

Donlin Gold Project

2025 TSF Main Dam Breach Assessment

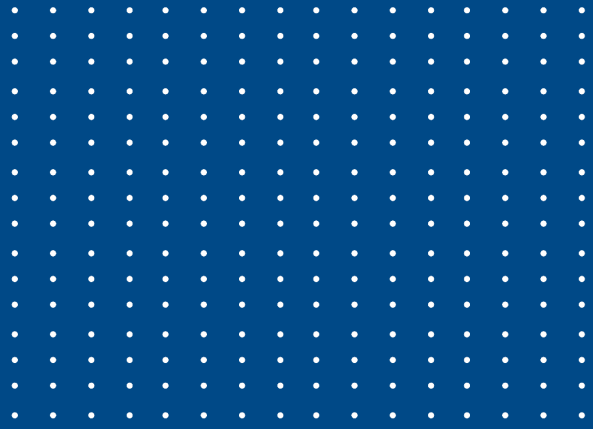
Hamish Weatherly, M.Sc., P.Geo.
Patrick Grover, Ph.D., P.Eng.

January 20, 2026



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Physical Setting

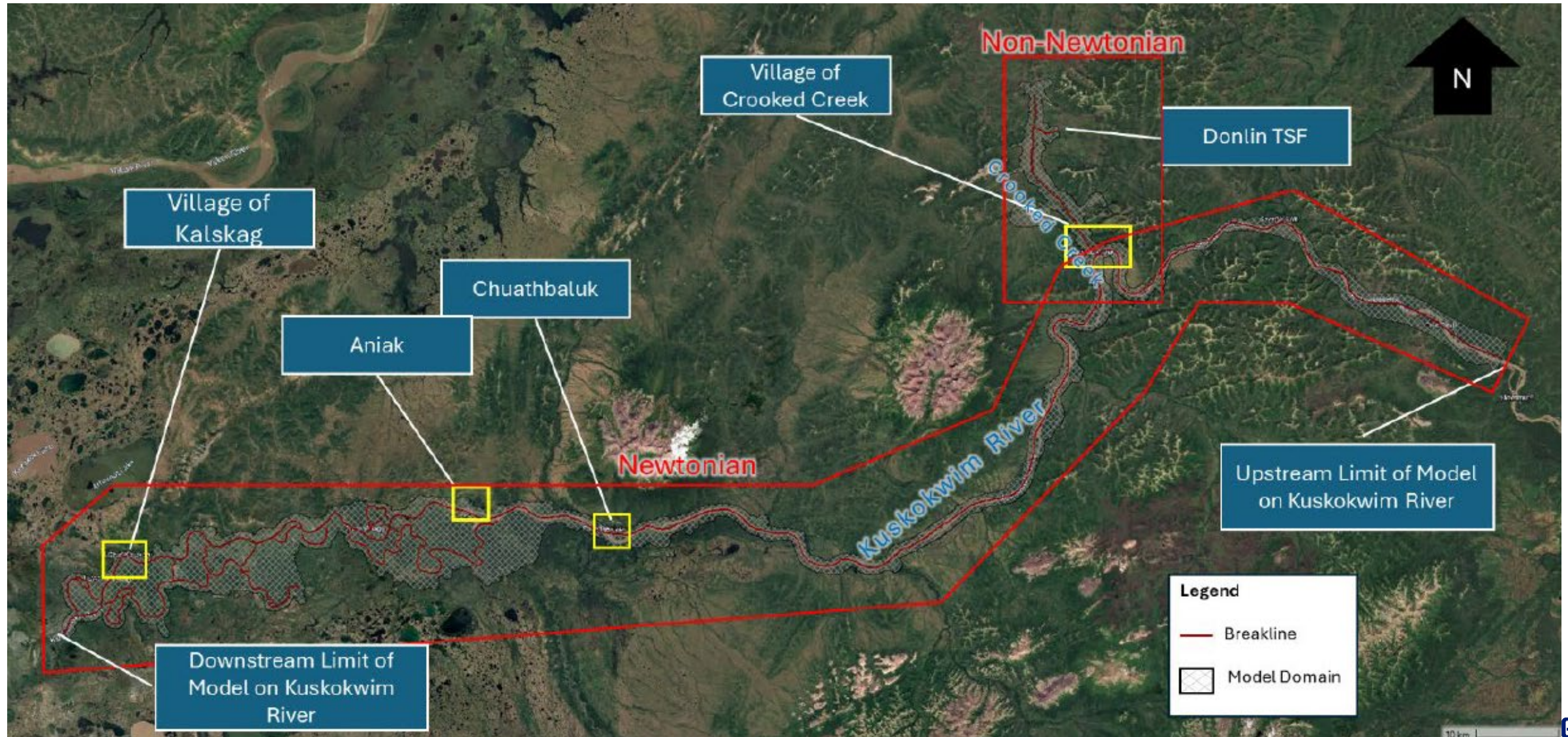


Location Map and Site Layout



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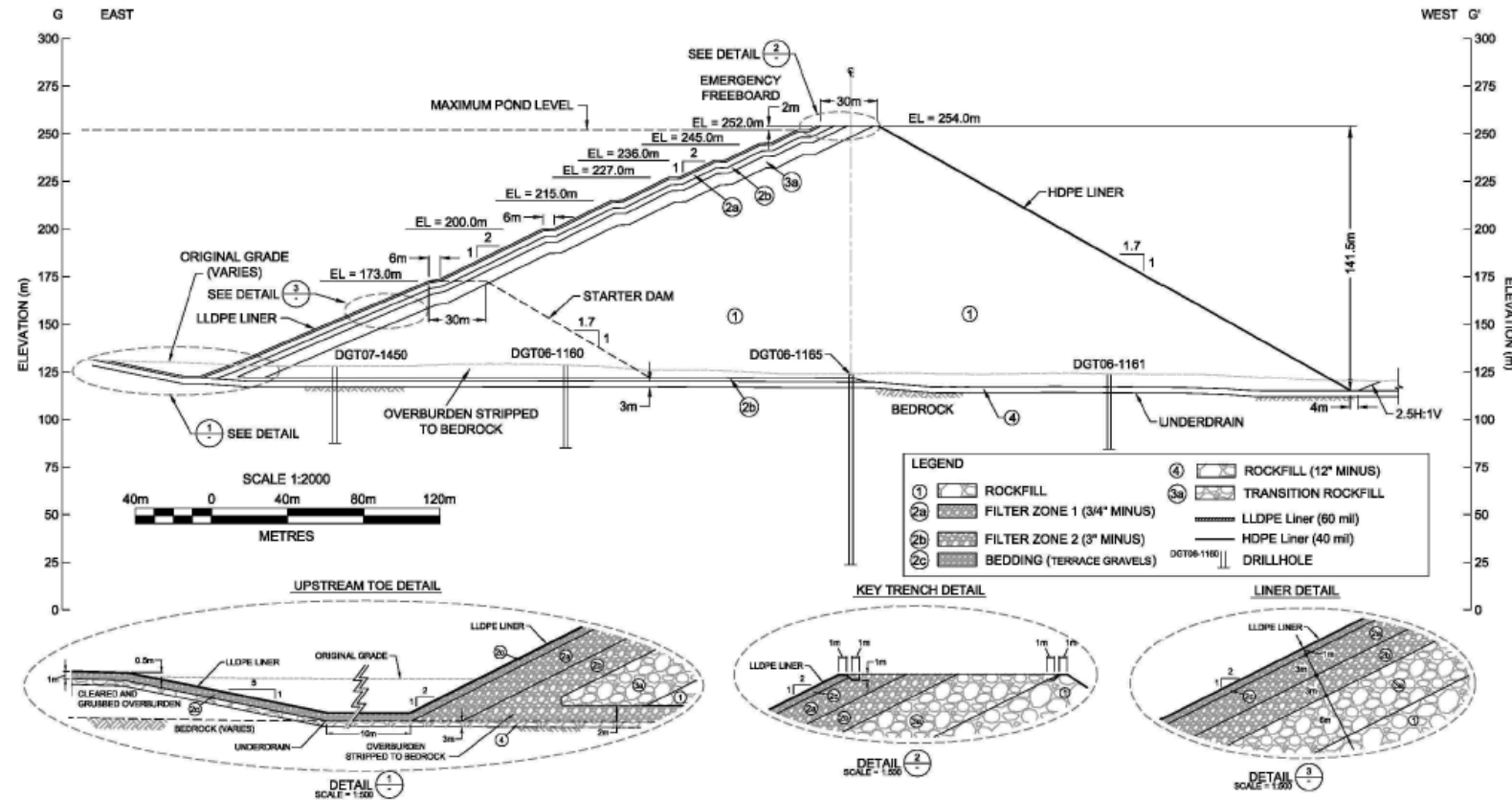
Model Domain



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TSF Main Dam Cross-Section

- Final height = 471 ft (144 m)
- Catchment = 5.9 sq.mi. (15.3 km²)
- End of operations, 568 million short tons of tailings in storage
- Tailings volume = 334,300 acre-ft (412.4 Mm³) of tailings
- Tailings area = 3.7 sq.mi. (9.5 km²)
- Estimated tailings porosity = 54%
 - Solids = 153,800 acre-ft (189.7 Mm³)
 - Interstitial water = 180,500 acre-ft (222.7 Mm³)
- Plus, a supernatant pond volume = 9,760 acre-ft (12.0 Mm³)

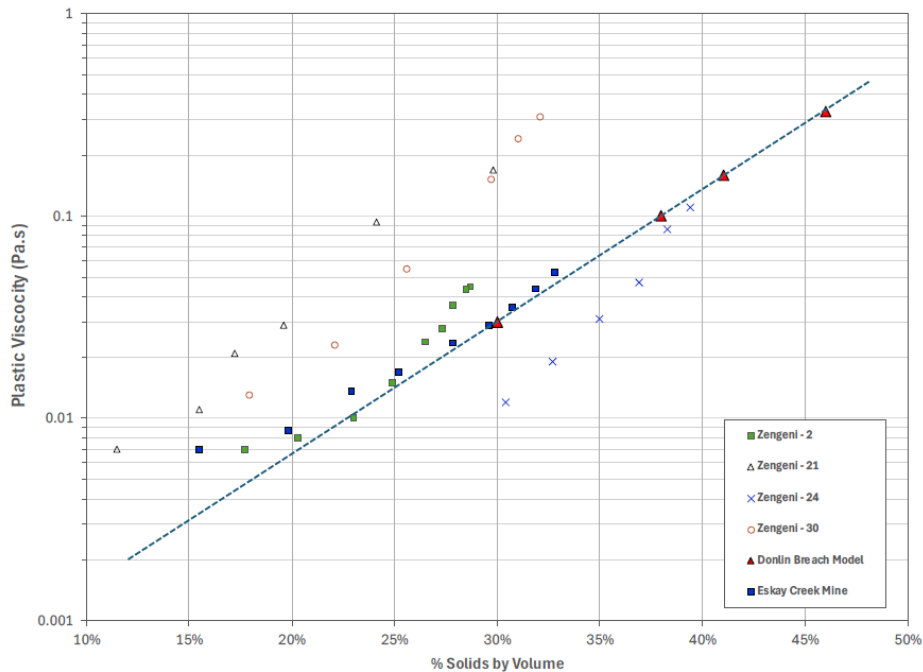
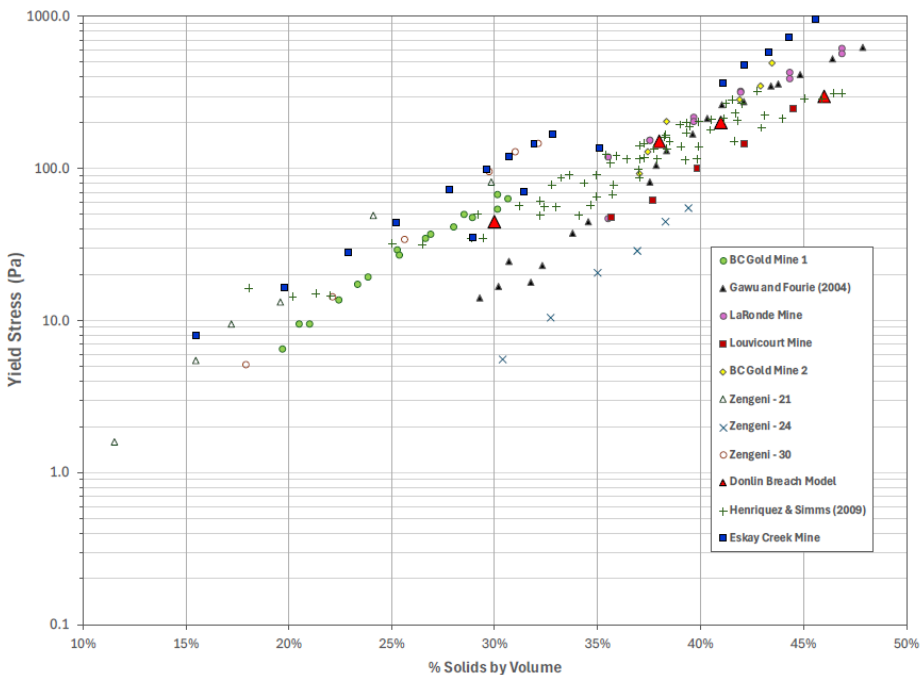


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Tailings Properties

- Low plastic silt = 5% sand, 80% silt, 15% clay
- Tailings settled dry density at end of operations = 78 pcf (1.25 t/m³)
- At this density, the deposited tailings have an approximate solids concentration of 70% by weight (46% by volume)
- The tailings rheology (yield stress and viscosity) are expected to vary as a function of solids concentration

