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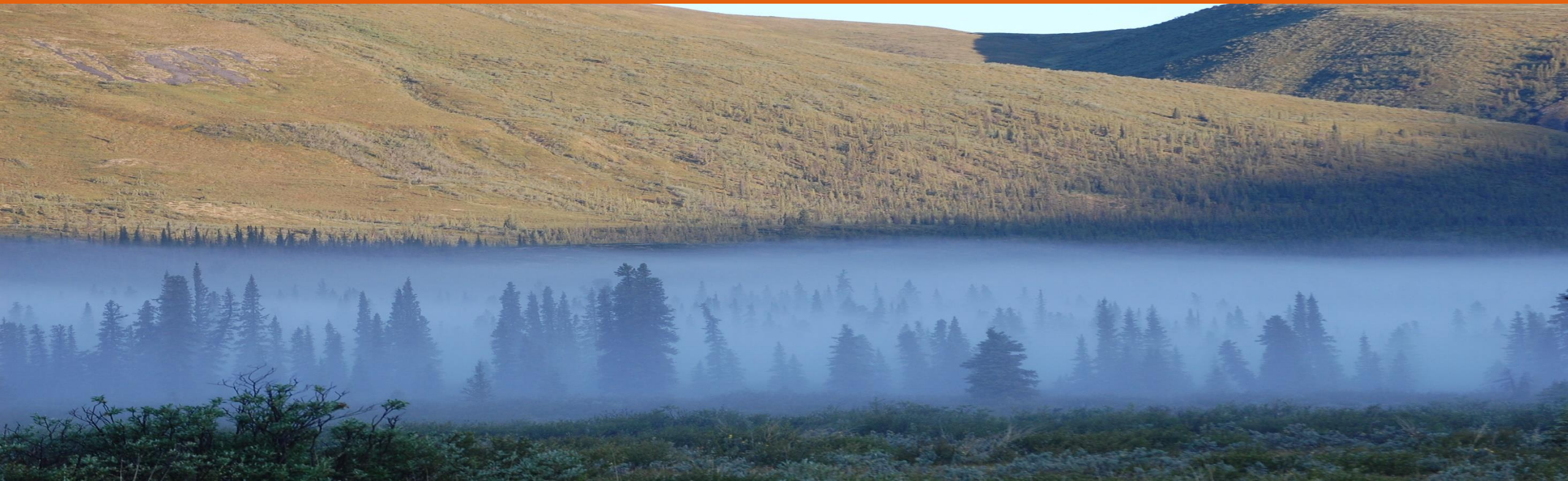
Evaluation of Crude Oil Spills and 70 years of Natural Reclamation along the Historic Canol Oil Pipeline, NWT



Presentation Outline

1. History of the Canol Project
2. Spill History and Oil Migration
3. Assessment Evaluation and Results
4. Evidence of Natural Reclamation

Acknowledgement- Dr. Peter Kershaw- True Pioneer

Adjunct professor at the University of Alberta

Studying the ecological characteristics of crude oil spills along the Canol Trail since 1980 (Ph.D. thesis)

Expert on crude oil spill behaviour and natural reclamation having established research sites along the Trail.

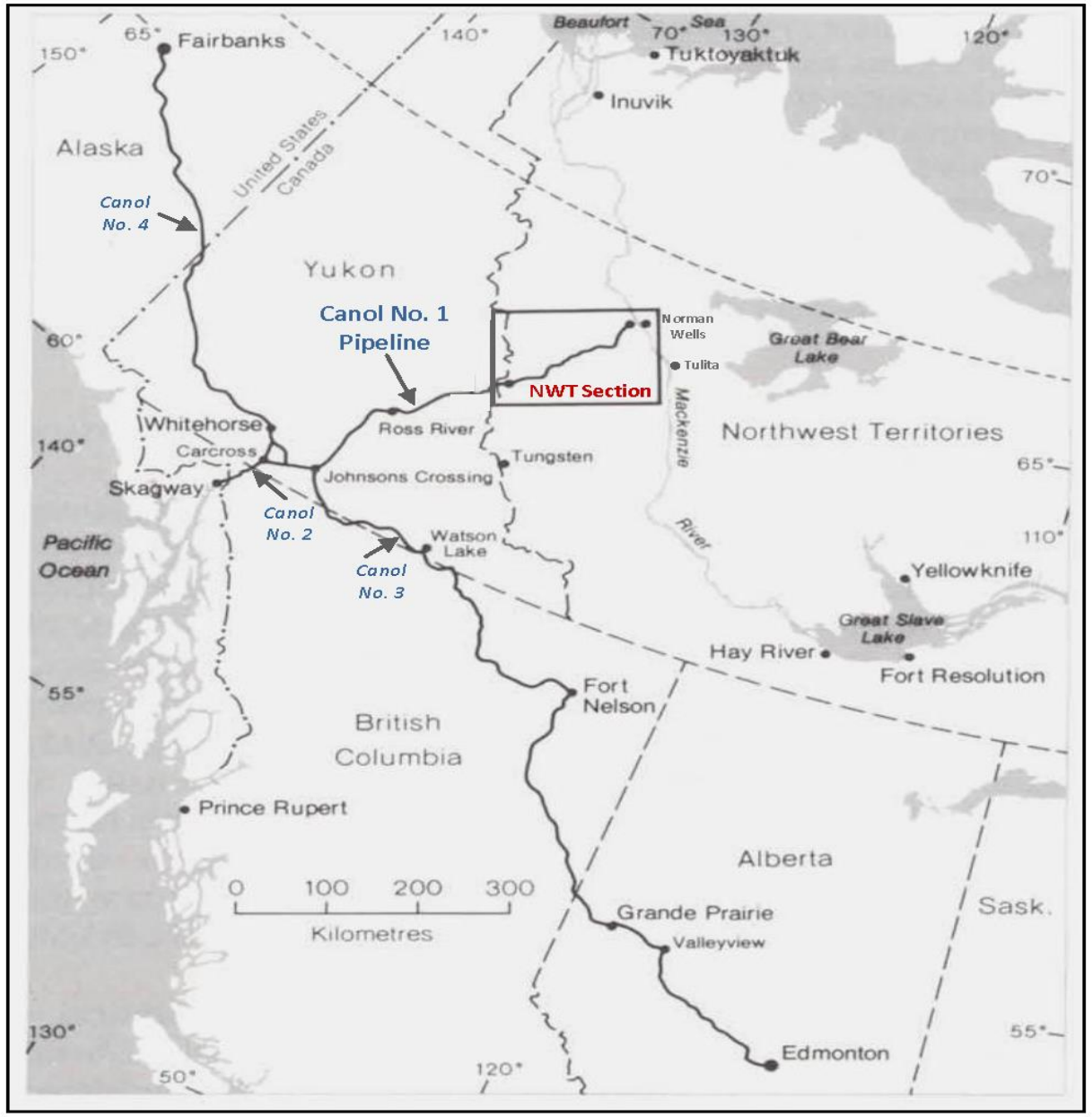
Canol Pipeline- Massive War Time Project

