Sussex Flood Study

Final Report

April 1, 2016

Prepared for:
The Town of Sussex

R.V. Anderson Associates Limited
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Sussex Flood Study

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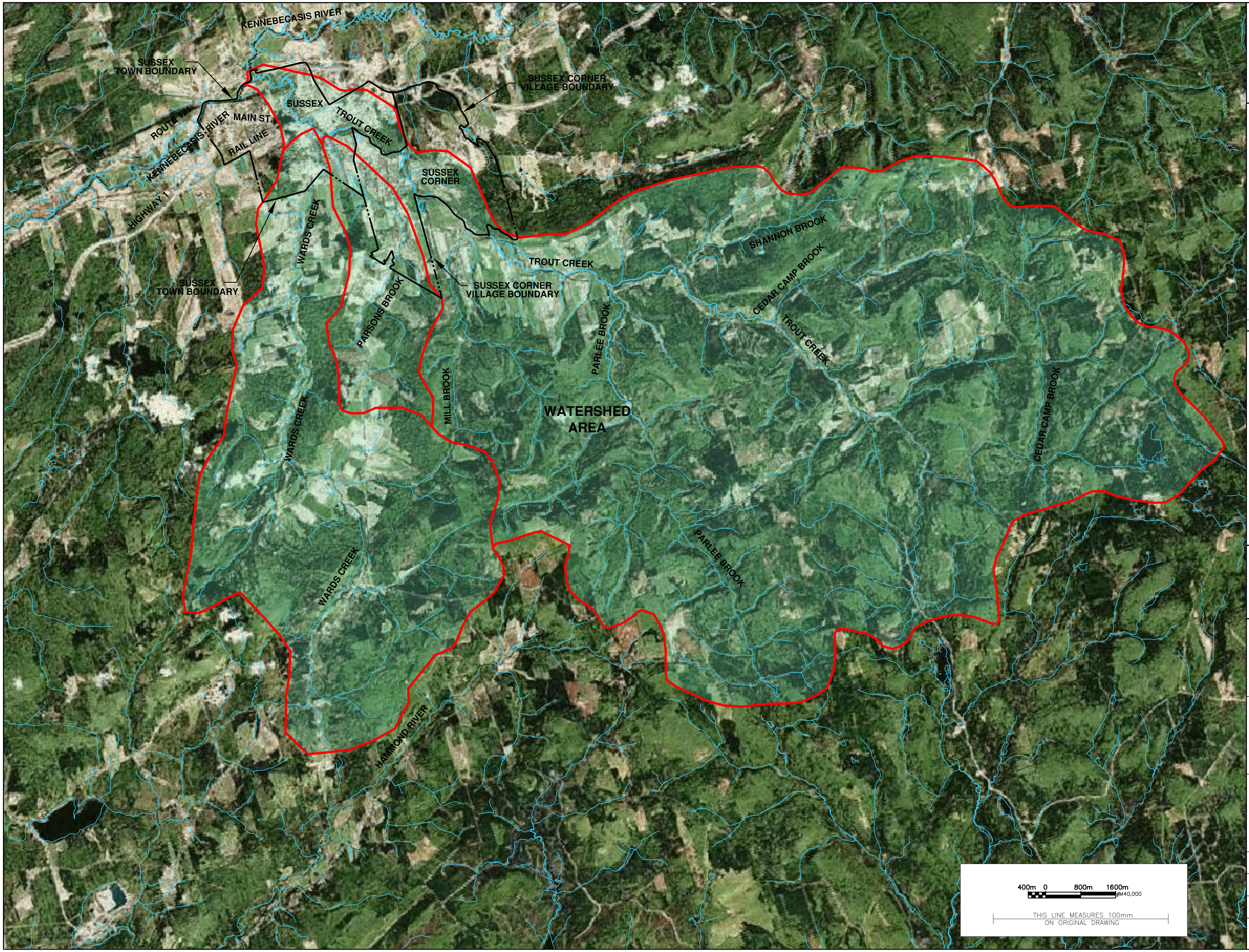
1.0 INTRODUCTION

The location of many municipalities in Canada along waterways carries an inherent risk of flooding during both large storms and the formation of ice jams during spring break up. The growth of municipalities and the conversion of undeveloped or rural land into urban development (urbanization), as well as the effects of climate change are increasing the risk, severity and frequency of flooding.

The primary objective of this study is to review the historic risk and severity of flooding in the Town of Sussex, define the expected future risk and severity of flooding, and identify and evaluate potential flood mitigation measures. This study will be performed at a conceptual level of detail and is intended to focus the future evaluation and detailed design of flood mitigation measures. The level of effort and deliverables were defined in our proposal dated August 10, 2014.

1.1 Study Area

The evaluation of flooding risk and the identification and evaluation of flood mitigation measures is limited to the area within the municipal boundaries of the Town of Sussex; while the evaluation of the hydrology and the hydraulics driving the flooding risk expands to include the watersheds of the Kennebecasis River, Trout Creek, Wards Creek and Parsons Brook and their watercourses. The municipal boundaries for the Town of Sussex and the Village of Sussex Corner and the watershed limits of Trout Creek, Wards Creek and Parsons Brook (primary sources of local flooding) are presented on Drawing 153074-1.



LEGEND

WATERSHED BOUNDARY
WATERCOURSES
MUNICIPAL BOUNDARIES

No.	Date	Revisions	By

N.B. GRID NORTH

METRIC

R.V. Anderson Associates Limited
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Project Title

TOWN OF SUSSEX
FLOOD RISK ANALYSIS

Dwg. Title

LOCAL WATERSHEDS

Scale 1 : 40,000

Drn. By	Ckd.	Calcs. By	Ckd.
JC	HA	JC	HA

Date	Date Issued
MARCH 30, 2016	

Project No.	Drawing No.
153074	153074-1

2.0 EXISTING INFORMATION

The existing information reviewed during this study included:

- Topographic information, including historic information (Natural Resources Canada, 1994-2010 and NB Department of Natural Resources, 1971) and current information (Leading Edge Geomatics, 2015).
- Development information, including zoning information (Town of Sussex, 2010) and land use information (Natural Resources Canada, 1994-2010; NB Department of Natural Resources, 1971 and Leading Edge Geomatics, 2015).
- Climate information, including historic and current data as well as trends in these data sets (Environment Canada Atmospheric Environment Services, 1990 and R.V. Anderson Associates Limited, 2010).
- Hydrometric information, historic and current information as well as trends in these data sets (Hydro-Com Technologies, 2009).
- Flood Risk Information, historic information (ADI, 1982; Environment Canada Inland Waters, 1985 and AMEC 2011) as well as revised mapping prepared for this study (Leading Edge Geomatics, 2015).

The above existing information was compared against current information to assess changes in the dynamics and magnitude of flooding in the Greater Sussex Region and develop future flooding scenarios. The methodologies and results of these comparisons are presented in the following report sections.

3.0 HYDROLOGY AND FLOOD FLOWS

The watershed hydrology of the watercourses running through the Town of Sussex (Trout Creek, Wards Creek and Parsons Brook) and past the Town of Sussex (Kennebecasis River) defines the flooding dynamics and flooding risk within Sussex, and is affected by changes in land use and development, as well as the effects of climate change. A detailed analysis of the hydrology of the above watersheds was performed by ADI and SNC during 1982 and was presented in the study report (ADI, 1982).

The drainage areas of the watersheds in and near the Town of Sussex are presented below in Table 3.1 (ADI, 1982). The general topography of these watersheds is rolling; the soils vary from glacial tills (upper reaches of the Kennebecasis River watershed) to sands and gravels (lower reaches of Trout Creek, Wards Creek and Parsons Brook); while the land use in these watersheds consists of minor urban development with a mix of forest cover and agriculture.

