INSTITUT NATIONAL DE LA RECHERCHE SCIENTIFIQUE

CENTRE EAU TERRE ENVIRONNEMENT

QUÉBEC

Suspended sediment modelling in the Nerepis River system.
Field sampling report.

By

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Reference to be cited:
Riahi K, St-Hilaire A (2022) *Suspended Sediment Modelling in the Nerepis River System. Field sampling report*. Québec: Institut national de la recherche scientifique, Centre Eau Terre Environnement; 13 pages. (INRS - Centre Eau Terre Environnement, Research Report # **2101**).

ISBN : 978-2-89146-997-5 (version numérique)

Dépôt légal - Bibliothèque et Archives nationales du Québec, 2025
Dépôt légal - Bibliothèque et Archives Canada, 2025

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1. Context

Landscape erosion and sedimentation of watercourses has been identified as a serious environmental issue at 5th Canadian Division Support Base (5 CDSB) Gagetown. To address this issue, the Department of National Defence has been conducting remediation works through a Sedimentation and Erosion Control Program (SECP). Work has included upgrades and decommissioning or roads, trails and water-crossings, re-vegetation of barren soils and stream restoration. Despite these efforts, landscape erosion and watercourse sedimentation continue to be an issue. A hydrological and suspended sediment models for the Nerepis River and Kerr Brook were developed under the Sedimentation and Erosion Control Program SECP, using the ArcGIS Soil Water Assessment Tool (SWAT). Some of the data that are needed to calibrate and validate the model were collected between 2009 and 2013. As the model will be completely re-calibrated as part of the present project, field monitoring was re-initiated during the summer of 2021. This report provides a summary of this field investigation.

2. Methods

2.1 Discharge

Environment and Climate Change Canada is monitoring discharge of the Nerepis River (Station # 01AP006; Nerepis River at Fowlers Corner). The drainage area at this location (45 30 12 N; 66 19 08 W) is 293 km^2 (wateroffice.ec.gc.ca) (figure 1). Daily mean flows are available since 1976.