Between 1942 and 1945, the Canol Project was a cooperative effort between the United States and Canada.

Constructed to ensure a continuous supply of oil to American forces stationed in the Pacific during World War II.

- Covered a total distance of approximately 800 km from Norman Wells in the Northwest Territories (NWT) to Whitehorse refinery in the Yukon.
- Employed upwards of 30,000 people- as many as 25,000 US troops in Canada
- Total costs have been estimated at $300 million dollars (1945$).

Study Area



So Why Norman Wells Oil

Alexander MacKenzie first noted oil seepages along the MacKenzie River during his explorations in late 1700s.

Seeps in the Norman Wells area were confirmed in 1888.

Oil production in the area started in the 1920s and considered high grade oil

The Challenge

First large-scale oil pipeline construction project in the arctic

- Mountain passes- up to 1700 masl
- low wetlands/marshes
- Unstable fluvial outwashes
- ice-rich soils- permafrost and discontinuous
- Over 65 major water crossings
- extreme climate and difficult access

NWT Construction and Infrastructure

- 372 kms of Pipeline - A 100 mm (four-inch) steel line placed directly on the ground surface without insulation.
- 6 Pump Stations – to keep the oil moving.
- 12 Maintenance Camps
- 9 Drum Caches/Vehicle boneyards
- 4 Emergency shelters
- 65 pile-driven bridges and 820 culverts


Pump Station 1, Mile 1
Norman Wells
Camp Canol, Mile 8
MacKenzie River
Dodo Canyon
Telephone Building, Mile 24
25 Mile Creek
Pump Station 2, Mile 36
Krump's Hill Barrel Dump, Mile 46
Little Keele Road Maintenance Camp, Mile 50
Emergency Shelter, Mile 54.4
Little Keele River
Pump Station 3, Mile 76
Blue Mountain Road Maintenance Camp, Mile 68
Plains of Abraham Road Maintenance Camp, Mile 80
Plains of Abraham
Carcajou River
Andy Creek Emergency Shelter, Mile 90
Bolstead Creek Road Maintenance Camps, Mile 100
Bolstead Creek
Pump Station 4, Mile 108
Devil's Pass
Emergency Shelter, Mile 118
Pipeline Oil Spill, Mile 111.4
Keele River
Twitya River Road Maintenance Camp, Mile 131
Pipeline Oil Spill, Mile 131.1
Twitya River
Keele River
Godlin River
Vehicle Boneyard, Mile 150
Drum Cache, Mile 160
Drum Cache, Mile 154 (Formerly known as Mile 142)
Ekoi River
Ram Head Outfitters
Pump Station 5, Mile 170
Former Camp & Drums, Mile 204
Vehicle Boneyard and Drum Cache, Mile 184
Pump Station 6, Mile 208
YUKON
Caribou Pass
Dechenla Lodge
Keele River
Vehicle Boneyard, Mile 202
Drum Cache, Mile 215
Drum Cache, Mile 212
Tsichu River
MacMillan Pass
Pipeline Oil Spill, Mile 221.5
Border
Camp and Vehicle Cache, Mile 222
Pipeline Oil Spill, Mile 225.2
Pipeline Oil Spill, Mile 224.6
Pipeline Oil Spill, Mile 222.5
NORTHWEST TERRITORIES

