2013 Arctic/Cold Regions Oil Pipeline Conference Report

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2013 Arctic/Cold Regions Oil Pipeline Conference Report Anchorage, Alaska

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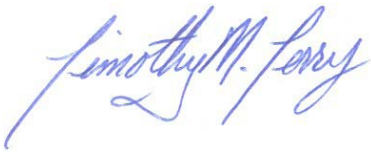

This report was prepared for the exclusive use of the ADEC and their representatives in the study of Arctic/Cold Regions Oil Pipelines. The summaries presented within this report are based on the information provided by the Conference presenters. The summaries should not be construed as definite conclusions regarding the capabilities of the presented regulations and technologies. The data presented in this report should be considered representative at the time of the Conference. Changes in technologies and the regulatory environment can occur with time, due to natural forces or human activity. In addition, changes in government codes, regulations, or laws may occur. Such changes are beyond one's control; therefore, these observations and interpretations may need to be revised in the future.

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EXECUTIVE SUMMARY

This document presents a summary of the Alaska Department of Environmental Conservation (ADEC) sponsored 2013 Arctic/Cold Regions Oil Pipeline Conference (Conference). Implementation of the Conference and development of this Conference report were conducted under Shannon & Wilson's ADEC Term Contract, Division of Spill Prevention and Response, Technical Support and Planning No. 18-7001-03.

The Alaska Risk Assessment project authorized by the Alaska State Legislature provided funding to sponsor the Arctic/Cold Regions Oil Pipeline Conference. The purpose of the Conference was to provide a forum to share information from established operators, governmental agencies, and private contractors regarding the unique challenges associated with the construction and operation of pipelines in the Alaskan Arctic/Cold Regions. The Conference also targeted new entrants to the Alaska Oil Industry.

A Planning Committee was formed consisting of individuals from both the private and public sectors. The Planning Committee comprised eight members; two from ADEC, and one each from the Alaska Department of Natural Resources (ADNR), Alyeska Pipeline Service Company (APSC), British Petroleum Exploration (Alaska), Inc. (BPXA), CH2MHill, ConocoPhillips Alaska, Inc. (CPAI), and URS Corporation. The committee was tasked with defining the relevant topics for the Conference and to identify and solicit speakers.

The Arctic/Cold Regions Oil Pipeline Conference was held at the Dena'ina Civic and Conference Center in Anchorage, Alaska on September 17 through 19, 2013. The Conference, open to the public, was attended by over 200 individuals representing industry, regulatory agencies, consultants, and the public.

The 29 presentations given at the Conference were organized into seven topic-specific sessions followed by a question and answer period for each session. The seven topics were:

- Alaska Specific Regulations
- Stakeholder Involvement and Land and Water Use
- Logistics and Seasonal Access
- Aboveground Pipeline Concerns
- Direct Burial Pipeline Concerns
- Offshore Pipelines
- Unresolved Challenges

The agenda for the Conference also included opening remarks on the first two days of the Conference; a ½-day workshop for pipeline risk assessment; two lunch sessions with keynote speakers; and an opening-day reception. In addition, an Exhibit Hall was set up at the Conference.

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DD	Pipeline Risk Assessment Essential Elements Workshop

ACRONYMS AND ABBREVIATIONS

ADCP	Acoustic Doppler Current Profiler
ADEC	Alaska Department of Environmental Conservation
ADNR	Alaska Department of Natural Resources
ADOT&PF	Alaska Department of Transportation & Public Facilities
APSC	Alyeska Pipeline Service Company
ASD	Allowable Stress Design
ASME	American Society of Mechanical Engineers
ATRT	Automated Tangential Radiographic Testing
AUV	Autonomous Underwater Vehicle
BLM	Bureau of Land Management
BOEM	Bureau of Ocean Energy Management
BPXA	British Petroleum Exploration (Alaska), Inc.
BSEE	Bureau of Safety and Environmental Enforcement
COF or CoF	Consequence of Failure
Conference	Arctic/Cold Regions Oil Pipeline Conference
CPAI	ConocoPhillips Alaska, Inc.
CPF	Central Production Facility
CUI	Corrosion-Under-Insulation
DAS	Distributed Acoustic Sensing
DMLW	Division of Mining, Land and Water
DTS	Distributed Temperature Sensing
EA	Environmental Assessment
EIS	Environmental Impact Statement
ESP	Environmental Studies Program
FEA	Finite Element Analysis
FOC	Fiber Optic Cable
FPIP	Facility Piping Inspection Program
HDR	HDR Alaska, Inc.
HSM	Horizontal Support Member
IAP	Integrated Activity Plan
ILI	In-Line Inspection
IMP	Integrity Management Program
IPS	Ice Profiling Sonar
IR	Infrared Thermography
KMC	Kinder Morgan Canada, Inc.
Kron	Kron Associates
LDS	Leak Detection System
LOF	Likelihood of Failure
LRUT	Long-Range Guided Wave Ultrasonic Testing
MFL	Magnetic Flux Leakage

ACRONYMS AND ABBREVIATIONS

NPR-A	National Petroleum Reserve in Alaska
OCS	Outer Continental Shelf
ODS	Oooguruk Drill Site
OTP	Onshore Tie-In Pad
PHMSA	Pipeline and Hazardous Materials Safety Administration
Pioneer	Pioneer Natural Resources, Alaska
PIP	Pipe-in-Pipe
PoF	Probability of Failure
PPSA	Production Processing & Services Agreement
PRCI	Pipeline Research Council International
PSL	Pressure Safety Low
PVD	Pipeline Vibration Damper
ROD	Record of Decision
ROF	Risk of Failure
ROV	Remotely Operated Underwater Vehicle
ROW	Right-of-Way
RT	Radiographic Testing
SBD	Strain Based Design
SBDA	Strain-Based Design and Assessment
SMYS	Specified Minimum Yield Strength
SOA	State of Alaska
SPCO	State Pipeline Coordinator's Office
TAPS	Trans Alaska Pipeline System
TRT	Tangential Radiographic Testing
TVA	Tuned Vibration Absorber
TWUP	Temporary Water Use Permit
USDOI	United States Department of the Interior
UT	Ultrasonic Technology
VSM	Vertical Support Member
WIV	Wind-Induced Vibration

2013 ARCTIC/COLD REGIONS OIL PIPELINE CONFERENCE REPORT ANCHORAGE, ALASKA

1.0 INTRODUCTION

This document presents a summary of the Alaska Department of Environmental Conservation (ADEC) sponsored Arctic/Cold Regions Oil Pipeline Conference (Conference). The purpose of the Conference was to provide a forum to share information regarding the unique challenges associated with the construction and operation of pipelines in the Alaskan Arctic/Cold Regions. The objectives of the Conference were to:

- Inform new entrants to the Alaska Oil Industry of the unique challenges of operation in Alaska;
- Share current best practices, proven technologies, and lessons learned for challenges unique to Alaskan pipelines in the Arctic/Cold Regions;
- Provide information from federal and state government agencies regarding regulatory oversight unique to Alaska; and
- Avoid preventable environmental impacts to Alaska.

This work effort was conducted under Shannon & Wilson's ADEC Term Contract, Division of Spill Prevention and Response, Technical Support and Planning No. 18-7001-03. Implementation of the 2013 Arctic/Cold Regions Oil Pipeline Conference and development of this Conference report were performed in general accordance with Shannon & Wilson's *Arctic/Cold Regions Oil Pipeline Conference Work Plan* of May 2013. ADEC authorization to proceed with this project task was received on March 1, 2013 with Notice to Proceed No. 18-7001-03-004.

1.1 Project Background

Alaska Arctic/Cold Regions exploration, production, storage and transportation facilities are located on the North Slope of the Brooks Range or within 15 miles offshore. The petroleum product is conveyed by small- and large-diameter flowlines and transmission pipelines. In general, production wells are located at drill sites constructed on onshore gravel pads or offshore gravel islands. Oil, gas, and water produced at individual wells are conveyed through facility oil piping in varying proportions to flowlines. Multi-phase fluid is carried by flowlines to central processing facilities where oil, gas, and water are separated. Produced oil on the North Slope is transported in crude oil transmission pipelines to Pump Station 1 and through the Trans Alaska Pipeline System (TAPS) approximately 800 miles to the Valdez Marine Terminal. Arctic/Cold

Regions pipelines from offshore islands are usually buried subsea and then are constructed above ground, similar to other North Slope pipelines, and supported on vertical support members (VSMs). Pipelines crossing rivers can be buried, above ground, or bridge-supported.

The Alaska Risk Assessment project, authorized by the Alaska State Legislature, provided funding to sponsor the Arctic/Cold Regions Oil Pipeline Conference. The Conference targeted new entrants to the Alaska Oil Industry and aimed to provide a forum to share information from established operators, governmental agencies, and private contractors.

A Planning Committee was established consisting of individuals from both the private and public sectors. The Planning Committee included a total of eight members: Keith Sanfacon and Roger Burleigh from ADEC; Dave Norton, P.E. from the Petroleum Systems Integrity Office of the Alaska Department of Natural Resources (ADNR); Kim Harb from Alyeska Pipeline Service Company (APSC); Ed Warren from British Petroleum Exploration (Alaska), Inc. (BPXA); Terrance Cheatham, P.E. from CH2MHill; Jay Murali from ConocoPhillips Alaska, Inc. (CPAI); and Jim Glaspell from URS Corporation. The committee was tasked with defining the relevant topics for the Conference and to identify and solicit speakers.

1.2 Conference Description

The Arctic/Cold Regions Oil Pipeline Conference was held at the Dena'ina Civic and Conference Center in Anchorage, Alaska on September 17 through 19, 2013. The Conference, open to the public, was attended by over 200 individuals representing industry, regulatory agencies, consultants, and the public. A list of the Conference participants including presenters, exhibitors and sponsors is summarized in Table 1.

The agenda for this 3-day Conference included opening remarks on the first two days of the Conference, 29 presentations organized into seven topic-specific sessions followed by a question and answer period for each session, a ½-day workshop, two lunch sessions with keynote speakers, and an opening-day reception. In addition, an Exhibit Hall was set up at the Conference.

Ms. Lynn Kent, Deputy Commissioner of the ADEC, started the Conference on September 17, 2013 with her opening remarks that focused on her understanding of the goal of the Conference – to minimize risk to Alaska's environment while supporting existing and new exploration and development. Admiral Tom Barrett, President of APSC, presented the opening remarks on the second day of the Conference, September 18, 2013. Admiral Barrett focused his opening remarks on Arctic/cold regions oil pipelines from an operator's perspective.

The Conference comprised seven sessions focusing on regulations, stakeholder involvement, logistics and unresolved challenges regarding onshore and offshore Arctic/cold regions oil pipelines. During each session, experts presented information regarding the unique challenges associated with the regulation, construction and operation of pipelines in the Alaskan Arctic/Cold Regions. Copies of the Microsoft PowerPoint (PowerPoint) presentations for each presenter (unless permission to reproduce was not granted) are included in Appendices A through CC. Brief Question and Answer Sessions were held following the final presentation for each session.

A ½-day workshop on pipeline risk assessment essential elements was given by Mr. Kent Muhlbauer of WKM Consultancy on the last day of the Conference, September 19, 2013. The workshop was attended by approximately 50 individuals. A copy of the workshop handouts is included in Appendix DD.

The Conference included two lunches served on September 17 and 18, 2013. Luncheon keynote speakers included Mr. John Tintera, former Executive Director of the Railroad Commission of Texas, who delivered a presentation on the topic of *The Over and Under of Effective Oil & Gas Regulation* and Mr. Larry Persily, Director of the Alaska Natural Gas Transportation Projects, who gave a presentation on the topic of *Economics of Natural Gas in Alaska*.

An Exhibit Hall was set up adjacent to the Conference room to provide a location where Arctic/Cold Regions Oil Pipeline product manufacturers or best practices providers displayed their products and technologies during the three-day event. A list of the companies/organizations presenting exhibits during the conference is provided in Table 1.

A reception was held in the Exhibit Hall during the first evening of the Conference on September 17, 2013 for the presenters, service providers, manufacturers, and exhibitors. Food and beverages provided during the reception, refreshment breaks, and two lunches were provided by the five Conference sponsors: ConocoPhillips Alaska, URS Corporation, Kakivik Asset Management, Nalco Champion, and Lynden.

Shannon & Wilson was responsible for providing facility planning, conference organization, and documenting conference proceedings. Ms. Julie Jessen of HDR Alaska, Inc. (HDR) facilitated the conference proceedings as the Conference Moderator. Ms. Lorell David of Visions assisted Shannon & Wilson in planning and facilitating the Conference and Exhibit Hall. Transcripts of the Conference presentations were prepared by Kron Associates (Kron). HDR, Visions, and Kron provided their services under subcontract to Shannon & Wilson.

2.0 SUMMARY OF CONFERENCE PRESENTATIONS

The Planning Committee established the specific topics to be addressed during the three-day conference. The seven sessions and the 29 presentations are listed in Table 2. Brief summaries of each of the 29 presentations and the ½-day workshop are provided in the following sections. The summaries are based on the information provided by each presenter in their PowerPoint presentations combined with the transcripts of the oral presentation.

2.1 Session 1 – Alaska Specific Regulations

Three presentations were given discussing Alaska-specific pipeline regulations including regulations for both onshore and offshore pipelines.

2.1.1 State Pipeline Coordinator's Office

Ms. Allison Iverson, representing the ADNR Pipeline Coordinator's Office, discussed the role of the State Pipeline Coordinator's Office (SPCO) in regulating pipeline construction and operation in Alaska. A copy of Ms. Iverson's PowerPoint presentation is included in Appendix A.

The SPCO provides four primary functions: issuing right-of-way leases, issuing permits for pipeline-related activities, coordinating among multiple state and federal agencies, and monitoring compliance. The SPCO functions under Alaska Statute 38.35 – The Right-of-Way Leasing Act that covers pipelines on State land valued over $1 million with the exception of gathering lines and pipelines within units. Currently, SPCO's jurisdictional pipelines consist of twelve existing pipelines, including TAPS, and eight proposed pipelines, including the Alaska Standalone Pipeline and the Point Thomson project.

The SPCO coordinates multiple agencies in the pipeline right-of-way leasing and permitting process. Several State agencies are co-located with SPCO which provides easy access for information sharing, coordination and decision making. A communication protocol has been established by SPCO to apply a significance filter to applicant questions or issues to determine the different State agencies requiring responses or input. SPCO utilizes the significance filter to generate one response, even though it may contain multiple mitigation factors, within a timely manner.

Ms. Iverson provided an overview of the application process. A reimbursable service agreement is formed such that costs associated with the SPCO are reimbursed by the lessee or the project proponent. Following receipt of the required applicant information, a commissioner's analysis and proposed decision are made to determine conflicts with existing uses and if the applicant is

technically and financially capable of conducting the proposed activities. The issued right-of-way lease establishes specific terms relating to duration, rental and reservations. Following issuance of the right-of-way lease, the project proponent must still submit project plans including engineering and construction documents to the SPCO for review and/or approval. At this stage, multi-agency coordination continues for the pipeline permitting process.

The Joint Pipeline Office, comprising both state and federal agencies, has been formed to help facilitate the permitting process. The SPCO, a component of the Joint Pipeline Office, is divided into sections including right-of-way, engineering and compliance. Each section is responsible for specific aspects of the pipeline permitting process. An annual report is published by SPCO and available online at http://dnr.alaska.gov/commis/pco.

2.1.2 Update on Oil & Gas Activities for BLM-Alaska

Mr. Bud Cribley, representing the Bureau of Land Management (BLM), provided an update on the National Petroleum Reserve in Alaska (NPR-A) Integrated Activity Plan (IAP)/Environmental Impact Statement (EIS) Record of Decision (ROD); the NPR-A Working Group, lease sale, and upcoming development; and the Interagency Working Group. A copy of Mr. Cribley's PowerPoint presentation is included in Appendix B.

The NPR-A is approximately 23 million acres of federal lands located on the North Slope. The IAP establishes a balanced approach to resource oil and gas development, while providing protection to valuable surface and subsistence resources. The February 21, 2013 IAP/EIS ROD specifies land allocations in the NPR-A, including land available for oil and gas leasing, and anticipated corridors for pipelines to facilitate transport of oil and gas from offshore production across the NPR-A and into TAPS.

The IAP/EIS ROD also provided for the formation of the NPR-A Working Group, which comprises both federal and state agency representatives, delegates from villages located both within and outside of NPR-A, and representatives from the Arctic Slope Regional Corporation, the North Slope Borough, and the Inupiat Community of the Arctic Slope. Mr. Cribley stated that the NPR-A Working Group "ensures that BLM's land managers engage in a continuing dialogue with North Slope residents; understand their economic, subsistence, and wider social issues and activities in the NPR-A; and gather scientific and traditional ecological knowledge related to key issues that arise during implementation of the plan, and as the BLM considers proposed activities in the NPR-A."

Mr. Cribley discussed the BLM annual NPR-A lease sales which were directed by President Obama on May 14, 2011. The BLM is currently conducting their third NPR-A lease sale. The

BLM has approximately 1.5 million acres of current leases and 2.6 million acres of lands that have relinquished lease tracts. The BLM has proposals for new development on the NPR-A, including potentially the first production wells by CPAI in the Greater Mooses Tooth Unit and Linc Energy in the Umiat area.

In summary, Mr. Cribley discussed the formation of the Interagency Working Group which was established through Executive Order 13580 on July 12, 2011 for coordination of domestic energy development and permitting in Alaska. The working group, comprising representatives from eleven federal agencies, produced the Integrated Arctic Management Plan. Mr. Cribley stated the recommendations from this plan are "to adopt an integrated Arctic management approach, ensuring ongoing high level White House leadership in Arctic issues, strengthen key partnerships, and promote better stakeholder engagement, and coordinate and streamline federal actions."

2.1.3 Offshore Oil Pipelines

Mr. David Johnston, representing the Bureau of Ocean Energy Management (BOEM), provided an overview of the functions of two federal agencies involved with offshore oil pipeline development: the BOEM and the Bureau of Safety and Environmental Enforcement (BSEE). A copy of Mr. Johnston's PowerPoint presentation is included in Appendix C.

The BOEM is responsible for managing development of the Outer Continental Shelf (OCS) resources in an environmentally and economically responsible way and is focused on planning and environmental assessment. The BSEE works to promote safety, protect the environment, and conserve resources offshore through regulatory oversight and enforcement, and is focused on the technical requirements of OCS development.

The BOEM's regulatory process is basically a five-year program starting with lease sales in the OCS. After obtaining a lease, ancillary activities are conducted on the lease to acquire information regarding sediments, potential shallow geohazards, archeological sites, or other relevant site data. Exploration plans are then developed and implemented to evaluate the lease as a viable resource. Assuming an economic accumulation is established, a development and production plan is then carried out with additional ancillary activities conducted as needed.

The BOEM works under at least 20 statutory requirements and seven executive orders. The OCS Lands Act is the statutory requirement under which the BOEM receives their authority. In addition to the multiple federal laws and executive orders, the BOEM interacts with over 20 stakeholder organizations and agencies to make integrated and adaptive management decisions regarding OCS development. The BOEM has an Environmental Studies Program (ESP) that is a

valuable resource for future development. The BOEM ESP has invested about $400 million in studying the OCS environment of offshore Alaska and developed more than 500 reports since 1973.

Oil and gas development must plan for Alaska OCS conditions including extreme cold, freezing spray, extended periods of low light, sea ice and other Arctic-related conditions compounded by the remote location and relative lack of infrastructure. Shallow hazard surveys should be conducted to evaluate seafloor hazards, subsurface geological hazards, man-made hazards and other critical features. Development plans must also consider the changes in sea ice conditions as well as seasonal ice formation and movement.

At this time, ancillary activities are being conducted in the Alaska OCS including an open water marine survey program in the Chukchi Sea by Shell and a geotechnical and seabottom investigation in the Beaufort Sea by BPXA.

2.2 Session 2 – Stakeholder Involvement and Land and Water Use

Six presentations were given during Session 2 - Stakeholder Involvement and Land and Water Use.

2.2.1 The Complex Nature of Federal and State Involvement in the Construction and Operation of the Trans-Alaska Pipeline System

Mr. Peter Nagel, representing APSC, discussed the complex nature of federal and state involvement in the construction and operation of the TAPS. Mr. Nagel provided an overview of the TAPS landscape, tools that APSC uses for operational compliance, and the Cooperative Agreement between federal and state agencies for TAPS construction. A copy of Mr. Nagel's PowerPoint presentation is included in Appendix D.

TAPS comprises a 48-inch diameter oil pipeline crossing 800 miles of Alaska from the Arctic Ocean to Prince William Sound and includes the Valdez Marine Terminal. The pipeline traverses 125 miles along 4 major rivers and crosses 42 state roads, 34 major streams, and 800 minor streams. TAPS passes through or adjacent to properties held by 300 private landowners and has 24 regulatory oversight agencies.

Four tools have been developed during the operating phase of TAPS to help interact with federal and state stakeholders. The tools include the Regulatory Compliance Information System, the Event Notification Form, the Permit Acquisition Guidelines Checklist, and the Right-of-Way Grant and Lease Manual. Use of the tools played a role in a major TAPS operational milestone, the right-of-way renewal.

Construction of TAPS required the cooperation of both federal and state agencies to obtain thousands of permits, including notices to proceed. In order to construct TAPS, a Cooperative Agreement was made on January 8, 1974 between the United States Department of Interior (USDOI) and the State of Alaska (SOA). The agreement brought the experience of two key positions, the federal authorized officer and the state pipeline coordinator, into the construction process.

2.2.2 Orchestrating the Permit Process for a North Slope Development

Ms. Lynn DeGeorge, representing CPAI, provided an overview of the permit process for a North Slope oil and gas project. Permission was not received to publish Ms. DeGeorge's PowerPoint presentation. A copy of Ms. DeGeorge's presentation summary prepared for the Conference Program is included in Appendix E.

Typical permitted activities include both exploration and new developments as well as day to day work. Activities requiring permits include drilling infrastructure, select maintenance work, facility upgrades, new modules and expansions, exploration wells, new developments, and water use.

The first step in the permit process is to determine the required permits. Permit requirements are based on the project scope, physical access, surface impacts, land ownership, and coverage of activity under an existing permit. It must also be determined whether an Environmental Assessment (EA) or EIS may be required. An EIS typically adds a minimum of 2 years onto the permit process time line. Challenges the permittee may encounter include multiple agency permits as well as the number of federal, state, and local agencies that may be involved in a single project.

Data gathering is conducted after the required permits are identified in order to complete permit applications. The data gathering may include information regarding biology, archaeology, lakes, habitat mapping, subsistence use, engineering studies, air monitoring and spill response planning. Sources of the data may come from agencies, previous studies, local knowledge, and consultants.

A pre-application meeting is often conducted during the permit process to discuss the proposed project, confirm the required permits, identify agency concerns, and inform the agencies of the project schedule. Additional meetings are typically held for larger projects as well as to include the community in the permit process. Ms. DeGeorge stressed that communication is key in the permit process.

The permittee completes and submits the permit applications to the appropriate authorizing agencies. The permit applications range from simple application forms to complex documents

including EA/EIS and air permits. Typically a comment period is required prior to a final determination and permit issuance. Some agencies will provide draft permits for the permittee to review.

Challenges to the permittee include project schedules and deadlines associated with observation of bird windows and winter construction season, budget constraints both within the company and the regulating agency, relationships with the agencies such as stresses associated with staff changes, agency to agency variances, and difficult permit stipulations.

2.2.3 Roads to Resources – Roads in Cold Places

Mr. Murray Walsh, representing the Alaska Department of Transportation & Public Facilities (ADOT&PF), provided an overview of the Roads to Resources Program. A copy of Mr. Walsh's PowerPoint presentation is included in Appendix F.

The Roads to Resource Program was established approximately 10 years ago to fund new roads in Alaska. The program was modeled after the 56-mile road constructed from the Red Dog Mine to the coast to facilitate transport via vessel. The State of Alaska, operating through the Alaska Industrial Development and Export Authority, issued bonds to raise money to build the road with Red Dog Mine reimbursing for the borrowed money over time. With this model, new roads are constructed with money borrowed from the financial market place without use of federal dollars and with limited state seed money.

New roads constructed under the Roads to Resource Program are permitted by the ADOT&PF, typically are constructed for industrial use as "long and skinny" roads, and are funded in partnership between the developer and the ADOT&PF. Two major projects within the last couple of years include plans for new roads extending off of the Dalton Highway to Umiat where Linc Energy is exploring for oil and gas production and the Ambler mining district where four mining interests are exploring including Nova Copper.

A major factor in the design and construction of the new roads under the Roads to Resources is permafrost. Permafrost is categorized into six types including cold, warm, thaw-stable, thaw-unstable, ice-rich, and massive ice. Human activity on top of the permafrost, including the construction of roads, generates heat which in turn melts the permafrost. Permafrost is present throughout a significant portion of Alaska and, therefore, must be taken into consideration when constructing roads. Mitigation techniques that can be used include air convection embankments, heat drains, longitudinal culverts, snow-free embankments, vegetative cover, and light-colored bituminous surface treatments.

Canada, Russia and China also have the challenge of constructing transportation corridors including highways and railroads through areas of permafrost. Canada has an on-going

experimental area along the Alaska Highway near Beaver Creek where they are testing twelve highway sections with various techniques for stabilizing permafrost. In Russia, travel time from Moscow to Vladivostok takes 11 days via the Russian Railroad due to permafrost damage resulting in warped rail and shifted roadbeds. In China, a new railroad was built from Golmud to Lhasa in Tibet where permafrost was encountered. China dealt with the challenge by elevating the portion of the railway passing through the permafrost zone on pilings, a relatively expensive solution. The overall message taken from these three countries is to spend a lot of money upfront on the design and construction of the road/railway to deal with permafrost issues or spend a lot of money down the road on maintenance.

2.2.4 Native Alaskan Concerns and Interface

Mr. Willie Hensley, an author, professor and Alaskan Leader, provided an overview of the interactions of the indigenous people of Alaska with the oil and gas industry. Mr. Hensley's biography and copy of the transcript of his presentation are included in Appendix G.

Mr. Hensley indicated that the Inuit were the first Alaska Natives to get involved with oil production in Alaska. The Inuit, who depended heavily on whale for light, heat, and food, participated in the commercial aspects of whaling to obtain western world products. The whaling industry declined in the Bering Sea and the Arctic due to a decrease in the whale population of about 90 percent. One of the reasons for the decline in the whaling industry, according to Mr. Hensley, was the discovery of petroleum and the use of coal oil. The indigenous people, who knew the country like the back of their hand, usually showed the westerners where gold and oil seeps were located.

The Alaska Natives still occupy the lands of their ancestors. Through the Alaska Native Land Claims Settlement Act, a percentage of their former lands was returned to the Alaska Natives. The oil industry helped resolve the land conflict issues of the Alaska Natives because it helped resolve their own problem of cleaning up the leases legally and getting a right-of-way for TAPS. Under the right-of-way permit for TAPS, the Alaska Natives were included in the construction and operation of the pipeline.

In addition, Alaska Natives received nearly a billion dollars which they used to capitalize their corporations. Alaska indigenously-owned corporations have been an integral part of the operation of TAPS even beyond the requirements of the right-of-way permit which is a credit to the owner companies. These Alaska Native corporations have constructed and operated oil rigs, catered workers, leased equipment, provided security, operated hotels, built utilities, provided vessels and environmental services, maintenance and equipment, and a wide array of other services. At least one Native Corporation has participated in bidding on Beaufort Sea leases and ended up with a small share of Endicott.

Mr. Hensley indicates that if there is a pipeline to be constructed in the future, small or large, short or long, Alaska indigenously-owned entities will want to be a part of something that makes business sense and is good for Alaska and Alaskans.

2.2.5 Off-Road Travel on State Land – Management and Impacts

Ms. Melissa Head, representing the ADNR, Division of Mining, Land, and Water (DMLW), discussed the management and impacts of summer and winter off-road tundra travel in Alaska. A copy of Ms. Head's PowerPoint presentation is included in Appendix H.

Two regulations define permitting for off-road travel on the North Slope. First, in the 1970s state land within the Umiat meridian was designated as special use requiring a permit for off-road travel activity. Second, the Dalton Highway corridor access restriction defined in Alaska Statute 19.40.210 prohibits the use of off-road vehicles within five miles of the right-of-way unless use is for oil and gas activities, a mining claim, or a snow machine traveling through the corridor.

The ADNR/DMLW issues permits for off-road travel including the construction of ice roads on state land on the North Slope. The permit process is relatively simple with five-year permits issued for a broad area and individually approved routes within the broad area on a case-by-case basis. Permits include stipulations to avoid and/or reduce damage to the underlying tundra vegetation and ecosystem and tundra rehabilitation if damage does occur. The permit process typically takes between 2 weeks to 2 months depending on the multiple agency review and public notice period required.

The summer off-road travel season extends from July 15 to freeze up. Numerous types of vehicles have been approved for off-road summer travel including a Dynahaul, Tucker Snocat, Argo Frontier, and Polaris Ranger. Several off-road travel considerations are observed since summer-approved vehicles can still cause tundra damage. Vehicle operator training is important such that the operator can identify vegetation types less likely to be impacted and recognize tundra disturbance versus damage. Walking the route ahead of the off-road vehicle is always encouraged to identify the best travel route.

The winter off-road travel season extends from freeze up to break up. Two components of winter off-road travel include construction of ice roads and general off-road travel. Winter off-road vehicles typically include Steigers, Rolligons, track-mounted tractors, seismic vibrators, and sled-mounted camps.

The North Slope has been divided into four different areas for determination regarding opening for off-road winter travel. Opening of these areas is dependent on snow depth and soil temperature. The ADNR/DMLW conducts weekly data collection at designated monitoring

stations throughout the winter season to determine the opening status for each of the four areas. Off-road travel status reports are issued weekly following monitoring. Opening reports are issued as soon as an area is declared open to winter off-road travel on the ADNR/DMLW Listserv and online status map.

The winter tundra travel season has fluctuated over the years with an apparent lengthening over the past ten years for ice roads. The lengthened ice road season is reportedly a result of the use of pre-packing a route, careful route selection during the summer season, and adding snow and ice to the ice road. Pre-packing is accomplished by using a summer-approved vehicle to pack the snow along the desired route.

2.2.6 Summer and Winter Tundra Travel Permitting –Water/Ice Withdrawals

Mr. Michael Walton and Mr. Henry Brooks, representing the ADNR/DMLW, discussed water permitting for the oil and gas industry in Alaska. A copy of Mr. Walton's and Mr. Brooks' PowerPoint presentation is included in Appendix I.

The Alaska Water Use Act under Alaska Statute 46.15 regulates the use of all water in the state regardless of the surface or subsurface ownership under which it is located. The term "Significant Amount of Water" is defined under 11 AAC 93.035 and applies to withdrawals, diversions or impoundments. This regulation also determines under which circumstances a permit application is required to be filed, whether for temporary water use or for a water right. Consumptive use refers to water that is removed from the source and not returned. Non-consumptive use refers to water that is removed from the source, immediately used, then returned to the source. The regulation defines maximum quantities of water use for both consumptive and non-consumptive uses as well as reserves the right to require a permit application for water use that may adversely affect the water rights of other appropriates or the public interest.

A water use permit application is typically handled in four phases as set forth in the state statutes and regulations. The phases include review of the application including source data; adjudication; issuance of authorization; and post issuance water use reporting and review. Three types of adjudication include application for a temporary water use permit (TWUP), application for water rights, and a certificate of reservation. A TWUP is generally issued for a five-year period, can be extended for up to one additional 5-year period, and can include up to five separate water sources under the one application. The application for water rights is a two-step process. First, a permit is issued to appropriate the water or begin water use. The second step entails receipt of the actual water right giving the owner the right to use the water for as long as

the water is beneficially used. A certificate of reservation is the third application type and is issued to maintain a certain flow or lake level.

The ADNR/DMLW water permitting goals for the North Slope include management for a sustainable water source; no interference with presently existing water rights; and water use is beneficial and minimizes impacts to the environment.

The permitting process begins with the submittal of a "complete" application. The application details source data including lake/river characteristics, volumes requested, and use time frames and purpose. The ADNR/DMLW will review the application packet and solicit input from other agencies such as Fish and Game, ADEC and the North Slope Borough.

The presence of fish in a water source will affect the winter permitted use volume for lakes. The winter use volume is limited to 15 percent if a species sensitive fish is present. The protection of fish is a prime issue on the North Slope.

The North Slope has multiple competing uses for water within the oil and gas industry. These uses include dewatering a mine site without fish for gravel extraction, withdrawal of water for beneficial uses such as ice road construction, drilling and support operations, and enhanced oil recovery efforts.

2.3 Session 3 – Logistics and Seasonal Access

Four presentations were given during Session 3 – Logistics and Seasonal Access.

2.3.1 Gravel vs. Roadless Construction

Mr. Chris Ledgerwood, representing Alaska Frontier Constructors/Nanuq, Inc., provided an overview of the multiple means of transportation on the North Slope and challenges associated with construction in the Arctic/Cold Regions. A copy of Mr. Ledgerwood's PowerPoint presentation is included in Appendix J.

Arctic/Cold Region construction logistical challenges include limited access, weather, regulations to protect the environment, and established best management practices. Mr. Ledgerwood focused on the limited access challenges associated with oil and gas exploration and production on the North Slope. Many of the larger oil reservoirs including Prudhoe Bay, Kuparuk, Endicott and Milne Point are accessible via an all weather road system. The majority of the new drill sites are located off of the established road system, requiring various forms of alternative transportation to construct and operate the sites.

Gravel infrastructure including roads and pads are established in the Deadhorse, Prudhoe Bay and Kuparuk areas. Transportation in these areas can be accomplished with traditional tire or track-mounted vehicles and equipment on a year-round basis.

Water transportation with boats and barges is used for near shore areas located within navigable waters. Boats are typically used for transportation of crew while barges move equipment. Water transportation is limited to the 90 to 100-day open water period on the North Slope.

Helicopter travel is used for transportation to both onshore and offshore sites. An advantage of helicopter travel is that the helipad area is relatively small as compared to a fixed-wing airstrip. The primary disadvantage of helicopter travel is weather which limits use of a helicopter in fog, clouds and freezing rain.

Fixed-wing aircraft provide another form of air transportation on the North Slope. The landing strip for the aircraft is larger than a helipad but still results in a reduced footprint as opposed to ice roads or tundra travel.

Tundra travel is used in areas that tend to be farther away from the road system and would require an ice road that is not feasible to construct. The drawbacks to tundra travel are the seasonal nature (cannot be utilized during breakup to July 15) and the slow travel speed.

Onshore and offshore ice roads are also forms of transportation, logistically allowing for the use of rubber or track-mounted vehicles and equipment. Ice roads are seasonal and require reconstruction each year. Offshore ice roads are also limited to construction within the shear zone.

North Slope operations, including the construction of offshore gravel islands and subsea pipeline installation, may require mining of gravel and gravel hauling. Gravel mine sites are typically opened during the winter when heavy equipment can be transported over ice roads. The mine sites tend to fill with water during spring breakup and become a water source, therefore, it is preferred to complete the gravel reclamation within one season, if possible.

Offshore gravel islands have been constructed along the coastline of the North Slope to facilitate offshore exploration and production. The islands are accessed via helicopter and water transportation in the summer. Subsea pipelines have been installed to connect the offshore gravel islands to the onshore infrastructure. Installation of the pipeline is similar to building an ice road. The ice is thickened along the pipeline corridor in order to support the loads imposed by the installation equipment.

2.3.2 Ice Roads, Ice Pads, Ice Bridges, & Ice Airstrips

Mr. Eric Wieman, representing Peak Oilfield Service Company, discussed the construction and usage of ice roads on the North Slope. A copy of Mr. Wieman's PowerPoint presentation is included in Appendix K.

Main purposes for the construction of ice roads on the North Slope are to support exploration and construction activities, and resupply existing facilities. The two types of ice roads include over land (tundra) ice roads and sea ice roads. Exploration pads, bridges and airstrips are other support structures constructed using ice.

A standard North Slope tundra ice road is typically 35 feet wide and 6 inches thick, with a 3 to 5 percent maximum grade. Roughly 1,000,000 gallons of water are required per mile of ice road construction. Delineators are installed every 50 feet on alternating sides of the ice road for visibility.

Route planning is the first step in the ice road construction. The proposed route must consider several factors including the availability of water resources; cultural sites; polar bear dens; and site topography and surface features such as tussocks, low lying areas, steep banks and side hills. Visually evaluating the planned route by flying is conducted with the route adjusted as needed. In addition, thermistors may be installed during the summer and fall along the planned route to monitor ground temperatures. The ADNR/DMLW may allow site specific access prior to the general tundra opening using the temperature data.

The ice road route is surveyed and staked in preparation for construction. In addition, the route may be pre-packed to reduce the insulating effects of snow and extend the ice road life. Side water casting is also conducted concurrent with pre-packing to further reduce snow insulating effects and to protect the tundra with a layer of ice. Construction of the ice road is initiated using an articulated water truck, also referred to as a Water Buffalo, and loader to pack down snow and create an ice layer to protect the tundra for the remainder of construction. The actual road construction entails the spreading of ice chips and/or snow with a grader, then adding water to saturate the material. As it freezes, the ice road is created. The ice road is completed by placing a freshwater cap and installing the delineators.

Snow, ice chips and water are recovered from permitted lakes for the construction of the ice road. The pumps used to extract water are equipped with an approved fish screen which limit the flow rate, generally ranging from 200 to 800 gallons per minute depending on the screen mesh size.

Oil and gas exploration activities also require the construction of sea ice roads, ice pads, ice bridges and ice airstrips. Similar route planning and construction efforts are conducted for the

construction of these ice structures. The ice thickness for sea ice roads, ice bridges and ice airstrips constructed over lakes or the sea is built up using conventional tundra ice road techniques discussed above, with pumping by free flooding the route using the underlying water source, or a combination of both techniques.

Specific activities are conducted at the end of the season to close out ice roads. Lakes that were used as a water source are inspected. Pump houses installed in the lakes are removed. Snow is used to backfill the hole where the pump house was removed. Stream crossings are cut per an approved plan with snow piles placed on each side of the crossing and marked with red dye. In addition, snow piles are placed at the entrance to the ice road to block future travel. Delineators and other material are removed from the ice road with the route flown in the summer to remove remaining debris.

2.3.3 Use of Other Company Pipelines – Interfacing with Infrastructure

Mr. David Hart, representing Pioneer Natural Resources, Alaska (Pioneer), discussed the infrastructure sharing between Pioneer and CPAI for transporting fluids produced at their offshore Oooguruk drill site (ODS) to TAPS. A copy of Mr. Hart's PowerPoint presentation is included in Appendix L.

The ODS, located approximately 5 miles offshore in Harrison Bay of the Beaufort Sea, is a self-contained drilling complex located on a gravel pad island. Approximately 5.7 miles of buried offshore subsea flowline and 2.4 miles of onshore flowline transports fluids between the ODS and Pioneer's Oooguruk onshore tie-in pad (OTP) where the produced oil, water and gas are metered. The OTP is positioned adjacent to the Kuparuk Drill Site 3-H owned and operated by CPAI. Fluids leave the OTP and tie into Drill Site 3-H then enter shared pipelines and facilities for processing. Six miles downstream, fluids enter CPAI's Central Production Facility (CPF) 3 for gas and liquid separation; fuel and lift gas treating, compression and delivery; and seawater pumping and delivery. Final processing of the production stream is conducted at CPAI's CPF-1 or CPF-2. CPF-1/CPF-2 are also the delivery point of sales for crude into the Kuparuk pipeline, the common carrier pipeline that transits the North Slope and ties into Pump Station 1 at the start of TAPS.

A Production Processing & Services Agreement (PPSA) was made between Pioneer and CPAI to define the infrastructure-sharing relationship. The PPSA comprises four primary components including the fee structure, backout compensation, fluid measurement, and conformance.

The financial portion of the PPSA is based on a negotiated fee structure including seven specific quantifiable components that can be accounted for on a daily basis and invoiced monthly. The components include fees for facility use, facility operation and maintenance, excess gas

compression, makeup gas infrastructure, makeup water, high pressure pump, and CPF-3 fuel gas allocation. The fees escalate annually based on a consumer price index for industrial equipment. A public tariff is also charged for use of the Kuparuk pipeline.

Pioneer also provides backout compensation to CPAI for the inferred reduction in capacity to produce their own fluids. CPAI developed a model to calculate backout compensation that is based on CPF-3 gas capacity, water injection hydraulics, production hydraulics and maintenance activities.

Measurement of the fluids is conducted at Pioneer's OTP prior to entering shared infrastructure. Metering includes measurement of the volume of oil and water using a Schlumberger VX multi-phase meter; produced gas using a Daniels Junior ultrasonic meter; return gas from the CPF-3 using a Daniels Senior ultrasonic meter; and return water from CPF-3 using a Rosemont vortex meter.

The final component of the PPSA focuses on conformance of the fluids entering the CPAI's infrastructure and repercussions for interference that Pioneer may cause for use of the facilities. Conformance metrics set for fluids include solids content, temperature, H2S and CO2 content, gas heating value, oil gravity and chemical/substance limitations. Pioneer is responsible to provide damage reimbursables for system interferences such as increased chemical usage. The PPSA also specifies that CPAI may shut off Oooguruk production for operational upsets that are not addressed in a timely manner.

In summary, the PPSA provides for coordinated use of pipeline and facility sharing of existing infrastructure. It avoids duplication of infrastructure, reduces the impact to the environment and provides viability for smaller companies to operate on the North Slope due to less capital, shorter schedule and flexible operations.

2.3.4 Pipeline Inspection and Maintenance

Mr. Ben Schoffmann, representing Kakivik Asset Management and CCI Industrial Services, provided an overview of pipeline inspection and maintenance operations on the North Slope. A copy of Mr. Schoffmann's PowerPoint presentation is included in Appendix M.

Pipeline inspection and maintenance are conducted for two principal reasons. First, over time everything gets old and does not work as well as when initially installed. Second, regular monitoring, exercise and maintenance are critical to long term health. Corporate responsibility to protect the environment, people and assets; regulatory requirements set forth by the US Department of Transportation and ADEC; and industry standards for pipelines and piping system components are the drivers for performing routine inspection and maintenance on pipelines.

Pipeline corrosion and damage can result from both internal and external mechanisms. Internal mechanisms include erosion from solids content or excessive fluid velocities; corrosion resulting in general or localized damage, preferential weld attack and stress cracking; and build up of scale and solids. External mechanisms for pipeline damage result from 3rd party damage such as impact from a vehicle, wind-induced vibration (WIV) causing piping fatigue and eventual failure, and corrosion-under-insulation (CUI).

Techniques are employed to maintain, monitor and inspect pipelines based on the relevant design and purpose of the pipeline. Operation monitoring is conducted routinely to track, monitor and manage pipeline pressures, flows, volumes and chemistry. The trends in the gathered data can provide advanced warning of a potential concern or problem. Corrosion inhibition is provided through inclusion of chemical additives used to treat pipeline fluids to mitigate pipe corrosion, dropping out scale or emulsions. Corrosion coupons and probes are tools used to monitor corrosion at a specific location along a pipeline. Maintenance pigging is utilized to clean a pipeline by removing water, sludge/wax, corrosion products, and bacterial build up. Internal "Smart Pigging" is employed to assess internal and external corrosion and erosion, scale sludge, impacts, and manufacturing defects.

External inspections of pipelines are conducted for non-piggable lines, to verify "smart pig" findings, and to assess specific areas of concern. External methods are less invasive to the pipeline, typically have less operational impact and provide real-time results. Techniques include ultrasonic (UT), weld x-rays, visual observations, infrared thermography (IR), profile tangential radiography, and long-range guided wave ultrasonic testing (LRUT).

CUI occurs at every facility, refinery, plant, and production area that has insulated piping and is affected by the surrounding environment, line temperature, insulation and coating types and the jacket integrity. CUI is therefore best controlled in the design stage where the pipe exterior coating, insulation and jacket type, and insulation joining/banding systems at welds are specified. A CUI inspection program is a must, despite pipeline design, because over time CUI will occur.

Pipeline maintenance is conducted to repair internal corrosion through removal of the corrosion product, in-situ coating applications and use of sleeves, clock-springs and cut-outs; to mitigate WIV through installation of vibration dampeners; to repair damaged pipe insulation; and to mitigate CUI through re-insulating and re-sealing. Prior to implementing the maintenance, the correct pipe must be identified and marked.

Execution of pipeline maintenance is contingent upon pipeline access. If the pipeline is off-road, tundra access may be needed which requires permits and annual reports. Elevated work platforms including scaffolding may need to be erected to reach the pipeline. A floating work

platform may need to be permitted and constructed to access pipelines suspended over water or ice that is too thin to support equipment loads. Rope access systems are also used in lieu of scaffolding or work platforms. Line lifts may be required to provide access to pipe saddles. Line lifts may comprise crib stacks with air bag systems, hydraulic jacks, loaders, cranes, and beam-lifting clamps. Finally, buried pipeline maintenance requires excavation and trenching.

2.4 Session 4 – Aboveground Pipeline Concerns

Six presentations were given during Session 4 – Aboveground Pipeline Concerns.

2.4.1 Integrity Management Program – An Approach for Managing Station Facility Risk

Mr. Eric Coyle and Mr. Brian Yeagley, representing Integrity Solutions, LTD, discussed facility risk ranking and presented a case study of how risk analysis methodology was used to prioritize inspection frequency of piping circuits for a production facility. A copy of Mr. Coyle's and Mr. Yeagley's PowerPoint presentation is included in Appendix N.

Facility risk ranking can be applied to various asset classes including oil and gas pipelines, gas distribution systems, oil and gas station facilities, and oil and gas facility production systems. A risk algorithm used to calculate Risk of Failure (ROF) is used in the risk ranking approach. ROF is the product of the Likelihood of Failure (LOF) times the Consequences of Failure (COF).

The LOF is a function of nine standard threats as defined in American Society of Mechanical Engineers (ASME) B31.8S. Other asset-specific threats on the North Slope are considered in determining LOF such as ice plugs and wind-induced vibrations (WIV) causing fatigue. Each threat has an exposure index that indicates the likelihood of force or failure mechanism reaching the asset when no mitigation is applied; a mitigation index that is based on the actions that are taken to keep the force or failure mechanism off of the asset; and a resistance index that is a function of the asset's ability to resist a force or failure mechanism applied to the asset. Each individual threat score is equivalent to the exposure threat remaining after applying mitigation and resistance, or in other words, the non-mitigated and non-resistant portion of the exposure from a threat. The LOF is the likelihood of failure from each individual threat mechanism as defined using the "OR Gate" concept. The "OR Gate" concept developed by Kent Muhlbauer is used to minimize bias of the LOF as a result of an asset having both individual high and low threat mechanisms.

Two tools are typically used for evaluating risk scores calculated for an entire system or facility. First, an ROF Ranking Matrix is generated for each asset by plotting the COF on the x-axis and LOF on the y-axis. In this matrix, the ROF increases as you move from the lower left to the

upper right on the plot. The second tool utilizes a component (or asset) ROF histogram that plots the ROF on the x-axis and the component frequency on the y-axis. The component ROF histogram tool was used in the following case study.

Risk ranking was conducted on the piping system for a production facility in a highly visible area. The ROF was calculated for each of the 1,400 pieces of unique pipe at the facility including piping for sour gas, sour crude, sweet gas, sweet crude, water, air, and other treatment products. The risk ranking challenge was how to apply the data to prioritize inspections of the 1,400 components to reduce risk to the facility. The data were plotted on a component ROF histogram such that the risk distribution, median, and standard deviations could be determined. Four risk tiers were determined using these statistical measures, with Tier 1 representing the highest risk components (ROF greater that the median plus 2 standard deviations) and Tier 4 the lowest risk components (ROF less than the median). A prevention and mitigation plan was then developed that defined the frequency of inspection for components falling within each tier. Each year the facility risk is re-ranked as the components within specific tiers are inspected and their resulting risk ranking changes.

