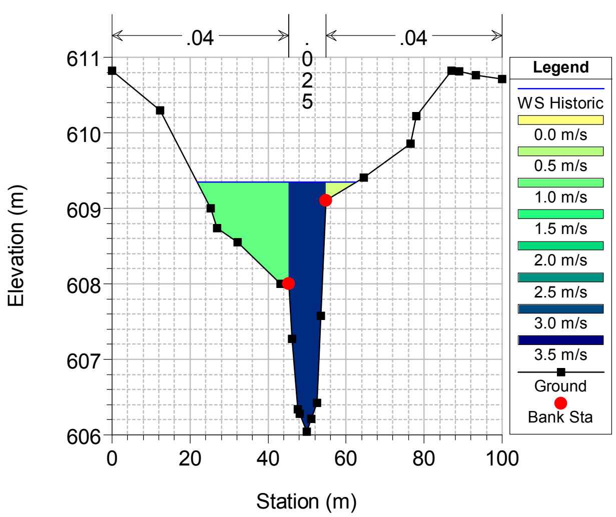
Windrem Plan: Plan 20 2018-12-04



Windrem Plan: Plan 20 2018-12-04



Windrem Plan: Plan 20 2018-12-04



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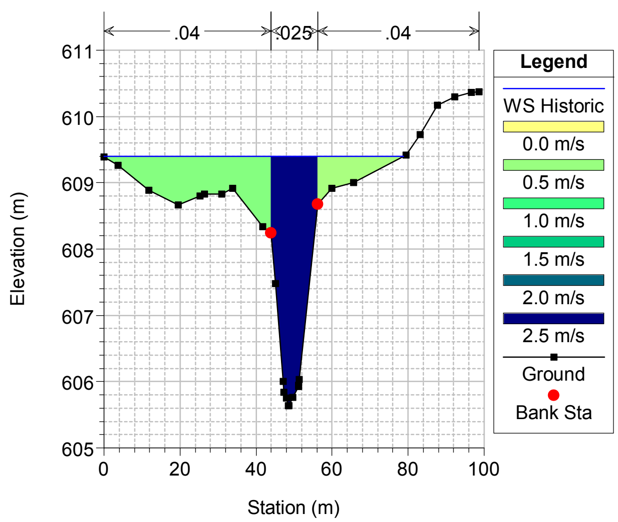

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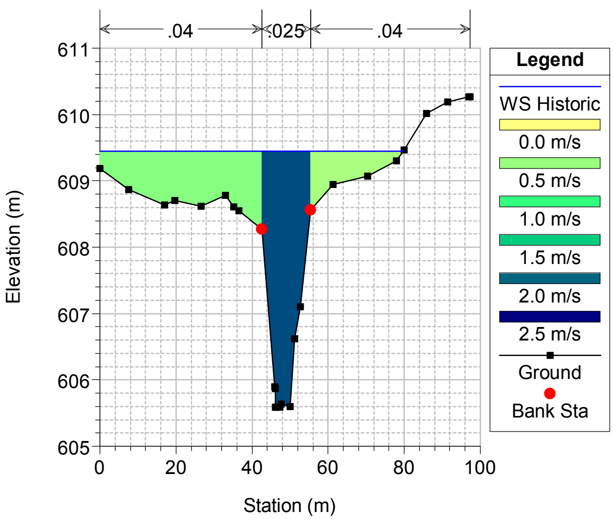

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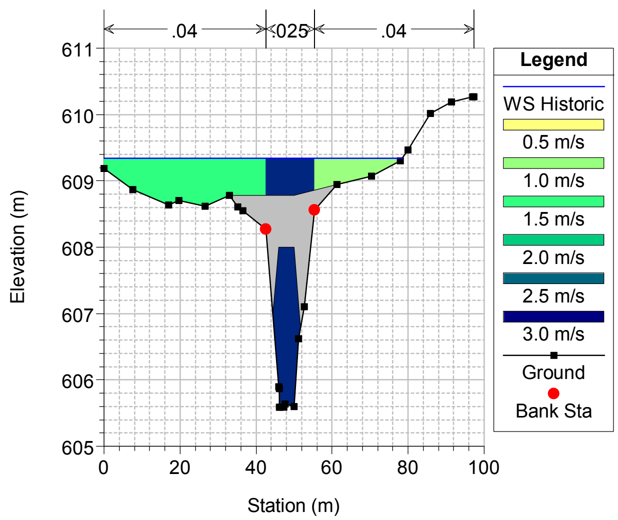