Mackenzie River- low lands

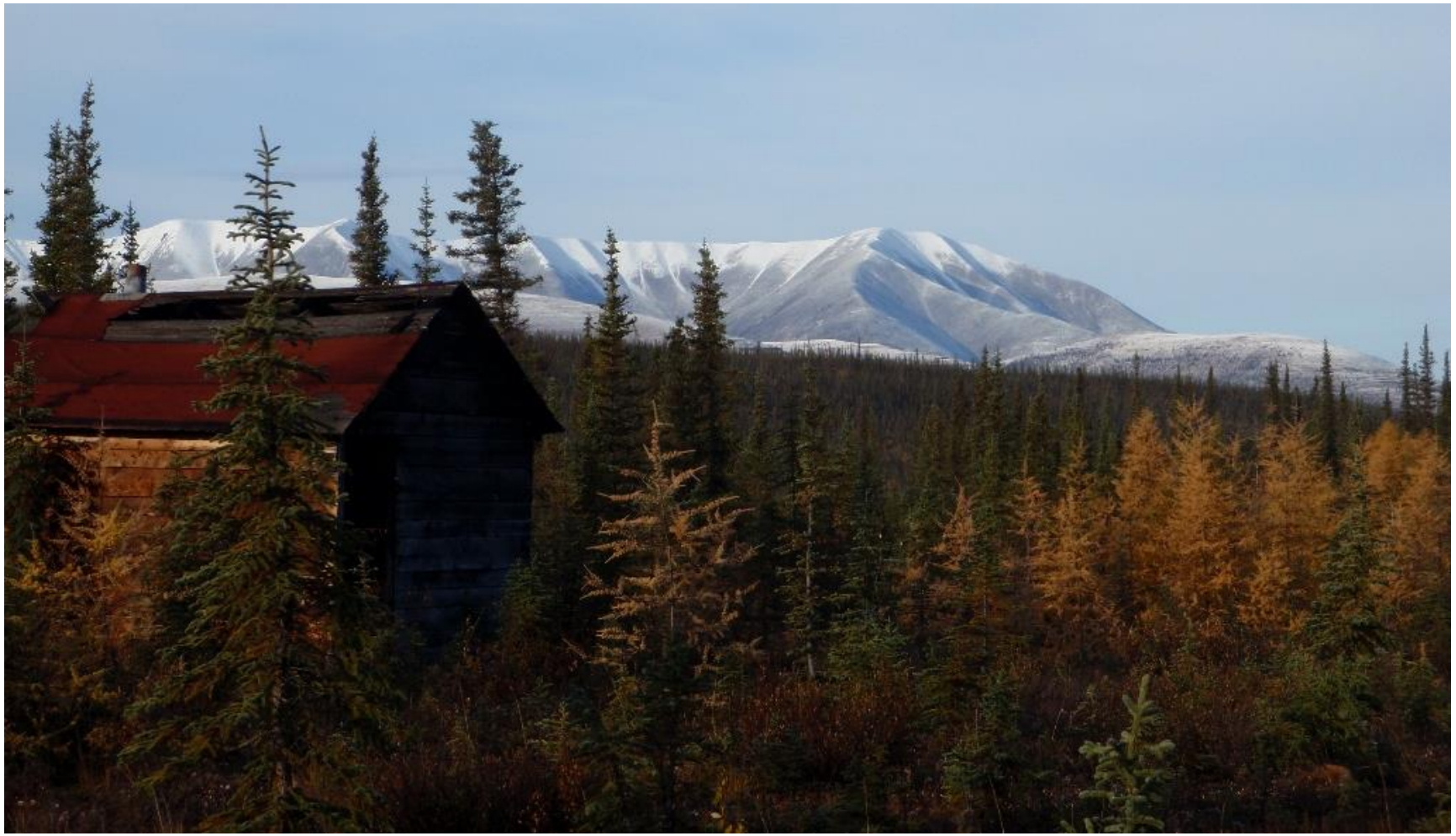
Mackenzie River- low lands

Dodo Canyon

Plains of Abraham

Interior Fluvial River Systems

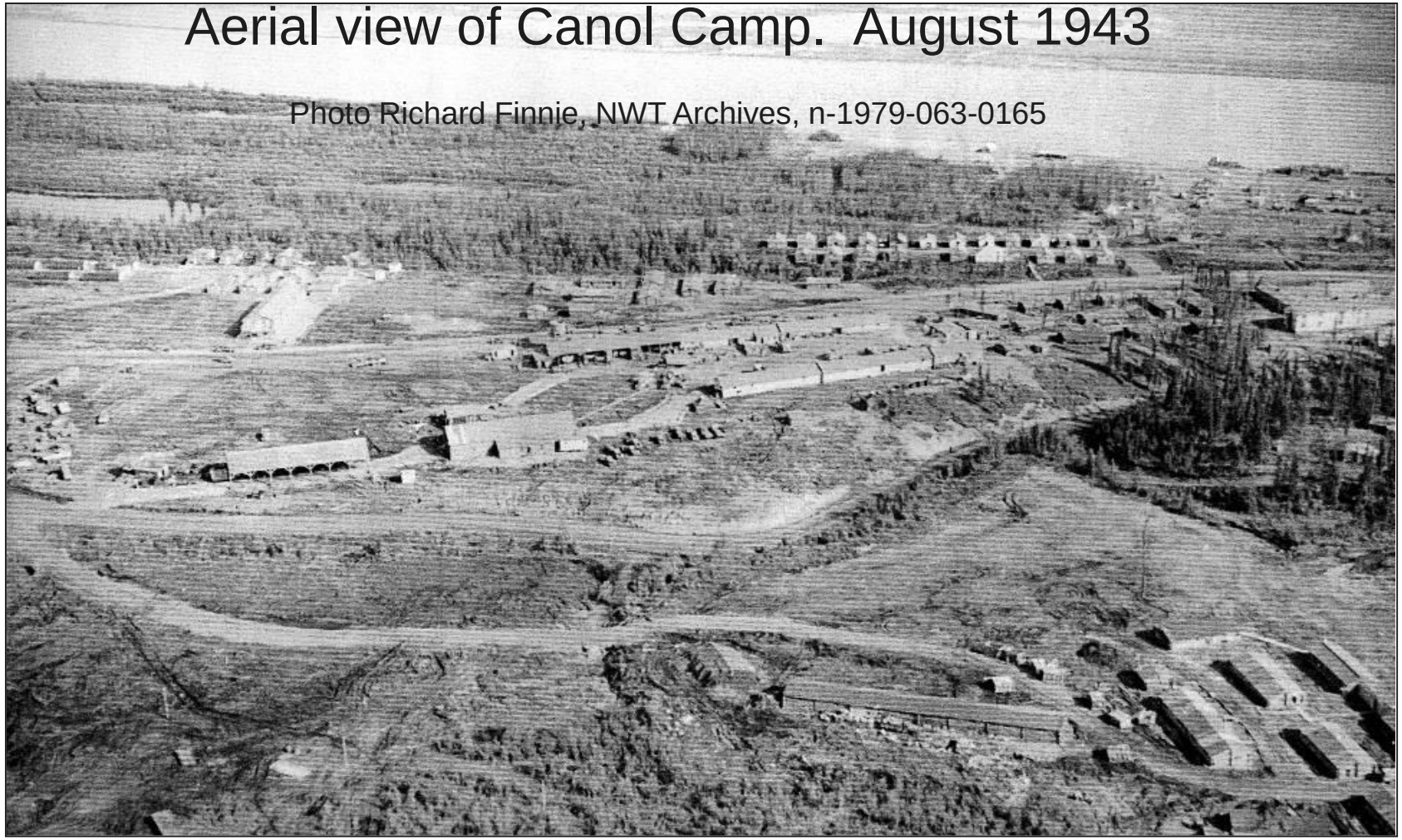
Forested Environments



Low-Lying Wetlands/Marshes

Yukon Border

Camp Canol- Mackenzie River



Road Construction

- No northern construction experience
- Crews scraped away the insulating organic rich surface layers
- resulting in rapid thawing of the ice-rich soils
- Local Permafrost is -2 to -3C
- thick mud enveloped equipment

Pipeline Construction-on land

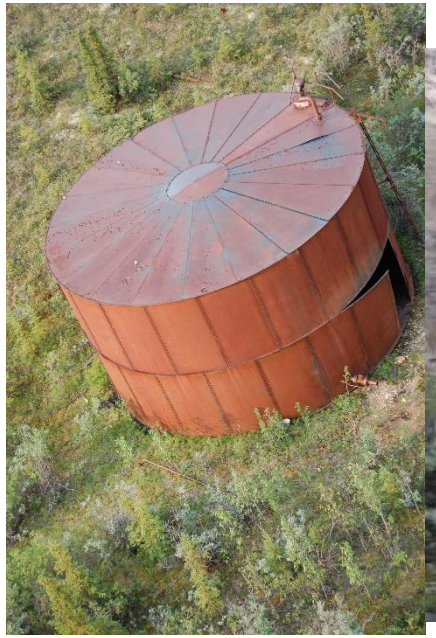
- The pipe was laid directly on the ground with no anchors
- No insulation was used due to the oil's low pour point (it remained viscous at -70 F)