An operator may want to conduct up-front planning to accommodate risk ranking for either an existing or a new facility. The operator should consider factors such as anticipated threats; how the mechanical integrity of their system will be handled, what assessment methods will be employed, what type of preventative and mitigative measures will be used and how will they be prioritized. The biggest consideration an operator must decide is what level will the risk ranking be conducted. Risk ranking can be applied on a broad level such as facility versus facility basis or a detailed level such as pipe versus pipe, as with the case study risk ranking. The component that is selected is the lowest level at which the ROF will be calculated and, therefore, is the level at which the data will be managed.

2.4.2 Pipeline Risk Assessment: The Essential Elements

Mr. Kent Muhlbauer, representing WKM Consultancy, provided an overview of the current state and essential elements of pipeline risk assessment. A copy of Mr. Muhlbauer's PowerPoint presentation is included in Appendix O.

A pipeline risk assessment is the centerpiece of a regulatory Integrity Management Program (IMP) because the risk assessment provides two critical outputs: how often integrity reassessments are conducted and whether additional preventative and mitigative measures are needed. Mr. Muhlbauer explained that risk assessment techniques and methodologies currently in industry standards and regulatory guidance do not adequately meet the objectives of an IMP. Further, industry has common complaints regarding risk assessments including not trusting the results, not being able to use the results, not understanding how the assessment calculates risk

and whether the assessment methodology is still acceptable. The Pipeline and Hazardous Materials Safety Administration (PHMSA) has also raised concerns regarding weaknesses and limitations of simple index models currently used for risk analysis. To respond to these concerns, a modern pipeline risk assessment needs to be developed that complies with the regulatory IMP.

Eight essential elements to be included in a pipeline risk assessment have been identified to make pipeline risk assessment meaningful, objective, and acceptable to stakeholders. These essential elements are designed to supplement, not replace, existing guidance, recommended practice, and regulations. A brief summary regarding each essential element is provided below.

1. Measurements in Verifiable Units. The first step in risk assessment is defining failure. The broadest definition of failure is not meeting the intended purpose while a more specific definition is loss of integrity or a spill. By defining failure, you define what the risk assessment is measuring. The estimates of probability of failure (PoF) and CoF must be verifiable. PoF must capture the effects of length and time. Further, the frequency of consequence must be evaluated temporally (over time) and spatially (over space).

2. Proper Probability of Failure Assessment. Possible failure mechanisms must be included in the assessment of PoF with each failure mechanism measured for exposure, mitigation and resistance. Further, the theoretical remaining life estimate must be produced for each time dependent failure mechanism. Estimating the exposure threat includes time independent attacks such as third party errors or weather issues and time dependent attacks such as external and internal corrosion. Estimating the effectiveness of mitigation measures includes a measure of a strong, single measure or the accumulation of multiple lesser measures. Estimating resistance is a function of the pipe strength.

3. Characterization of Potential Consequences. The risk assessment must identify the full range of possible consequences including the most probable and the worst case scenario.

4. Full Integration of Pipeline Knowledge. The risk assessment must be inclusive of available information.

5. Sufficient Granularity. The risk assessment model must appropriately divide the pipeline into segments with no changing risks to eliminate compromises of using averages or extremes. A proper analysis will require a minimum of 10 to 20 segments per mile of pipeline with some current models containing thousands of segments per mile.

6. Bias Management. Since subjectivity cannot be completely avoided, a risk assessment must state the level of conservatism employed and be free of inappropriate bias that tends to force incorrect conclusions.

7. Profiles of Risk. The risk assessment must be performed at all points along the pipeline and produce a continuous profile of changing risks. Step profiles of risk should be avoided.

8. Proper Aggregation. The risk assessment must include a process for aggregation of the risks from multiple pipeline segments.

2.4.3 Structural Design

Mr. Paul Wallis, representing Michael Baker Corporation, provided an overview of structural design of cross-country aboveground pipeline support assemblies. A copy of Mr. Wallis's PowerPoint presentation is included in Appendix P.

A typical cross-country aboveground pipeline support assembly comprises a pipe saddle support assembly (also referred to as a rolled saddle plate), a horizontal support member (HSM), a cap plate, and a VSM. The rolled saddle plate functions are to help distribute the load from the pipe without damaging the pipe insulation and to control lateral and/or longitudinal movement of the pipe. The HSM is designed to support a variety of different loads imposed upon the pipeline system. The cap plate delivers the entire load from the pipeline through the HSM and into the VSM. The VSM is the foundation of the pipeline support assembly and can comprise up to four members per support location.

The pipeline support assembly is designed to accommodate different loading conditions both on the pipeline and on the support assembly. In their design, structural engineers "chase the load" meaning when the system is subjected to an external loading, they have to start at the point of application of that load and follow the load all the way through the structure into the ground. Typical loads include transverse loading to the pipeline such as wind loads, vertical loading to a pipeline including the self-weight of the pipeline and contents, and longitudinal loading often experienced due to slugging of product moving intermittently through the pipe. The pipeline design must also incorporate transient environmental loads from wind, earthquakes, snow and ice.

Principal design issues consider the pipeline influences on the support assembly, the soil structure interaction, and the structural design of the pipeline support assembly. Factors that are addressed regarding the pipeline include the pipe's size, wall thickness, content's density, and operating temperature as well as the number and alignment of the pipes. Soil structure interaction design must consider VSM settlement including differential settlement and jacking. The structural design also considers project-specific requirements including the basis for the design such as client-based specifications, code mandates and local conditions; limit states including strength and serviceability; and special design consideration such as durability, constructability and costs.

2.4.4 Limit States Design of Arctic Pipelines

Mr. Robert Appleby, representing ExxonMobil, discussed limit states design of Arctic pipelines. A copy of Mr. Appleby's PowerPoint presentation is included in Appendix Q.

Loss of containment is the key limit state for design of pipelines and may result in Arctic pipelines subjected to strains caused by ground deformation or movement of supports. Frost heave, thaw settlement, landslides, seismic motions, ice gouge and fault crossings are each potential causes of pipe deformation (strain), typically inducing longitudinal strain on short sections of pipeline. Resulting failure modes are compressive buckling of the pipe and tensile rupture of the pipe and welds.

In designing for large deformations using strain based design (SBD) limit states, the pipe wall thickness is first determined using conventional allowable stress design (ASD) which limits hoop stress to a fraction of the yield strength (typically 72 or 80 percent). The strain capacity of the pipe and pipe weld system is then derived from finite element model of the system. The model is based on the results of extensive full-scale pressurized tests using a comprehensive set of small-scale material property tests, and verified by limited full-scale pressurized testing with project pipe. The strain demand is estimated using large displacement non-linear pipe-soil interaction models. The model uses representative stress-strain properties of the pipe and load-displacement properties of the soil. In the design process, it is necessary to ensure that the maximum longitudinal strain demand is less than the longitudinal strain capacity with an adequate safety margin. The pipe wall thickness determined using ASD may need to be increased to ensure adequate strain capacity. In addition, the weld strength is typically designed to be greater than the pipe strength.

An operator implementing SBD technology must recognize that additional design and integrity management requirements are necessary to ensure operational integrity. Adequate route data needs to be collected to identify longitudinal loads the pipeline will be subjected to. Typically SBD is used if sections of the pipeline will be subjected to strains greater than 0.5 percent. Deformation monitoring and maintenance is recommended throughout operation of an SBD pipeline to ensure design integrity.

SBD limit states are an evolving technology with no uniformly adopted codified approach. Current codes and standards include some limited guidance but need to be further developed to provide more specific guidance for SBD. The codes and standards need to provide a distinction between SBD requirements for installation and operation, address the differences when pipeline configuration is controlled by imposed displacements or limited by geometric constraints, and provide requirements for estimating the tensile and compressive strain capacity.

2.4.5 Aboveground Pipeline Concerns: Wind-Induced Vibration (WIV)

Mr. Jim Hart, representing SSD Inc., provided an overview of current WIV design practices for pipelines on the North Slope. A copy of Mr. Hart's PowerPoint presentation is included in Appendix R.

Pipelines on the North Slope are subjected to sustained winds that may result in the buildup of vortex shedding that induces vertical pipeline oscillations, also referred to as WIV. The primary concern of WIV is high cycle fatigue damage at the pipeline girth widths. Pipeline characteristics that are more susceptible to WIV include smaller diameter pipes, longer pipeline span lengths, lighter pipe contents, pipeline routes that are more perpendicular to prevailing winds, and exterior lines on the leading edge of a pipe rack.

WIV on pipelines on the North Slope has been studied since the late 1980s. Multiple studies have focused on pipeline structural dynamics and aerodynamics, wind speed and direction statistics, and WIV mitigation methods. Testing equipment employed in these studies included accelerometers, displacement transducers, strain gages, and anemometers typically placed at or near pipeline supports and anchors.

Pipeline Vibration Dampers (PVDs) and Tuned Vibration Absorbers (TVAs) have been installed on pipelines on the North Slope to mitigate WIV. Over 30,000 PVDs are estimated to have been installed across the North Slope and are a well-accepted and proven technology for WIV mitigation. TVAs have been more recently developed and have been found to outperform PVDs for WIV mitigation in both lab and field tests. TVAs also improve upon PVDs with a longer life span and the ability to avoid under pipe clearance restrictions.

Pipeline structural dynamics incorporate key pipeline parameters such as diameter, span length, density of contents, wall thickness and location. Multi-span finite element modeling using the known pipe parameters is used to determine the pipeline dynamics including mode shapes, frequencies and modal stresses, and the stress in the pipe per inch of movement. Field pluck tests are performed to determine a pipeline's experimental frequency. Comparison of the experimental frequency with the model analytical frequency is used to validate the accuracy of the model.

Pipeline aerodynamics is a function of vortex shedding excitation which imparts a pressure fluctuation. The fluctuating lift force on the pipe is a complex behavior that depends on several parameters including the Reynolds number of the flow, the turbulence intensity of the flow, and the surface roughness upstream of the pipeline. Using these parameters, pipeline aerodynamics (WIV analysis) are modeled with a program called EXTRA. The model predicts the maximum

pipe displacements and stress ranges on pipelines that are un-damped versus mitigated with PVDs and TVAs.

2.4.6 Corrosion Under Insulation Prevention and Inspection

Mr. Mark Nelson, representing CPAI, discussed the prevention and inspection of CUI. A copy of Mr. Nelson's PowerPoint presentation is included in Appendix S.

CUI occurs between the pipeline and insulation in the presence of water and oxygen. The presence of chlorides, typically found in the polyurethane foam insulation or marine environments, can accelerate CUI. CUI affects both carbon and stainless steel piping, tanks, and vessels causing general corrosion, pitting and stress corrosion cracking.

A typical Arctic pipeline is coated with a factory-applied polyurethane foam insulation protected by galvanized sheet metal jacketing. A field-applied polyurethane foam insulation wrapped in additional metal jacketing with caulk and band clamps is placed at pipe welds. Water ingress typically occurs at these weld pack locations resulting in wet insulation and then CUI.

Many technologies have been developed to inspect a pipeline for CUI, however, one specific tool does not provide a comprehensive inspection. The data from multiple tools typically must be used together to determine if pipeline mitigation is needed. Smart pigging, or in line inspection, is used in piggable lines to gather quantitative data along the entire length of the pipeline. Smart pigging does not provide data regarding the insulation, only points where corrosion is already occurring in the pipeline. Automated tangential radiographic testing (ATRT) provides an image of the pipeline in the 6 o'clock position for detection of wet insulation and corrosion. ATRT does not identify CUI in other positions around the pipeline girth. Tangential radiographic testing (TRT) with a C-arm employs a manual hand-held device that provides a real-time x-ray of the pipe to detect corrosion and wet insulation. Manual radiographic testing (RT) provides similar information as TRT using a radiation source to expose film at the pipeline location being inspected. Infra Red (IR) is a quick technology that can scan for the presence of wet insulation but does not detect corrosion. Finally, LRUT is used to inspect below-grade pipelines for the presence of CUI.

Once CUI has been identified, mitigation techniques are used to repair and/or prevent further CUI. Typically, the pipeline will be stripped at the identified CUI location with the wet insulation removed, any corrosion removed, and an ultra-sonic inspection conducted to measure the wall thickness. The pipeline is then re-insulated in a manner to minimize water ingress and CUI. A layer of paste is applied to the pipeline which is then wrapped with Denso tape to

provide an initial water barrier. The pipeline is then re-insulated and sealed with a protective metal jacketing and gaskets.

CUI is best controlled in the design stage. Mitigation features that are being implemented on new pipelines include the use of insulation with a corrosion inhibitor, leaving a one-inch gap between the pipe and insulation so wet insulation does not contact the pipe, and installing a new saddle design that has a plastic liner between the pipe and saddle and slots to drain water. Even with implementation of these new mitigation features, inspection for CUI is still necessary.

2.5 Session 5 – Direct Burial Pipeline Concerns

Five presentations were given during Session 5 – Direct Burial Pipeline Concerns.

2.5.1 Geothermal Design of Warm Pipelines in Thaw Unstable Permafrost and Chilled Pipelines in Frost-Heaving Soils

Mr. Beez Hazen, representing Northern Engineering & Scientific, discussed the geothermal design of buried pipelines in thaw-unstable permafrost and in frost-heaving soils. A copy of Mr. Hazen's PowerPoint presentation is included in Appendix T.

Thaw settlement of the pipeline and/or pipeline right-of-way (ROW) occurs in thaw-unstable permafrost. Clearing trees and disturbance of vegetation along the ROW corridor generally leads to an increase in ground surface temperature that in permafrost areas will increase the seasonal thaw depth (active layer) resulting in thaw consolidation and surface settlement. The thaw depth and surface thaw settlement may continue to increase in areas of warm permafrost. By operating a pipeline continuously below freezing, settlement of the pipeline can be prevented; however, settlement of soil could still occur within the ROW.

Extensive experimental research has been conducted on the effects of vegetative cover on settlement in thaw-unstable permafrost by the US Army Cold Regions Research and Engineering Laboratory since the 1940s at their Alaska field station near Fairbanks. The measured thaw depths from the experimental research correspond well with model predictions based on day-to-day ambient temperatures and snow depths. Additional soil data collected during the Alyeska and Foothills Pipeline Yukon projects have been used to predict thaw strain for a wide range of soil properties and types. The information gathered from the former research is being used in finite-element modeling to determine the potential benefit of cycling pipeline temperatures to cause a pipeline to settle at the similar rate as the ROW.

Pipeline frost heave occurs when a chilled pipeline passes through unfrozen, frost-susceptible soil. A frost bulb is created by freezing of pore water and additional water drawn to the freezing

front causing the pipeline to heave upward due to an increase in the water volume as it freezes. Frost heave has been researched by industry under numerous projects since the 1970s including six test locations in Alaska by the Alaska Natural Gas Transportation System. Data gathered from the frost heave research have led to the development of equations that can be used to predict frost heave using conventional soil tests. Further, finite-element modeling can be used to accurately predict pipeline frost heave.

Mr. Hazen presented a study conducted by the North Slope Borough on a direct-bury utility system in Barrow prior to implementing the utility system in each of their villages. Instead of using utilidor-style burials, the utility pipes were insulated and buried with a fluid heat trace system. The study compared measured subsurface temperatures with predicted temperatures and was used to determine the design of the utility trench, specifically with respect to the boardstock insulation required to prevent thawing.

2.5.2 Design for Ground Motion Effects on Buried Pipelines

Mr. Toby Lovelace, representing Michael Baker Corporation, discussed the design of buried pipelines for seismic ground motion effects. A copy of Mr. Lovelace's PowerPoint presentation is included in Appendix U.

Earthquakes impact the design of buried pipelines due to induced ground motions. The majority of earthquakes result from movements between the tectonic plates covering the earth's surface. An earthquake imparts four types of waves through the ground: P-waves and S-waves that occur deeper in the lithosphere, and Love waves and Rayleigh waves which occur at the surface. The earthquake magnitude is most commonly quantified using the Richter magnitude which is based on a logarithmic scale of seismic wave amplitude. Earthquake magnitudes are also quantified using the surface wave magnitude which is based on the amplitude of surface waves with a period of 20 seconds and the moment magnitude which is based directly on forces over the area of the fault rupture.

Multiple seismic hazards result from earthquakes such as differential fault movement and ground rupture, ground shaking, liquefaction, landslides and tsunamis or seiches. Differential fault movement and ground rupture occur above faults. Pipeline design must consider differential movements if the route crosses over a fault. Many fault lines are known in Alaska including active faults that are crossed by TAPS. Ground shaking typically does not affect buried pipelines because they are encased in the ground. Liquefaction is a primary concern in the design of buried pipelines. Different types of liquefaction may cause damage to buried pipelines including lateral spread, flow failures, loss of bearing capacity, subsidence, and buoyancy of the pipeline which will tend to "float" in liquefied soil. In the design stage, the selected pipeline alignment

should avoid areas identified with potential landslide conditions. If a landslide occurs, it will typically take the pipeline with it.

Consequences of damage to buried pipelines resulting from seismic hazards include economic from loss of services and product; safety and environmental causing harm to facility personnel, general public and the environment; and interruption of vital delivery services (lifelines) to hospitals, emergency aid centers and other utilities such as heat, electricity, and water pumping. These operations are essential to maintain public safety and well being.

Research in earthquake engineering specifically with respect to buried pipelines has been ongoing since the late 1960s. Several guidance documents have been developed over the years for the seismic design of oil and gas pipelines; however, codes have not been established. The documents provide guidance regarding quantification of seismic hazards, design criteria considerations, differential ground movement effects, wave propagation effects, soil spring determination, and operation and maintenance considerations.

Design for seismic wave propagation is taken from the July 2001 "*Guidelines for the Design of Buried Steel Pipe*" by American Lifelines Alliance. The resultant strain induced on the pipeline is considered a result of the longitudinal axial strain with flexural strains from ground curvature typically considered negligible. The resultant strain is a function of the peak ground velocity generated by the earthquake, the apparent propagation velocity for seismic waves, and a factor of 2.0 for shear waves and 1.0 for surface waves. The effects of seismic wave propagation at bends in the pipeline must also be considered.

Design for permanent ground displacement must consider both axial and bending effects on the pipeline and is usually evaluated using finite element analysis. Factors that will affect the pipeline performance during ground displacement include the depth of burial, trench configuration, amount of ground displacement, fault crossing angle, soil properties, and effective unanchored lengths.

The performance of pipelines in historic earthquakes has generally met design expectations. Documented failures have typically been attributed to large ground deformation, landslides, liquefaction or ground failure resulting in pipeline cracks, ruptures, and buckling. In reviewing historic pipeline performance, modern construction methods and welding appear to be key to performance of the pipeline in earthquake events.

2.5.3 Pipeline Strain-Based Design and Assessment

Mr. Paul Carson, representing Michael Baker Corporation, discussed the use of strain-based design and assessment (SBDA). Mr. Carson's PowerPoint presentation is not provided because

Pipeline Research Council International (PRCI) owns the copyright. A copy of Mr. Carson's presentation summary included in the Conference Program is included in Appendix V.

SBDA is a complementary procedure to conventional stress-based design procedures for evaluating and ensuring pipeline integrity for potential pipeline hazards that can cause significant ground deformation. SBDA has been used for both offshore and onshore pipelines including TAPS. Code requirements are based on traditional stress-based design which focuses on the allowable stress limit (maximum elastic strain point) and the specified minimum yield strength (SMYS) of a material. The SMYS is defined at 0.5 percent strain which comprises some limited deformation. Although the SMYS may be exceeded, the pipeline may not actually rupture or buckle until as high as 3 to 5 percent strain. SBDA is used in combination with stress-based design to calculate the serviceability limit state at loads above the SMYS with the design margin located between the expected target strain demand and the pipeline strain capacity.

SBDA may be applied to sections of pipeline where significant ground deformation is anticipated. Environmental route loadings including seismic faulting, thaw settlement, frost heave, ice gouging, slope stability, liquefaction and subsidence may result in tensile and compressive strains at localized sections of the pipeline. SBDA has several features that differentiate it from the stress-based design approach including tighter material specifications and tolerances, QA/QC programs that ensure conformity from design through operations, tracking of materials from procurement through placement in the ditch, and routine operational monitoring to detect pipeline displacement.

Currently, limited guidance is available for SBDA in US regulatory codes. The Canadian Standards Administration Code Z662, ASME B31.4 and B31.8, American Petroleum Institute RP11.11 and the Det Norske Veritas each provide reference to the use of strain limits in pipeline design, however, no single "go-to" authority exists. The PRCI project was partly implemented to try to determine common definitions and terminology among the industry and regulators.

The concepts and tools to estimate strain demand are generally well advanced although there is limited availability of skilled and experienced analysts. In order to quantify strain demand, route hazards must be identified and evaluated through terrain unit mapping, collection of geotechnical data, and geothermal simulation. In addition, the anisotropic steel properties of the pipe and the anticipated large displacement or deformation are considered in determining the strain demand.

The strain demand is compared to the strain capacity in SBDA with the strain capacity focused on the identification of key material and fabrication parameters. Tensile strain capacity is a function of the weld procedures and weld acceptance criteria. Compressive strain capacity is a function of the pipe geometry including diameter and wall thickness. Statistical procedures,

finite element models, and full-scale validation tests are used to determine the acceptable strain capacity to be used in SBDA.

2.5.4 Lessons Learned from Ten Years of Tundra Restoration on Three Experimental Gas Pipeline Trenching Sites in Alaska

Dr. Bill Streever, representing BPXA, provided an overview of tundra restoration efforts at three experimental gas pipeline trenching sites. A copy of Dr. Streever's PowerPoint presentation is included in Appendix W.

In the winter/early spring of 2002, BPXA conducted a trenching experiment at three sites to test the ability and speed of their trenching equipment in permafrost conditions. The experiment included digging 12 to 13 trenches at each of the three approximately 37-acre sites, totaling approximately 3 miles of trench. The trenches were excavated in a similar manner at each site with the soil excavated and side cast along the edge of the trench, then reused to backfill the trench. Snow and ice accumulating in the trench during excavation and entrained in the excavated soil was left in place or placed back in the trench during backfilling. BPXA estimated the expected subsidence due to the frozen conditions and capped each trench with mounded soil up to 1.3 meters above grade.

The Washington Creek site is located about 30 miles north of Fairbanks in a highly visible location along the west side of the Steese Highway. The black spruce trees covering the site were cleared, chipped, and spread as duff over the surface of the site. The trench experiment was conducted with the trenches backfilled and mounded. Within four months, the trenches had collapsed due to subsidence caused by melting snow and ice entrained within the backfill and thermal erosion of the underlying permafrost. In addition, on-site and off-site hydraulic erosion was occurring due to surface water flowing across the site. Tunnels were forming in the ground and collapsing along with the trenches. BPXA received a notice-of-noncompliance from the Corps of Engineers due to off-site erosion beyond the site's permitted footprint. Mitigation measures were employed to attempt to stop the subsidence and hydraulic erosion. A silt fence was installed to keep eroded material from moving off site. Hay bales were placed at strategic locations within the trenches to intercept the surface water flow, reduce the flow velocity and decrease the erosion. Fiber mats were placed to stabilize surface soil. The site was also revegetated. The mitigation measures were successful in arresting the hydraulic erosion which in turn appeared to stop exacerbation of the thermal erosion. Ten years after the trenching experiment, the trench locations are still visible as the vegetation type that regrew in the mineral soil of the trenches is different from the vegetation which was re-established in the surrounding cleared areas where the spruce duff was placed. In addition, ground surface elevation measurements of the trenches collected in 2008 indicate that shallow ground ice may again be thawing causing additional subsidence of the trenches.

The MS3 site is located on the North Slope along the Haul Road approximately 3 kilometers south of Deadhorse. The site, covered with tundra, was underlain by permafrost that was visually apparent due to the polygonized-ground patterning formed by ice wedges and basins created in the near surface soil within the permafrost. Within several years of the trench experiment, portions of the trenches collapsed due to subsidence from thermal erosion. In addition, the trenching triggered melting of the ice wedges between the polygons which raised the question of whether the thermal erosion would continue across the site. Placement of additional fill and ditch-plugs comprises harvested tundra sod that were used to mitigate the thermal erosion. Due to the off-road tundra location of the test site, the mitigation measures could not be conducted during the summer time when the trenches were visible. The collapsed trench areas were therefore marked in the summer while visible. An ice road was permitted and constructed to access the site in the winter, then the estimated quantity of fill needed to backfill the trenches was placed in the marked locations with the sod placed on top. Ten years after the trench experiment, subsidence is still ongoing with the trenches widening. Vegetation is possibly starting to re-establish in some of the collapsed trench locations.

The Put 23 site is located at a bend in the Put River adjacent to a gravel mine at Prudhoe Bay. Mitigation of the trench subsidence that resulted from the trenching experiment was not required at Put 23 because the site was later slated to be mined for gravel.

Many lessons were learned from the three trench experiments. Mounding of soil over the trench is not a complete solution to prevent subsidence. Both short and long-term thermal erosion and potentially hydraulic erosion should be expected. Mitigation measures may need to be employed and must consider site specific factors such as whether revegetation through seeding will be effective, contractor availability, and site access. During the life of the project, the site owner should inspect the site, work closely with the agencies, conduct public outreach and systematic reporting, and be innovative.

2.5.5 River Crossings – What Have We Learned in 40 Years?

Mr. Wim Veldman, representing Wim M. Veldman Consulting Inc., provided an overview of lessons he has learned over the past 40 years in the design, construction and monitoring of pipeline river crossings. A copy of Mr. Veldman's PowerPoint presentation is included in Appendix X.

Five major flood events have occurred since the beginning of TAPS that provide valuable information regarding the design, construction and monitoring of pipeline river crossings. The events include the 1992 Sag River flood which was about twice as large as the design flood, the 1997 Glacier damn lake release on the Tazlina River which was larger than the design flood, the 2001 Sag River unusual icing conditions, the 1994 100-year flood event on the Middle Fork of

the Koyukuk, and the 2006 Pineapple Express storm in Valdez which resulted in a 100- to 500-year flood event. These events help address the questions "So What?" and "What If?" that must be considered in the design, construction, and monitoring of a pipeline river crossing. In summary, design for the anticipated river crossing conditions must be based on acceptable risks.

Design considerations for river crossings need to consider the flow and scour conditions so the pipe burial depth may be determined. At the beginning of TAPS, limited data were available for rivers north of the Brooks Range. Forty years later, sufficient data have been gathered for adequate flood frequency analysis for more recent North Slope projects. Unique conditions at crossing sites must be considered in flow analysis including the influence of lakes/wetlands resulting in "releases" of outlets in the spring, ice jam releases, and glacier dammed lake releases. As observed in the 1997 Tazlina River event, these type of releases may result in flood surges causing significant scour. Unique conditions can also impact water levels at river crossings due to spring floods, ice jam releases, and aufeis (icing that typically forms in areas experiencing cold with little or no snow conditions).

Scour must be considered in river crossing design including both general straight channel scour and local scour at bends, confluences, debris jams and structures. Typical design depth for local scour is 1.5 to 3.5 times the general scour depth. Local scour is considered more significant than general scour in river crossing design. Unique conditions for scour include spring scour over ice, ice jam releases, alluvial fan depositions, channel changes, debris flows, and thermal conditions. Bank erosion caused by high floods must also be considered in the river crossing design.

Various construction techniques have been developed over the years to accommodate both environmental and Arctic construction factors. Techniques for pipeline installation include frozen "dry" ditch and open cut "wet" ditch installation; flow isolation with flumes or by pumping; a Sauerman dragline for open cuts; horizontal directional drilling; and boring.

Over the past 40 years of pipeline river crossing design and construction, the following eight lessons have been learned:

- Adapt to conditions
- Schedule for conditions
- Challenge conventional design wisdom
- Challenge conventional regulatory wisdom
- Understand scope of commitment
- Utilize operational performance data
- Understand value of hands-on knowledge
- Utilize local knowledge.

2.6 Session 6 – Offshore Pipelines

Three presentations were given during Session 6 – Offshore Pipelines.

2.6.1 Year-Long Upward Looking Sonar Mooring Measurements of Sea Ice Keel Distributions: Implications for Ice Gouging

Mr. Ed Ross, representing ASL Environmental Sciences, Inc., discussed the use of upward looking sonar to collect measurements of sea ice keel distributions. A copy of Mr. Ross's PowerPoint presentation is included in Appendix Y.

The extent of sea ice in the Arctic has been measured since 1979 with data showing a long-term trend of decreasing extent. Design of offshore pipelines, however, must consider ice gouging which requires information on temporal and regional sea ice conditions. Parameters relevant to the design include the ice draft, keel geometry, velocity and momentum. Mitigation measures that may be used for ice gouging include towing the ice away from the pipeline, shielding the pipeline, and burial of the pipeline.

Upward looking sonar has been developed in order to collect pertinent data for the design of the offshore pipeline with respect to potential ice gouging risks. Historically, ice thickness was measured by augering through the ice. With the development of sonar, upward looking sonar was used on submarines in the 1950s and 1960s to gather information regarding sea ice. In the early 1990s, the modern, stationary upward looking sonar device was developed where the instrument was moored at a specific location to collect data over time. The upward looking sonar mooring can be equipped with instrumentation to measure multiple parameters including distance to the ice canopy, ocean currents, ice velocities, salinity and temperature.

ASL Environmental Sciences, Inc. has developed an Ice Profiling Sonar (IPS) that has a range resolution of approximately 2 centimeters, an adjustable sampling rate of 1 to 2 measurements (pings) per second, up to 5 target recordings per ping, and a data storage capacity of 1 to 3 years. The IPS is often co-deployed with an Acoustic Doppler Current Profiler (ADCP) that measures the ice velocities. A two-dimensional spatial profile of the ice canopy can be resolved by combining the IPS and ADCP data. IPS sensors have been deployed throughout the Arctic Ocean and have been used in other configurations to measure ice conditions in shallow water bodies such as rivers, lakes and near coastlines. The IPS can measure two massive ice features that are of concern to offshore pipeline design in the Alaska Arctic waters including large individual ice keels and ice hummocks.

The IPS data sets are used to create various products for use in the pipeline design. Monthly ice charts showing maximum ice draft distributions can be developed to show how sea ice develops throughout the year. For mooring locations with multiple years of data, a chart illustrating

maximum draft distribution over the entire employment period from year to year can be developed. Also, daily counts of features that pass over the IPS can be plotted. Extremal analysis is used to select extreme keels and return values for different recurrence intervals. The IPS data can also be used to distinguish between first-year and multi-year ice in order to categorize the stage of ice development.

2.6.2 Offshore Oil Pipeline Leak Detection Technologies for Arctic/Cold Regions

Dr. Premkumar Thodi, representing INTECSEA, provided an overview of leak detection technologies for subsurface offshore oil pipelines in Arctic regions. A copy of Dr. Thodi's PowerPoint presentation is included in Appendix Z.

Rapid and reliable leak detection for subsea pipelines is an important aspect of safe and economic oil and gas development in the offshore Arctic regions. Potential causes of pipeline leakage in the Arctic environment include high bending strain resulting from ground movement, ice gouging and strudel scour. Leakage may also occur due to failure of pipeline connections, valves and fittings; structural degradation from corrosion, erosion, and fatigue cracking; and other failure mechanisms including buckling, rupture, water-induced vibrations, and unsupported span. The consequences of a pipeline leak range from concerns regarding safety and environmental contamination to economic impacts from shut down of the operation, cleanup costs and a perceived negative reputation.

Key state and federal regulations require a leak detection system (LDS) on single and multi-phase flowlines. The Alaska State Regulation 18 AAC 75 stipulates a single phase pipeline should have a LDS that can continuously detect a daily discharge of at least 1 percent of daily throughput and flow verification through a computational pipeline monitoring system. The state regulations also stipulate that the entire circumference of multi-phase pipelines be contained and, if it is a pipe-in-pipe (PIP) system, the annulus be provided with a department approved LDS. The key federal regulations 49 CFR 195 and 30 CFR 250 provide the requirements for LDS on pipelines located in high consequence areas.

Three types of existing and emerging pipeline leak detection technologies are internal-based systems, external-based systems, and periodic leak testing systems. Preferred attributes considered for the selection of the type of LDS include sensitivity to large and small leaks, detection time, avoidance of false alarms, installation and operation challenges, ability to detect single and multi-phase flow conditions, proven track record and commercial availability.

Internal-based LDS use measurements of the internal fluid parameters such as pressure, temperature, density, acoustics, velocity and product data at interface locations to infer a leak in the pipeline. Typical internal-based LDS include line-balancing methods such as mass balance,

pressure monitoring systems, real-time transient monitoring, bubble emission methods and pressure safety low (PSL) switches. Internal-based LDS have been widely used in industry, can detect large leaks, and are relatively easy to install and maintain. Notable disadvantages associated with internal-based LDS include the limited ability to detect small, chronic leaks of less than 1 percent of daily through put; the limited capability to accurately establish the leak location; the systems are prone to false alarms; and the inability to use under low-flow or non-flow conditions.

External-based LDS measure physical properties such as temperature, acoustics, the presence of oil particles, and capacitance outside the pipeline exterior to infer a leak in the pipeline. Typical external-based LDS which are either fixed on the pipeline exterior or kept adjacent to the pipeline include capacitance sensors, hydrocarbon vapor sensing tubes, optical camera methods, biosensors, fiber optic cable (FOC) sensors, and acoustics. Key advantages of external-based LDS are the ability to detect small, chronic leaks, the capability to locate the small leak accurately, and use for continuous leak monitoring. Disadvantages include dependence on contact between the leaking fluid and the sensor, difficulty in quantifying the size and rate of small leaks, requirement for permanent installation, false alarms and difficulties associated with the installation and maintenance.

Periodic leak testing systems are not continuously monitoring LDS and are typically employed when a leak is suspected or for routine checks for a leak. Periodic leak testing systems include smart pigging, acoustic pigging, remotely operated underwater vehicle (ROV)/autonomous underwater vehicle (AUV) inspections, leak surveillance patrol using underwater gliders, subsea towed systems and remote sensing methods.

FOC is an evolving external-based LDS that provides continuous monitoring for pipeline leaks. The FOC sensing system relies upon distributed temperature sensing (DTS) and distributed acoustic sensing (DAS). The DTS detects a thermal anomaly such as an oil leak causing a local rise in temperature or a gas leak leading to local cooling. The FOC is the sensor and the data link for DTS. The principal of operation for FOC DTS is through the Ramen band and Brillouin band systems. The DAS acts as a hydrophone by capturing acoustic signatures generated by a leaking fluid. The requirement of the leaking fluid to contact the sensor is negated with DAS. The principal of operation for FOC DAS is through the Rayleigh band system which basically measures the minute strain effects on the FOC caused by acoustic vibrations arising from the leaking fluid.

Technology gaps that have been identified by industry for subsea pipeline LDS include false alarm reduction, system reliability, uncertainty of minimum thresholds of detection, long pipeline application, cable positioning, and life expectancy of LDS. To close the gaps currently found in the LDS technologies, the Joint Industry Project through Petroleum Research

Newfoundland and Labrador has been formed to address the technology gaps and enhance leak detection technology.

2.6.3 Subsea Arctic Pipelines - Design and Construction Challenges

Mr. Craig Young, representing INTECSEA, discussed the design and construction challenges for subsea Arctic pipelines. A copy of Mr. Young's PowerPoint presentation is included in Appendix AA.

A functional definition of a subsea Arctic pipeline is a marine pipeline subjected to Arctic loading and operating conditions such as sea ice, permafrost, remote location and a sensitive physical and social environment. Three pipeline/flowline bundles are presently operational in the Beaufort Sea including the PBXA Northstar pipeline bundle installed in the winter of 2000, the Pioneer Oooguruk flowline bundle installed in the winter of 2007, and the Eni Nikaitchuq flowline bundle installed in the winter of 2009. Other developments utilizing subsea Arctic pipelines are currently being evaluated.

Pipeline design is based on multiple codes and regulations with stress-based design always considered first to ensure compliance. Due to limit states associated with subsea Arctic pipelines, strain-based design is then used to design for the pipeline strain limit states. Strain-based design was used for both the Oooguruk and Eni Nikaitchuq flowline bundles.

Primary ice loading conditions on subsea Arctic pipelines include ice scour/gouge loading and sub-gouge seabed soil deformations. Most subsea Arctic pipelines, at least in the near shore, are buried due to potential ice loading. Design must also consider upheaval buckling where the pipeline "jumps" out of the trench. Sufficient backfill must be placed over the pipeline to keep the pipeline constrained. Permafrost thaw settlement must also be considered in the pipeline design. The heat bulb created by the pipeline bundle and ancillary utility lines may impact surrounding permafrost. Strudel scour causing seabed erosion can result from springtime river overflooding sea ice or from a rising pipeline bundle heat bulb weakening overlying ice. Both are unique Arctic loading conditions that should be considered in the pipeline design.

Pipeline design should consider specific elements such as the use of PIP construction for thermal insulation. Secondary functions of PIP include a means for leak detection and containment in the event of a pipe leak. It is noted that the strain capacity of the outer pipe is most likely less than the primary internal pipe and will fail first thus negating its function as secondary containment. The pipeline may be installed in either an open or closed bundle. Open bundles have been used in the Beaufort Sea subsea pipelines as closed bundles are more challenging to install. The subsea Arctic pipeline will most likely have a greater wall thickness to increase its strain

capacity to handle the anticipated loading conditions. The pipeline tie-ins and shore approaches will also need to be designed for unique Arctic loading conditions such as shoreline ice ride-up and erosion and permafrost.

Construction of the subsea Arctic pipeline can be conducted in the winter or summer; however, winter construction presents fewer construction challenges. The three existing Beaufort Sea subsea pipelines were each installed in winter. Winter construction is conducted from on top of the ice canopy overlying the pipeline route. The primary steps followed in the winter construction of the subsea pipeline include ice thickening to support the additional bearing pressures associated with the construction equipment; ice cutting and slotting which forms the trench through the ice along the route of the pipeline; trench excavation to remove soil to the design pipeline burial depth; pipeline make up and bundling which includes welding and assembling the pipe bundle on the ice; bundle installation to place the pipeline through the ice slot and into the formerly excavated subsea trench; and trench backfilling which must accommodate the excavated soil.

Once the subsea Arctic pipeline is installed, the pipeline is monitored for maintenance and repair. It is important to conduct surveys, monitoring and pigging to establish baseline conditions and then monitor changes to those conditions. In-line inspections include caliper, wall thickness, and 3-D geometry survey pigging. Site inspections are conducted at structure tie-in and shore approaches and remote valve stations. Seabed surveys evaluate coastal and seabed erosion, ice gouge and strudel scours, and trench backfill replenishment zones. Repair of a subsea Arctic pipeline is logistically difficult and should be avoided through conservatism in the pipeline design and scheduled monitoring efforts to conduct minor repairs.

2.7 Session 7 – Unresolved Challenges

Two presentations were given during Session 7 – Unresolved Challenges.

2.7.1 Inspection of Difficult-to-Inspect Pipelines: Kinder Morgan Canada's Experience

Mr. Nelson Tonui, representing Kinder Morgan Canada, Inc. (KMC), provided an overview of technologies used by KMC to inspect unpiggable pipelines. A copy of Mr. Tonui's PowerPoint presentation is included in Appendix BB.

Piggable pipelines are pipelines that can be internally inspected using conventional unidirectional in-line inspection (ILI) tools. Unpiggable pipelines are pipelines that are difficult to inspect with conventional ILI tools due to the piping characteristics. These characteristics

may entail limited access on one or both ends of the pipeline; dual diameter piping; multiple bends with unknown radii in the pipeline; presence of un-barred tees, off-takes and branches; no permanent launch and receive traps; low flow and low pressure conditions; and intermittent services.

KMC implemented a system-wide Facility Piping Inspection Program (FPIP) in 2012 to inspect unpiggable pipe segments located primarily at their tank farms, terminals and pump stations. The main drivers for performing the FPIP were the need to meet regulatory compliance and to promote pipeline integrity with the main integrity threat being metal loss due to internal and external corrosion. Since implementation of the FPIP, five types of inspection tools have been used to inspect more than 30 percent of the facility's unpiggable piping.

Tethered ILI tools can be used to inspect pipe segments that have only one point of entry. The ILI tool is pushed into the pipe segment using pressured nitrogen then pulled back out using a line tethered to the tool. KMC experimented on three separate pipe sections at one of their terminals with a tethered gauge tool. In each experiment they encountered difficulties as a result of residual liquid or vacuum remaining in the line. The experiments demonstrated the need to verify the line profile prior to using tethered ILI to help ensure the pipe is completely drained of fluid; to predetermine the maximum amount of pressure required to push the tethered ILI tool; and to provide adequate venting ensuring the absence of a residual vacuum.

Self-propelled tools are similar to tethered ILI tools except they do not require pressured nitrogen to move through the pipe. KMC inspected two crude oil lines successfully using a self propelled tool. They were unsuccessful in inspecting an iso-octane pipeline due to lack of lubricity and scale build up damage to the tool's onboard pumps. The experiments on the three lines suggested that the use of self propelled tools increased the chance of a successful inspection over a tethered ILI tool.

Free swimming ILI tools require two access points where the tool is launched from one point then received from the second point. KMC inspected two crude oil lines successfully where launching and recovery of the free swimming ILI tool was conducted at an in-line spool and blind flange locations. Inspection of an iso-octane pipeline failed with the tool becoming stuck three times and eventually requiring cutting of the pipe to free the tool. Low flow and physical properties of iso-octane (lighter, less viscous and lower lubricity) were determined to be the cause of the failure. The free swimming ILI experiments highlighted the need to consider the physical properties of the conveyed product, how it will affect the tool run, and why detailed tool tracking during the inspection is essential.

External Magnetic Flux Leakage (MFL) technology is relatively easy and inexpensive to run on accessible sections of above ground pipes and exposed sections of buried pipes. The tool is

essentially wrapped around then pushed along the pipe exterior. Prior to inspection, KMC validated the external MFL tool by measuring pipe anomalies with both the MFL tool and a conventional UT tool, then comparing the results. The results were considered acceptable, falling within a 10 percent range. Limitations of the MFL tool include incomplete coverage due to the need to move the equipment around supports and obstacles and the need to remove some types of coatings from the pipe exterior prior to inspection.

Guided wave inspection has been used by KMC to successfully inspect exposed sections of buried pipe for wall corrosion while the lines remain in service. Limitations of guided wave inspection include the presence of a heavy coating retarding the movement of the sound waves; interference from the presence of bends, welds and branches; and the lack of ability to differentiate between internal and external corrosion.

Through the results of their FPIP, KMC has concluded that there is no single tool for inspecting all unpiggable pipe segments. The pipeline characteristics must be known such that the proper inspection tool can be selected for a successful inspection. Further, tool runs in unpiggable pipe segments require extensive planning and hazard assessments by properly trained personnel.

2.7.2 Design Challenges of Arctic Pipelines – Technology Gaps and Advanced Analysis Solutions

Mr. Basel Abdalla, representing MCS Kenny, discussed the use of finite element analysis for the design of pipelines subject to three specific Arctic-related challenges: ice gouging, permafrost thaw settlement, and frost heave. A copy of Mr. Abdalla's PowerPoint presentation is included in Appendix CC.

Approximately 22 percent of the World Oil Reserve is located in the Arctic according to a statistic published by the United States Geological Survey in 2008. Many challenges that are related to the location, climate, environment and nature of the Arctic must be addressed in the design of pipelines in Arctic conditions. A specific concern is the environmental condition of zero discharge or zero emission. Finite element analysis (FEA) is being used in the design of Arctic pipelines to develop safe, innovative and economic solutions while reducing unnecessary conservatism. Specifically, FEA has been applied in the design of pipelines subjected to ice gouging, permafrost thawing, and frost heave.

Mitigation methods for ice gouging typically entail avoiding direct contact between the ice and pipeline via burial. In addition, the pipeline is buried two to three times deeper than the scour depth to mitigate potential pipeline strains induced via soil deformation. FEA is being applied to optimize the required burial depth, maintain pipeline integrity, determine tolerable permanent deformation, and reduce intervention cost. Primary challenges of ice scour modeling include the

need to simulate large soil/pipe deformations, complex soil conditions and the ice-soil-pipe contact. The Coupled Eulerian Lagrangian method is used in the FEA for modeling the interactions between the iceberg, soil and pipeline.

Permafrost thaw settlement occurs when a warm pipeline is buried in a permafrost area. A thaw bulb may form with the soil settling and inducing strains on the pipeline. The objective of FEA for permafrost thaw settlement is to simulate the thermal and mechanical interactions, differential settlement and pipeline response. The model is a three step analysis that simulates heat transfer using a 2D model, maps the thaw bulb profile using a 3D model, and predicts the thaw settlement and pipeline deformation. FEA is used in thaw settlement mitigation to design thermosyphons for permafrost stabilization.

Frost heave is induced on a cold pipeline due to the expansion of pore water upon freezing and the freezing of water that migrates to the cold front due to capillary suction. Three models have been developed to simulate frost heave including the Rigid Ice model, the Segregation Potential model, and the Porosity Rate Function model. The numerical analysis methodology is based on a three step process including the geothermal finite element analysis, frost heave modeling and pipeline strain calculations.

2.8 Pipeline Risk Assessment Essential Elements Workshop

Mr. Kent Muhlbauer, representing WKM Consultancy, conducted a half day workshop regarding essential elements of a pipeline risk assessment. A copy of Mr. Muhlbauer's workshop handouts is included in Appendix DD. The workshop targeted anyone interested in a basic knowledge of pipeline risk concepts and how they can be practically integrated into pipeline operations, maintenance, design, or regulatory compliance. The workshop was designed to equip attendees with the ability to recognize the essential elements of risk assessment, allowing for the subsequent set up and implementation of a comprehensive risk management program for pipelines as part of an overall safety management system.