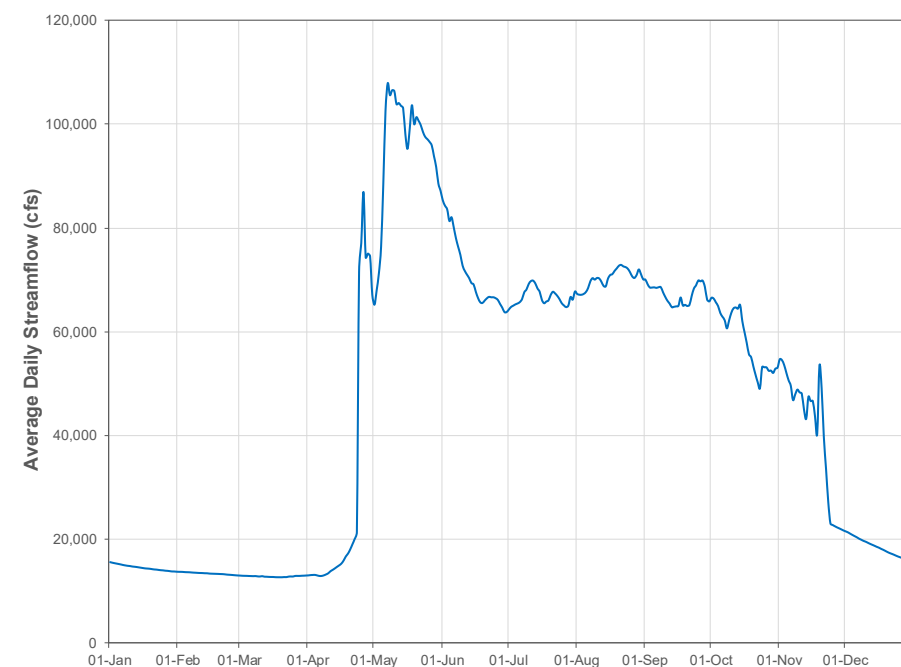
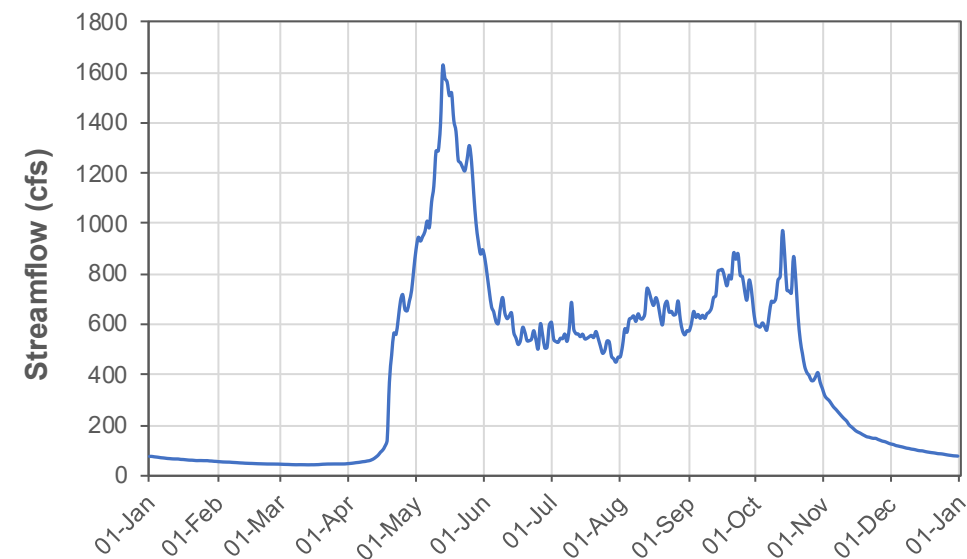
C _v (%)	C _w (%)	Yield Stress (Pa)	Viscosity (Pa.s)
46	70	300	0.33



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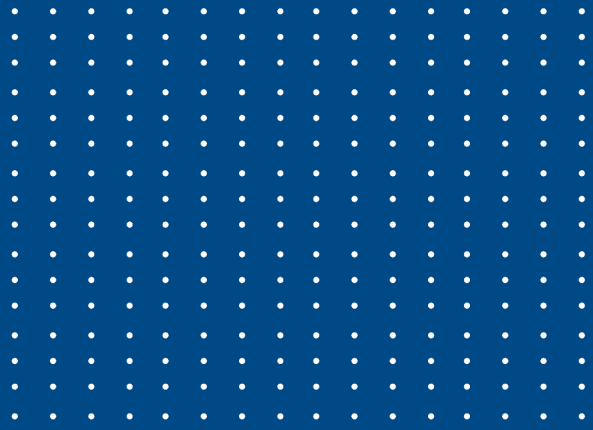
Hydrology

- Crooked Creek and Kuskokwim River are both gaged by the USGS
- Watershed area of 330 sq.mi. (855 km²) reports to the Crooked Creek gage (2007-present)
- Watershed area of 31,100 sq.mi. (80,610 km²) reports to the Kuskokwim River gage (1993-present)
 - 100x larger



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Credible Dam Failure Scenario



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2014 Early-Stage FMEA Workshop

Table 3-1 Credible TSF Main Dam breach scenarios identified in the 2014 early-stage FMEA workshop (after SRK, March 2015). The rows highlighted in yellow were modelled by BGC (June 1, 2015) as part of the FEIS for the Donlin Gold Project.

#	Scenario	Full or Partial Breach	Consequence Severity	Likelihood	Risk Rating
1	Downstream failure of dam due to material variability results in partial breach and loss of material (1620 acre-ft / 2 Mm ³) that reaches Crooked Creek.	Partial	Major	Unlikely	Moderately High
2	Poor QA/QC during construction of filter/liner materials results in a leak and ultimately a piping failure and a catastrophic breach.	Full	Critical	Very Unlikely	Moderately High
4	Liner rupture directly above the underdrain leads to sinkhole and outflow of tailings through underdrain.	Partial	Critical ¹	Unlikely	Moderately High
11	Spillway blockage by ice and snow leads to overtopping and breach of the dam.	Full	Critical	Very Unlikely	Moderately High
20	Rupture of the liner leads to piping of native materials into the underdrain and release of tailings and formation of a sinkhole over time ² .	Partial	Moderate	Very Unlikely	Low
24	Mass wasting failure at the abutment (landslide) occurs following construction results in catastrophic failure of the dam.	Full	Critical	Very Unlikely	Moderately High
37	Deep-seated failure of the dam foundation due to undiscovered conditions leads to catastrophic failure of the dam.	Full	Critical	Very Unlikely	Moderately High

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Partial Failure Scenarios Modelled by BGC in 2015

- As a follow-up to the FMEA workshop and as part of the FEIS, BGC was requested to evaluate the effects of a partial tailings release
- Release of up to 1,620 acre-ft (2 Mm³) of tailings (0.5% of the total volume) and process-affected water from a partial breach of the TSF Dam due to i) piping and ii) liner rupture leading to a sinkhole (Scenarios #1 and 4 from preceding table).
- Four scenarios were modelled by BGC.

Table 3-2 Scenarios modelled by BGC (June 1, 2015).

Scenario	Description
1	Partial piping breach under normal operating conditions, 1,620 acre-ft (2 Mm ³) of tailings released
2	Partial piping breach under normal operating conditions, 1,620 acre-ft (2 Mm ³) of pond water released
3	Liner rupture leading to underdrain flow, 1,620 acre-ft (2 Mm ³) of tailings released
4	Liner rupture leading to underdrain flow, 1,620 acre-ft (2 Mm ³) of pond water released

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Selected Dam Breach Scenario

Additional dam failure scenarios identified in the FMEA included:

- **Scenario #2 – piping failure leading to a catastrophic breach of the dam**
- Scenario #11 – blocked spillway leading to overtopping and breach of the dam
- Scenario #24 – a landslide occurs at the abutment
- Scenario #27 – deep-seated failure of the dam foundation due to undiscovered conditions

For this FEIS update, a catastrophic piping failure of the TSF Main Dam was considered the most plausible failure mode. The potential root cause of a piping failure was:

- Poor QA/QC
- Seepage flow starting due to a liner defect
- Ponded water against the upstream lined dam face.

This seepage could lead to retrogressive slumping from the downstream toe, then settlement of the dam crest, and overtopping.

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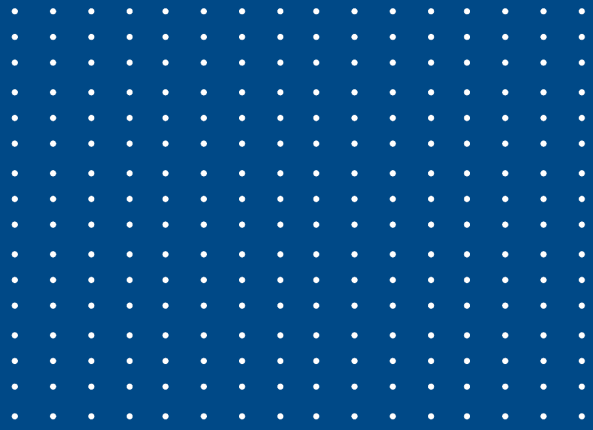
Selected Dam Breach Failure Conditions

The hypothetical tailings releases were modelled under the following conditions:

- “Sunny day” hydrologic conditions
- Ultimate dam height of 471 ft (144 m)
- A tailings volume of 334,300 acre-ft (412.4 Mm³) at 54% porosity
- A supernatant pond volume of 9,760 acre-ft (12.0 Mm³), which is the 50th percentile pond volume at the end of operations and represents normal operating conditions.

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Tailings Release Volume



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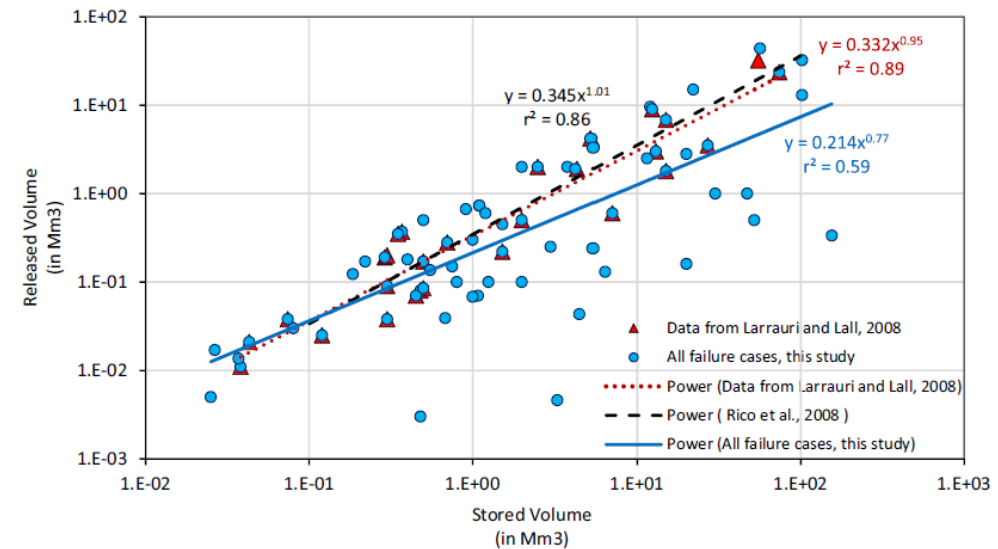
Tailings Release Volume

Table 4-1 Tailings release volume estimates using various empirical methods.

Method	Tailings Storage Volume (acre-ft)	Release Volume (acre-ft) ⁵	Release Percentage
Piciullo et al. (2022) – single regression ¹	334,300	17,910	5.4%
Piciullo et al. (2022) – multiple regression ²	334,300	44,350	13.3%
Larrauri and Lall (2018) ³	334,300	82,140	24.6%
3° backscarp angle (75 ft above the upstream dam toe)	334,300	120,440	36%
Rico et al. (2008) ⁴	334,300	125,780	38%

Note:

1. 71 cases with linear regression of release volume versus storage volume.
2. 71 cases with multiple regression of release volume versus storage volume and dam height.
3. 28 cases with linear regression of release volume versus storage volume.
4. 21 cases with linear regression of release volume versus storage volume.
5. 50th percentile pond volumes at the end of operations would be added to these release volumes for dam breach modelling.



$$\rightarrow V_R = 10^{0.330} \cdot H^{0.994} \cdot V_T^{0.611}$$

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Tailings Release Volume

- Empirical equations/methods indicate tailings release volumes that range between 5% and 38% of the total storage volume
- Previous EISs have used the empirical relation of Larrauri and Lall (2018) to provide an estimate of the release volume for action alternatives.
- The largest facility in the Larrauri and Lall dataset is 60,000 acre-ft (74 Mm³) compared with 356,714 acre-ft (440 Mm³) for the proposed TSF Main Dam
- Specific embankment construction methods are not factored into the empirical equations.

Each of the methods acknowledges that predicting the release volume for a specific tailings facility is highly variable due to site- and facility-specific consideration. Therefore, it was determined that a range of hypothetical volumes should be modeled for the current study, including 0.5% (as per the original FEIS value), 5.4%, 13.3%, and 24.6%.

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Tailings Release Volume

Table 4-2 TSF Main Dam breach scenarios including release volume and rheological parameters.