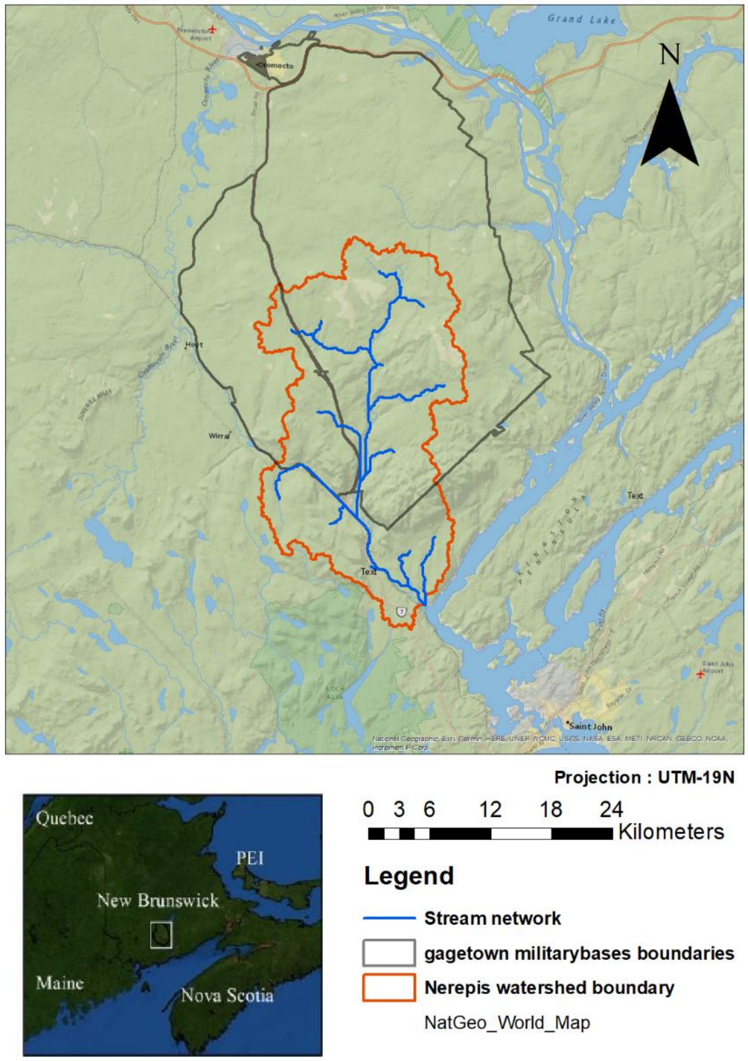

Figure 1: Atlantic Canada, Gagetown and the Nerepis watershed

Fisheries and Oceans Canada (DFO) recorded water levels every 30 minutes in Queens Brook form 7 July 2021 to 27 October 2021 using an Ott water level gauge connected to a Campbell Scientific CR1000 data logger. These data were provided to INRS and are included in this report.

In addition, water level gauges were deployed in two other monitored tributaries of the Nerepis River. These unvented gauges measure total pressure (barometric and hydrostatic). The barometric pressure was also measured so that it can be subtracted from the total pressure measured in the water column. At each tributary, spot discharge measurements were taken at each field visit for all stations except at the ECC Station 01AP006. These measurements were taken using a velocity-area method with a Marsh McBirney 2000 FlowMate flow meter. To measure discharge, a minimum of 15 velocity measurements were taken at 60% of total depth along a lateral transect at each site. Depth and lateral distances were recorded at the same locations to reconstruct the wetted area of the cross-section. Discharge was computed by summing the products of velocity and section sub-areas at each measurement point. Spot discharge measurements are provided in Table 1, except for Queen's Brook, where discharge was measured by DFO. The number of measurements in Queen's Brook was sufficient to construct a rating curve for this site, shown in Equation 1:

$$Q = 19.45 * (H - 0.175)^{2.16} \quad (1)$$

2.2 Turbidity and suspended sediment concentrations

Turbidity meters were deployed at five stations in the Nerepis River system: Two on the river main stem (Nerepis River at Flowler's Bivouac; Nerepis River at Tok Chong Bridge) and three in the tributaries: River George, Queen and Sucker Brook. Turbidity is an indirect measure of suspended sediment concentrations. As it is an optical measure, it is affected by local variables such as water colour, sunlight, and sediment grain size distribution (Sirabahenda et al, 2019). To minimize the possible biases associated with these environmental factors, calibration is performed *in situ*. To achieve this, a large volume of river water collected on site was mixed with a quantity of stream-bottom sediment in a 20 L recipient. Sediment grab samples were sieved so that only grain sizes ≤ 60 µm were used for calibration, as recommended by Alberto et al. (2016). This filtration was repeated a second time to ensure that any sediment that settled in the first mixture would be excluded. The sediments were kept in suspension by manually mixing the water in the recipient. For a given concentration, three turbidity readings were taken and averaged (once the readings stabilized) and a 500 mL grab sample was collected for each reading. The amount of sediment in the calibration water was augmented incrementally to cover the observed range of turbidity readings.

In the laboratory, each grab sample was filtered through a Whatman GF/C 100 mm filter paper (1.2 µm pore size). The filtrate was oven-dried at 70°C for 24 hours and then weighed. The net weight was divided by the filtered volume to obtain suspended sediment concentrations (SSC) in milligrams per litre.

3. Results

3.1 Precipitation and discharge

Precipitation was measured by DND at two rain gauges located near Queens Brook (CT03) and River George (CT06). Rain gauges are retrieved in the fall and in the summer of 2021, the retrieval occurred on 19 October. Rainfall time series indicate that the most important rain events occurred during the first, second and last week of September. Total precipitation recorded between 15 August and 19 October 2021 was 94.1 mm (CT03) and 89.2 mm (CT06) respectively (Figure 2).