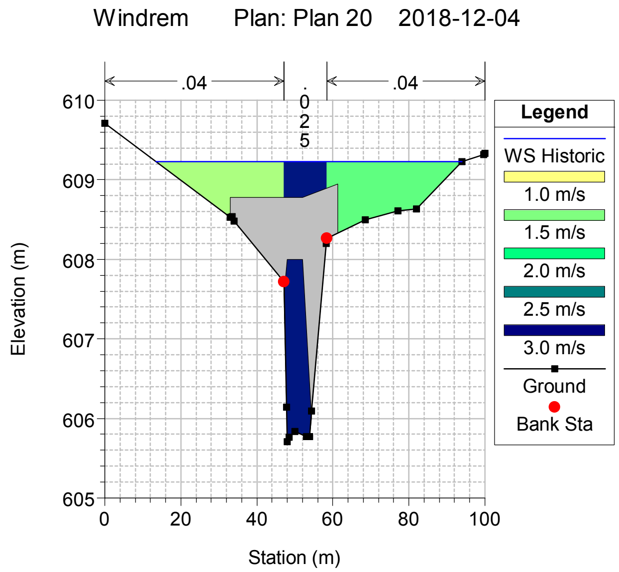
Windrem Plan: Plan 20 2018-12-04
.04
.025
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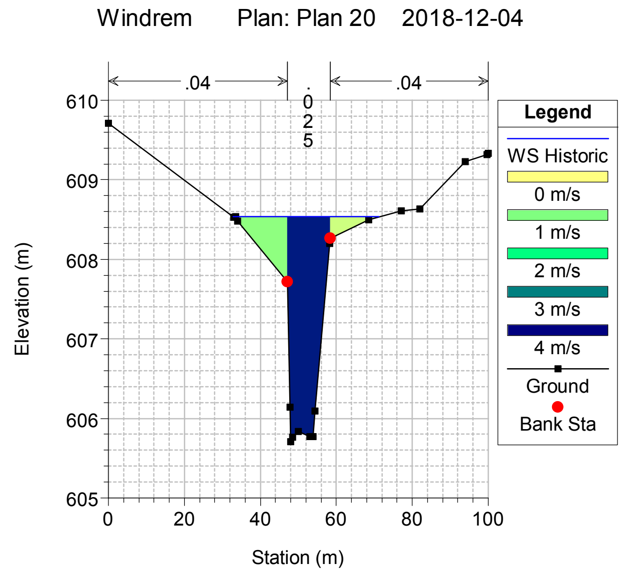
Elevation (m)
Station (m)
Legend
WS Historic
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
Ground
Bank Sta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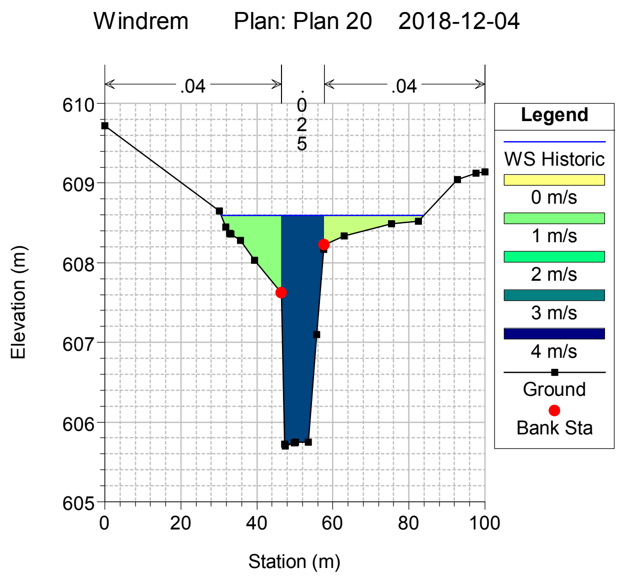
Elevation (m)
Station (m)
Legend
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Bank Sta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Legend
WS Historic
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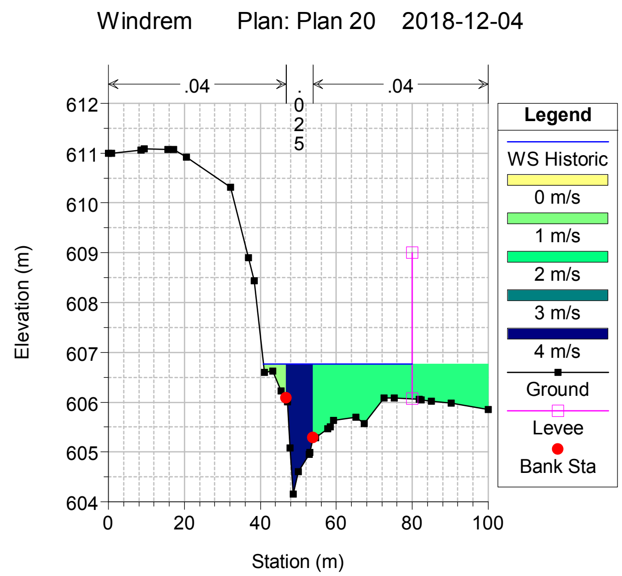
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
WS Historic
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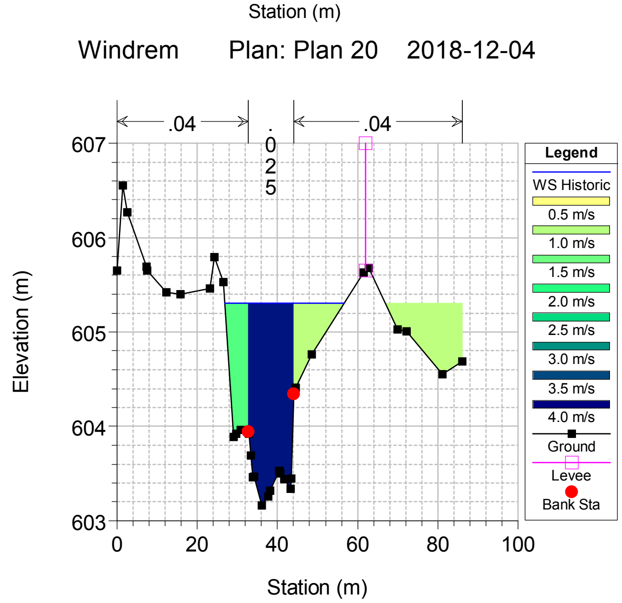
2 m/s
3 m/s
4 m/s
Ground
Levee
Bank Sta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Station (m)
Legend
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2.5 m/s
3.0 m/s
3.5 m/s
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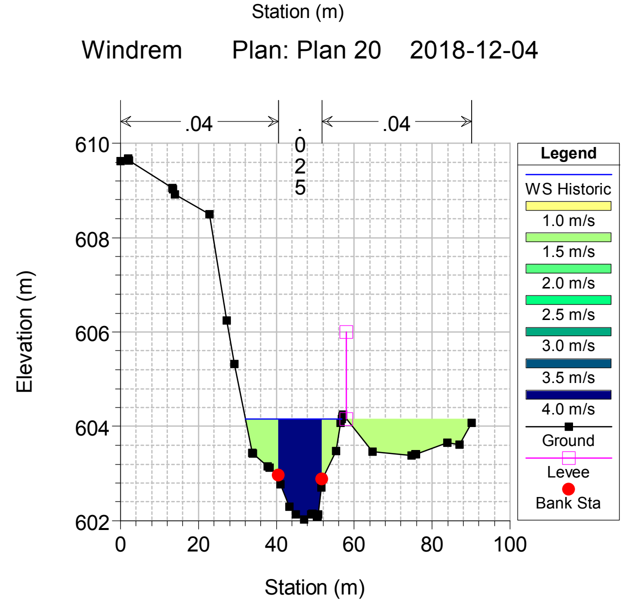
Ground
Levee
Bank Sta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Elevation (m)
Station (m)
Legend
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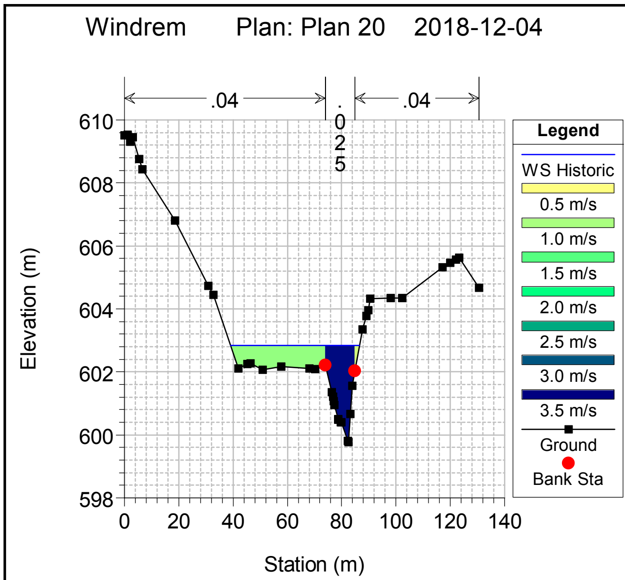
Ground
Levee
Bank Sta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2.5 m/s
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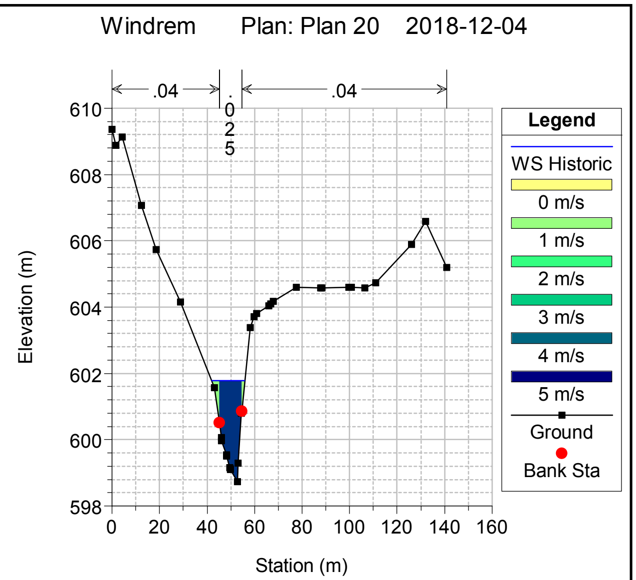
3.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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Legend
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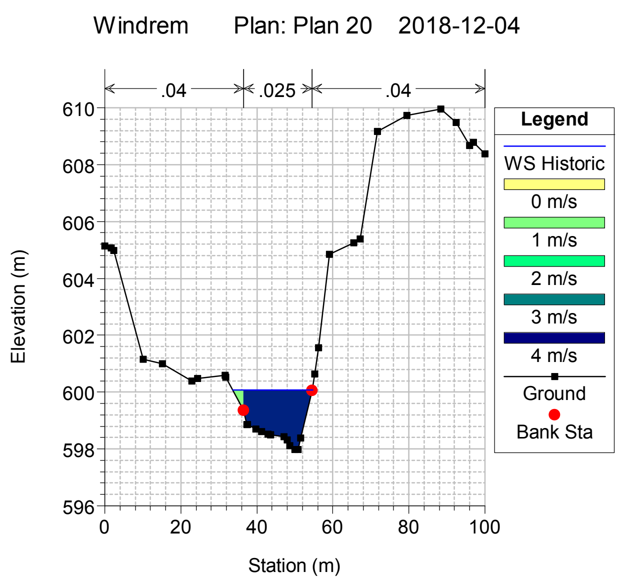
3 m/s
4 m/s
5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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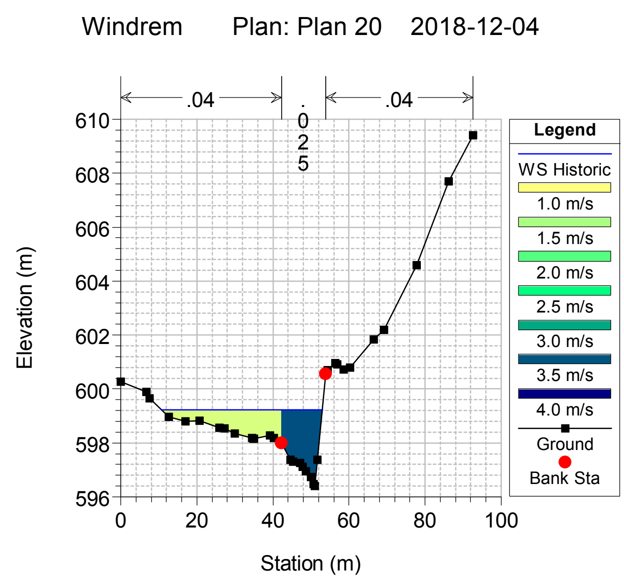
4 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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Legend
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3.0 m/s
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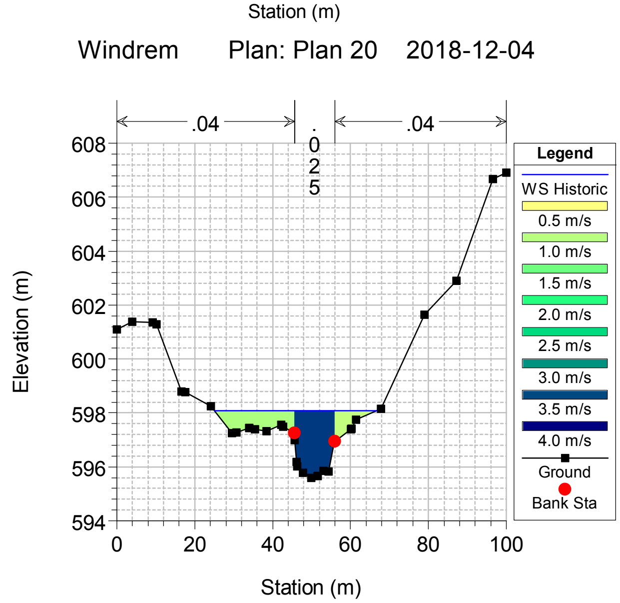
Ground
Bank Sta
Elevation (m)
Station (m)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Legend
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1.5 m/s
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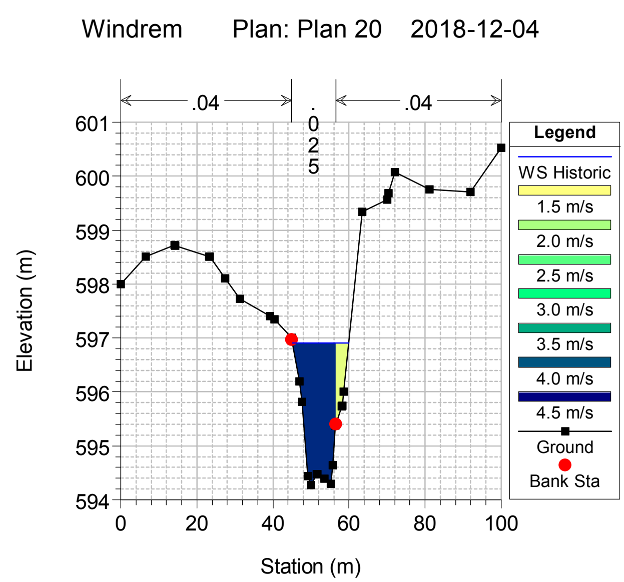
3.0 m/s
3.5 m/s
4.0 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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Legend
WS Historic
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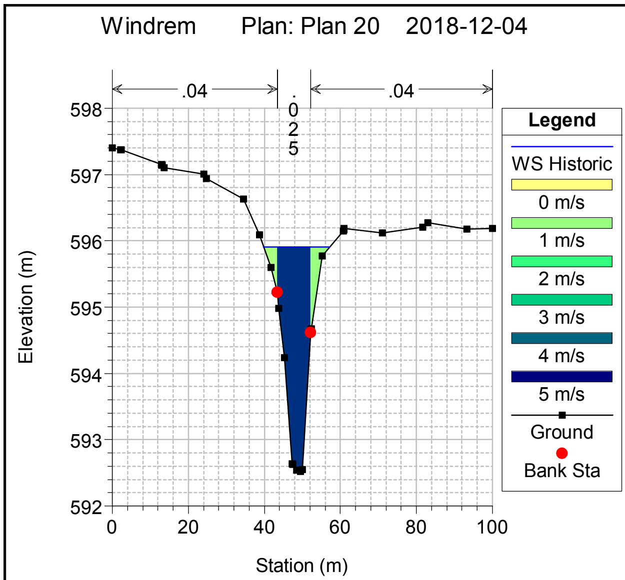
3.5 m/s
4.0 m/s
4.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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Legend
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3 m/s
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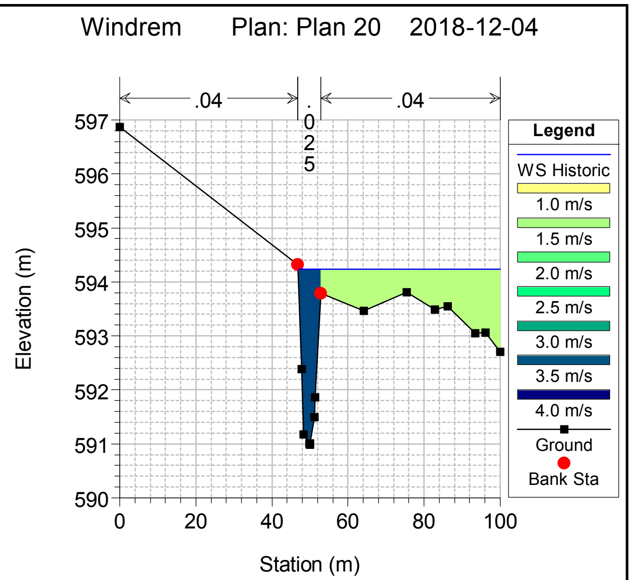
Ground
Bank Sta
Elevation (m)
Station (m)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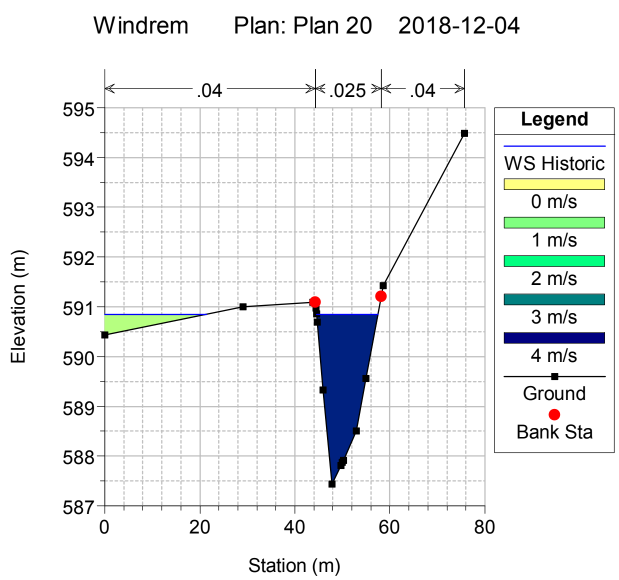
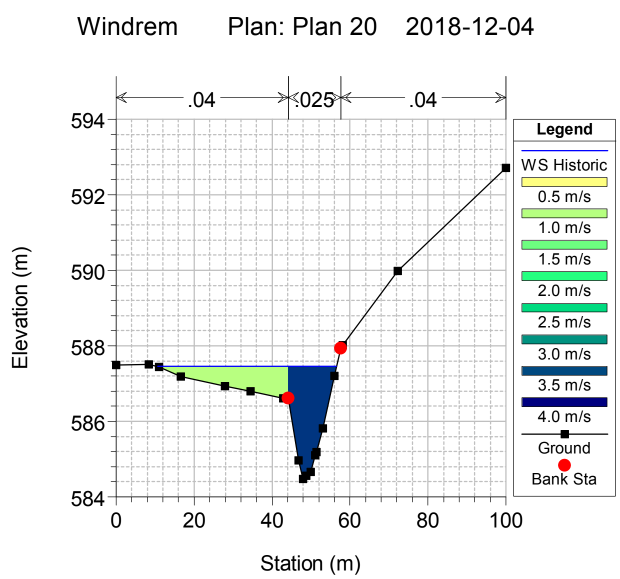
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
4.0 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Windrem Plan: Plan 20 2018-12-04
.04
.025
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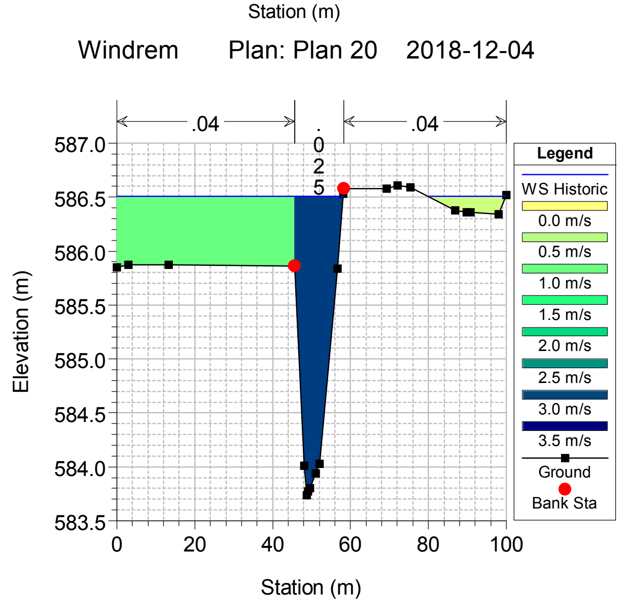
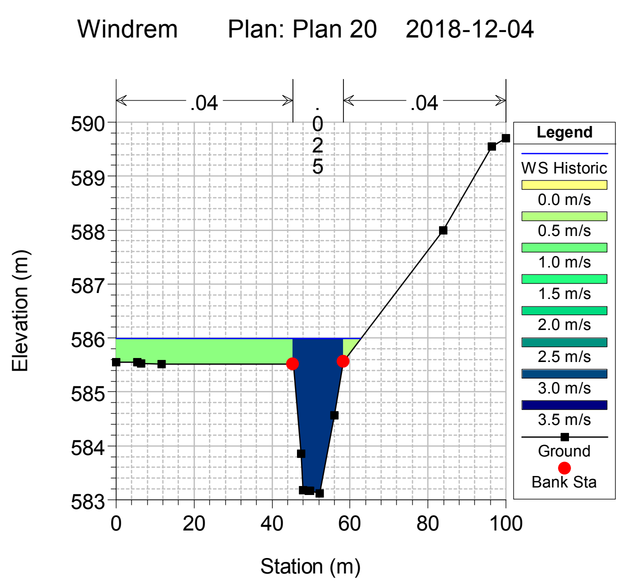
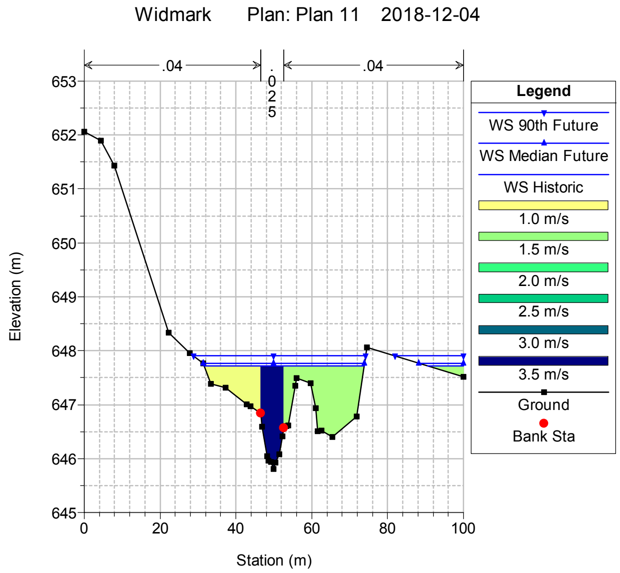
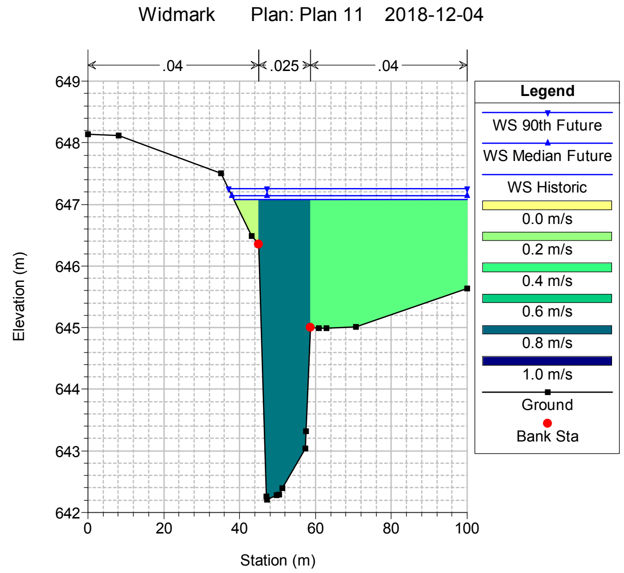
Legend
WS Historic
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
4.0 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Windrem Plan: Plan 20 2018-12-04
.04
.025
.04
Legend
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Widmark Plan: Plan 11 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
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.025
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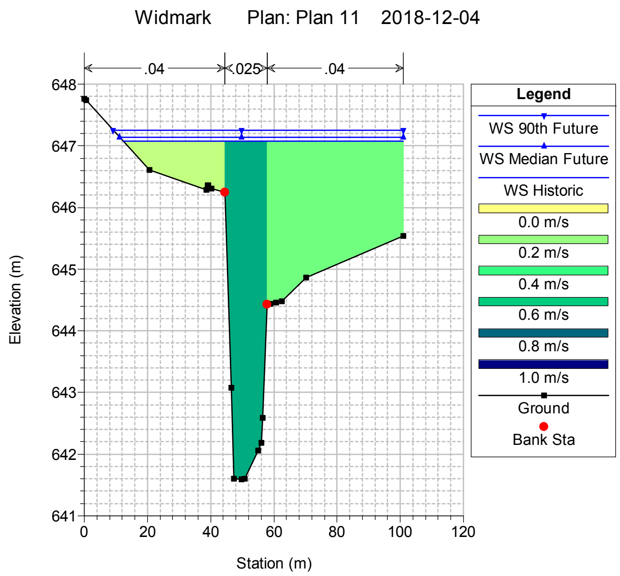
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
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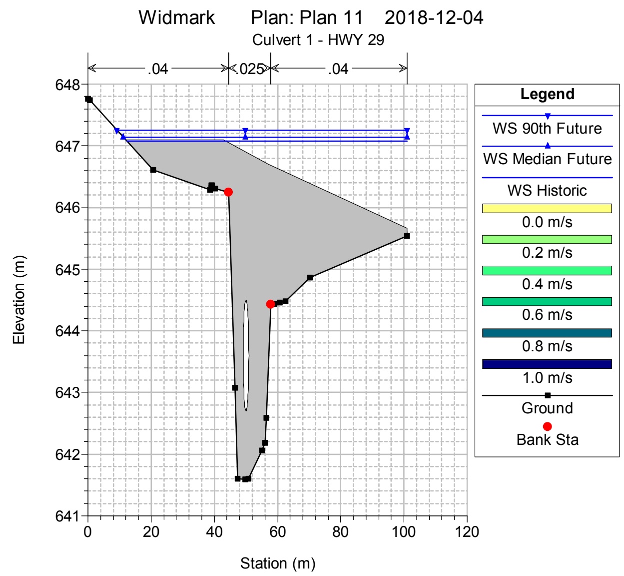
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
Culvert 1 - HWY 29
.04
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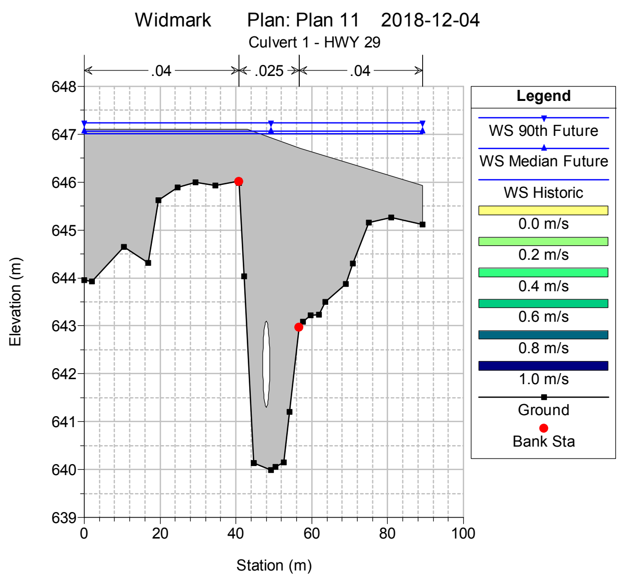
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
Culvert 1 - HWY 29
.04
.025
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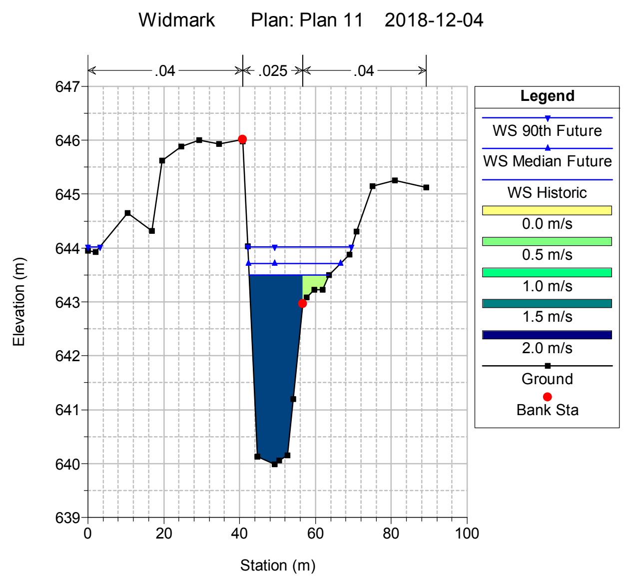
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
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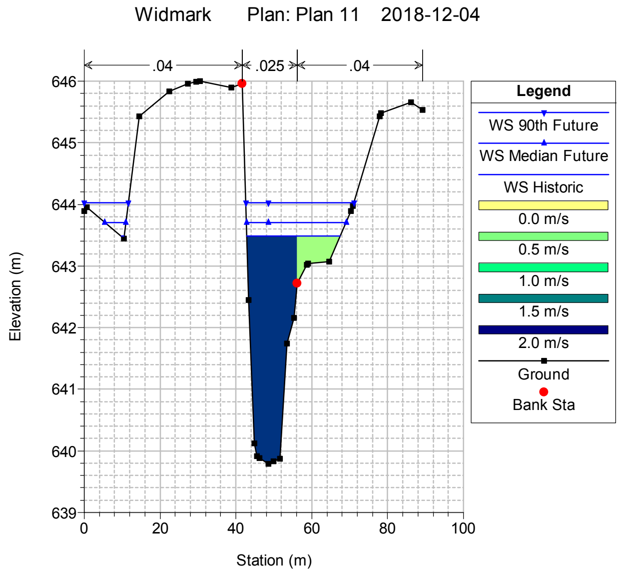
WS Median Future
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
Ground
Bank Sta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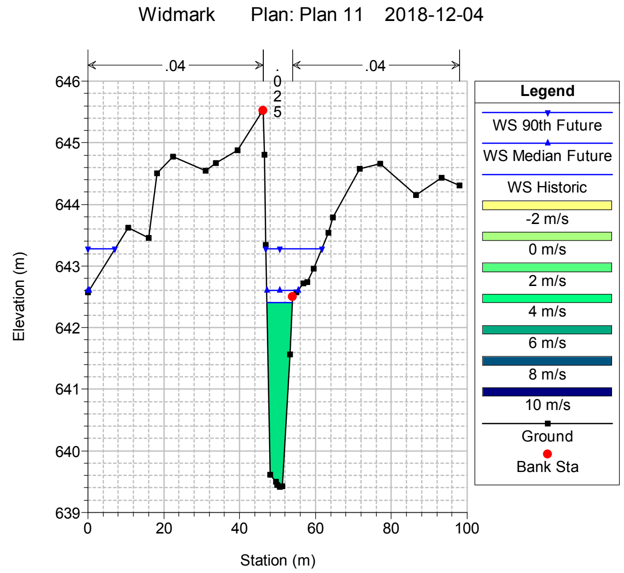
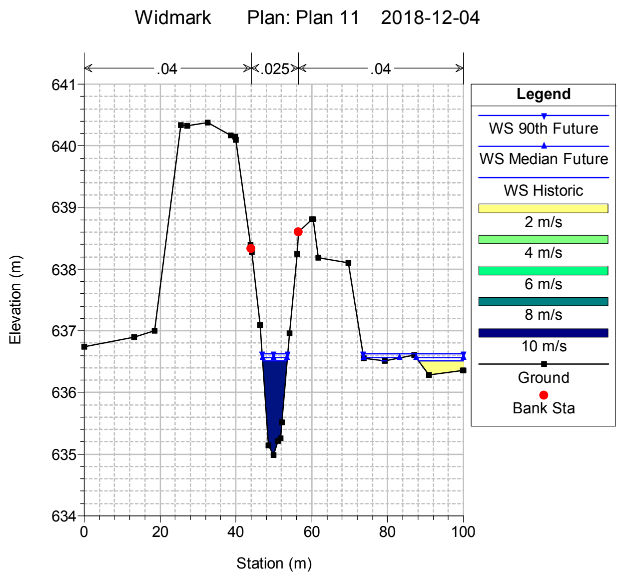
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
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.025
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Elevation (m)
Station (m)
Legend
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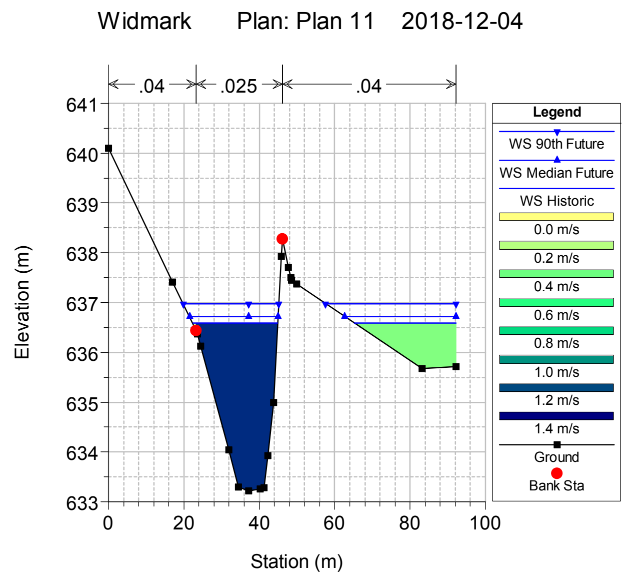
WS Median Future
WS Historic
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
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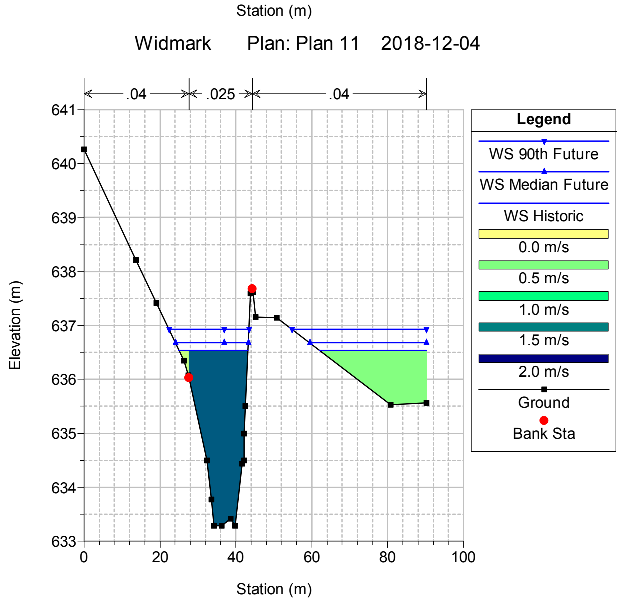
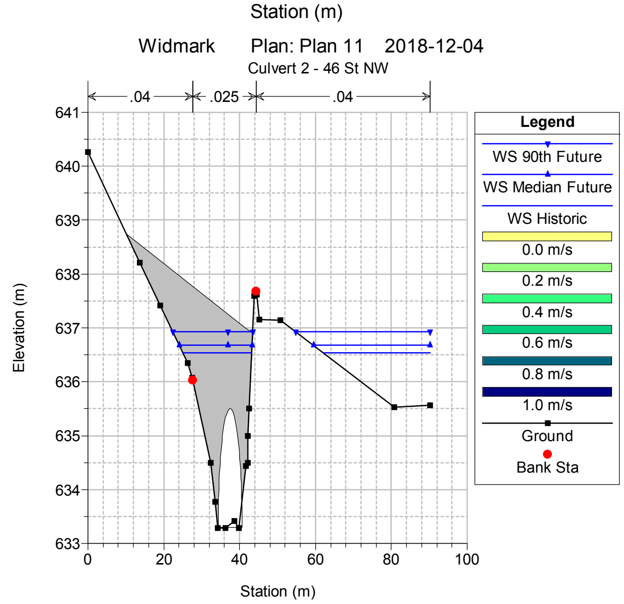
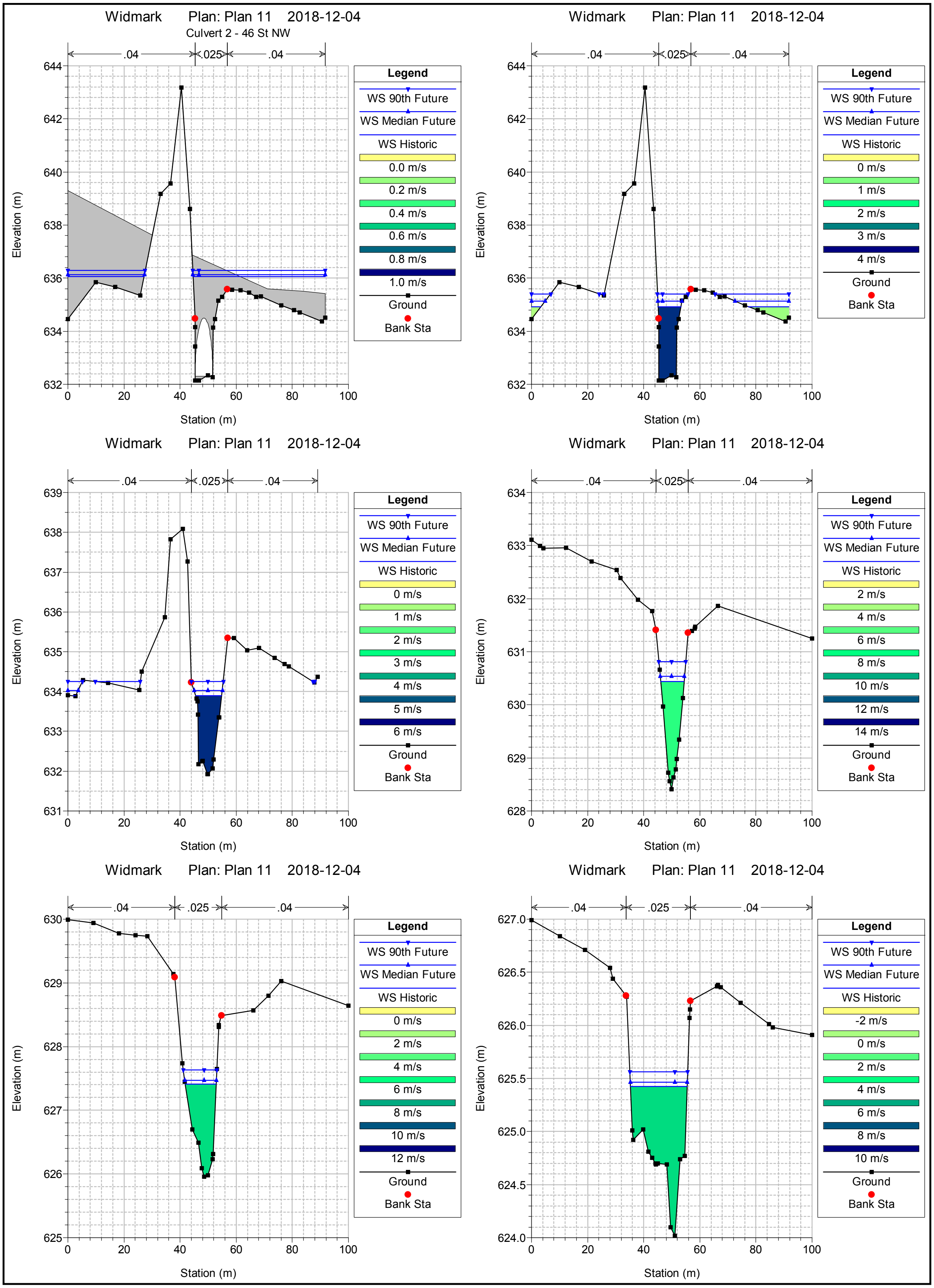
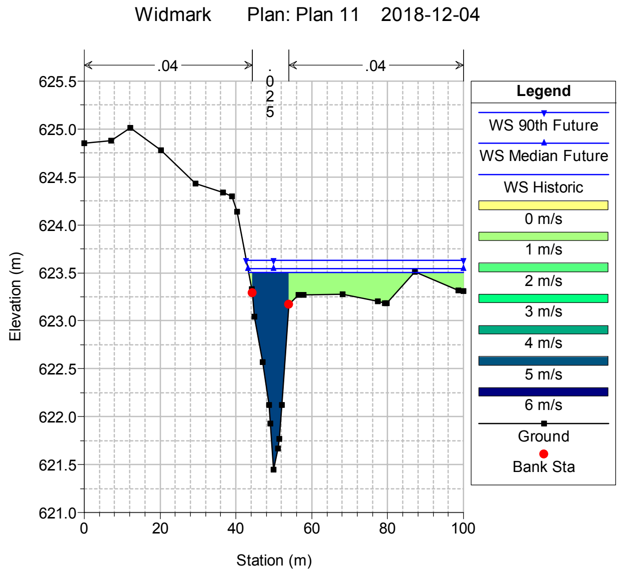
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
1.4 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
Culvert 2 - 46 St NW
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Bank Sta



