Addressing Sediment Transport Through Tobin Lake, Saskatchewan

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Environmental Engineering
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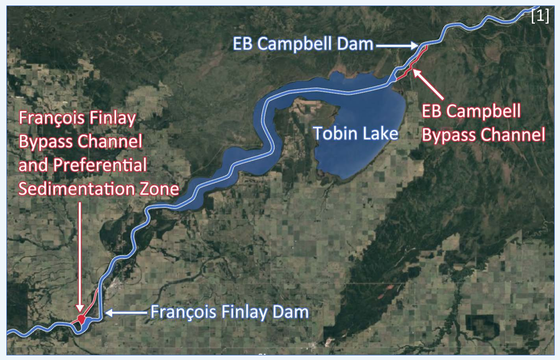
PROJECT DESCRIPTION



The construction of the EB Campbell and François Finlay dams, along with the subsequent creation of the artificial Tobin Lake, has been starving the ecosystem downstream in the Saskatchewan River Delta of nutrient-rich sediment [2].

The project goal is to design a solution to transport sediment downstream to help rehabilitate the ecosystem.

DESIGN OBJECTIVES

QUANTITY OF SEDIMENT DEPOSITION DOWNSTREAM

Double the annual amount of sediment currently passing through Tobin Lake system (from 3% of incoming sediment to 6%).

LIFECYCLE COST

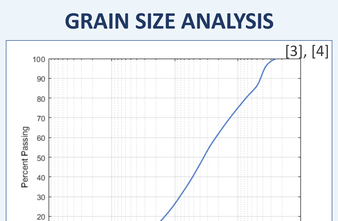
Minimize cost of implementing the design and avoid loss of revenue for SaskPower.

EXTENSION OF DAM LIFETIME

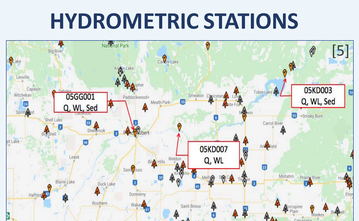
Recover cost of design by increasing available storage space in reservoir and extending the operating life of the dams.

SITE CHARACTERIZATION

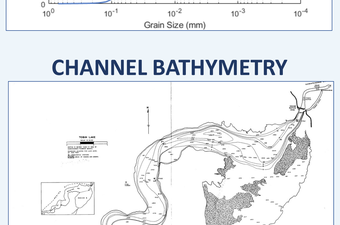
GRAIN SIZE ANALYSIS



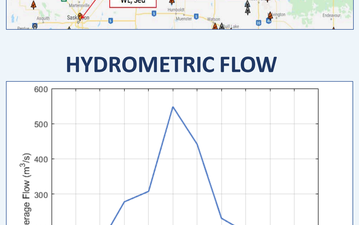
HYDROMETRIC STATIONS



CHANNEL BATHYMETRY



HYDROMETRIC FLOW



HEC-RAS MODELLING

Analysis performed to determine the sediment fall location (d_{84} particle fall velocity method):

1. CREATE ELEVATION CONTOURS

- Elevation contours generated from a Digital Elevation Model[8] using GlobalMapper 19[9].
- Channel depth contours drawn from bathymetry map[7].

2. BUILD CIVIL3D SURFACE

- Convert elevation contours into Civil3D (2019)[11].

3. BUILD HEC-RAS MODEL

- Export surface to HEC-RAS (5.0.7) and calibrate[12].

4. RUN MODEL

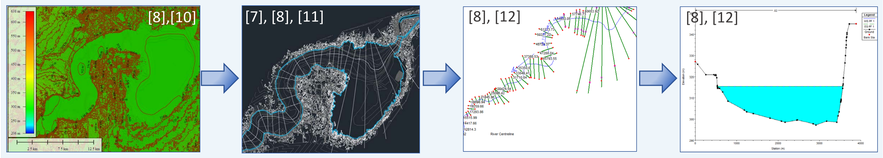
- Determine velocities throughout Tobin Lake.

KEY ASSUMPTIONS AND LIMITATIONS:

- Tobin Lake sediment data samples are representative of incoming sediment.
- Steady and low flow.
- Bathymetry data from 1966[7].

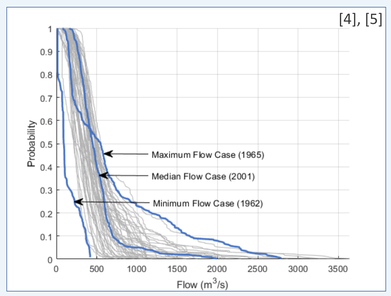
MODEL PARAMETERS

- Set upstream and downstream elevations.
- Manning's n: 0.02[13]
- Constant flow rate (453 m^3/s)



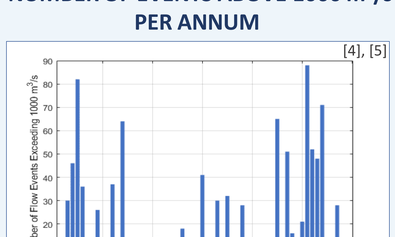
OPERATION DESIGN

CUMULATIVE DENSITY FUNCTION

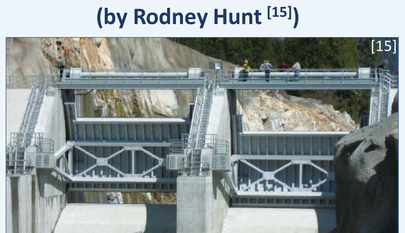


- Flows above 1000 m^3/s can be discharged in the bypass channel without loss of revenue [14].
- Variations in cumulative density functions for each year from 1958-2019 show no trend. Therefore, the average was used.
- On average, flows above 1000 m^3/s occur 18 times a year, with an average discharge of 1380 m^3/s.
- Total volume of sediment moved by channels was determined using: a design lifetime of 40 years, return periods for flows between 1000-1450 m^3/s, and average sediment concentration.