TABLE 1 - SUMMARY OF CONFERENCE PARTICIPANTS

Function	Last Name	First Name	Participating Company or Organization
Sponsor	-	-	Alaska Department of Environmental Conservation
Sponsor	Hegna	Joe	URS Corporation
Sponsor	Lewis	Derek	Nalco Champion
Sponsor	Irwin	Vik Lord	Kakivik Asset Management, LLC
Sponsor	DeLaCruz	Jerome	ConocoPhillips Alaska, Inc.
Sponsor	St.John	Jeanine	Lynden Logistics
Moderator	Jessen	Julie	HDR Alaska, Inc.
Organizer	Terry	Tim	Shannon & Wilson, Inc.
Opening Remarks	Barrett	Tom	Alyeska Pipeline Service Company
Opening Remarks	Kent	Lynn	Alaska Department of Environmental Conservation
Keynote Speaker	Persily	Larry	Alaska Natural Gas Transportation Projects
Keynote Speaker	Tintera	John	Railroad Commission of Texas
Presenter	Abdalla	Basel	MCS Kenny, a Wood Group Kenny Business
Presenter	Appleby	Robert	ExxonMobil Development Company
Presenter	Brooks	Henry	ADNR Division of Mining, Land and Water
Presenter	Carson	Paul	Michael Baker Corporation
Presenter/Exhibitor	Coyle	Eric	Integrity Solutions, LTD
Presenter	Cribley	Bud	Bureau of Land Management
Presenter/Exhibitor	DeGeorge	Lynn	ConocoPhillips Alaska, Inc.
Presenter	Hart	David	Pioneer Natural Resources
Presenter	Hart	Jim	SSD, INC.
Presenter	Hazen	Beez	Northern Engineering & Scientific
Presenter	Head	Melissa	ADNR Division of Mining, Land and Water
Presenter	Hensley	William	Author, Professor, Alaskan Leader
Presenter	Iversen	Allison	ADNR Pipeline Coordinator's Office
Presenter/Exhibitor	Johnston	David	Bureau of Ocean Energy Management
Presenter	Ledgerwood	Chris	Alaska Frontier Constructors
Presenter	Lovelace	Toby	Michael Baker Corporation
Presenter	Muhlbauer	Kent	WKM Consultancy
Presenter	Nagel	Peter	Alyeska Pipeline Service Company
Presenter	Nelson	Mark	ConocoPhillips Alaska, Inc.
Presenter/Exhibitor	Ross	Ed	ASL Environmental Sciences, Inc.
Presenter/Exhibitor	Schoffmann	Ben	Kakivik Asset Management, LLC
Presenter	Streever	Bill	BP Exploration (Alaska) Inc.
Presenter	Thodi	Premkumar	INTECSEA, WorleyParsons Canada
Presenter	Tonui	Nelson	Kinder Morgan Canada, Inc.
Presenter	Veldman	Wim	Wim M. Veldman Consulting, Inc.
Presenter	Wallis	Paul	Michael Baker Corporation
Presenter	Walsh	Murray	Alaska Department of Transportation & Public Facilities
Presenter	Walton	Michael	ADNR Division of Mining, Land and Water
Presenter	Wieman	Eric	Peak Oilfield Service Company
Presenter/Exhibitor	Yeagley	Brian	Intergrity Solutions, LTD
Presenter	Young	Craig	INTECSEA

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Function	Last Name	First Name	Participating Company or Organization
Exhibitor			ASL Environmental Sciences, Inc.
Exhibitor			Bureau of Ocean Energy Management
Exhibitor			ConocoPhillips Alaska, Inc.
Exhibitor			Enduro Pipeline Services, Inc
Exhibitor			Integrity Solutions, LTD
Exhibitor			Kakivik Asset Management, LLC
Exhibitor			Lynden Logistics
Exhibitor			National Corrosion Center/TAMU/TEES
Exhibitor			SLR International Corporation
Audience/Exhibitor	Abrahams	Judith	ConocoPhillips Alaska, Inc.
Audience	Adleman	Jennifer	ADNR Division of Oil and Gas
Audience	Arlington	Jim	Afognak
Audience	Baker	Jeff	Michael Baker Corporation
Audience	Barrett	Joe	URS Corporation
Audience	Barthlow	Joanne	Alaska Department of Environmental Conservation
Audience/Exhibitor	Beighle	Bruce	Integrity Solutions, LTD
Audience/Exhibitor	Beighle	Brooke	Integrity Solutions, LTD
Audience/Exhibitor	Benedetti	Deanna	Bureau of Ocean Energy Management
Audience	Bentley	Marc	Alaska Department of Environmental Conservation
Audience/Exhibitor	Bentz	Christina	SLR International Corporation
Audience	Bitney	John	North Slope Borough
Audience	Blanche	Paul	ADNR Division of Oil and Gas
Audience/Exhibitor	Boldrick	Lauren	Bureau of Ocean Energy Management
Audience	Braun	Trisha	BP Exploration (Alaska) Inc.
Audience	Bray	Edward	CH2MHILL
Audience	Brown	Gerry	Alaska Department of Environmental Conservation
Audience	Brown	Michelle	BP Pipelines (Alaska) Inc.
Audience	Brown	Shawn	Tesoro
Audience	Brown	Tammas	ADNR Pipeline Coordinator's Office
Audience	Browne	Susan	ADNR Division of Oil and Gas
Audience	Brudie	Nina	ADNR Division of Oil and Gas
Audience	Bruno	Jeff	ADNR Office of Project Management
Audience	Bruns	Christopher	ADNR Pipeline Coordinator's Office
Audience	Burleigh	Roger	Alaska Department of Environmental Conservation
Audience/Exhibitor	Camden	Dani	Lynden Logistics
Audience/Exhibitor	Carella	Samuel	ConocoPhillips Alaska, Inc.
Audience	Carpenter	Carey	Affiliation not indicated on registration
Audience	Catalano	Steve	Cook Inlet Regional Citizens Advisory Council
Audience	Cataldi	Eugene	Alaska Department of Environmental Conservation
Audience	Ceder-Reinke	Philip	Alyeska Pipeline Service Company
Audience	Chiupka	Rod	Northland Fuels & Energy
Audience	Colonell	Joseph	ENVIRON International Corp

TABLE 1 - SUMMARY OF CONFERENCE PARTICIPANTS

Function	Last Name	First Name	Participating Company or Organization
Audience/Exhibitor	Cougan	Karen	SLR International Corporation
Audience	Crosby	Clara	UIC UMIAQ
Audience	Crosley	Marie	ADNR Gas Pipeline Office
Audience/Exhibitor	Csaszar	Albert	Bureau of Ocean Energy Management
Audience	Cullin	Matthew	University of Alaska - Anchorage
Audience	De La Pena	Gracia Mireya	Michael Baker Corporation
Audience	Delgado-Plikat	Josephina	ADNR Pipeline Coordinator's Office
Audience	Dennis	Alan	BP Pipelines (Alaska) Inc.
Audience	DeValpine	Andrew	ADNR Division of Oil and Gas
Audience	Dillon	Chris	Affiliation not indicated on registration
Audience	Dillon	Jessica	Dillon & Findley
Audience	Easton	John	ADNR Division of Oil and Gas
Audience	Eddy	Allen	ADNR Division of Oil and Gas
Audience	Eisler	Benjamin	Genesis
Audience	Eldred	John	BP (Alaska) Inc.
Audience	Emery	Nathaniel	ADNR Division of Oil and Gas
Audience/Exhibitor	Endorf	Ryan	ConocoPhillips Alaska, Inc.
Audience	Epstein	Lois	The Wilderness Society
Audience	Evans	Michael	Alaska Department of Environmental Conservation
Audience	Fan	Timothy	URS Corporation
Audience	Farley	Katie	ADNR Pipeline Coordinator's Office
Audience	Fernandez	Hever	University of Alaska - Anchorage
Audience	Fernando	Milca	ADNR Division of Oil and Gas
Audience	Finger	Thomas	Bureau of Land Management/Office of Pipeline Monitoring
Audience	Foley	Chris	Alaska Department of Environmental Conservation
Audience/Exhibitor	Forsythe	Michael	Lynden Logistics
Audience/Exhibitor	Fox	Pete	ConocoPhillips Alaska, Inc.
Audience/Exhibitor	Freeman	Jared	ConocoPhillips Alaska, Inc.
Audience	Friedman	Bonnie	Bureau of Land Management/Office of Pipeline Monitoring
Audience	Fueg	James	Donlin Gold
Audience	Gallagher	Tim	HDR Alaska, Inc.
Audience	Gano	Jake	Alaska Department of Environmental Conservation
Audience	Glaspell	James	URS Corporation
Audience	Goodwin	James	CCI Industrial Services, LLC
Audience	Greenan	Dawn	ADNR Division of Oil and Gas
Audience	Greenhill	Sanjana	Michael Baker Corporation
Audience	Grundman	Christopher	ADNR Pipeline Coordinator's Office
Audience/Exhibitor	Haller	Michael	Bureau of Ocean Energy Management
Audience	Han	Melanie	University of Alaska - Anchorage
Audience	Hansen	Eric	ENVIRON International Corp
Audience	Hansen	Valisa	University of Alaska - Anchorage
Audience	Harb	Kim	Alyeska Pipeline Service Company
Audience/Exhibitor	Harrison	Jacob	Lynden Logistics
Audience	Harvey	Susan	Affiliation not indicated on registration
Audience	Heath	Nolan	Bureau of Land Management/Office of Pipeline Monitoring
Audience	Heroy	Catherine	ADNR Pipeline Coordinator's Office

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Audience	Heumann	Jim	Alaska Department of Environmental Conservation
Audience	Hisey	Dan	Hisey and Associates, LLC
Audience/Exhibitor	Hochstatter	Jennifer	SLR International Corporation
Audience/Exhibitor	Hodson	Matt	Enduro Pipeline Services, Inc.
Audience/Exhibitor	Hodson	Shannon	Enduro Pipeline Services, Inc.
Audience	Isaacs	Jon	URS Corporation
Audience	Jarrett	Pat	ADNR Pipeline Coordinator's Office
Audience	Johnson-Kroon	Hannah	University of Alaska - Anchorage
Audience	Kaminski	Scott	ASRC Energy Services
Audience	Karn	Amy	ADNR Division of Oil and Gas
Audience/Exhibitor	Karnos	Nick	Lynden Logistics
Audience	Kelly	Colleen	STG Incorporated
Audience	Keppers	Craig	eni petroleum
Audience	Khadjinova	Rada	HDR Alaska, Inc.
Audience	Kiland	Daniel	Affiliation not indicated on registration
Audience	King	Kathleen	ADNR Division of Oil and Gas
Audience	Kirchner	Joseph	Golder Associates
Audience	Kirk	Timothy	University of Alaska - Anchorage
Audience/Exhibitor	Klieforth	Robert	SLR International Corporation
Audience	Klimasauskas	Edward	Bureau of Land Management/Office of Pipeline Monitoring
Audience	Kruse	Kim	ADNR Division of Oil and Gas
Audience	Kuckertz	Thomas	Prince William Sound Regional Citizens' Advisory Council
Audience	Lalla	Douglas	Bureau of Land Management
Audience	Lane	Nathan	Baker Hughes
Audience	Law	Timothy	Alaska Department of Environmental Conservation
Audience	Lee	Sophia	URS Corporation
Audience	Lever	DeJuan	LORD Corporation
Audience	Lindberg	Jennifer	Alaska Department of Environmental Conservation
Audience	Lindstrom	Joel	DOE NETL Arctic Energy Office
Audience	Liverance	Tom	Hilcorp Alaska, LLC
Audience	Longan	Sara	ADNR Office of Project Management
Audience	Lopez	Nekeisha	Bureau of Land Management/Office of Pipeline Monitoring
Audience	Lynn	Lorene	HDR Alaska, Inc.
Audience/Exhibitor	Mahajanam	Sudhakar	ConocoPhillips Alaska, Inc.
Audience	Maloney	Thomas	CH2MHILL
Audience	Manaois	Corazon	ADNR Division of Oil and Gas
Audience/Exhibitor	McCullough	Kristy	ConocoPhillips Alaska, Inc.
Audience	McDermott	Karen	Alaska Department of Environmental Conservation
Audience	McKay	Erin	Hilcorp Alaska, LLC
Audience	McWhorter	Rob	Argonne National Lab
Audience	Miller	Don	HDR Alaska, Inc.
Audience	MIller	Michael	Granite Construction Company
Audience/Exhibitor	Miner	Lydia	SLR International Corporation
Audience/Exhibitor	Moreau	Ian	Kakivik Asset Management, LLC
Audience/Exhibitor	Morningstar	Spencer	ConocoPhillips Alaska, Inc.
Audience	Morones	Mark	ADNR Gas Pipeline Office

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Function	Last Name	First Name	Participating Company or Organization
Audience	Munger	Michael	Cook Inlet Regional Citizens Advisory Council
Audience	Munson	Dianne	Alaska Department of Environmental Conservation
Audience	Murphy	Kevin	Enterprise Engineering
Audience	Myles	Melanie	ADNR
Audience	Neogi	Bhaskar	Alyeska Pipeline Service Company
Audience	Nodurft	Elizabeth	Alaska Department of Environmental Conservation
Audience	Noland	Laura	ENVIRON International Corp
Audience	Norris	Mark	LORD Corporation
Audience	Norton	Dave	ADNR Division of Oil and Gas
Audience	Oliver	Eileen	Bureau of Land Management/Office of Pipeline Monitoring
Audience	Olson	Robert	Bureau of Land Management/Office of Pipeline Monitoring
Audience	Olzack	William	BP (Alaska) Inc.
Audience	Osgood	LeeAnne	Shannon & Wilson, Inc.
Audience	Owens	Jennifer	ADNR Division of Oil and Gas
Audience	Oyster	Shane	STG Incorporated
Audience	Pascual	Erichson	University of Alaska - Anchorage
Audience/Exhibitor	Pate	Sara	ConocoPhillips Alaska, Inc.
Audience	Pavia	Clare	Alaska Department of Environmental Conservation
Audience	Pawlowski	Robert	ADNR Division of Oil and Gas
Audience	Peltier	Ann	Affiliation not indicated on registration
Audience/Exhibitor	Pettijohn	Pat	Kakivik Asset Management, LLC
Audience	Pierce	Sandra	ADNR Pipeline Coordinator's Office
Audience	Pish	Gene	LORD Corporation
Audience	Quimby	Thomas	University of Alaska - Anchorage
Audience	Raiha	Andy	University of Alaska - Anchorage
Audience	Ramert	Paul	ASRC Energy Services
Audience	Rasmussen	Diann	Bureau of Land Management/Office of Pipeline Monitoring
Audience	Rathert	Daniel	Resource Data, Inc.
Audience/Exhibitor	Reitmeier	Cameron	ConocoPhillips Alaska, Inc.
Audience	Renfro	Erin	Pioneer Natural Resources
Audience	Reub	Greg	ENVIRON International Corp
Audience	Riley	Michael	BP (Alaska) Inc.
Audience	Robinson	Brandon	BHI
Audience	Rockwell	Theodore	Battelle Memorial Institute
Audience/Exhibitor	Rodamaker	Richard	ConocoPhillips Alaska, Inc.
Audience/Exhibitor	Romberg	Barry	ConocoPhillips Alaska, Inc.
Audience	Rose	Laurette	Brooks Range Petroleum Corporation
Audience	Ross	Gary	Pioneer Natural Resources
Audience	Ruebling	Edward	URS Corporation
Audience	Ryan	Kristin	Alaska Department of Environmental Conservation
Audience	Saengsudham	Surath	Alaska Department of Environmental Conservation
Audience	Sanfacon	Keith	Alaska Department of Environmental Conservation
Audience/Exhibitor	Schmidt	Dan	ConocoPhillips Alaska, Inc.
Audience/Exhibitor	Schmidt	Kay	Bureau of Ocean Energy Management
Audience	Schorr	Betty	Alaska Department of Environmental Conservation
Audience/Exhibitor	Schuna	Ron	Kakivik Asset Management, LLC

TABLE 1 - SUMMARY OF CONFERENCE PARTICIPANTS

Function	Last Name	First Name	Participating Company or Organization
Audience	Shillington	Blaine	URS Corporation
Audience	Silfven	Laurie	Alaska Department of Environmental Conservation
Audience/Exhibitor	Singh	Probjot	ConocoPhillips Alaska, Inc.
Audience	Skerbeck	Damian	Kiewit
Audience	Slemons	Jonne	ADNR Division of Oil and Gas
Audience	Smith	Samantha	BP Exploration (Alaska) Inc.
Audience	Spiegel	Rebecca	Alaska Department of Environmental Conservation
Audience	Spivak	Yelena	BP Exploration (Alaska) Inc.
Audience	Stergiou	Elizabeth	Alaska Department of Environmental Conservation
Audience	Sterrett	Alyssa	Bureau of Land Management/Office of Pipeline Monitoring
Audience	Stevens	Christopher	SRK Consulting (U.S.), Inc.
Audience	Strang	Erin	Ahtna Engineering
Audience	Summers	Steven	BP (Alaska) Inc.
Audience	Sun	Hejian	BP (Alaska) Inc.
Audience	Swiss	Linda	Prince William Sound Regional Citizens Advisory Council
Audience/Exhibitor	Taylor	Ray	National Corrosion Center/TAMU/TEES
Audience	Thomas	Jonathan	LORD Corporation
Audience/Exhibitor	Timmerman	Sherry	ConocoPhillips Alaska, Inc.
Audience	Timmons	Saree	ADNR Division of Oil and Gas
Audience	Troutman	Alrona	ADNR Division of Oil and Gas
Audience	Turner	Don	BP Pipelines (Alaska) Inc.
Audience/Exhibitor	Wagner	Garey	ConocoPhillips Alaska, Inc.
Audience/Exhibitor	Wall	Rance	Bureau of Ocean Energy Management
Audience	Walsh	Jason	ADNR Pipeline Coordinator's Office
Audience	Warren	Edward	BP (Alaska) Inc.
Audience	Watkins	Robert	ASRC Energy Services
Audience	Wiggin	Mark	Brooks Range Petroleum Corporation
Audience/Exhibitor	Wijaya	Agus	ConocoPhillips Alaska, Inc.
Audience	Williamson	Conor	ADNR Division of Oil and Gas
Audience	Wilson	Craig	MWH Americas
Audience/Exhibitor	Wingerter	Joseph	ConocoPhillips Alaska, Inc.
Audience	Wood	Graham	Alaska Department of Environmental Conservation
Audience	Woolf	Wendy	ADNR Division of Oil and Gas
Audience	Wrabetz	Michael	Bureau of Land Management/Office of Pipeline Monitoring
Audience	Yares	Lori	ADNR Division of Oil and Gas
Audience	Yarmak	Ed	Arctic Foundations, Inc.
Audience/Exhibitor	Young	Kathleen	ConocoPhillips Alaska, Inc.

TABLE 2 - SUMMARY OF CONFERENCE PRESENTATIONS

Session No.	Presentation Title	Presenter Name(s)	Company/Agency Name	Presentation Summary
Day 1 - Opening Remarks	Opening Remarks	Lynn Kent	ADEC Deputy Commissioner	The overarching goal of the conference is to minimize risk to Alaska's environment while supporting existing and new exploration and development. The five main conference objectives are 1) to inform entrants to the Alaska oil and gas industry of the unique operating environment; 2) to share knowledge of current best practices, proven technologies, and lessons learned for challenges unique to pipelines in the Arctic and cold regions; 3) to inform industry and the public with federal and state regulations and oversight; 4) to have an appreciation of the public process; and 5) to avoid preventable environmental impacts.
1: Alaska Specific Regulations	State Pipeline Coordinator's Office	Allison Iversen	State Pipeline Coordinator's Office (SPCO)	This presentation provided an Introduction to the SPCO - the Role of SPCO within ADNR - Alaska Statute 38.35 – The Right-of-Way Leasing Act - Jurisdiction pipelines - Coordinating with agencies; SPCO flow charts - Communication protocol - State and Federal processes - Reimbursable Service Agreements - Lease adjudication and Joint Pipeline Office (JPO) - Application information - Commissioner's Analysis and Proposed Decision - Lease elements and stipulations - Multi-agency coordination - JPO agencies; SPCO sections - Right-of-way - Engineering - Compliance; Conclusion - Annual report - Website information
	Update on Oil & Gas Activities for BLM-Alaska	Bud Cribley	Bureau of Land Management (BLM)	Bureau of Land Management Alaska State Director Bud Cribley provided an overview of the 2013 Integrated Activity Plan/Environmental Impact Statement Record of Decision for the National Petroleum Reserve in Alaska (NPR-A) and the working group that the Record of Decision directed be established to provide collaboration and continued dialogue with North Slope communities, organizations, and Alaska Native corporations. Cribley also provided information on BLM's upcoming NPR-A lease sale and development projects and concluded with a review of BLM-administered oil and gas activity outside of the NPR-A.
	Offshore Oil Pipelines	David Johnston	Bureau of Ocean Energy Management (BOEM)	Within the U.S. Department of the Interior, the regulatory authority governing the installation of pipelines on the Outer Continental Shelf (OCS) is shared between the BOEM and the Bureau of Safety and Environmental Enforcement (BSEE). Operators seeking to construct a pipeline on the OCS need to provide BOEM and BSEE with information regarding the design, installation, and operation of pipelines. BOEM's role in the regulatory process governing pipelines is broad and overarching, and focuses on the assessment of the environmental impacts and geological hazards along proposed pipeline routes. BSEE's role is technical, and focuses on pipeline design standards, pipe specifications, geotechnical considerations, and safety provisions. As part of BOEM's regulatory process, any proposal to construct a pipeline on the OCS must be reviewed and thoroughly vetted to ensure that the appropriate pipeline route was selected. Shallow hazard surveys need to be conducted and the necessary environmental data collected by industry. This information is submitted to BOEM under a Development and Production Plan (DPP), which would describe the development project including plans for pipeline construction. BOEM then reviews the DPP under 30 CFR 550.241-262, conducts environmental analysis under the National Environmental Policy Act, discusses the safety and suitability of the plan with BSEE, and consults with other Federal agencies, Federal recognized tribes, the State of Alaska, and concerned stakeholders. BOEM renders a favorable determination if it concludes the project can be done safely, without unreasonably interfering with other users of the OCS, and does not cause undue harm or damage to the human, marine or coastal environment. BOEM generally prefers a pipeline to be constructed for the safe and reliable transportation of hydrocarbons retrieved in the Alaska OCS. As a condition of an OCS lease, BOEM will require the construction of the pipeline: (a) if pipeline rights-of-way can be determined and obtained; (b) if laying such pipelines is technologically feasible and environmentally preferable; and (c) if, in the opinion of BOEM, pipelines can be laid without net social loss. Net social change takes into account any incremental costs of pipelines over alternative methods of transportation and any incremental benefits in the form of increased environmental protection or reduced multiple-use conflicts. BOEM provides appropriate analytical and comprehensive oversight if a pipeline is proposed for development for any OCS leases. Several energy companies have active OCS leases, including Shell, ConocoPhillips, BP, and Statoil. In recent years, Shell is the company most active on the Alaska OCS, initiating the drilling of two exploratory wells in 2012 (one well at its Burger Prospect in the Chukchi Sea and the other well at its Sivulliq Prospect in the Beaufort Sea), and more recently collecting geological data along possible pipeline routes from various lease blocks in the Chukchi Sea to onshore. BP is also actively pursuing development of its Liberty Prospect in the Beaufort Sea. BOEM anticipates that BP will submit a DPP for the Liberty Prospect by the end of 2014.
2: Stakeholder Involvement and Land and Water Use	The Complex Nature of Federal and State Involvement in the Construction and Operation of the Trans Alaska Pipeline System	Peter Nagel	Alyeska Pipeline Service Company	This presentation described the involvement of federal and state agencies in permitting and monitoring the construction and operation of the Trans Alaska Pipeline System. The system, owned by four oil and gas companies (BP Pipelines (Alaska), Inc., ConocoPhillips Transportation Alaska, Inc., ExxonMobil Pipeline Company and Unocal Pipeline Company), comprises a 48-inch diameter oil pipeline crossing the state from the Arctic Ocean to Prince William Sound and including the Valdez Marine Terminal where tanker ships are loaded. The presentation described select successes and challenges of engaging the public agencies in permitting and monitoring concentrating on the two major land-management agencies, the U.S. Bureau of Land Management and the Alaska Department of Natural Resources.
	Orchestrating the Permit Process for a North Slope Development	Lynn DeGeorge	ConocoPhillips Alaska Inc.	Obtaining permits from Federal, State, and Local agencies becomes more challenging each year. What does it take to obtain permits for a project on the North Slope of Alaska? Who are the stakeholders? What is the timeline and where do you begin? ConocoPhillips provided an overview of the process from exploration through production. Recently permitted projects were used to provide timely examples of what to expect when permitting a major development.
	Roads to Resources - Roads in Cold Places	Murray Walsh	Alaska Department of Transportation & Public Facilities	This presentation described: 1. Roads to Resources (R2R) Initiative - Review of current and recent R2R projects with a focus on cold regions and the Arctic. Criteria and background for R2R project selection. Brief review of financial realities for surface transportation. Review of the issues that arise with proposals to extend roads to places that are or were previously isolated. 2. Permafrost - Review of permafrost realities in Alaska. 3. Research on Mitigation - Brief review of Beaver Creek and various Canadian and Alaskan activities. Examples from elsewhere. 4. Bottom Line - Pay now or pay later.

TABLE 2 - SUMMARY OF CONFERENCE PRESENTATIONS

Session No.	Presentation Title	Presenter Name(s)	Company/Agency Name	Presentation Summary
2: Stakeholder Involvement and Land and Water Use	Native Alaskan Concerns and Interface	Willie Hensley	Author, Professor, Alaskan Leader	The presentation provided an overview of the interactions of the indigenous people of Alaska with the oil and gas industry. The oil industry helped resolve land conflict issues of the Alaska Natives because it helped resolve their own problem of cleaning up the leases legally and getting a right-of-way for TAPS that included the Alaska Natives in the construction and operation of the pipeline. Alaska indigenously-owned corporations have since been an integral part of the operation of TAPS. If there is a pipeline to be constructed in the future, Alaska indigenously-owned entities will want to be a part if it makes business sense and is good for Alaska and Alaskans.
2: Stakeholder Involvement and Land and Water Use	Off-Road Travel on State Land - Management and Impacts	Melissa Head	Alaska Department of Natural Resources (ADNR) Division of Mining, Land, and Water (DMLW)	Off-road travel (tundra travel) and ice roads are the primary methods for accessing remote and road less areas on the North Slope of Alaska. Often such access is needed for pipeline inspection, maintenance, and installation activities. The ADNR - DMLW manages summer and winter tundra access to allow for the greatest access possible while minimizing impacts to the tundra. The DMLW consistently monitors snow, soil temperature, and weather conditions in support of winter off-road travel and ice road construction activities. Vehicle testing is also an important part of the DMLW program; low-impact vehicles are tested on the tundra to determine if they meet minimum standards for summer off-road travel operations.
	Summer and Winter Tundra Travel Permitting - Water/Ice Withdrawals	Michael Walton and Henry Brooks	ADNR - DMLW Water Resources Section	This presentation briefly covered the most pertinent laws, regulations and practices associated with authorizing water/ice withdrawals on the North Slope, or other cold regions, for use in constructing ice roads or other infrastructure associated with oil and gas exploration, development, operation and maintenance, including constructing and operating oil pipelines in Arctic/Cold Regions of Alaska. Under the Alaska Water Use Act (AS 46.15) and regulations thereunder (11 AAC 93), the ADNR - DMLW Water Resources Section regulates the use of water in the State. Water is defined to mean all water of the State, surface or subsurface, occurring in a natural state, except mineral and medicinal water. This includes freshwater, brackish water (located onshore or offshore), and ice. The use of seawater or the emergency use of water for protection of life or property is generally exempt unless DNR determines that the use should be regulated in the public interest. Seawater means water, taken from the sea or ocean, with salinity of 35 parts per thousand or greater. This regulatory authority extends to all areas in the State, regardless of the surface or subsurface ownership. Alaska Administrative Code Section 11 AAC 93.035 defines the term “significant amount of water”, and it also establishes when an application for a water right or an application for a temporary water use authorization must be submitted to the DNR Water Resources Section. Under AS 46.15.180, a person may not construct works for an appropriation, or divert, impound, withdraw, or use a significant amount of water without a permit to appropriate water, certificate of appropriation, or temporary water use authorization. Temporary water use authorizations are issued for a maximum of five years per authorization (including one extension if granted), and are used to authorize water/ice use related to exploration, construction and other transitory purposes. Winter-time under-ice water withdrawals from North Slope lakes and gravel pit water reservoirs are limited (to a specified percentage of calculated under-ice water volume) based on lake/reservoir depth, fish presence, and type of fish present, if any. With the necessary approval(s), gravel pit water reservoirs that do not contain fish may be dewatered to utilize the water and/or access gravel resources. Winter-time water withdrawals from North Slope rivers is only very rarely authorized (and under stringent conditions if authorized) due to low flows. Ice removal from lakes is restricted to areas of naturally grounded ice at the time of ice removal that is not more than four feet deep. Ice removal from gravel pit water reservoirs is prohibited for safety reasons. Depending on fish presence in a water source, Fish Habitat Permit(s) may also be needed from the Alaska Department of Fish and Game, Habitat Division.
Luncheon Keynote Speaker	The Over and Under of Effective Oil & Gas Regulation	John Tintera	Former Executive Director, Railroad Commission of Texas	The presentation provided an overview of effective oil and gas regulations. Three primary goals of an effective regulation, in order of importance, are 1) public safety, 2) environmental protection and 3) economic development. An effective regulation should cover the entire lifecycle of the regulated facility. The amount of regulation must be considered as over regulation will stagnate your industries while under regulation threatens public safety.
3: Logistics and Seasonal Access	Gravel vs. Roadless Construction	Chris Ledgerwood	Alaska Frontier Constructors - Nanuq, Inc.	This presentation discussed gravel mining and placing for North Slope construction for drill sites, roads and airstrips. Construction on Alaska’s North Slope has logistical challenges due to limited access, governmental rules and regulations, as well as Best Management Practices utilized in the oil industry. While many well sites from the larger reservoirs such as Prudhoe Bay, Kuparuk, Endicott and Milne Point can be reached on an all weather road system, many new drill sites are roadless and depend on airplanes and helicopters, crew boats and barges and/or ice roads for operational access. Gravel Road Access – Civil construction from gravel roads requires less infrastructure, has a larger season and the ability to stage materials required for the project. Roadless Areas – Civil construction from areas without gravel roads is seasonal, for minimal impact to the surrounding area, takes place in the winter after snow or ice roads are built and needs to be completed prior to the spring break up period. The concept of reducing the footprint impacted has increased construction of drill sites such as offshore gravel islands and remote drill sites with airstrips or helicopter landing areas.
	Ice Roads, Ice Pads, Ice Bridges, & Ice Airstrips	Eric Wieman	Peak Oilfield Service Company	Building pipelines on the North Slope of Alaska with minimal impact to the tundra requires the use of ice roads. Using water, snow and ice from lakes makes it possible to construct roads, pads, bridges and runways using the resources in the area where a pipeline is to be built. Once construction of the pipeline is complete the ice roads melt in the summer leaving little to no impact. This does require inspections to be completed by summer approved vehicles or in the winter. The presentation reviewed applicability to different Arctic areas, typical permitting requirements, standard equipment and crews, non-standard equipment, measures taken to ensure minimal spills or impact to the tundra, rig road vs. standard road, mobilization to remote locations via rolligon, side casting water, and prepacking with rolligons to reduce impact to tussocks and discussed different challenges with sea ice roads vs. tundra ice road and grounded vs. floating ice airstrips.

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3: Logistics and Seasonal Access	Use of Other Company Pipelines - Interfacing with Infrastructure	David Hart	Pioneer Natural Resources, Alaska	Pioneer Natural Resources, Alaska operates the Oooguruk Unit (OU) on the North Slope of Alaska. Production is collected and metered at the Oooguruk Tie-in Pad, then delivered in an Oooguruk multiphase pipeline to the ConocoPhillips-operated Kuparuk River Unit (KRU) Drill Site 3H. From this point KRU pipelines and infrastructure process OU crude into sales quality, and deliver to the Kuparuk Transportation Company (KTC) transit pipeline to Alyeska Pump Station 1. This presentation discussed in general terms the OU/KRU Production Processing and Services Agreement (PPSA) which governs all financial and operational interactions between Pioneer and ConocoPhillips. Processing fees, hydraulic backout, prorations, and other challenges in managing this complex agreement were discussed.
	Pipeline Inspection and Maintenance	Ben Schoffmann	Kakivik and CCI Industrial	This presentation summarized the types of inspections needed, inspection techniques and technologies utilized, and considerations and requirements for pipeline access as a function of location and season. Kakivik, an inspection company, performs non-destructive testing and pipeline inspection, including Corrosion Under Insulation (CUI) External Inspections using a variety of inspection techniques and associated equipment, including automated tangential radiography (ATRT), C-Arm Radiography, and Ultrasonic Testing (UT). When inspection or test results indicate potential corrosion, CCI Industrial is able to strip the insulation and coating from the pipe to allow direct inspection, again, by the inspection company. Data is gathered, appropriate repairs or mitigations are made, and coatings and insulation are returned to the pipe by CCI Industrial. Access to the pipelines influences the timing of both inspection and repair/refurbishment. While some pipelines were constructed with adjacent access roads, many are elevated above the tundra at some distance from service road networks. Personnel and vehicle tundra access is strictly governed by ADEC [ADNR], with seasonal considerations (ice roads, tundra travel utilizing specialty vehicles designed to minimize disturbance, etc.). The presentation addressed the types of inspections and maintenance repairs needed, how they are affected by access restrictions, and how technology can play a role in optimizing maintenance activities.
Day 2 - Opening Remarks	TAPS - America's Arctic Pipeline	Admiral Tom Barrett	Alyeska Pipeline Service Company	Opening remarks focused on the brilliant design, construction, operation and maintenance of the Trans Alaska Pipeline System (TAPS) from an operator's perspective. Operation of TAPS is challenging on a continuous basis. Risk to TAPS is dynamic due to changing conditions such as flow capacity, increased age, changing technologies, and reduction in efficiency. Operation and maintenance must be adjusted to meet the challenges of the changing conditions.
4: Aboveground Pipeline Concerns	Integrity Management Program - An Approach for Managing Station Facility Risk	Eric Coyle and Brian Yeagley	Integrity Solutions, LTD	This presentation used a real life case study of how a risk analysis methodology can prioritize production facility piping circuits for various assessment types and the frequency for which they should be assessed in an American Petroleum Institute (API) 570 type program. With this methodology, the data gathering, integration and risk ranking algorithm were reviewed along with how the risk results can drive down the likelihood of failure for the subject piping circuits. This program used the risk ranking methodology, a statistical analysis of the risk results, and a five-year 'look forward' to predict the potential for lowering risk and leaks at the production facility. The predicted outcome was compared to the real life results this program produced when also including prevention and mitigation measures in step with the assessments.
	Pipeline Risk Assessment: The Essential Elements	Kent Muhlbauer	WKM Consultancy	Risk assessment is the key ingredient to pipeline risk management. Pipeline design and O&M are essentially the practice of risk management. Current disparity in the practice of pipeline risk assessment is leading to concerns among stakeholders in the pipeline industry. In this presentation, a concise list of risk assessment essential elements was proposed, in order to inject a sufficient amount of standardization into this important practice.
	Structural Design	Paul Wallis	Michael Baker Corporation	Above-ground, cross-country pipelines must be supported in such a manner as to resist a myriad of environmentally and operationally induced loads. External effects of weather, including wind, earthquake, ice and snow must be accounted for not only in the design of the line pipe, but also in the structures which serve to support it. Internally transmitted stresses, such as thermal longitudinal expansion and contraction must be factored into the design of line pipe supports, which collect and individually resist these imposed forces. Existing below-grade conditions, such as subgrade type and consistency can also have an appreciable impact on the design of line pipe support assemblies. For deep foundations, such as pile structures, the soil-structure interaction must anticipate not only the impact of seasonal changes, but also long-term climate issues. Key concepts presented include: - General Support Design Philosophy - Pipeline-Specific v. Pipeline Support Assembly Design - Design Environment - Principal Design Issues
	Limit States Design of Arctic Pipelines	Robert Appleby	ExxonMobil	The vast majority of pipeline designs have been based on application of "working stress" design rules assuming stresses in a pipe wall stay below the yield strength of steel, usually taken as below 0.5% strain. Pipelines installed in difficult conditions, made to withstand seismically induced ground movement or to resist collapse caused by external pressure and bending of deepwater pipelines, etc., may be constructed and operated safely so long as the pipeline's structural integrity- defined in terms of the pipeline's limit states- is well understood, and that well-defined engineering practices are used. Limit States Design has been the standard of practice for deepwater pipelines for over 20 years. This presentation described the applicability of Limit States Design of Arctic pipelines using Strain-Based Design and Assessment (SBDA) principles. The presentation briefly summarized current industry practices, discussed the treatment of SBDA in codes, standards and regulations, and included a hypothetical Arctic pipeline example using SBDA approaches. It is noted that a pipeline designed using SBDA will have equal or greater wall thickness than if it were designed using current codes and standards. While these codes currently have only limited discussion of SBDA, there is active work underway to incorporate SBDA principles into them based on increased knowledge of SBDA technology, founded on ongoing research and development. It is well understood that SBDA requires use of well-defined pipe material properties, that emphasis on quality throughout the construction process is needed, and that operation of these pipelines will involve ongoing monitoring and assessment. A key challenge is in timely development of consensus SBDA safety standards that incorporate the needs of all stakeholders.

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4: Aboveground Pipeline Concerns	Aboveground Pipeline Concerns: Wind-Induced Vibration (WIV)	Jim Hart	SSD Inc.	Wind-induced vibration (WIV) is a known threat to above-ground Arctic pipeline configurations due to high-cycle fatigue loading. This presentation provided a brief history of North Slope WIV together with an overview of current design practice including discussion of pipeline dynamics, aerodynamics, wind speed and direction statistics and proven WIV mitigation approaches.
	Corrosion Under Insulation Prevention and Inspection	Mark Nelson	ConocoPhillips Alaska Inc.	Corrosion Under Insulation (CUI) is one of the primary threat mechanisms to piping systems in the Arctic. CUI inspection and remediation can consume a large amount of resources. By implementing improved insulation system designs and efficient inspection methods the risks associated with CUI can be reduced.
Luncheon Keynote Speaker	Economics of Natural Gas in Alaska	Larry Persily	Alaska Natural Gas Transportation Projects	This presentation focused on the current economics of the light natural gas (LNG) market in Alaska. The feasibility for the LNG market is dependent on several factors including the delivered price of the LNG, the changing market for LNG, and the world-wide competition for LNG production. Advantages for the Alaska LNG market include the LNG reserves have been proven, low production costs, higher productivity for liquefaction plants in cold climate, and a shorter delivery run to the Asian market. Disadvantages include the gas reserves are 800 miles from a tidewater port, construction costs are among the highest in the world, the difficult Arctic condition logistics, and the uncertainty in the tax structure for the market.
5: Direct Burial Pipeline Concerns	Geothermal Design of Warm Pipelines in Thaw Unstable Permafrost and Chilled Pipelines in Frost-Heaving Soils	Beez Hazen	Northern Engineering & Scientific	This presentation described geothermal design, construction and operating aspects for warm utility pipelines buried in thaw-unstable permafrost, settlement of a large-diameter pipeline and the cleared right-of-way in thaw-unstable permafrost and frost heave of a large-diameter chilled pipeline in thawed soils. Comparisons between measured and predicted temperatures and pipeline frost heave were discussed.
	Design for Ground Motion Effects on Buried Pipelines	Toby Lovelace	Michael Baker Corporation	Buried pipelines are particularly susceptible to the effects of transverse and longitudinal seismic loads due to seismically-induced ground motion; especially as they may coincide with thermal and other loads. Each new major earthquake has the potential to provide insight into the effectiveness of the state of the art in earthquake engineering. Over the last century, design to mitigate damage due to earthquake-induced loading has progressed from the literally contrived to the scientifically considered. It is no understatement that today our understanding of seismically-induced ground motion and dynamic soil-structure interaction stands at a point which fairly eclipses that of engineers and scientists just a few generations removed. As a result, protecting buried structures from catastrophic loss due to a seismic event, according primarily to the concepts of strength limit states, is giving way to design for serviceability as the principal design consideration. Cost-effective alternatives for seismic-resistant construction continue to develop. As a result, the opportunity to design structures for not only earthquake survivability but for post-earthquake operability is rapidly becoming an available alternative for many owners of dynamically sensitive buried pipeline systems. Key concepts presented include: a) Brief history of earthquake design in the United States b) General Developments in seismology c) Overview of dynamic and pseudo-static modeling of buried pipelines, and d) Design and detailing of buried pipelines to resist effects of seismically-induced ground motions.
	Pipeline Strain-Based Design and Assessment	Paul Carson	Michael Baker Corporation	Appropriately designed pipelines subjected to significant ground deformation can accommodate longitudinal bending loads that induce tension and/or compression loads well beyond yield without impacting pressure containment. Strain-based design and assessment (SBDA) approaches for evaluating and ensuring pipeline integrity for such potential pipeline hazards are being safely used today for both offshore and onshore pipelines – the approach is particularly suitable for Arctic pipeline loadings such as thaw settlement and frost heave. SBDA approaches place an increased emphasis on identifying the limiting conditions for strain development, i.e., the limit states, and the pipeline properties that contribute to a quantitative evaluation of these limit states. At its core, SBDA focuses the problem of ensuring pipeline integrity when subjected to significant ground displacement on estimating two entities: the longitudinal bending strain that is likely to occur in the pipe due to a route hazard, i.e., the strain demand, and the potential of the pipeline to safely accommodate this demand, i.e., the strain capacity. Furthermore, given the uncertainties inherent in both sets of calculations, to ensure safety it is imperative that strain capacity is well in excess of strain demand so this evaluation is also part of the SBDA assessment process. This presentation outlined the basis and current state-of-art for SBDA, including how it works in tandem with conventional stress-based design along with a synopsis of some past projects that have employed SBDA principles.
	Lessons Learned from Ten Years of Tundra Restoration on Three Experimental Gas Pipeline Trenching Sites in Alaska	Bill Streever	BP Exploration (Alaska) Inc.	Gas pipeline construction, as usually envisioned, requires trenching and burial of pipelines in areas with shallow permafrost. In 2002, gas pipeline trenching was undertaken on an experimental basis at two North Slope sites and one site in central Alaska. At each trial site, about three miles of experimental trenches were excavated and reburied. At all sites shallow permafrost thawed, leading to unexpected thermokarst (thermal erosion expressed as subsidence). Although backfill was mounded over the trenches, the degree of thermokarst varied substantially even across short spans of apparently homogenous soils, leaving some trenches with excessive backfill and others with significant collapse below the surrounding tundra surface. Substantial remedial earthwork was needed at one of the North Slope sites and at the interior site. Remedial earthwork at the North Slope site required repeated efforts because thermokarst continued to spread for more than five years after project completion. Revegetation was also surprisingly challenging even along the relatively narrow (about 10 feet) strips of disturbed ground. After ten years, the North Slope sites have not revegetated. Although the interior Alaska site has revegetated, the species composition is different than that of the original community. Two key lessons have been learned from the work on these sites. First, careful planning with the involvement of soil scientists and ecologists might reduce post-construction tundra restoration challenges. Second, construction of a pipeline should be accompanied by plans for ten years or more of tundra restoration efforts.

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5: Direct Burial Pipeline Concerns	River Crossings - What Have We Learned in 40 Years?	Wim Veldman	Wim M. Veldman Consulting Inc.	This presentation discussed the design challenges for Arctic pipelines, especially 40 years ago when TAPS and the Prudhoe Bay Development were initially constructed, where minimal hydrologic data, the variability of aufeis and its impact on breakup water levels and the impact of glacier dammed lakes on the design flow and water levels at crossings were unknown. The design lessons learned plus the value of the "what if" principle in data scarce areas, were highlighted via the impact of four major floods since the beginning of operations of TAPS. The winter construction challenges in the Arctic are well known. For river crossings, however, winter conditions can also facilitate construction and reduce environmental impacts compared to non-Arctic conditions. From operational monitoring experience, the impact of breakup floods versus late summer floods, regarding water levels and channel changes, were compared. The variability in time and location of aufeis, its relationship to weather conditions and its resultant impact on crossings and floodplain structures were discussed. In summary, from the lessons learned in the last 40 years, do Arctic pipeline river crossings pose greater, equal or lesser design, construction and operational challenges than non-Arctic pipelines?
6: Offshore Pipelines	Year-Long Upward Looking Sonar Mooring Measurements of Sea Ice Keel Distributions: Implications for Ice Gouging	Ed Ross	ASL Environmental Sciences Inc.	Upward looking sonar (ULS) instruments have been widely used since the mid-1990s to provide accurate measurements of sea ice drafts and ice velocities in support of oil and gas exploration programs in the Arctic Ocean and marginal ice zones, with modern programs starting in the Chukchi Sea in 2003. Operated from subsurface moorings located safely below the sea ice canopy, ULS measurements are made continuously at time intervals of 1 or 2 seconds for periods of one year or longer. Modern ULS instruments provide unprecedented horizontal resolution of approximately 1 m of the underside of the sea ice. The analysis results from ULS ice data are used to provide key inputs to the engineering of offshore platform design, subsea systems including pipelines and ship-based ice management programs required to safely and effectively conduct exploration and production in ice-infested waters. Improved analysis methods were presented which provide quantitative characterizations separately for highly deformed sea ice features. These features include large individual ice keels and segments of highly concentrated large hummocky (rubbled) ice. Individual large ice keels have the largest ice thickness of up to 20 m or more while large hummocky ice features have greater horizontal scales of 100 to several hundred meters with lesser ice thickness.
	Offshore Oil Pipeline Leak Detection Technologies for Arctic/Cold Regions	Dr. Premkumar Thodi	INTECSEA Worley Parsons	Multiple fields have been developed over the past three decades offshore Alaska, and the world demand for oil and gas will continue to drive Arctic development. Arctic pipelines are used for the safe and economic transportation of hydrocarbons. While pipelines are designed not to leak, excessive strains due to the effects of ice gouging, strudel scour, frost heave and permafrost thaw settlement along with other loading and failure mechanisms (e.g., corrosion, third party damage) could result in a leak. Failure to detect leaks in a timely manner could have severe safety, environmental, and economic impacts. Large leaks can easily be detected, but small chronic leaks may go undetected for a period of time, especially when pipelines are in remote locations or under seasonal ice cover. First, this presentation reviewed existing Leak Detection System (LDS) technologies for their potential use on the Arctic oil pipelines. Technology evaluation based on regulatory requirements and functional criteria suggests that the Fiber Optic Cable (FOC) distributed sensing systems have high potential to be used for Arctic pipeline applications. Distributed sensing FOC can be used to detect and locate leakages. Pipeline leakage would generate a local change in temperature. These thermal anomalies can be captured by FOC Distributed Temperature Sensing (DTS) systems with good spatial and temporal resolution. Similarly, the acoustic signature generated by leaking fluid can be detected using FOC Distributed Acoustic Sensing (DAS) systems. Inelastic Brillouin and Raman backscattering principles are used for measuring temperature in DTS, whereas the Rayleigh backscattering principle is used for measuring acoustics in DAS. This presentation covered operating principles, optical budgets, SCADA integration, sensor positioning, installation/maintenance assessment, technology readiness level, and field implementation challenges.
	Subsea Arctic Pipelines - Design and Construction Challenges	Craig Young	INTECSEA Houston	An overview of the key design and construction challenges associated with buried subsea pipelines for Arctic applications was provided. Key topics are a) Pipeline Design including Design Codes & Strain Based Design; Primary Loading Conditions (e.g., Ice & Strudel Scour, Upheaval Buckling, Permafrost Frost Heave & Thaw Settlement); Pipe in Pipe, Thick-walled Pipe, Bundled Pipes; Facility Tie-ins; and Shore Approaches; b) Construction including Summer vs. Winter; Ice operations; Trenching – Requirements and Capabilities/Limitations; and Pipeline Installation; and c) Operations, Maintenance, and Repair including Leak Detection; Surveys / Route Monitoring / Smart Pigging; Pipeline Integrity Management; Trench & Shore Erosion Remediation, and Repair Options.
7: Unresolved Challenges	Inspection of Difficult-to-Inspect Pipelines: Kinder Morgan Canada's Experience	Nelson Tonui	Kinder Morgan Canada, Inc.	Kinder Morgan Canada (KMC) operates crude oil and refined products pipeline systems in Canada and the United States. Like most North America pipeline infrastructures, the system is aging and there is an increasing scrutiny on the integrity of these assets by both the regulators and the public. KMC's pipeline integrity programs require that all pipe segments are periodically inspected. While the company's mainlines are 100% piggable using standard uni-directional in-line inspection tools, most of the piping at the pump stations, tank farms and terminal facilities are not because of various limitations including access restriction at one or both ends and absence of permanent launch/receive facilities. Ensuring the integrity of these difficult-to-inspect pipelines is important for continued safe operation of the system. KMC has over the years tried to inspect facility piping using various available inspection tools and technologies. This presentation discussed the company's experiences with some of the technologies and tools used which include guided wave technology, external magnetic flux leakage (MFL) tools, tethered ILI tools and free-swimming ILI tools. The presentation also outlined the successes and challenges of these inspection technologies and provided some comparison between the data reported by the tools and those from validation digs/inspections.