Widmark Plan: Plan 11 2018-12-04
Culvert 2 - 46 St NW
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Bank Sta
Widmark Plan: Plan 11 2018-12-04
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Bank Sta
Widmark Plan: Plan 11 2018-12-04
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
6 m/s
Ground
Bank Sta
Widmark Plan: Plan 11 2018-12-04
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
12 m/s
14 m/s
Ground
Bank Sta
Widmark Plan: Plan 11 2018-12-04
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
12 m/s
Ground
Bank Sta
Widmark Plan: Plan 11 2018-12-04
.04 .025 .04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
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.025
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Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
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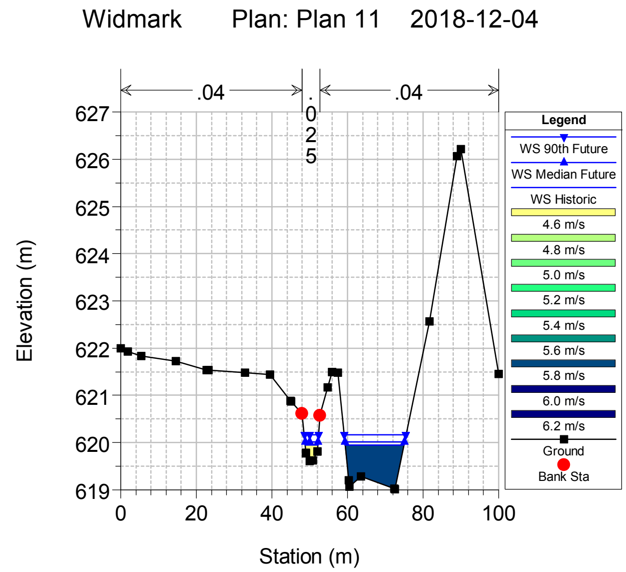
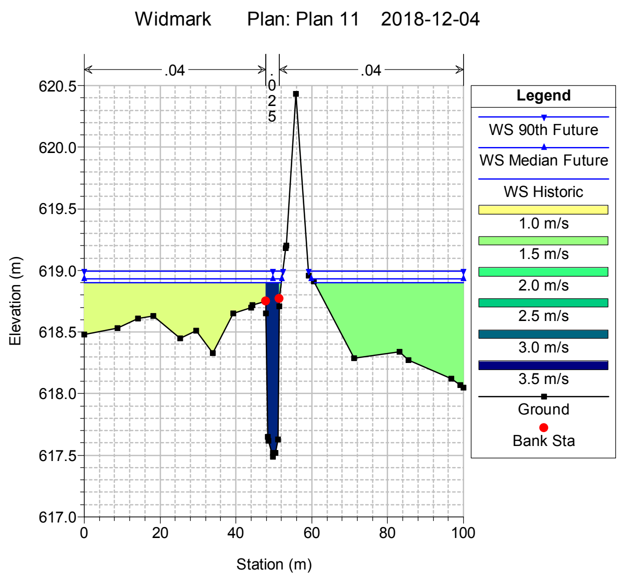
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
6 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
4.6 m/s
4.8 m/s
5.0 m/s
5.2 m/s
5.4 m/s
5.6 m/s
5.8 m/s
6.0 m/s
6.2 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
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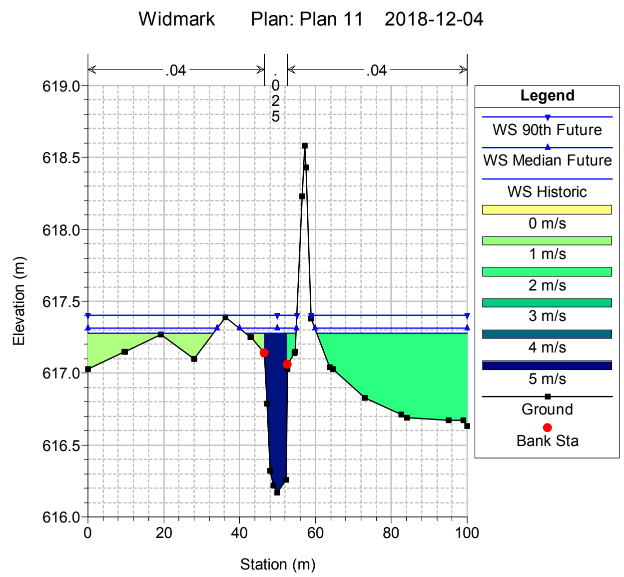
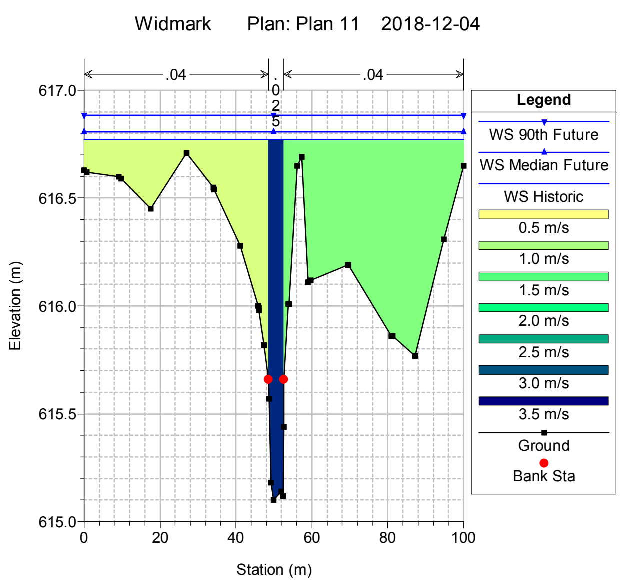
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
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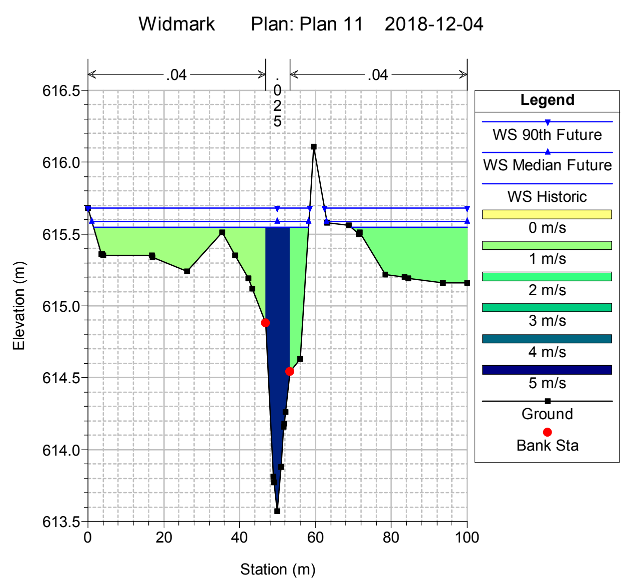
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
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.025
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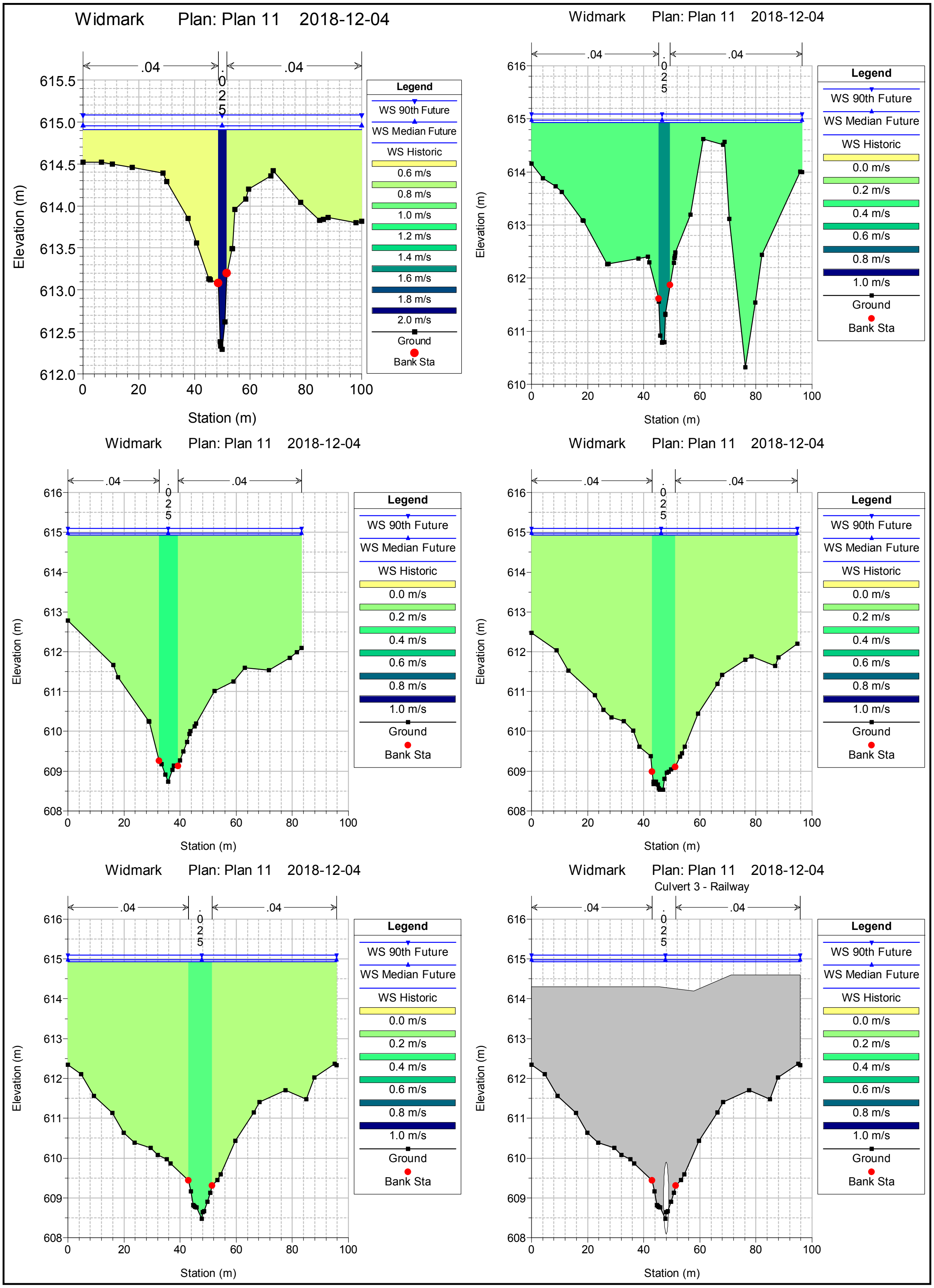
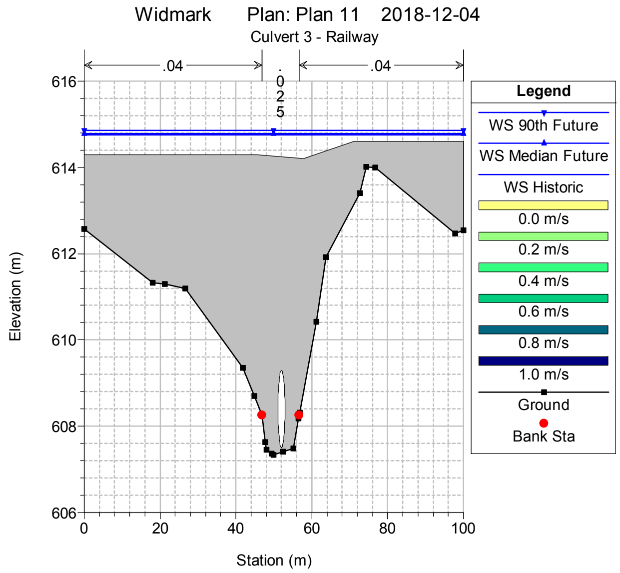
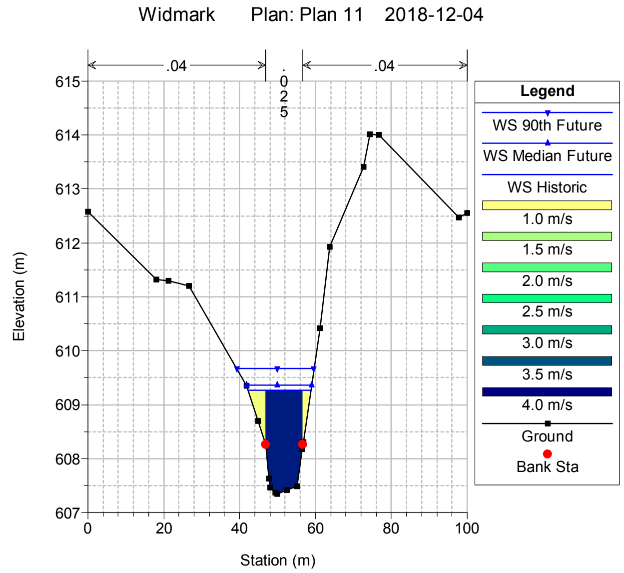
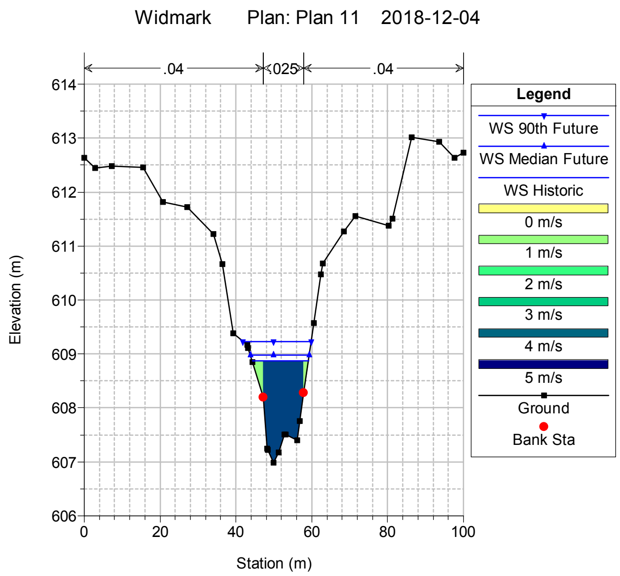
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Bank Sta