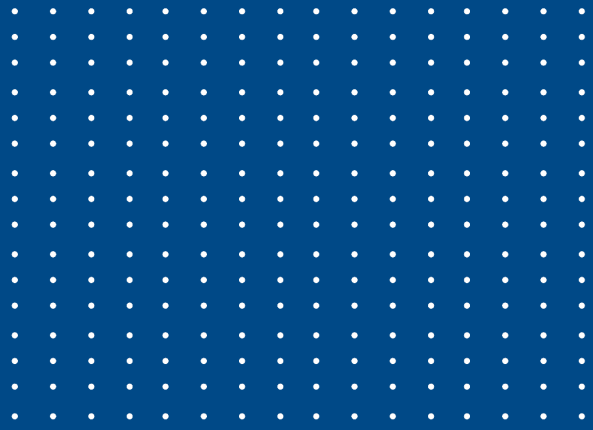
% tailings release	Tailings Release Volume ¹ (acre-ft)	Pond Volume (acre-ft)	Total Release Volume (acre-ft)	C _v (%)	Yield Stress (Pa)	Plastic Viscosity (Pa·s)
24.6	82,140	9,730	91,870	41%	200	0.16
13.3	44,350	9,730	54,080	38%	150	0.10
5.4	17,910	9,730	27,640	30%	45	0.03
0.5	1,670	0	1,670	46%	300	0.33

Note:

1. Volume includes tailings solid and void water with an assumed sediment concentration volume (C_v) of 46%.

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Tailings Breach Hydrographs

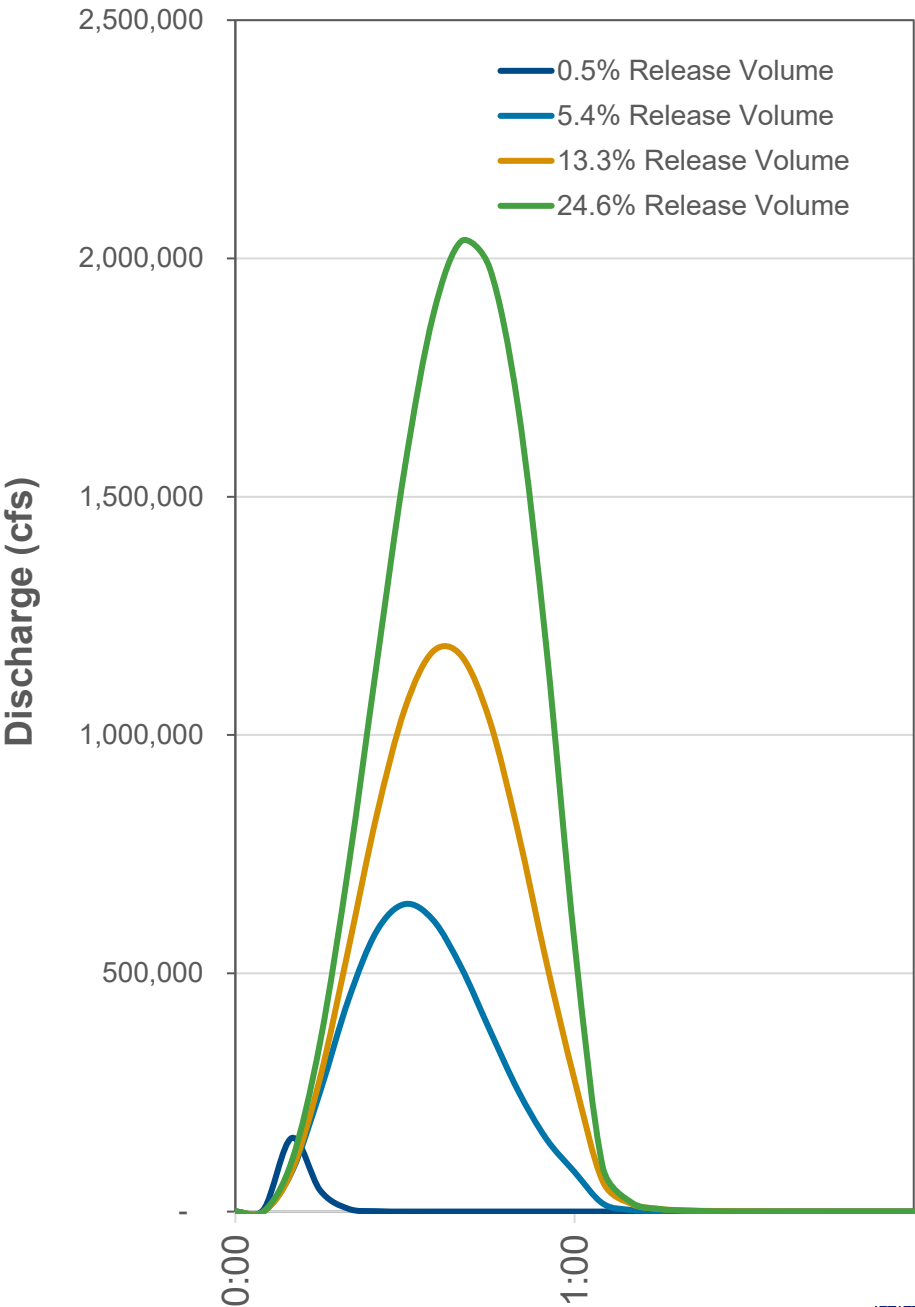


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HEC-HMS Breach Hydrographs

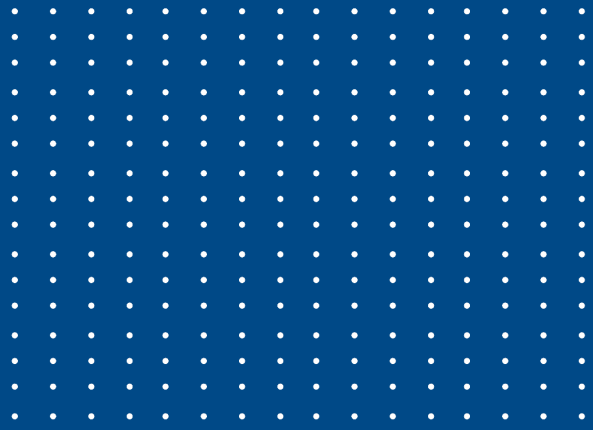
Table 5-2 Breach parameters used to generate the breach hydrograph and summary of the breach hydrograph.

Parameter	Release Volume Scenario (Percentage of Storage Volume)			
	0.5%	5.4%	13.3%	24.6%
Dam Breach Parameters				
Top Elevation (ft)	824	824	824	824
Bottom Breach Elevation (ft)	525	492	492	459
Bottom Breach Width (ft)	410	410	410	410
Side Slopes (xH:1V)	1	1	1	1
Breach Formation Time (hrs)	1	1	1	1
Breach Mechanism	Piping	Overtopping	Overtopping	Overtopping
Piping Elevation (ft)	541	N/A	N/A	N/A
Summary of Breach Dam Hydrographs				
Peak Outflow (cfs)	197,000	647,000	1,190,000	2,047,000
Time of Peak Outflow (h:mm)	1:11	1:30	1:36	1:41
Release Volume (acre-ft)	1,671	27,640	54,080	91,870



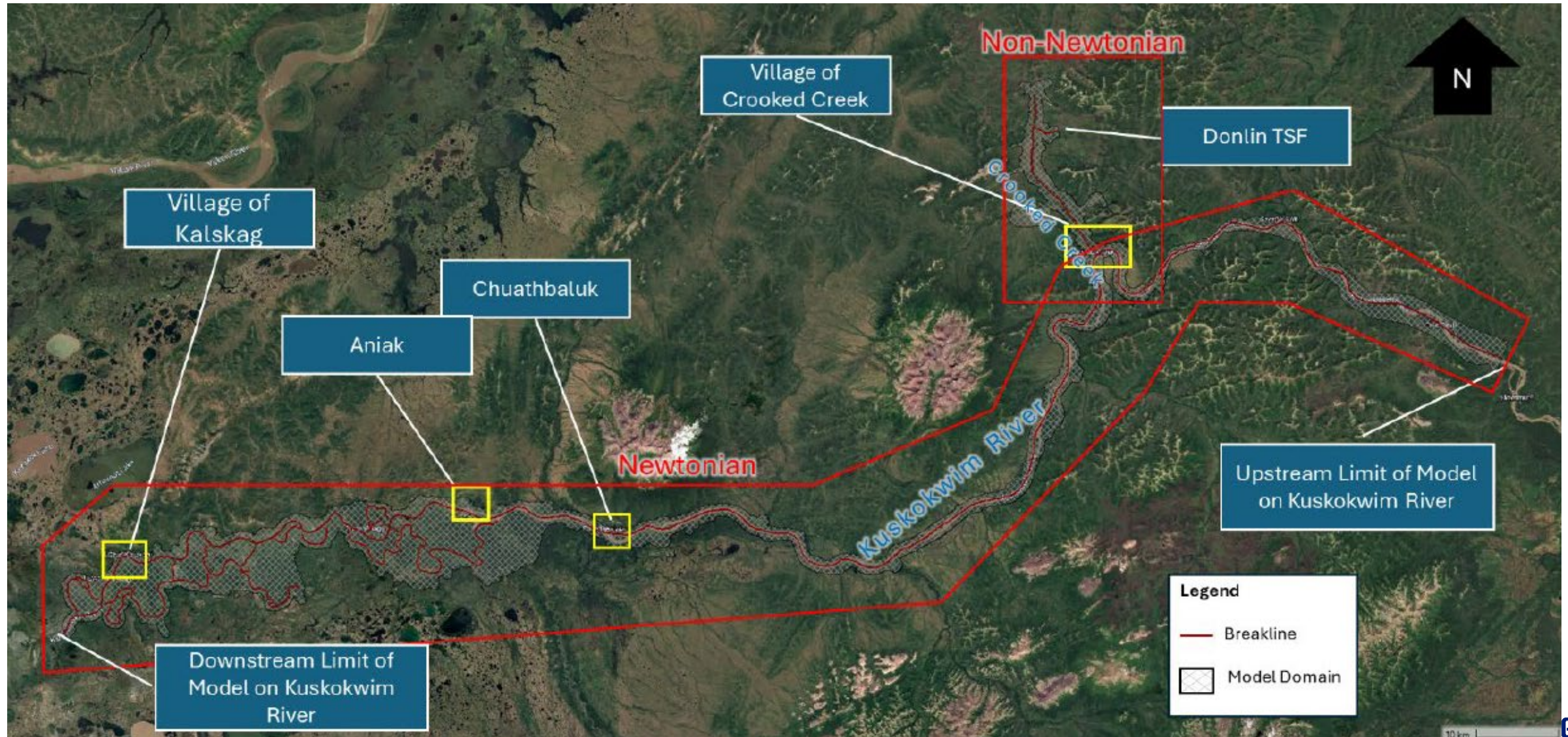
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Hydrodynamic Modelling



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HEC-RAS Model Domain



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Model Domain

- 2D modelling using HEC-RAS
- Model domain includes Crooked Creek and 120 miles of Kuskokwim River
- CDA (2021) guidelines note that modelling of the downstream flooding should extend to the point where the incremental flow effects of a failure would no longer represent a threat to life, properties and the environment, or where sufficient warning time would exist.
- For Sunny day scenarios, FEMA (2013) recommends the study extend until the flows decrease to be within the river channel (i.e., within a 2-year flood that is typically considered to be a bankfull flood),

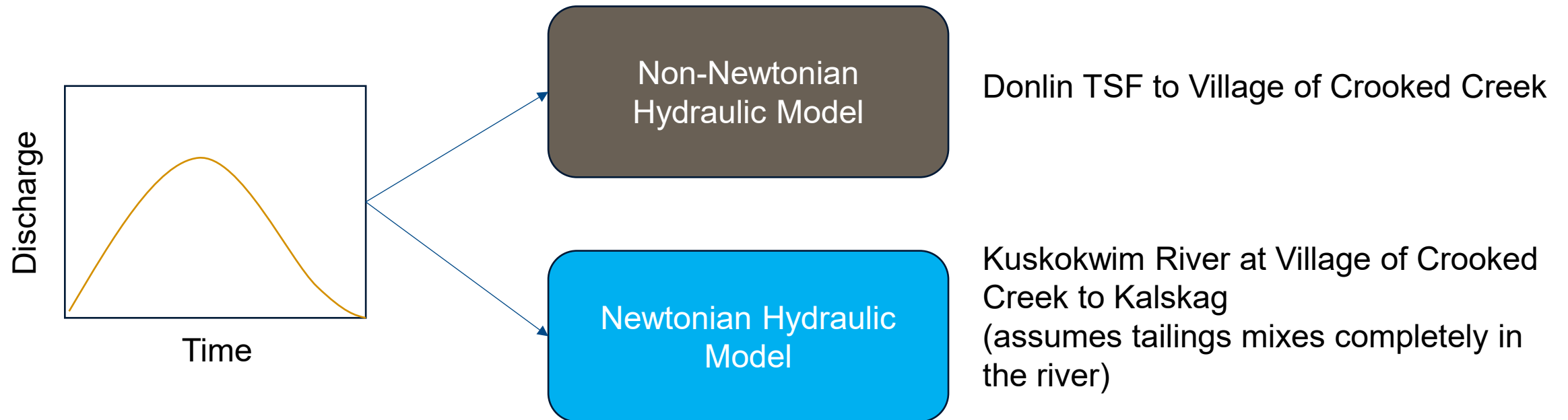
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Topography and Bathymetry

- Model DEM developed the 16-foot (5-meter) Digital Elevation Model (DEM) data for Alaska, obtained from the U.S. Geological Survey's National Map 3D Elevation Program (USGS, 2022)
- The DEM excludes elevations beneath water surfaces. Data regarding bathymetric elevations was unavailable for Anaconda Creek, Crooked Creek, and the Kuskokwim River.
- For Anaconda and Crooked creeks, the absence of bathymetric data is considered to have a negligible impact and was not considered. This is because the magnitude of the breach flood waves is much greater than the capacity of these two watercourses.
- For the Kuskokwim River, however, the absence of detailed bathymetric information required an adjustment to the model's discharge input.

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Non-Newtonian and Newtonian Modelling



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HEC-RAS Mesh

- non-Newtonian mesh (i.e., Crooked Creek) uses a base mesh resolution of 82 ft (25 m)
- Newtonian mesh (i.e., Kuskokwim River) uses a coarser resolution of 164 ft (50 m) due to broader, more uniform flow in the valley bottom
- Both meshes incorporated breaklines along the centrelines of the main channels and major secondary channels to align mesh elements with the direction of water flow
- Manning’s $n = 0.06$ for floodplains and 0.035 for the watercourses

Table 6-1 HEC-RAS mesh properties.