Table 3.1 – Drainage Areas

Watershed	Drainage Area (km^2)
Kennebecasis River	762
Trout Creek at Kennebecasis River	215
Trout Creek at Wards Creek	167
Trout Creek at Parsons Brook	155
Wards Creek	48
Parsons Brook	12

3.1 Land Use and Development

The land use and development within a watershed will affect the watershed hydrology and the watercourse flood flows, with increased urbanization (conversion of land use from either forest or agricultural to urban) resulting in increased runoff and flood flows. The information used in the 1982 study by ADI and SNC was based on aerial photography flown in 1971. In order to evaluate the effects of urbanization, the land use shown in the 1971 aerial photography was compared against aerial photography and satellite imagery collected during 2010 or later. The land use within the combined municipal boundaries of the Town of Sussex and the Village of Sussex Corner was evaluated separately from the land use within the sections of watersheds outside of these combined municipal boundaries to evaluate the local effects on the watershed hydrology.

The land use within the combined municipal boundaries of the Town of Sussex and the Village of Sussex Corner (approximately 17.7km^2) for both 1971 and 2010 were measured from aerial and satellite imagery and are summarized below in Table 3.2.

Table 3.2 – Municipal Land Use and Development

Land Use	1971	2010	Change
Urban Development	22.7%	35.9%	+13.2%
Wooded/Forest	33.9%	29.9%	-4.0%
Agricultural/Pasture	43.4%	34.2	-9.2%
Total	100%	100%	0%

The land use within the rural sections of four different watersheds (i.e. areas outside of the combined municipal boundaries of the Town of Sussex and the Village of Sussex Corner) consisted primarily of forest (approximately 40% to 70%) and agriculture (approximately 30% to 60%) with negligible urban development, and was found to have remained relatively unchanged from 1971 to 2010. Although the aerial and satellite imagery for both 1971 and 2010 do show evidence of clearcutting, there did not appear to be a significant increase in the total area cut from 1971 to in 2010.

The sections of the four watersheds within the combined municipal boundaries of the Town of Sussex and the Village of Sussex Corner represent 0.1%, 5.5%, 2.2% and 17.4% of the total drainage areas of the Kennebecasis River, Trout Creek, Wards Creek and Parsons Brook, respectively. The expected increases in flood flows resulting from total changes in land use and urbanization from 1971 to 2010 for the four watercourses draining through and past the Town of Sussex (accounting for both the rural and urban sections of these watersheds) are summarized in Table 3.3. These predicted increases in flood flows were found to be minor on a watershed level.

Table 3.3 – Urbanization Flood Flow Increases

Watershed	Flood Flow Increase (%)
Kennebecasis River	<0.1%
Trout Creek	0.4%
Wards Creek	0.1%
Parsons Brook	1.2%

3.2 Climate Change

The effects of climate change in eastern Canada that could affect flood risk include: changes in the spatial and temporal distribution of precipitation, changes in the severity and frequency of large storm event, changes in the distribution and amount of snowfall, changes in the onset, breakup and thickness of ice covers and changes in the number of ice breakup events.

The primary impact of climate change on the magnitude of flood flows is due to potential increases in the intensity and frequency of severe precipitation events. The impact of other effects of climate change on flooding is far less severe and is mainly limited to the dynamics of flooding. The potential increases in the intensity and frequency of severe precipitation events and their impact on the local severity of flooding in the Town of Sussex are discussed in this section, while the other effects of climate change and their potential impacts on the flooding dynamics are discussed in section 4 of this report.

A review of climate trends in New Brunswick (R.V. Anderson Associates Limited, 2010) indicates a general warming trend, increased amounts of annual precipitation and decreased amounts of snowfall in the southern half of the province. This would indicate likely increases in future precipitation and flood flows in the Sussex area.

A review of hydrometric trends in New Brunswick (Hydro-Com Technologies, 2009) indicates a non-statistically significant downward trend in annual maximum daily and peak instantaneous flows on the Kennebecasis River, a statistically significant downward trend in these same parameters for the Lepreau River and a statistically significant upward trend in these same parameters for the Canaan and Petitcodiac Rivers. Although this represents a “mixed bag” for southern New Brunswick, the results for the Petitcodiac River are deemed to represent an indication of likely increases in future flood flow, especially in light of the fact that the Kennebecasis River and Petitcodiac River watersheds share a common watershed divide (i.e. they are neighbouring watersheds).

Analysis of extreme precipitation events using global circulation models indicate increases in severe precipitation events of up to 20% in precipitation intensity by the year 2100 in Atlantic Canada.

Based on the above information, the potential effects of climate change for the purposes of this study were assumed to consist of a 20% increase in precipitation intensity over historic values.

This increased precipitation intensity is primarily associated with convective type storm systems (i.e. fall hurricanes and tropical depressions) which have limited spatial coverage, rather than frontal type storm systems which have wide spatial coverage. The reduced spatial coverage of this type of storm system results in a much smaller probability of increases in runoff and flood flows for larger watersheds as compared to smaller watersheds. We therefor expect the increases in flood flows and flood water levels within the Town of Sussex near the Gateway Mall to be larger on Trout Creek than on the Kennebecasis River, and have used the more conservative flood water level increases at the mouth of Trout Creek to estimate the flood risk immediately upstream of Route 1 (the Gateway Mall area).

The expected increases in flood flows resulting from a 20% increase in precipitation intensity for the remaining three watercourses are summarized in Table 3.4.

Table 3.4 – Climate Change Flood Flow Increases

Watershed	1:20 Flood Flow Increase (%)	1:100 Flood Flow Increase (%)
Trout Creek	16.1%	16.2%
Wards Creek	14.4%	15.2%
Parsons Brook	14.9%	15.3%

3.3 Updated Flood Flows

The effects of land use and development (section 3.1) and climate change (section 3.2) on the magnitude of flood flows calculated in 1982 (as presented in the ADI and SNC 1982 report) were combined and are presented in Table 3.5.

Table 3.5 – Updated Flood Flows

Return Period	Flow	Trout Creek	Wards Creek	Parsons Brook
20 years	1982 Flow	219 m^3/s	83 m^3/s	34 m^3/s
	Increase	16.5%	14.5%	16.1%
	2100 Flow	255 m^3/s	95 m^3/s	39 m^3/s
100 years	1982 Flow	312 m^3/s	122 m^3/s	51 m^3/s
	Increase	16.6%	15.3%	16.5%
	2100 Flow	364 m^3/s	141 m^3/s	59 m^3/s

The increases in flood water level elevations for both the future (year 2100) 1:20 year and the 1:100 year flood scenarios along Trout Creek, Wards Creek and Parsons Brook were estimated using conveyance capacity. These water level elevation increases were projected over the updated topographic information collected by Leading Edge Geomatics (Leading Edge Geomatics 2015) and updated flood risk mapping was developed. The results of this are presented in section 4 of this report.

4.0 FLOODING DYNAMICS AND RISK

4.1 Flooding Dynamics

4.1.1 Historic Flooding Dynamics

A thorough review of the flooding dynamics in the Sussex Area was performed during the 1982 Hydrotechnical Study by ADI and SNC. This review indicated approximately 50% of the newsworthy floods are spring freshets, 40% are winter thaws and 10% are fall floods. Also, roughly 75% of floods are related to rainfall and snowmelt, while 25% of floods are related to the formation of ice jams.