NUMBER OF EVENTS ABOVE 1000 m^3/s PER ANNUM



RADIAL TAINTER GATE (by Rodney Hunt [15])



STRUCTURES

Structure	Width (m)
1 (FF - Inlet - Radial Gate)	35
2 (SZ - Inlet - Radial Gate)	30
3 (SZ - Outlet - Weir Gate)	20
4 (FF - Outlet - Radial Gate)	35
5 (EBC - Inlet - Radial Gate)	35
6 (EBC - Culvert 1 - Box Culvert)	35
7 (EBC - Culvert 2 - Box Culvert)	35

GATE OPERATING REGIME

Flow < 1000 m^3/s

- Gate 1 and 3 closed, Gate 2 opened.

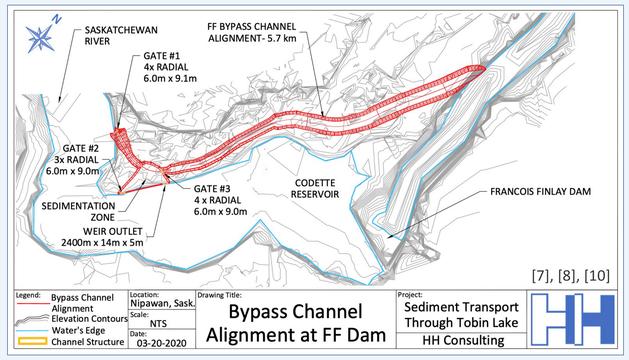
1000 m^3/s < Flow < 1450 m^3/s

- Gate 1 and 3 partially opened, Gate 2 closed.

Flow > 1450 m^3/s

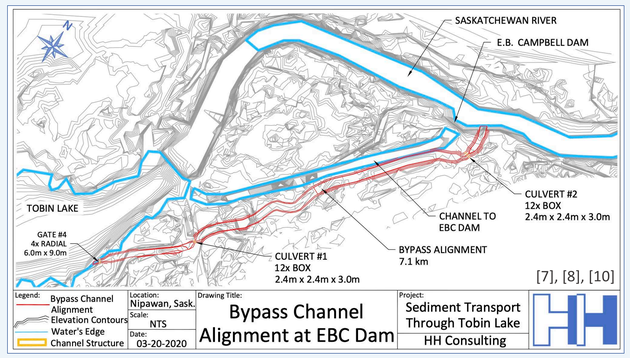
- Gate 1 and 3 fully opened, Gate 2 closed.
- Overflow will route through SaskPower's existing emergency spillway at FF Dam.

CHANNEL DESIGN



FF Bypass Channel

- Sediment naturally collects on the inside of river bends.
- A large sedimentation area will be created by excavating the land connected to the river.
- Innovative approach to utilize existing river alignment.



EBC Bypass Channel

- Reusing the pre-dam channel alignment to reduce construction cost.
- Two sets of box culverts will be installed for road crossings.

Parameter	FF Channel	EBC Channel
Total Length	5.7 km	7.1 km
Length of Earthen Channel	1870 m	5470 m
Length of Concrete Channel	3850 m	1620 m
Minimum Bed Slope	0.002 m/m	0.0012 m/m
Maximum Bed Slope	0.01 m/m	0.007 m/m
Median Bed Slope	0.0025 m/m	0.003 m/m
Net Volume of Cut	2.5×10^7 m^3	1.7×10^7 m^3
Side Slope	2:1	2:1

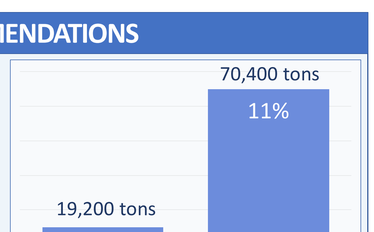
TOTAL COST

[16], [17], [18], [19]

Category	Items	Cost
Concrete	Material, equipment, shipping, and labour for the bypass channels, sedimentation zone wall, concrete strips, and culverts 1 and 2.	$ 2.8 M
Excavation	Equipment, labour and disposal of cut from the channel construction.	$ 15.7 M
Gates	Supply and installation of three sets of radial tainter gates and one weir gate.	$ 8.4 M
Operation & Maintenance	Removal of vegetation at bypass channels, operation and maintenance of gates, maintenance of concrete items.	$ 1.3 M
	TOTAL	**$ 28.2 M**

CONCLUSIONS & RECOMMENDATIONS

- Quantity of sediment deposition increased from 3% to 11%.
- Bypass channels are a cost-effective solution if we leverage the revenue from the increase in dam lifetime ($ 88 M NPV).
- The bypass channels increase the dam lifetimes by four years.
- Modelling of sedimentation and scour in the sedimentation zone is required to optimize its operations and efficiency.
- Reservoir sedimentation is a known issue which can be rectified with the installation of sluice gate during dam constructions.



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Programs Used: MATLAB R2018a, CIVIL 3D 2019, HEC-RAS 5.0.7, GlobalMapper 19, Excel 16.35

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