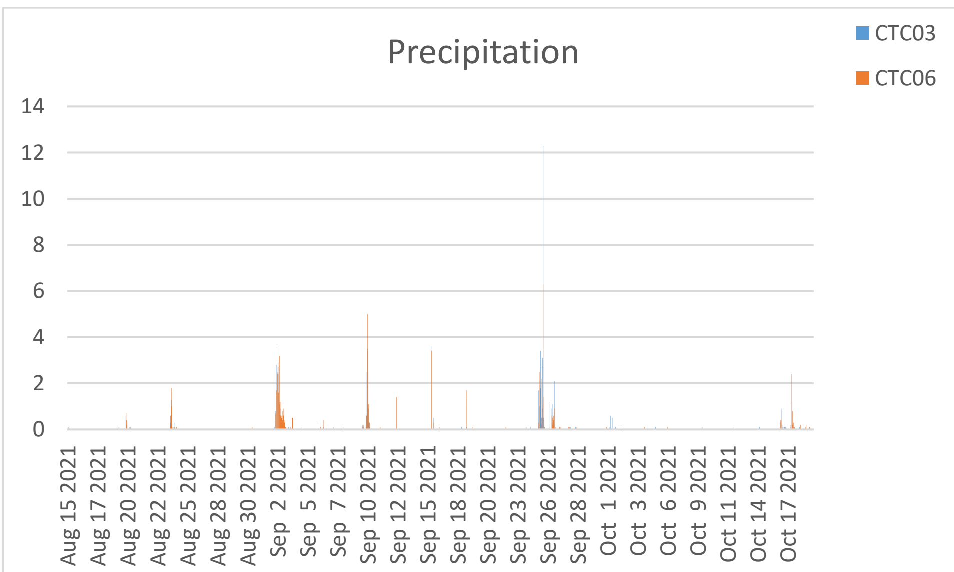

Figure 2. Precipitation measured at two locations during the monitoring period.

Figure 3 shows the discharge in Queen's Brook. Three main hydrological events can be observed during the sampling period. One occurred in early July. The only station that was monitored during this event is Queen's Brook (by DFO). The two other important events occurred in early September and during the last week of September and first week of October. This latter event is the largest, with a peak flow of 15.1 m^3/s. Total precipitation during the last week of September was 25.2 mm.

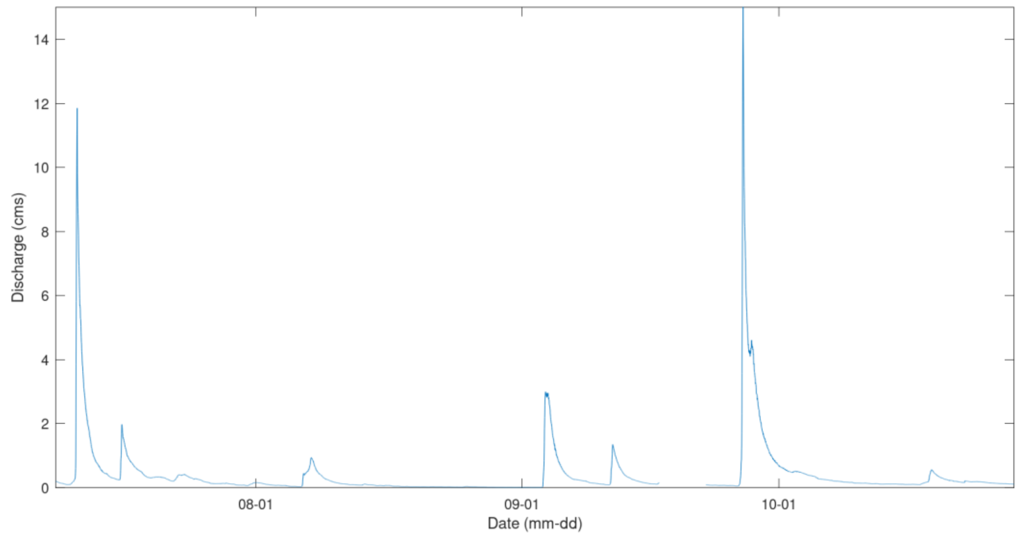

Figure 3 Time series of discharge in Queen's Brook, summer 2021 (data provided by DFO).