Property	Non-Newtonian Model (Crooked Creek)	Newtonian Model (Kuskokwim River)
Number of Mesh Cells	136,793	352,400
Average Mesh Face Length (ft)	89	154
Average Cell Size (sq.ft)	7,780	23,530

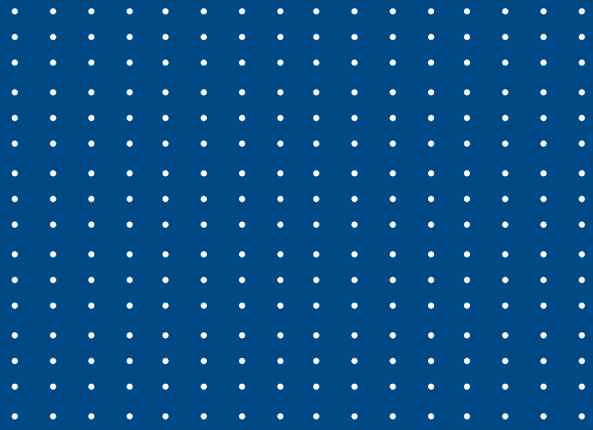
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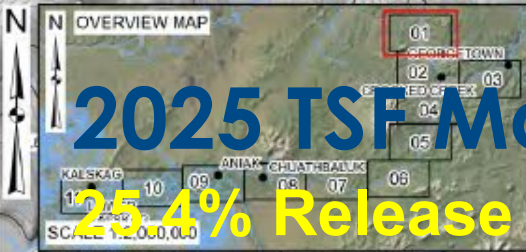
Hydrologic Conditions and Boundary Conditions

- Water elevation at the Kuskokwim River USGS gage on the date of DEM acquisition was 140 ft (42.6 m), which represents a streamflow of 34,330 cfs (985 m³/s)
- However, the water elevation at the gage in the DEM is 3 ft (0.9 m) lower, implying that the DEM had been hydro-flattened. $Q = 32,100$ cfs (910 m³/s)
- While a Sunny day failure could occur at anytime of the year, BGC elected to model average conditions during the June to September period
- Average flow in the June to September period at the Kuskokwim gage is 68,900 cfs (1950 m³/s). Therefore, a steady state inflow of 36,700 cfs (1040 m³/s) was used as an inflow boundary condition to the model at the upstream model domain boundary of the Kuskokwim River.
- The approach of adjusting the discharge to account for the lack of bathymetry in the DEM is a simplification and the river channel is depicted as much shallower than it is. This artificially reduced channel depth increases the frictional resistance within the model, since water encounters more contact with the channel bed and banks.

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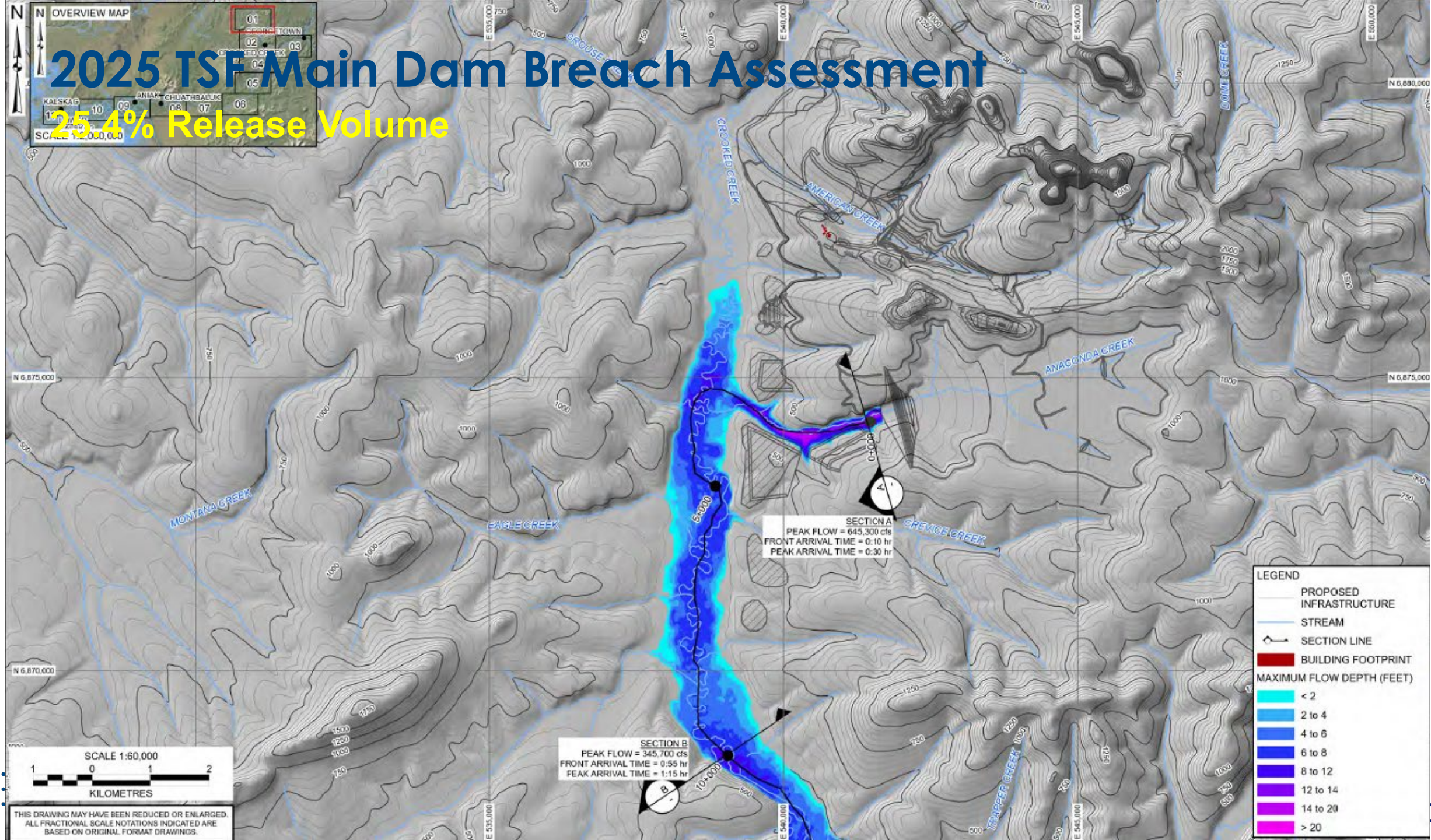
Results





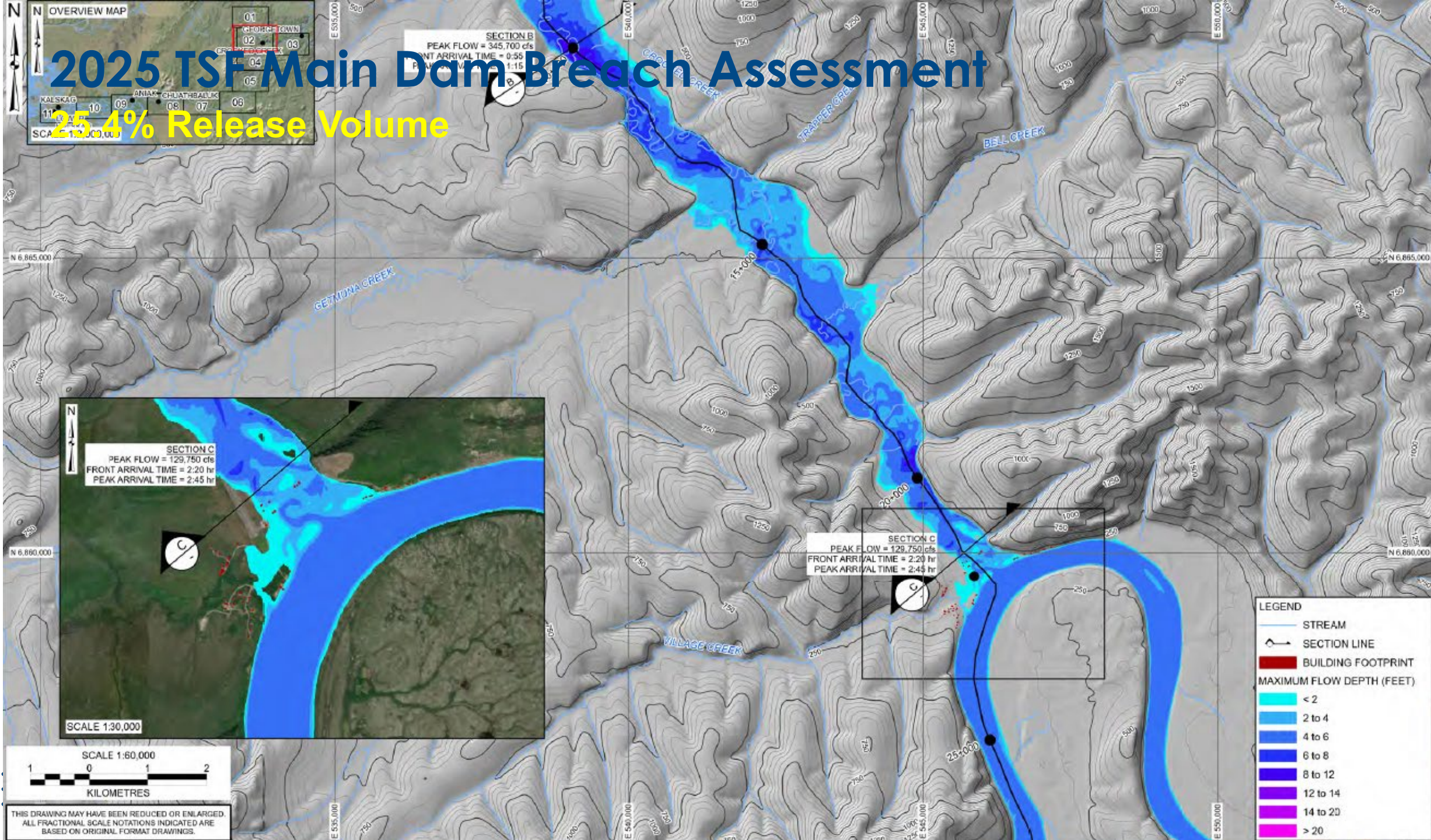
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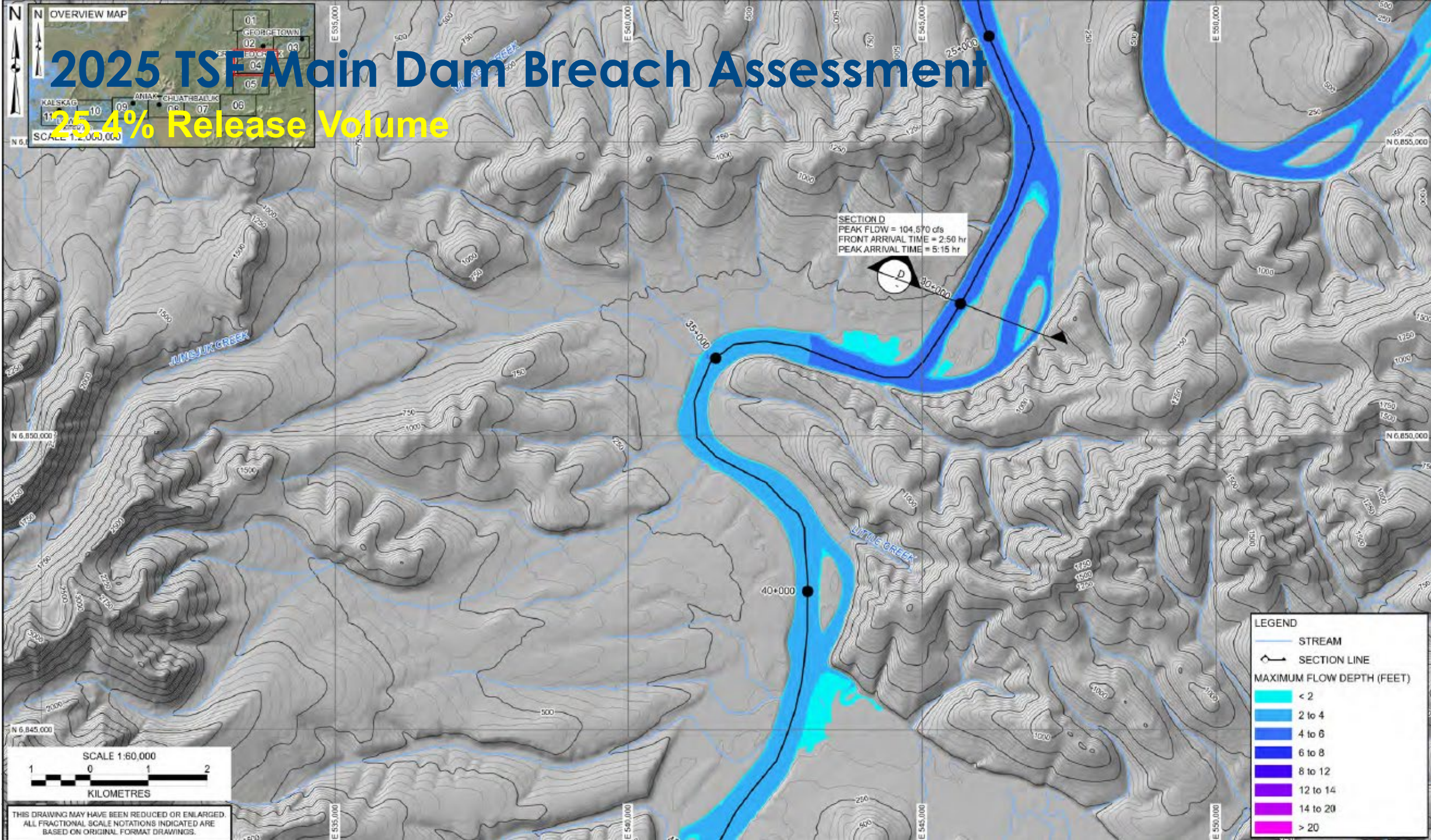
25.4% Release Volume



