


SWIFT CALGARY 2012

# Challenges and Solutions to Airfield Pavement Design and Construction in the North with Severe Climatic Conditions – A Case Study

**Ludomir Uzarowski, Ph.D., P.Eng. and Rabiah Rizvi, B.A.Sc., Pavement and Materials, Golder Associates Ltd., Ontario**


## ACKNOWLEDGEMENTS

**The authors would like to thank the following people:**

- **Andrew Turner, P.Eng., MMM Group Limited, Toronto**
- **Nelson Pilgrim, Airport Manager, Churchill Falls Airport**
- **Michael Maher, Ph.D., P.Eng., Golder Associates Ltd.**
- **Gary Farrington, C.E.T., Golder Associates Ltd.**
- **Chris Philips, P.Eng., Golder Associates Ltd.**

## ORDER OF PRESENTATION

- Introduction
- Churchill Falls Airport
- Available information review
- Field investigation
- Pavement designs
- Construction
- QC/QA
- Summary – lessons learned

## INTRODUCTION

- Typical challenges for runway design and construction in the North

- Severe climatic conditions
  - Severe winters
    - Deep frost penetration
    - Permafrost
- Soil and water conditions
  - Typically glacial till
  - Undulating bedrock
  - Shallow water
- Difficult construction conditions
  - Short construction season
  - Long distances
  - Poor roads

## INTRODUCTION

- Typical challenges for runway design and construction in the North
  - Remote locations and low human population
  - High construction cost
  - Design
    - New challenges
    - Custom specifications required
  - Limited experience and technology?
  - Few contractors available
  - Lack of quality materials
  - QC/QA
    - Difficult
    - Expensive

Golder Associates

Golder Associates

# CHURCHILL FALLS AIRPORT

- In Labrador
- 280 km west of Goose Bay and 250 km east of Labrador City
- Operated by Nalcor Energy Company, Newfoundland Labrador Hydro
- Facilities
  - Runway 13/31
  - Taxiway Alpha
  - Apron
- Aircraft traffic
  - Provincial Airlines
    - Dehavill and Dash 8
  - Nalcor Energy
    - Beech King Air 250
  - Occasionally large aircrafts

Golder Associates

# CHURCHILL FALLS AIRPORT


Golder Associates

## CHURCHILL FALLS AIRPORT

- Originally constructed in 1969
- Runway 13/31 – 1676 m by 46 m
- Pavement history
  - Construction – 90 mm of HMA, 230 mm of base, 610 mm of subbase
  - First rehabilitation in 1989 – 50 mm of HMA overlay
  - Second rehabilitation in 2000
    - 50 mm HMA overlay
    - 250 mm sub-drains installed 6 m north of E/P
- Existing pavement condition from previous investigations
  - Distresses
    - Cracking
    - Roughness
    - Frost heaving

## CHURCHILL FALLS AIRPORT

- Initial scope of work
  - Review existing information
  - Visual condition inspection
  - Indentify locations for immediate repair
  - Develop rehabilitation alternatives
  - Life cycle cost analysis
  - Drainage recommendations
- Additional Work
  - Limited geotechnical investigation
  - Geophysical survey using GPR

## CHURCHILL FALLS AIRPORT

- Pavement condition evaluation
  - Document the present pavement condition
  - Determine distresses that require immediate treatment in 2011
  - Distresses and frost heaves areas locations to be addressed in 2012 major rehabilitation
- Gary Farrington, Senior Pavement Specialist
- Runway divided into 100 m sections
- Distresses documented and photographed for each section
- Locations for 2011 repairs marked out in the field

Golder Associates

## CHURCHILL FALLS AIRPORT

- Condition inspection findings
  - Extensive high severity block cracking
  - High severity longitudinal and transverse cracking
  - Similar extent and severity of cracking in keel and non keel sections
  - Frost heaving at numerous locations
  - 2010 crack repairs in very poor condition – ravelling and cracking
  - Depressions and soft spots in granular shoulders
- Distresses due to environment, drainage and materials and not due to structural deficiency