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7: Unresolved Challenges	Design Challenges of Arctic Pipelines – Technology Gaps and Advanced Analysis Solutions	Basel Abdalla	WCS Kenny	The world demand for oil and gas is growing at an increasing rate and, as a result, there is a demand to explore new regions for more petroleum production. The Arctic is one of the remaining unexplored areas where such exploration can still be undertaken. At the same time, technology gaps still exist and will have to be bridged in order to enable optimized developments to proceed. In this presentation, design challenges to Arctic pipelines subjected to three different loading scenarios were discussed. These are ice gouging, permafrost thawing, and frost heave. The safe and economic solution to such challenges will require innovation, realistic simulation, and optimization by reducing unnecessary conservatism. Advanced finite element techniques can be used to address these highly complex and nonlinear phenomena. First, a three-dimensional (3D) Finite Element (FE) model which utilizes the Coupled Eulerian Lagrangian (CEL) formulation has been developed to model iceberg/ridge soil/pipe interaction, and provide direct and explicit estimation of pipe stresses/strains and ice keel scour depths. Then, a 3D FE model to study the interaction between buried pipelines transporting warm hydrocarbons and the surrounding permafrost was presented. Finally, the frost heave of a buried chilled gas pipeline is simulated with a fully coupled heat and displacement 2D FE model that predicts the transient frost heave with time by integrating the porosity rate function which is a formulation consistent with continuum mechanics. The developed models help in accurate prediction of pipe strains by using finite element continuum modeling method. For safe operations, the pipe should be designed so that the induced strains under different design conditions do not exceed the ultimate limit state conditions.
Workshop	Pipeline Risk Assessment Essential Elements	Kent Muhlbauer	WKM Consultancy	Risk management has been embraced by both the pipeline industry and regulatory agencies as a way to not only increase public safety but also to optimize all aspects of pipeline design, operations, and maintenance. This basic workshop was designed to equip attendees with the ability to recognize the essential elements of risk assessment, allowing for the subsequent set up and implementation of a comprehensive risk management program for pipelines as part of an overall safety management system. It included a condensed overview explaining the latest quantitative methods for risk profiling and assessments. The focus was on the establishment of a program that not only fulfills regulatory requirements, but also gives the pipeline owner/operator a long-term decision support tool. The workshop began with a review of risk concepts and methodologies and then focused on the most effective risk assessment techniques available to the pipeline industry. The emphasis throughout was on practical, ready-to-apply techniques that yield immediate and cost-effective benefits. The workshop was structured so that it was appropriate for either the practicing or the beginning risk manager with each leaving with the necessary tools to begin or strengthen risk assessment techniques leading to a formalized risk management program. As much as was possible, the course content was directed to specific audience interests.

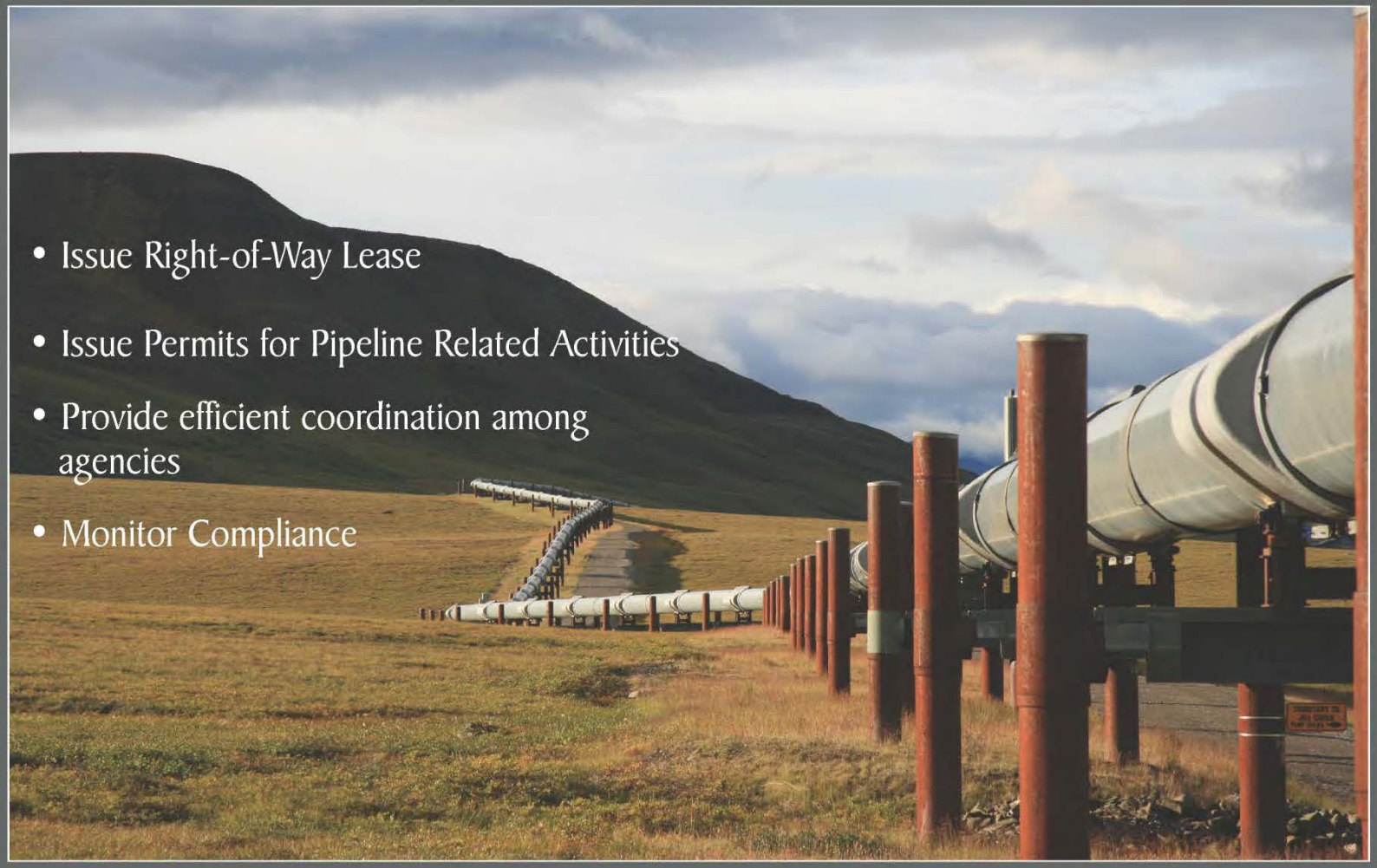
APPENDIX A

STATE PIPELINE COORDINATOR'S OFFICE

Alaska Department of
Natural Resources

State Pipeline Coordinator's Office

Why the SPCO?



- Issue Right-of-Way Lease
- Issue Permits for Pipeline Related Activities
- Provide efficient coordination among agencies
- Monitor Compliance

Alaska Statute 38.35: Right-of-Way Leasing Act

- All Pipelines on State Land
  - Value > $1,000,000
- Gathering Line Exemption
  - Unit Exemption

Jurisdictional Pipelines

Alaska Statute 38.35 • Right-of-Way Leasing Act

Existing Pipelines

- Alpine Oil, Diesel & Utility
- Badami Sales & Utility
- Endicott
- Kenai Kachemak Natural Gas
- Kuparuk & Kuparuk Extension
- Milne Point Oil & Product
- Nikiski Alaska
- North Fork
- Northstar Oil & Gas
- Nuiqsut Natural Gas
- Oliktok
- TAPS

Proposed Pipelines

- Alaska Stand Alone Pipeline/ASAP*
- Point Thomson**
- Polar LNG
- Donlin Gold Mine
- Southcentral LNG/APP
- Trans-Foreland Pipeline
- Spectrum LNG
- AIDEA North Slope LNG project

**ROW lease issued in July 2011*
***ROW lease issued Oct. 2012*

SPCO Coordinate Agencies

Department of Health & Social Services

Department of Environmental Conservation*

Department of Fish & Game*

Department of Labor & Workforce Development*

Department of Law

Department of Natural Resources*

Department of Public Safety*

Department of Revenue

Department of Transportation & Public Facilities

Regulatory Commission of Alaska

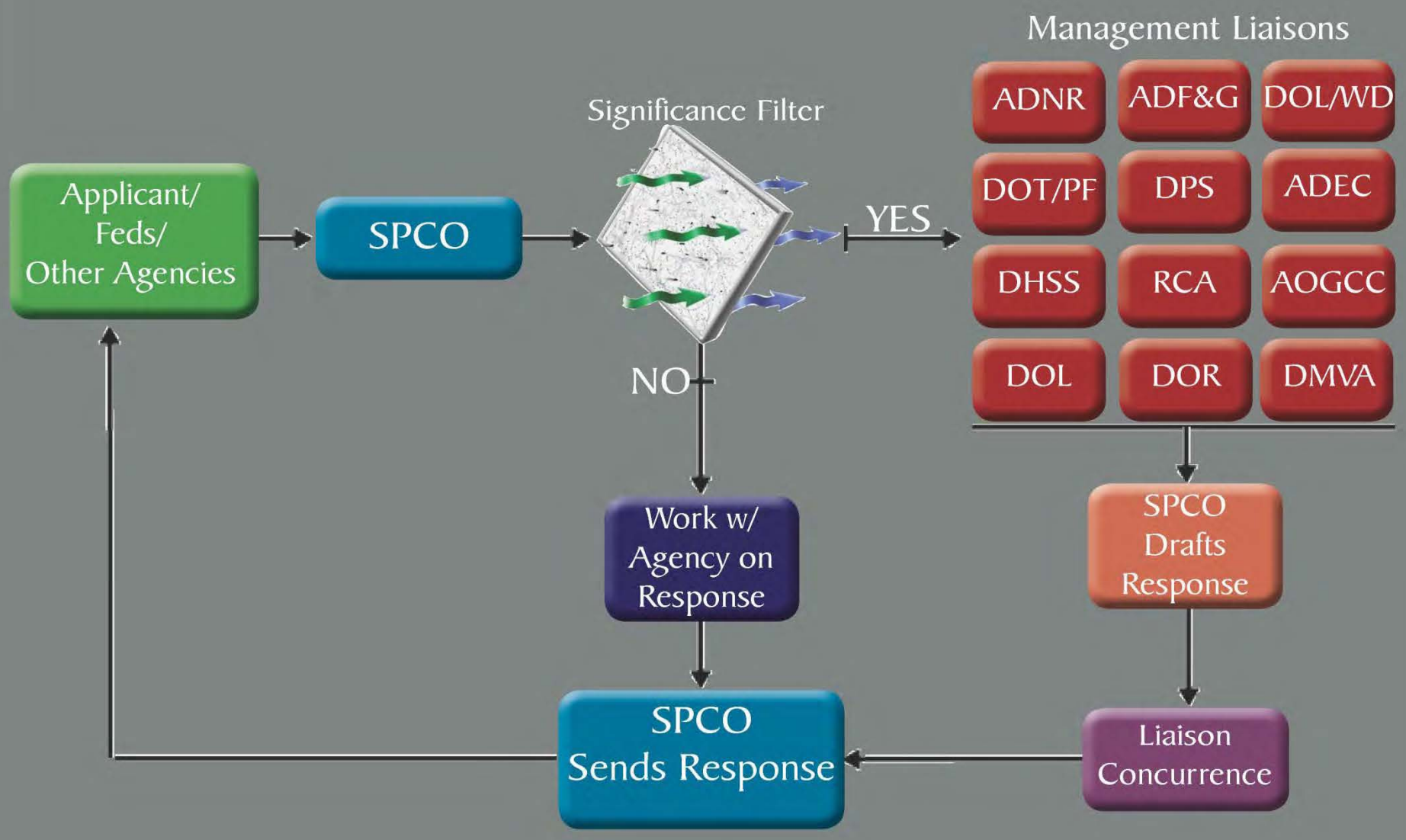
Alaska Oil & Gas Conservation Commission

Division of Homeland Security & Emergency Management

** co-located*

Communication Protocol

for State Agency Coordination



SPCO Pre-lease to Lease Overview

Applicant & SPCO - Pre-application discussion
(AS 38.35, Process, Costs, Timelines, Coordination)

Applicant submits to SPCO

MOU for reimbursement

Permit and application consultation between applicant, SPCO and relevant agencies:

- Overall timeline & schedule
- Application needs & expectations
- Communication protocol & liaisons
- ID of permits issued through SPCO

APPLICATION

Public notice - 60 days

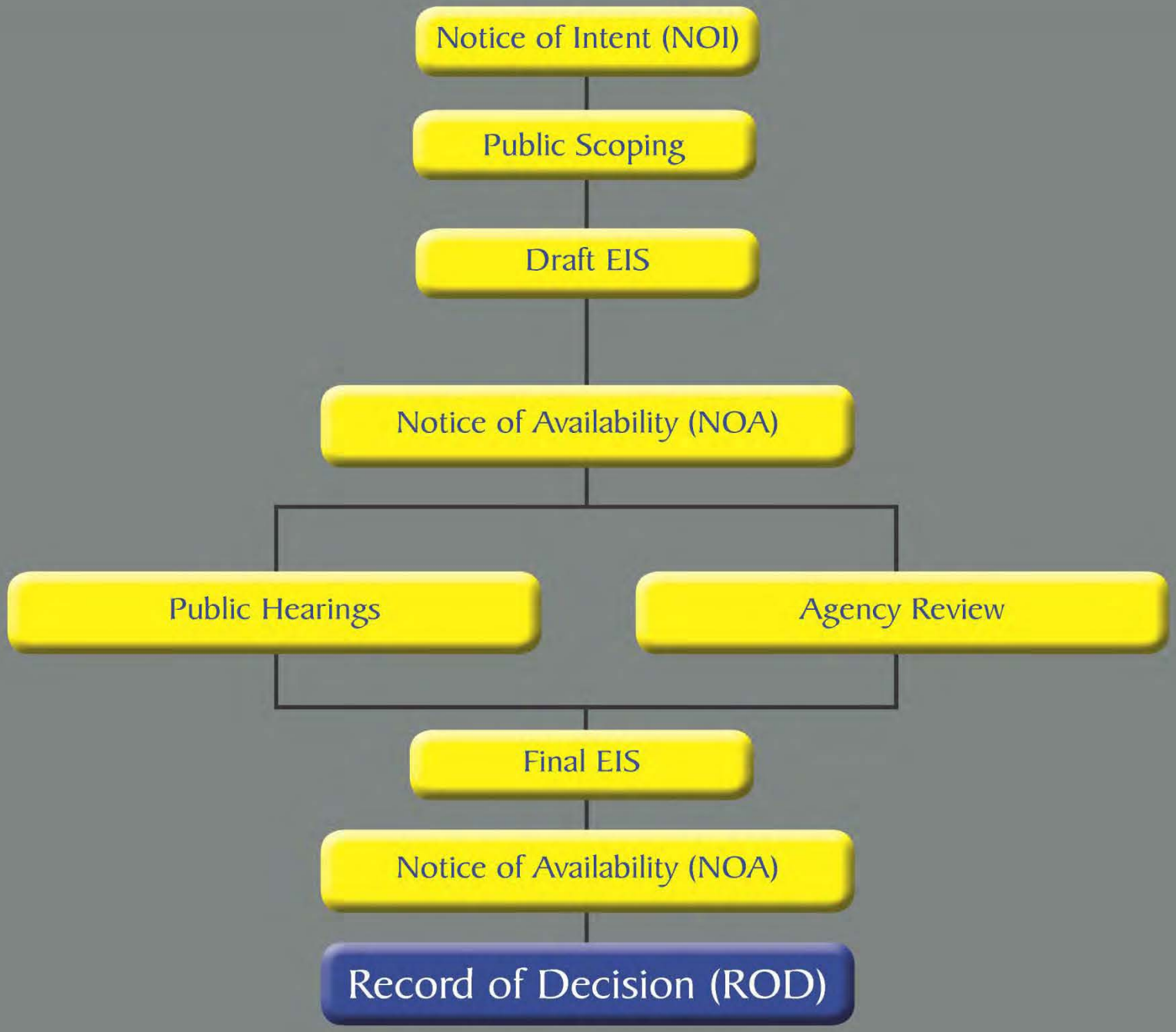
Pre-construction permits

Draft Analysis and lease documents, coordinate review, negotiate lease, financial guarantee

Coordination of permits from other agencies

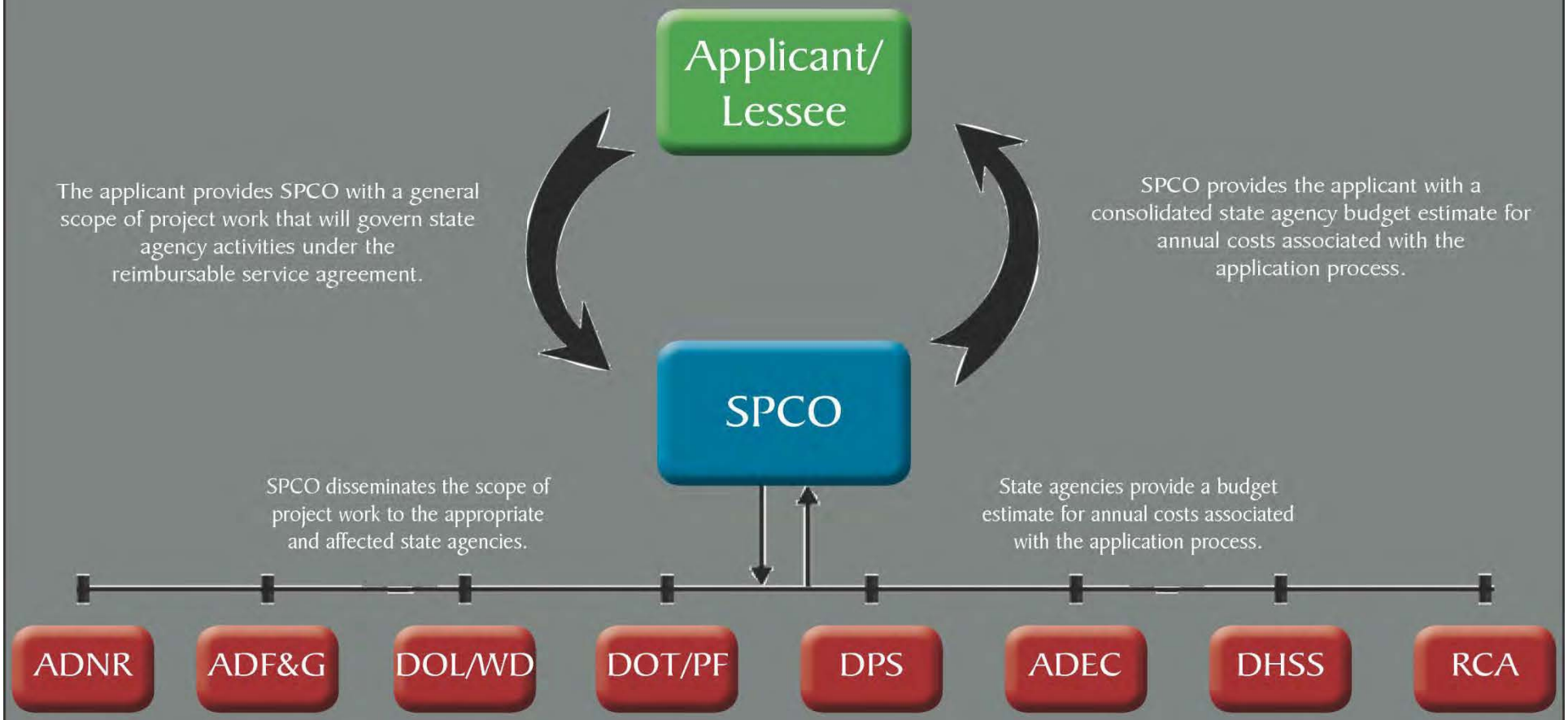
Public notice of Analysis and Draft Lease - 30 days

Federal EIS Process



State Agency Cost Reimbursement Process

as required by Alaska Statute 38.35



Right-of-Way Application Information

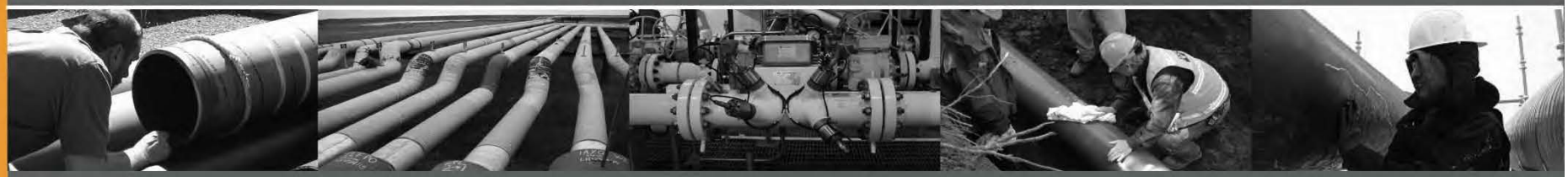
- Proposed route
- Project description
  - Design basis
- Availability of interconnections, terminal and storage facilities
- Safeguards for people, property and the environment
- Safeguards for individuals relying on subsistence resources in the area of the proposed right-of-way
- Financial information
- Other information to be considered when processing the application

Commissioner's Analysis and Proposed Decision

Fit, Willing and Able Determination

- Unreasonable conflict with existing uses?
- Technical and financial capability to:
  - protect State and private property
  - prevent significant adverse environmental impact
  - undertake necessary restoration or revegation, or both
  - protect the interests of persons living in the general area and rely on fish, wildlife and biotic resources for subsistence purposes
  - pay for reasonable foreseeable damages arising from pipeline construction, operation, maintenance or termination

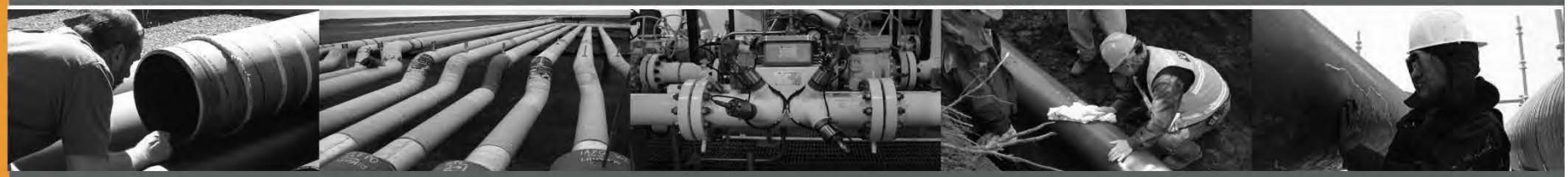
Right-of-way Lease



Terms include (but are not limited to):

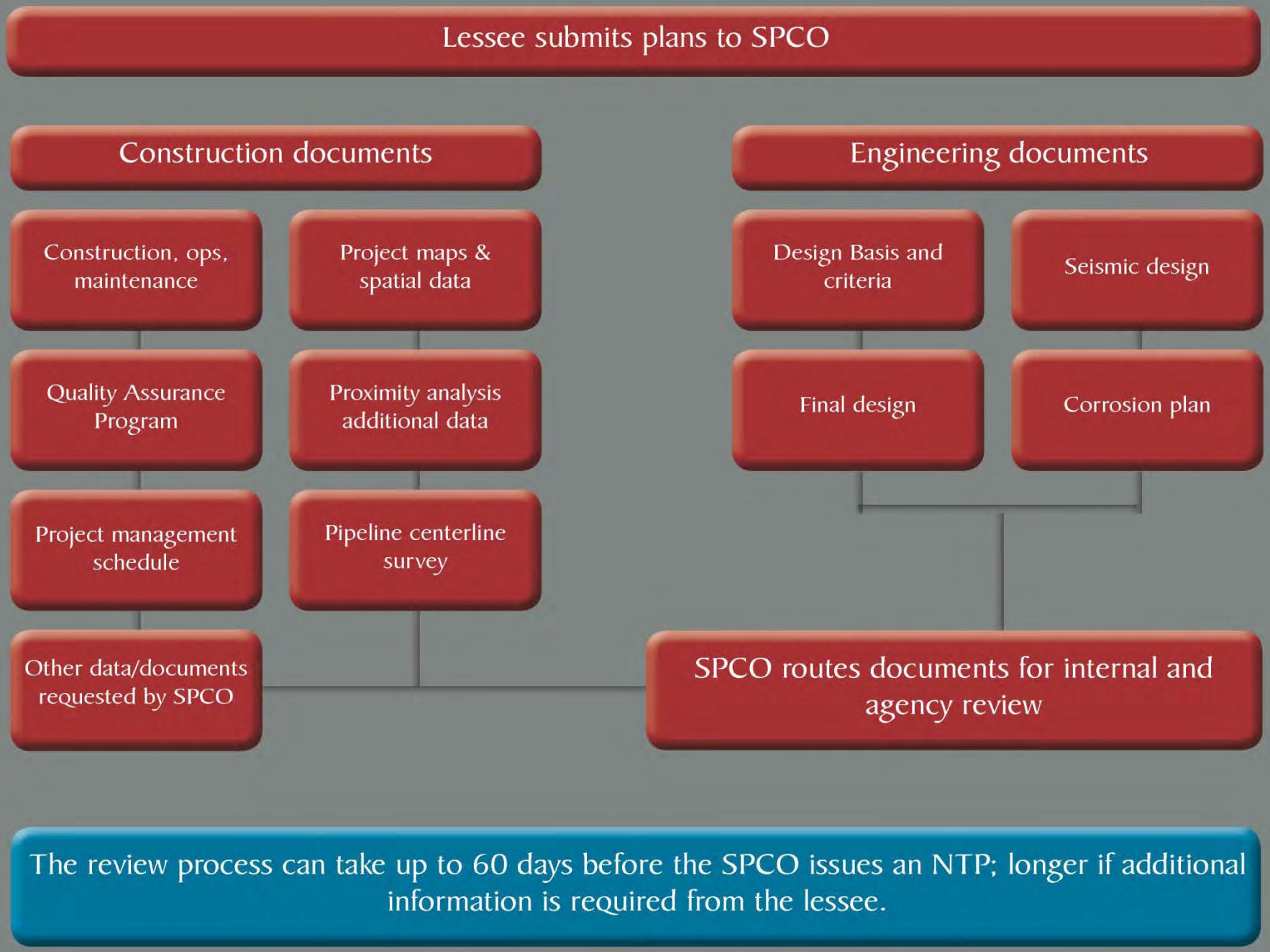
- Duration
- Rental and payment
- Reservations
- Access to navigable and public waters
- Connections for delivery
- Compliance with design criteria, plans and programs (quality, surveillance, etc)
- Liability and indemnity clauses
- Local hire
- AS 38.35 covenants

Stipulations

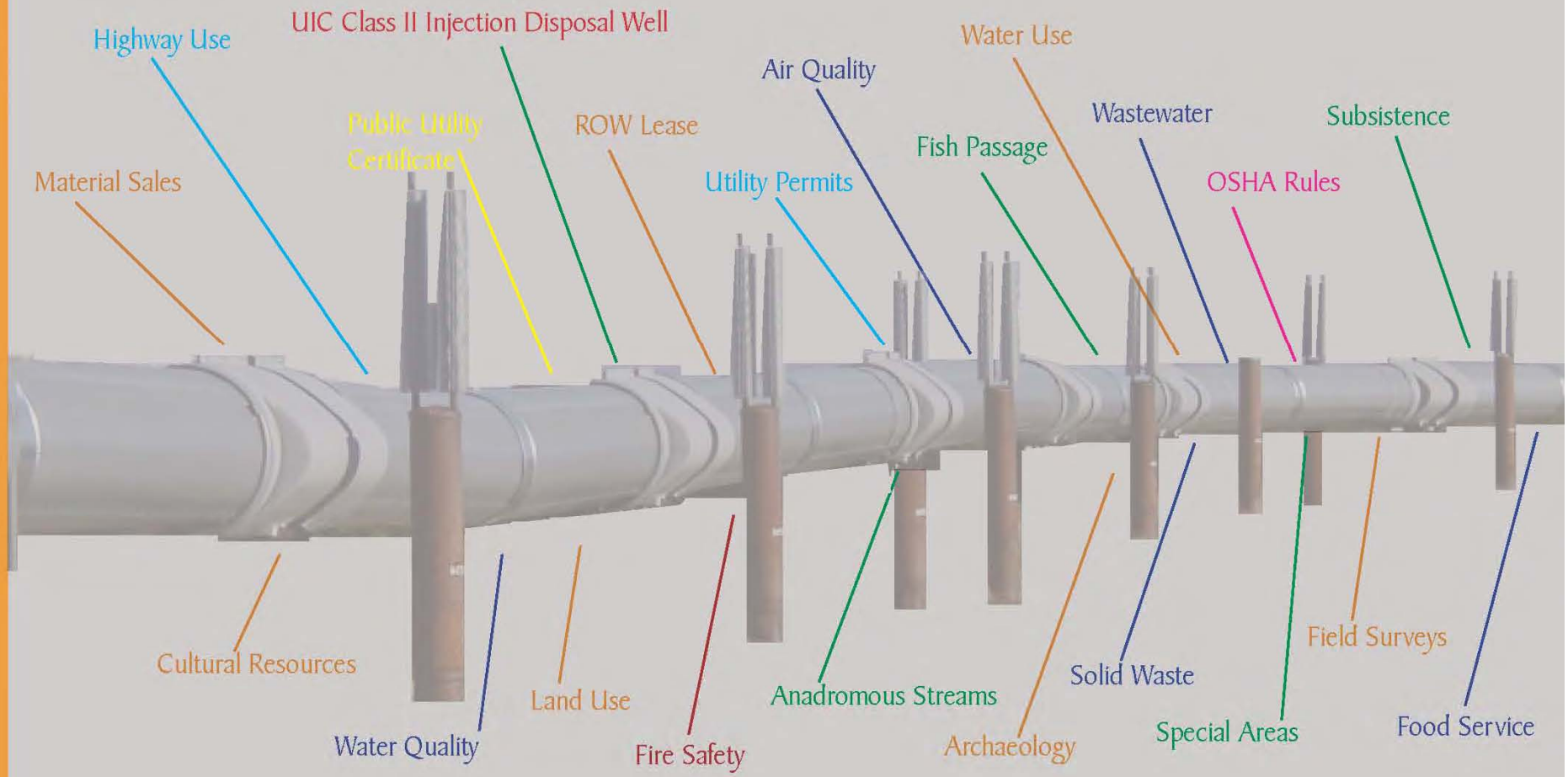


- Notices to Proceed (NTP) or permission to construct
- Technical documents
- Construction plans
  - environmental
  - contingencies and mitigations
  - safety
- Quality management program
- Written authorizations

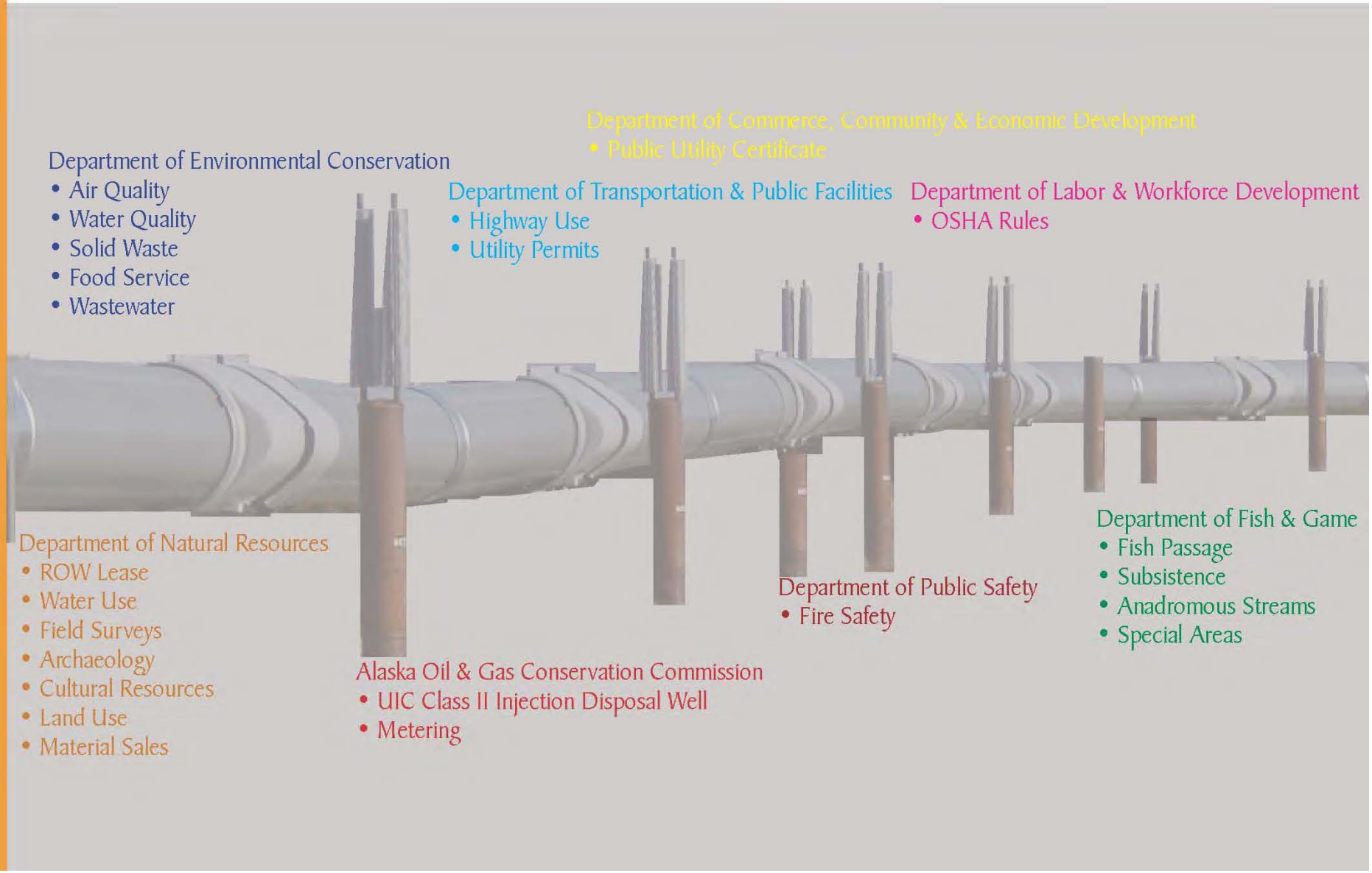
SPCO Notice-to-Proceed Process Summary



Multiple State Agency Requirements
AS 38.35 Pipelines



State Agency Coordination



State/Federal Joint Pipeline Office

Established by Executive Council Agreement and supported by Operating Agreement

Federal Agencies

Department of the Interior:
Bureau of Land Management/Office of Pipeline Monitoring
Bureau of Ocean Energy Management, Regulation & Enforcement

Department of Transportation:
Pipeline & Hazardous Materials Safety Administration

Environmental Protection Agency

Department of Homeland Security:
Coast Guard
Transportation Security Administration

Department of Defense:
Army Corps of Engineers

State Agencies

Department of Natural Resources

Department of Environmental Conservation

Department of Labor & Workforce Development

Department of Fish & Game

Department of Public Safety

Department of Transportation & Public Facilities

SPCO Sections

Right-of-Way Section

- ROW lease applications & amendments
- Project-specific authorizations
- Easements
- Temporary water use permits
- Temporary land use permits
- Material Sales
- Lease administration

Rentals, appraisals, letters of non-objection, corporate guaranties, etc.

Engineering Section

- Provides technical oversight of facilities, infrastructure, activities
- Makes recommendations to DNR Commissioner & SPC on technical issues
- Verifies technical requirements of lease are met
- Performs code reviews and participates in design bases for pipelines
- Coordinates with other agencies on technical matters and incident response
- Follows Alyeska's progress on low-flow issues

Compliance Section

- Statewide oversight responsibility
- AS 38.35 jurisdictional pipeline rights-of-way
- AS 38.05 rights-of-way grant
- 1,236 pipeline miles

Special Projects

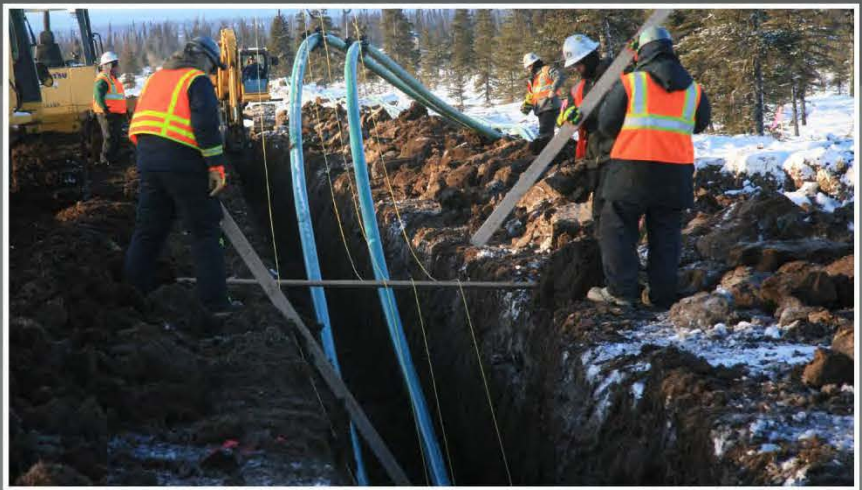
- Serves as main point-of-contact for proposed projects and applicants
- Facilitates agency coordination
- Negotiates lease terms with applicants
- Drafts leases and stipulations

Pipeline Surveillance Program

- Quality Assurance
- Right-of-Way Monitoring
  - surveillance checklists
- Document Verification
- Code Reviews & Technical Oversight of Design Basis
- Trip Reports
- Written Surveillances

Compliance Surveillance Photos: Pipeline Construction

Spools of Fiberspar LinePipe staged for North Fork Pipeline construction



SPCO lease compliance specialist Ben Hagedorn observes the North Fork Pipeline construction in early 2011

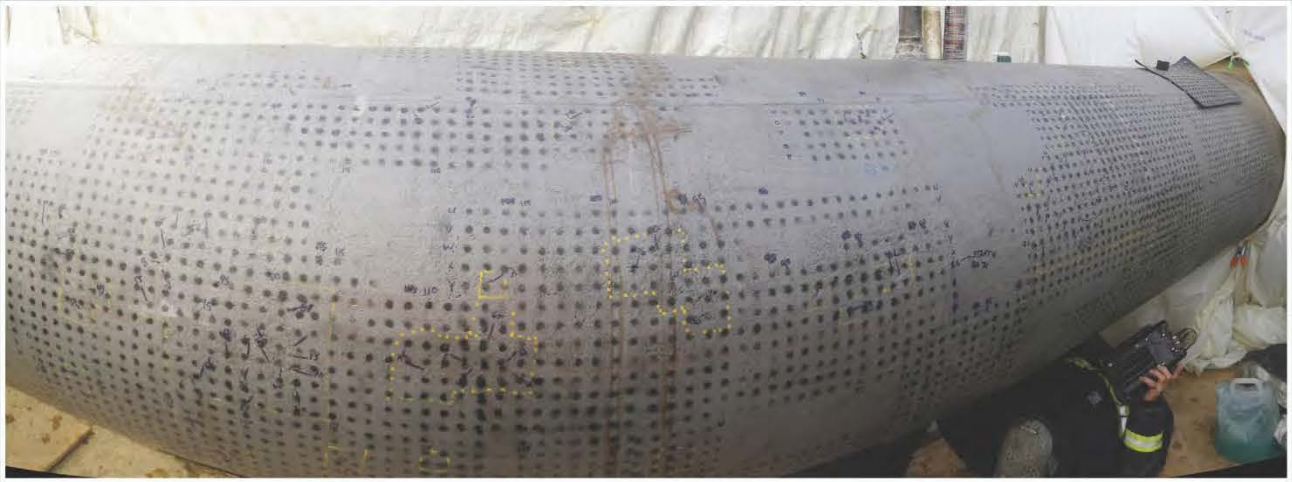
Work crews install VSMs for Point Thomson Export Pipeline

Point Thomson VSMs installed in 2012/2013

Compliance Surveillance Photos: 2012/2013 Field Seasons

SPCO compliance specialist Justin Selvik observes an integrity dig near TAPS pipeline milepost 756.

SPCO conducts a walking-speed survey of Northstar Pipeline on the North Slope.



SPCO observes an ultrasonic inspection of TAPS near Pump Station 7.

2012 ANNUAL REPORT

STATE
PIPELINE
COORDINATOR'S
OFFICE

SPCO 2012 ANNUAL REPORT
Copies available in print and online at
http://dnr.alaska.gov/commis/pco

Visit the SPCO website to view previous annual reports and a repository of information about SPCO-regulated pipelines.

APPENDIX B

UPDATE ON OIL & GAS ACTIVITIES FOR BLM-ALASKA

Alaska DEC 2013

Arctic/Cold Regions Oil Pipeline Conference

BLM - Alaska
Bud C. Cribley,
State Director

September 2013

Update on Oil & Gas Activities for BLM-Alaska

- NPR-A IAP/EIS Record of Decision
- NPR-A Working Group
- Lease Sale
- Upcoming Development
- Trans-Alaska Pipeline
- Interagency Working Group

Other On-Shore Agencies

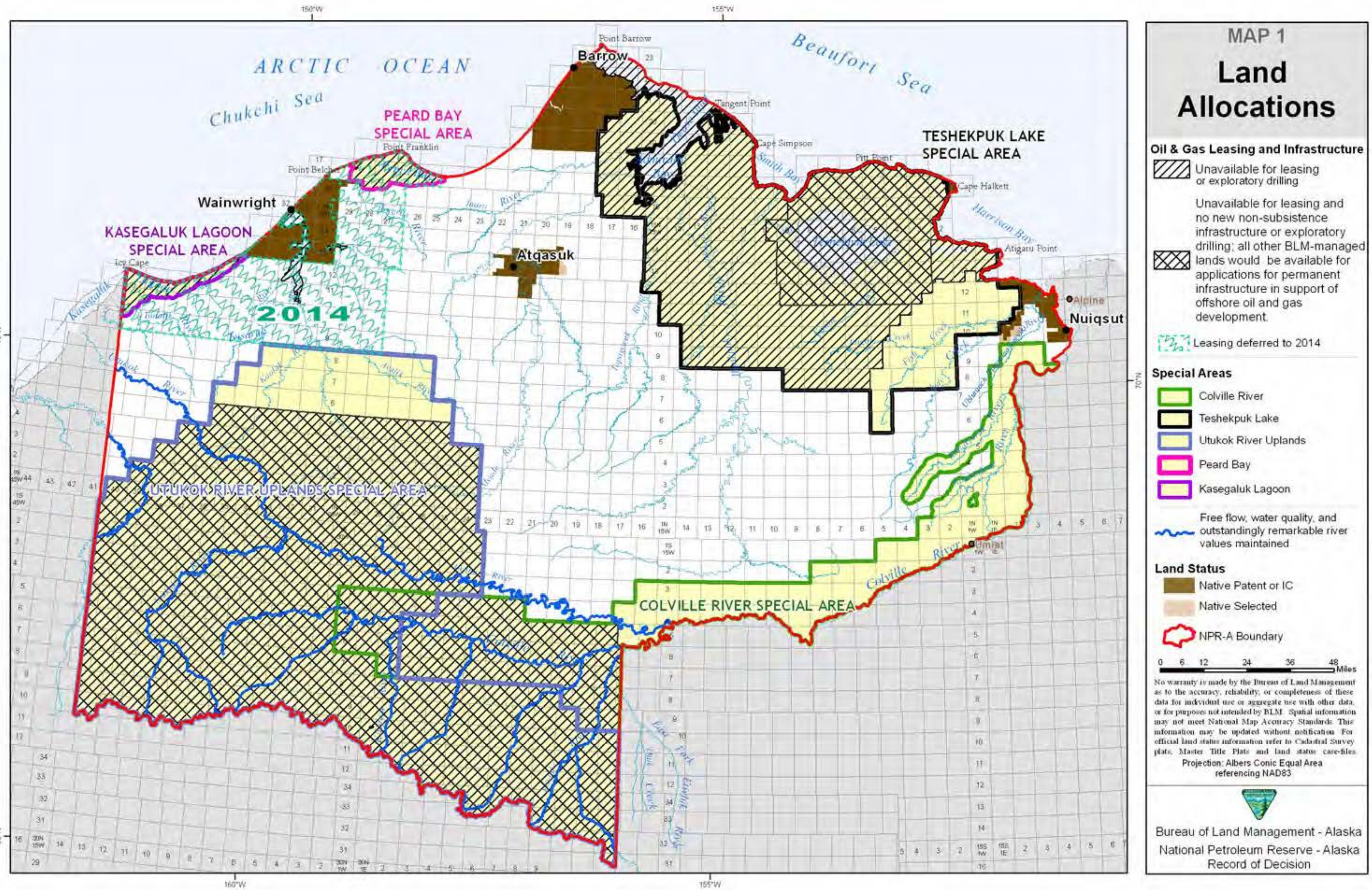
- U.S. Army Corps of Engineers (USACE)
- U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA)
- Environmental Protection Agency (EPA)
- U.S. Fish and Wildlife Service (USFWS)

National Petroleum Reserve in Alaska

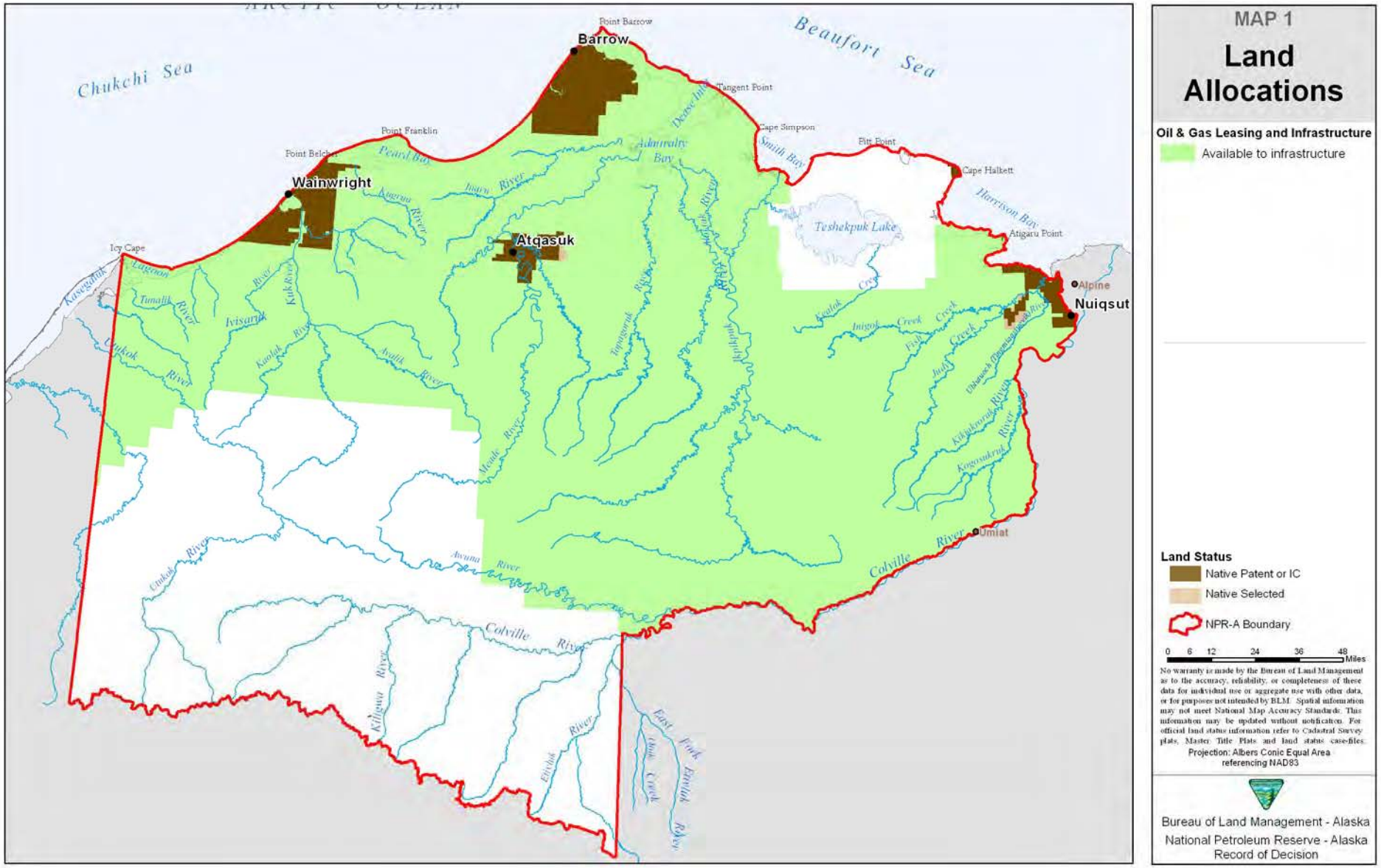
Integrated Activity Plan/Environmental Impact Statement Record of Decision