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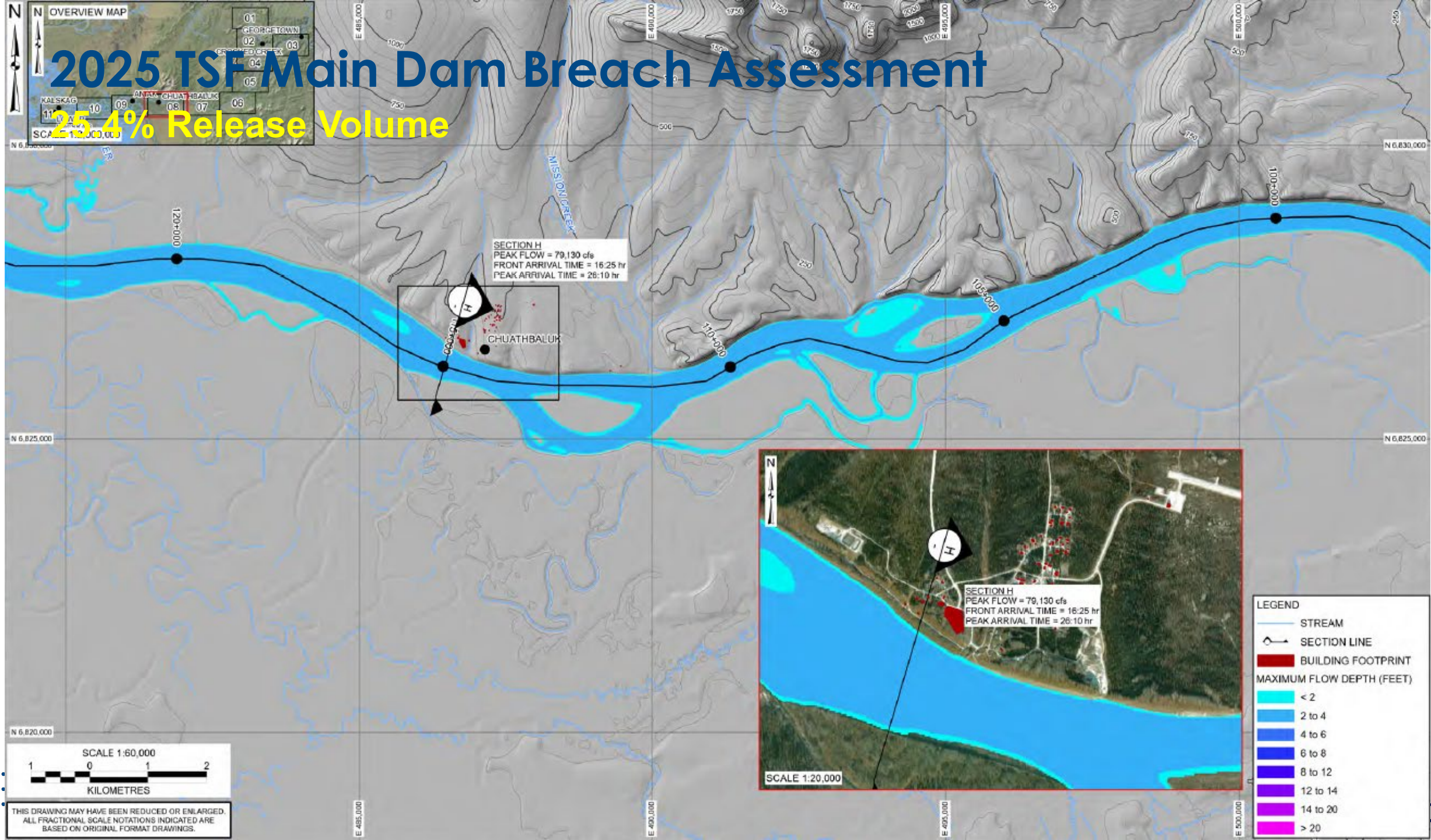
25.4% Release Volume





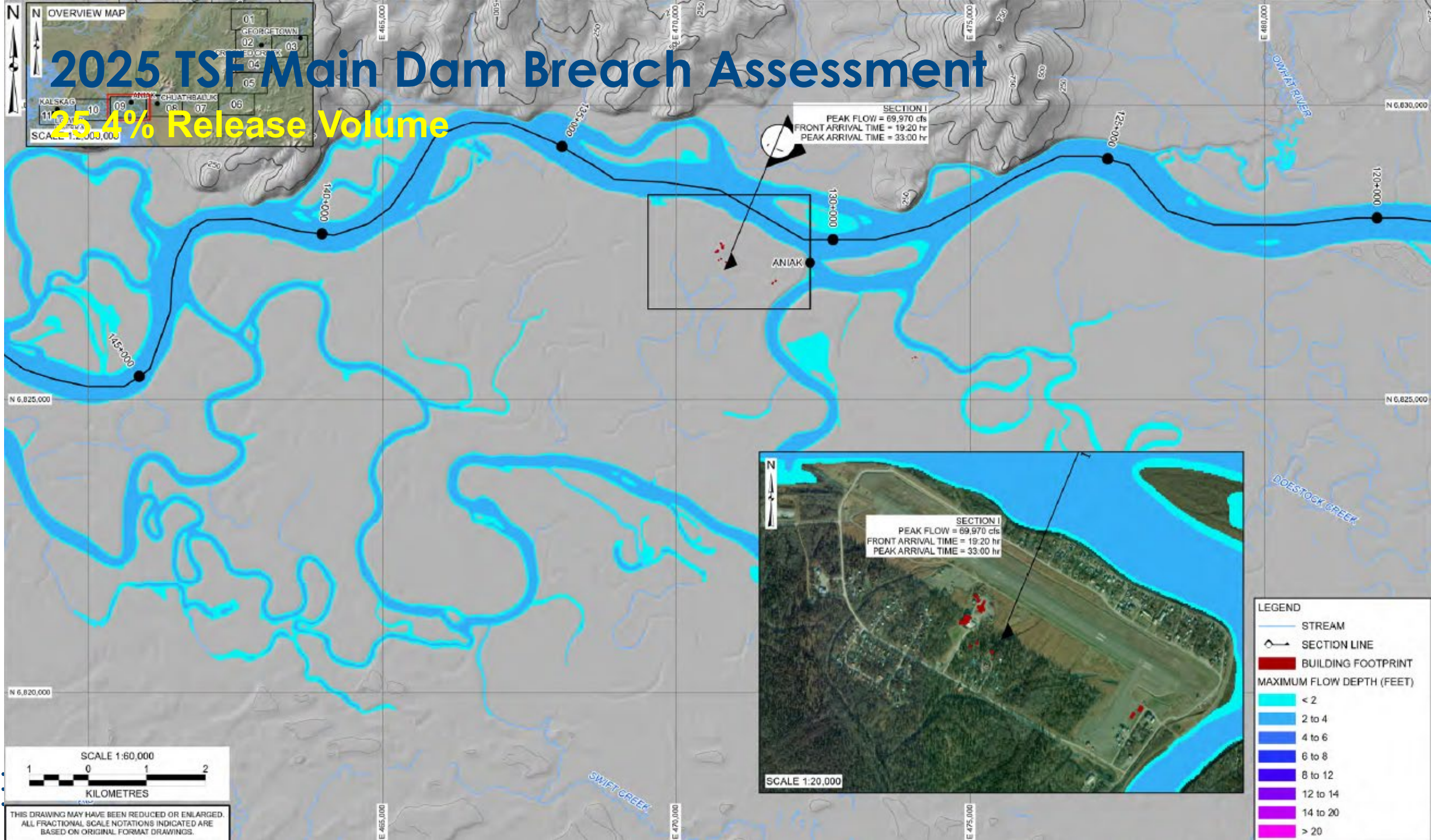
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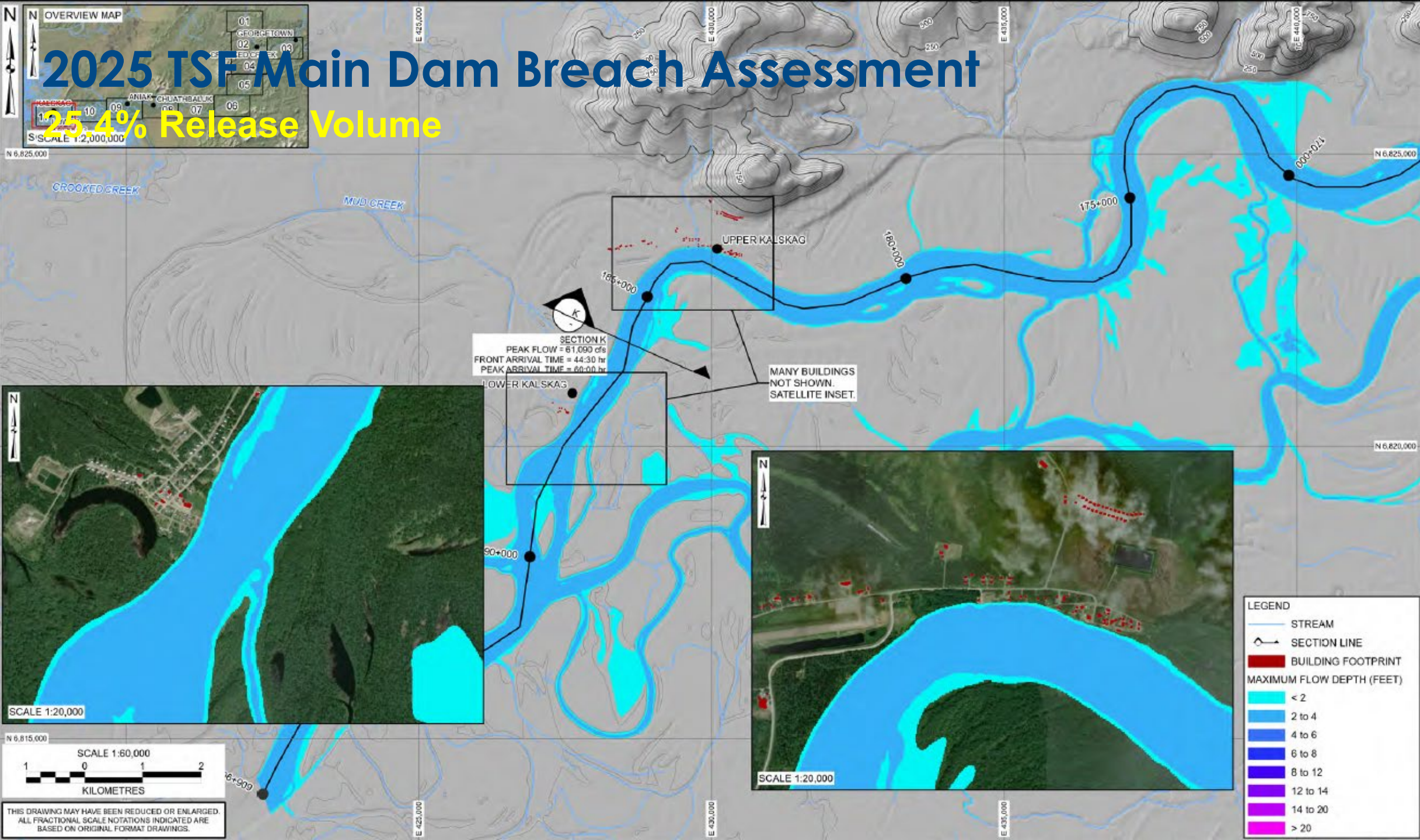
25.4% Release Volume