Spot discharge measurements were conducted at four sites during field visits. Values are shown in Table 1. These spot discharge measurements will be used in addition to flow time series from the gauging station (Nerepis River at Flowler's Bivouac) to calibrate the hydrological module in SWAT.

Table 1 Spot discharge measurements on the Nerepis drainage basin during summer and fall 2021

Site	**Date**	**Discharge (m^3/s)**
Sucker Brook	18-08-21	0.18
	27-10-21	0.04
Queen's Brook	27-10-21	0.16
Nerepis River at Tok Chong Bridge	18-08-21	0.05
	27-10-21	0.014
George Brook	18-08-21	0.08

3.2 Calibration curves

Figures 4 to 7 show the calibration curves used to convert turbidity measurements to SSC. A linear regression model was selected to estimate SSC from turbidity, as per Alberto et al. (2015). Linear regression can be fitted using two parameters (slope and intercept) of one parameter (slope and forcing the intercept at 0). The latter was selected. Forcing the intercept to zero implies that when turbidity measured be the sensor is zero, so is the associated SSC. This also means that because there is only one parameter used to adjust the regression line, the fit is not as good as if two parameters were adjusted. The calibration curves explained variance (R^2) varying between 70% and 90%. Queen's Brook SSC data were provided by DFO. The regression equation was provided but without the calibration curve.