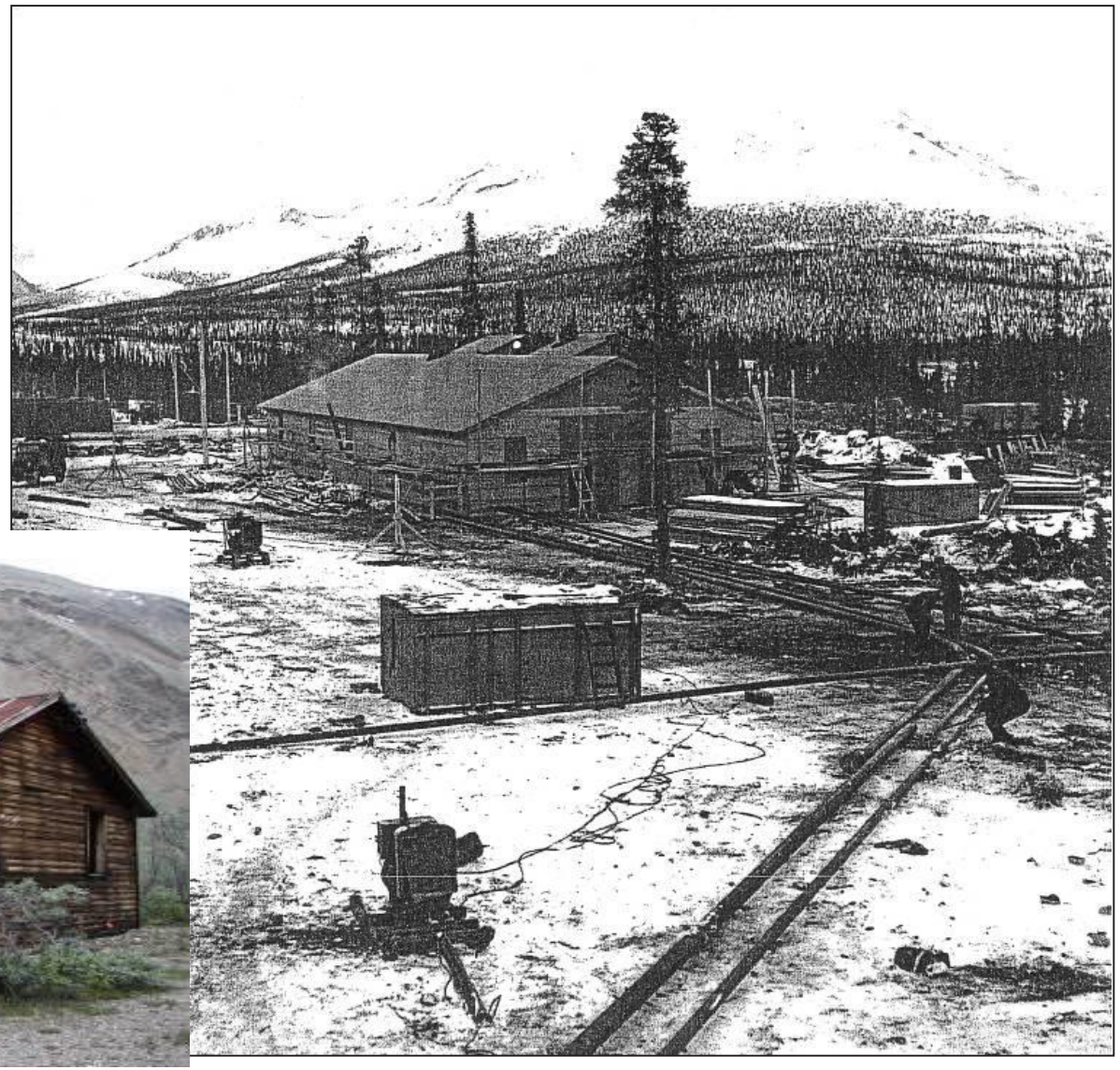
Pipeline Construction – across water

- Pipe laid on the stream bed.
- Temporary supports were used directly on the ice surface at river crossings
- Suspension bridges, pipe trusses and road bridge crossings

Pump Stations

- Pumphouse, above-ground storage tanks, generator building, mess hall, dormitories





Pipeline Operation

- Operated for 16 months, from December 1943 to April 1945.
- 5 months into operation (April 1944), oil finally reached Whitehorse
- Unrefined crude oil which was sufficiently “light” to allow for direct use in diesel pumps and motors.
- Operating pressures up to 1600 psi- 100 psi higher than specs.

In April 1945, after less than one year of operation, the entire project was cancelled and Canol No 1 Pipeline was abandoned.

Mystery - Unaccounted Crude Oil

- 185 M litres of crude oil entered the pipeline at Pump Station 1- only 154 M litres reached Whitehorse facility- **Missing 31M litres**
  - 3.5M L used in operations
  - 9.5 M L left in pipeline and storage tanks at abandonment
  - Leaves 17M L unaccounted for during operations

➢ The pipe suffered a great deal of damage from construction equipment, rock slides, river washouts, and even rifle bullets.

Documented Oil Spills- Operations

- Despite the short timeframe, 81 known spills were reported during the operation of the pipeline inspected by Hemstock (1945).
  - Spills identified by location (mile marker), date, volume and cause
  - Estimated 4M litres of crude oil spilled from these 81 spill sites
- The first reported oil spill occurred at Mile Marker 18 - 12 hours after the pipeline was commissioned

Pipeline Decommissioning and Oversight