Golder Associates

## CHURCHILL FALLS AIRPORT

## CHURCHILL FALLS AIRPORT

- Geotechnical evaluation
  - AMEC 2011 report
  - AMEC 2010 report
  - Jaques Whitford 2005 report
  - Golder Associates Test Pits
- AMEC 2011 Investigation
  - 11 boreholes through Runway pavement
  - Approximately 200 mm of HMA
  - Limited thickness of Granular < 100 mm
  - Bedrock depths ranging from 0.5 to 1.7 m
  - Water seepage in 8 boreholes
  - Ponding water on granular shoulder
  - Frost susceptible subgrade soils

## CHURCHILL FALLS AIRPORT

- AMEC 2010 Investigation
  - 14 test pits excavated in granular shoulder
  - Highly frost susceptible soils
  - Bedrock depths ranging from 0.5 to 2.9 m
  - Frost penetration depth of up to 3 m
- Jacques Whitford 2005 Investigation
  - Six test pits in the granular shoulders
  - Frequent cobbles and boulders ranging in size from 0.5 to 2.0 m
  - Bedrock depth ranging from 0.5 to 2.8 m
  - Groundwater level ranging from 1 to 2 m

## CHURCHILL FALLS AIRPORT

- Golder Test Pits
  - 4 test pits excavated through runway pavement
  - 6 test pits excavated through granular shoulder
  - Subgrade soils – silty sand with cobbles and boulders
  - Water infiltration in 2 runway and 2 shoulder test pits
  - Samples obtained for lab testing
  - Pavement Structure

| Test Pit ID | Layer Thickness (mm) | | |
|---|---|---|---|
| | Asphalt | Granular Base | Granular Subbase |
| TP7 | 170 | 190 | 505 |
| TP8 | 185 | 245 | 560 |
| TP9 | 155 | 245 | 490 |
| TP10 | 195 | 165 | 520 |
| Average | 176 | 211 | 519 |

# CHURCHILL FALLS AIRPORT

Golder Associates

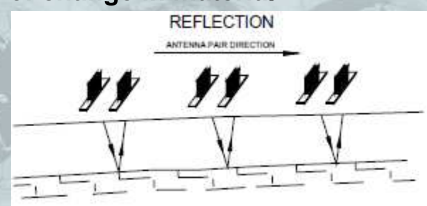
# CHURCHILL FALLS AIRPORT

- GPR survey by Golder Geophysical Department June 23 to 24, 2011
- Objective
  - Delineate the bedrock beneath the Runway
- Smart Tow Noggin System
- 500 MHz antenna used
- Analysis – Reflexw software
- Survey grid
  - Three line parallel to runway centreline – 1680 m long and 22 m apart
  - 175 lines perpendicular to runway centreline – 45 m long and 10 m apart
  - Four supplementary lines on grass east and west of runway

Golder Associates

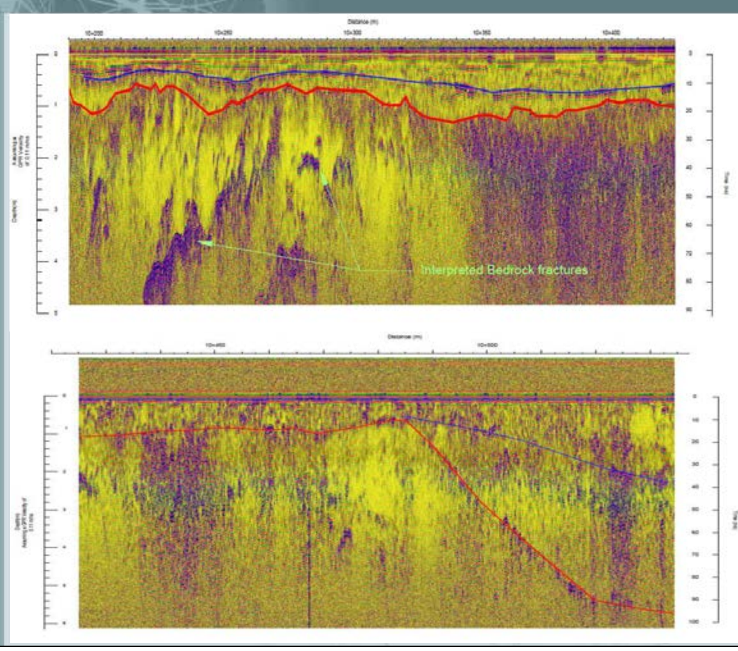
# CHURCHILL FALLS AIRPORT

- Ground Penetrating Radar (GPR) – basics
  - Two antenna – transmitter and receiver
  - Control console and computer for real time graphic display
  - Transmitter emits electromagnetic energy
  - Emitted waves are reflected back and recorded by the receiver
  - Waves are reflected at abrupt changes in subsurface material
  - Time between the transmitted and received wave indicates depth of change in material