Flooding at the western end of Sussex (Gateway Mall area) appears to be the result of general flooding (lasting up to a few days) of the Kennebecasis River and the jamming of ice from Trout Creek in the main channel of the Kennebecasis River. Flooding through the rest of the Sussex area appears to be confined to local flooding of the smaller tributaries (typically lasting only a few hours) generally initiated at sharp bends and obstructions in the channels (Maple Avenue and CN Rail bridge, sharp bends on Wards Creek near Sussex Town limits and Trout Creek near Sussex Town limits). Flooding along Parsons Brook appears to be general in nature covering the large flood plain immediately upstream of Main Street and may be aggravated by ice/debris jams at the watercourse crossing of Main Street.

The severity of ice jam related floods along Trout Creek, Wards Creek and Parsons Brook was limited by the relatively small amount of ice available in these watercourses. This is expected to result in the maximum ice jam flood stages in the greater Sussex area to be below the 1:20 year open water flood stage, with the exception of Trout Creek near the Town of Sussex municipal boundary where the maximum ice jam flood stages are expected to approach the 1:100 year open water flood stage.

It was also noted that the highly pervious sands and gravels underlying the Sussex area result in flooding and damage to foundations even though there is no direct surface flooding from nearby watercourses.

4.1.2 Expected Future Flooding Dynamics

Based on the predicted effects of climate change such as generally milder winters, decreased amounts of snowfall, more frequent and smaller ice break up events, and more severe and more frequent summer and fall storm events, we anticipate a reduction in the percentages of newsworthy floods that are spring freshets and winter thaws, and a corresponding increase in fall floods. The predicted effects of climate change such as reduced ice thickness, less stable ice covers, more frequent (and thus less severe) ice break up events is expected to reduce the percentage of floods related to the formation of ice jam events.

The above changes are expected to result in a reduction in the frequency and severity of ice jam related floods, and increase in frequency and severity of precipitation based floods, and a shift from spring and winter floods to fall floods. These expected changes reinforce the validity of the flood water level elevations calculated in 1982 (analyses were based on open water flooding scenarios) and the corresponding flood risk zones defined from this data in 1985. We recommend the flood flows and corresponding flood water level elevations be recalculated using a 20% increase in precipitation intensity, but that these new results be considered an upper bound on potential flood levels and risks for the year 2100.

4.2 Flooding Risk

4.2.1 1982 and 2100 Flooding

The risk of flooding in the Greater Sussex Area was previously defined for 1:20 year and 1:100 year open water flood events using 1971 land use and development information, and pre-1982 flood flows. The magnitude of the 1:20 year and 1:100 year open water flood events were updated using current land use and development data as well as climate change predictions for the year 2100 (as summarized in Table 3.5).

The increases in flood water level elevations for both the future (year 2100) 1:20 year and the 1:100 year flood scenarios along Trout Creek, Wards Creek and Parsons Brook were estimated using conveyance capacity calculations and are presented in Table 4.1. The water level elevation data presented in Table 4.1 references the most downstream section of each watercourse (i.e. Trout Creek at the confluence with the Kennebecasis River, and Wards Creek and Parsons Brook at the confluence with Trout Creek) while the increase in water level elevation would decrease towards to upper end of the watershed. This reduction in water level increases is reflected in the updated flood risk mapping.

Table 4.1 – Updated Flood Water Level Elevations

Return Period	Elevation	Trout Creek	Wards Creek	Parsons Brook
20 years	1982	17.08 m	20.31 m	20.92 m
	Increase	0.29 m	0.19 m	0.18 m
	2100	17.37 m	20.50 m	21.10 m
100 years	1982 Flow	17.74 m	21.01 m	21.73 m
	Increase	0.36 m	0.25 m	0.25 m
	2100 Flow	18.10 m	21.26 m	21.98 m

In the interpretation of these new flood water level elevations it should be noted the above conveyance capacity calculations are approximate in nature and that the future flood water level elevations should be considered an upper bound at a conceptual level of detail. Refinement of the accuracy and reliability of the future flood water level elevations would require updating the computer model used in 1982, and is outside of the scope of this study.

4.2.2 2014 Flooding

The locations and elevations of estimated high water marks associated with the April 2014 flood event throughout the Town of Sussex were surveyed, and are presented on Drawing 153074-2. The elevations of these high water levels were compared against the 1985 and predicted 2100 flood levels to estimate the return period of the flood event, and are presented in Table 4.2.

In the interpretation of these high water levels, it should be noted their generally is a significant amount of uncertainty and variability in the definition of high water marks, resulting in the definition of flood levels and the estimation of a flood event return period being approximate. The uncertainty and variability in the definition of high water marks results from:

- the timing of the observations not always coinciding with the cresting of the flood waters,
- observed high water levels may be the result of localized flooding (blocked storm drains and/or local minor culverts), and
- observed high water levels may the result of (local) ice or debris jams.

The high water levels at the Gateway Mall Sobeys, Leonard Drive near Perry Street and 26 Oak Court appear to be significantly higher than other nearby high water levels and should be interpreted with caution when defining the return period of the April 2014 flood event.

METRIC

No.	Description	By	Date	App'd	Date
1	ISSUED FOR FINAL REPORT	JC	28–03–2016		

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TOWN OF SUSSEX
FLOOD RISK ANALYSIS

Scale	Designed		Project No.	APRIL 2014 FLOOD EVENT SURVEYED FLOOD POINTS	Dwg No.
1 : 7,500	Checked	HA	153074		153074-2
	Drawn	JC	Date 29–03–2016		Issue

Table 4.2 – April 2014 Flood Water Level Elevations

Location	1985 WSE (m)		April 2014		2100 WSE(m)	
	1:20 Year	1:100 Year	Return Period	WSE (m)	1:20 Year	1:100 Year
Gateway Mall Parking Lot	16.56	17.28	<20	16.41	16.85	17.64
Gateway Mall Sobeys	16.59	17.31	>20	17.29	16.88	17.67
Gateway Mall McDonald's	16.66	17.38	<20	16.49	16.95	17.73
10 Maxwell Drive	18.19	18.95	>100	19.50	18.47	19.30
Wallace Court PS	18.35	19.12	>20	18.77	18.63	19.46
Town Hall Rear Parking Lot	19.33	20.17	>100	20.24	19.61	20.51
Maple Ave.at Fire Hall	19.56	20.49	>20	20.21	19.83	20.83
Main Street/Summer Street	19.64	20.55	>100	20.99	19.92	20.89
Winter Street/Magnolia Ave.	19.98	20.80	>100	21.21	20.25	21.13
8TH Hussars Sports Centre	20.06	20.84	>100	21.38	20.33	21.18
Leonard Dr. near Perry St.	20.62	21.31	>100	21.90	20.88	21.64
Leonard Drive/Main Street	20.64	21.49	100	21.42	20.91	21.82
26 Oak Court	21.53	22.22	>100	23.34	21.79	22.54

WSE = Water Surface Elevation

The comparison of the April 2014 flood event survey points to the 1985 and predicted 2100 flood levels shows the return period of the April 2014 flood event to break down into three general reaches as follows:

- In the Gateway Mall area (downstream of the confluence of the Kennebecasis River and Trout Creek) the flood levels were around a 20 year return period event.
- From the confluence of the Kennebecasis River and Trout Creek Trout to the bridge on Maple Avenue, the flood levels varying from being in excess of a 20 year return period event to being in excess of a 100 year return period event.
- Upstream of the Maple Avenue Bridge the flood levels either match or exceed a 100 year return period event.