Department of Mines and Resources had concerns over the possible hazards to forests and wildfires from releasing the oil during the dismantling of the pipeline with regular patrols.

“The pipe is first punctured on the lower side with acetylene torch at approximately twenty foot intervals, the escaping oil immediately ignites and is allowed to burn until drainage is completed”

Missing Crude Oil and Spills

Represents the single largest environmental data gap and uncertainty

"I suppose I'll be the one
to mention the elephant in the room."

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What does the Research Tell us about Crude Oil Spill Behaviour

Crude Oil Spill Migration in Arctic Environments

- 1973 experimental spill of 7950 L (50 barrel) of Norman Wells crude oil at the Norman Wells, NWT spill site
- 1976 Cold Regions Research & Engineering Laboratory (US Army Corps of Engineers) experimental oil spill of 7600L of Prudhoe Bay Crude oil on the permafrost-underlain black spruce forest of the interior of Alaska.

Oil spill migration in arctic environments

- Oil flow was preferential following shallow topographic channels
- A winter spill will produce a larger surface oiled area than a summer spill- as the ground is frozen
- Oil mobility is influenced by the high organic materials
- The final size of the spill area is typically achieved within the time frame of days, final stability within months

Common visual impacts to the environment

- Oil turns to a Black tarry substance on the soil surface
- Kill zones of Black Spruce -dead tree lines with limited new growth
- Abundance of new variety of plant life like cotton grass tussocks and other sedges

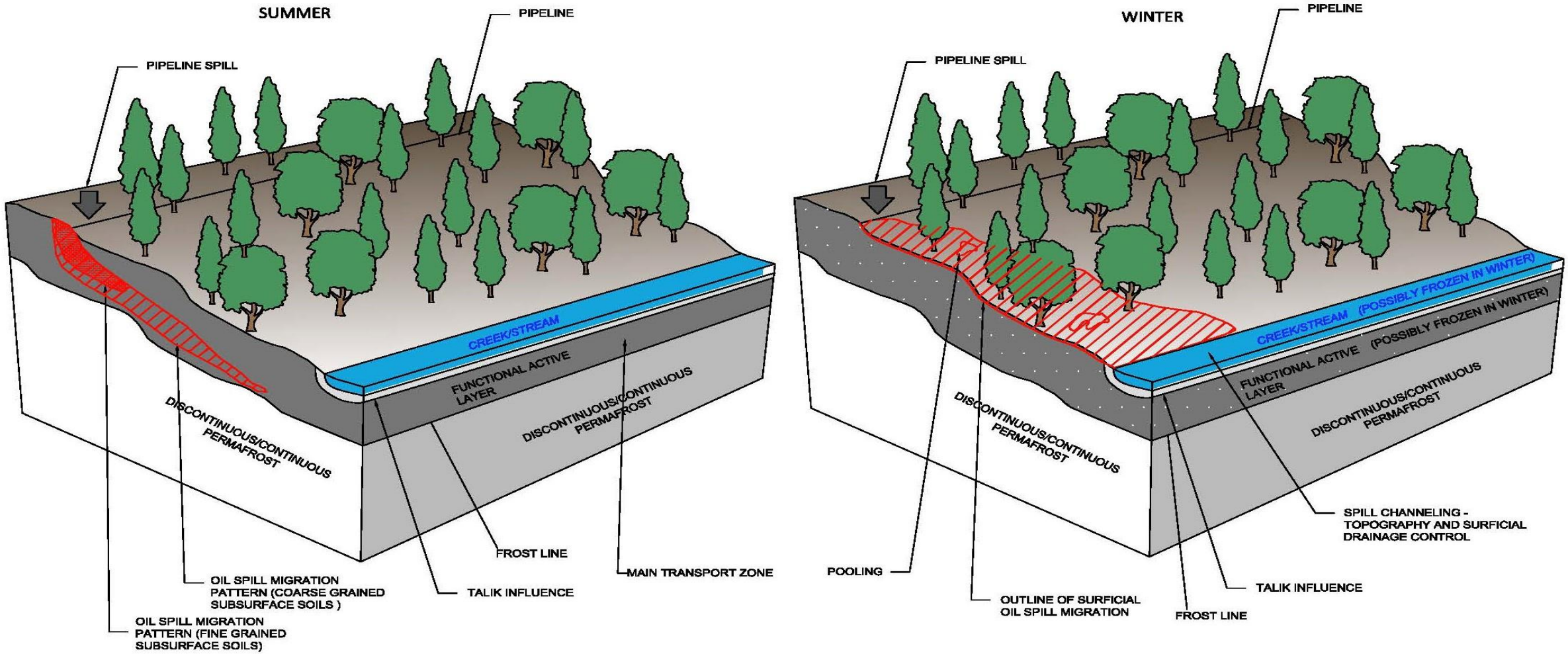
From this Research and Observations Developed Four Conceptual Models