Golder Associates

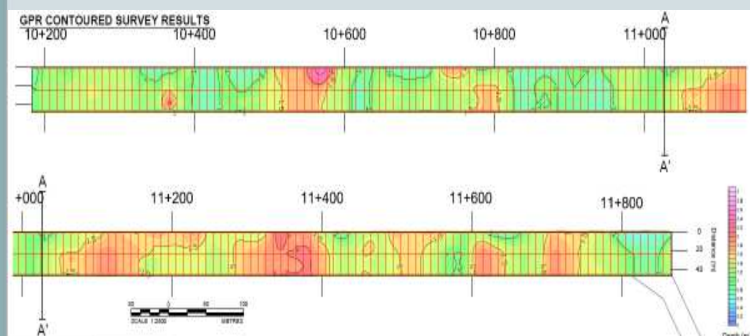
# CHURCHILL FALLS AIRPORT




Golder Associates

## CHURCHILL FALLS AIRPORT

- GPR results
  - Verified against AMEC and JW reports findings and Golder's test pits
  - Produce a bedrock contour map
  - Difficult to delineate due to fractured bedrock and presence of cobbles and boulders
  - Bedrock depth ranged from 0.5 to 2.85 m




Golder Associates

## CHURCHILL FALLS AIRPORT

- Laboratory results
  - Base and subbase material generally within Transport Canada ASG-06 envelope
  - Base and subbase material was relatively clean with low percent passing 75µm sieve
  - High and variable silt and clay content for subgrade material from 20 to 60 percent

- Groundwater
  - Water infiltration in 2 pavement test pits and 2 shoulder test pits
  - Water level ranging from 0.6 to 2.0 m
  - Water generally at bedrock level

Golder Associates

## CHURCHILL FALLS AIRPORT

- Summary of existing pavement condition
  - Heavily distressed pavement including high severity cracking and frost heaving
  - Crack repairs carried out in 2010 were severely deteriorated
  - Highly frost susceptible subgrade soils with large cobbles and boulder
  - Deep frost penetration depth of up to 3 m
  - Undulating and shallow bedrock and groundwater
  - Good quality existing granular material

## CHURCHILL FALLS AIRPORT - DESIGN

- Pavement designs – initially 4 alternatives
- TC/PWGSC "Manual of Pavement Structural Design ASG-19"
  - Verified using FAA and ICAO methodologies
- Parameters

| Parameter | Value |
|---|---|
| Air Freezing Index | 2677 °C-days |
| Subgrade Bearing Strength, S | 65 kN |
| Aircraft Load Rating (ALR) | 9 |
| Tire Pressure | > 1 MPa |

- Required equivalent granular thickness 105 cm
- Frost penetration 3.0 m
- Marginal landing of ALR 11 aircraft required

## CHURCHILL FALLS AIRPORT - DESIGN

- **Alternative 1**
- **Reconstruction without grade raise**
  - 10 cm new HMA
  - 30 cm granular base
  - 60 cm subbase
- **Design life 15 years**
- **Sequence**
  - Remove existing pavement to a depth of 1.0 m
  - Install sub-drains
  - Place subbase, base and HMA
- **Drainage – critical aspect**
  - Deep sub-drains required

Golder Associates

## CHURCHILL FALLS AIRPORT - DESIGN

- **Alternative 2**
- **Reconstruction with 0.5 m grade raise**
  - 10 cm new HMA
  - 30 cm granular base
  - 60 cm subbase
- **Design life 15 years**
- **Sequence**
  - Remove existing pavement to a depth of 0.5 m
  - Install sub-drains
  - Place subbase, base and HMA
- **Benefits**
  - Reduced frost penetration into subgrade
  - Better protection against frost heaving
  - Shallower sub-drains required