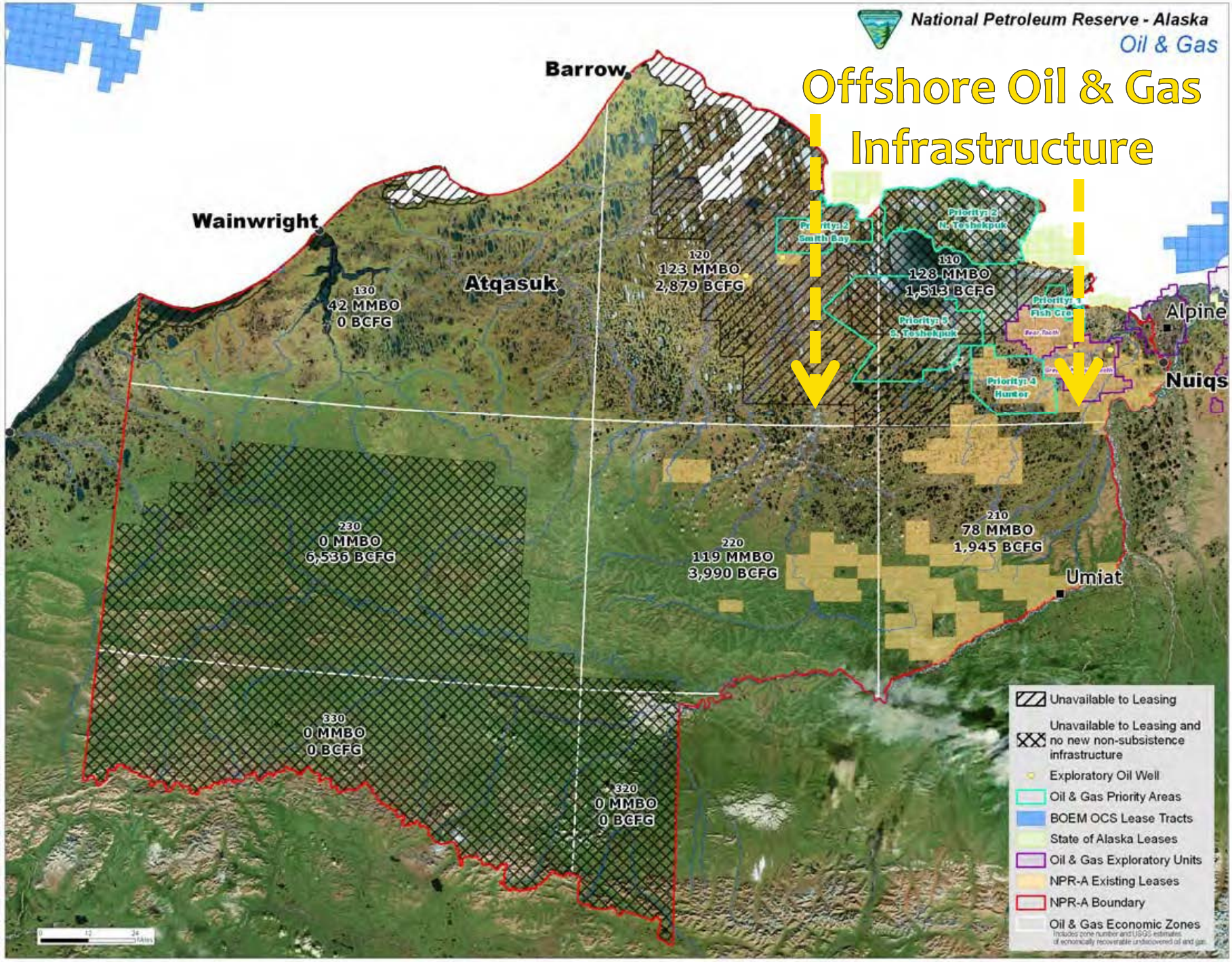
February 21, 2013

Land Allocations

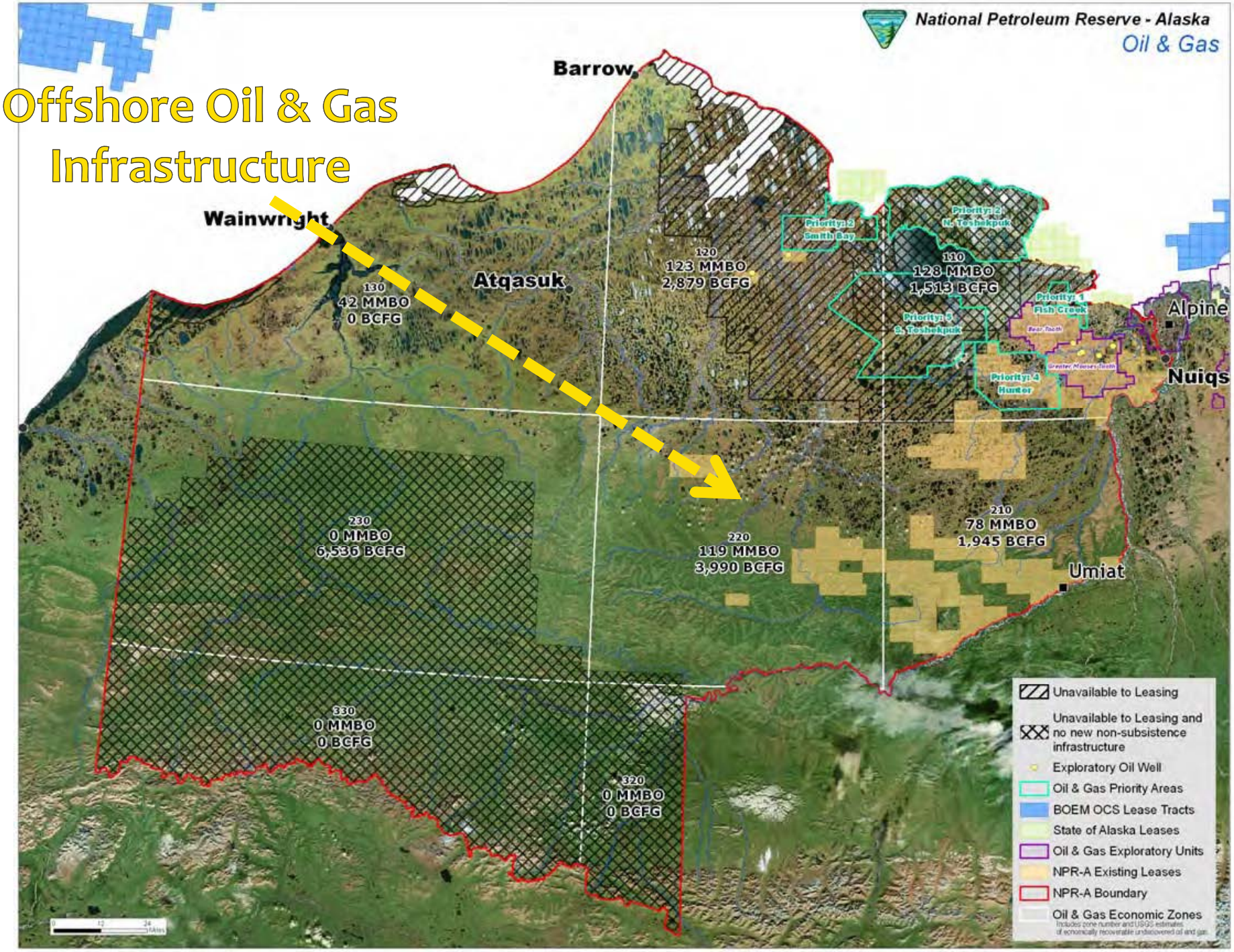


Land Allocations




National Petroleum Reserve - Alaska
Oil & Gas
Offshore Oil & Gas Infrastructure
Barrow
Wainwright
Atqasuk
Alpine
Nuiqs
Umiat
130
42 MMBO
0 BCFG
120
123 MMBO
2,879 BCFG
110
128 MMBO
1,513 BCFG
230
0 MMBO
6,536 BCFG
220
119 MMBO
3,990 BCFG
210
78 MMBO
1,945 BCFG
330
0 MMBO
0 BCFG
320
0 MMBO
0 BCFG
Priority: 2
Smith Bay
Priority: 2
N. Teshekpuk
Priority: 3
S. Teshekpuk
Priority: 4
Hunter
Unavailable to Leasing
Unavailable to Leasing and no new non-subsistence infrastructure
Exploratory Oil Well
Oil & Gas Priority Areas
BOEM OCS Lease Tracts
State of Alaska Leases
Oil & Gas Exploratory Units
NPR-A Existing Leases
NPR-A Boundary
Oil & Gas Economic Zones

Offshore Oil & Gas Infrastructure



NPR-A Working Group

NPR-A Working Group

BLM-Alaska State Director
as delegated

State of Alaska

Other federal agencies: invited to participate on issues with which they have responsibility

Villages located within NPR-A

- **Alaska Native Corporation:**
  - Barrow
  - Nuiqsut
  - Atqasuk
  - Wainwright
- **Local Government:**
  - Barrow
  - Nuiqsut
  - Atqasuk
  - Wainwright
- **Federally Recognized Tribe:**
  - Barrow
  - Nuiqsut
  - Atqasuk
  - Wainwright

Villages located outside of NPR-A
1 Rep. each

- Anaktuvik Pass
- Kaktovik
- Point Lay
- Point Hope

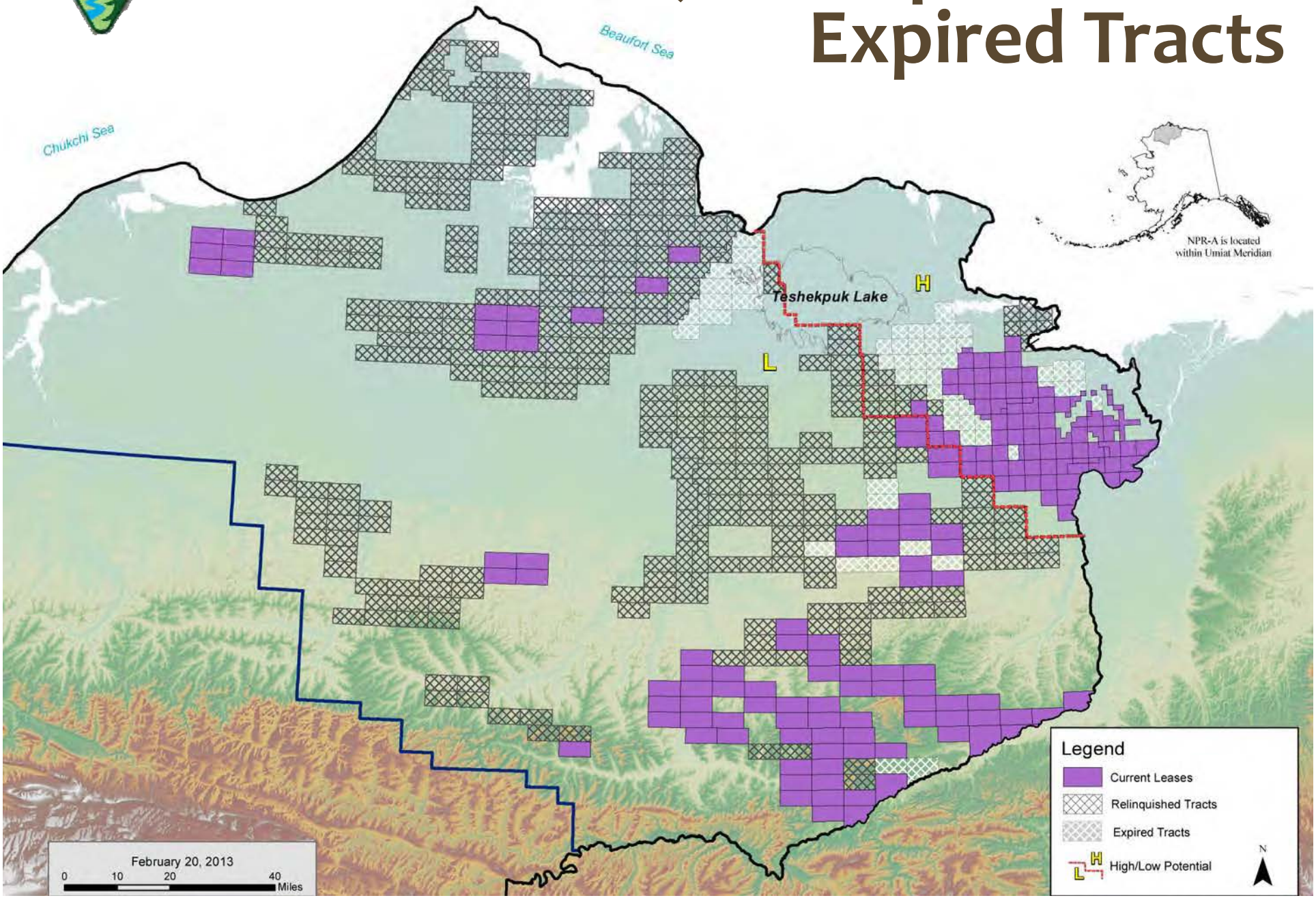
Regional Organizations
1 Rep. each

- Arctic Slope Regional Corporation
- North Slope Borough
- Inupiat Community of the Arctic Slope

NPR-A Lease Sale

On May 14, 2011 President Barack Obama, in his weekly address, directed the Bureau of Land Management to conduct annual lease sales for the NPR-A.

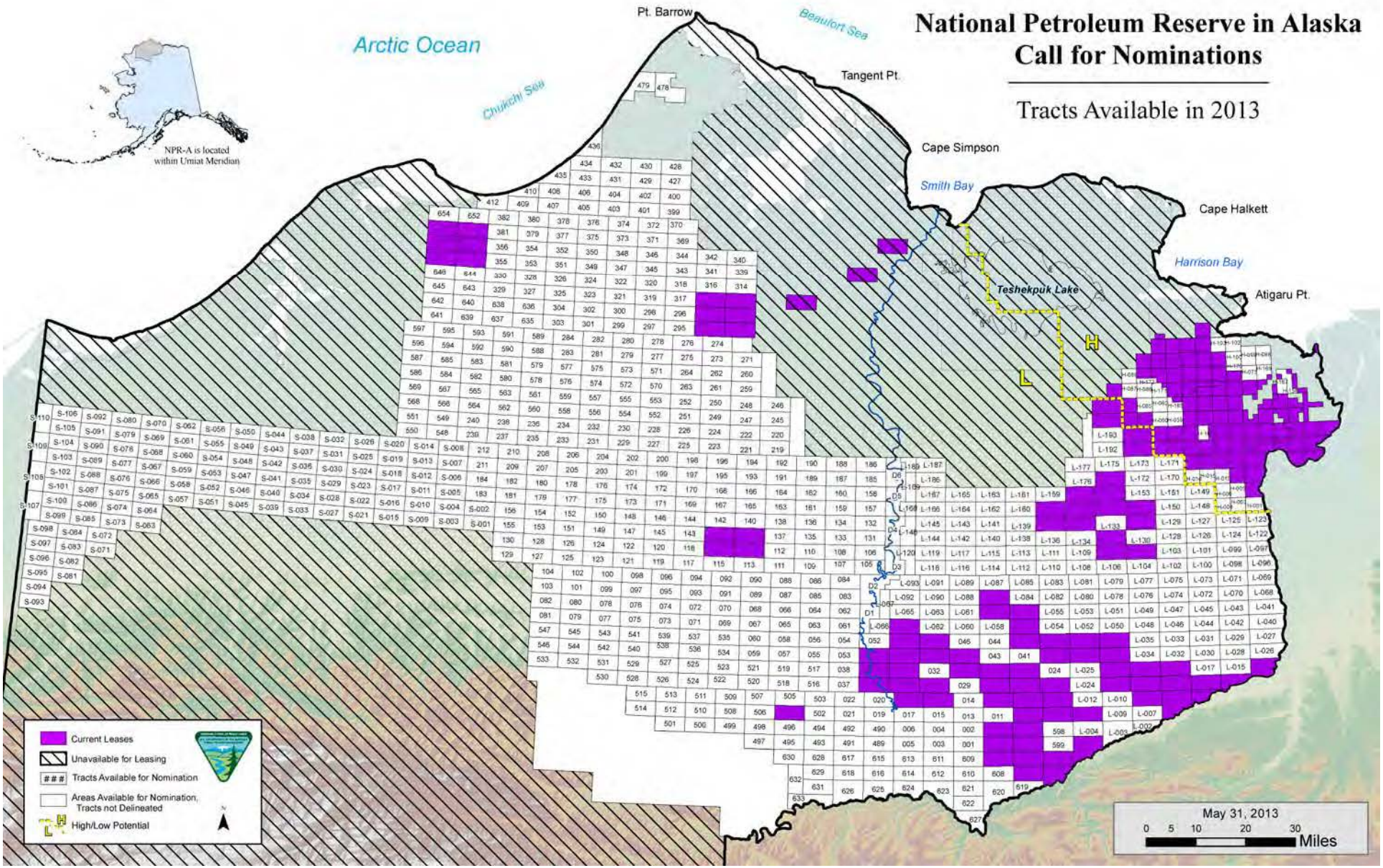
NPR-A Current, Relinquished and Expired Tracts



Call for Nominations & Comments for the 2013 BLM NPR-A Oil & Gas Lease Sale

- BLM publishes Notice of Sale in *Federal Register* by **October 4, 2013**
- Deadline for bid submission: **November 4, 2013**
- BLM Lease Sale intended to coincide with **November 6, 2013** State of Alaska Lease Sale

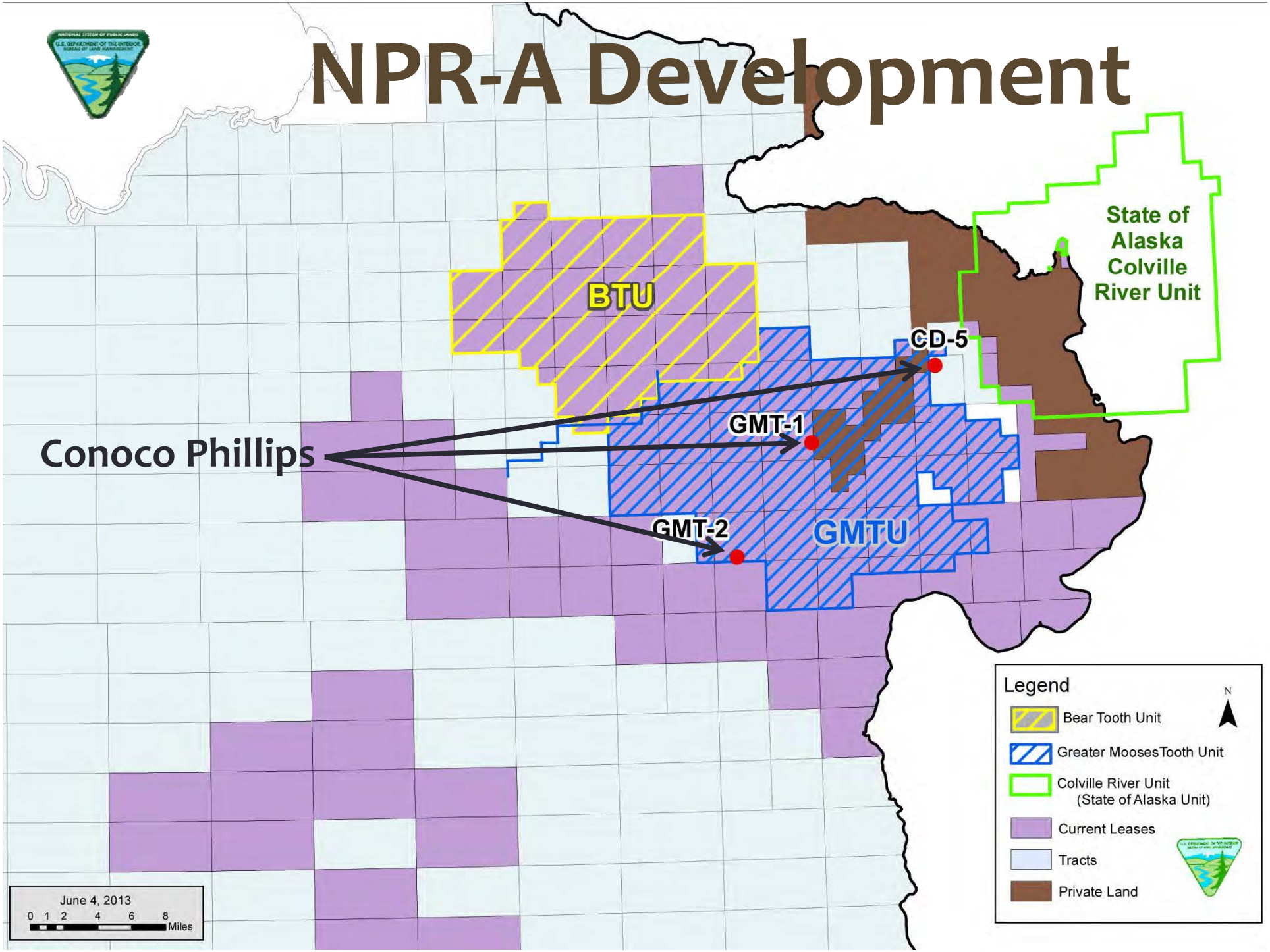
NPR-A 2013 Tract Map



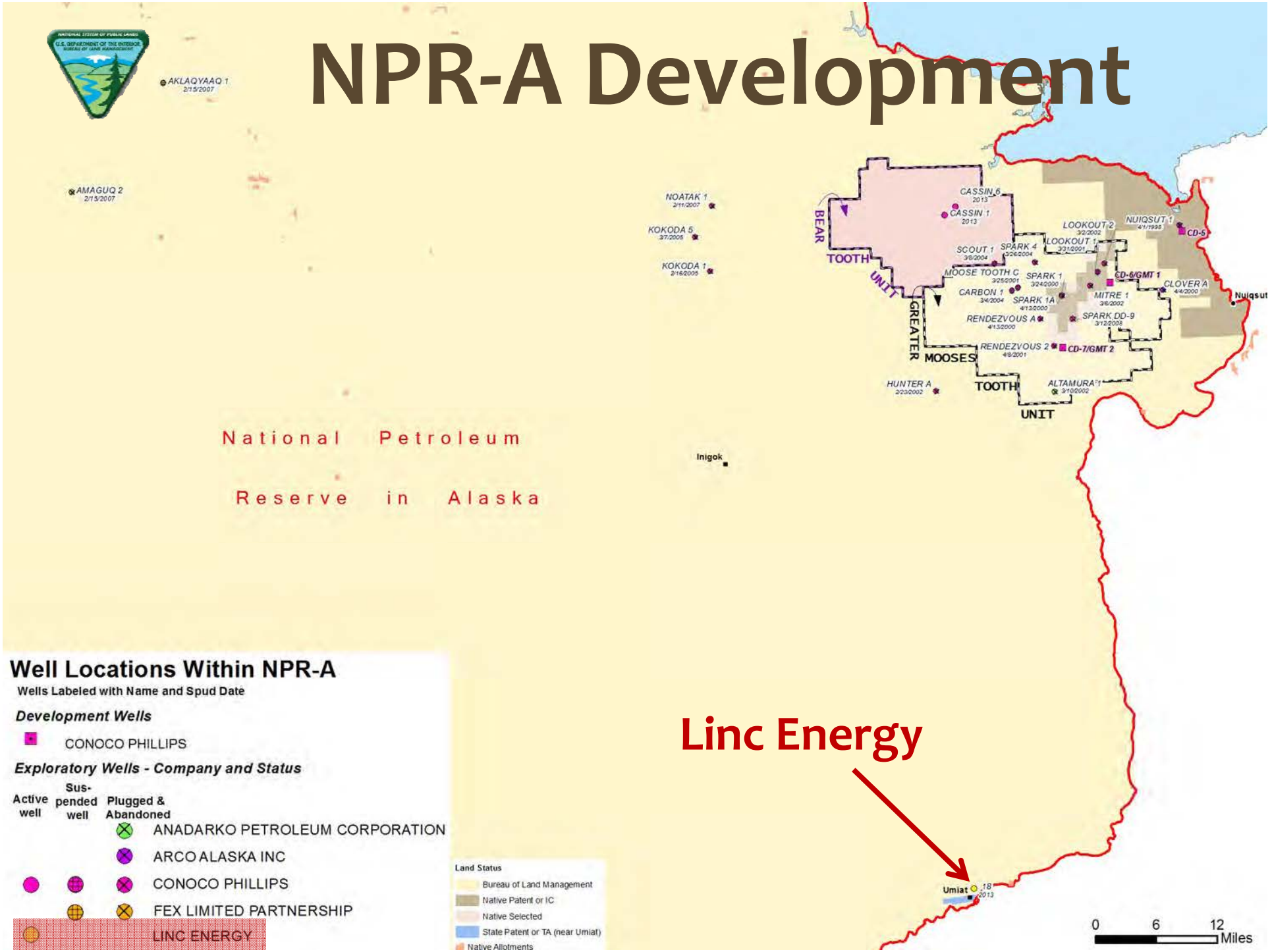
NPR-A Development

NPR-A Development

NPR-A Development



NPR-A Development



Trans-Alaska Pipeline System

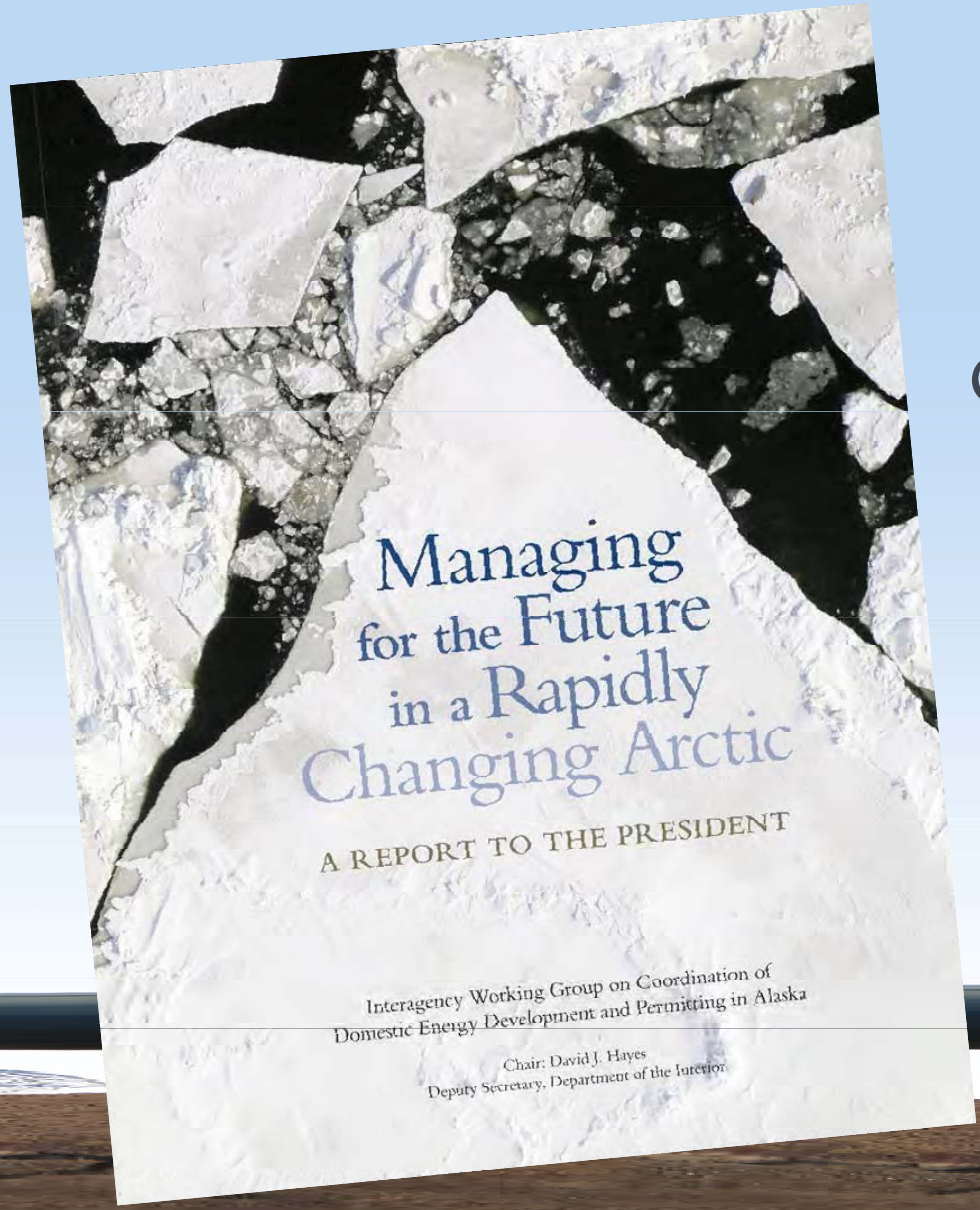
Interagency Working Group

On July 12, 2011 Executive Order **13580** established the Interagency Working Group on Coordination of Domestic Energy Development and Permitting in Alaska.

Interagency Working Group

- Office of the Secretary of the Interior
- Commerce
- Defense
- Agriculture
- Energy
- Homeland Security
- Office of the Federal Coordinator
- Council on Environmental Quality
- Office of Science and Technology Policy
- OMB
- National Security Staff

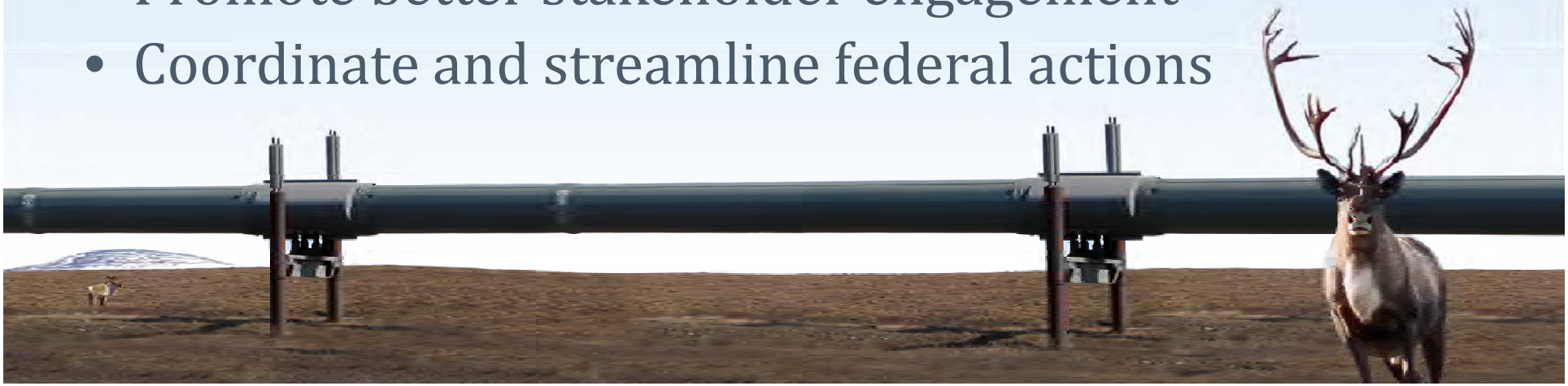
Interagency Working Group



Coordination of Domestic Energy Development and Permitting in Alaska

Interagency Working Group

- Adopt an Integrated Arctic Management approach when making stewardship and development decisions affecting the U.S. Arctic
- Ensure ongoing high-level White House leadership on Arctic issues
- Strengthen key partnerships
- Promote better stakeholder engagement
- Coordinate and streamline federal actions



Questions?

APPENDIX C

OFFSHORE OIL PIPELINES

BOEM
Bureau of Ocean Energy Management

Alaska OCS Region

Offshore Oil Pipelines

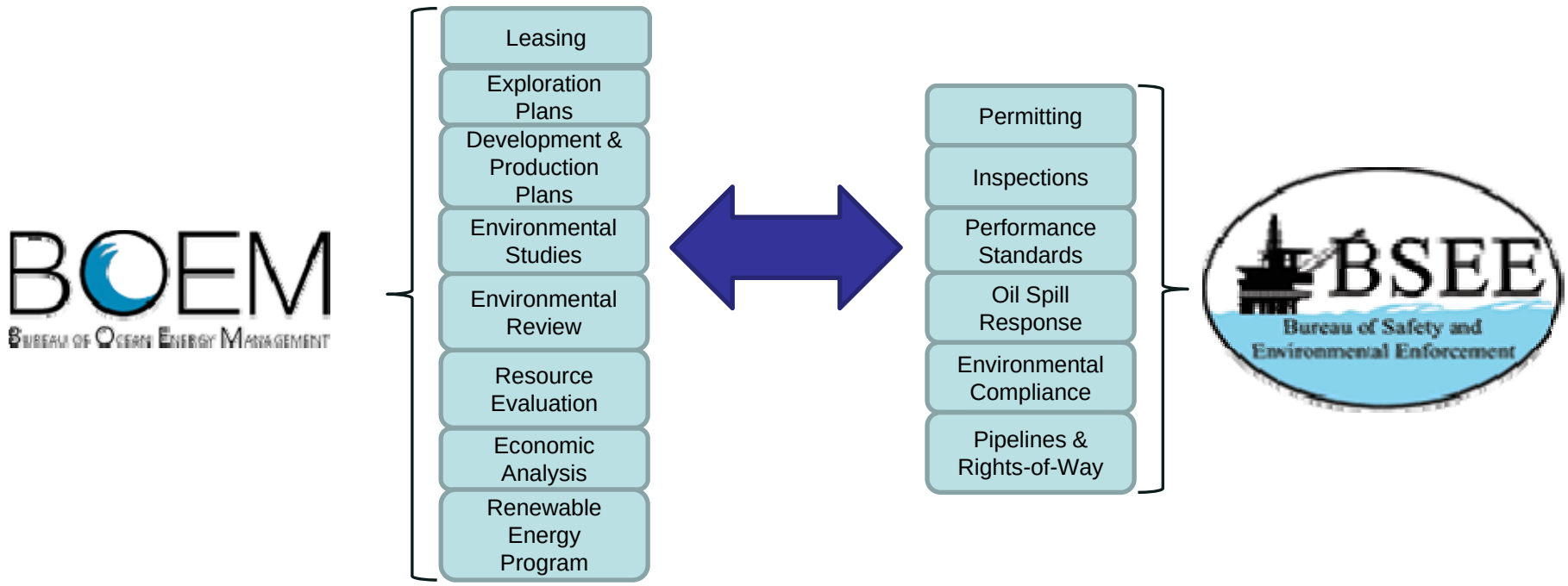
Arctic/Cold Regions Oil Pipeline Conference
September 17, 2013
Anchorage, Alaska

David Johnston
Regional Supervisor of Leasing and Plans, Alaska
Department of the Interior, Bureau of Ocean Energy Management

BOEM and BSEE Partnership

Created simultaneously on May 21, 2010 by Secretarial Order 3299.

- BOEM is responsible for managing development of the nation's offshore resources in an environmentally and economically responsible way.
- BSEE works to promote safety, protect the environment, and conserve resources offshore through regulatory oversight and enforcement.



BOEM and BSEE Regulatory Responsibilities

BOEM

Lease Stipulation

- Chukchi Sea Lease Sale Stipulation #3

Ancillary Activities:

- Pipeline Rights-of-Way Survey data
  - Shallow Hazards assessment
  - Geotechnical assessment

Development and Production Plans

- Facilities and Operations/Transportation Systems Information
  - Pipelines routes

National Environmental Policy Act

  - Environmental Assessments (EA) or Environmental Impact Statements (EIS)

Decommissioning Information

BSEE

Design Requirements

  - Design Pressures
  - Protective coating

Pipeline Right-of-Way Grants

Installation, Testing and Repair Requirements

  - Burial depths
  - Pressure Testing

Safety Equipment Requirements

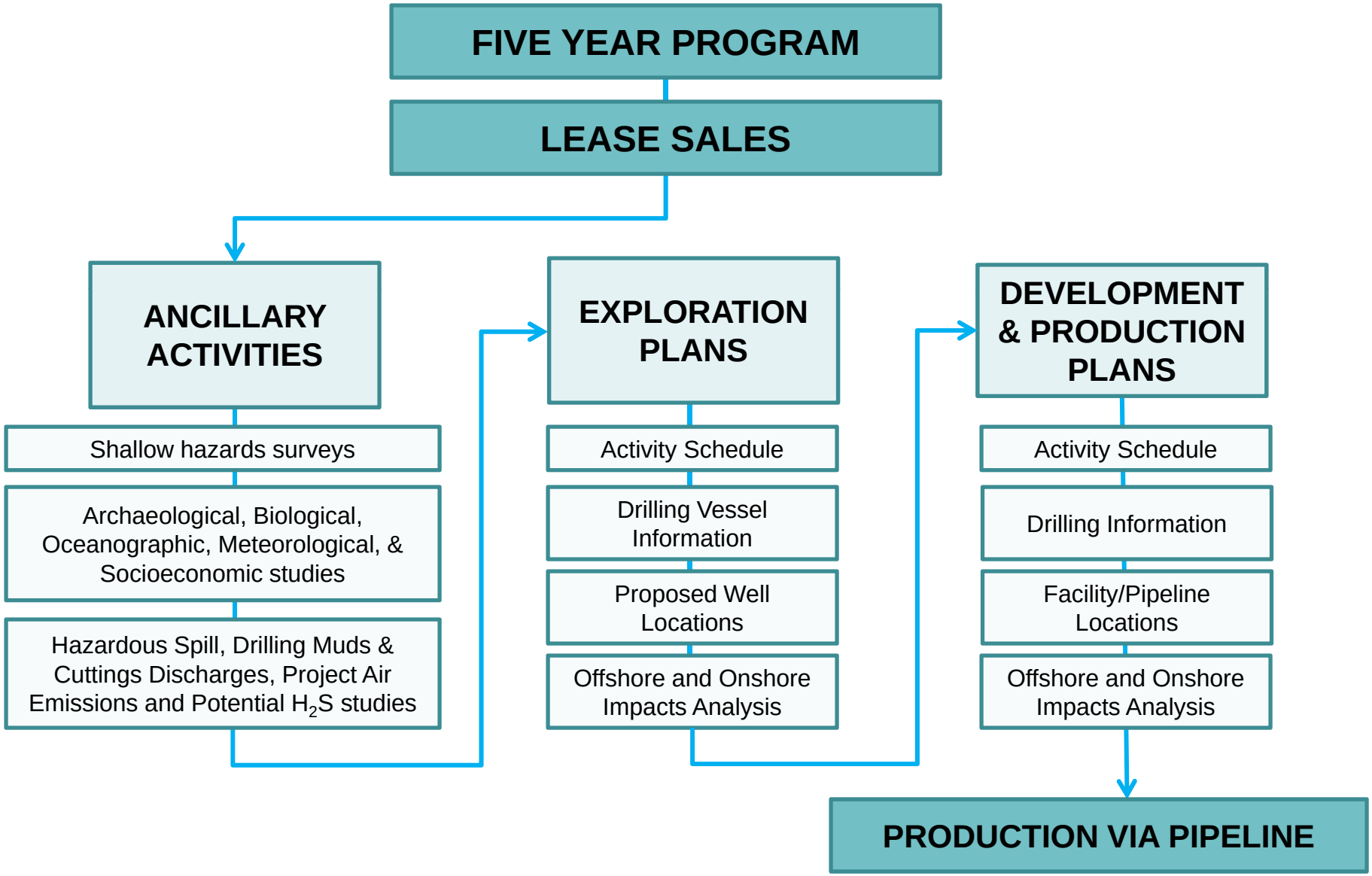
  - Departing pipelines
  - Incoming pipelines

Inspection Requirements

Decommissioning Requirements

BOEM
Bureau of Ocean Energy Management

BOEM's Regulatory Process



Federal Laws and Executive Orders

Statutory Requirements:

- OCS Lands Act
- Endangered Species Act
- Clean Air Act
- Clean Water Act
- Marine Mammal Protection Act
- Magnuson – Stevens Fishery Conservation and Management Act
- National Environmental Policy Act
- National Historic Preservation Act
- Oil Pollution Act
- Submerged Lands Act
- Energy Policy and Conservation Act
- Export Administration Act
- Migratory Bird Treaty Act
- Pollution Research and Control Act
- Rivers and Harbors Appropriation Act
- Ports and Waterways Safety Act
- Federal Oil and Gas Royalty Management Act
- Arctic Research and Policy Act
- Resource Conservation and Recovery Act
- Marine Plastic Pollution Research and Control Act

Executive Orders:

- 12898: Environmental Justice
- 13112: Aquatic Invasive Species
- 13212: Actions to Expedite Energy-Related Projects
- 13175: Consultation and Coordination with Indian Tribal Governments
- 13158: Marine Protected Areas
- 12114: Environmental Effects Abroad
- 13580: Interagency Working Group on Coordination of Domestic Energy Development and Permitting in Alaska

Stakeholder Organizations and Agencies

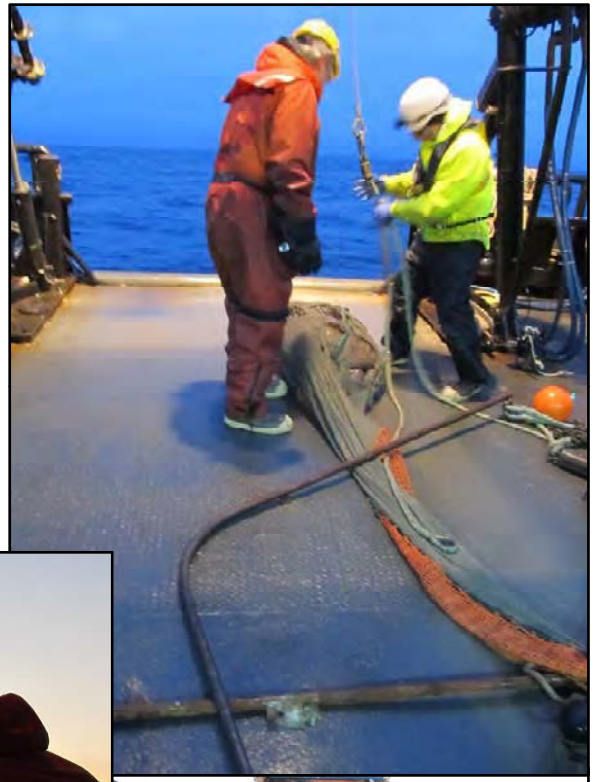
Stakeholder organizations and agencies that BOEM and BSEE interact with to make integrated and adaptive management decisions:

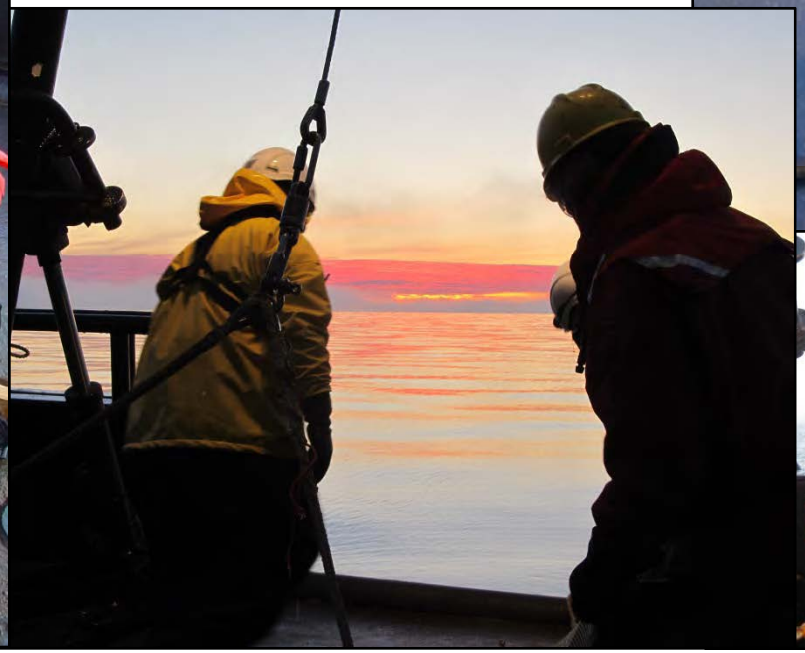
- Department of Agriculture
- Department of the Interior agencies
- Department of State
- Environmental Protection Agency
- National Oceanic and Atmospheric Administration
- Corps of Engineers
- U.S. Coast Guard
- National Science Foundation
- National Security Staff
- Arctic Policy Group - Department of State, U.S. Extended Continental Shelf Task Force - National Ocean Council/Department of State, Department of Defense Task Force on Climate Change
- State of Alaska – Resource Agencies
- North Slope Borough
- Interagency Working Group on Coordination of Domestic Energy Development and Permitting in Alaska
- Committee on the Marine Transportation System
- National Ocean Council
- U.S. Arctic Research Commission
- Interagency Arctic Research Policy Committee
- Alaska Marine Ecosystem Forum
- North Slope Science Initiative
- Alaska Climate Change Executive Roundtable
- Smithsonian Institution

Environmental Studies

BOEM's Environmental Studies Program (i.e. ESP) develops, conducts and oversees world-class scientific research specifically to inform decisions regarding development of Outer Continental Shelf energy and mineral resources.

BOEM has invested about $400 million studying the OCS environment of offshore Alaska, and developed more than 500 reports since 1973.





BOEM ESP 2011 Beaufort Fish Survey
Source: BOEM Photo Gallery

Alaska OCS Conditions

Conditions operators can reasonably expect on the Alaska OCS:

- Extreme cold
- Freezing spray
- Snow
- Extended periods of low light
- Strong winds
- Dense fog
- Sea ice
- Strong currents
- Dangerous sea states

ALL conditions are compounded by remote location and relative lack of infrastructure.