The above return periods are historic (i.e. 1985 mapping) but do not appear to change when compared against the year 2100 water level predictions. In conclusion, the flood event of April 2014 appears to be the result of a storm event with a relatively short duration resulting in localized flooding and increased return periods associated with the flood in the upper reaches of the Trout Creek watershed. The return period of the April 2014 flood is estimated to be a 20 year event along the Kennebecasis River and approximately a 100 year event along Trout Creek.

4.3 Flood Risk Mapping

The “Flood Risk Map Sussex Area, New Brunswick” published by Environment Canada Inland Waters and New Brunswick Department of the Environment Water Resources Branch in 1985 was based on the flood flows and water surface modelling information calculated in the 1982 ADI and SNC report and developed using topographic information based on 1971 photogrammetry. A copy of the 1985 flood risk map (zoomed into the general municipal limits of the Town of Sussex) is presented in Appendix A, while an interpretation of the information shown on this map is presented in section 4.3.1 below.

The topographic information developed using the recent LiDar information is far more accurate and detailed than the 1971 information. In order to evaluate if the improved topographic information would significantly alter the 1985 flood risk information, we have projected the original flood water level elevation information calculated in the 1982 ADI and SNC report over the new LiDar based topography. The revised “hybrid” flood risk map is presented in Appendix B, while an interpretation of this map is presented in section 4.3.2 below.

Finally, the updated flood water level elevation information presented above was projected over the new LiDar based topography. The updated flood risk map is presented in Appendix C, while an interpretation of this map is presented in section 4.3.3 below.

4.3.1 Original 1985 Flood Risk Mapping (1971 topography)

The original flood risk map shows general flooding along the Kennebecasis River in the western section of Sussex (Gateway Mall area), limited flooding along Trout Creek during the 1:20 year flood and widespread flooding along Trout Creek north of Maple Avenue during the 1:100 year flood, limited flooding along Wards Creek during both the 1:20 year and 1:100 year floods, and widespread flooding along Parsons Brook during both the 1:20 year and 1:100 year floods.

4.3.2 Hybrid 1985 Flood Risk Mapping (LiDar topography)

The hybrid flood risk map generally corresponds well with the original 1985 map but as expected shows the flood limits at a much higher resolution. It should be noted that although the spatial extent of the flood limits are shown at a much higher resolution, the original flood water level elevations are still based on a relatively coarse (by today’s standards) backwater computer model with a vertical resolution of plus or minus 0.10 m at best.

The flood limits shown on the hybrid flood risk map generally correspond well to the flood risk limits shown on the original 1985 flood risk map, with the following notable deviations:

- The flooding north of Maple Avenue and east of Trout Creek (northern end of Stewart Avenue) is more widespread.
- The flooding along the southern bank of Trout Creek, north of Main Street between Harding Avenue and Clover Court (Sussex Corner) is more widespread.
- The flooding of Trout Creek extends into an ancient streambed between the sharp bend in Trout Creek at the upper end of the Sussex Town limit and the intersection of Leonard Drive and Cougle Road (and further north to the Kennebecasis River). This indicates that during high flood stages above approximate elevation 26.30 m at this location, flow from Trout Creek would divert to the Kennebecasis River rather than flow through down-town Sussex. The flood limits associated with this diverted flow shown on the hybrid flood risk map presented in Appendix B are an approximation as the actual width of the local flooding will be a function of the amount of flow diverted through this ancient streambed.

4.3.3 Projected 2100 Flood Risk Mapping

The increases in flood water level elevations projected for the year 2100 (Table 4.1) are expected to result in generally having the future 1:20 year flood limits move approximately halfway between the historic (1985) 1:20 year and 1:100 year flood limits, while the future 1:100 year flood limits move beyond the historic 1:100 year flood limits.

The flooding impacts of these changes are expected to be minor along Wards Creek (steep valley walls and a well-defined flood plain and flood way) and Parsons Brook (wide flood plain with significant existing flooding), and significant along Trout Creek. The area of town along Trout Creek north of Maple Avenue is expected to be most severely affected, particularly the eastern or right hand bank (Holman Avenue, Stewart Avenue, McLean Street and Mills Lane).

5.0 FLOOD RISK MITIGATION

This section of the report identifies and evaluates potential flood mitigation measures. These measures include structural measures (e.g. flood levees or berms, pumping stations and flood diversion channels) as well as non-structural measures (development control and flood proofing of individual buildings and infrastructure). It should be noted that the evaluation of potential flood mitigation measures is done at a conceptual level of detail during this study and is intended to focus the future study and design of selected measures.

5.1 Potential Flood Risk Mitigation Measures

Based on the information presented in the previous sections of the report, the following potential flood mitigation measures were identified. The presentation sequence of these measures is random and does not represent a particular order of preference or effectiveness.

5.1.1 Gateway Mall Flood Berm

The flood berm would run along the south or left hand bank of the Kennebecasis River and extend from Route 1 to Wesley Drive (the western edge of Kingswood University). The berm would have a length of approximately 500 m and a maximum height of approximately 3.0 m to protect against the future 1:100 year flood. In order to ensure the drainage of runoff from the area behind the berm (mall and associated parking lots) an aboiteau and/or pumping station would be required. We understand sections or this alignment already contain a berm.

This measure will protect only against overland flooding and does not provide protection against flooding through the highly pervious sands and gravels underlying the Sussex area as noted in section 4.1.1.

5.1.2 Wallace Court Flood Berm

The flood berm would run along the western left hand bank of Trout Creek and extend from Maple Avenue, behind Wallace Court to the approximate midpoint of Maxwell Drive. The berm would have a length of approximately 550 m and a maximum height of approximately 2.5 m to protect against the future 1:100 year flood. In order to ensure the drainage of runoff from the area behind the berm (Town Hall, Fire Hall, Arnold Avenue, Wallace Court, Pine Street, …) an aboiteau and/or pumping station would be required.

It should be noted that this measure will protect only against overland flooding and does not provide protection against flooding through the highly pervious sands and gravels underlying the Sussex area as noted in section 4.1.1.

5.1.3 Holman Avenue/McLean Street Flood Berm

The flood berm would run along the eastern of right hand bank of Trout Creek and extend from Maple Avenue, behind Holman Avenue and McLean Street to Route 1. The berm would have a length of approximately 1,250 m and a maximum height of approximately 2.5 m to protect against the future 1:100 year flood. In order to ensure the drainage of runoff from the area behind the berm (the area north of Maple Avenue and east of Trout Creek) an aboiteau and/or pumping station would be required.

This measure will protect only against overland flooding and does not provide protection against flooding through the highly pervious sands and gravels underlying the Sussex area as noted in section 4.1.1.

5.1.4 East Town Limit Flow Diversion Channel

A detailed review of topography indicates the presence of a historic flow channel from the sharp bend on Trout Creek near the eastern limit of the Town of Sussex to the intersection of Leonard Avenue and Cougle Road and onward to the Kennebecasis River. This historic flow channel is believed to be one of the previous alignments of Trout Creek before meandering of the main channel would have resulted in the current alignment of Trout Creek. The severe flooding near the intersection of Leonard Avenue and Cougle Road may be an indication that flow is already diverted from Trout Creek into this historic flow channel (possibly as through-ground flows) during significant flood events.

Approximately 60% of the entire Trout Creek drainage area is located upstream of this flow diversion channel, allowing a large percentage of flood flows to be diverted around Sussex's down-town. The flow diversion channel would have a length of approximately 1,400 m, while the cross-section of the channel would need to be determined based on the desired rate of flow to be diverted. A minimum base width of 5 m, a minimum depth of 3 m, and 3 horizontal to 1 vertical side slopes would be recommended to maximize constructability.