Golder Associates

## CHURCHILL FALLS AIRPORT - DESIGN

- Alternative 3
- Major rehabilitation with 0.5 m grade raise
  - Pulverize existing asphalt and mix 50/50 with existing granular base
  - Place 40 cm of new granular base
  - Place 10 cm of new HMA
- Design life 15 years
- Benefits
  - Similar to those of Alternative 2
  - Using reclaimed materials
  - Lower cost
  - Shallower sub-drains required

Golder Associates

## CHURCHILL FALLS AIRPORT - DESIGN

- Alternative 4
- Pavement insulation and rehabilitation
- Design by Golder's Alaska Office
- Design
  - 10 cm new HMA
  - 30 cm granular base
  - 15 cm subbase
  - 15 cm extruded polystyrene insulation
  - 45 cm subbase (pulverized asphalt and granular base)
- Allowed frost penetration into subgrade 200 to 230 mm
- Design life 18 years

Golder Associates

## CHURCHILL FALLS AIRPORT - DESIGN

- **Alternative 5**

- Requested by Transport Canada
- Based on previous experience at CF
- Design
  - Localized repairs
  - Mill entire thickness of asphalt
  - Place 10 cm of new granular base
  - Place 10 cm of new HMA
- Design life about 10 years
- Drainage – critical aspect
  - Besides deep sub-drains granular base of good permeability required

Golder Associates

## CHURCHILL FALLS AIRPORT - DESIGN

- Drainage
  - Generally 0.5 m below the top of subgrade

Table 12: Recommended Sub-Drain Depth below the Ground Surface

| Option Number | Depth Below Existing Ground Surface |
|---|---|
| 1 | 2.5 |
| 2 | 2.0 |
| 3 | 2.0 |
| 4 | 1.5 |
| 5 | 2.5 |

- Two longitudinal sub-drains along the N and S edges of pavement and the intercept ditch
- Initially lateral subdrains considered but then eliminated due to potential for differential frost heave
- Protection of new sub-drains against frost heave

Golder Associates

## CHURCHILL FALLS AIRPORT - DESIGN

➢ Life Cycle Cost Analysis

| OPTIONS | STRATEGY DESCRIPTION | INITIAL COST | MAIN'T COST | LCC | RANKING |
|---|---|---|---|---|---|
| 1 | Reconstruction without Grade Raise | $15,875,237 | $3,629,954 | $19,505,191 | 4 |
| 2 | Reconstruction with Grade Raise | $14,800,988 | $3,369,205 | $18,170,193 | 3 |
| 3 | Major Pavement Rehabilitation with Drainage Improvement | $12,408,534 | $3,418,436 | $15,826,970 | 1 |
| 4 | Pavement Insulation and Rehabilitation | $18,113,928 | $3,011,525 | $21,125,453 | 5 |
| 5 | Pavement Rehabilitation without Grade Raise | $10,063,654 | $6,641,407 | $16,705,061 | 2 |

- Alternative 4 the most reliable
- Alternative 3 more reliable than Alternative 5
- Alternative 5 has the lowest initial cost
- Alternative 5 selected for construction – there are concerns associated with it

Golder Associates

## CHURCHILL FALLS AIRPORT - DESIGN

### Paving specifications

- Customized to meet local conditions
  - Aircraft loading – required strength
  - Surface texture
  - Available materials
  - Local experience
- Granular base material
  - 90% crushed, MicroDeval <25, LA <35
  - maximum 5% passing 75 µm sieve
- Asphalt paving
  - Durable asphalt mixes
  - Tight mat and joint compaction requirements
  - Paving in echelon using ShuttleBuggy
  - Infrared heaters