Wainwright Airport
Source: BOEM Photo Gallery (2011)

Tugs in ice
Source: BOEM Photo Gallery (2012)

Arctic OCS Geographic Considerations

Chukchi Sea Leases

- Water depth: 130 to 170 feet
- Range to land: 60 to 190 nautical miles
- Extreme ice features:
  - Small area of landfast ice along shore
  - Mobile pack ice within lease area,
  - Permafrost: near shore; varied
  - Strudel scour and seafloor gouging
- Subsistence hunting areas
- Endangered & threatened species and critical habitats

Beaufort Sea Leases

- Water depth: 30 to 230 feet
- Range to land: 3 to 45 nautical miles
- Extreme ice features:
  - Landfast ice: October to July
  - Mobile pack ice within lease area
  - Permafrost: near shore; varied
  - Strudel scour and seafloor gouging
- Subsistence hunting areas
- Endangered & threatened species and critical habitats

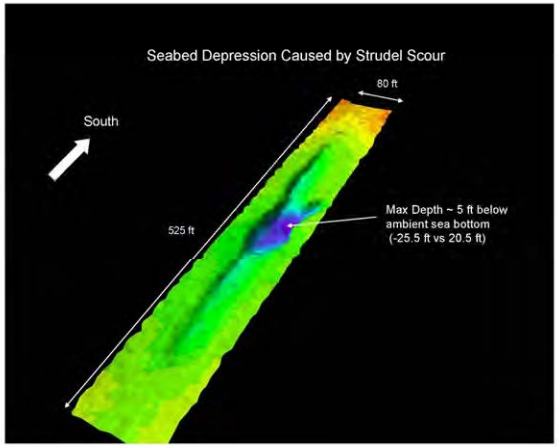
Shallow Hazard Surveys

- **Seafloor Hazards:**
  - Ice Gouges
  - Strudel Scours
  - Fault Escarpments
  - Diapiric Structures
  - Gas Vents
  - Unstable Slopes
  - Slumps
  - Chemosynthetic Communities
  - Hydrate Mounds
  - Rock Outcrops

- **Subsurface Geological Hazards:**
  - Erosion Truncation Surfaces
  - Faults
  - Hydrate Zones
  - Gas-charged Sediments
  - Abnormal Pressure Zones
  - Buried Channels
  - Slumps

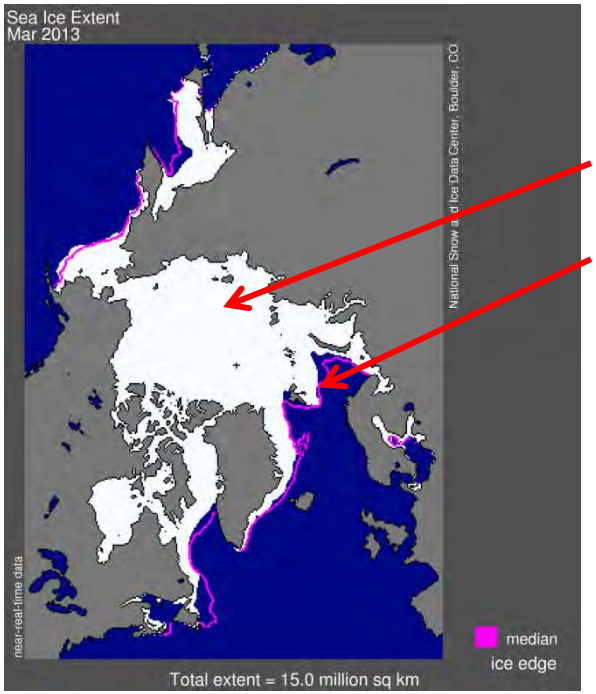
- **Man-made Hazards:**
  - Pipelines
  - Wellheads
  - Shipwrecks
  - Drowned Archeological Resources
  - Miscellaneous Debris

- **Other Critical Features:**
  - Subsurface Expression And Deformation [associated with Ice Gouges]
  - Strudel Scours and Associated Pockmarks
  - Potential Biological Activity
  - Drowned Archaeological Resources



Strudel Scour
Source: Coastal Frontiers (2013)

Sea Ice Changes



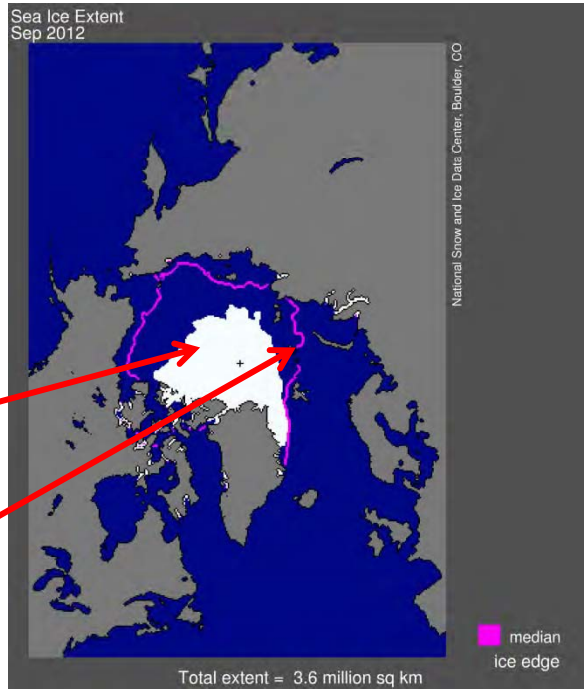
Changing Sea Ice coverage: 1979 to 2013

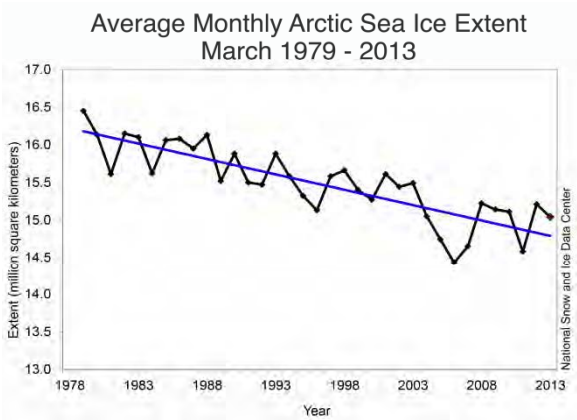
Maximum sea ice extent (in white) March 2013

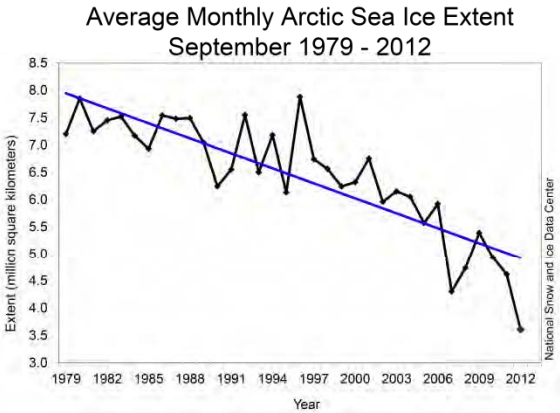
Median sea ice extent (red line) for the period 1979–2012.

Minimum sea ice extent (in white) September 2012

Median sea ice extent (red line) for the period 1979–2012.

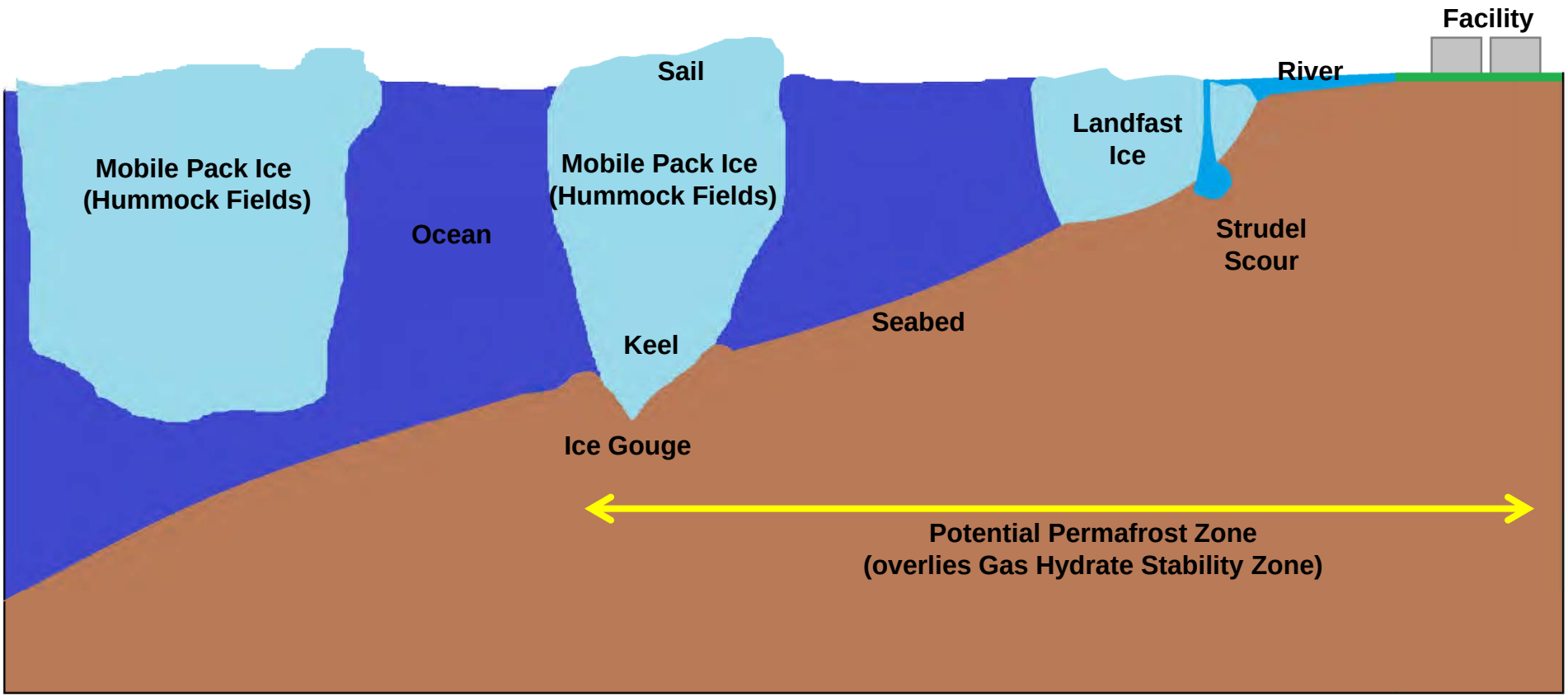




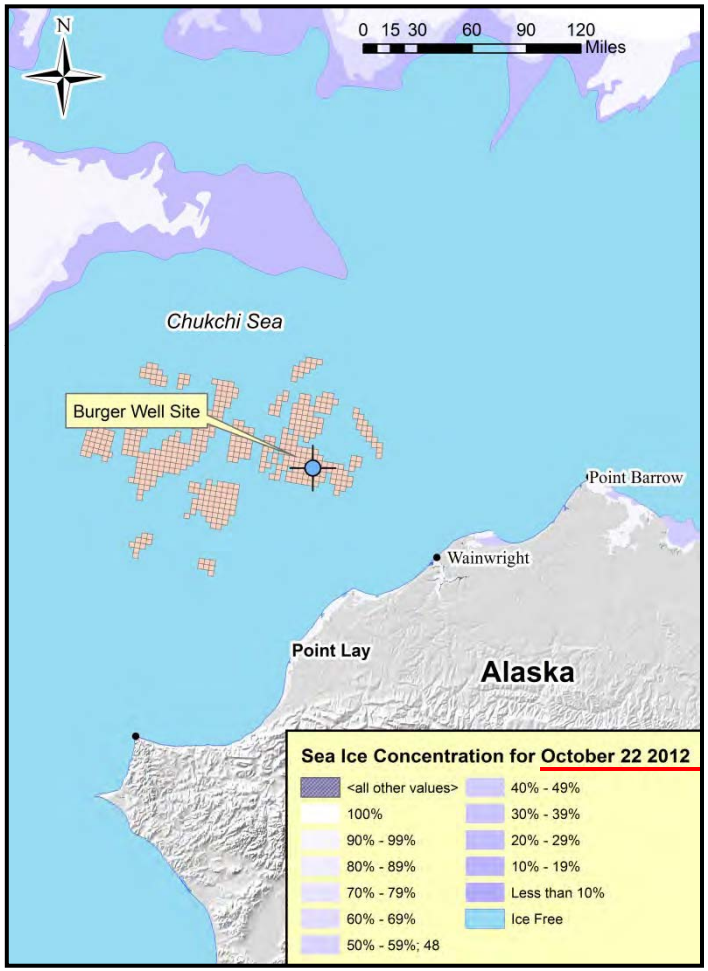


Data from National Sea Ice Data Center http://nsidc.org/

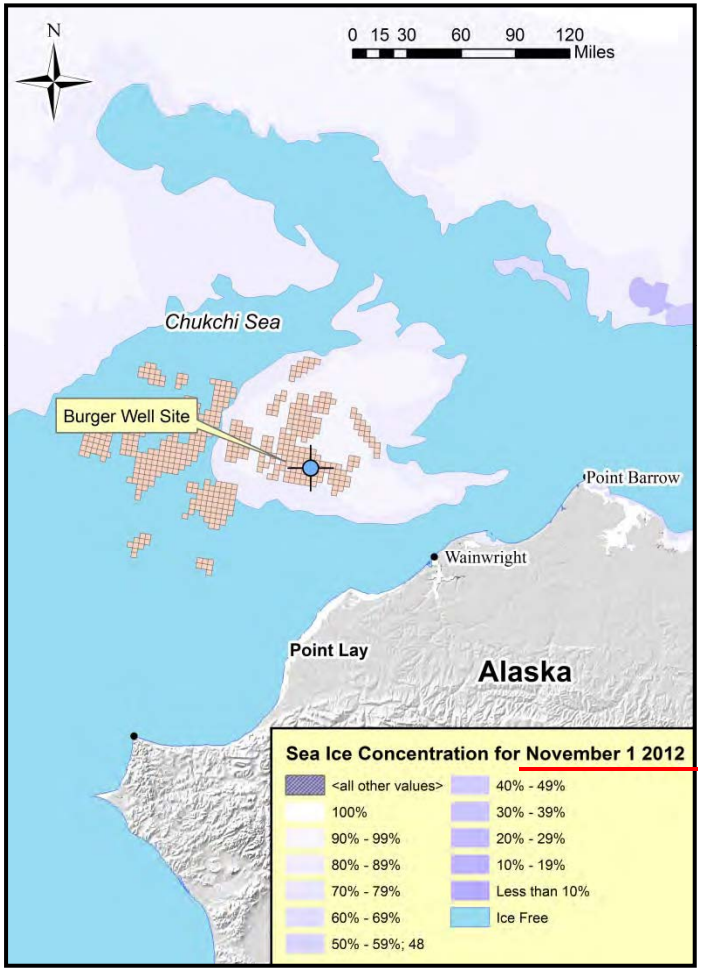
Extreme Ice Features



Ice Formation and Movement



- BOEM limited drilling into hydrocarbon zones just prior to freeze-up in the Chukchi Sea
- Each year, BOEM estimates freeze-up using hindcasting techniques, and establishes a “trigger date” for the drilling hiatus
- Consistent with adaptive management, BOEM may refine the “trigger date” in light of real time sea ice forecasting



Sea Ice data files interpreted by the National Ice Center (NIC)

On-Going Arctic Activities

Ancillary Activities: 2013

Shell:

- Open water marine survey program in Chukchi Sea

BP:

- Geotechnical & Seabottom Investigation in Beaufort Sea

Over 60 on-going Environmental Studies researching:

- Physical Oceanography
- Fates and Effects
- Habitats and Ecology
- Marine Mammals and Protected Species
- Social Systems
- Information Management
- Integrated Studies.

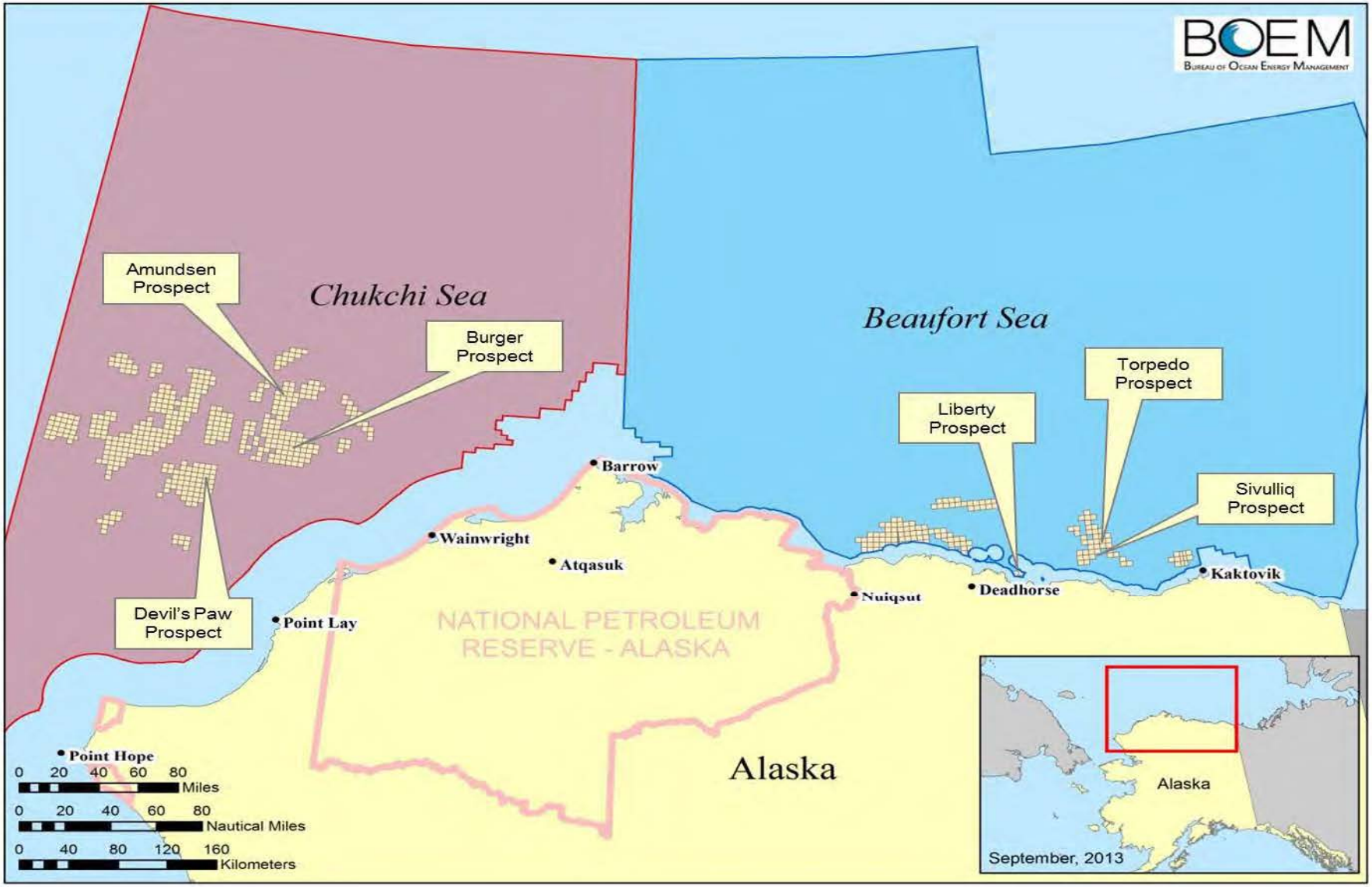
Seismic Survey Activities: 2013

TGS:

- Open water 2D G&G Seismic Survey in the Chukchi Sea

View of Tow Viking II from the Discoverer
Source: BSEE Photo Gallery

Current OCS Leases



Proposed BPXA Development – Liberty Prospect

Location: Beaufort Sea, 5.5 miles offshore in 20 feet of water

Reserves: Approximately **150 million barrels** of recoverable, high-quality crude oil

Timeline:

Aug 1991: Leases issued

Feb 1998: BPXA submits 1st DPP [gravel island]

Jan 2002: BPXA puts Liberty on hold

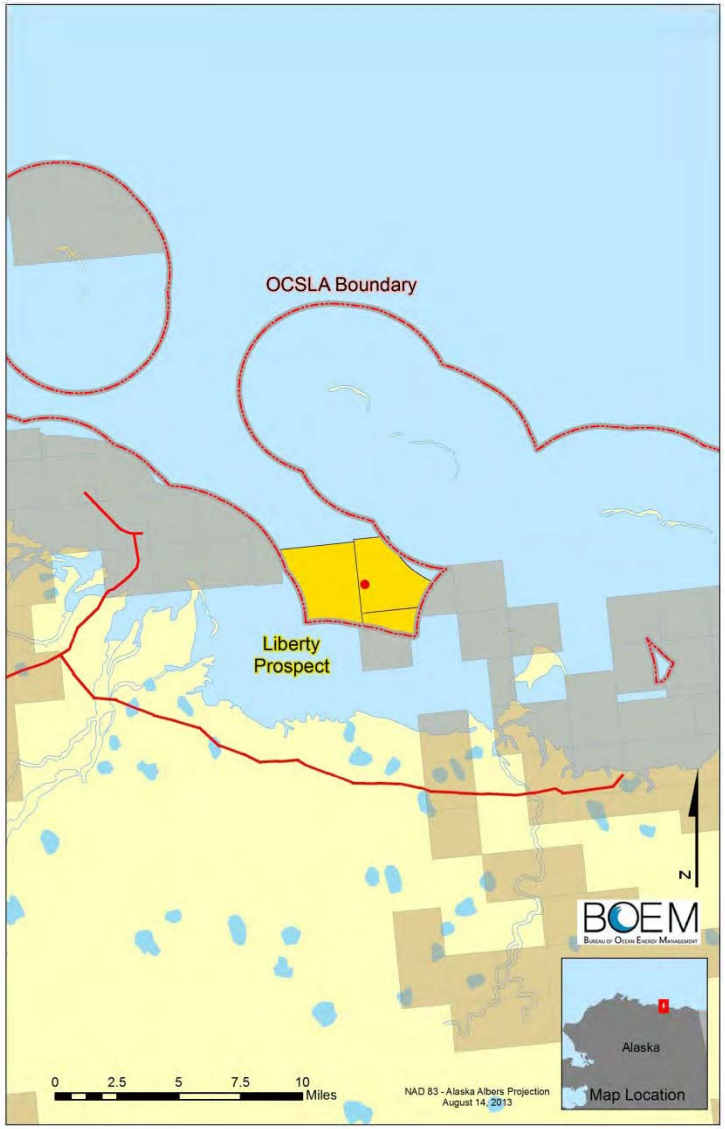
Jan 2007: BPXA submits 2nd DPP [ultra-extended reach drilling (uERD)

Jan 2008: 2nd DPP approved

Jun 2012: BPXA decides against uERD

Dec 2012: BSEE grants Suspension of Production (SOP) - Final design and construction with production by Dec. 2020

Dec 2014: BPXA to submit new DPP



BOEM
Bureau of Ocean Energy Management

THANK YOU

APPENDIX D

THE COMPLEX NATURE OF FEDERAL AND STATE INVOLVEMENT IN THE CONSTRUCTION AND OPERATION OF THE TRANS ALASKA PIPELINE SYSTEM

The Complex Nature of Federal and State Involvement in the Construction and Operation of the Trans Alaska Pipeline System

Alaska Department of Environmental Conservation
2013 Arctic/Cold Regions Oil Pipeline Conference
September 17-19, 2013
Dena'ina Civic and Conference Center
Anchorage, Alaska

Peter C. Nagel, Lands Manager
Peter.Nagel@alyeska-pipeline.com

Outline

- Overview of the Public Landscape
- Four Tools for Operational Compliance
- Comparison - Construction & Operation Phases

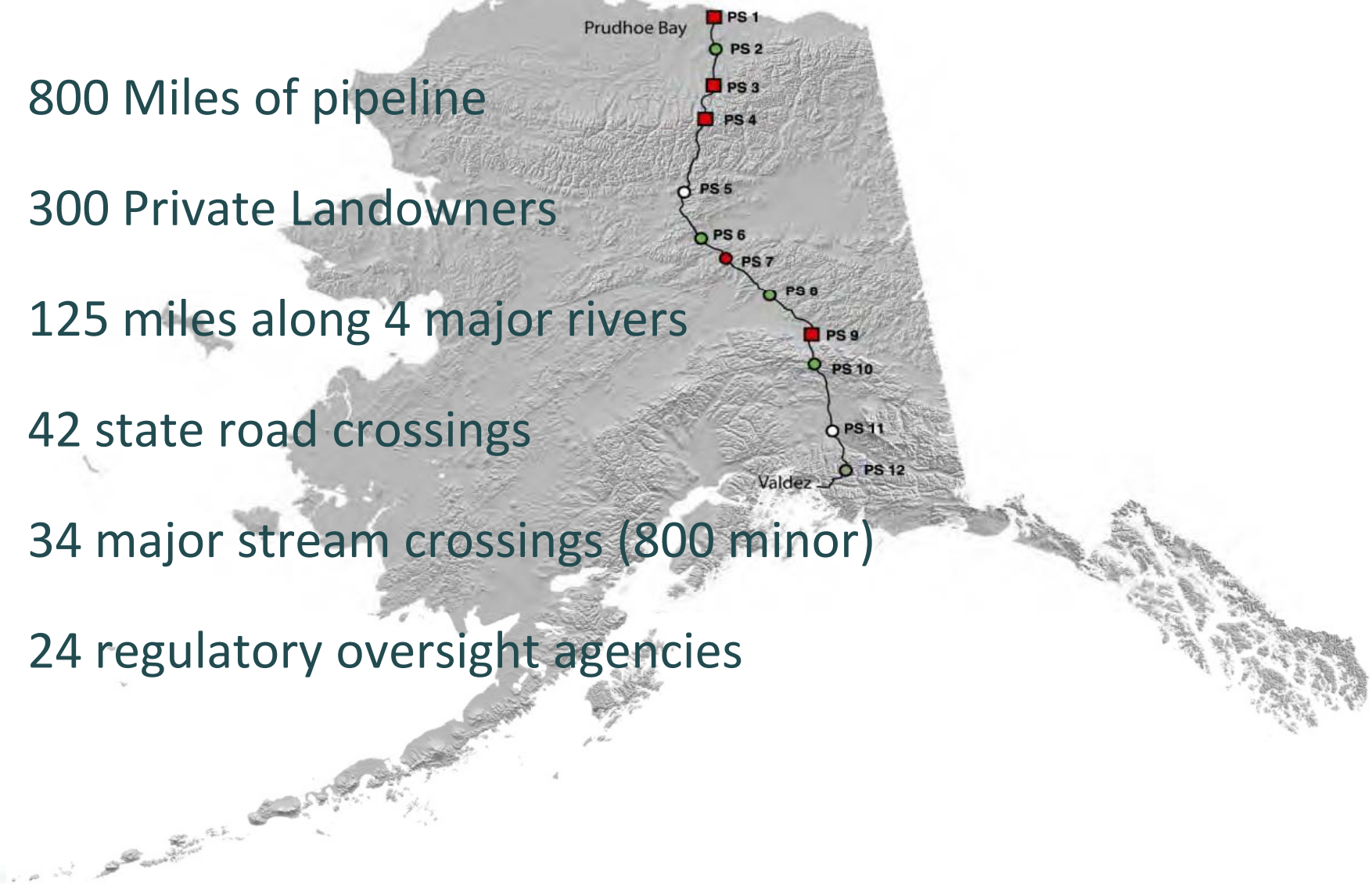
Or consider

International Right of Way Association's Course 304 title

When Public Agencies Collide

- Sources of Public Agency conflict
- Personality and behavior factors
- Primary drivers/motivators of Public Agencies
  - The role of bureaucracies
  - The influence of politics
- Processes for conflict resolution

The Landscape



- 800 Miles of pipeline
- 300 Private Landowners
- 125 miles along 4 major rivers
- 42 state road crossings
- 34 major stream crossings (800 minor)
- 24 regulatory oversight agencies

Four Tools For Compliance

- Regulatory Compliance Information System
- Event Notification Form
- Permit Acquisition Guidelines Checklist
- Right-of-Way Grant and Lease Manual

Regulatory Compliance Information Search

Search by :

Keyword:

☑ Search Document title only

Regulation: -ALL-

Agency: ADEC(2) - Alaska Department of Environmental Conservation

Regulatory Specialist:

Method:

Status:

Department Group:

Position Title:

Advanced Keyword Search

- ADEC(2) - Alaska Department of Environmental Conservation
- ADF&G - Alaska Department of Fish & Game
- ADHSS - Alaska Department of Health and Social Services
- ADOL - Alaska Department of Labor & Workforce Development
- ADNR - Alaska Department of Natural Resources
- AKOSH - Alaska Department of Occupational Safety & Health
- ADPS - Alaska Department of Public Safety
- ADOR - Alaska Department of Revenue
- ADOT/PF - Alaska Department of Transportation & Public Facilities
- DMV - Alaska Division of Motor Vehicles
- AOGCC - Alaska Oil & Gas Conservation Commission
- APUC - Alaska Public Utilities Commission
- ASFM - Alaska State Fire Marshall's Office
- AST - Alaska State Troopers
- ATC - Alaska Transportation Commission
- AFD - Anchorage Fire Department
- COE - Army Corps of Engineers
- BATF - Bureau of Alcohol, Tobacco & Firearms
- BIA - Bureau of Indian Affairs
- BLM - Bureau of Land Management
- MOA - City of Anchorage
- Cordova - City of Cordova
- Fairbanks - City of Fairbanks
- Valdez - City of Valdez
- DOHHS - Depart of Health & Human Services
- DOA - Department of Agriculture
- DOC - Department of Commerce
- DOD - Department of Defense
- DOE - Department of Energy
- DHS - Department of Homeland Security

Regulation Information

Alyeska pipeline

Title: 18 AAC 70 Article 01

Last Updated: 10/7/2012

Description: Statewide Water Quality Standards - antidegradation policy, protected water use classes, water quality criteria, whole effluent toxicity limit, classification of state waters.

Status:
- (●) Reviewed
- ( ) Pending Review
- ( ) Needs Review

Last Reviewed By: 177873

Applicable to APSC: ☑

Last Reviewed for Applicability: 7/10/2012

Primary Specialist: Connor, David (907) 787-8806

Alternate Specialist: Gryder-Boutet, Donna (907) 522-6776

Required Record Keeping: All monitoring and reporting records as required by the associated permits must be maintained for the duration of the permit or as required by the permit.

RedFlags:

Additional Notes: 4/12/10: Transferred primary RS duties from Adam Owen to Dave Connor per e-mail from Carl Rutz dtd 4/7/10. S. Martin

Agency: Add Agency

Acronym	Name
ADEC(1)	Alaska Department of Environmental Conservation

Methods of Compliance: Add/Edit Method of Compliance

ID	Short Description	Long Description	Type
ED-108-1	Excavation Dewatering, Hydrostatic Testing &	Excavation Dewatering, Hydrostatic Testing & Domes	Document
ED-108-2	Quality Assurance Program Plan	Quality Assurance Program Plan	Document
EN-43-	Environmental Protection Manual: Water Use,	Environmental Protection Manual: Water Use, Drinki	Document

Responsibilities: Add Responsibility

Work Task	Responsible Group	Responsible Position	
Understand Article 1 as relates to NPDES permits	Environmental Manager	Water Quality SME	Delete
Understand Article 1 as relates to NPDES permits	VMT BWT	Environmental Coordinator-VMT	Delete

Event Notification

Event Notification
This form to be completed and sent by OCC only.

☐ Anticipated ☐ Follow-up (Update)
☐ Initial Unscheduled ☐ Drill (If a Drill Write Boldly Across the Form "This is a Drill")

(Use for Drills Also)

1.

☐ a. Fire, Stipulation 1.17.1
☐ b. Serious Accidents, Stipulation 1.20.1
☐ c. Threats to Pipeline Integrity (See Back), Stipulation 1.21.1
☐ d. High inventory and tanker suspension
☐ e. Unscheduled Slow Down (≥ 20% Reduction at Pump Station 1)
☐ f. Unscheduled Shut Down (No Mainline Pumps Running)
☐ g. Other: _____
☐ h. Security
☐ i. Bomb Threat
☐ j. Spill > 55 Gallons

NOTE: Any Reportable Release Under the State Spill Reporting Requirement Summary, Including Third Party Spills Which Alyeska Responds to, Must Be Reported Via the Alyeska Spill Reporting System.

2. Report Number (YYMMDD##)	3. Sent By:	4. Date and Time Sent:

5. **Use Distribution List in Outlook labeled: DL, Event Notification (Form 2124) to disseminate this form.**

6. Phone to: (Note Instructions On Reverse)

7. Event Location:	8. Event Date and Time:

9. Event Description & Action Taken (Attach Additional Pages if Needed)

Permit Acquisition Guidelines – Checklist

(sample for River Training Structure near highway)

PERMITTED ACTIVITY	V	PERMIT TYPE	LEAD TIME	SUBJECT MATTER EXPERT
Land Use		Federal R/W Amendment	60-90	P. Nagel
Incl. INSIDE ROW ACTIVITIES		State R/W Amendment	120	P. Nagel
Access Ramp Cutting (2.4.3)		Stipulation Authorizations (see list left)	1-30	P. Nagel
Special Access(2.9)				
Cult. Res. Clearances (2005 PA)				
Water Use		Temporary Water Use Permit	45-60	K. Wilson (D. Schmidt)
Fill Placement		404 Fill Permit	0-120	P. Nagel
		401 Certificate/Short-term WQ Variance	0-120	D. Connor
Water Discharge		General Wastewater NOD Approval	30-45	K. Wilson (D. Schmidt)
		General Stormwater PPP Approval	30-60	K. Wilson (D. Schmidt)
Fish Habitat Interference		Title 16 Fish Habitat Protection Permit	30-60	K. Wilson (D. Schmidt)
New Construction		Notice to Proceed	30-90	P. Nagel or A. Beckett
Outside or In ROW boundaries		Local Gov't Development Permit	45-60	P. Nagel
		State Fire Marshal Approval	45-60	D. Knutson
Mineral Material Mining		Material Sale Contract	20-90	P. Nagel
Road/Highway Encroachment		Utility Permit	30	P. Nagel
		Lane Closure Permit	5-20	Permitted Activity Initiator

Grant and Lease Compliance Manual Section on Port Valdez Terminal Facility

- Federal Grant -requires a ballast water treatment facility
- State Lease - requires access for USDOI representatives

- Alyeska Method of Compliance - in 2001, BLM(JPO) analyzed related regulatory developments and relieved in writing APSC from Section 23 responsibility, mostly.

TAPS Construction

Federal

Grant & Agreement

for Right-of-Way

(Jan 1974)

- 1969 ROW application
- ANCSA 17c and

  Public Land Order 5150
- TAP Authorization Act
- 515 permits / 465 NTP's
- Federal Authorized Officer

State

Right-of-Way Lease

(May 1974)

- Pipeline ROW Leasing Act
- Mineral Closing Orders
- Purchase of PS01 & VMT
- 832 permits / 403 NTP's
- State Pipeline Coordinator

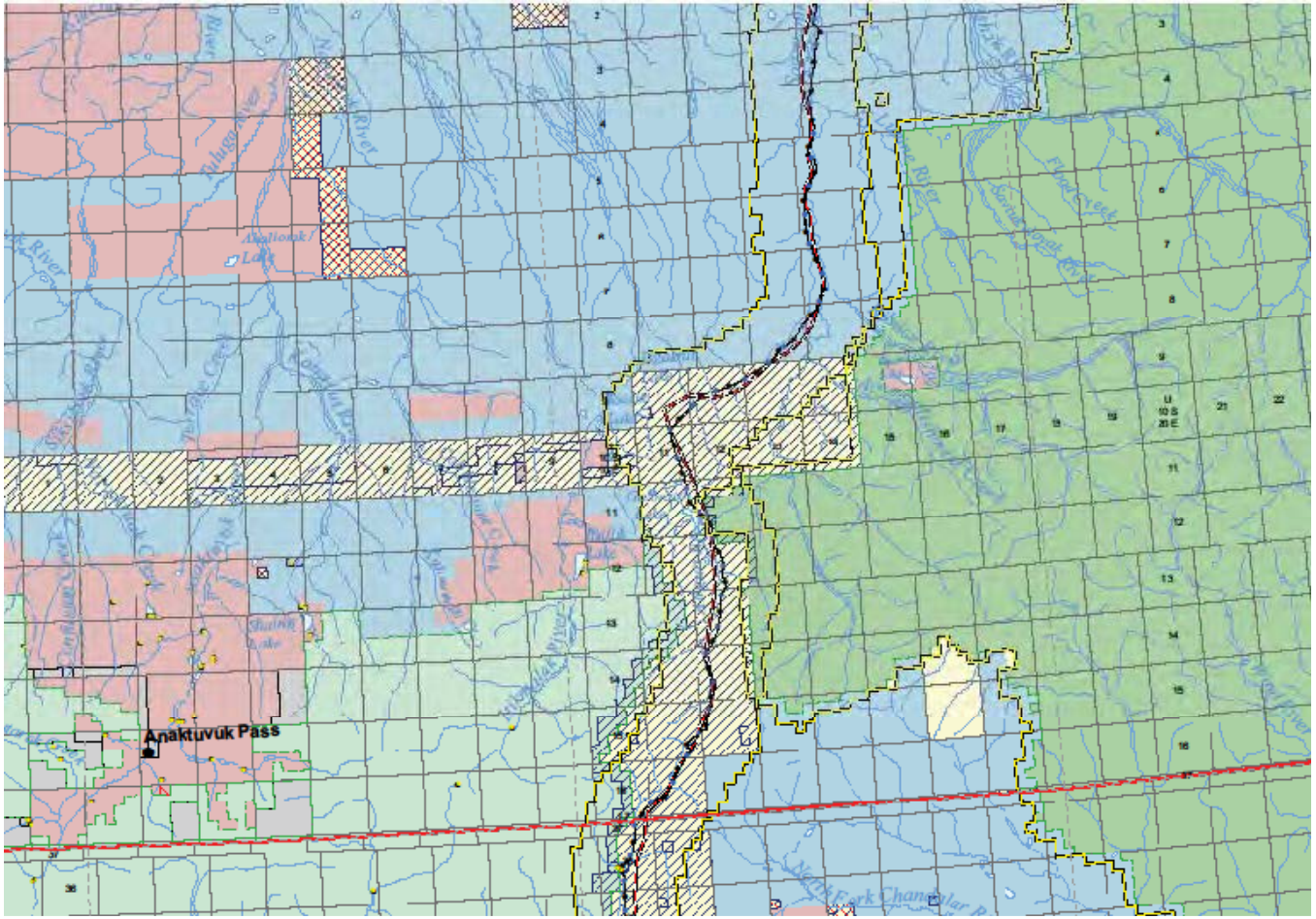
Cooperative Agreement, USDOI & SOA for Proposed Trans-Alaska Pipeline January 8, 1974

- Land Categories
- Surveillances
- State Highway and Airports
- Stipulations

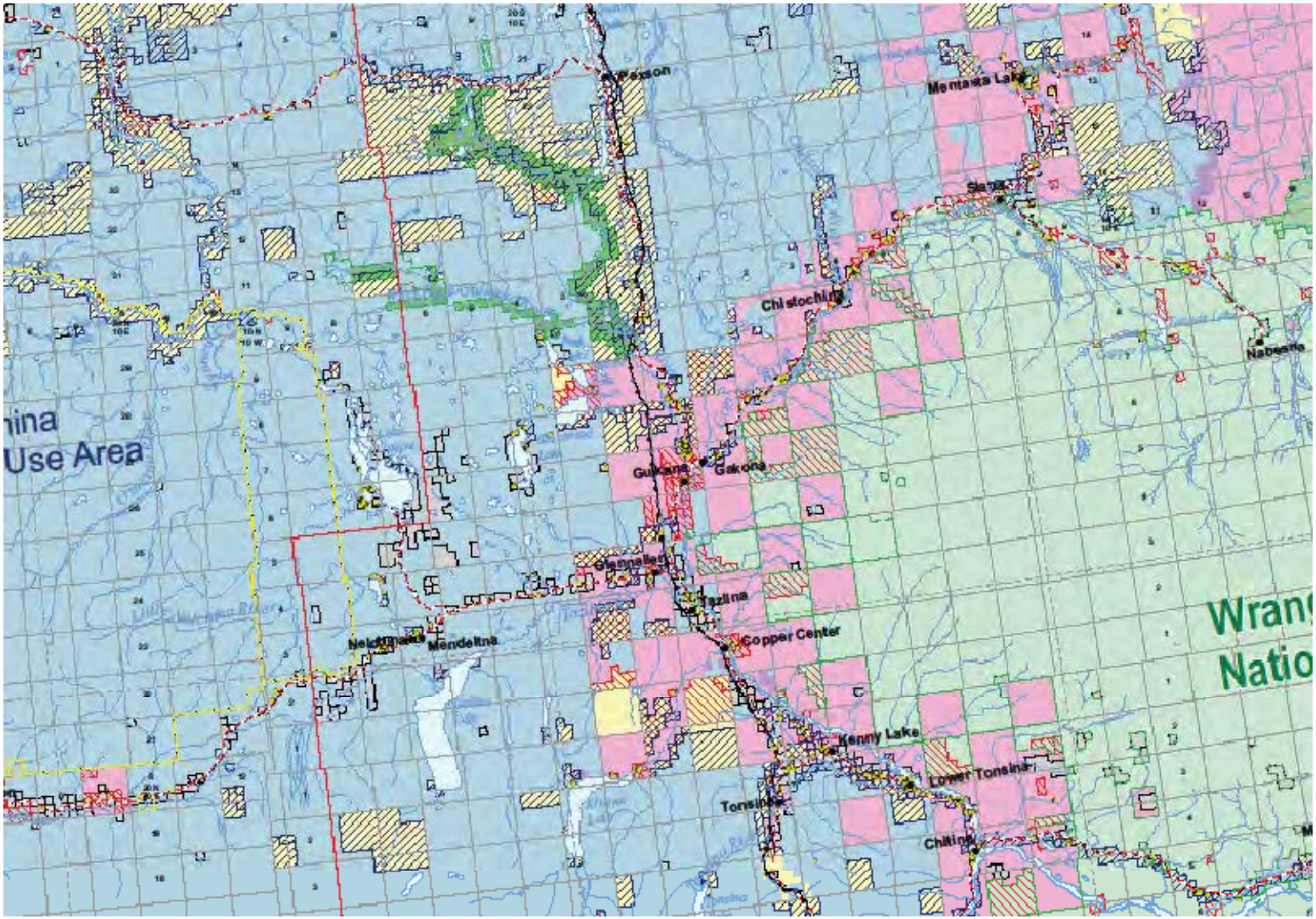
Operations

- Land Conveyances & ANILCA Conservation System Units
- Joint Pipeline Office & Spill Contingency Plans

Atigun Pass



Ahtna Region

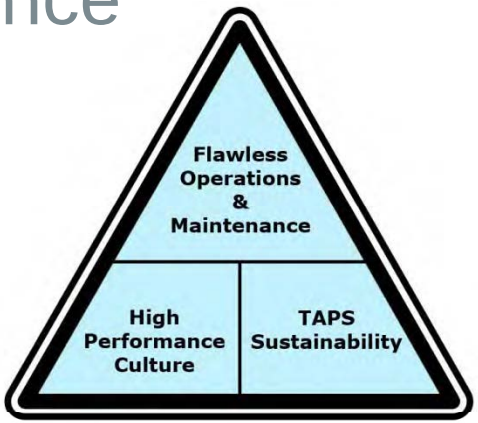


Alaska Land Use

Remember, we are tenants on the lands of Alaska. Conduct your activities at all Alyeska facilities with the care and respect of an invited guest.

Alyeska Poster Message

- Operational excellence
- High performance
- Sustainability



2012 WORLD'S MOST ETHICAL COMPANIES
WWW.ETHISPHERE.COM

5 CULTURAL ATTRIBUTES

Alyeska pipeline
35 YEARS
DELIVERING EXCELLENCE

APPENDIX E

ORCHESTRATING THE PERMIT PROCESS FOR A NORTH SLOPE DEVELOPMENT

Session 2: Presentation 2 – Orchestrating the Permit Process for a North Slope Development

Company Name: ConocoPhillips Alaska, Inc.
Speaker: Lynn DeGeorge
Website URL: http://alaska.conocophillips.com/EN/Pages/default.aspx

Obtaining permits from Federal, State, and Local agencies becomes more challenging each year. What does it take to obtain permits for a project on the North Slope of Alaska? Who are the stakeholders? What is the timeline and where do you begin? ConocoPhillips will provide an overview of the process from exploration through production. Recently permitted projects will be used to provide timely examples of what to expect when permitting a major development.