Scenario 1 - Forested – mixed brush, more mature stand

Scenario 2 – Fluvial deposit adjacent to fast moving waters/river

Scenario 3 – High Alpine - grasses, steep topography

Scenario 4 - low-lying marsh, karst, no surface water receptors nearby



FACTORS EFFECTING FATE AND TRANSPORT			
SEASON	**PRIMARY FACTORS**	**SECONDARY FACTORS**	MODIFYING FACTORS
SUMMER	- DEPTH TO ACTIVE LAYER - GRAIN SIZE (COARSE V.S. FINE) - SLOPE OF TERRAIN - DISTANCE TO SURFACE WATER - SOIL MOISTURE CONTENT - SPILL VOLUME - SPRAY V.S. DIRECT RELEASE	- SURFICIAL ORGANIC MATERIAL - SURFICIAL DRAINAGE - OIL TEMPURATURE	- RIVER BANK & SLOPE WASHOUT - SURFICIAL WEATHERING OF OIL - VEGETATION RE-GROWTH - THERMOKARST - BURNING
WINTER	- FROZEN SURFACE SOILS - SLOPE OF TERRAIN - SURFICIAL DRAINAGE - SPILL VOLUME - SPRAY V.S. DIRECT RELEASE	- GRAIN SIZE - DISTANCE TO SURFACE WATER - SURFICIAL ORGANIC MATERIAL - OIL TEMPURATURE	- RIVER BANK & SLOPE WASHOUT - SURFICIAL WEATHERING OF OIL - VEGETATION RE-GROWTH - THERMOKARST - BURNING

Final Phase On-site Spill Investigation

1. Historical Air Photos
2. Site Reconnaissance
3. Environmental Site Investigations

Purpose was to understand the overall behaviour of the spills

Air Photo Interpretation

Led by Dr. Kershaw- with a focus on the 81 spills reported by Hemstock (1945)

Overall not very successful

- many of the images were not available
- some sites along river or stream flood plains could not be found
- Of the remaining sites, 21 were found on aerial photography.

Air Photo of Spill Site

Site Reconnaissance programs

- Extensive Recon programs were completed starting in 1977
- Unfortunately, there was very limited visual and physical evidence of impacts to soil and vegetation, thus making the detection of the spills very difficult
  - Problem was that we couldn’t find them
- Dr. Kershaw identified 9 spill sites – now established research sites

Weather Crude Oil

Weathered tar like material.

Stressed Vegetation

Case Study Investigation Program

- Based on airphotos and recons - a list of 11 candidate spill sites were selected for investigations
- Program included:
  - Drilling- portable auger (beaver) and pionjar sampling equipment
  - installing groundwater/active layer monitoring wells
  - vegetation sampling
  - soil and groundwater sampling

Level of Effort- 11 sites

At each site:

- 8-12 boreholes or test pits
- groundwater wells installed in boreholes
- Vertical and horizontal soil sampling
- Groundwater monitoring for free phase and dissolved phase