Although the diversion channel would connect to the upper reaches of an existing watercourse that drains to the Kennebecasis River, the hydraulic capacity of the existing culvert under Route 1 on this existing watercourse would have to be assessed but is expected to be inadequate to be able to convey the desired diversion flows and would require upgrading at significant cost.

It should be noted that this measure will reduce the risk of flooding in the areas of Sussex along Trout Creek between this diversion and the confluence of Trout Creek and the Kennebecasis River, and that the reduced risk of flooding in this area applies to both overland flooding as well as flooding through the highly pervious sands and gravels underlying the Sussex area as noted in section 4.1.1.

5.1.5 East Town Limit Trout Creek Channel Realignment

The sharp bend in Trout Creek near the eastern limit of the Town of Sussex referenced in the previous flood mitigation measure has been subject to significant erosion in the past. The extent of this erosion was assessed by CBCL Limited during 2015 and documented in a report dated August 07, 2015. The continued erosion of the channel at this location could result in flooding near the intersection of Leonard Drive and Cougle Road.

The realignment of Trout Creek would mitigate the risk of flooding the area near the intersection of Leonard Drive and Cougle Road and ensure trafficability of the roads in this area during flood events. The area for which protection against overland flooding would be provided by this mitigation measure is entirely located outside of the municipal boundary of the Town of Sussex.

5.1.6 Parsons Brook Flood Storage

The creation of flood storage along Parsons Brook would reduce the magnitude of flooding in down-town Sussex. The volume of storage required to make a significant difference in the down-town flood levels would however have to be substantial and the presence of development on the Parsons Brook flood plain complicates this potential flood remediation measure.

There are two locations on Parsons Brook that would be particularly suited to create flood storage: immediately upstream of Main Street and immediately upstream of Newline Road. The construction of a flow control structure immediately upstream of Newline Road could potentialy be augmented by a 600 m long flow relief channel that would divert part of the flood flows from Parsons Brook through the Sussex Corner Elementary School property into Trout Creek. This augmentation would increase the effectiveness of this flood mitigation option, but would have to be carefully designed to ensure it does not aggravate flooding along Trout Creek between the Sussex Corner Elementary School and the confluence of Trout Creek and Parsons Brook.

It should be noted that the protection against flooding provided by this mitigation measure would include both overland and through-ground flooding. It should also be noted that the amount of flooding protection will vary with the severity and the duration of the flood event, and that detailed further study will be required to determine the size of the flood storage and to quantify the level of flood protection accurately.

5.1.7 Main Street Trout Creek Reconstruction/Flood Berm

The reconstruction of Trout Creek along Main Street between Maple Avenue and Leonard Drive, and the construction of a flood berm along both banks of Trout Creek would improve the conveyance capacity of Trout Creek through this section of Sussex and provide protection against overland flooding along this section of Main Street and the area containing the 8th Hussars Sport Centre. A preliminary design of this flood mitigation measure was prepared by Parish Geomorphic Ltd during 2012 and a disaster mitigation application was submitted during 2015 to Small Communities Fund of the New Building Canada Fund.

This measure will protect only against overland flooding and does not provide protection against flooding through the highly pervious sands and gravels underlying the Sussex area as noted in section 4.1.1.

5.1.8 Dredging of Trout Creek

The sands and gravels underlying the greater Sussex area result in highly erodible channel banks and high rates of sediment transport in local watercourses. This is particularly evident in Trout Creek through the down-town area of Sussex where the deposition of sediment may increase local flood risks and flood levels. The movement of sediment and bed forms down Trout Creek is a natural process balancing channel size, depth and width with channel slope and the size of channel bed material.

Although dredging material from the main channel of Trout Creek will mitigate the increased local flood risk and flood level, the mitigation will be temporary as sediment naturally transported down Trout Creek from upstream areas will quickly fill in the dredged areas. The timing of infilling previously dredged areas with new sediment is unpredictable and is likely to occur during major flood event, eliminating the flood mitigation benefit when it is needed most.

Dredging as a flood mitigation measure requires continuous effort and cannot be relied upon to provide flood mitigation when needed.

5.1.9 Local Drainage Improvements

The review of historic flooding in the Sussex area indicates flooding of a number of properties that cannot be readily explained by the estimated or measured flood water levels on the major watercourses flowing through Sussex. The flooding of these properties is likely the result of local drainage system surcharging (i.e. blocked small diameter culverts, blocked catch basins of drain inlets, obstructed ditches or drainage swales). A review of the minor (storm sewers and buried drainage infrastructure) and major (overland flow routes such as ditches, swales, street gutters) drainage systems is expected to identify measures that would mitigate local flooding.

5.1.10 Development Controls

Although the introduction of development controls would not reduce the frequency or severity of flooding, it would provide a simple and low-cost option to reduce the amount of damage from future flood events. Development controls could include: the provision of flood risk information (definition of flood risk zones and predictions of flooding depths), the restriction of development within defined flood zones, the definition of minimum finished floor elevations, the definition of basement construction standards to accommodate through ground flooding, and adopting storm water management requirements for new development.

5.2 Practicality and Effectiveness

In order to evaluate the practicality and effectiveness of the flood mitigation measures presented in the previous section of this report, as well as allow a relative comparison of these measures, information on the cost, area protected and number of developed properties protected was developed. This information was developed at a conceptual level of detail and is intended to guide the further evaluation of preferred flood mitigation measures.

The selection of preferred flood mitigation measures for further evaluation and possible implementation will be a political decision by elected officials or the general public. The technical and financial information presented below is intended to inform this political decision and does not identify preferred mitigation measures nor rank them.

5.2.1 Gateway Mall Flood Berm

Area Protected	**24 ha**
Properties Protected	
Residential	18
Commercial	10
Institutional	1
Park/Recreational	0
Federal	0
Total	29
Cost	$920,000
Cost/ha	$38,333
Cost/Property	$31,724

This mitigation measure has a moderate capital cost and land/space for the construction of this berm is readily available. A section of this berm is already in place (not reflected in the above cost). Inland drainage can be accommodated with reasonable effort and cost.

5.2.2 Wallace Court Flood Berm

Area Protected	**15 ha**
Properties Protected	
Residential	108
Commercial	3
Institutional	1
Park/Recreational	0
Federal	1
Total	113
Cost	$840,000
Cost/ha	$56,000
Cost/Property	$7,434

This mitigation measure has a moderate capital cost and although land/space for the construction of the berm is available, but it is limited. The properties protected include the Fire Hall, Post Office and the back parking lot of Town Hall. Inland drainage can be accommodated with moderate effort and cost (possibly more than one storm sewer outfall).

5.2.3 Holman Avenue/McLean Street Flood Berm

Area Protected	68 ha
Properties Protected	
Residential	117
Commercial	10
Institutional	0
Park/Recreational	0
Federal	0
Total	127
Cost	$1,560,000
Cost/ha	$22,941
Cost/Property	$12,283

This mitigation measure has a high capital cost and land/space for the construction of the berm is very limited. Inland drainage can be accommodated with significant effort and cost (likely multiple storm sewer outfalls and storm water storage).

5.2.4 East Town Limit Flow Diversion Channel

Area Protected	119 ha
Properties Protected	
Residential	190
Commercial	16
Institutional	1
Park/Recreational	6
Federal	1
Total	214
Cost	$3,630,000
Cost/ha	$30,504
Cost/Property	$16,963

This mitigation measure has a very high capital cost. Land/space for the construction of the berm is readily available but is located outside the Town of Sussex municipal boundary and is privately held. Cooperation of the Province of New Brunswick would also be required as this measure is expected to include upgrading culverts underneath Route 1. This mitigative measure provides flood protection (both overland and through-ground) to most of Sussex with the exception of the Gateway Mall area, and does not require inland drainage.