Widmark Plan: Plan 11 2018-12-04
.04
.025
.04
Legend
WS 90th Future
WS Median Future
WS Historic
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
1.4 m/s
1.6 m/s
1.8 m/s
2.0 m/s
Ground
Bank Sta
Elevation (m)
Station (m)
Widmark Plan: Plan 11 2018-12-04
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Bank Sta
Elevation (m)
Station (m)
Widmark Plan: Plan 11 2018-12-04
Widmark Plan: Plan 11 2018-12-04
Widmark Plan: Plan 11 2018-12-04
Widmark Plan: Plan 11 2018-12-04
Culvert 3 - Railway


Widmark Plan: Plan 11 2018-12-04
Culvert 3 - Railway
.04
.025
.04
Elevation (m)
616
614
612
610
608
606
Station (m)
0
20
40
60
80
100
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
.04
.025
.04
Elevation (m)
615
614
613
612
611
610
609
608
607
Station (m)
0
20
40
60
80
100
Legend
WS 90th Future
WS Median Future
WS Historic
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
4.0 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
.04
.025
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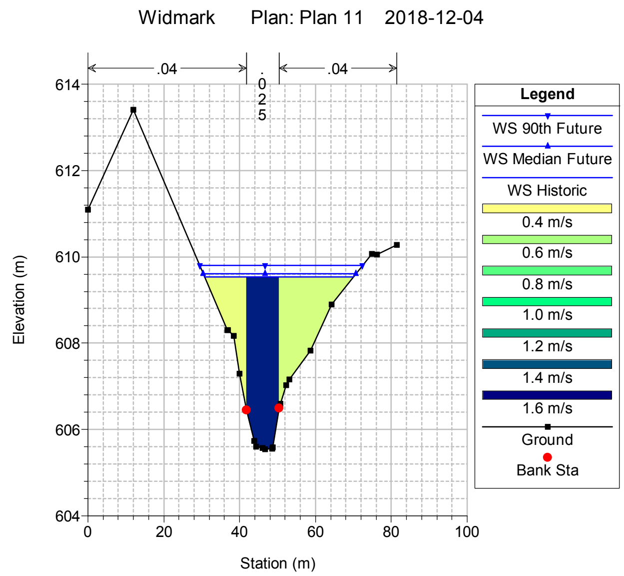
Elevation (m)
614
613
612
611
610
609
608
607
606
Station (m)
0
20
40
60
80
100
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
.04
.025
.04
Elevation (m)
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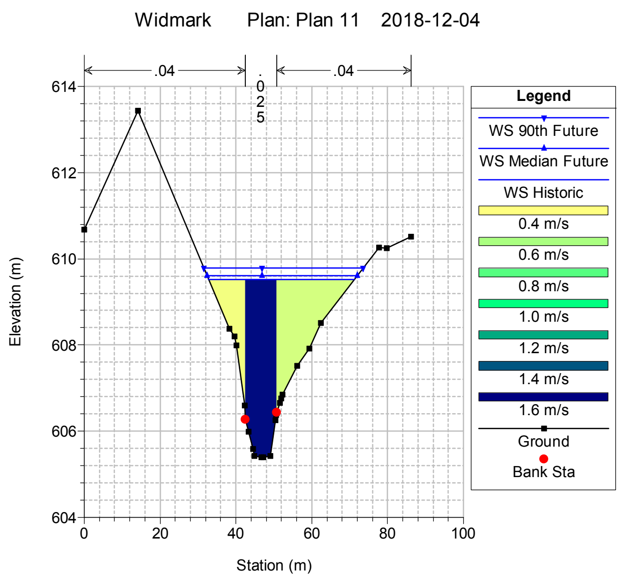
612
610
608
606
604
Station (m)
0
20
40
60
80
100
Legend
WS 90th Future
WS Median Future
WS Historic
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
1.4 m/s
1.6 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
.04
.025
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Elevation (m)
614
612
610
608
606
604
Station (m)
0
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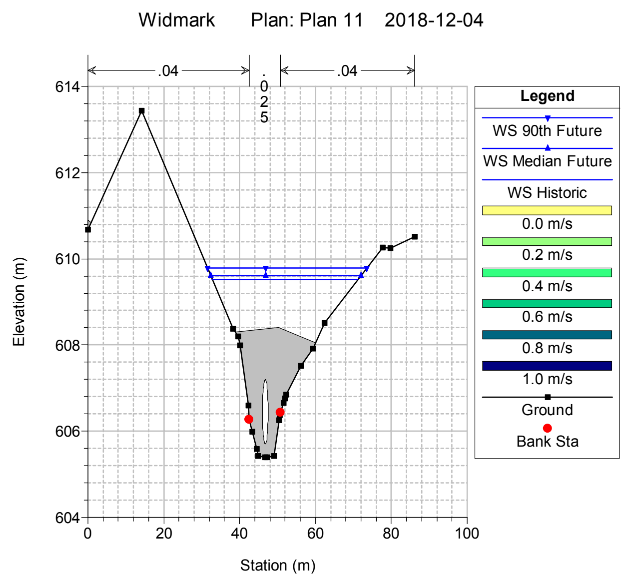
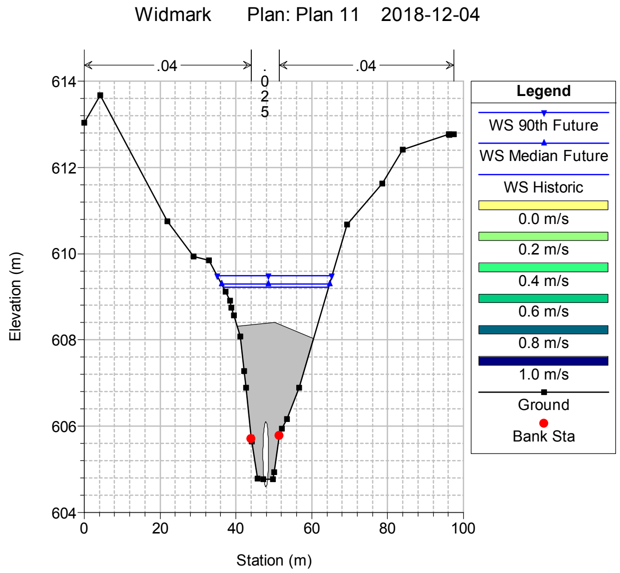
40
60
80
100
Legend
WS 90th Future
WS Median Future
WS Historic
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
1.4 m/s
1.6 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
.04
.025
.04
Elevation (m)
614
612
610
608
606
604
Station (m)
0
20
40
60
80
100
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Bank Sta