Final

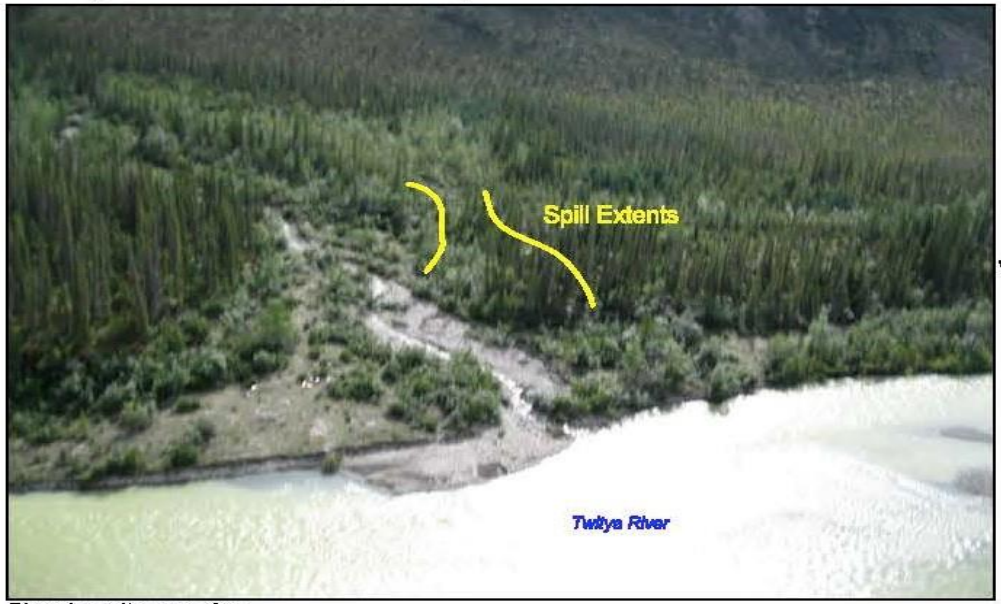
>200- soils samples-PHCs/PAHs

61 Groundwater Wells-Active Layer

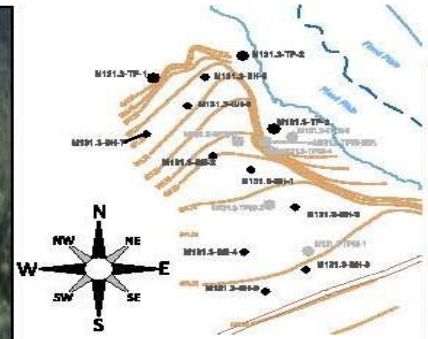
Showing site overview and approximate spill extents.

Showing site location in relation to surrounding features.

Mile 131.3

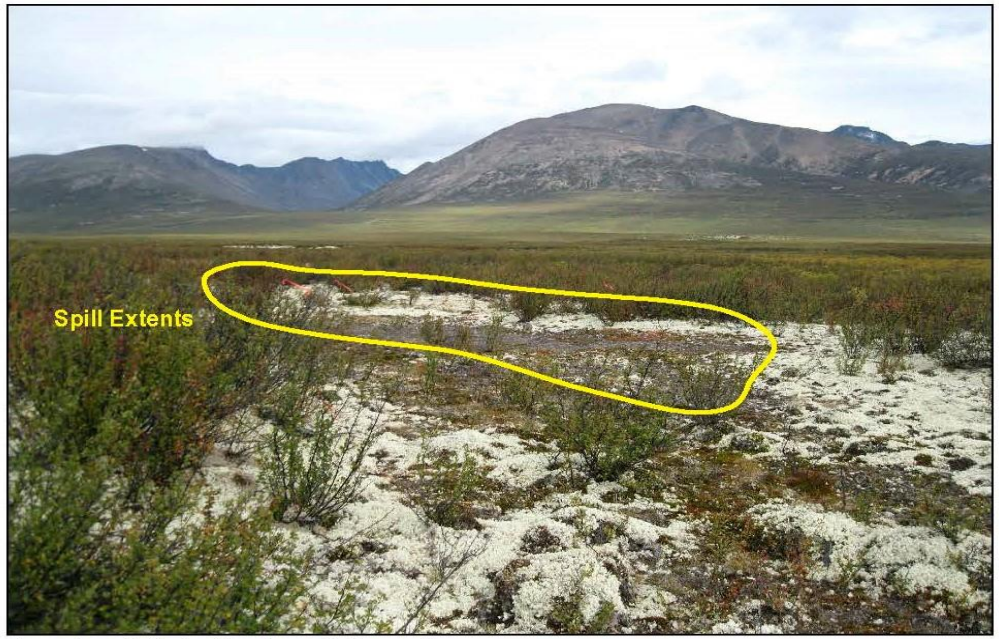


Showing site overview.



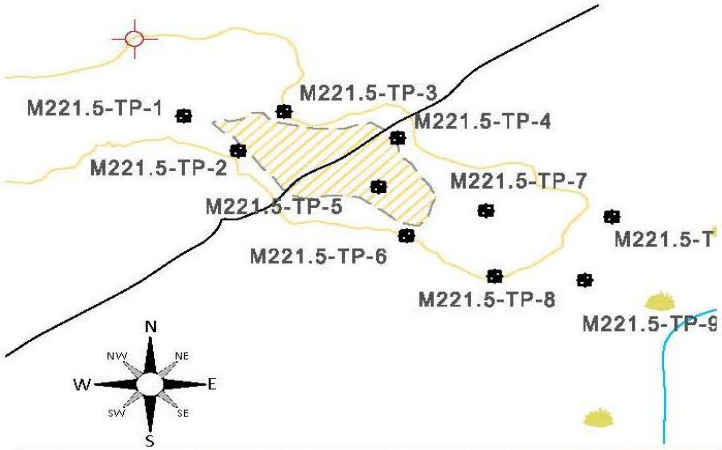
Showing drainage creek from study area to Twitya River.

Mile 221.5



Overview of site looking towards the north.

Soil staining and stressed vegetation at site.



Stressed vegetation at site.

Overview of site looking towards the southwest.

Overview of site looking towards the east. Pond in the background.

Soil staining observed at M221.5-BH-9.

What did we learn- Spill Morphology and Mobility

- Vertical penetration of oil into the subsurface influenced by topographic lows –associated with more residence time.
- Oil spills were typically long and thin following topography.
- The visual surface area of the spill area usually did not provide a clear understanding of the oil impacts.