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25.4% Release Volume

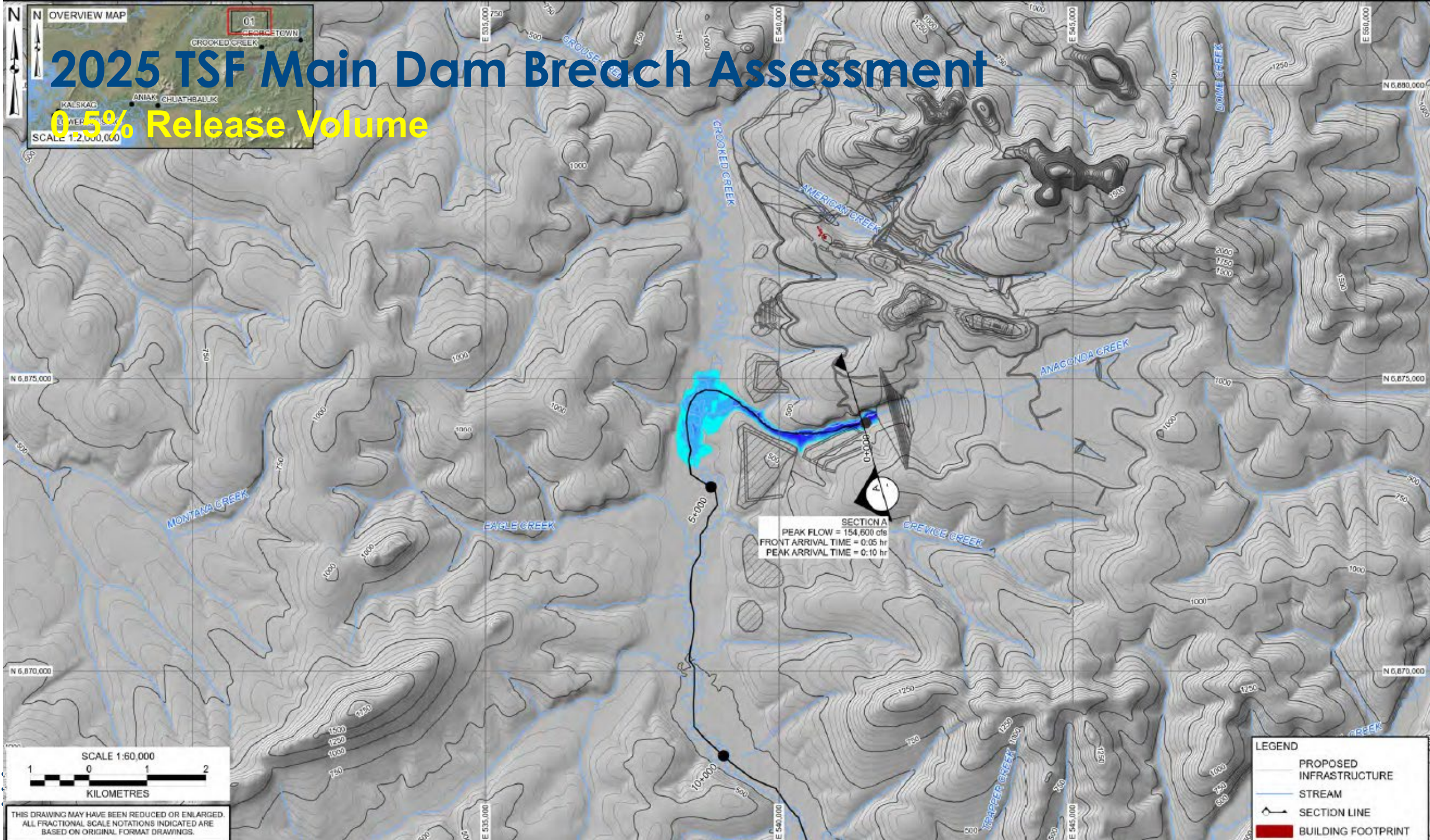






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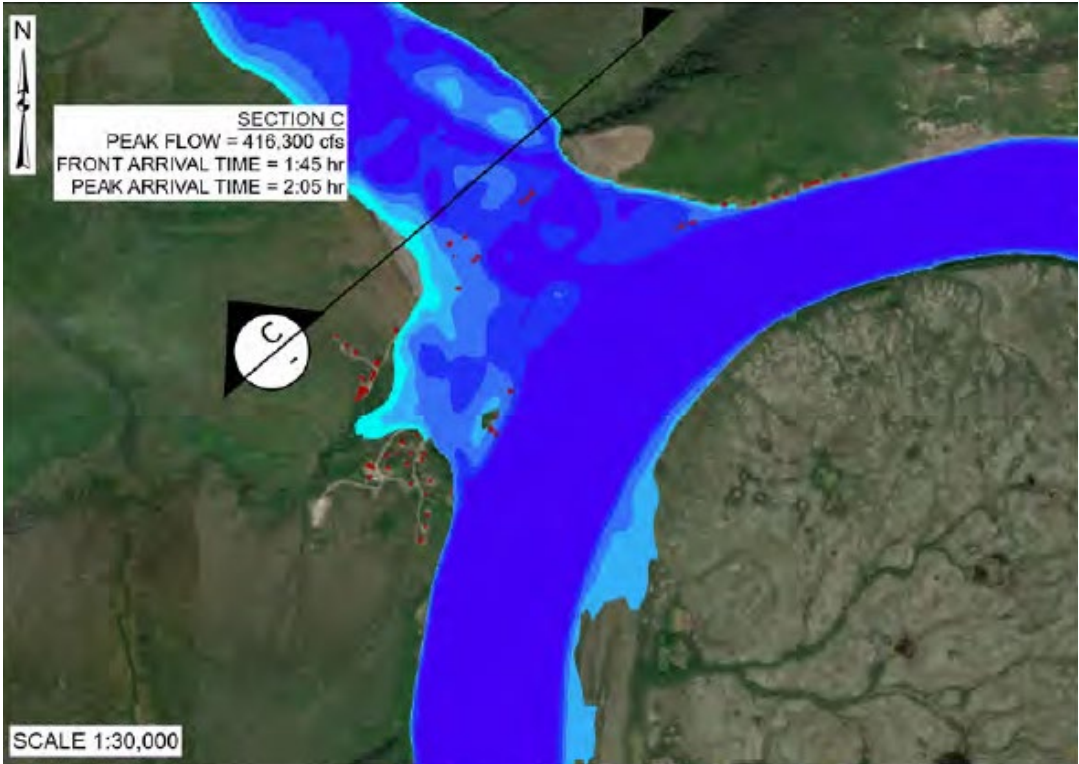
0.5% Release Volume



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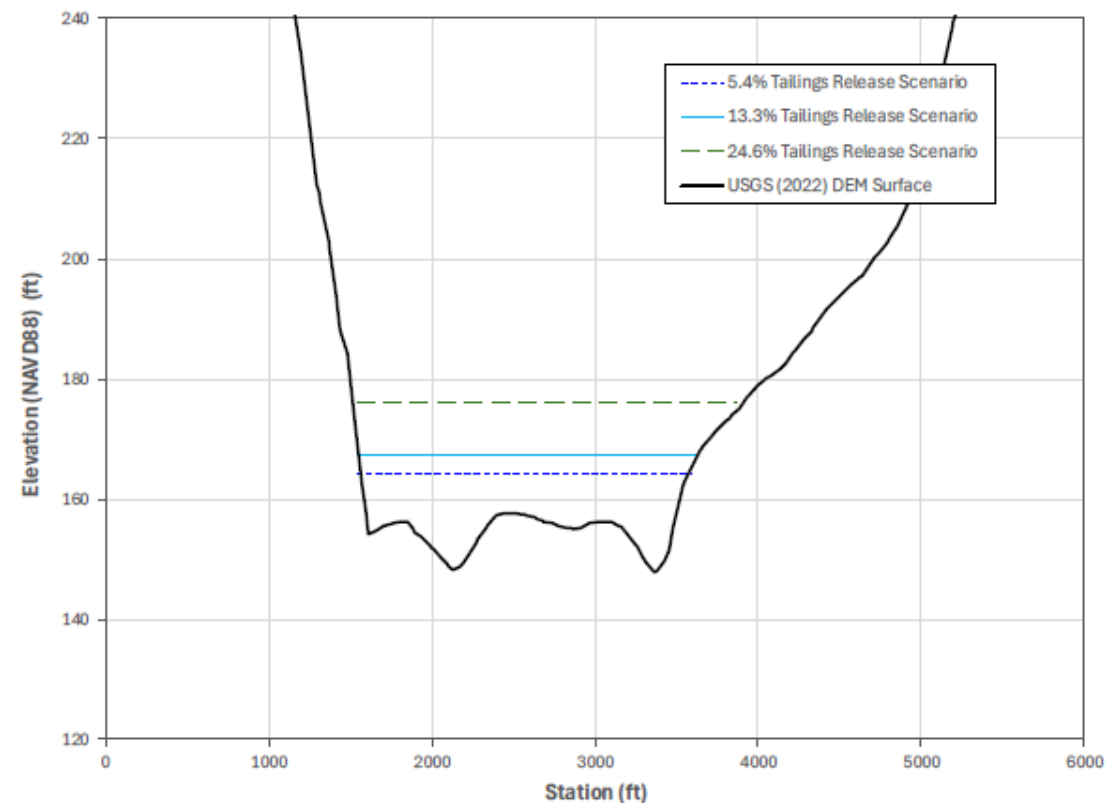
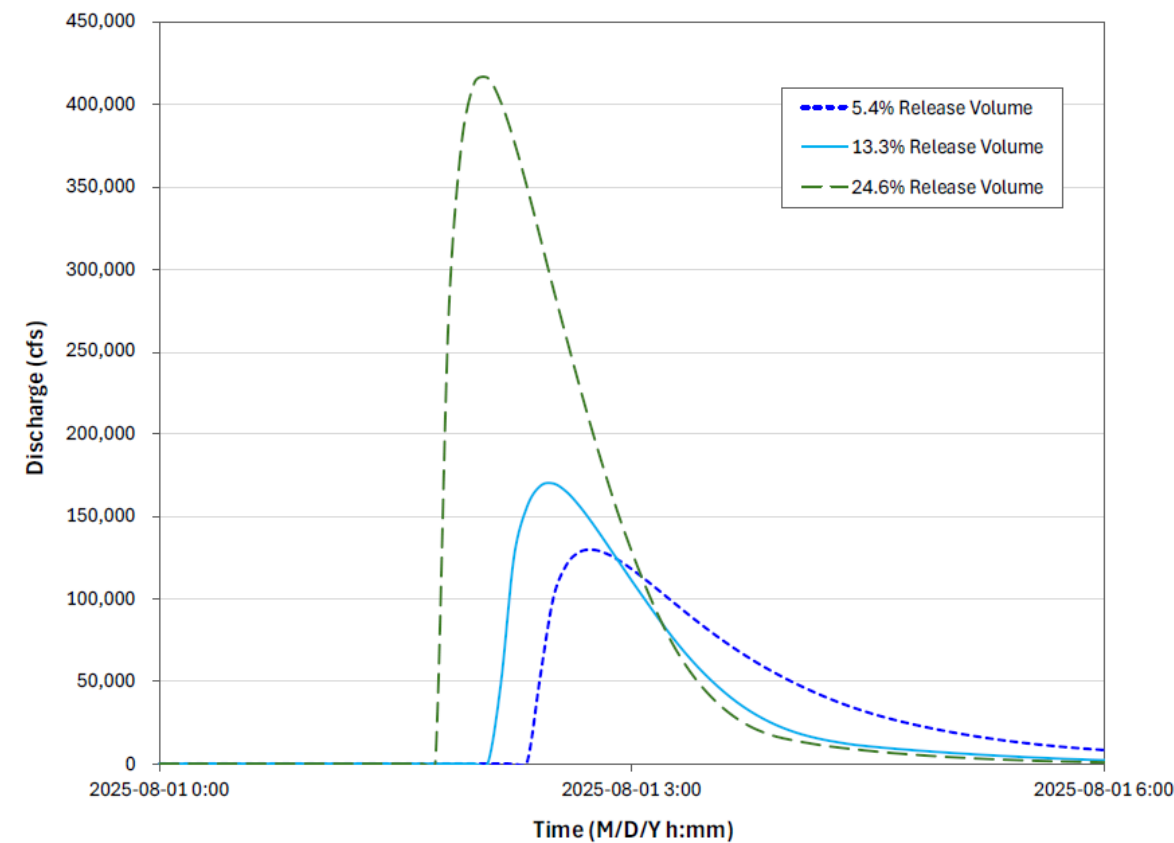
Village of Crooked Creek

Location	Tailings Release Scenario		
	24.6%	13.3%	5.4%
	Front Arrival Time (h:mm)		
Crooked Creek	1:45	2:10	2:20
Chuathbaluk	13:45	16:05	16:25
Aniak	16:30	19:00	19:20
Kalskag	37:10	45:00	44:30
	Peak Arrival Time (h:mm)		
Crooked Creek	2:05	2:30	2:45
Chuathbaluk	25:05	27:00	26:10
Aniak	31:10	32:20	33:00
Kalskag	58:40	60:20	60:00



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Village of Crooked Creek



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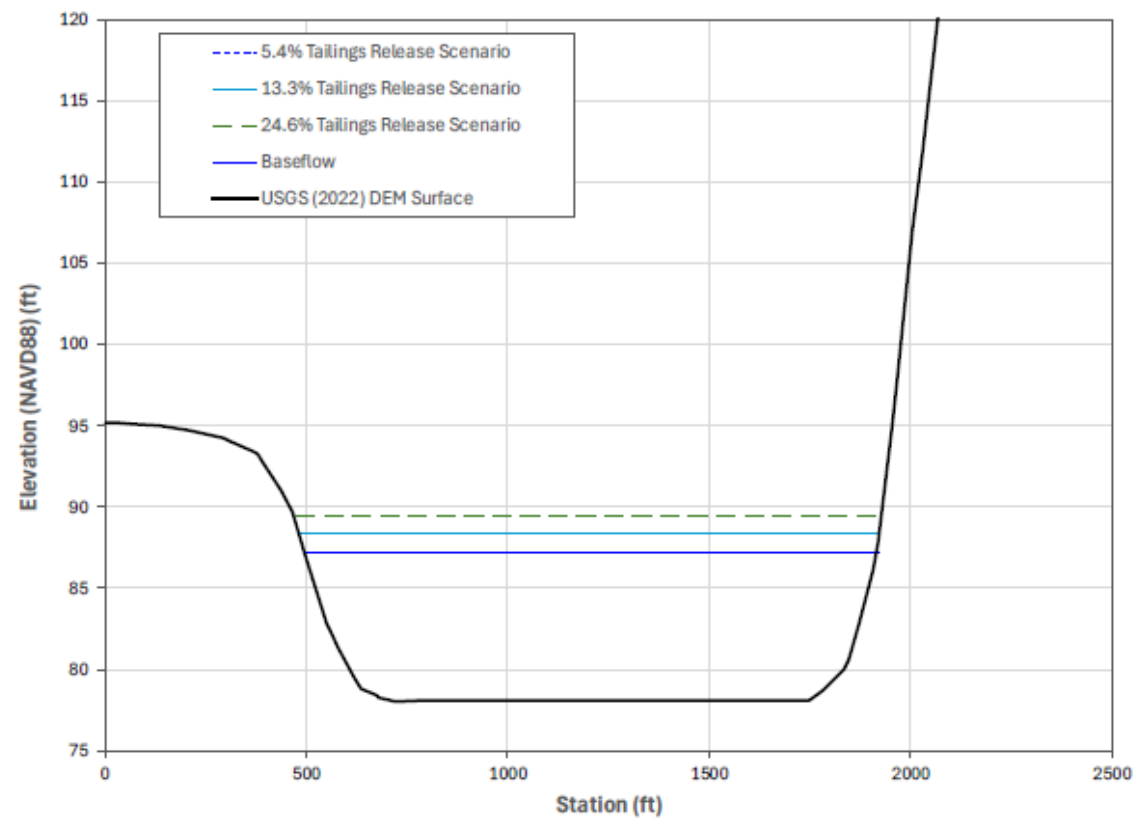
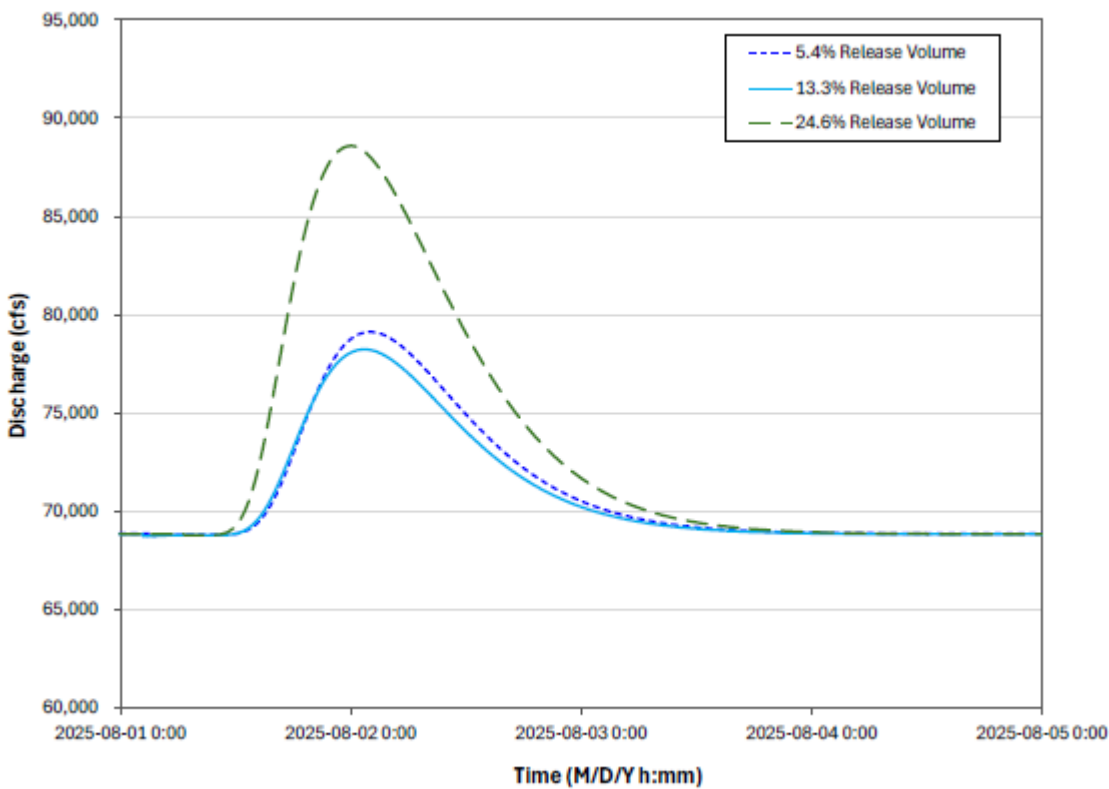
Village of Chuathbaluk