The likely environmental effects will need to be assessed and permits from environmental regulatory agencies will be required.

5.2.5 East Town Limit Trout Creek Channel Realignment

Area Protected	0 ha
Properties Protected	
Residential	0
Commercial	0
Institutional	0
Park/Recreational	0
Federal	0
Total	0
Cost	$640,000
Cost/ha	n/a
Cost/Property	n/a

This mitigative measure has a moderate capital cost and will minimize the risk of future severe bank erosion and channel realignment at this location on Trout Creek. This in-turn will minimize the risk of severe flooding near the intersection of Leonard Avenue and Cougle Road (affecting approximately 5 ha and 5 commercial properties all located in the Village of Sussex Corner), and will maximize the trafficability of this entrance into/exit from the Town of Sussex.

5.2.6 Parsons Brook Flood Storage

The creation of flood storage along Parsons Brook immediately upstream of Main Street is expected to provide protection to approximately 10% of the downstream flood prone areas and developed properties.

Area Protected	15 ha
Properties Protected	
Residential	25
Commercial	5
Institutional	1
Park/Recreational	1
Federal	1
Total	33
Cost	$1,150,000
Cost/ha	$76,667
Cost/Property	$34,848

This mitigative measure has a high capital cost and land/space for the construction of the control structure and associated impoundment is limited. In particular the potential impacts on existing development in the Village of Sussex Corner will need to be evaluated and protective measures may have to be provided. These protective measures would be outside the Town of Sussex municipal boundaries.

The likely environmental effects will need to be assessed and permits from environmental regulatory agencies will be required.

The creation of flood storage along Parsons Brook immediately upstream of Newline Road and the construction of Main Street is expected to provide protection to approximately 5% of the downstream flood prone areas and developed properties.

Area Protected	**8 ha**
Properties Protected	
Residential	13
Commercial	3
Institutional	1
Park/Recreational	1
Federal	1
Total	19
Cost	$1,496,000
Cost/ha	$187,000
Cost/Property	$78,737

This mitigative measure has a high capital cost and land/space for the construction of the control structure and associated impoundment is limited. In particular the flow relief channel through the Sussex Corner Elementary School property will need to be evaluated. It should also be noted that this mitigative measure is outside the Town of Sussex municipal boundary.

The likely environmental effects will need to be assessed and permits from environmental regulatory agencies will be required.

5.2.7 Main Street Trout Creek Reconstruction/Flood Berms

Area Protected	36 ha
Properties Protected	
Residential	0
Commercial	21
Institutional	0
Park/Recreational	6
Federal	0
Total	27
Cost	$1,600,000
Cost/ha	$44,444
Cost/Property	$59,259

This mitigation measure has a high capital cost and land/space for the construction of the berms is readily available. Inland drainage can be accommodated with moderate effort and cost (likely two storm sewer outfalls).

5.2.8 Dredging of Trout Creek

Area Protected	4 ha
Properties Protected	
Residential	0
Commercial	14
Institutional	0
Park/Recreational	0
Federal	0
Total	14
Cost	$30,000/year
Cost/ha	$7,500/year
Cost/Property	$2,143/year

This mitigative measure has no capital cost but a significant annually recurring cost. It should also be noted the level of flood protection is variable and may not be available during significant flood events when it is needed most.

The likely environmental effects will need to be assessed and permits from environmental regulatory agencies will be required.

5.2.9 Local Drainage Improvements

Based on experience in other municipalities, the identification of local drainage issues and the construction of mitigative/corrective measures have low one-time capital costs (a few hundred thousand dollars) and significantly reduce both local flood damage and municipal operational efforts and cost. A review of local drainage systems (both minor and major systems) in low-lying areas (such as Oak Court and Birch Street) and areas with changes in topography from steep to flat, and a review of municipal operational records are expected to identify potential local drainage improvements.

The identification and correction of local drainage issues can be expanded to private property using a Flood Damage Reduction Subsidy Program. These programs generally cost-share eligible flood damage reduction measures in identified flood prone areas such as installation of back-flow preventers, raising of finished floors (foundation jacking), modification of basements (e.g. drainage, ventilation, vapour barriers, pressure equalization), and flood proofing measures (e.g. bulkheads for windows and doors, water proofing of walls).

5.2.10 Development Controls

The implementation of development controls has a low capital cost and provides significant benefits in minimizing/eliminating flood damage in future development. Most municipalities have adopted, or are in the process of adopting controls and storm water management requirements for new development.

5.3 Cost Estimating Information

The cost estimates provide in the previous report section were based on the following information. It should be noted that these costs are based on a conceptual level of detail and are intended for the preliminary evaluation and relative comparison of flood mitigative measures. Costs of mitigative measures selected for implementation should be confirmed following the completion of detailed designs.

Cost of a 3.0 m high flood berm is approximately $1,200 per running m.

Cost of a 2.5 m high flood berm is approximately $1,000 per running m.

Cost of a diversion channel is approximately $1,200 per running m.

Cost of a flood water pumping station ranges from $250,000 to $400,000.

Cost of an aboiteau ranges from $75,000 to $200,000.

Cost of Route 1 culvert upgrade ranges from $1,500,000 to $2,500,000.

Cost of East Town limit Trout Creek channel realignment is approximately $640,000, as presented in CBCL Limited report dated August 07, 2015.

Cost of Main Street Trout Creek reconstruction and flood berms is approximately $1,600,000, as presented in preliminary design prepared by Parish Geomorphic Ltd during 2012 and the disaster mitigation application submitted during 2015 to Small Communities Fund of the New Building Canada Fund.

6.0 CLOSURE

The information presented above has quantified the risk and extent of flooding along the major watercourses within the Town of Sussex, identified potential flood mitigation measures and provided technical and financial information for these measures. This information was developed at a conceptual level of detail to assess the practicality and effectiveness of the potential flood mitigation measures, and is intended to guide the further evaluation of preferred measures.

In order to advance this initiative, we recommend the acceptability of the above potential flood mitigation measures be reviewed and confirmed, preferred flood mitigation measures be selected for further evaluation, the level of technical design and financial cost estimating detail be refined for these preferred measures, and that this information again be reviewed before any flood mitigation measures are implemented.