Widmark Plan: Plan 11 2018-12-04
.04
.025
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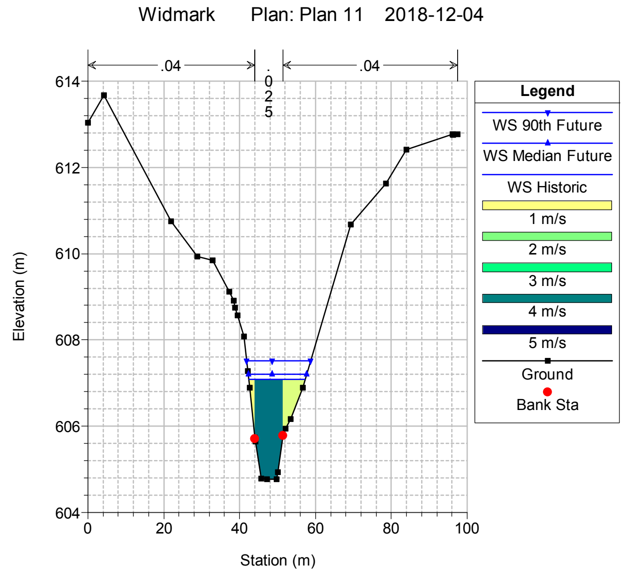
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Widmark Plan: Plan 11 2018-12-04
.04
.025
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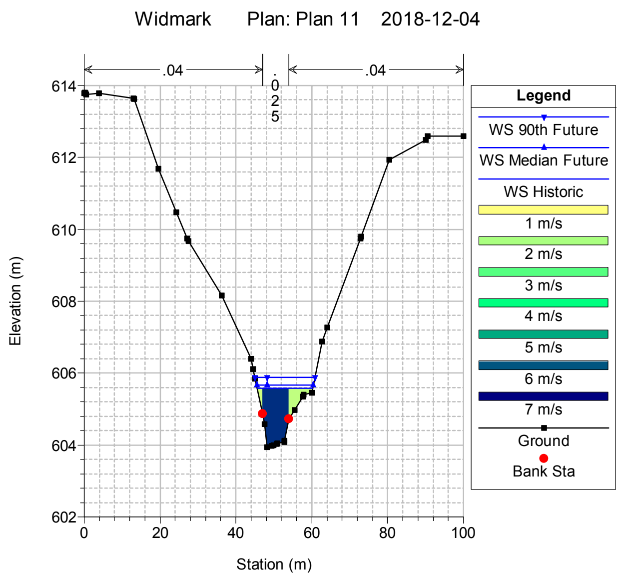
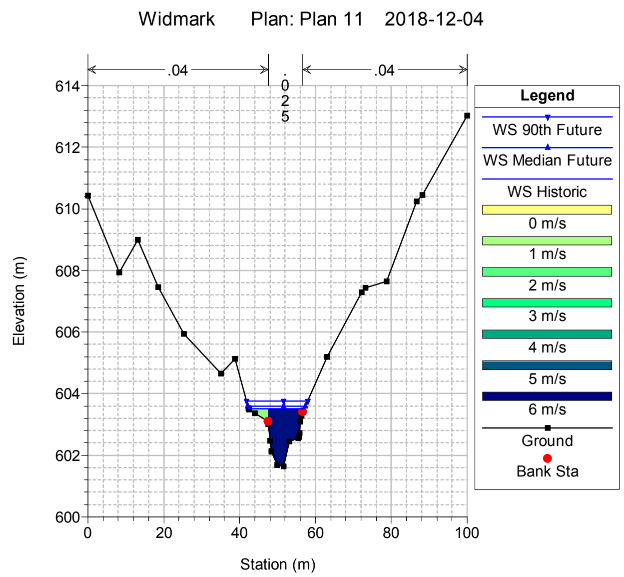
Legend
WS 90th Future
WS Median Future
WS Historic
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Widmark Plan: Plan 11 2018-12-04
.04
.025
.04
Legend
WS 90th Future
WS Median Future
WS Historic
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
6 m/s
7 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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.04
.025
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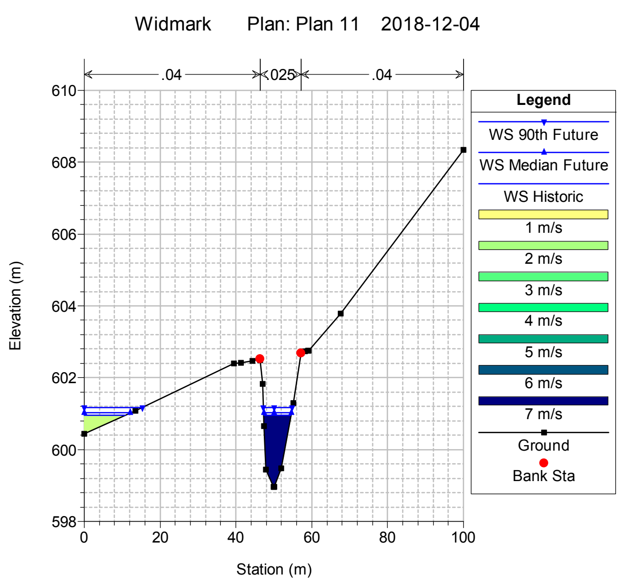
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
6 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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.025
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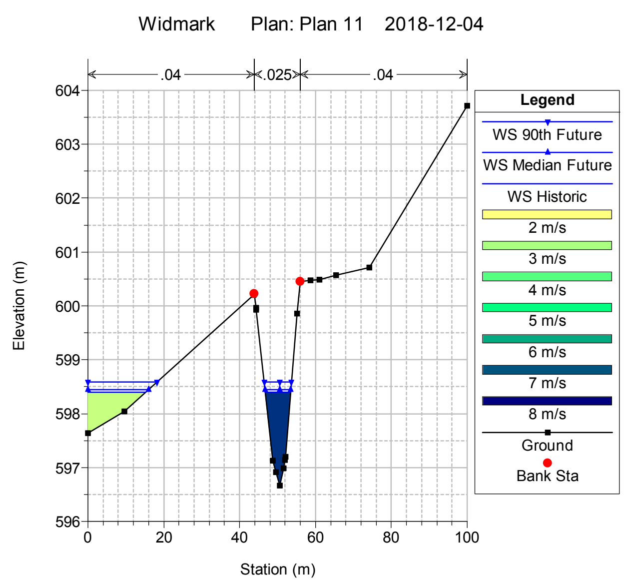
Legend
WS 90th Future
WS Median Future
WS Historic
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
6 m/s
7 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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Legend
WS 90th Future
WS Median Future
WS Historic
2 m/s
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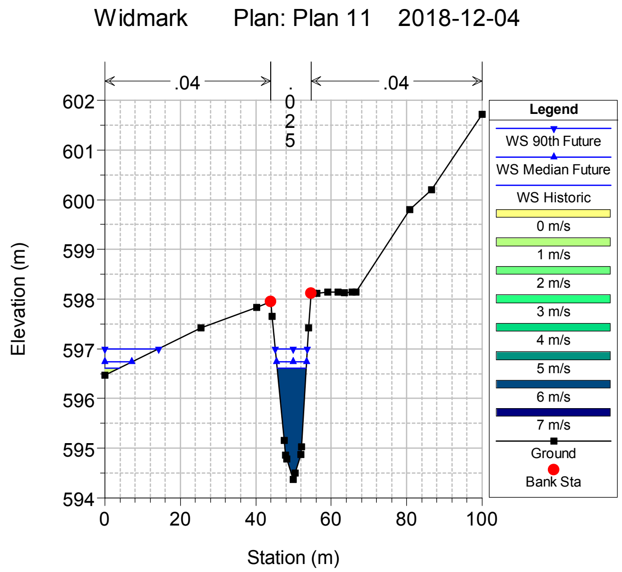
4 m/s
5 m/s
6 m/s
7 m/s
8 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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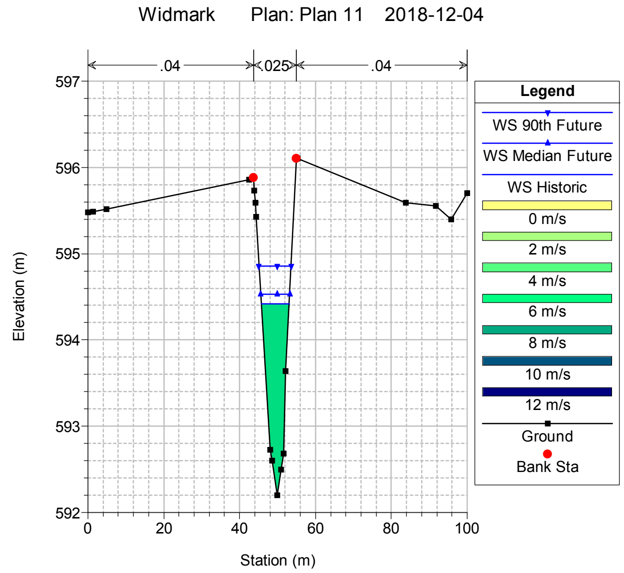
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
6 m/s
7 m/s
Ground
Bank Sta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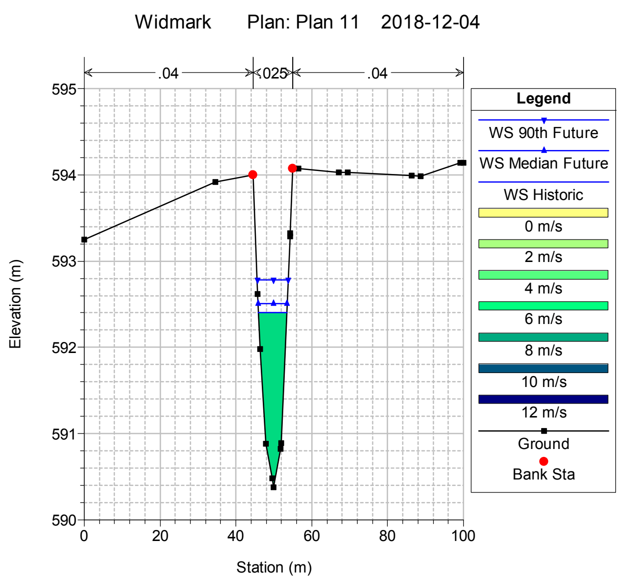
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
12 m/s
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
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2 m/s
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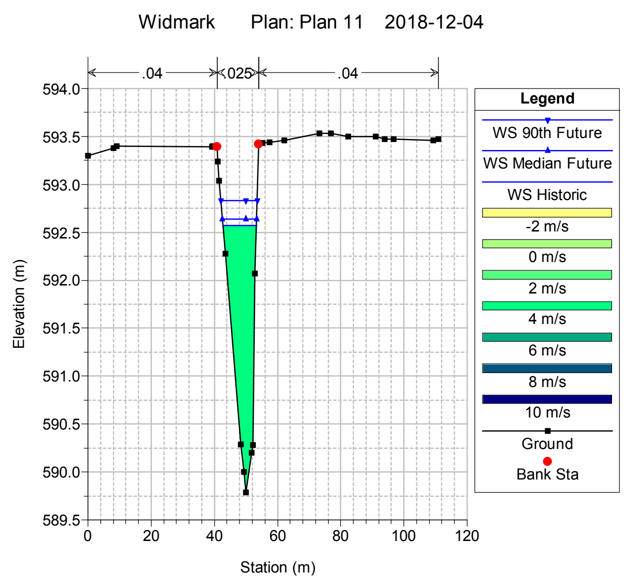
10 m/s
12 m/s
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
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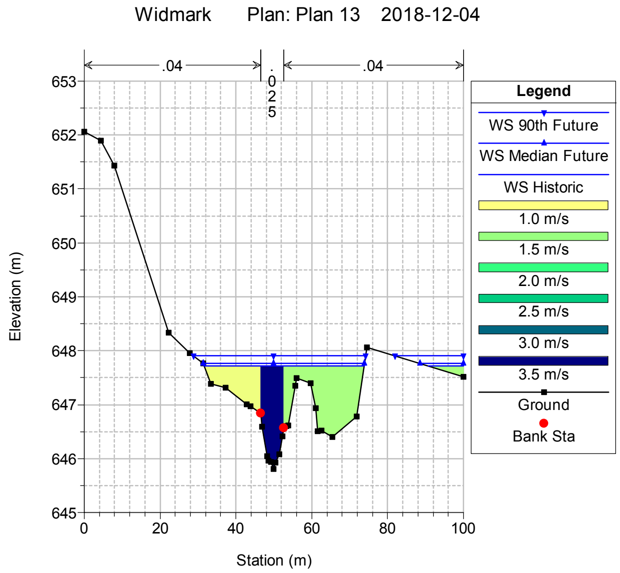
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta


Widmark Plan: Plan 13 2018-12-04
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.025
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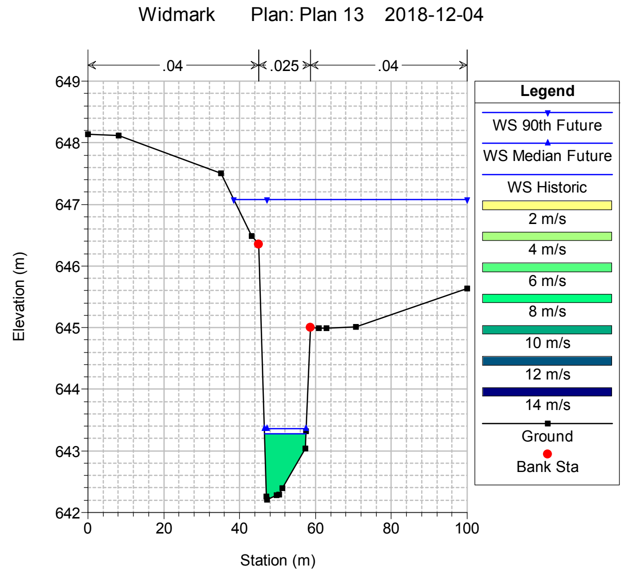
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta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.025
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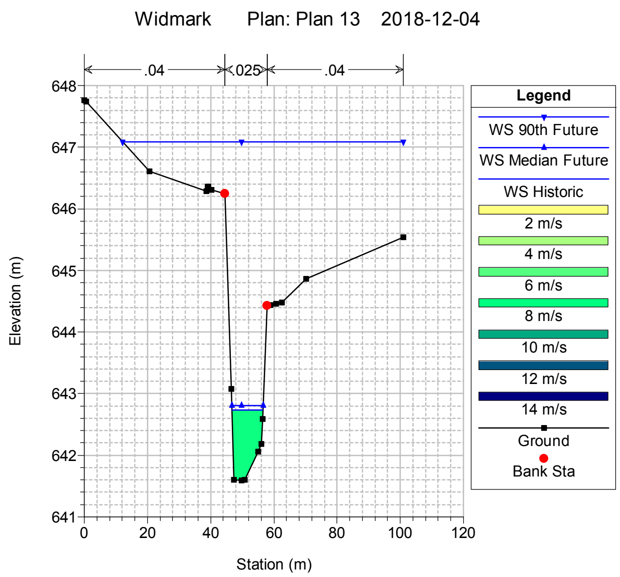
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
12 m/s
14 m/s
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
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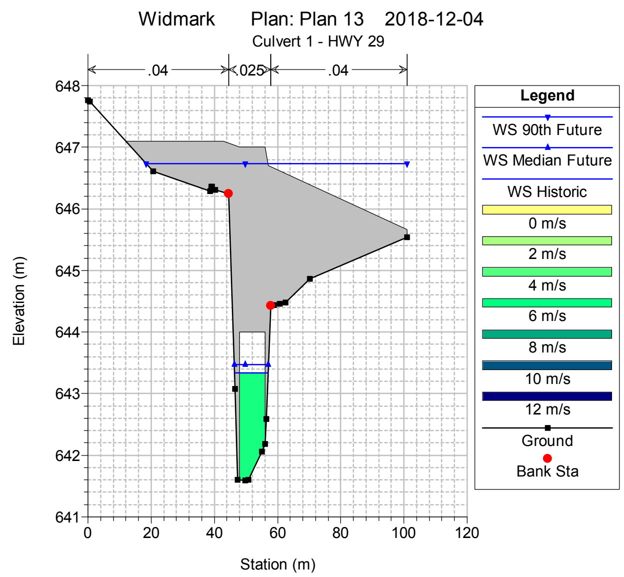
4 m/s
6 m/s
8 m/s
10 m/s
12 m/s
14 m/s
Ground
Bank Sta


Widmark Plan: Plan 13 2018-12-04
Culvert 1 - HWY 29
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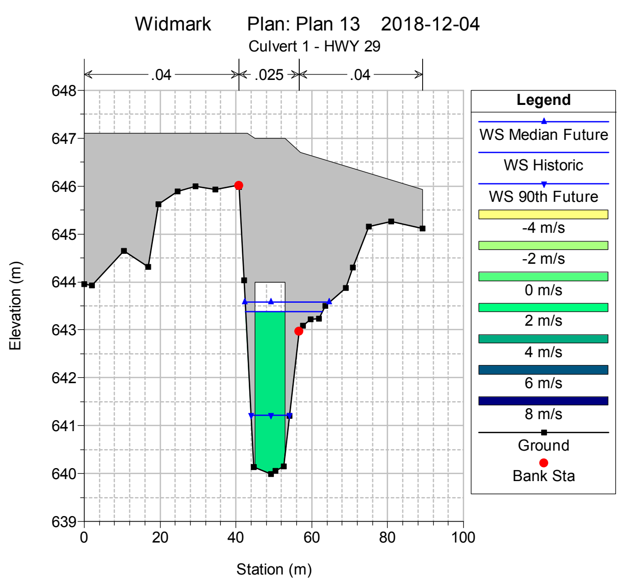
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
12 m/s
Ground
Bank Sta


Widmark Plan: Plan 13 2018-12-04
Culvert 1 - HWY 29
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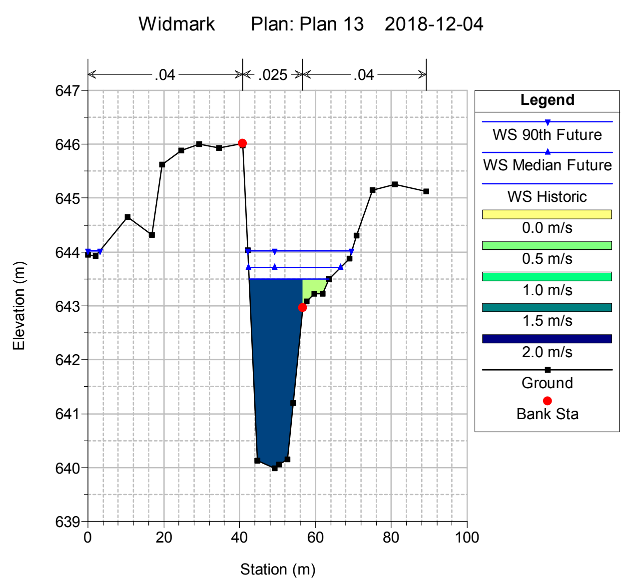
.025
.04
Elevation (m)
Station (m)
Legend
WS Median Future
WS Historic
WS 90th Future
-4 m/s
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
Ground
Bank Sta