Location	Tailings Release Scenario		
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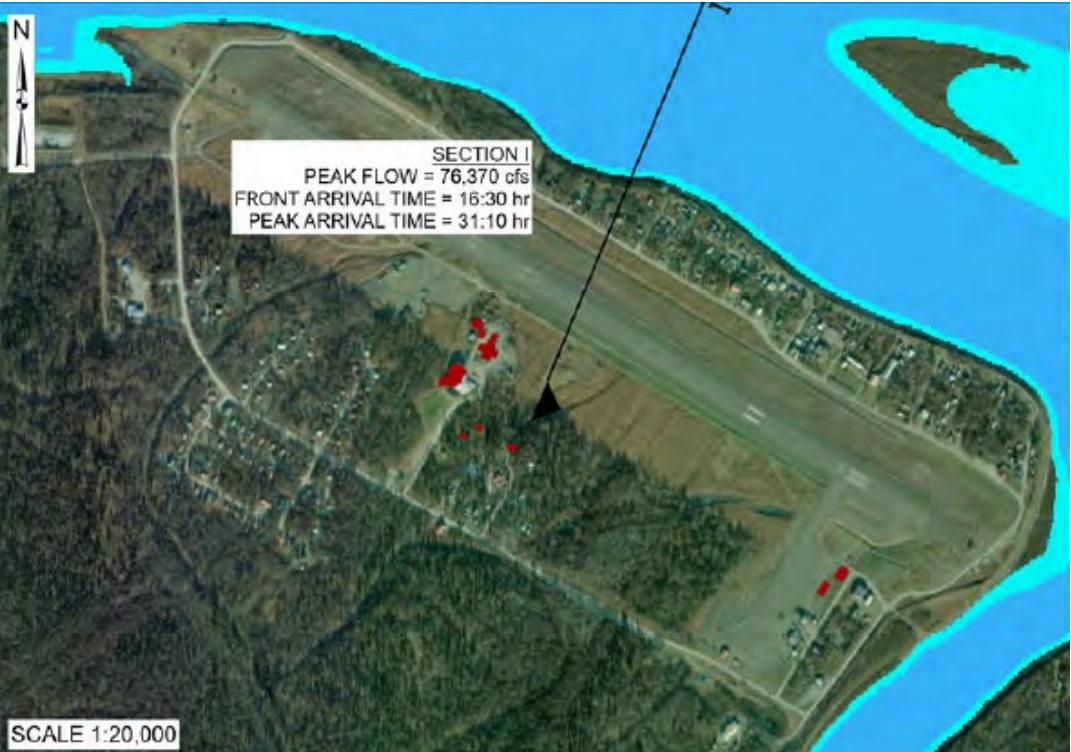
Village of Chuathbaluk



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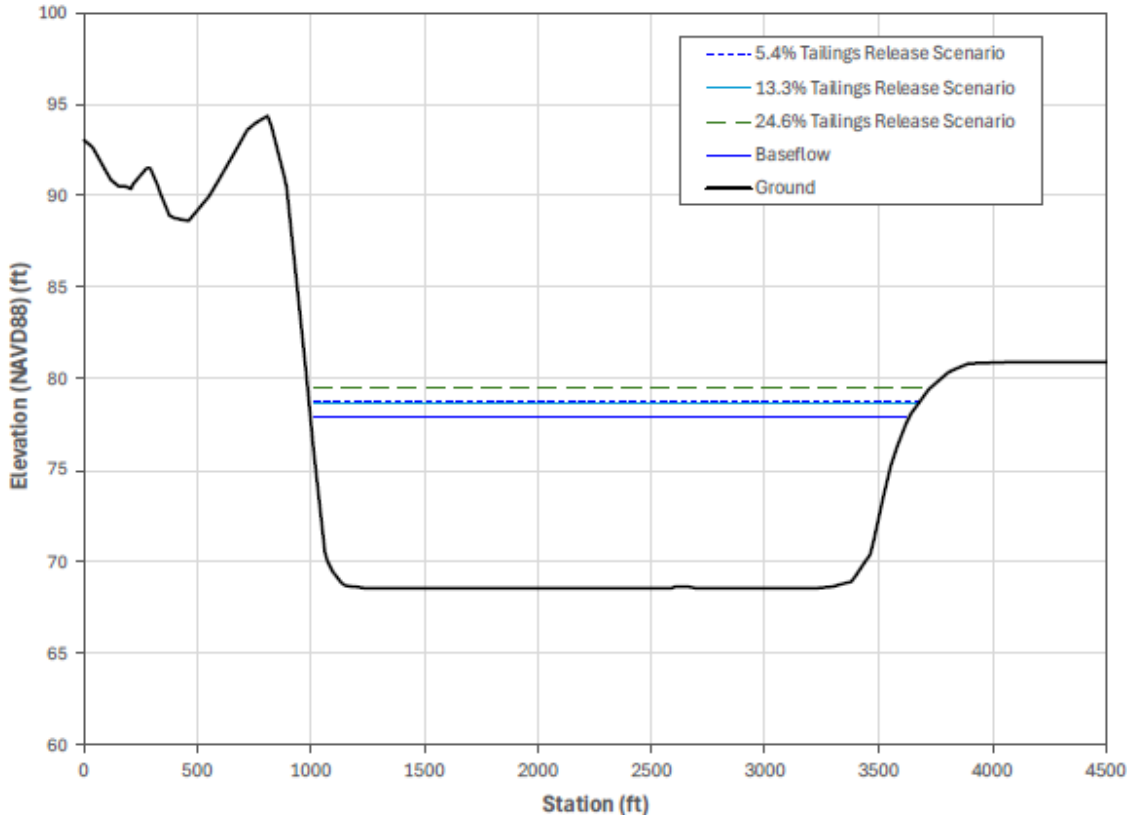
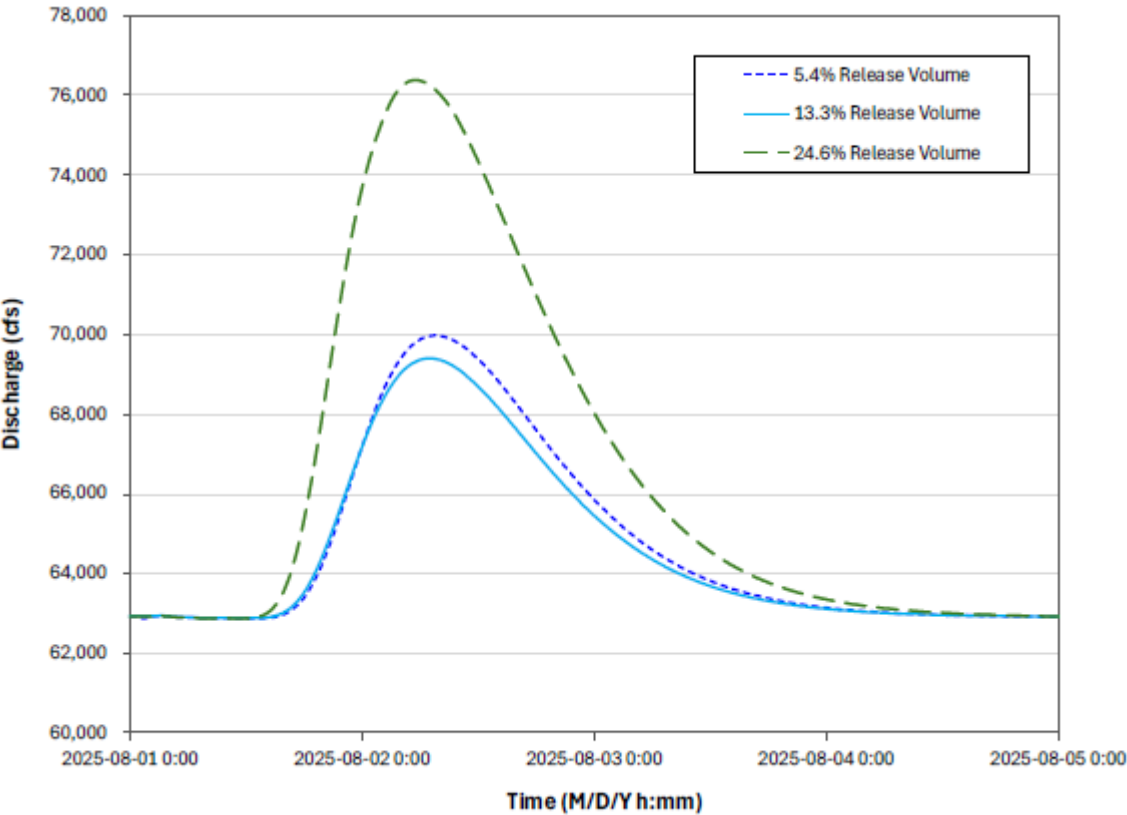
Village of Aniak

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	Front Arrival Time (h:mm)		
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Chuathbaluk	13:45	16:05	16:25
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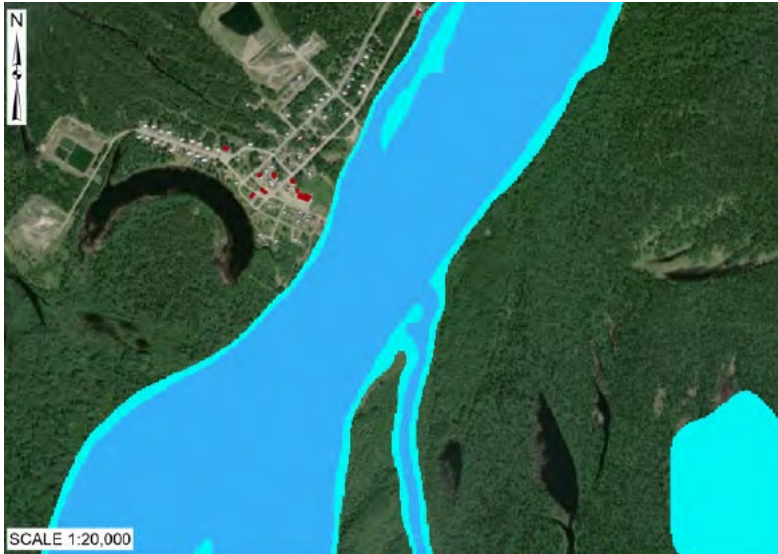
Village of Aniak