7.0 REFERENCES

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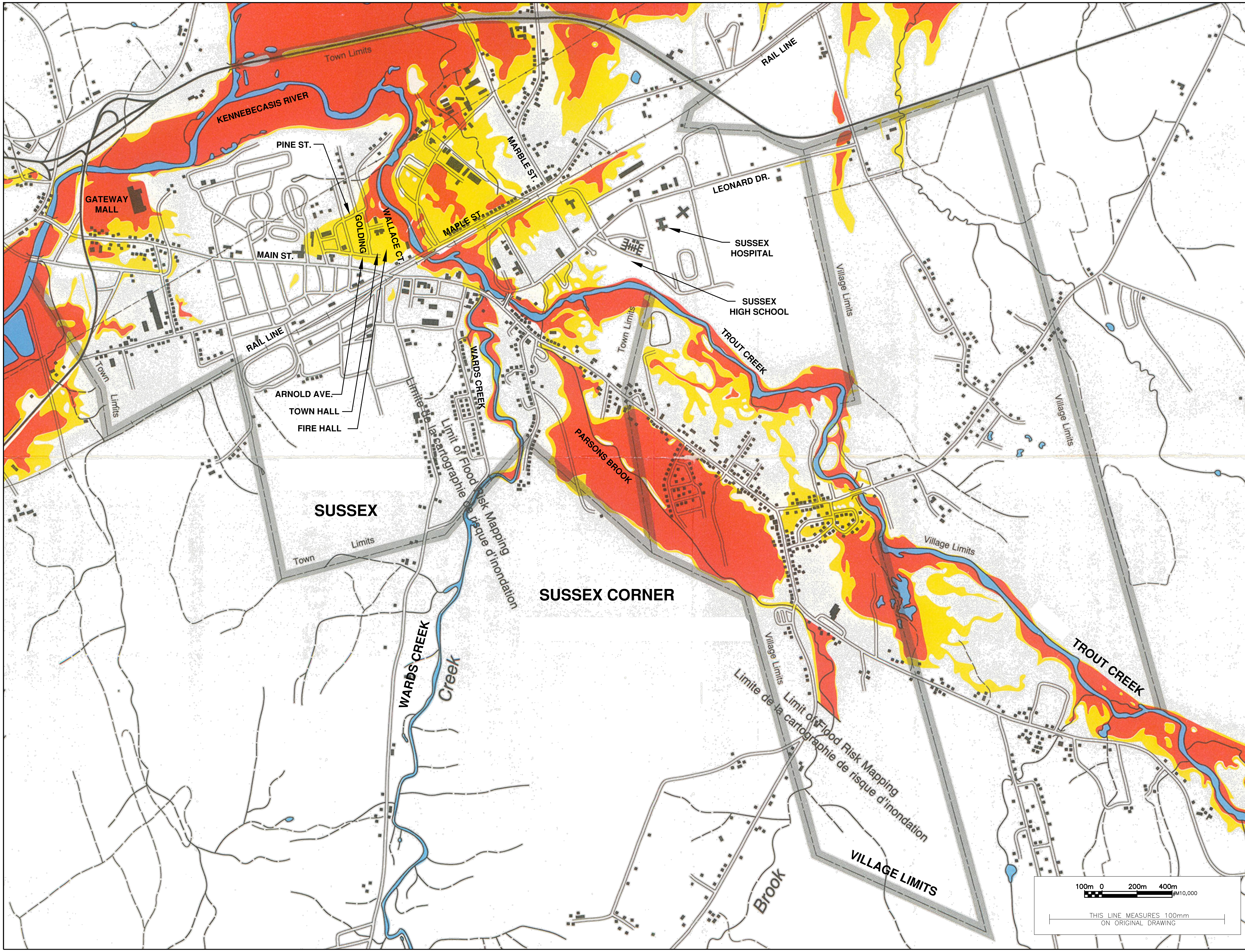
APPENDIX A

Original 1985 Flood Risk Mapping
(1971 Topography)



LEGEND

1 in 20 YEAR FLOOD ZONE
1 in 100 YEAR FLOOD ZONE
NORMAL WATER SURFACE

No.	Date	Revisions	By
1	28-03-2016	ISSUED FOR FINAL REPORT	JC

N.B. GRID NORTH

METRIC

R.V. Anderson Associates Limited
engineering · environment · infrastructure

Project Title
TOWN OF SUSSEX
FLOOD RISK ANALYSIS

Dwg. Title
1985 FLOOD RISK MAPPING
1971 TOPOGRAPHY

Scale 1 : 10,000

Drn. By	Ckd.	Calcs. By	Ckd.
JC	HA	JC	HA

Date MARCH 30, 2016
Date Issued

Project No. 153074
Drawing No. 153074-A1

APPENDIX B

Hybrid 1985 Flood Risk Mapping
(LiDar Topography)

THIS MAP IS FOR GENERAL INFORMATION ONLY AND WAS DEVELOPED USING 1982 AND 1985 FLOOD RISK INFORMATION AND ESTIMATED INCREASED IN FLOOD FLOWS AND FLOOD LEVELS. THE INFORMATION SHOWN ON THIS MAP IS APPROXIMATE AND SHOULD NOT BE USED AS A DEFINITIVE CHARACTERIZATION OF FLOOD LEVELS OR FLOOD INUNDATION LIMITS.

No.	Date	Revisions	By
1	28-03-2016	ISSUED FOR FINAL REPORT	JC

N.B. GRID NORTH

METRIC

R.V. Anderson Associates Limited
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Project Title

TOWN OF SUSSEX
FLOOD RISK ANALYSIS

Dwg. Title

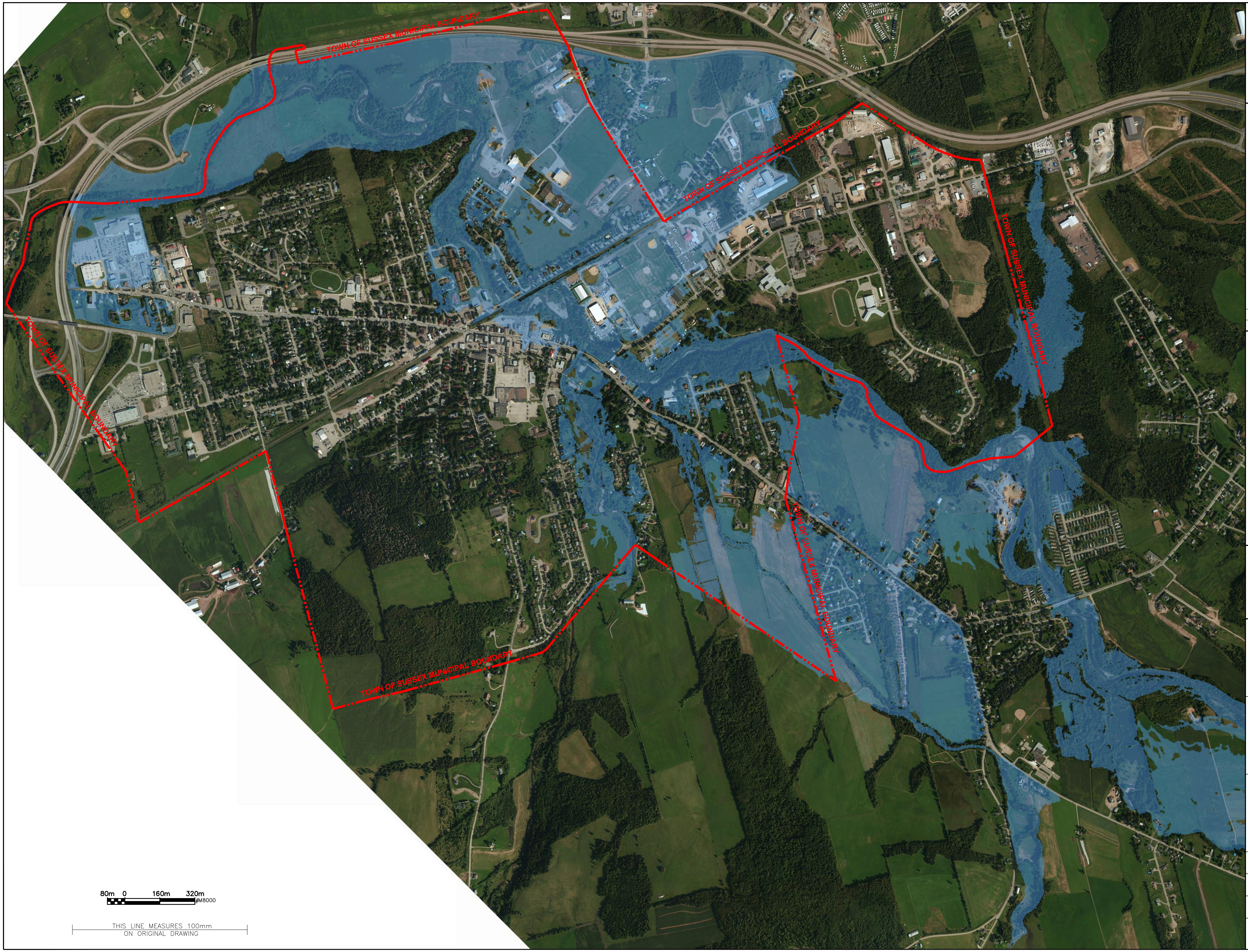
HYBRID 1985
FLOOD RISK MAPPING
20 YEAR EVENT