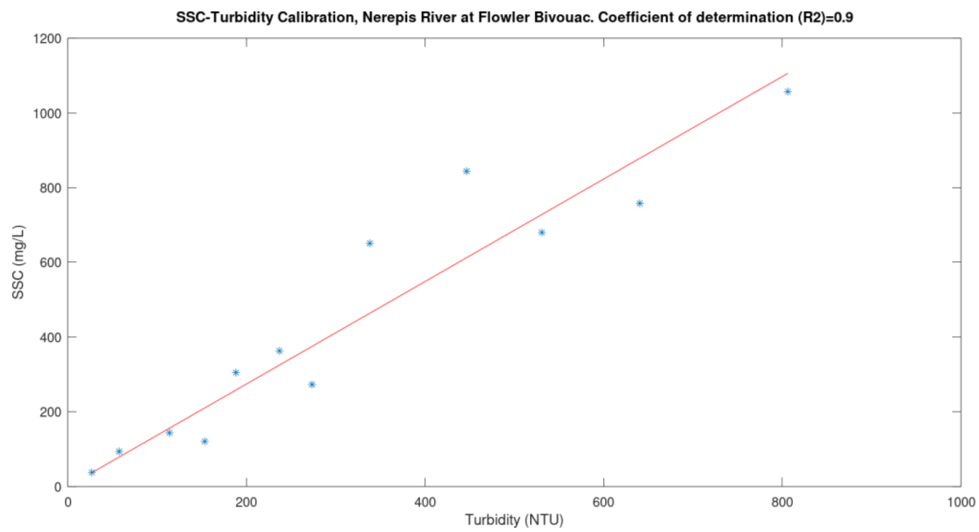

Figure 4 SSC-Turbidity Calibration Curve. Nerepis River at Flowler's Bivouac

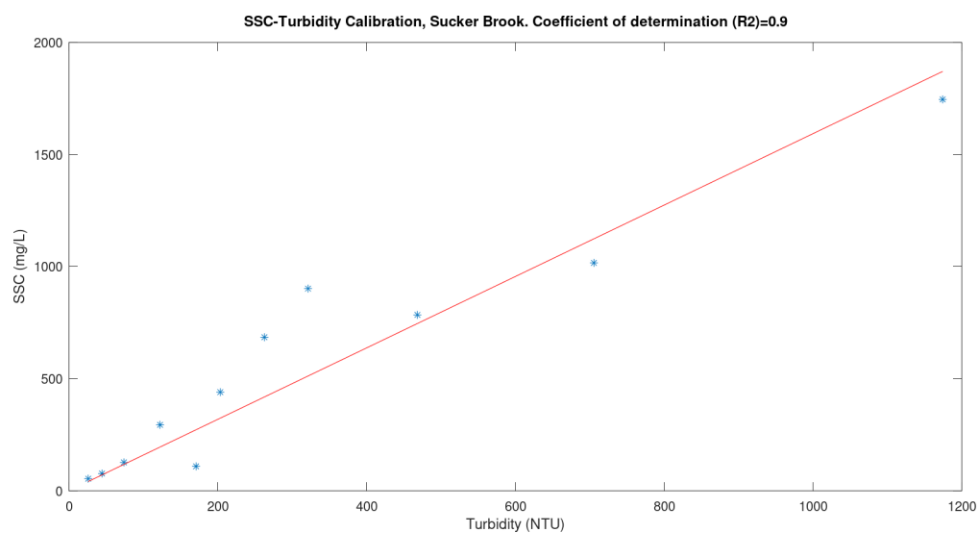

Figure 5 SSC-Turbidity Calibration Curve. Sucker Brook

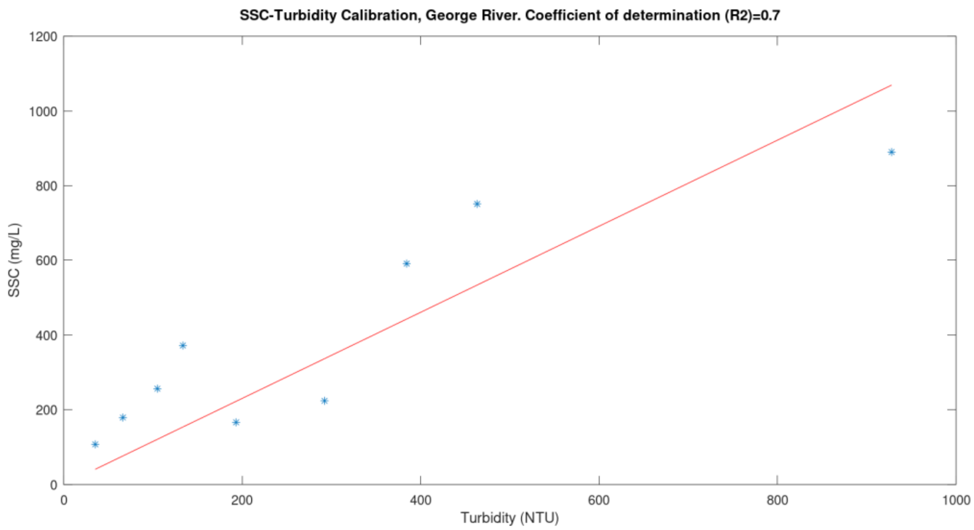

Figure 6 SSC-Turbidity Calibration Curve. River George

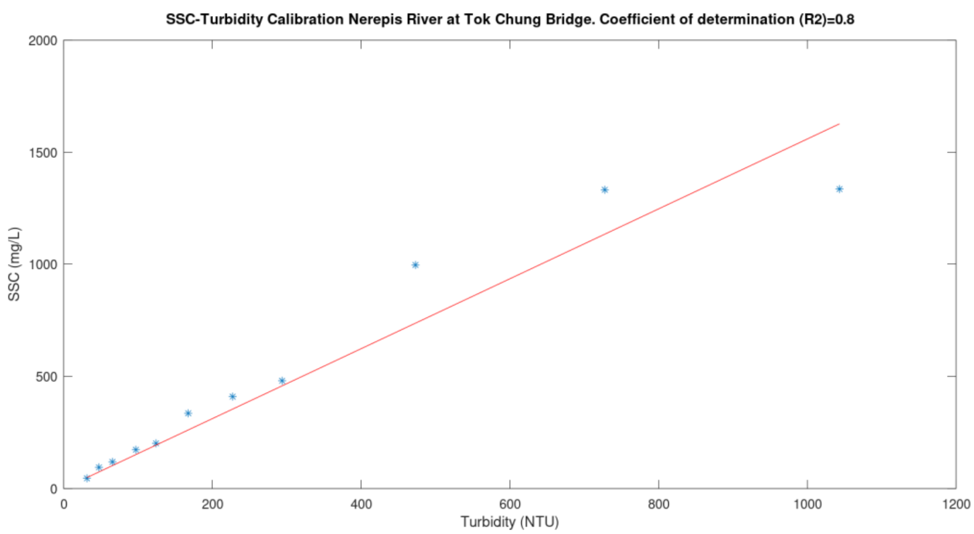

Figure 7 SSC-Turbidity Calibration Curve. Nerepis River at Tok Chong Bridge

3.3 Suspended sediment Concentrations

Figures 8 to 12 show the time series of turbidity converted to SSC using the calibration curves shown in the previous section. An outlier detection algorithm was applied on the raw data. This algorithm defines outliers as values that are higher than the six preceding and six following values (moving window of 12) by a factor corresponding to two standard deviations of the values in the same window.

As summarized in Table 2, during the 2021 sampling period, mean SSC was highest at River George (7.45 mg/L) and lowest at Sucker's Brook (1.11 mg/l). Variability was highest at River George (standard deviation of 25.11 mg/L) and lowest at Tok Chong Bridge (6.26 mg/L)). The Highest SSC value was also from River George (252.4 mg/L; see Figure 10). This high value was preceded by a relatively steady rise of SSC during the 10 previous measurements and