APPENDIX F

ROADS TO RESOURCES – ROADS IN COLD PLACES

Alaska Department of Transportation & Public Facilities

Roads to Resources
Roads in Cold Places

September 17, 2013 DEC Arctic/Cold Regions Conference

Patrick Kemp, P.E.
Commissioner

Murray Walsh.
Roads to Resource Manager

Roads to Resources Program

- Road to Resources funds have previously been used on smaller economic development projects
- Focus expanded to larger projects to fill the pipeline, create jobs, and increase commerce

Roads to Resources Program

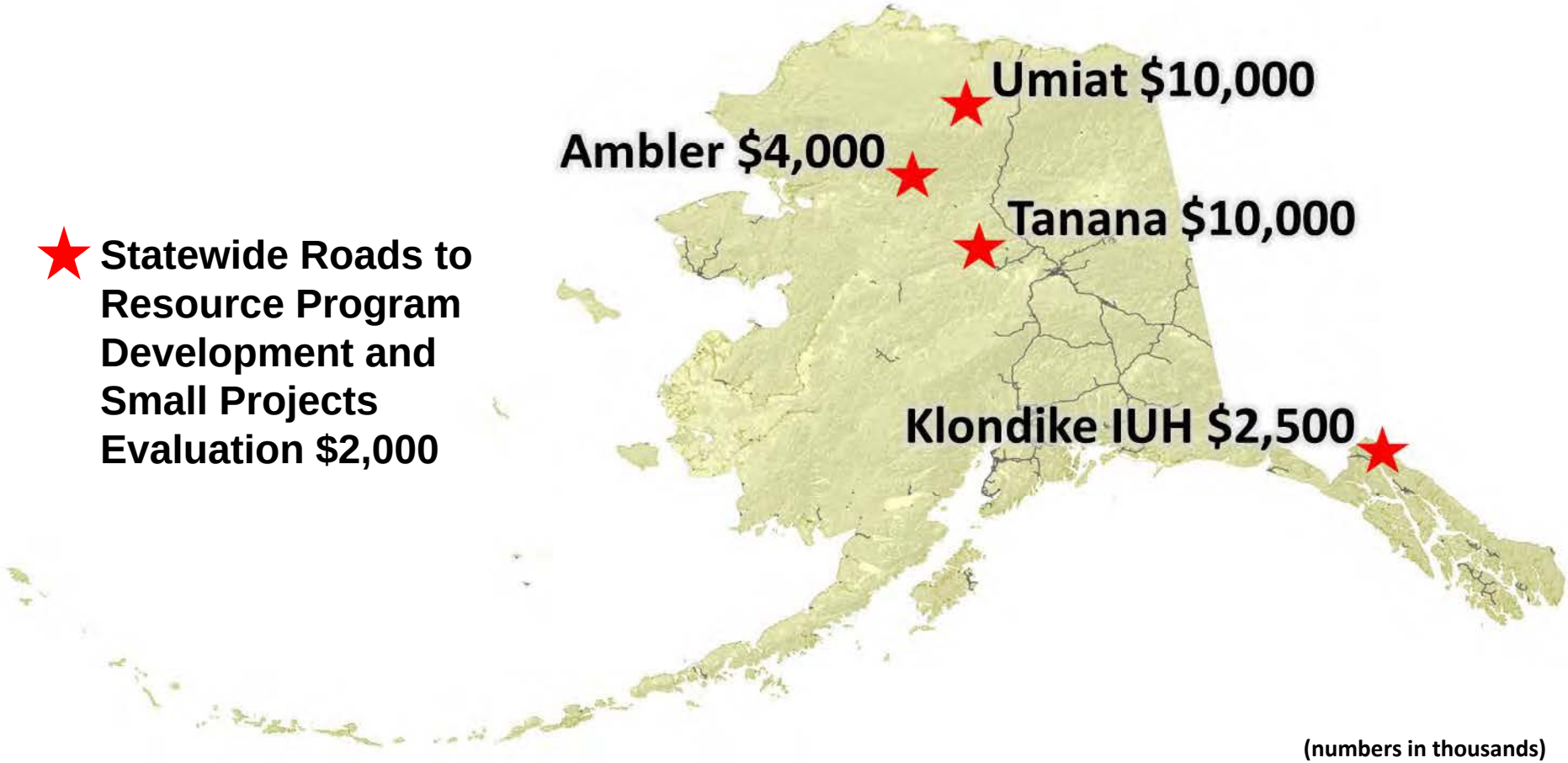
- Road is improved to higher standards as traffic and development dictates
- Funding to improve the road will be borne by the resource developers
- Roadway could be designated an “Industrial Use Highway” in order to charge tolls to industrial users (AS 44.62)
- Annual M&O costs could be funded with IUH receipts

Roads to Resources Program

<u>Guidelines for funding and design standards</u>:

- Initial permitting accomplished by DOT&PF
- Initial road is “long and skinny” constructed to minimum design standards to support development startup
- Initial road is funded either by DOT&PF or in partnership with the developer
- A long-range public/private partnership agreement would be forged to best fit both partners

Roads to Resources
2013 Capital Budget



★ **Statewide Roads to Resource Program Development and Small Projects Evaluation $2,000**

(numbers in thousands)

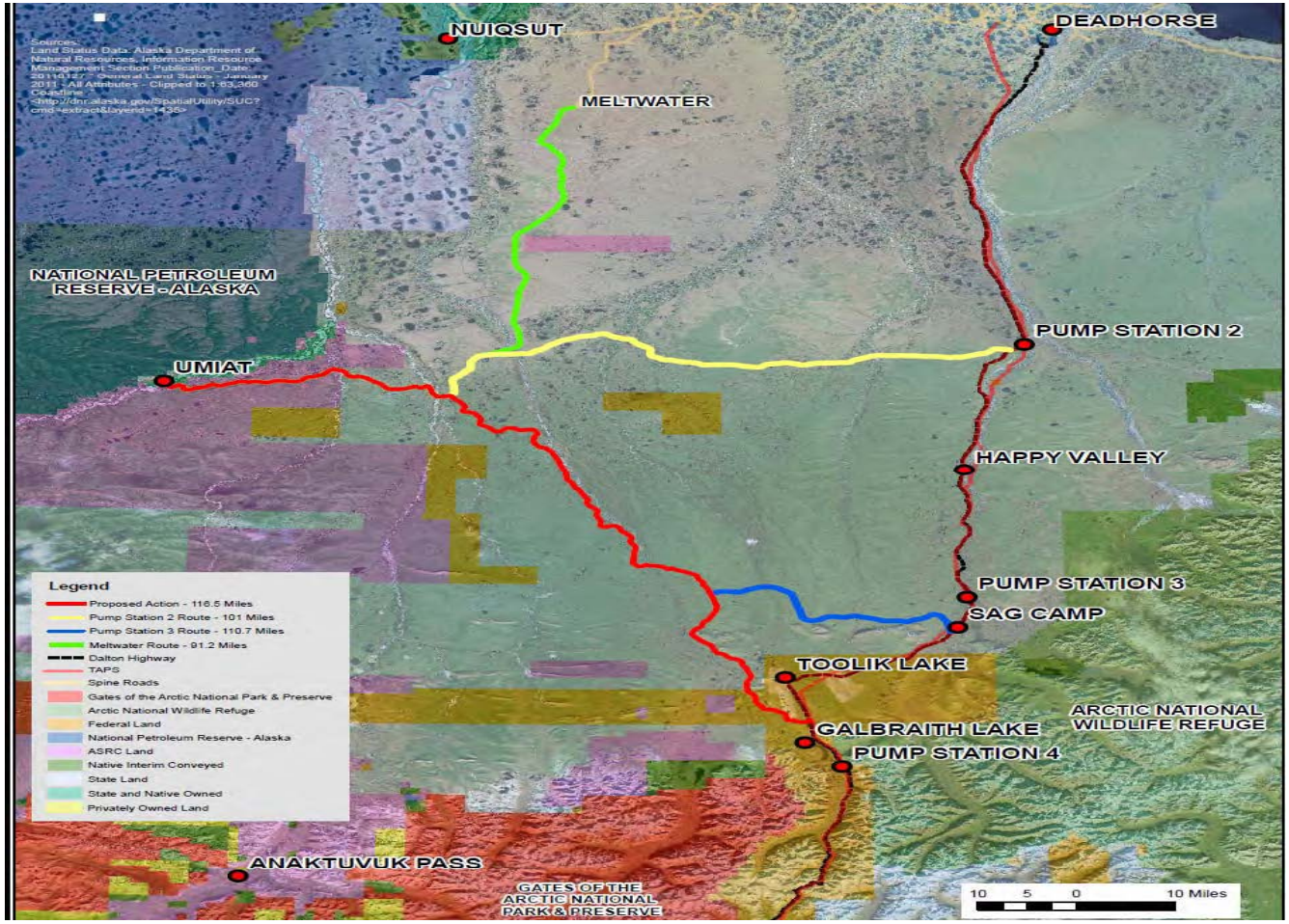
Roads to Resources
2014 Capital Budget Request

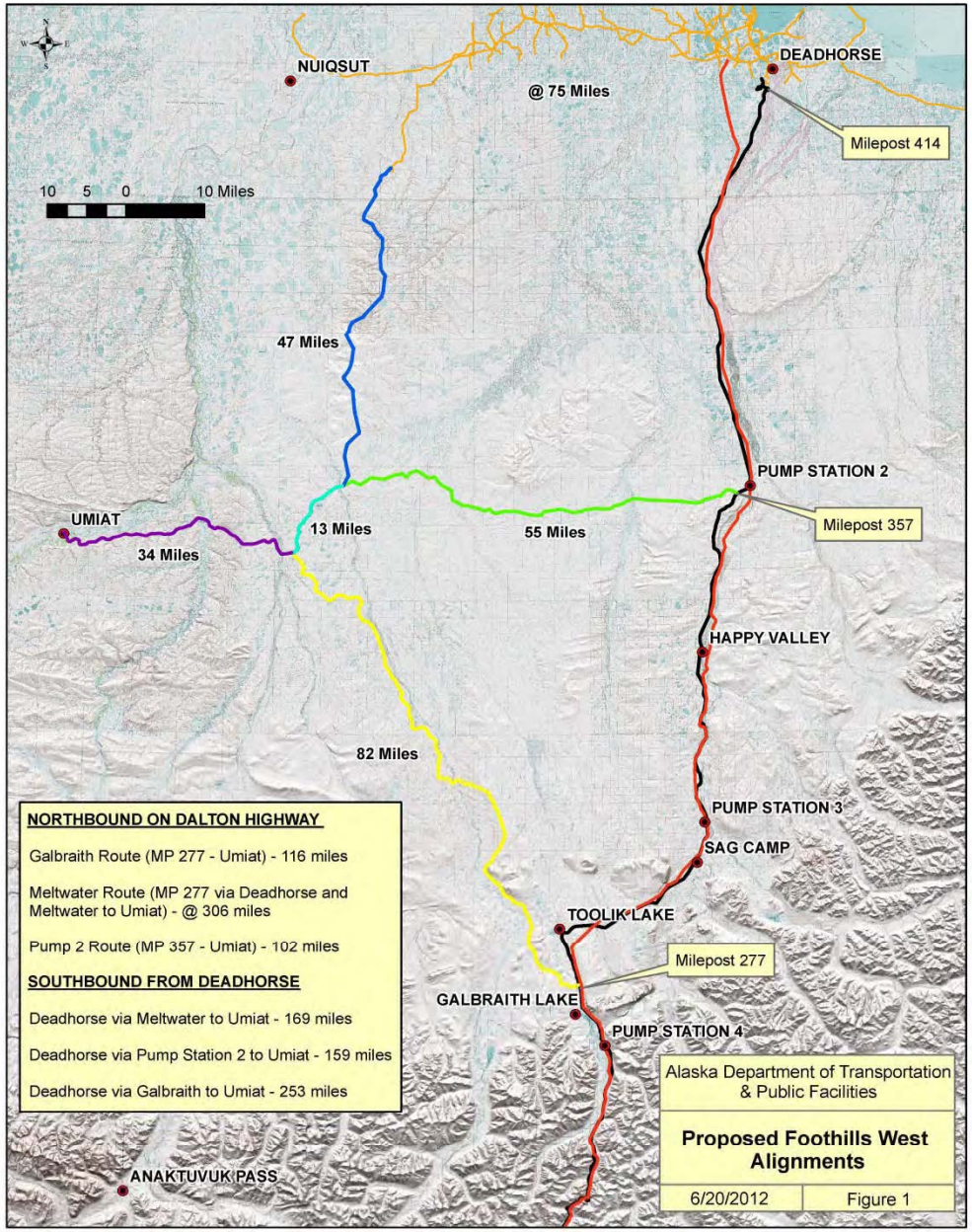
- **Statewide Roads to Resource Program Development and Small Projects Evaluation $2,000,000**

- **Ambler Access, $8,500,000 in AIDEA budget request**

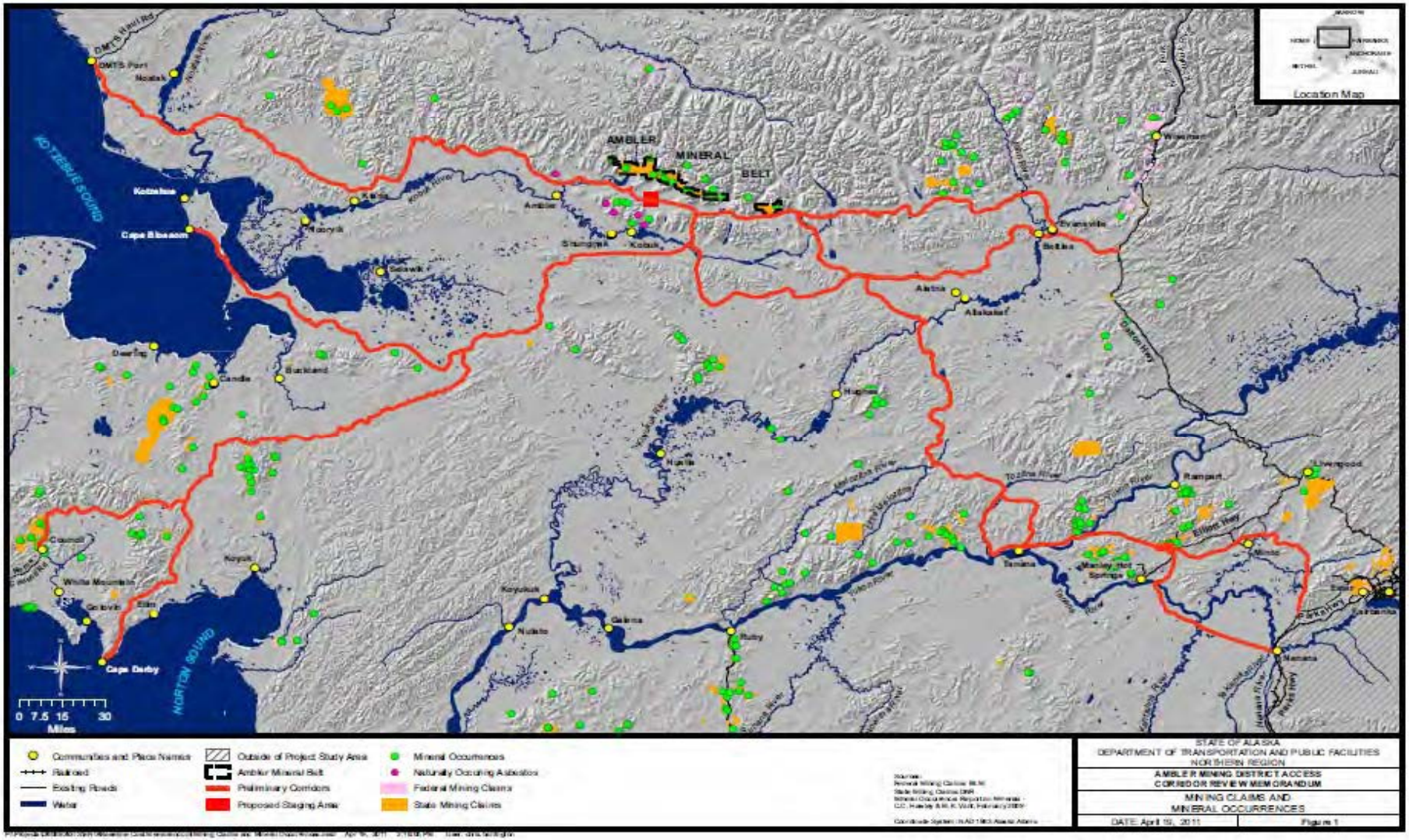
- **Dalton Highway Upgrade, $7,500,000**

Road to Umiat – Foothills West




NUIQSUT
@ 75 Miles
DEADHORSE
Milepost 414
10 5 0 10 Miles
47 Miles
PUMP STATION 2
Milepost 357
UMIAT
13 Miles
55 Miles
34 Miles
HAPPY VALLEY
82 Miles
PUMP STATION 3
SAG CAMP
TOOLIK LAKE
Milepost 277
GALBRAITH LAKE
PUMP STATION 4
ANAKTUVUK PASS
NORTHBOUND ON DALTON HIGHWAY
Galbraith Route (MP 277 - Umiat) - 116 miles
Meltwater Route (MP 277 via Deadhorse and Meltwater to Umiat) - @ 306 miles
Pump 2 Route (MP 357 - Umiat) - 102 miles
SOUTHBOUND FROM DEADHORSE
Deadhorse via Meltwater to Umiat - 169 miles
Deadhorse via Pump Station 2 to Umiat - 159 miles
Deadhorse via Galbraith to Umiat - 253 miles
Alaska Department of Transportation & Public Facilities
Proposed Foothills West Alignments
6/20/2012
Figure 1

Ambler Mining District Access



Roads in Cold Places

What is Permafrost?

Permafrost is defined as rock or soil material that has remained below 32 degrees Fahrenheit (ie, frozen) for two consecutive years. Alaska is the only state in the U.S. that must deal routinely with permafrost and its effects on highways, public facilities, rail lines and airports. Permafrost also exists in high mountain areas of the U.S. West.

Permafrost occurs almost continuously above the Arctic Circle and discontinuously throughout northern, central, and western Alaska. Southeast Alaska is permafrost-free. Permafrost differs according to water (i.e., ice) content and the types of solid material (ie, rock, gravel and sand) in which the water is suspended. The stability of the permafrost is closely related to these factors. The categories of permafrost are:

1. **Cold Permafrost**, which remains below 30°F or as low as 10°F / -12°C and can take considerable heat without thawing;

2. **Warm Permafrost**, which remains just below 32°F; very little additional heat may cause it to thaw;

3. **Thaw-Stable Permafrost**, which is found in bedrock, and in well-drained, coarse-grained sediments such as sand and gravel mixtures; movement of thaw-stable permafrost is minor, so the foundation remains essentially sound even under thawing conditions;

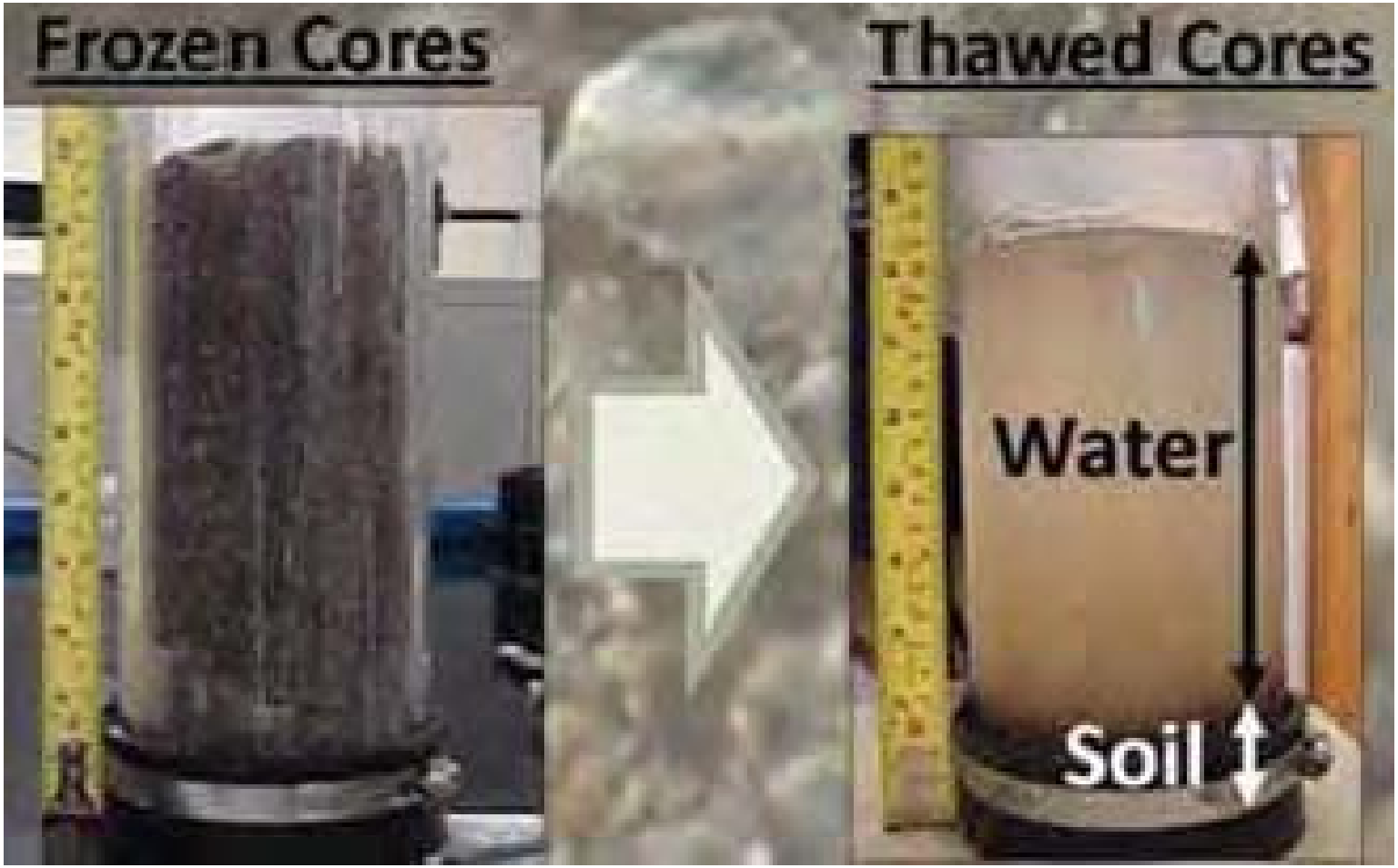
4. **Thaw-Unstable Permafrost**, which is found in poorly drained, fine-grained soils, especially silts and clays where ice is the main structural component; thawing can cause loss of strength, excessive settlement, and soil containing so much moisture that it flows;

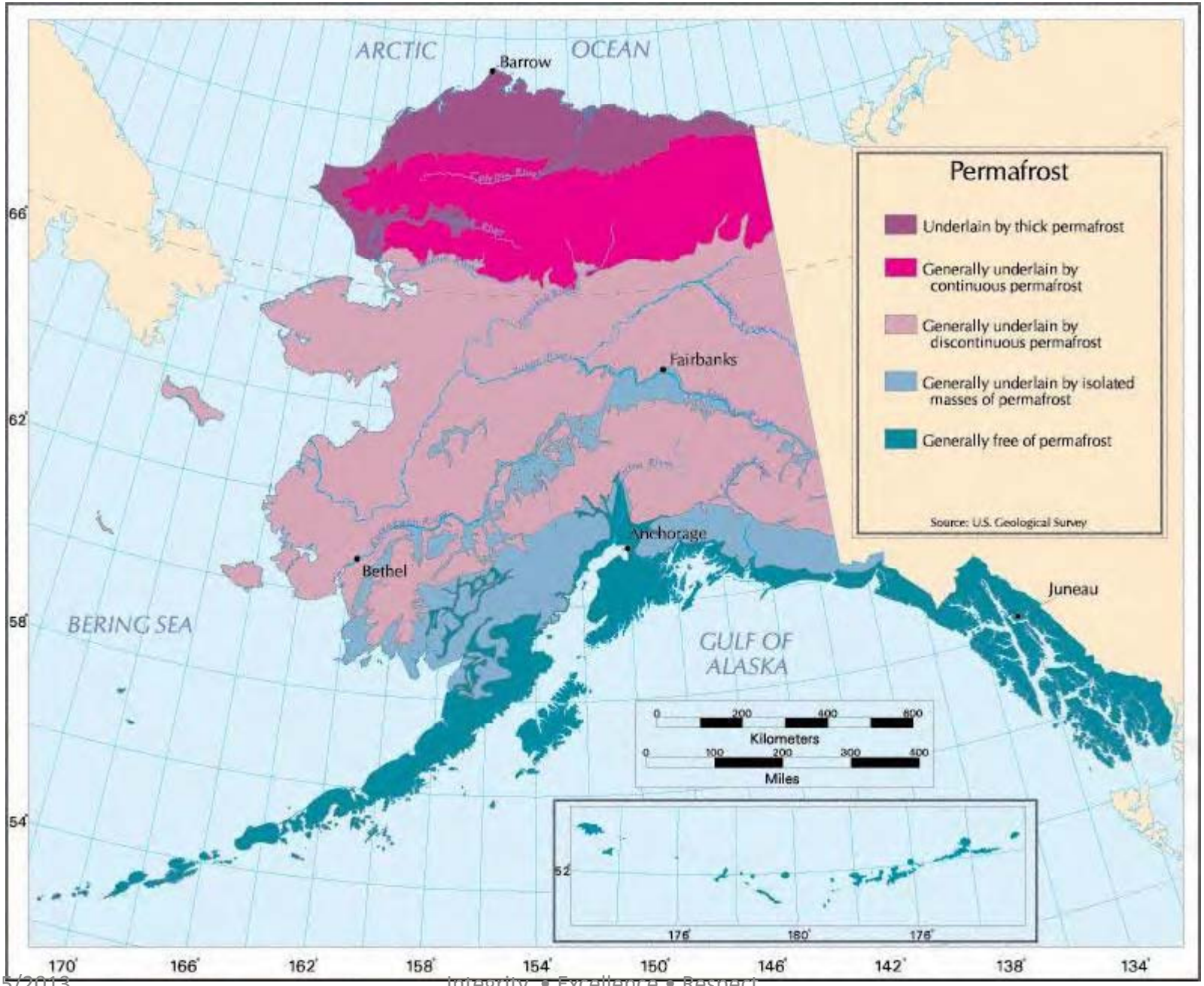
5. **Ice-Rich Permafrost**, which contains 20% to 50% visible ice, and;

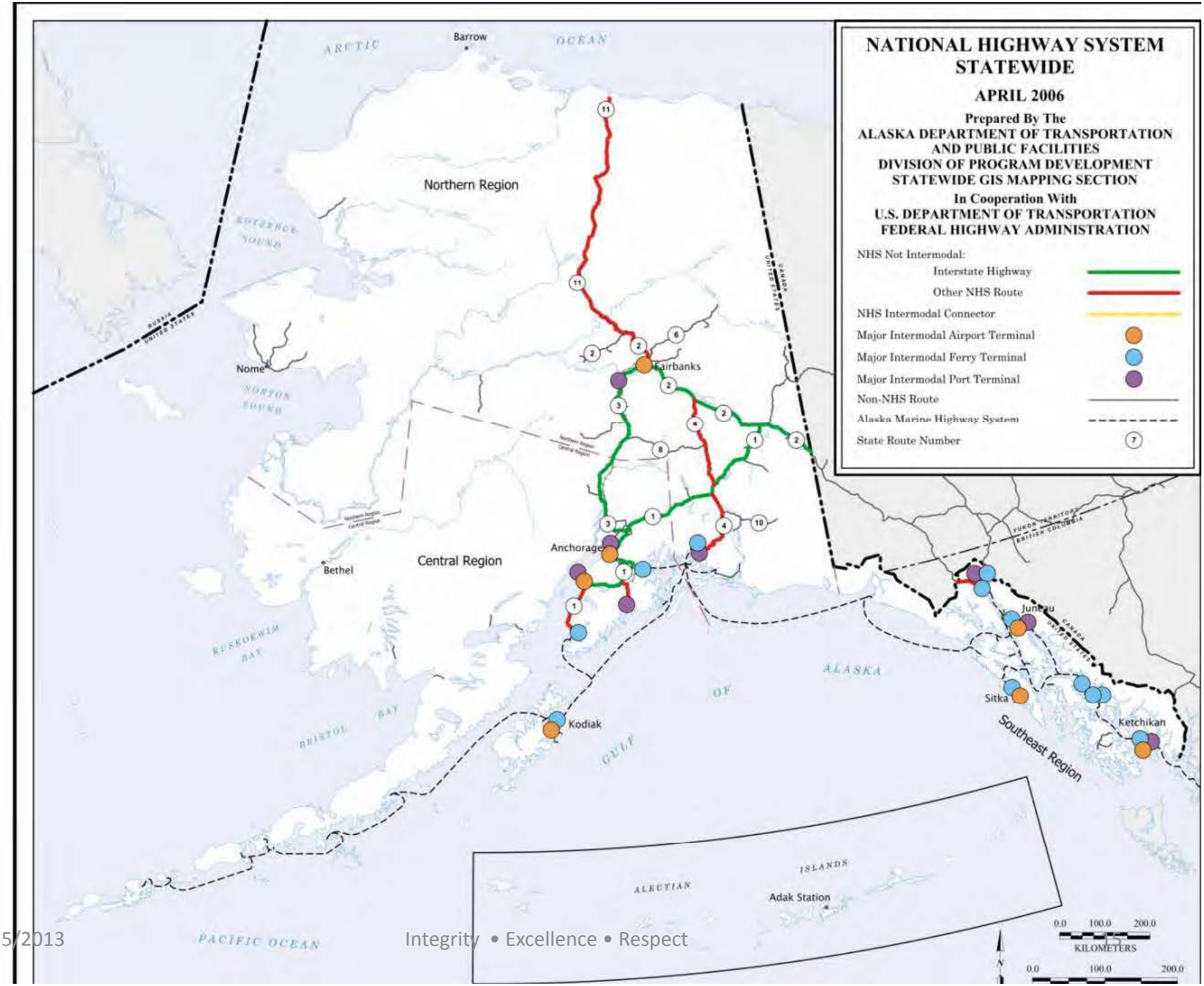
6. **Massive Ice Permafrost**, which describes structures consisting almost entirely of ice lenses and wedges.

The permafrost types with the greatest potential for thawing, and which consequently pose the greatest risks to infrastructure, are the warm, thaw-unstable, massive and ice-rich types. Generally speaking, massive permafrost occurs in the Brooks Range and North Slope, while thaw-unstable, warm and ice-rich permafrost lies in the discontinuous zone in Interior and Western Alaska and in the Yukon-Kuskokwim Delta area.

The next picture shows massive ice permafrost adjacent to the Itkillik River, along one of the alternative routes of the proposed resource road to Umiat. The bluff is approximately 100 feet high and 1,000 feet in length, extending past the right-hand edge of the photograph..

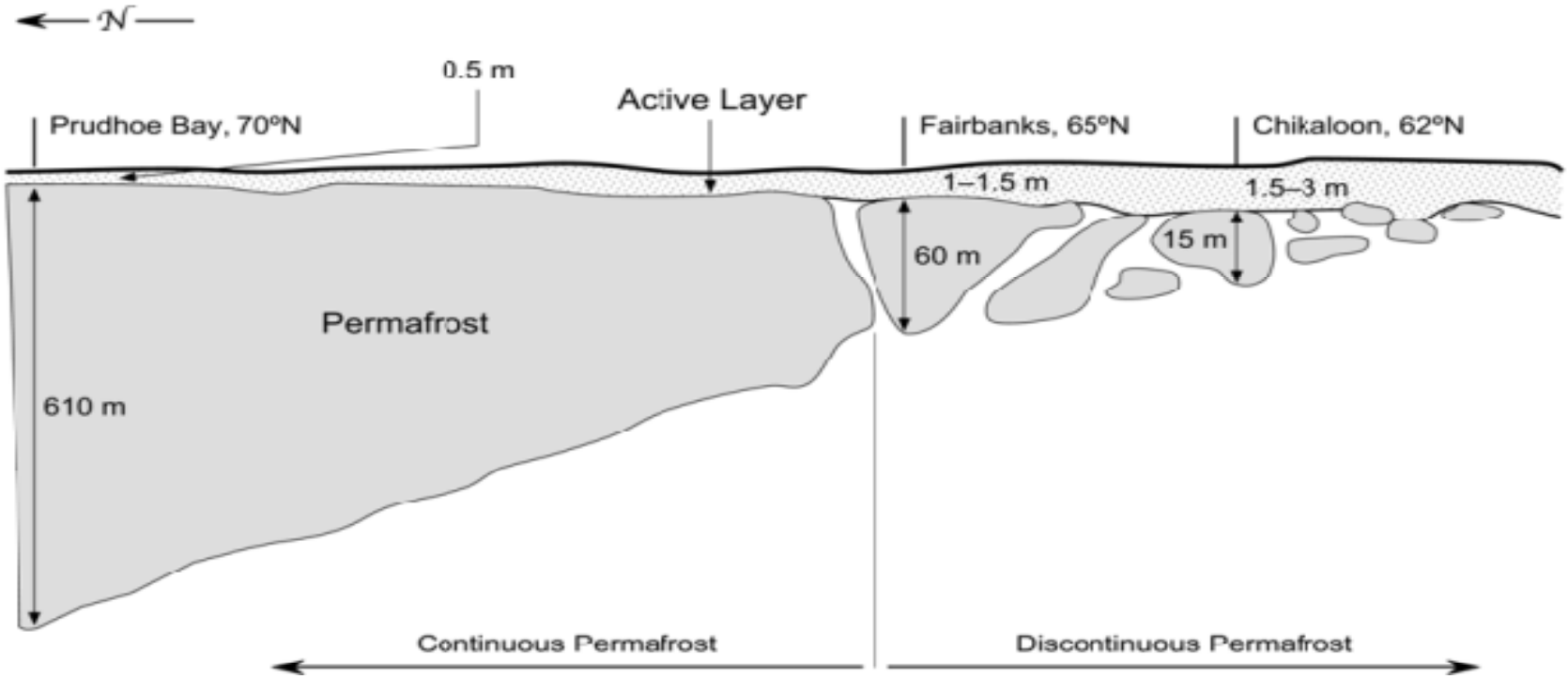

Frozen Cores
Thawed Cores
Water
Soil


ARCTIC OCEAN
Barrow
Permafrost
Underlain by thick permafrost
Generally underlain by continuous permafrost
Generally underlain by discontinuous permafrost
Generally underlain by isolated masses of permafrost
Generally free of permafrost
Source: U.S. Geological Survey
Fairbanks
Anchorage
Bethel
Juneau
BERING SEA
GULF OF ALASKA
0 200 400 600
Kilometers
0 100 200 300 400
Miles
66°
62°
58°
54°
52°
170° 166° 162° 158° 154° 150° 146° 142° 138° 134°
176° 180° 176°


NATIONAL HIGHWAY SYSTEM
STATEWIDE
APRIL 2006
Prepared By The
ALASKA DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES
DIVISION OF PROGRAM DEVELOPMENT
STATEWIDE GIS MAPPING SECTION
In Cooperation With
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
NHS Not Intermodal:
Interstate Highway
Other NHS Route
NHS Intermodal Connector
Major Intermodal Airport Terminal
Major Intermodal Ferry Terminal
Major Intermodal Port Terminal
Non-NHS Route
Alaska Marine Highway System
State Route Number
Barrow
ARCTIC
OCEAN
Northern Region
Central Region
Southeast Region
Fairbanks
Anchorage
Nome
Bethel
Kodiak
Juneau
Sitka
Ketchikan
Adak Station
ALASKA
GULF
OF
ALEUTIAN
ISLANDS
PACIFIC OCEAN
BRISTOL
BAY
KUSKOKWIM
BAY
NORTON
SOUND
KOTZEBUE
SOUND
RUSSIA
UNITED STATES
CANADA
UNITED STATES
YUKON TERRITORY
BRITISH COLUMBIA
KILOMETERS
0.0
100.0
200.0

Roads in Cold Places

Significant portions of the state's National Highway System and Alaska Highway System are underlain by permafrost. Almost the entire length of the Dalton Highway between the Jim River and Deadhorse, is underlain by continuous, typically deep permafrost, while the area between Fairbanks and the Jim River is underlain by discontinuous and transitional permafrost.



Beaver Creek Experimental Area, Yukon Territory. Beaver Creek is located at milepost 1202 of the Alaska highway, approximately 20 miles from the Alaska border. The Canadian Arctic is also experiencing rising temperatures and thawing permafrost, with the attendant risk of failure along sections of the Alaska Highway. Created by the Yukon Department of Transportation, the experimental area consists of twelve highway sections where techniques for stabilizing permafrost can be tested, and compared to a control section where standard (ie, historic) construction practices were used.

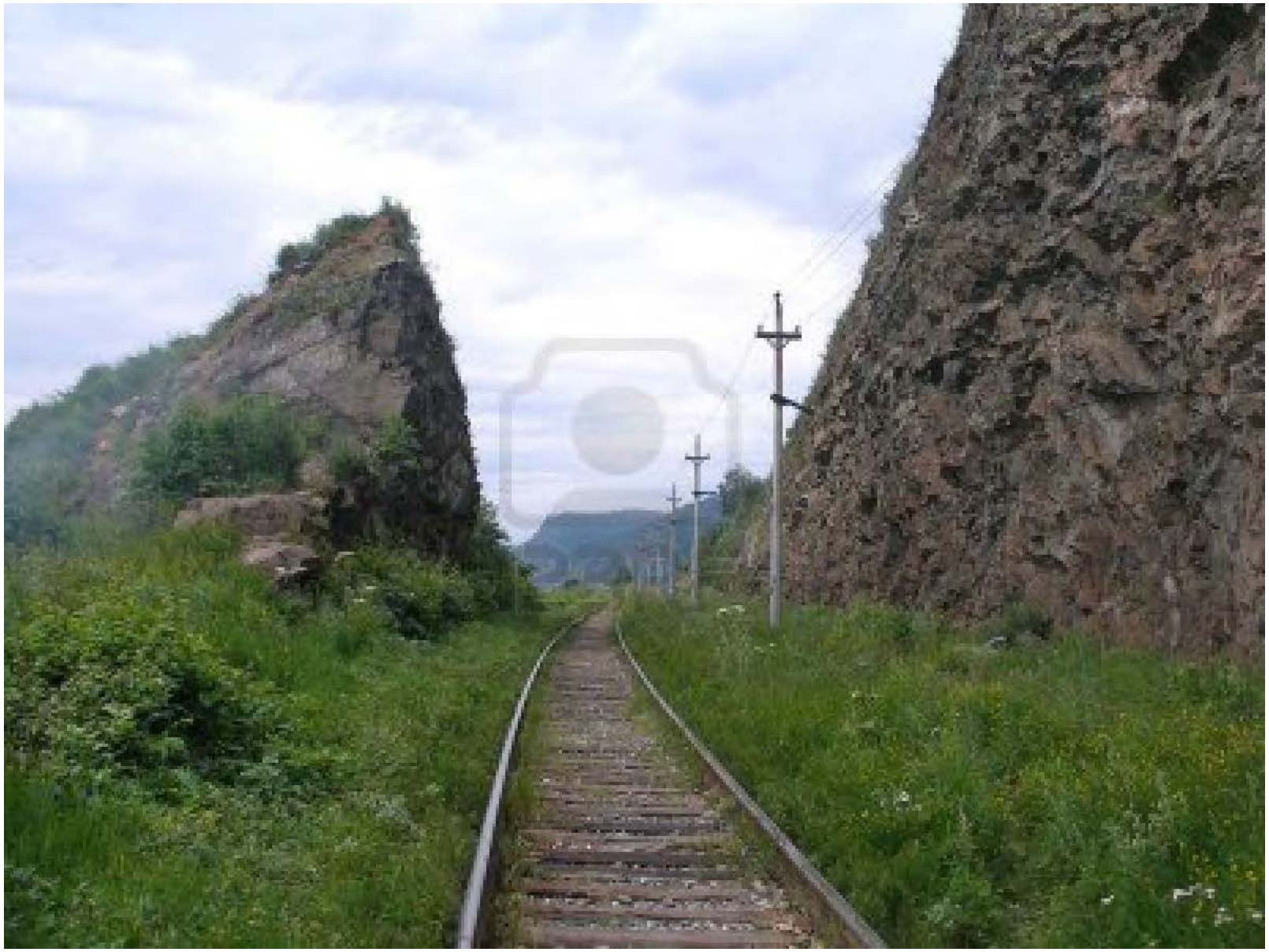
What can you do?

Mitigation techniques include:

- Air convection embankments,
- Heat drains,
- Longitudinal culverts,
- Snow-free embankments,
- Vegetative cover,
- Light-colored bituminous surface treatments.

Early results indicate that air convention embankments, longitudinal culverts and snow removal show good potential; however, several additional years of data gathering will be necessary before results are conclusive. Some of the research work at Beaver Creek involves the University of Alaska Fairbanks, through the University Alaska Transportation Center and the College of Engineering and Mines, and has applicability to Alaska circumstances.

RUSSIA
SIBERIA
MONGOLIA
Moscow
URAL MOUNTAINS
Yekaterinburg
Yenisey River
Novosibirsk
Krasnoyarsk
Listvyanka
Lake Baikal
Irkutsk
Ulan Ude
Ulaanbaatar
Amur River
Khabarovsk
Vladivostok
Train route
0
400
MILES



Permafrost Extent

Rail Economics—Freight

Mode of Transportation

One Barge

One Rail Car

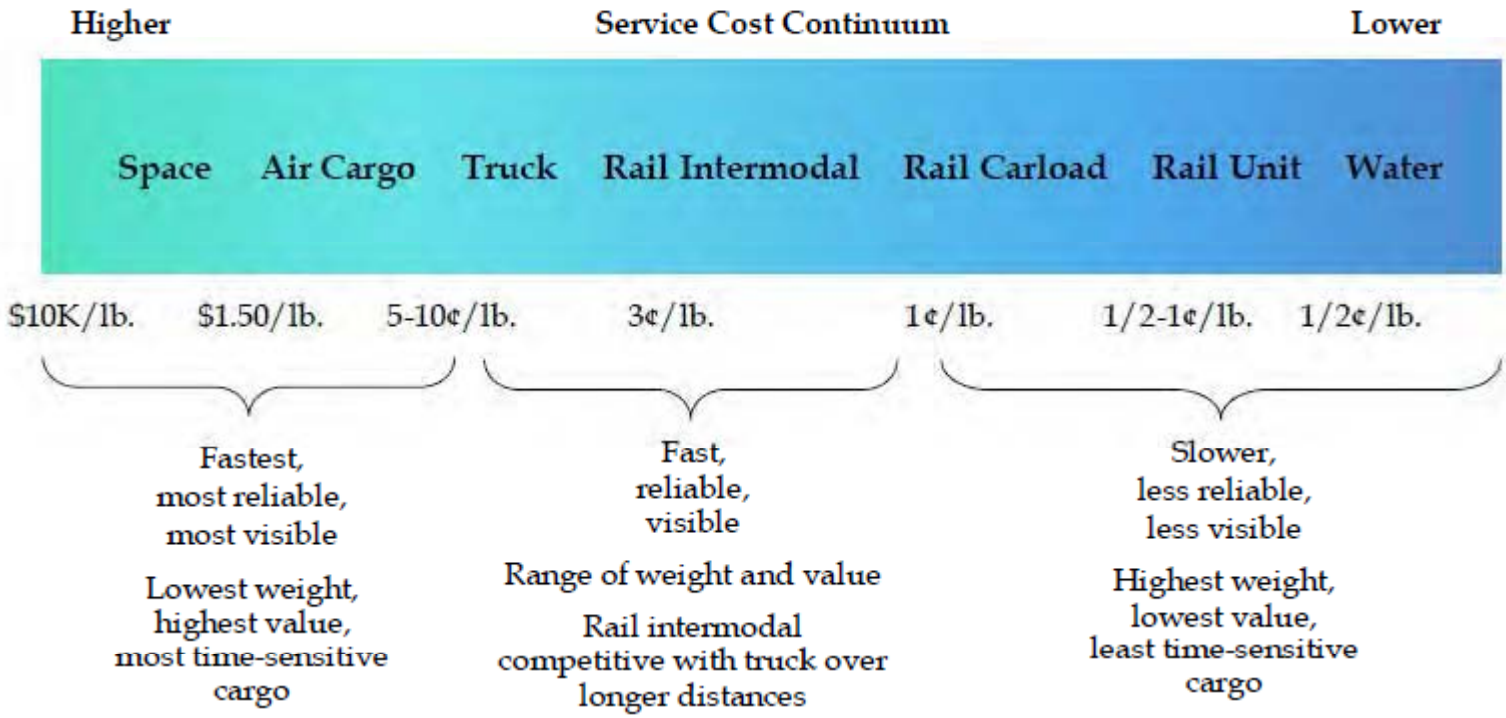
100-car Train Unit

Large Semi

Tons	Bushels	Gallons	Miles per Gallon (1 ton of cargo)
1,500	52,500	453,600	514
100	3,500	30,240	
10,000	350,000	3,024,000	469
26	910	7,865	59

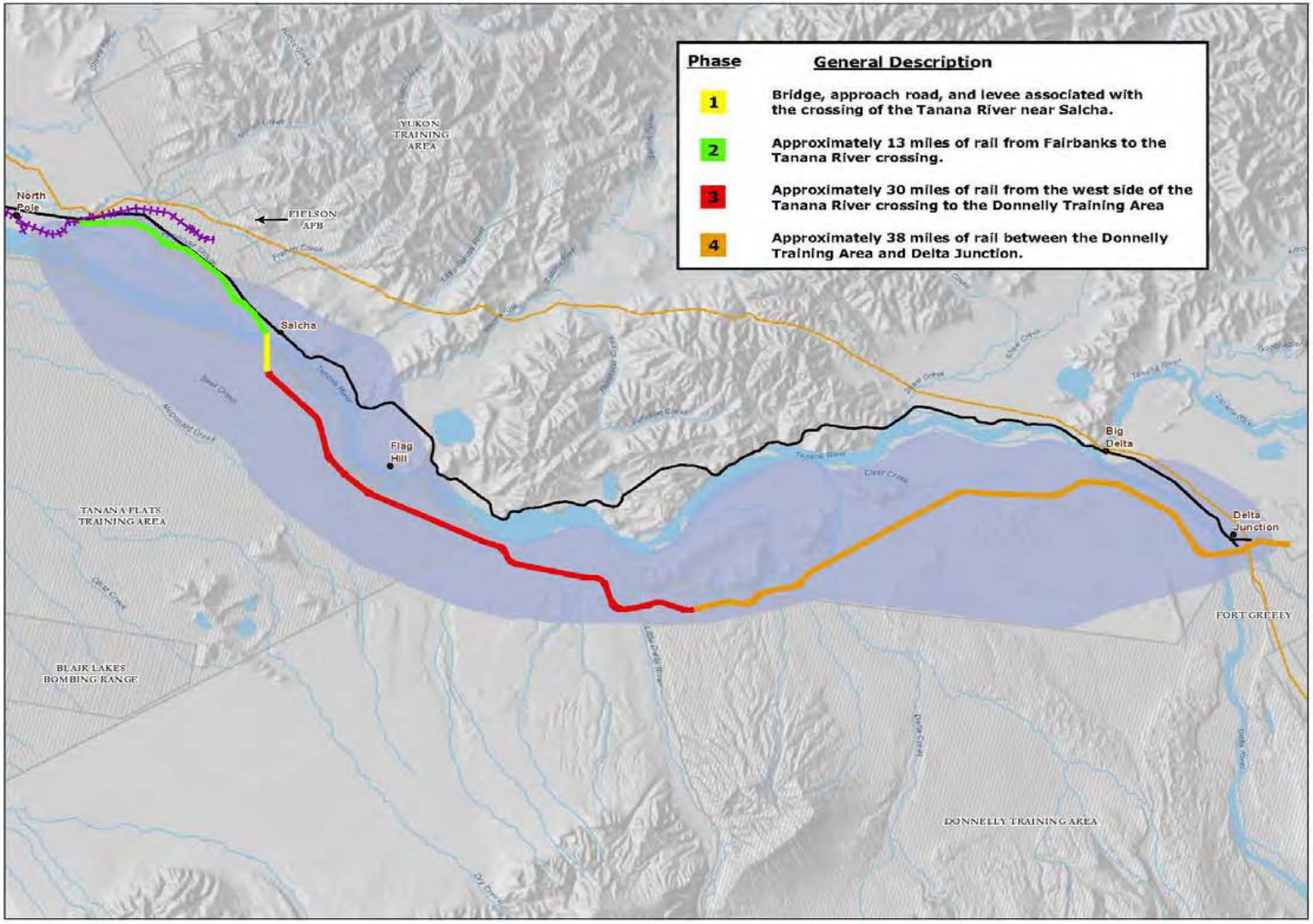
*Information courtesy of the Iowa Department of Transportation

Freight Transportation Service Spectrum



Source: Global Insight, Inc., TRANSEARCH database, and U.S. Department of Transportation Freight Analysis Framework data.

Northern Rail Extension



Alaska Railroad Northern Rail Extension Project

ARRC & HDR

Phase 1-4

Figure 2.2-2

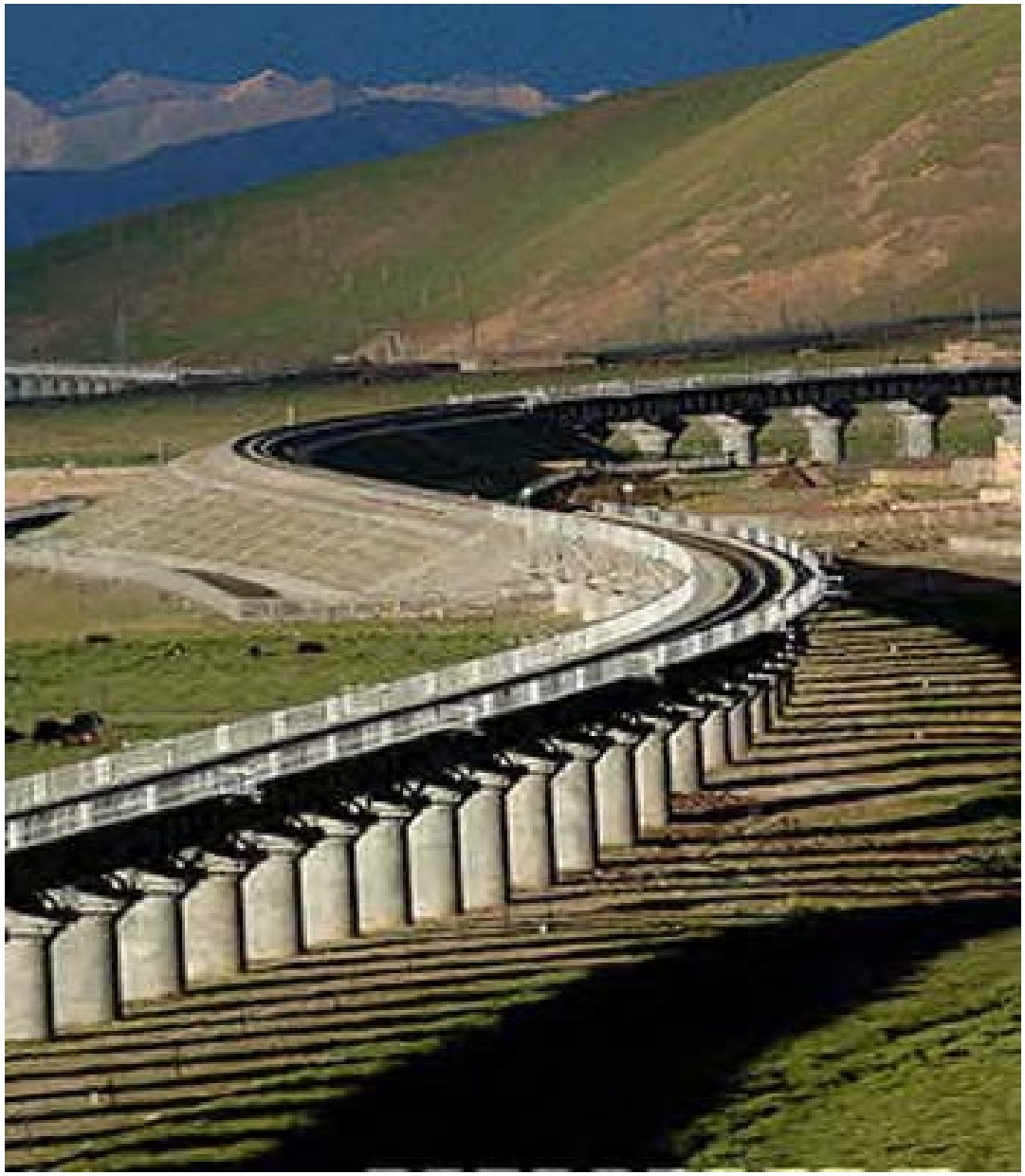
Legend

- Corridor Area
- Military Boundary
- Existing Railroad
- Trans-Alaskan Pipeline
- Richardson Highway
- Rivers and Streams

0 5 Miles

The information displayed here is for planning and review purposes only.