Widmark Plan: Plan 13 2018-12-04
.04
.025
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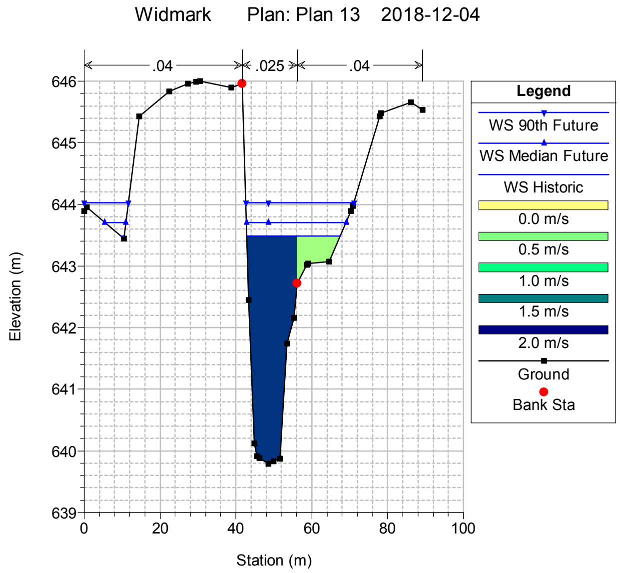
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
Ground
Bank Sta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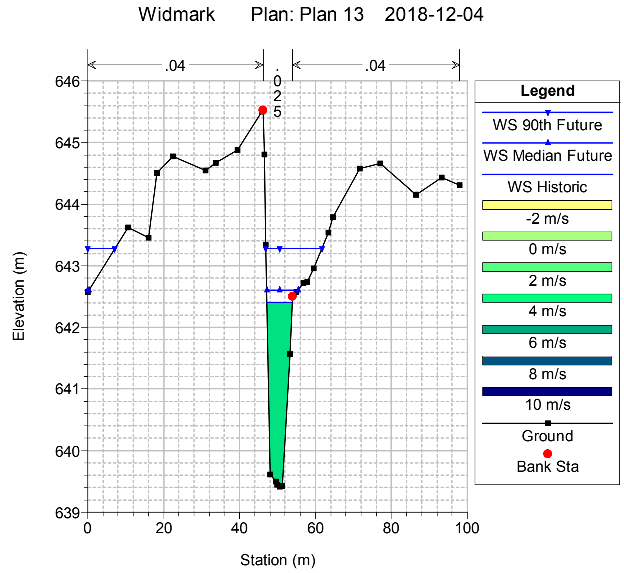
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
Ground
Bank Sta


Widmark Plan: Plan 13 2018-12-04
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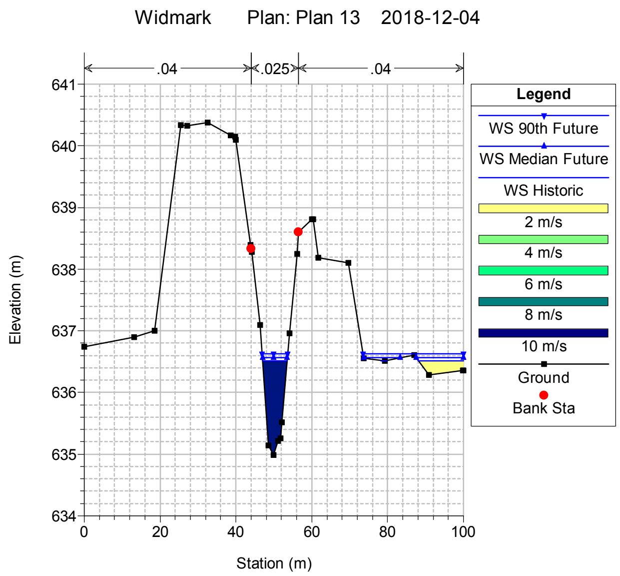
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta


Widmark Plan: Plan 13 2018-12-04
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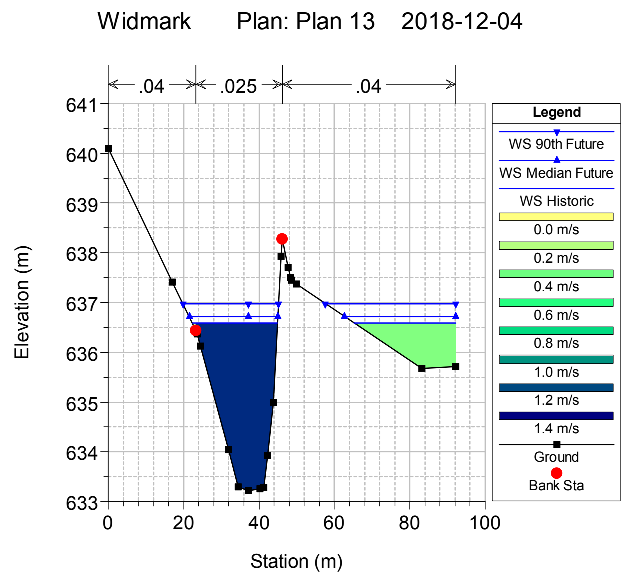
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta


Widmark Plan: Plan 13 2018-12-04
.04
.025
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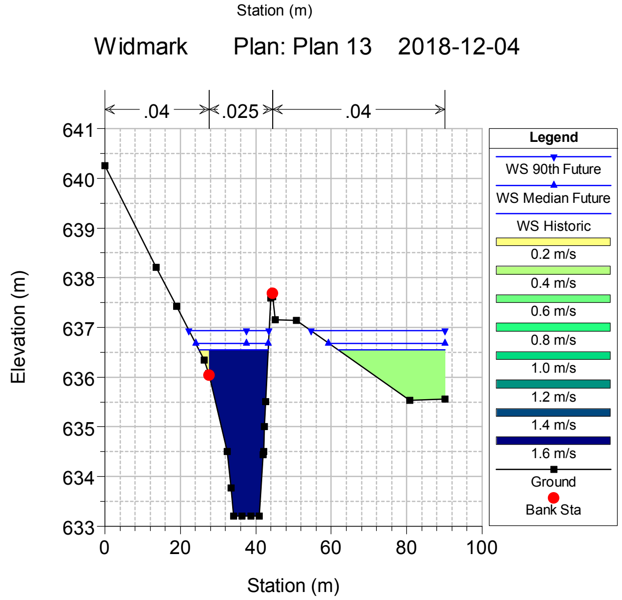
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
1.4 m/s
Ground
Bank Sta


Widmark Plan: Plan 13 2018-12-04
.04
.025
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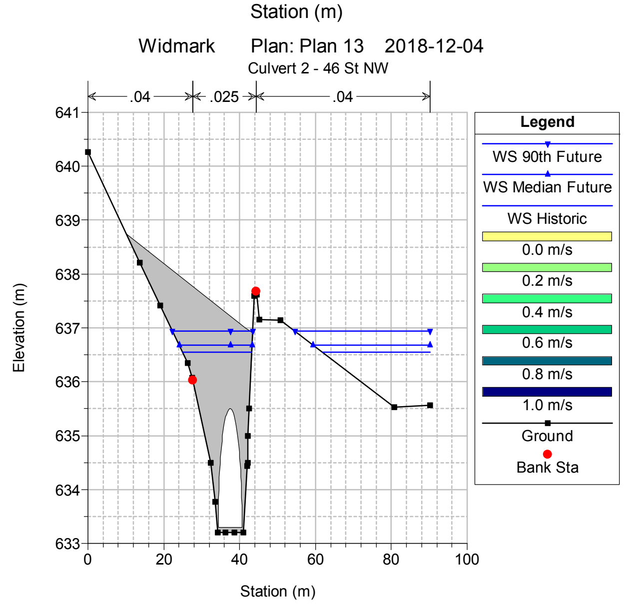
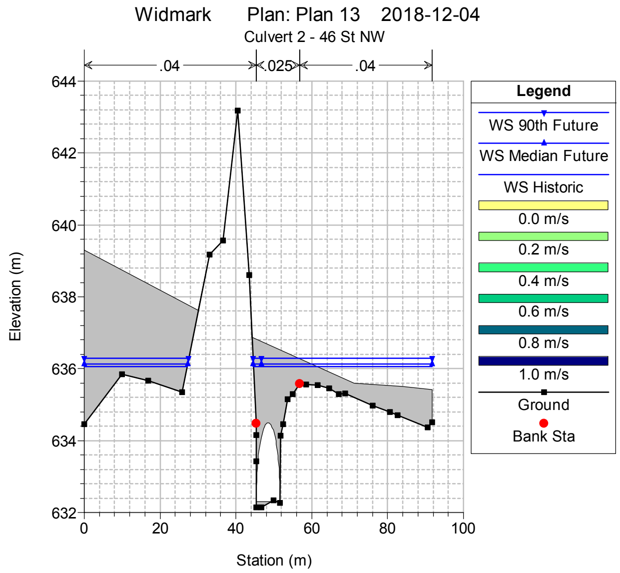
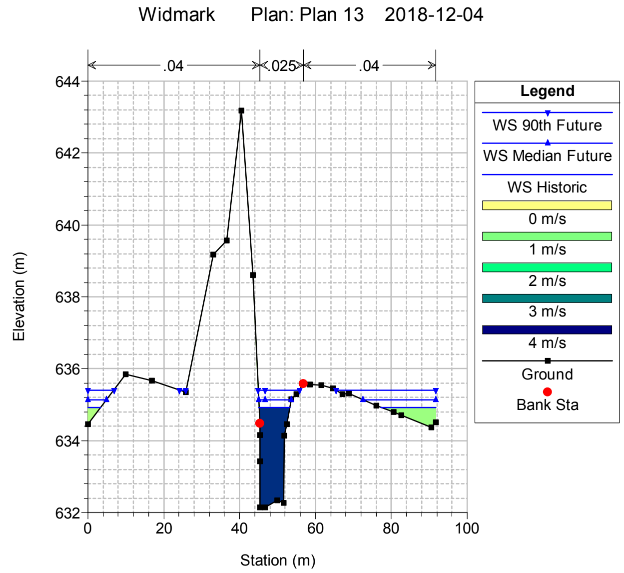
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
1.4 m/s
1.6 m/s
Ground
Bank Sta

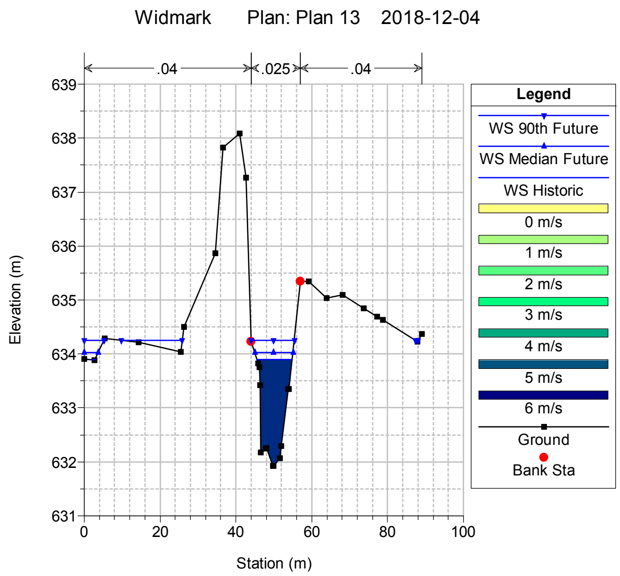

Widmark Plan: Plan 13 2018-12-04
Culvert 2 - 46 St NW
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Bank Sta



Widmark Plan: Plan 13 2018-12-04
Culvert 2 - 46 St NW
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.0 m/s
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
Ground
Bank Sta



Widmark Plan: Plan 13 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Bank Sta



Widmark Plan: Plan 13 2018-12-04
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.025
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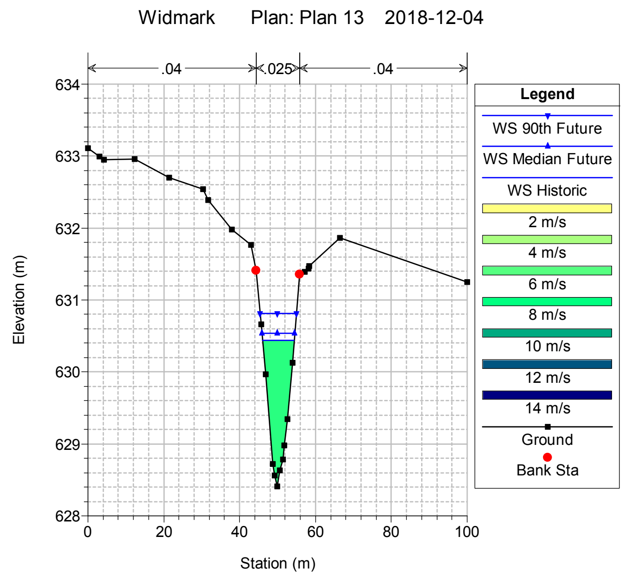
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
6 m/s
Ground
Bank Sta



Widmark Plan: Plan 13 2018-12-04
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.025
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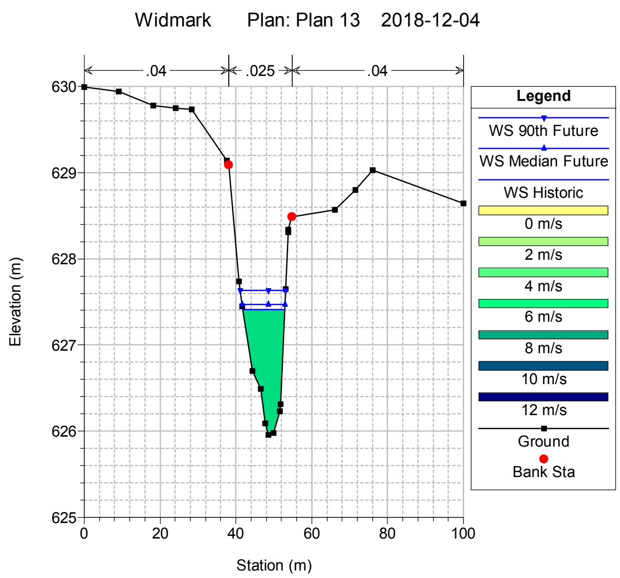
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
12 m/s
14 m/s
Ground
Bank Sta



Widmark Plan: Plan 13 2018-12-04
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Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
2 m/s
4 m/s
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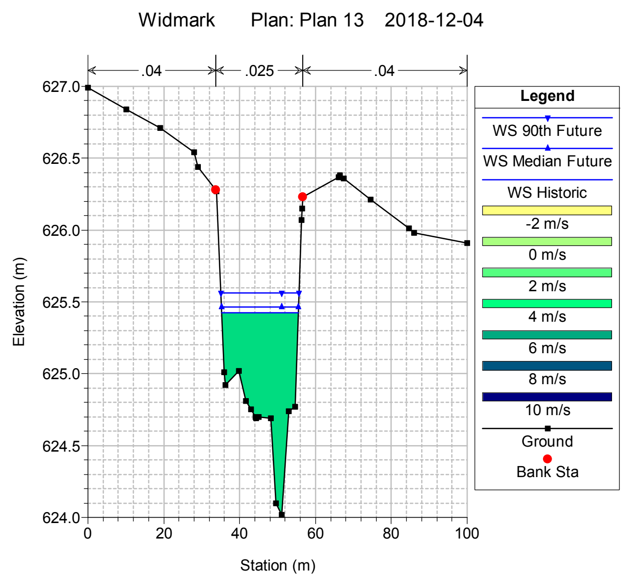
12 m/s
Ground
Bank Sta



Widmark Plan: Plan 13 2018-12-04
.04
.025
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Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
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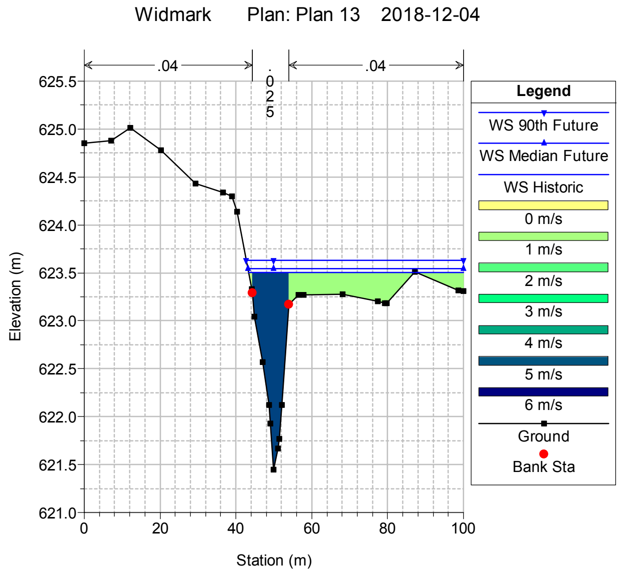
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta


Widmark Plan: Plan 13 2018-12-04
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.025
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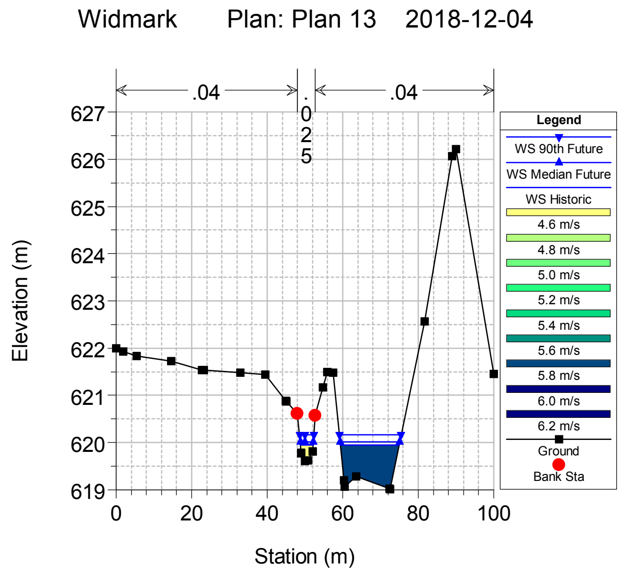
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
6 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Widmark Plan: Plan 13 2018-12-04
.04
.025
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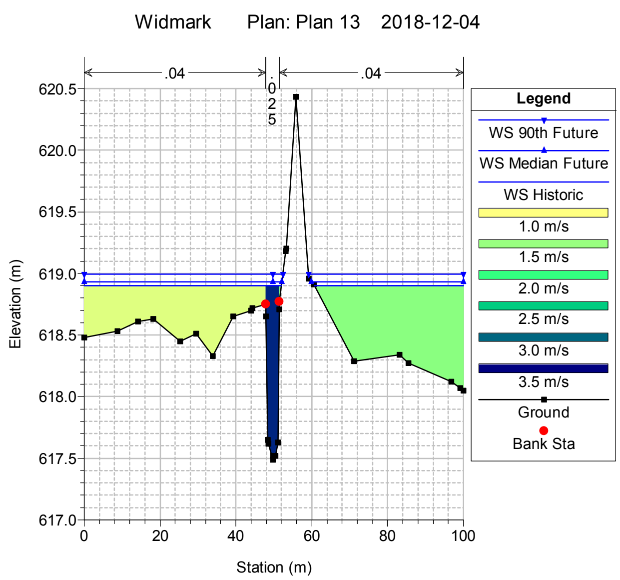
Legend
WS 90th Future
WS Median Future
WS Historic
4.6 m/s
4.8 m/s
5.0 m/s
5.2 m/s
5.4 m/s
5.6 m/s
5.8 m/s
6.0 m/s
6.2 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Widmark Plan: Plan 13 2018-12-04
.04
.025
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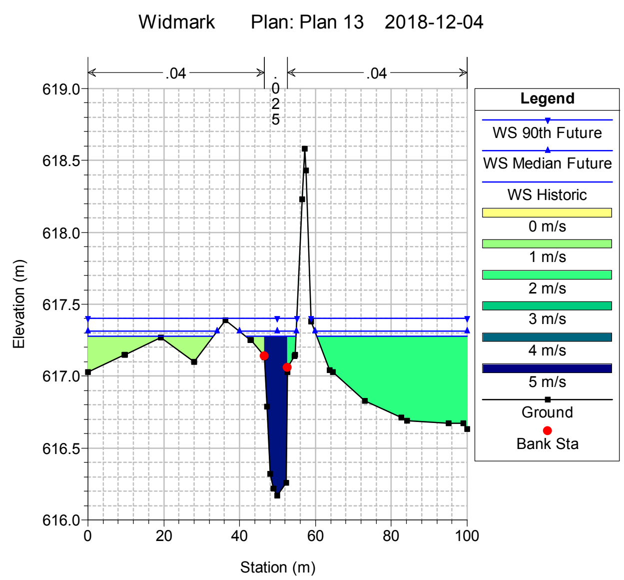
Legend
WS 90th Future
WS Median Future
WS Historic
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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Legend
WS 90th Future
WS Median Future
WS Historic
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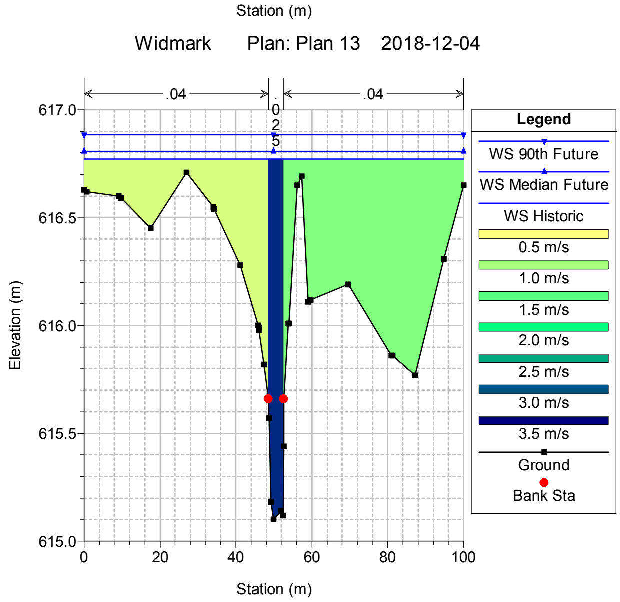
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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Legend
WS 90th Future
WS Median Future
WS Historic
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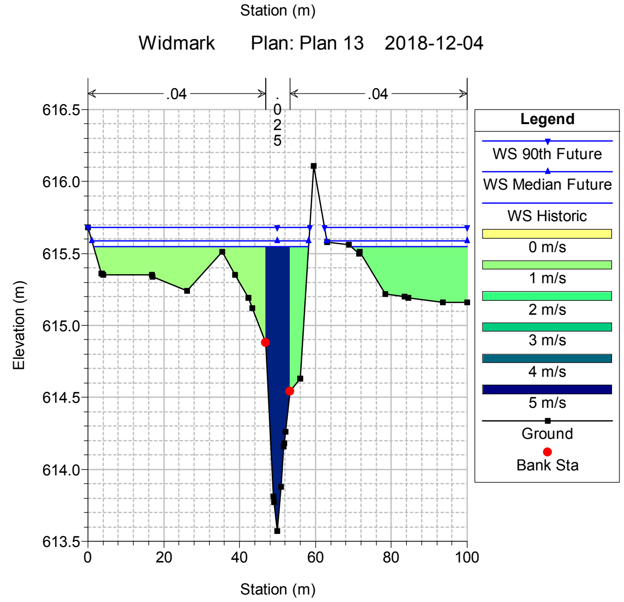
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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Legend
WS 90th Future
WS Median Future
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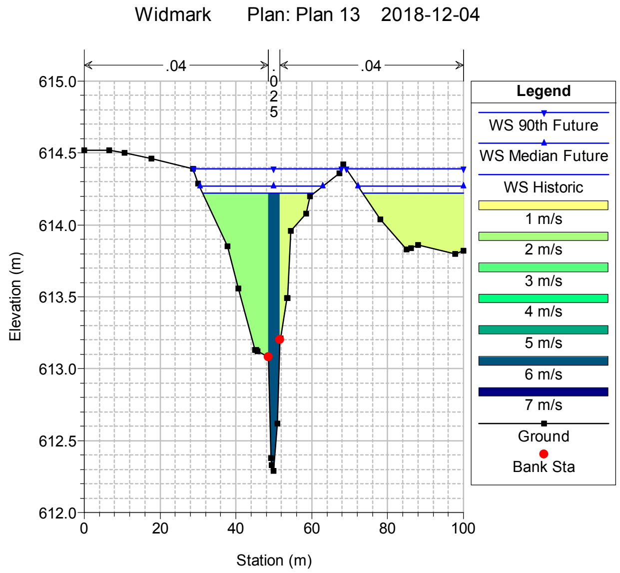
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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Legend
WS 90th Future
WS Median Future
WS Historic
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2 m/s
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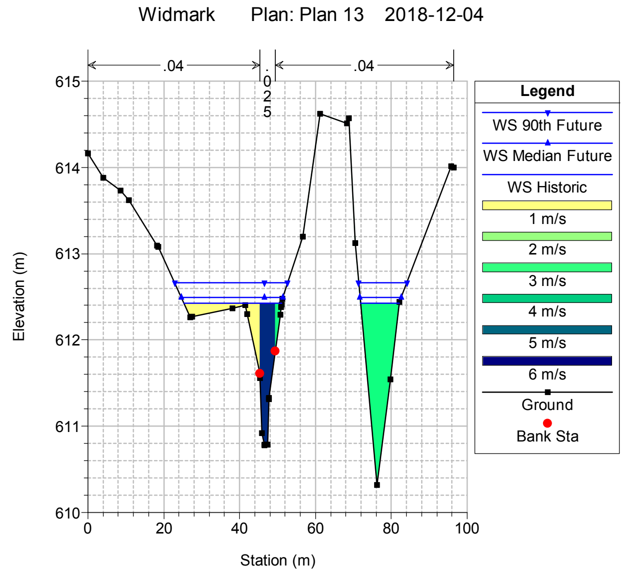
4 m/s
5 m/s
6 m/s
7 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Widmark Plan: Plan 13 2018-12-04
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.025
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Legend
WS 90th Future
WS Median Future
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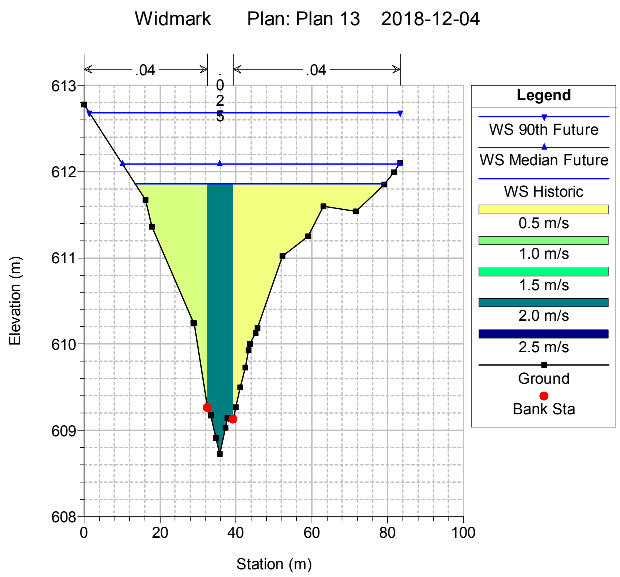
3 m/s
4 m/s
5 m/s
6 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Widmark Plan: Plan 13 2018-12-04
.04
.025
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Legend
WS 90th Future
WS Median Future
WS Historic
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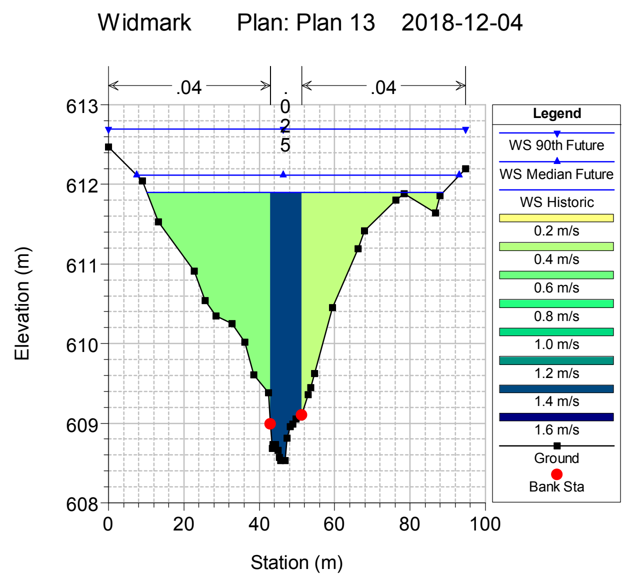
1.5 m/s
2.0 m/s
2.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Widmark Plan: Plan 13 2018-12-04
.04
.025
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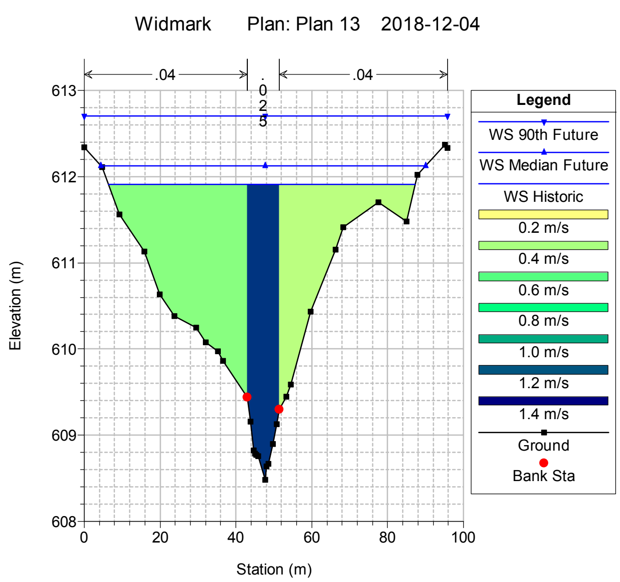
Legend
WS 90th Future
WS Median Future
WS Historic
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
1.4 m/s
1.6 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Widmark Plan: Plan 13 2018-12-04
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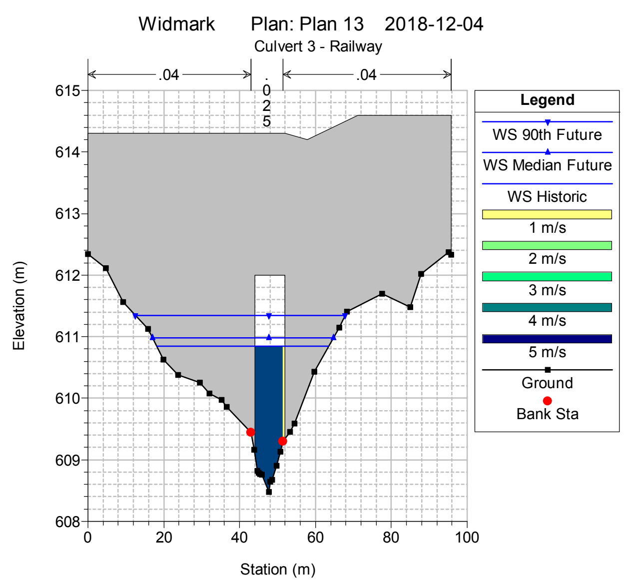
Legend
WS 90th Future
WS Median Future
WS Historic
0.2 m/s
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
1.4 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Widmark Plan: Plan 13 2018-12-04
Culvert 3 - Railway
.04
.025
.04
Legend
WS 90th Future
WS Median Future
WS Historic
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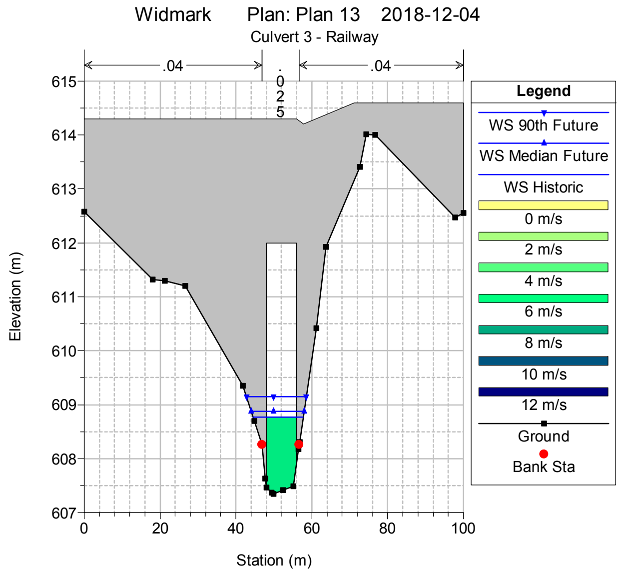
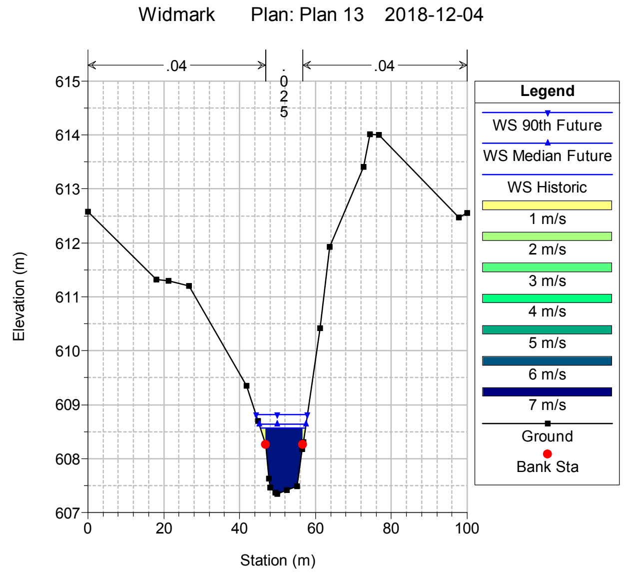
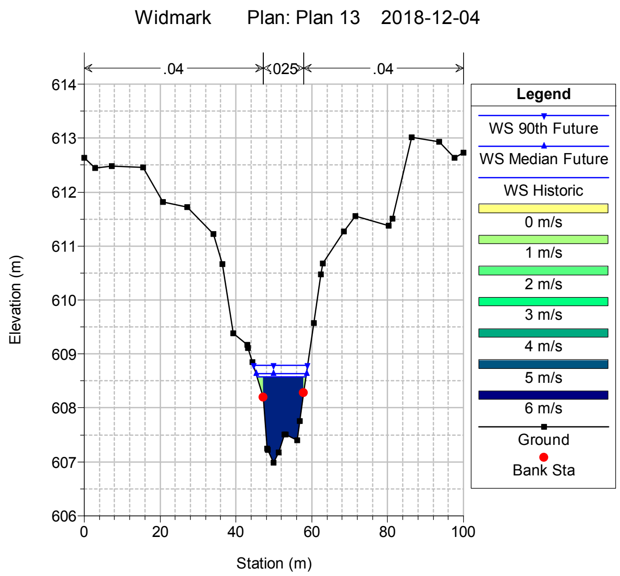
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


