OVERVIEW

- DESIGN
- CONSTRUCTION
- OPERATIONS
THemes

- SO WHAT?
  - Interesting? Does it matter?

- WHAT IF?
  - We will never know everything
  - Thus how do we ensure acceptable risks
DESIGN – STEPS

- **FLOW**
  - Water Level $\rightarrow$ Scour = Pipe Depth

- **SCOUR**
  - Bank Erosion $\rightarrow$ Floodplain Changes = Crossing Extent
FLOW – THEN

- Limited/no data north of Brooks Range
  - Used very conservative rainfall/runoff model
  - BUT, 1992 flood >> design flow

FLOW – NOW

- 35 – 40 years of data north of Brooks Range
  - Adequate for flood frequency analysis

- Unique conditions
  - Influence of lakes/wetlands. “Release” of outlets in spring
  - Ice jam releases – up to 5X peak flow possible
  - Glacier dammed lake releases
FLOW
GLACIER DAMMED LAKE RELEASES

- History of releases? Flow data?
- Triggered by:
  - Snow melt (typical)
  - And/or heavy rain (Tazlina R, 1997)
  - Neither – some mid-winter releases (Tazlina R, 2005)
What if/Impact?
- Buried crossing
- Elevated crossing
- River training structures
- 1997 Tazlina River Flood greater than design
WATER LEVELS

- **Summer floods**
  - Same as non-arctic rivers

- **Spring floods**
  - Flow over ground - fast icings
  - Ice jams/jam releases
AUFÉIS (ICINGS) LEVELS

- General theory =
  - Cold + Low Snow = maximum icings

- But site specifically, the opposite can occur
  - 1975 Dietrich River, cold, low snow = maximum icing at MP197 = long dike required to protect TAPS
  - 1976 Dietrich River, warm, high snow = maximum icing one mile downstream = flooding of the Dietrich camp.
WATER LEVELS – WHAT IF S

- Impact of aufeis (icing) levels on:
  - Buried crossings – minimal
  - Elevated line/crossings – could be significant
  - River training structures – could be significant

- Terraces can limit maximum icing levels

- Flow downcuts through icings or deteriorates the ice in 3-5 days.
SCOUR – TYPES

- **General**
  - straight channel scour during floods
  - usually not significant if stream is in “regime”

- **Local scour**
  - At bends, confluences, debris jams and structures
  - 1.5 to 3.5 x general scour depth
SCOUR COMPUTATION

- **General Scour**
  - Regime
  - Competent Velocity
  - Mathematical Models

- **Local Scour**
  - Present and future channel conditions
  - Qualitative/empirical data

- **SO WHAT ?**
  - General scour not significant generally
  - Local scour much more significant
  - Is pipeline exposure = failure?
SCOUR – UNIQUE CONDITIONS

- **Spring**
  - Over ice/frozen ground
  - Minimal scour

- **Ice jams**
  - Severe scour at jam
  - Scour during jam release

- **Alluvial fans/debris flows**
  - Deposition
  - Channel changes

- **Mackenzie River Delta**
  - Hydraulic/thermal conditions
BANK EROSION/CHANNEL CHANGES

- **Summer Floods**
  - Same as non-arctic rivers
  - Survey historic erosion during major floods. Use this as a “trigger” to determine when bank protection is required for operating lines.
  - Bank erosion, especially in treed areas which generate debris, is a prime threat to buried pipelines

- **Spring Floods**
  - Frozen/snow covered banks = little bank erosion
  - Overflows in floodplains = little scour or channel changes in the floodplain. Structures can be affected.
BANK EROSION/CHANNEL CHANGES

- Caused primarily by:
  - High floods = sediment movement = debris = channel changes = bank erosion
  - All things being equal, less changes on Arctic rivers especially those north of the Brooks Range
# DESIGN – RELATIVE IMPORTANCE BURIED CROSSINGS

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Quantitative vs. Qualitative Analysis
## Design – Relative Importance Elevated Crossings

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CONSTRUCTION

- Various techniques for:
  - Environmental reasons
  - Construction reasons

- Arctic construction – hot oil pipelines
  - A “dry” frozen ditch is not necessarily optimum
  - Impact of icings on feasible flow isolation methods
CONSTRUCTION TECHNIQUES

Frozen “dry” ditch

Open cut, wet ditch.

Flow Isolation- Pipe Flume

Flow Isolation-Pumping
OTHER CONSTRUCTION TECHNIQUES

Open Cut – Sauerman Dragline

HDD

Bore

Flow Isolation - Superflumes
ELEVATED CROSSINGS

Free span of pipe

Pile Supports

Girder Bridge

Suspension Bridge
OPPORTUNATIONAL MONITORING

- Extreme event - 2006
- Impact on:
  - Access roads and highways
  - Buried pipeline
  - Elevated pipeline
- Consequences of impact
  - Access
  - Integrity
  - Rebuild or upgrade
LESSON #1

Adapt to Conditions
LESSON #3

Challenge Conventional Design Wisdom
LESSON #4

Challenge Conventional Regulatory Wisdom
“Do You Know What Tsina River Means”
LESSON # 5

Understand Scope of Commitment
LESSON #6

Utilize Operational Performance Data
LESSON #7

Value of Hands-On Knowledge
LESSON #8

Utilize Local Knowledge
THANK YOU