Golder Associates

## CHURCHILL FALLS AIRPORT - DESIGN

- Asphalt cement PG 52-40 PM
- Aggregate requirements

| Physical Test | Test Method | Requirement | |
|---|---|---|---|
| | | Surface Course | Base Course |
| Los Angeles Abrasion - % Maximum (1) | ASTM C131 | 37 | 37 |
| Absorption - % Maximum | ASTM C127 | 1.75 | 2 |
| Magnesium Sulphate Soundness - 5 Cycles - % Maximum (2) | ASTM C88 | 12 | 12 |
| Petrographic Number - Maximum | CSA A23.2-15A | 135 | 135 |
| Freeze-Thaw Test - 5 Cycles - Percent Maximum | CSA A23.2-24A | 8 | 10 |
| Crushed Particles - % Minimum (3) | ASTM D5821 | 90 | 90 |
| Flat & Elongated Particles - % Maximum (4) | ASTM D4791 | 20 | 20 |
| Loss by Washing - % Maximum Passing (5) | ASTM C117 | 1.75 | 1.75 |
| Micro Deval - % Maximum | ASTM D6928 | 18 | 18 |
| Clay Lumps - % Maximum | CSA A23.2-3A | 1 | 1 |
| Low Density Particles - % Maximum | CSA A23.2-4A | 1 | 1 |
| Friable or Slatey Siltstone - % Maximum | CSA A23.2-15A | 1 | 1 |

Golder Associates

## CHURCHILL FALLS AIRPORT - DESIGN

- Mix requirements
  - Gradation – modified TC based on NF/L experience

Table 4 – Physical Properties of Asphalt Mixtures

| Physical Property | Surface Course | | Binder Course | |
|---|---|---|---|---|
| | Minimum | Maximum | Minimum | Maximum |
| Asphalt Cement Content Percent | 5.3 | - | 5.0 | - |
| Marshall Stability N. at 60C | 10,000 | - | 9,000 | - |
| Marshall Flow Index (mm) | 2.5 | 4.25 | 2.5 | 4.25 |
| Percent Air Voids (1) | 2.5 | 4.5 | 3.0 | 5.0 |
| Target Percent Air Voids (1) | 3.5 | | 4.0 | |
| Percent Voids in Compacted Mineral Aggregate | 15 | - | 14 | - |
| Modified Lottman AASHTO T283 - Tensile Strength Ratio | 0.8 | - | 0.8 | - |
| Moisture Content of Hot-Mix Asphalt by Oven Method, AASHTO T329 as Percent of HMA | - | 0.3 | - | 0.3 |

# CHURCHILL FALLS AIRPORT - DESIGN

- QA to verify QC
- Acceptable, borderline and rejectable zones
- HMA acceptance
  - Asphalt cement content
  - Gradation
  - Air voids
  - Filed compaction
  - Joint compaction
  - Smoothness
  - (Marshall stability and flow – no payment items)

Golder Associates

# CHURCHILL FALLS AIRPORT - CONSTRUCTION

- QC results
  - Granular base

| Physical Test | Result | Specifications |
|---|---|---|
| Los Angeles Abrasion | 19.5 % | < 35 % |
| Percent Crushed | 98.8 % | > 90 % |
| Plasticity Index | 0 | 0 |
| Petrographic Number | 136[1] | < 150 |
| Micro-Deval – Coarse | 6.1 % | < 25 |
| Micro-Deval - Fine | 13.8 % | < 30 |

  - HMA aggregates

| Coarse Aggregate | 1/2" Stone | 3/4" | Surface Specifications | Base Specifications |
|---|---|---|---|---|
| Los Angeles Abrasion, % | 19.0 | 21.8 | < 37 | < 37 |
| Specific Gravity | 2.696 | 2.698 | | |
| Absorption, % | 0.604 | 0.560 | < 1.75 | < 2 |
| Soundness, % | < 1 | < 1 | < 12 | < 12 |
| Petrographic Number | 134 | *In Progress* | < 135 | < 135 |
| Freeze-Thaw 5 cycles | 7.2 | *In Progress* | < 8 | < 10 |
| Crushed Particles, % | 100.0 | 100.0 | > 90 | > 90 |
| Flat & Elongated Particles, % | 4.2 | 6.2 | < 20 | < 20 |
| Loss by Washing, % | 1.1 | 1.0 | < 1.75 | < 1.75 |
| Micro-Deval, % Loss | 7.4 | 6.2 | < 18 | < 18 |
| Clay Lumps, % | 0 | 0 | < 1 | < 1 |
| Low Density Particles, % | 0 | 0 | < 1 | < 1 |
| Friable or Slatey Siltstone, % | 0 | 0 | < 1 | < 1 |