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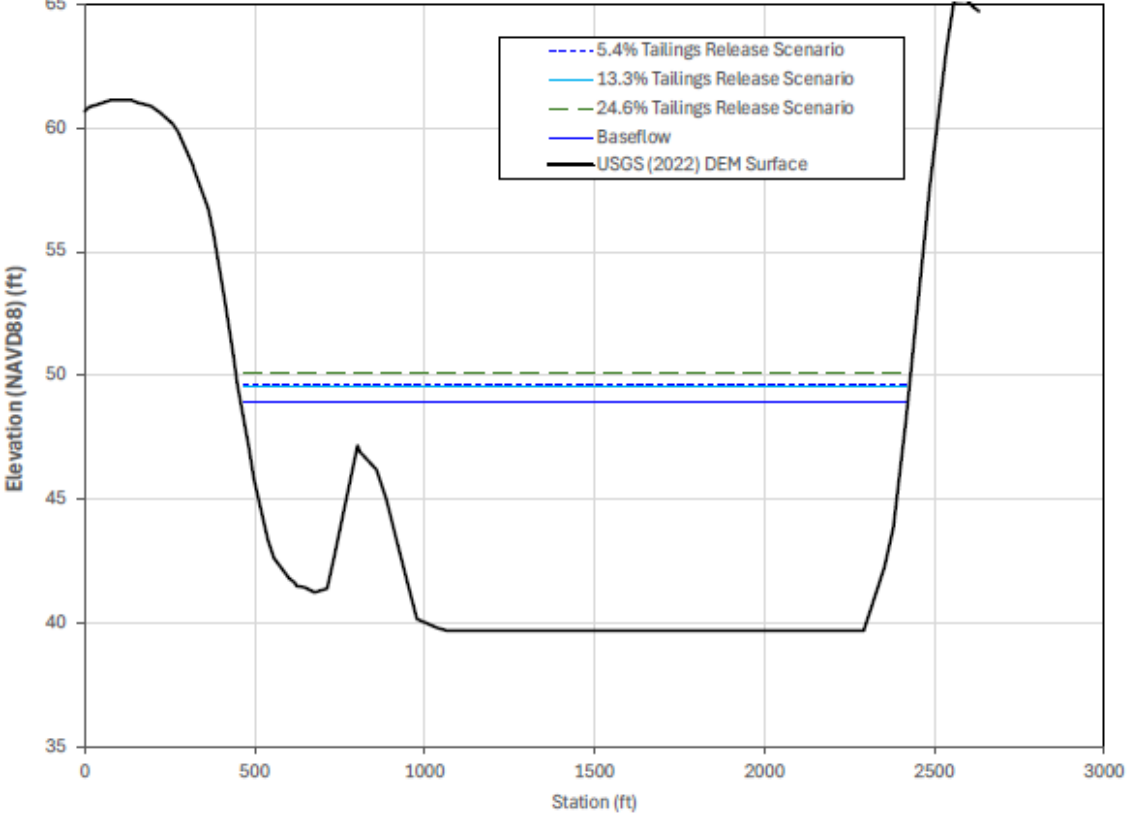
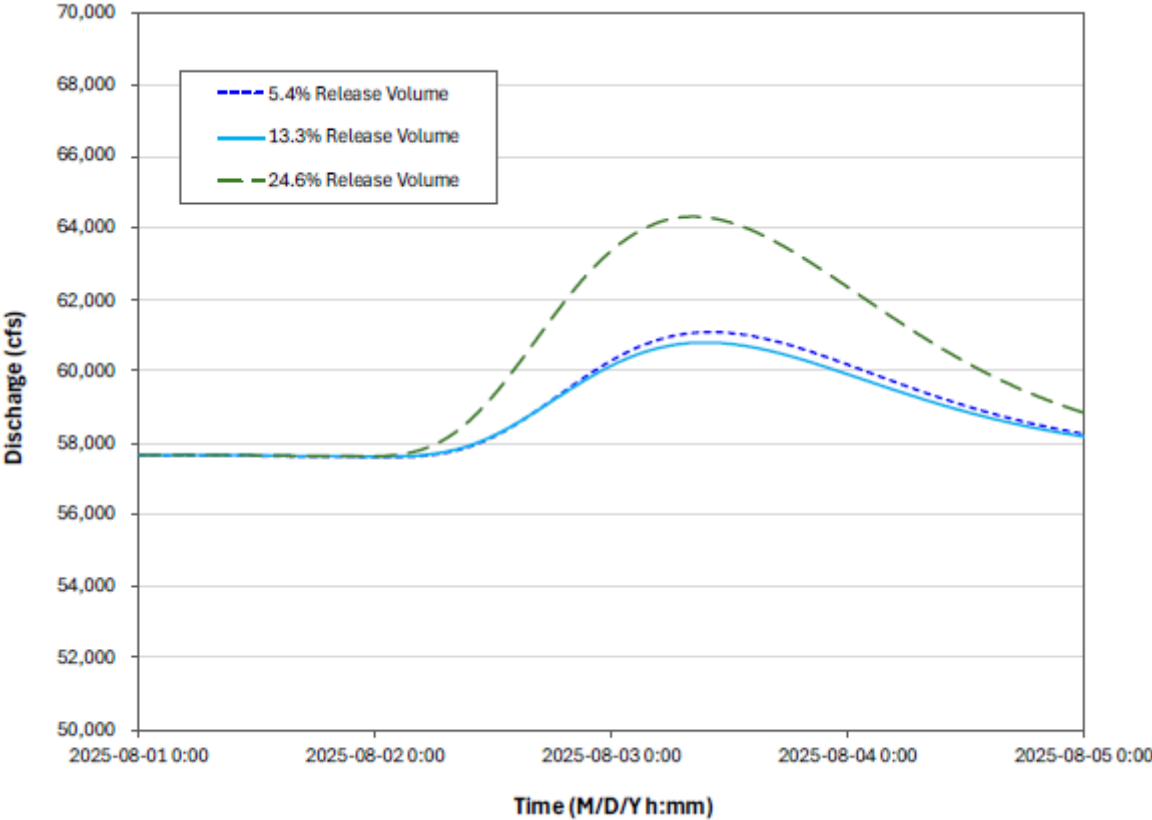
Village of Kalsag

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	24.6%	13.3%	5.4%
	Front Arrival Time (h:mm)		
Crooked Creek	1:45	2:10	2:20
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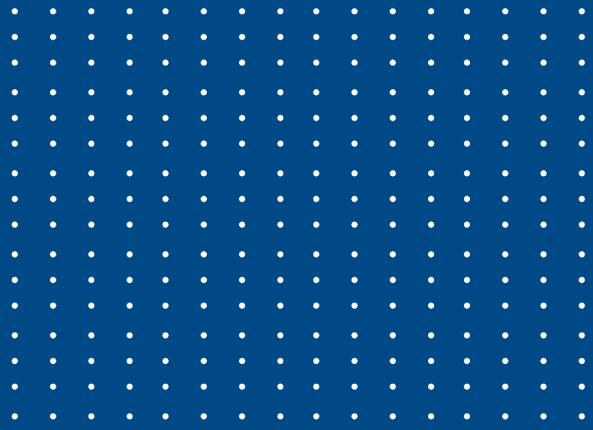
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Village of Upper/Lower Kalsag



2025 TSF Main Dam Breach Assessment

Tailings Deposition



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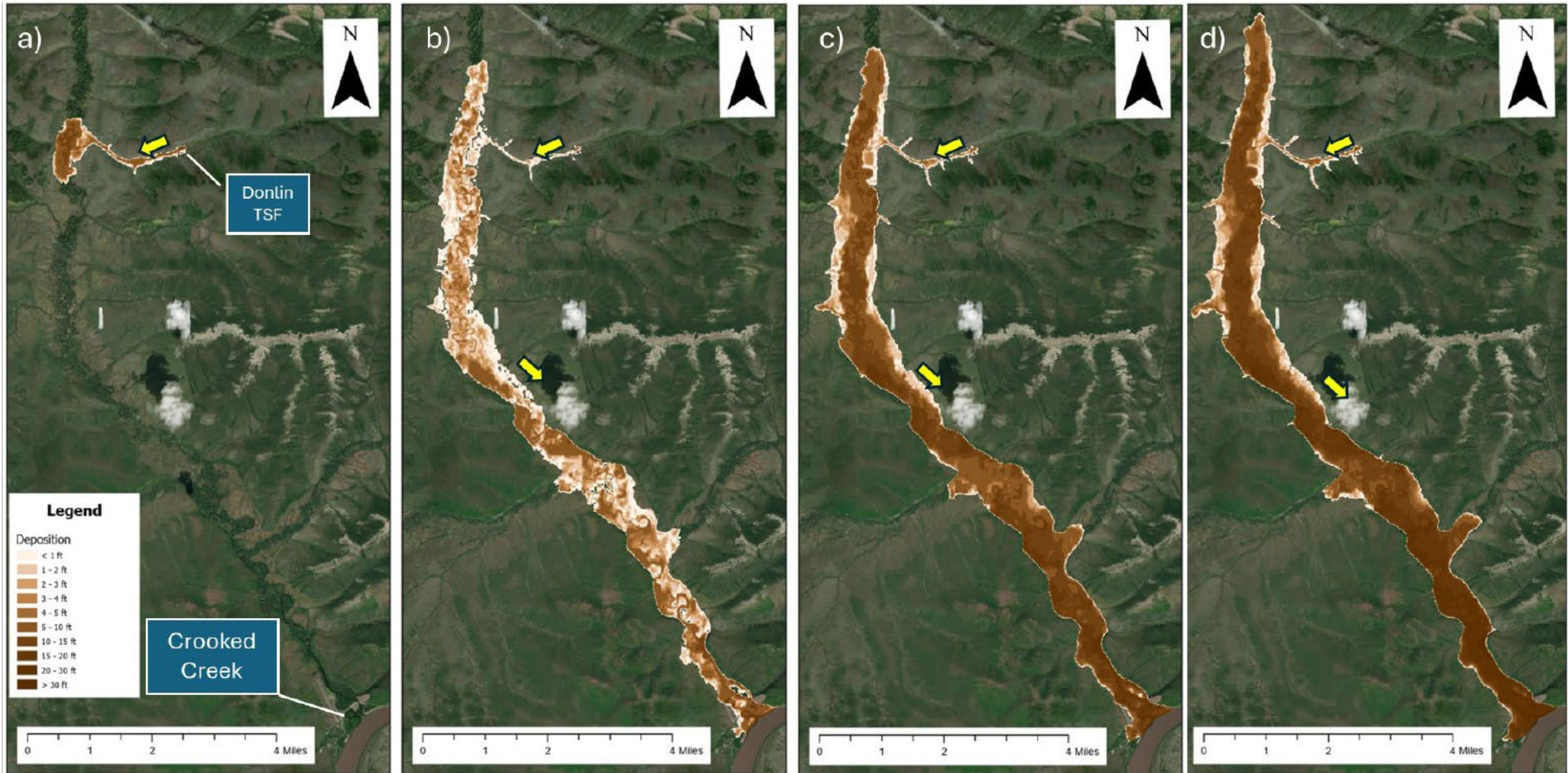


Figure 6-10 Crooked Creek tailings deposition for the a) 0.5% release volume, b) 5.4% release volume, c) 13.3% release volume and d) 24.6% release volume. The yellow arrow represents the flow direction.

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Tailings Deposition

Tailings Release Scenario (%)	Volume of Tailings Released (acre-ft)	Tailings Deposition in Crooked Creek (acre-ft)	Deposition in Crooked Creek (%) ¹	Discharged to Kuskokwim River (acre-ft) ²
24.6	82,140	61,464	75%	30,406
13.3	54,080	40,780	92%	13,300
5.4	27,640	11,495	64%	9,730
0.5	1,670	1,670	100%	0

A majority (>80-90%) of the tailings not deposited in Crooked Creek is expected to be transported in suspension by the Kuskokwim River due to its fine-grained nature (mostly silts and clays), ultimately reaching the mouth of the river at the Bering Sea.

Whether the tailings get transported during the initial flood wave or re-entrained over several seasons would be dependent on flows in the Kuskokwim River.

2025 TSF Main Dam Breach Assessment

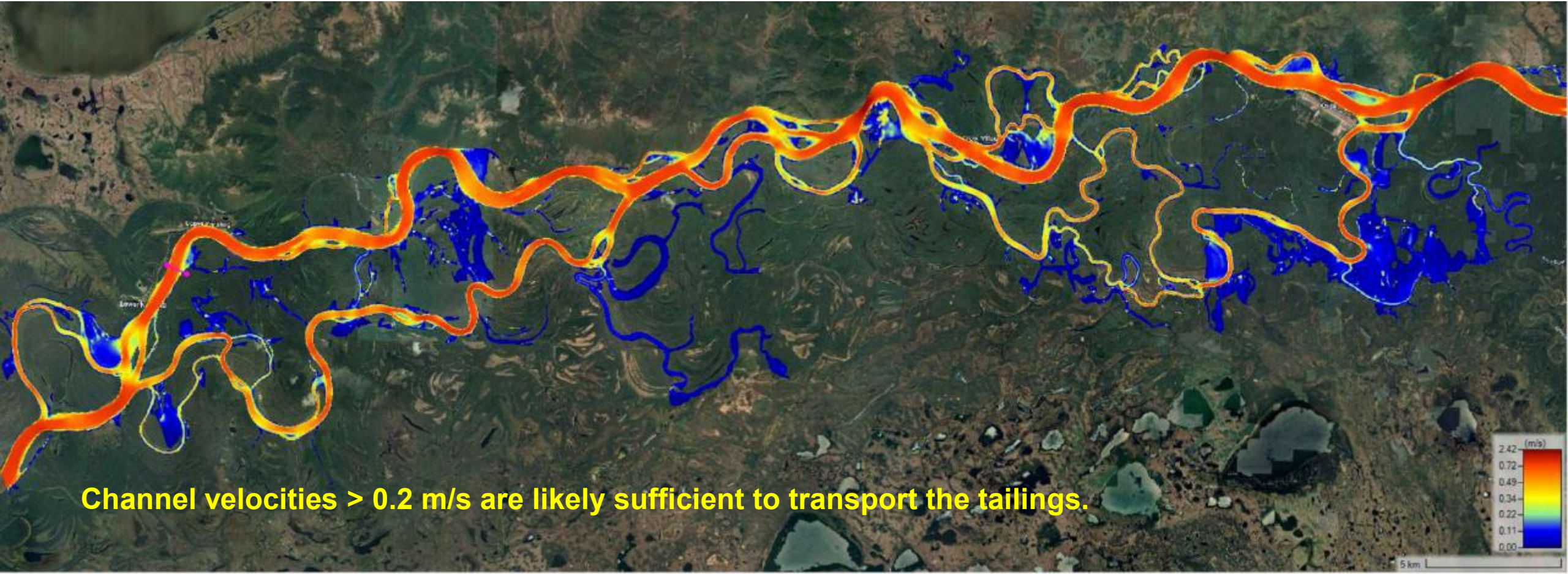
Side Channel Tailings Deposition

- The remaining suspended sediment (<10-20%) will likely be deposited where the flood wave inundates side channels of the Kuskokwim River, where channel velocities are expected to be much lower than in the main channel.



2025 TSF Main Dam Breach Assessment

25% Release Volume – Modelled Flow Velocities



Closing

This presentation required a number of complex issues to be reduced to general concepts in a series of concise bullet points, photographs, and/or diagrams. The content of this presentation is not intended for design decisions or construction. This presentation is for general informational purposes only. BGC Engineering Inc.'s report(s) may contain more specific details concerning the issues identified in this presentation. Please consult BGC for further clarification if you have any questions or concerns.

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