Scale 1 : 8,000

Drn. By	Ckd.	Calcs. By	Ckd.
JC	HA	JC	HA

Date: MARCH 29, 2016
Date Issued:

Project No.: 153074
Drawing No.: 153074-B1



THIS MAP IS FOR GENERAL INFORMATION ONLY AND WAS DEVELOPED USING 1982 AND 1985 FLOOD RISK INFORMATION AND ESTIMATED INCREASED IN FLOOD FLOWS AND FLOOD LEVELS. THE INFORMATION SHOWN ON THIS MAP IS APPROXIMATE AND SHOULD NOT BE USED AS A DEFINITIVE CHARACTERIZATION OF FLOOD LEVELS OR FLOOD INUNDATION LIMITS.

No.	Date	Revisions	By
1	28-03-2016	ISSUED FOR FINAL REPORT	JC

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METRIC

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Project Title

TOWN OF SUSSEX
FLOOD RISK ANALYSIS

Dwg. Title

HYBRID 1985
FLOOD RISK MAPPING
100 YEAR EVENT

Scale 1 : 8,000

Drn. By	Ckd.	Calcs. By	Ckd.
JC	HA	JC	HA

Date	Date Issued
MARCH 29, 2016	

Project No.	Drawing No.
153074	153074–B2

APPENDIX C

2100 Flood Risk Mapping

THIS MAP IS FOR GENERAL INFORMATION ONLY AND WAS DEVELOPED USING 1982 AND 1985 FLOOD RISK INFORMATION AND ESTIMATED INCREASED IN FLOOD FLOWS AND FLOOD LEVELS. THE INFORMATION SHOWN ON THIS MAP IS APPROXIMATE AND SHOULD NOT BE USED AS A DEFINITIVE CHARACTERIZATION OF FLOOD LEVELS OR FLOOD INUNDATION LIMITS.

No.	Date	Revisions	By
1	28-03-2016	ISSUED FOR FINAL REPORT	JC

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METRIC

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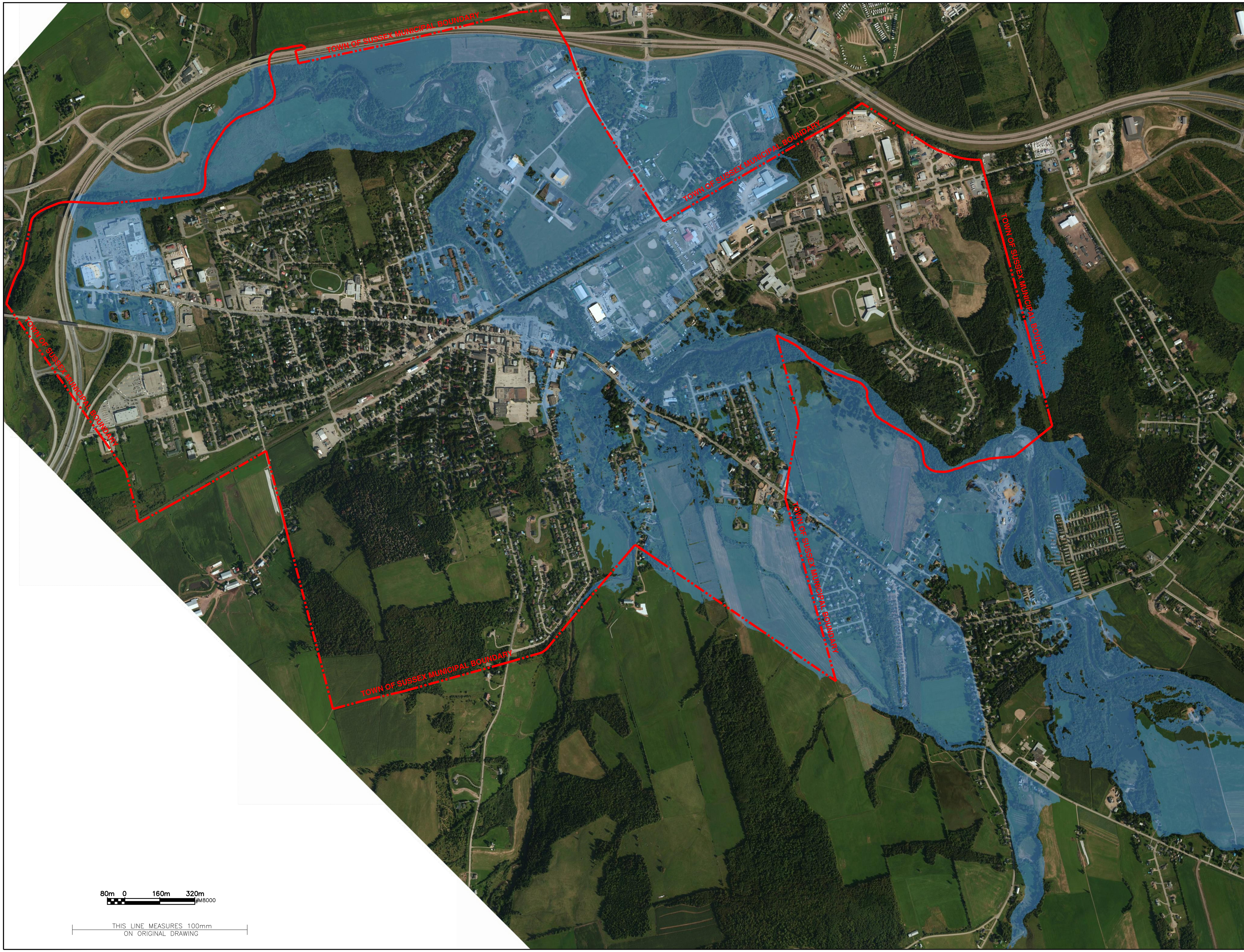
Project Title

TOWN OF SUSSEX
FLOOD RISK ANALYSIS

Dwg. Title

PROJECTED 2100
FLOOD RISK MAPPING
20 YEAR EVENT

Scale: 1 : 8,000			
Drn. By: JC	Ckd.: HA	Calcs. By: JC	Ckd.: HA
Date: MARCH 29, 2016		Date Issued:	
Project No.: 153074		Drawing No.: 153074-C1	



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No.	Date	Revisions	By
1	28–03–2016	ISSUED FOR FINAL REPORT	JC

N.B. GRID NORTH

METRIC

R.V. Anderson Associates Limited
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Project Title

TOWN OF SUSSEX
FLOOD RISK ANALYSIS

Dwg. Title

PROJECTED 2100
FLOOD RISK MAPPING
100 YEAR EVENT

Scale
1 : 8,000

Drn. By	Ckd.	Calcs. By	Ckd.
JC	HA	JC	HA

Date: MARCH 29, 2016
Date Issued

Project No.: 153074
Drawing No.: 153074–C2