followed by two other high values (231 and 235 mg/L) and hence does not appear to be an outlier. The same validation process was used for the maximum value at Sucker Brook (150.4 mg/L). This peak value was preceded by 12 values > 50 mg/L and followed by a steady decline to 1 mg/L over the next five measurements.

Time series of SSC show that except for Sucker Brook, all stations recorded relatively high SSC during the last week of September and the first week of October. As shown in Figures 2 and 3, this peak SSC is associated with the largest precipitation and flow event recorded during the monitoring period. A number of high SSC values were recorded during the months of October and November, except at Sucker Brook. This information also needs to be corroborated with military activity and rainfall as potential drivers of elevated SSC.

Table 2 Descriptive statistics (mean, maximum and standard deviation) of SSC time series at each site

Site	Maximum (mg/L)	Mean (mg/L)	Standard deviation (mg/L)
River George	252.40	7.45	25.11
Sucker Brook	150.41	1.11	6.36
Queen's Brook	81.78	4.22	6.43
Nerepis at Flowler's Bivouac	131.72	4.96	8.05
Nerepis at Tok Chong Bridge	97.47	1.90	6.26

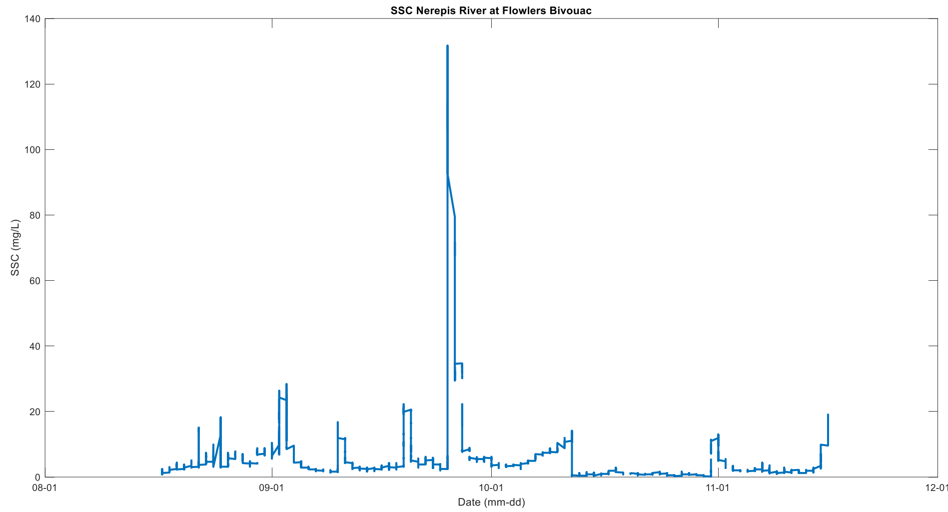

Figure 8 Time series of suspended sediment concentrations. Nerepis River at Flowler's Bivouac