Widmark Plan: Plan 13 2018-12-04
Culvert 3 - Railway
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
12 m/s
Ground
Bank Sta


Widmark Plan: Plan 13 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
6 m/s
7 m/s
Ground
Bank Sta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.025
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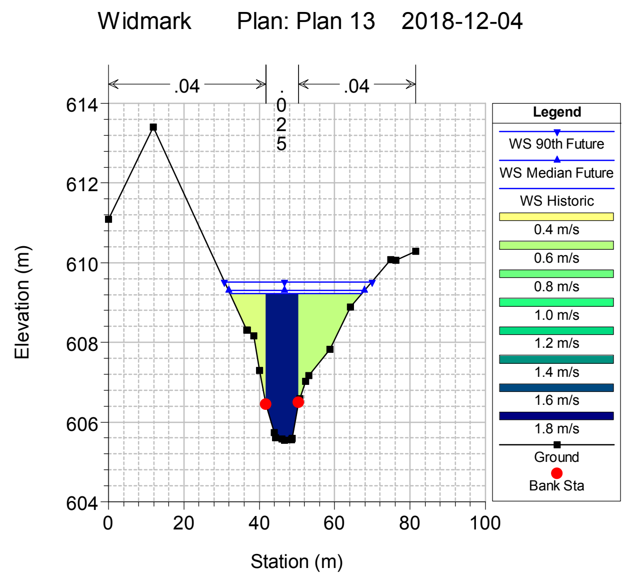
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
6 m/s
Ground
Bank Sta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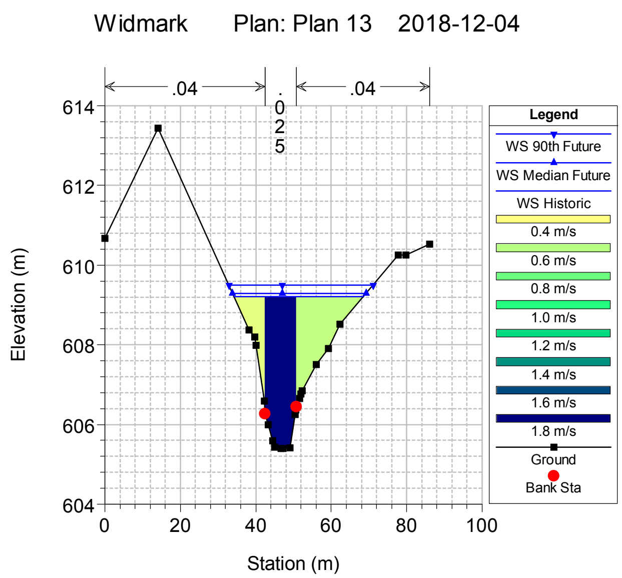
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
1.4 m/s
1.6 m/s
1.8 m/s
Ground
Bank Sta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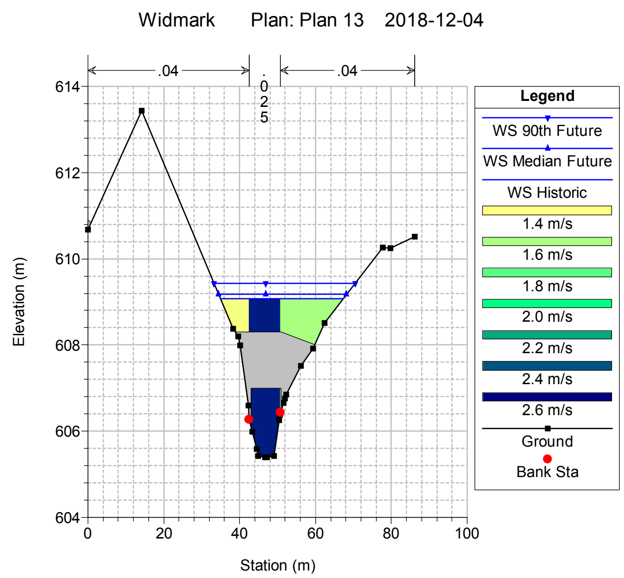
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0.4 m/s
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
1.4 m/s
1.6 m/s
1.8 m/s
Ground
Bank Sta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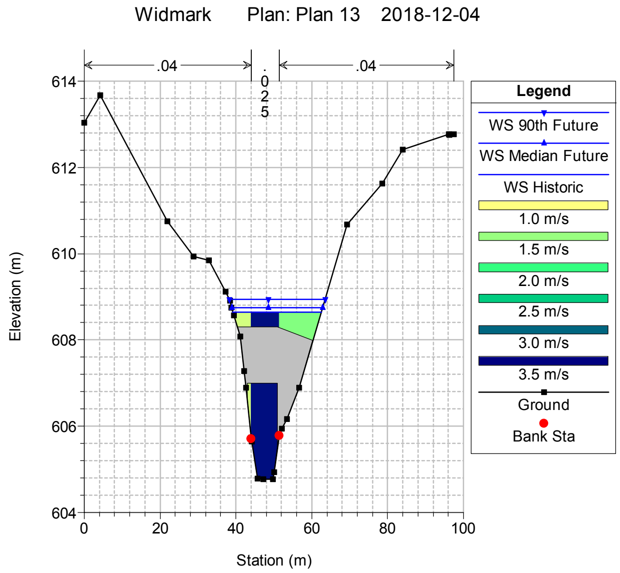
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
1.4 m/s
1.6 m/s
1.8 m/s
2.0 m/s
2.2 m/s
2.4 m/s
2.6 m/s
Ground
Bank Sta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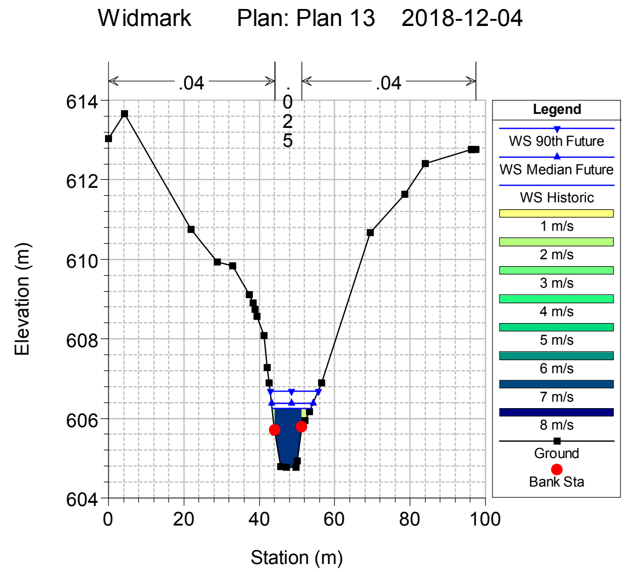
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
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5 m/s
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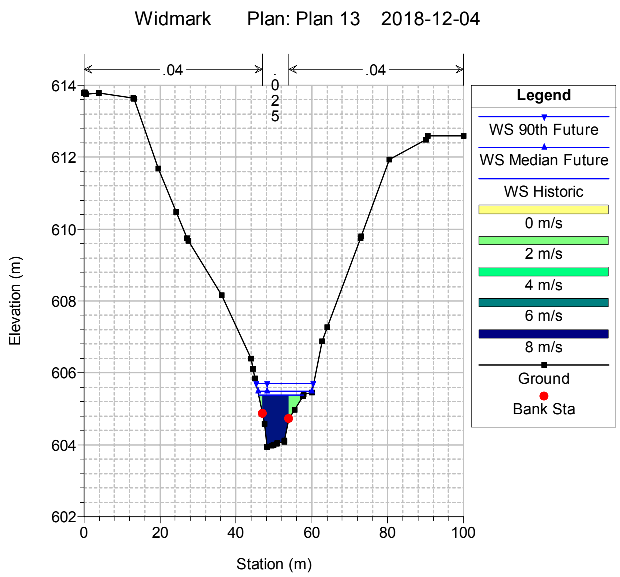
7 m/s
8 m/s
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
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WS Median Future
WS Historic
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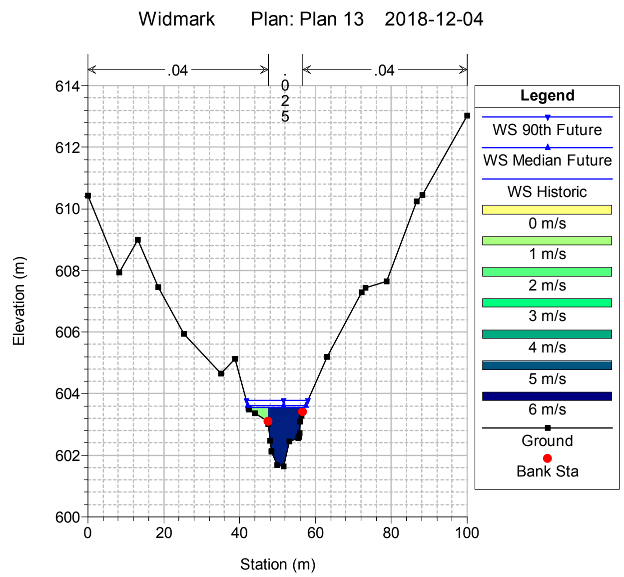
2 m/s
4 m/s
6 m/s
8 m/s
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
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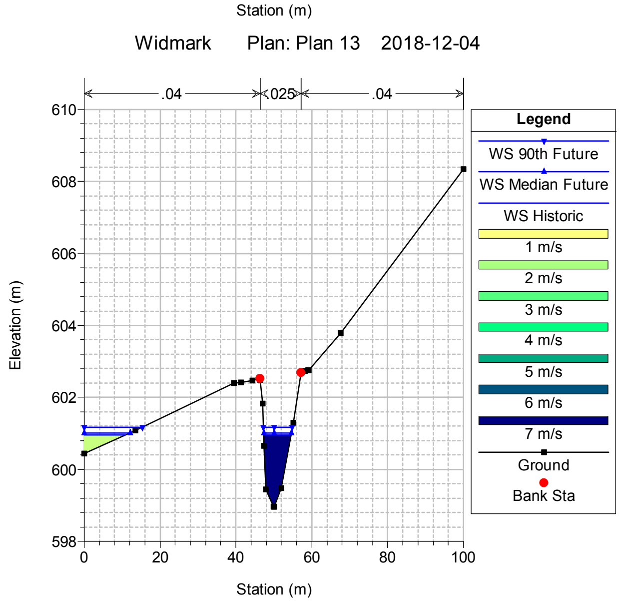
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
6 m/s
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
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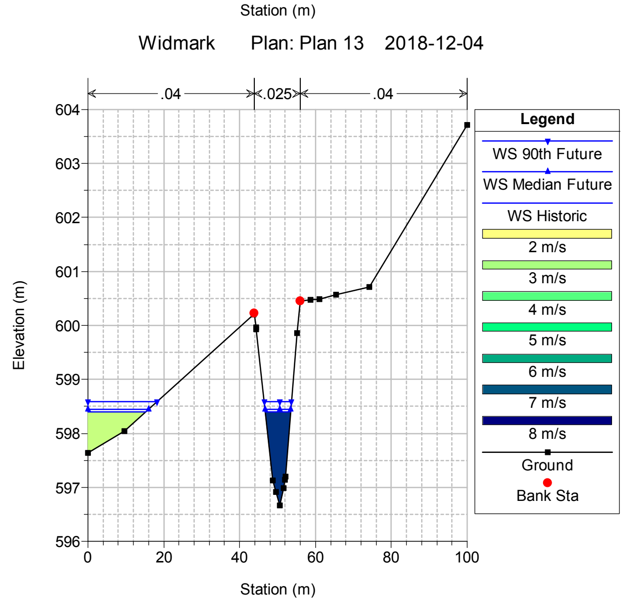
2 m/s
3 m/s
4 m/s
5 m/s
6 m/s
7 m/s
Ground
Bank Sta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Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
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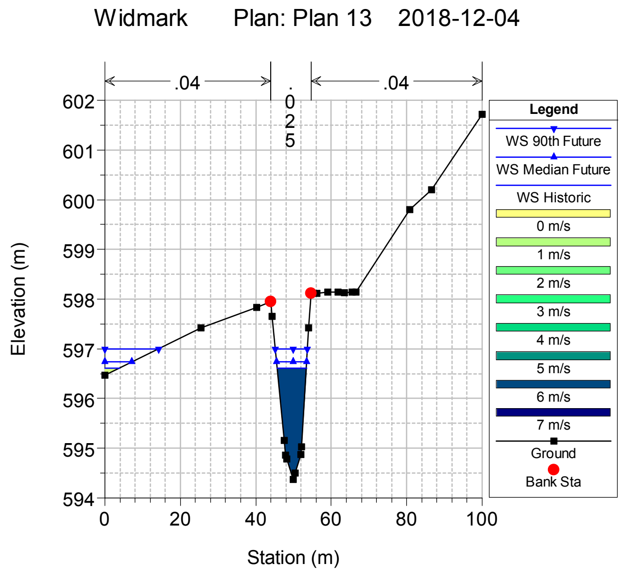
3 m/s
4 m/s
5 m/s
6 m/s
7 m/s
8 m/s
Ground
Bank Sta



Widmark Plan: Plan 13 2018-12-04
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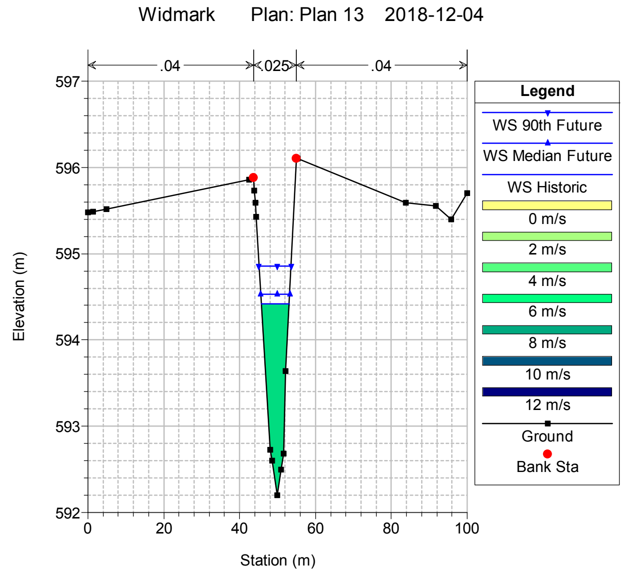
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
6 m/s
7 m/s
Ground
Bank Sta



Widmark Plan: Plan 13 2018-12-04
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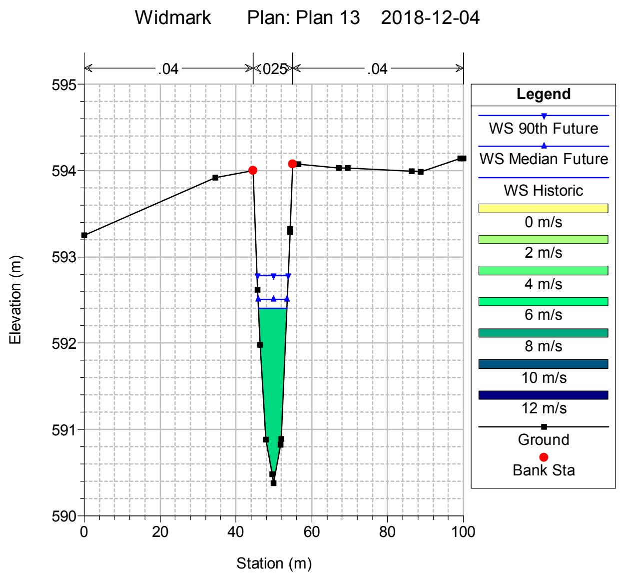
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
12 m/s
Ground
Bank Sta



Widmark Plan: Plan 13 2018-12-04
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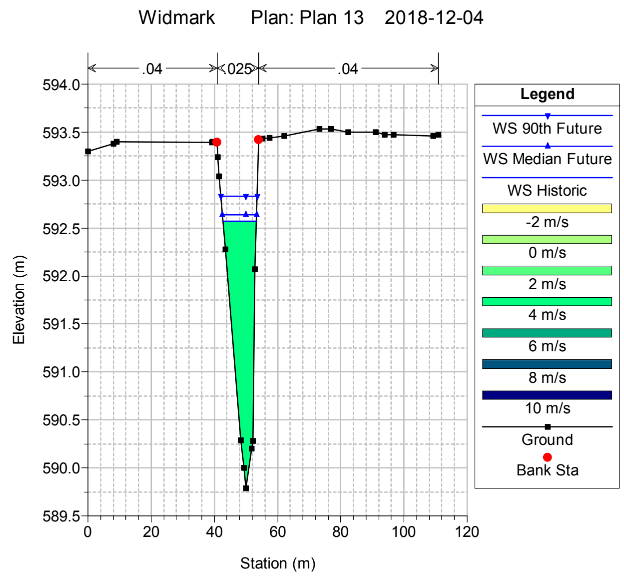
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
12 m/s
Ground
Bank Sta



Widmark Plan: Plan 13 2018-12-04
.04
.025
.04
Elevation (m)
Station (m)
Legend
WS 90th Future
WS Median Future
WS Historic
-2 m/s
0 m/s
2 m/s
4 m/s
6 m/s
8 m/s
10 m/s
Ground
Bank Sta