Golder Associates

# CHURCHILL FALLS AIRPORT - CONSTRUCTION

- QC - HMA
  - Surface course

| Aggregate Source | Aggregate Type | Aggregate Percent | Specific Gravity | Agg Absorp. | Cumulative Percent Passing | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 25000 | 19000 | 12500 | 9500 | 4750 | 2000 | 425 | 150 | 75 |
| Combined Aggregate Characteristics | | | 2.684 | 0.89 | | | 100 | 96.7 | 87.7 | 67.6 | 42.7 | 16.4 | 8.7 | 5.7 |
| Churchill Falls Airport Gradation Specification | | | | | | 100 | | 93-100 | | 55-75 | 35-55 | 15-30 | 5-20 | 3-8 |

Marshall Properties

| Trial Number | AC, % | Air Voids, % | VMA, % | Stability, kN | Flow, mm | Bulk Density $(kg/m^3)$ | Max. Density $(kg/m^3)$ | Absorption, % | Film Thickness, µm | Dust Ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| Selected | 5.9 | 4.0 | 16.3 | 10.6 | 3.3 | 2379 | 2477 | 0.65 | 8.4 | 1.09 |
| Specification | | 2.5 - 4.5 | > 15.0 | > 10.0 | 2.5-4.25 | | | | | 0.6-1.2 |

- Base course

| Aggregate Source | Aggregate Type | Aggregate Percent | Specific Gravity | Agg Absorp. | Cumulative Percent Passing | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 25000 | 19000 | 12500 | 9500 | 4750 | 2000 | 425 | 150 | 75 |
| Combined Aggregate Characteristics | | | 2.688 | 0.84 | | | 100 | 84.8 | 75.3 | 55.8 | 36.7 | 15.1 | 8.3 | 5.4 |
| Churchill Falls Airport Gradation Specification | | | | | | 100 | | 70-85 | | 40-65 | 20-42 | 15-30 | 5-20 | 3-8 |

Marshall Properties

| Trial Number | AC, % | Air Voids, % | VMA, % | Stability, kN | Flow, mm | Bulk Density $(kg/m^3)$ | Max. Density $(kg/m^3)$ | Absorption, % | Film Thickness, µm | Dust Ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| Selected | 5.4 | 3.6 | 14.7 | 9.5 | 2.7 | 2416 | 2506 | 0.76 | 8.1 | 1.17 |
| Specification | | 3.0 - 5.0 | > 14.0 | > 9.0 | 2.5-4.25 | | | | | 0.6-1.2 |

Golder Associates

# CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Sub-drains construction
  - Extensive rock cutting
  - Large volume of excavation


## CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Granular materials and aggregate production

Golder Associates

## CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Granular materials and aggregate production

Golder Associates

## CHURCHILL FALLS AIRPORT - CONSTRUCTION

- HMA production




Golder Associates

## CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Granular base
  - Generally good
  - Localized segregation


Golder Associates

## CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Material hauling issue
  - Long distance
  - Gravel roads – dust

## CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Paving in echelon using a ShuttleBuggy

## CHURCHILL FALLS AIRPORT - CONSTRUCTION

- HMA mat paved in echelon

Golder Associates

## CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Using millings for shoulders

Golder Associates

## CHURCHILL FALLS AIRPORT - CONSTRUCTION

- QC issues
  - Initial mix production
  - QC/QA initial correlation
  - Extraction/gradation versus ignition oven
  - Marshall stability and laboratory air voids



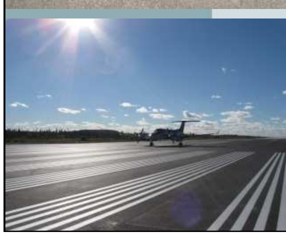
## CHURCHILL FALLS AIRPORT - CONSTRUCTION

- Construction completed successfully in September 2012

## CHURCHILL FALLS AIRPORT - CONSTRUCTION

Golder Associates

## LESSONS LEARNED



- **Projects in the North**
  - **Be aware of challenges**
  - **Experience is critical**
  - **Team work**
  - **Insist on quality**
  - **Identify and solve issues early**
  - **Be open to innovations**
  - **The cheapest solutions may not always be the best for long term performance**


THANK YOU !
QUESTIONS ?
luzarowski@golder.com
rrizvi@golder.com