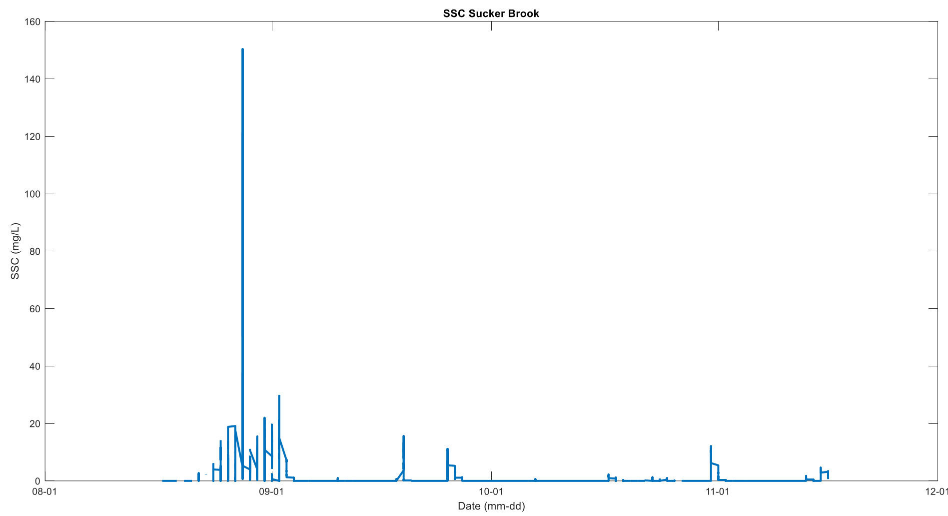

Figure 9 Time series of suspended sediment concentrations. Sucker Brook

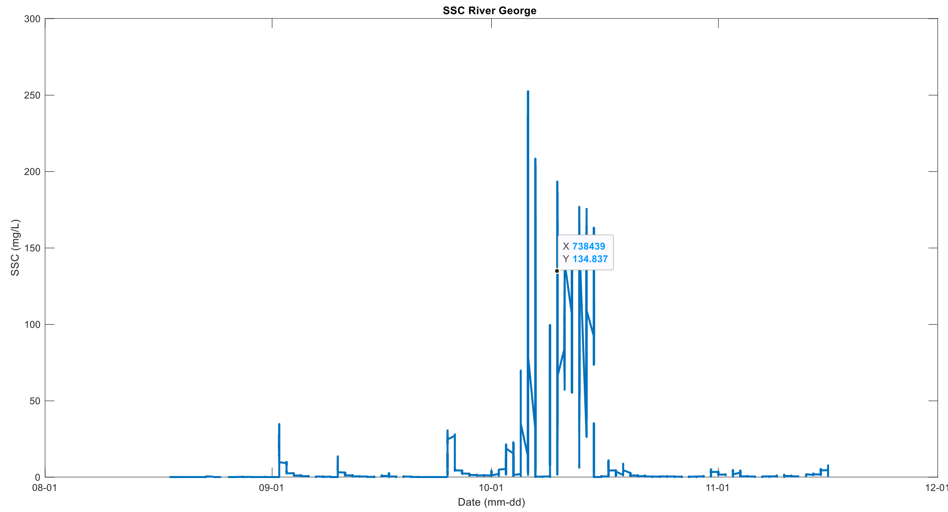

Figure 10 Time series of suspended sediment concentrations. River George

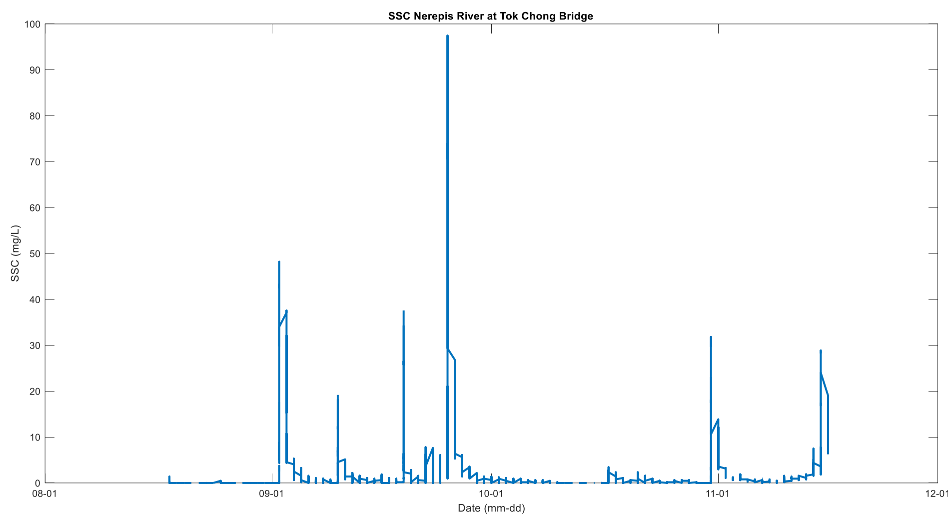

Figure 11 Time series of suspended sediment Concentrations. Nerepis River at Tok Chong Bridge

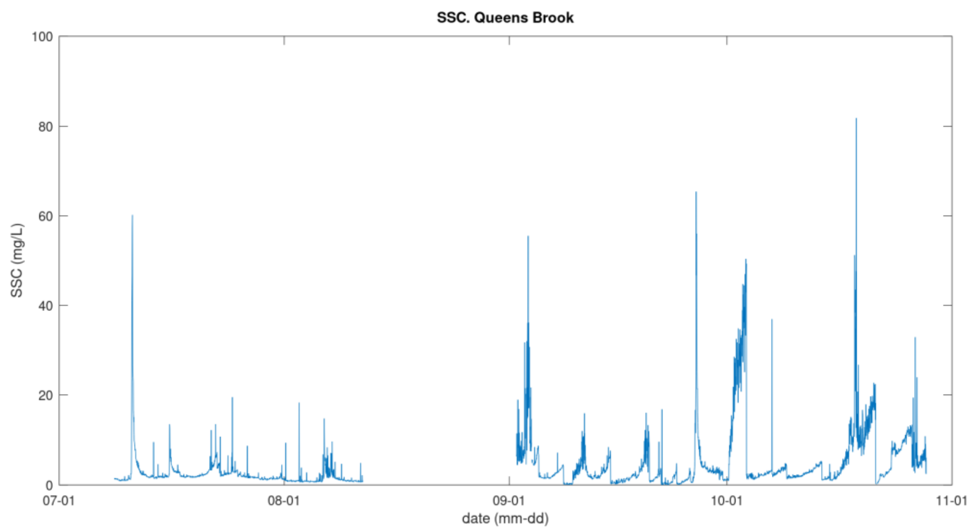

Figure 12 Time Series of suspended sediment concentrations. Queen's Brook, upstream of culvert (data provided By DFO).

4. Conclusion and next steps

This short report provides a summary of the field survey methodology, data gathering and descriptive analysis associated with sediment monitoring on the Nerepis River drainage basin during the summer and fall of 2021. These data will be added to the historical data provided by DND for model calibration and validation. The modelling effort will focus on mitigation scenarios to minimize suspended concentrations and loads at key locations in the system.

References

Alberto, A., M Van den Heuvel, A. St-Hilaire, S.C. Courtenay. 2016. Monitoring Stream Sediment Loads in Response to Agriculture in Prince Edward Island, Canada. Published online *Environmental Monitoring and Assessment*. DOI : 10.1007/s10661-016-5411-3

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