PHC Observations and Analytical Results

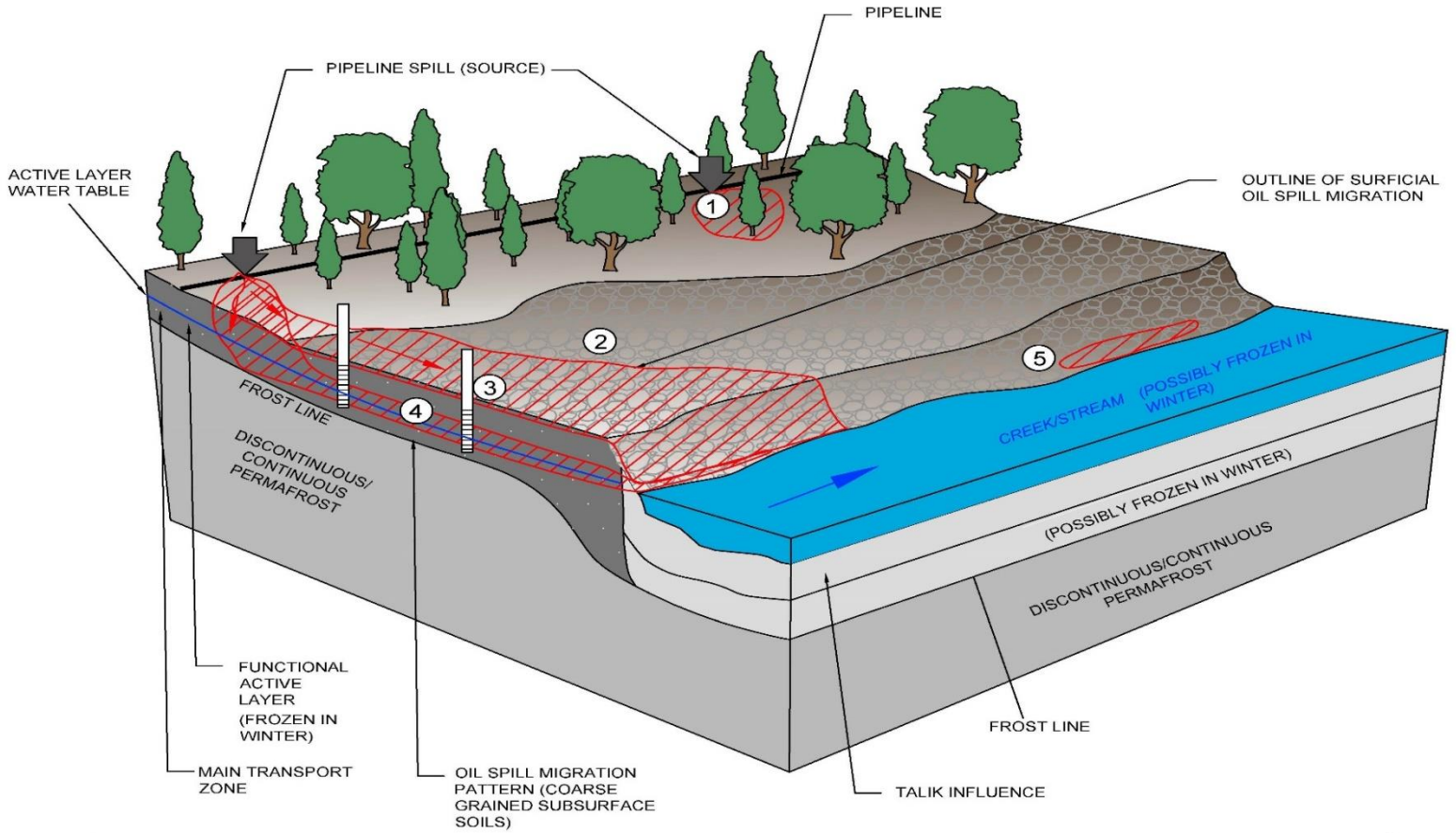
- Weather tar like material on the surface soils reported minor PHC odours and staining.
- Only 2 sites had any indication of free oil in shallow test pits or boreholes
- Soil analytical results – the main PHC fractions were the F3 and F4- heavier fractions
- There was no indication of free oil on the water table in the active layer at depth.
- At Spill Sites where groundwater was recovered, the PHC chemistry was generally below the EQGs- Natural Attenuation in cold climates.

Site Impacts

- Overall, the field and chemical data (mass balance) does not support the documented historical spill volumes (e.g. >100,000 litres of spilled oil).
- The documented area affected by spills on the Canol Trail would be no more than a few hectares.
- Despite all the work and reconnaissance completed to:
  - No Active, seepage faces of crude oil or sheens along banks or in sediments at major drainage areas/water bodies
  - No evidence of downgradient impacts

➢ There is still uncertainty

Program Level -Risk Managing the uncertainties



Data Gap ID	Data Gap Description
1	Unknown location of Hemstock defined spill sites
2	Incomplete delineation of PHC impacts in soils- horizontally and/or vertically
3	Incomplete PHC groundwater characterization
4	Unknown presence of free phase pipeline oil at depth
5	Presence of mobile free phase pipeline oil discharging to surface water

But we have Good news- Natural Recovery

- Ongoing natural decomposition of the crude oil
- Oil impacts are tar-like and appear stable
- Kershaw reports a significant increase in number of taxa within the spill areas between 35, and 55 and 70 years after the oil release
- New plant communities.

What's at Stake- Future Remedial Activities

It's clear that any intrusive remedial work will damage the fragile ecosystem

The main issues will come in the form of damage:

- to the new plant communities;
- surficial scaring of the soils and
- disturbance of permafrost/soil conditions.

Goal is to preserve the Natural Capital of the trail for all beneficial land uses.

Now call the "Canol Heritage Trial"

Thank-you and Questions!