Beijing to Lhasa



From – To	Distance (km)	Hard Seat Price	Hard Sleeper Price	Soft Sleeper Price
Beijing West – Lhasa	3753	$49	$102	$158

Beijing-Lhasa is 4,064 km, of which 1,110 km are over the newly-built Qinghai-Tibet railway

Train T27 will start from Beijing West Railway Station at 21:30 and arrive at Lhasa Railway Station at 20:58 on the third day after 47 hours and 28 minutes' running. Train T28 will depart from Lhasa Railway Station at 8:00 am. and arrive in Beijing west at 8:00 am on the third day with a 48-hour-trip.

Roads in Cold Places

Bottom line:

Pay now, or

Pay later

APPENDIX G

NATIVE ALASKAN CONCERNS AND INTERFACE

Session 2: Presentation 4 – Native Alaskan Concerns and Interface

Speaker: Willie Hensley
Occupation: Author, Professor, Alaskan Leader
Website URL: http://williehensley.com/

Biography

Willie Iggiagruk Hensley is a distinguished visiting professor in the Department of Business and Public Policy at UAA. He recently retired from Alyeska Pipeline Service Company where he served as manager of Federal Government Relations in Washington, D.C. Prior to his employment with Alyeska, Mr. Hensley was appointed commissioner of Commerce and Economic Development by Governor Tony Knowles. He also served on the Oil and Gas Policy Council, the Board of Directors of the Alaska Permanent Fund Corporation, the Alaska Railroad, and the Alaska Industrial Development Authority. He also served terms as an elected state representative and state senator. Mr. Hensley was born in Kotzebue. He lived with his parents, John and Pricilla Hensley, and their large family in the Noatak Delta area. His book, *Fifty Miles from Tomorrow, a Memoir of Alaska and the Real People*, is about his experiences growing up and working on the Alaska Native Claims Settlement Act. Mr. Hensley attended a boarding school in Tennessee where he received his high school diploma. He attended the University of Alaska in Fairbanks and graduated with a degree in political science from George Washington University in Washington, D.C. He wrote a seminal research paper for Judge Jay Rabinowitz in graduate school while at the University of Alaska in Fairbanks entitled *Alaska Native Claims, the Primary Issue*, which outlined historical land rights for Alaska Natives, arguing for a just settlement of the issue. President Richard Nixon signed the Alaska Native Claims Settlement Act in December 1971, forever changing the land tenure map of Alaska. Mr. Hensley is the founder of NANA. He served 20 years as the director and became head of NANA Development Corporation, and finally president of NANA Regional Corporation. He was a founder of the Alaska Federation of Natives and served as director, executive director, president and co-chair. Mr. Hensley currently serves as a chair of the First Alaska Institute. He and his wife, Abby, have a total of six children and nine grandchildren.

Presentation

The reality is that Alaska Natives do not represent any particular mindset even today. Our many cultures were spread over a landmass covering 365 million acres. Each had their own languages and own way of life. There was warfare. There was trade. Many covered hundreds and thousands of miles in their very seaworthy vessels. We learned to harvest a 60-ton whale. The cultural footprint of the Inuit alone, spread all the way from Kodiak all the way up north, across the Canadian Arctic, all the way to what's now Hudson's Bay, parts of Quebec, Labrador, and on to Greenland. If you say the word qikiqtaq that Shelikohov used when he attacked the Island of Kodiak in the late 1700s, that very sound would be understood clear across those vast spaces,

despite thousands of miles and thousands of years. Of course, I come from (Speaking in Inupiaq) which is an island. Qikiqtaq is an island. Qikiqtaq is a small island. I'd like to say that -- I often say that -- if we had a couple hundred more years, we could have founded Europe.

I must admit that the Inuit got involved in the first oil era as well. When the global whale hunters finally hunted out the whales in the North Atlantic, Greenland, South Atlantic, and finally found the 30,000 or so whales that inhabited the Bering Sea, despite the fact that the Inuit depended very heavily on the whale for light, for heat, for food, they did participate in the commercial aspects of whaling. They wanted and needed the products from the western world that enabled them to have an easier life: the knives, the rifles, the cloth, the tobacco -- darn it -- the tea, sugar, flour, all the nasty stuff, the needles, axes and other tools. The baleen that shaped the hourglass figures of women in Europe and America helped make an easier life for our people. Sadly, the decimation of the whales by the whaling fleets resulted in less food for our people as well. One of the reasons for the decline of the whaling industry, of course, was the discovery of petroleum and the use of coal oil. As in other parts of the world, the whale population in the Bering Sea and the Arctic declined by about 90 percent.

Getting into the modern era, as is often the case, the Aborigines usually showed the westerners where the gold was or told the explorers about the oil seeps. The indigenous people knew the country like the back of their hand. Historically speaking, the modern era is but a blip on the indigenous screen. Unlike other Native Americans, we still occupy the spaces our people have learned to love and appreciate for the past 8,000 to 10,000 years. We have not been set out on a Trail of Tears and moved out into some other people's territory as has happened in the Lower 48. Despite the Russians not having more than 800 of their kind in Alaska at any one time, despite the fact that they never visited most of Alaska, and despite the fact that their zone of control was minimal, and that even in Sitka, at the time of their deal with the United States, when the gates were shut into the Russian compound at night, the Tlingit were outside the walls. It's not as if the Russians were safe, even in their colonial capital. Their so-called sovereignty was indeed thin. This game of discovery and the claiming of territory across the globe is not ancient history to Native Alaskans. It is something that has followed to those of us living today.

The Lands Claim Settlement returned a small percentage of our former lands and close to a billion dollars to capitalize our corporations. Don't get me wrong. We value that settlement despite the fact that in the context of the billions that have come out of the North Slope for the leaseholders, the State of Alaska, contractors, federal government, it was a modest settlement.

So what does all this have to do with another pipeline? Alaska Natives are pretty pragmatic. We know Alaska is not an easy place to live. It is thinly populated. It is expensive, especially for energy. It is not exactly a breadbasket and it is far from the marketplace of the world. But it is home. We made the best of a bad situation. With the help of Richard Nixon and some courageous Alaskans who worked to resolve our land conflict, we came together on a solution to a very complex problem. The oil industry helped resolve that issue because it helped resolve

their own problem of cleaning up the leases legally and getting a right-of-way for the pipeline. The right-of-way included us in the construction and operation of the pipeline. By us, I mean we, the indigenous people. Since then, our indigenously owned companies have been an integral part of the TAPS System and that is a credit to the owner companies who went beyond the requirements of the right-of-way. This has been a true partnership for many years.

When I was with NANA, we participated in the bidding with BP in the Beaufort Sea leases and ended up with a small share of Endicott, along with four other regions. In those days, few Alaskans had any concept of what it was like to deal with the oil industry and this was a learning curve not only for Alaskans in general, but for Alaskan Natives in particular. We were all nervous about large corporations because of Alaska's history with the huge canned salmon industry and the steamship company that controlled shipping, you know, the Guggenheims. People were nervous about large corporations. We constructed and operated oil rigs, catered workers, leased equipment, provided security, operated hotels, built utilities. Other corporations provided vessels and environmental services, maintenance and equipment, and a wide array of other services since those early days. Our corporations have expanded their reach nationally and globally in both substance and complexity over the course of time. So, if there is a pipeline, small or large, short or long, our entities will want to be a part of something that makes business sense and is good for Alaska and Alaskans.

In the early days of the formation of the North Slope Borough, there was a great deal of concern about how the Inuit would deal with industry. I think time has shown that the Borough and industry have all learned to work together. Industry had a steep learning curve in operating in the Arctic and there have been some rough spots along the regulatory process. But even with the contentious offshore experience, industry learned that the Inuit have a perspective that matters and have made positive improvements to the operating plan. Safe operating conditions, minimizing impacts to nature and our food sources, and opportunities to work are all important to us.

We Alaskans have been blessed. Those of us with roots here that go back millennia want our Alaskan society to succeed. It has not been an easy road from many perspectives. But for 35 years, we Alaskans have lived in a golden age, so to speak, with services, programs, facilities and infrastructure never thought of in the territorial or earliest statehood days. There has been opportunity for all of us.

In closing, let me say it will take all of our collective efforts and will to ensure it continues. Kliana and have a wonderful conference. Thank you.

APPENDIX H

OFF-ROAD TRAVEL ON STATE LAND - MANAGEMENT AND IMPACTS

Off-Road Travel on State Land

Management and Impacts

Alaska Department of Natural Resources
Division of Mining, Land and Water

Melissa Head, Natural Resource Manager

North Slope Special Use Area

NOTICE

DESIGNATION OF SPECIAL USE LANDS - NORTH SLOPE AREA

Pursuant to Section 153.00(b) of the Miscellaneous Land Use Regulations (11 AAC 01.153.00(b), all State lands in the Umiat Meridian are hereby designated as "Special Use Lands" and the following activities are listed as the activities that will require a permit in addition to the activities requiring a permit under Section 153.00(a) of the regulations:

Geophysical Activity
Other Exploration Activity
Construction Activity
Transportation Activity, except along established roads.

F. J. Keenan, Director

Dalton Highway Corridor

Prohibition of Off-Road Vehicles

AS 19.40.210

Off-road vehicles are prohibited on land within five miles of the right-of-way of the highway. However, this prohibition does not apply to

(1) off-road vehicles necessary for oil and gas exploration, development, production, or transportation;

(2) a person who holds a mining claim in the vicinity of the highway and who must use land within five miles of the right-of-way of the highway to gain access to the mining claim; or

(3) the use of a snow machine to travel across the highway corridor from land outside the corridor to access land outside the other side of the corridor; this paragraph does not permit the use of a snow machine for any purpose within the corridor if the use begins or ends within the corridor or within the right-of-way of the highway or if the use is for travel within the corridor that is parallel to the right-of-way of the highway; in this paragraph, "highway corridor" means land within five miles of the right-of-way of the highway.

A land use permit, issued by the DNR/DMLW, is required for all off-road travel on all state land on the North Slope.

- 5-year permits; individual routes of travel are approved on a case-by-case basis
- Stipulations intended to avoid/reduce damage to tundra vegetation and ecosystem
- Permits require tundra rehabilitation to the satisfaction of the DNR/DMLW if damage occurs

Permitting process

- Permits issued for off-road travel (summer and winter) and ice road construction
- $100 application fee; no fees for travel
- Agency review
- Public notice (when warranted)
- Decision and permit
- Adjudication can take between 2 weeks and 2 months

Individual routes of travel approvals

- Each route must be individually approved
- Requests are generally sent via email
- Approvals emailed, usually the same day

Off-Road Travel Seasons

Summer: July 15 to freeze-up

Winter: Freeze-up to break-up

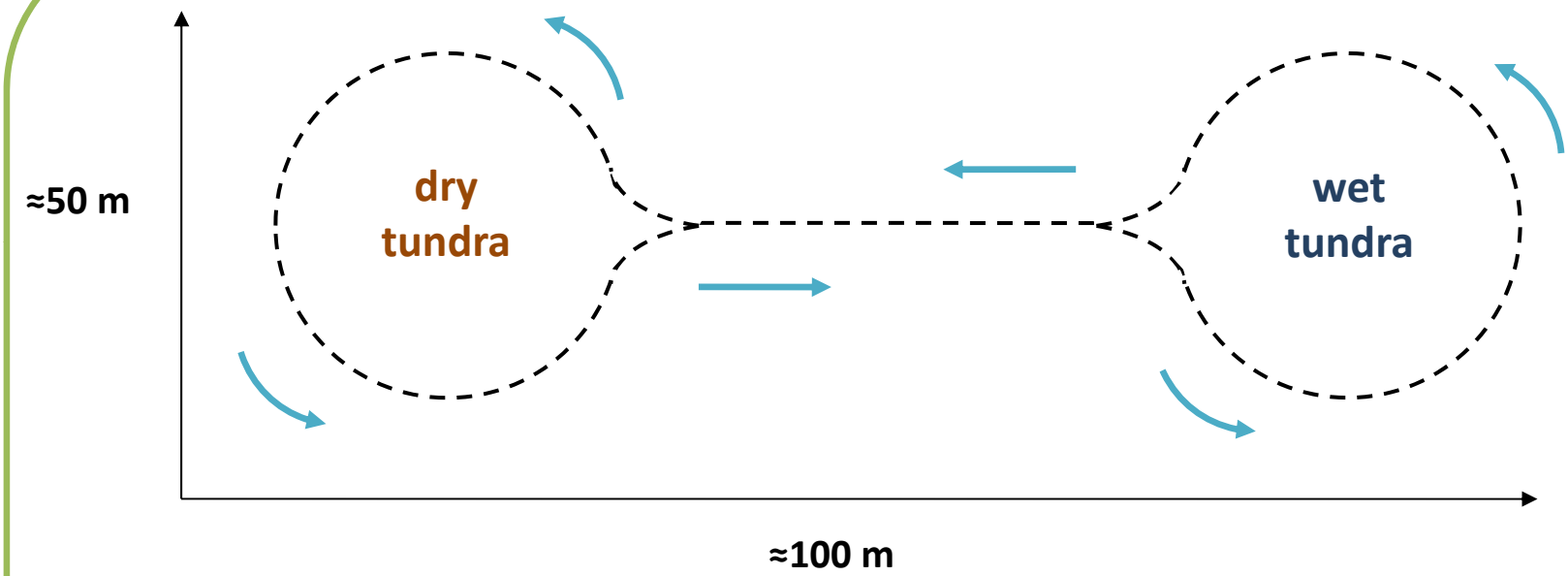
***No travel except for emergencies*:**

Break-up to July 15

Dynahaul vehicle test, July 16, 2012

Summer Off-Road Travel

Vehicle testing



Vehicle test course diagram
(arrows indicate travel direction)

Summer approved vehicles

1. Argo 8 I/C with smooth tracks.
2. Argo 6X6 Frontier 580 with Supertracks.
3. Argo 8X8 Avenger 750 HDi with Supertracks.
4. Roller-driven vehicles equipped with large, bag-type tires (ex. Rimpull)
5. Haggland Bearcat with smooth track configuration.
6. Tucker Snocat with smooth track configuration.
7. Tucker-Terra Sno-Cat model 1600 with smooth track configuration.
8. Tucker Terra 2000 with smooth track configuration.
9. Pisten Bully 100 Trail with smooth track configuration.
10. Polaris Ranger 800 6X6 configuration with smooth tires (maximum payload, including passengers, is 1,200 lbs).
11. Polaris Ranger 800 6X6 with smooth tires and plastic smooth-bottom sled (maximum payload is 100 lbs in vehicle bed and 1,000 lbs in sled).
12. Kubota RTV900 with Litefoot tracks (payload, including passengers, must be under 500 lbs).
13. Lindsey Snow Walker (used only during pre-packing operations).
14. Airboats (for use in spill drills,exercises, and responses only).

TUCKER
SNOCAT

POLARIS
RANGER

ARGO FRONTIER
580 6X6

Summer off-road travel considerations

- Summer approved vehicles can still cause damage.
- Operator training is key.
  - Vegetation types
  - Disturbance vs. damage
- Walk routes ahead of vehicles to identify best travel location.
- When in doubt, rely on HSE personnel and DNR/DMLW expertise.

Winter Off-Road Travel

STEIGER and TRAILER

ROLLIGON
GOLIATH
LINK-BELT
Bimpull

D-7 TRACTOR

SLED-MOUNTED CAMP
DIESEL FUEL TANK
NO SMOKING WITHIN 50'
DIESEL

SEISMIC VIBRATORS

Tundra Areas and Management Standards

Coastal Areas

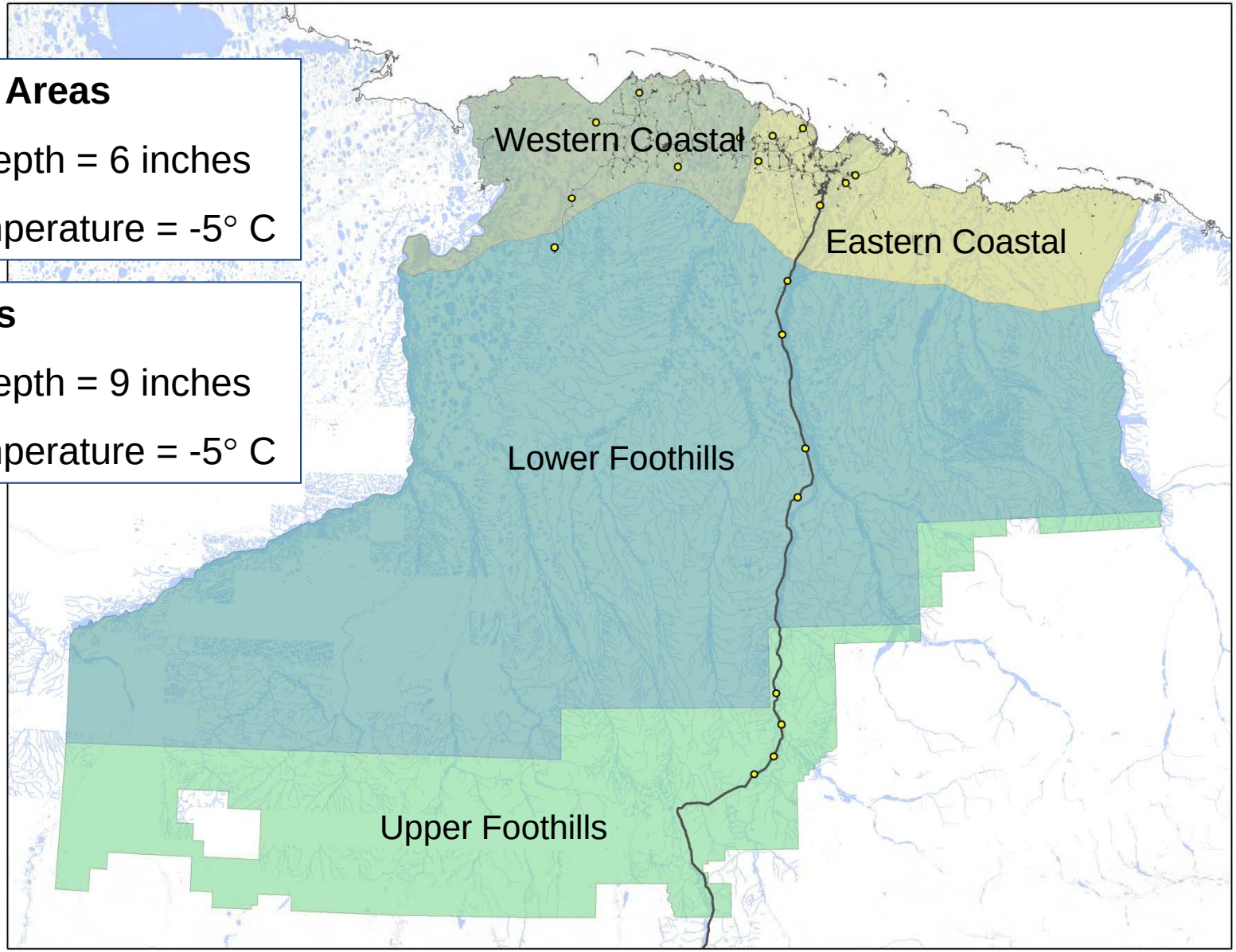
Snow Depth = 6 inches

Soil Temperature = -5° C

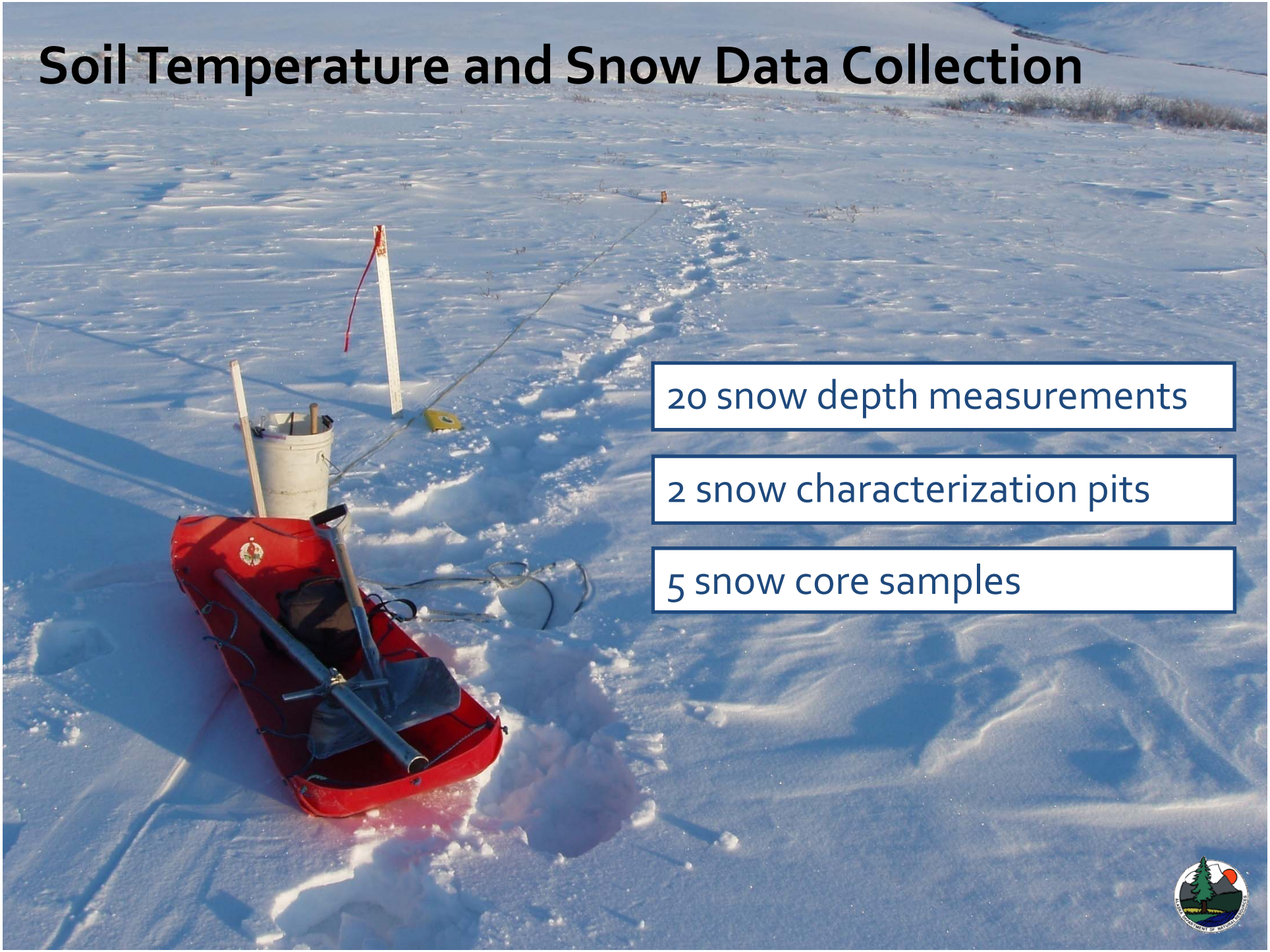
Foothills

Snow Depth = 9 inches

Soil Temperature = -5° C



Soil Temperature and Snow Data Collection

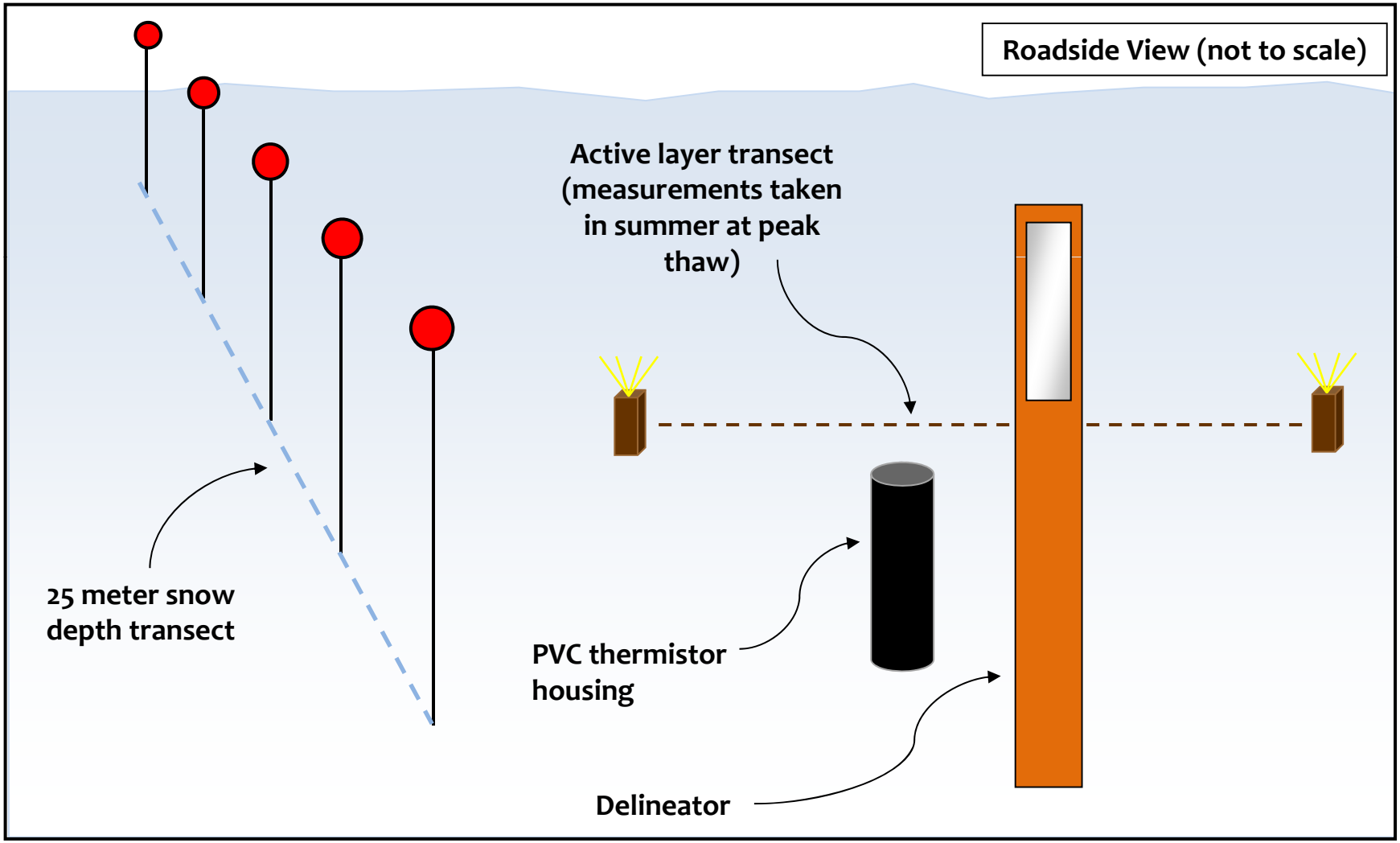


20 snow depth measurements

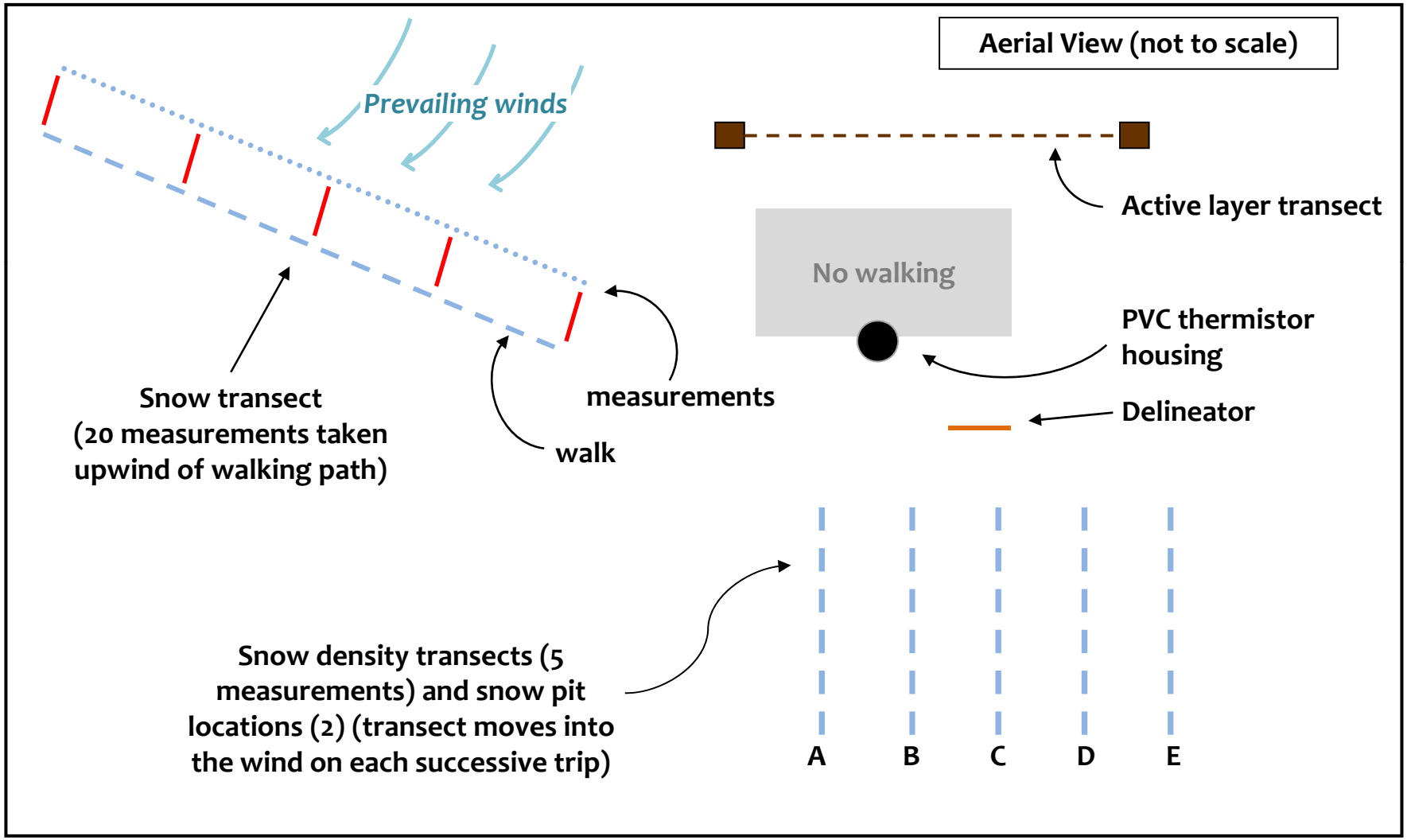
2 snow characterization pits

5 snow core samples

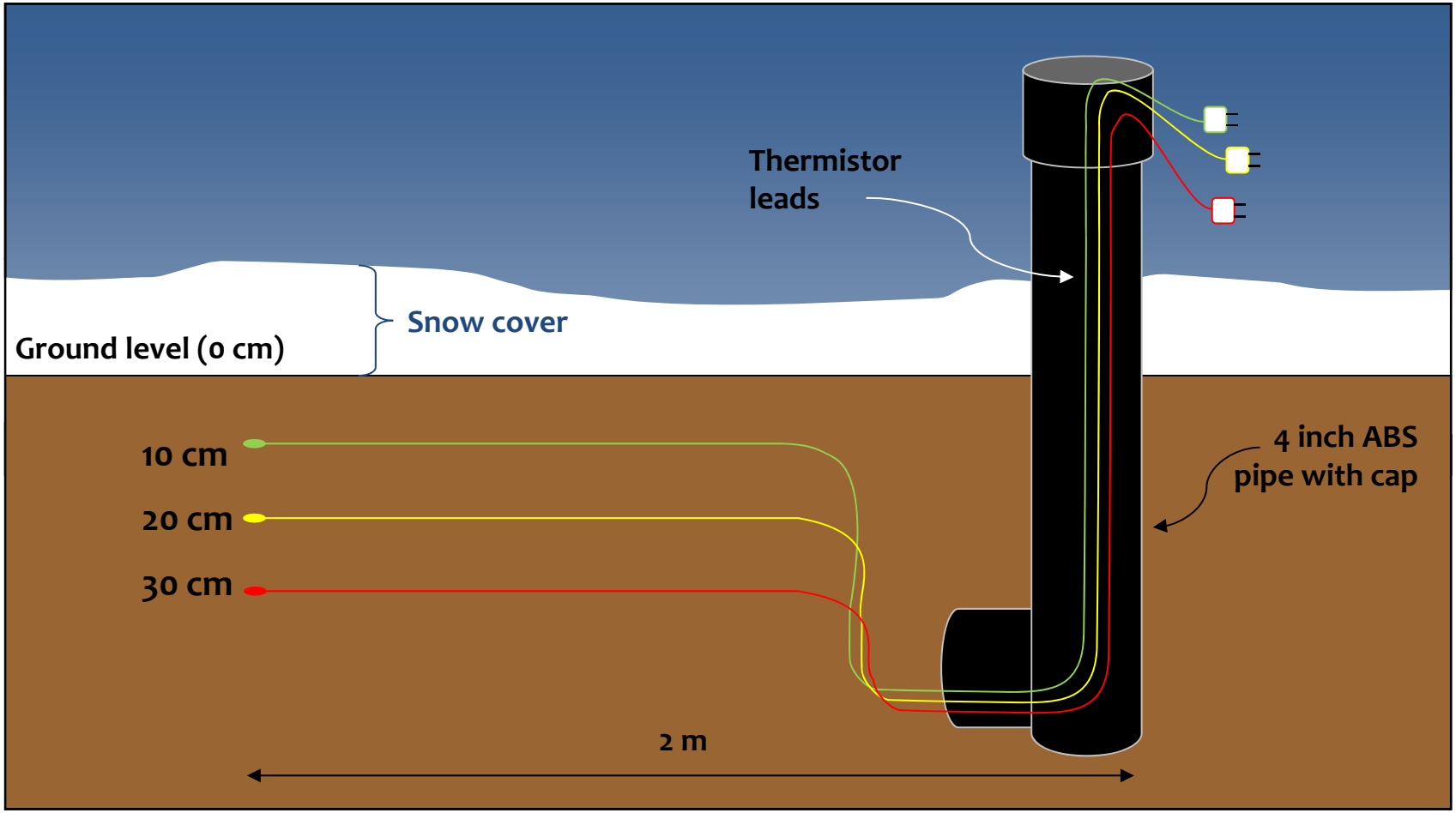
Typical monitoring station set up



Typical monitoring station set up



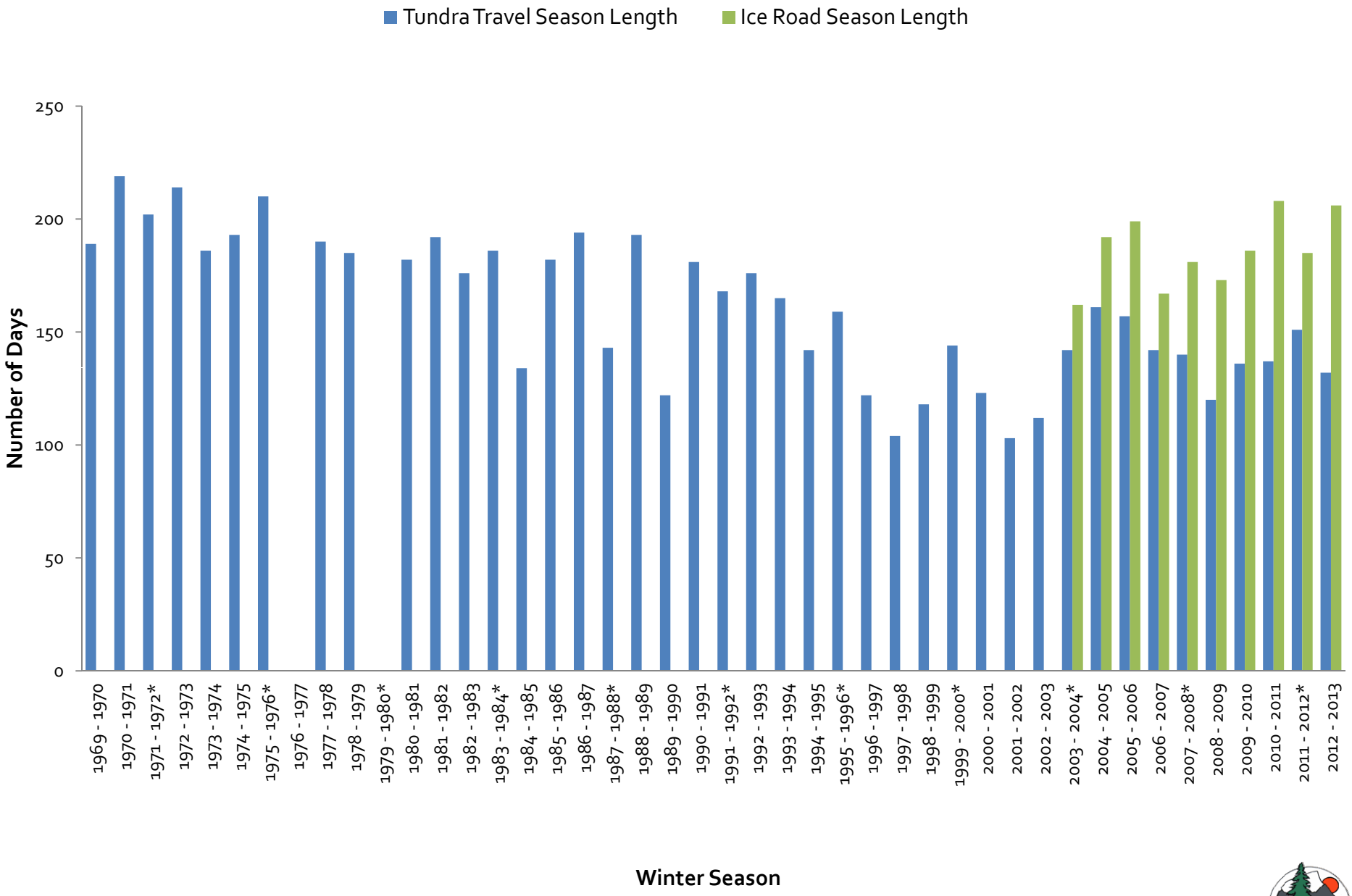
Soil temperature monitoring equipment



Status and opening reports

- Off-road travel status reports issued weekly after monitoring
- Opening reports issued as soon as an area is open to winter off-road travel
- Listserv: http://list.state.ak.us/soalists/DMLW.Tundra.Notification/jl.htm
- Online status map: http://www.arctic-transportation.org/map-xml.php

Winter Travel Season Lengths



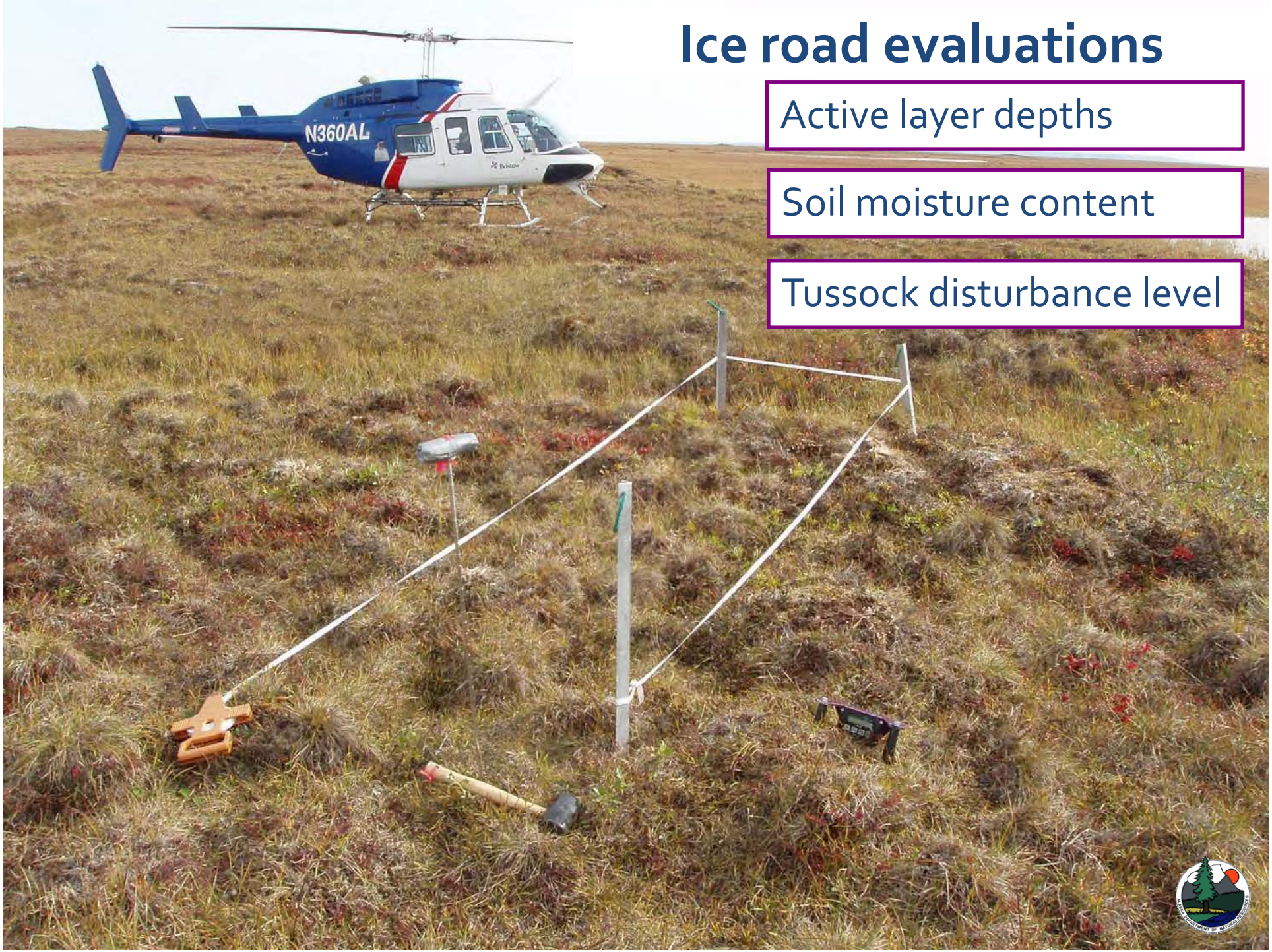
How have we extended the ice road season?

- Utilize low-impact vehicles for initial pre-packing activities
- Carefully choose routes based on vegetation and landforms that are more resistant to damage
- Amendments of snow and/or ice chips
- Evaluate new methods of ice road construction. (i.e. Rolligon water side-casting)

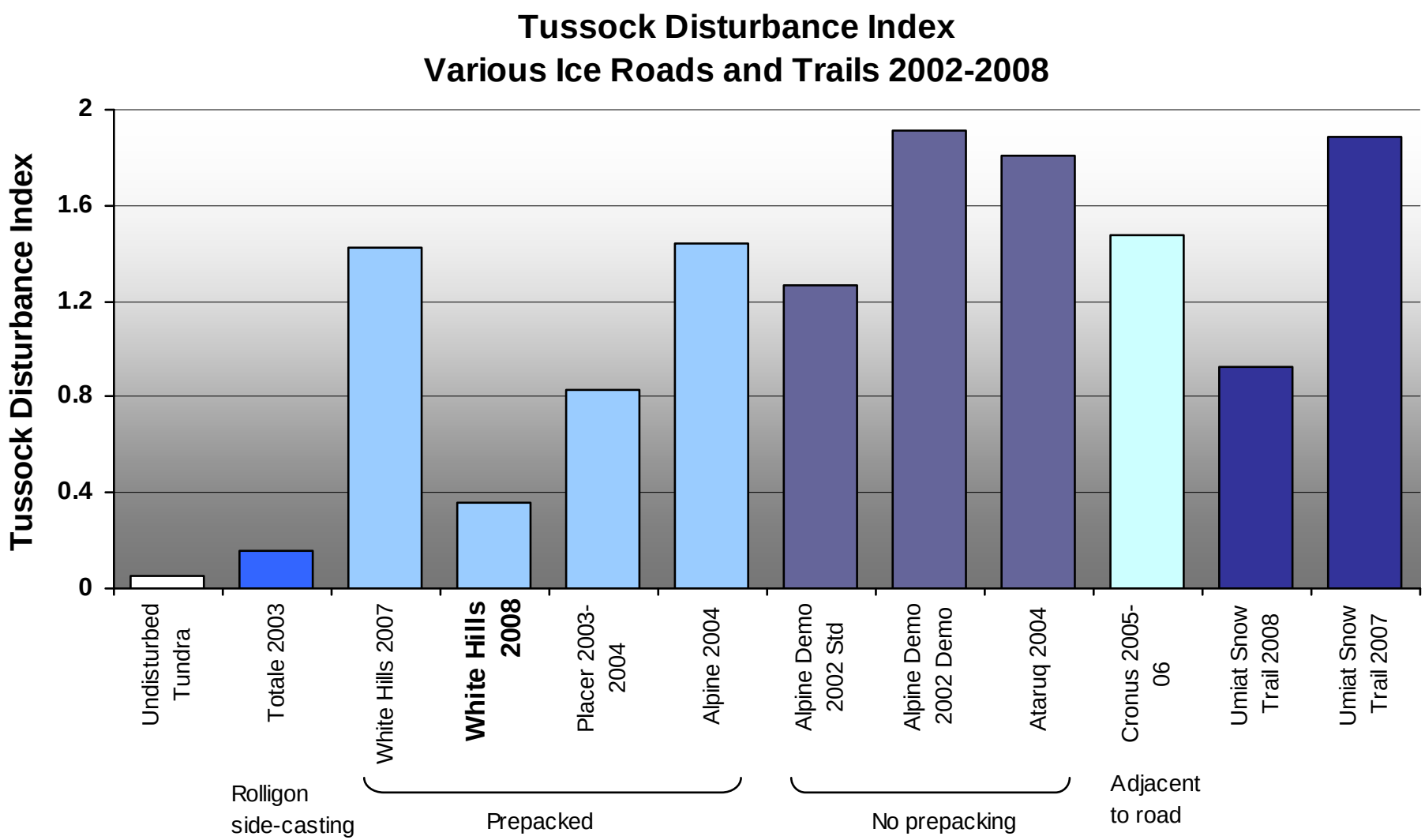
Increased pressure to open winter tundra travel earlier

- Allows for a longer oil and gas exploration season
- Increases the potential for tundra damage (i.e. scuffing, gouging, scraping)
- Increased wildlife impacts
- Increased fuel spill potential on the tundra

Ice road evaluations



- Active layer depths
- Soil moisture content
- Tussock disturbance level


Tussock Disturbance Index
Various Ice Roads and Trails 2002-2008
Tussock Disturbance Index
2
1.6
1.2
0.8
0.4
0
Undisturbed Tundra
Totale 2003
White Hills 2007
White Hills 2008
Placer 2003-2004
Alpine 2004
Alpine Demo 2002 Std
Alpine Demo 2002 Demo
Ataruq 2004
Cronus 2005-06
Umiat Snow Trail 2008
Umiat Snow Trail 2007
Rolligon side-casting
Prepacked
No prepacking
Adjacent to road

DNR Management Guidelines

- Open tundra using snow depth criterion (6" in coastal, 9" in foothills) and soil temperature (-5° C).

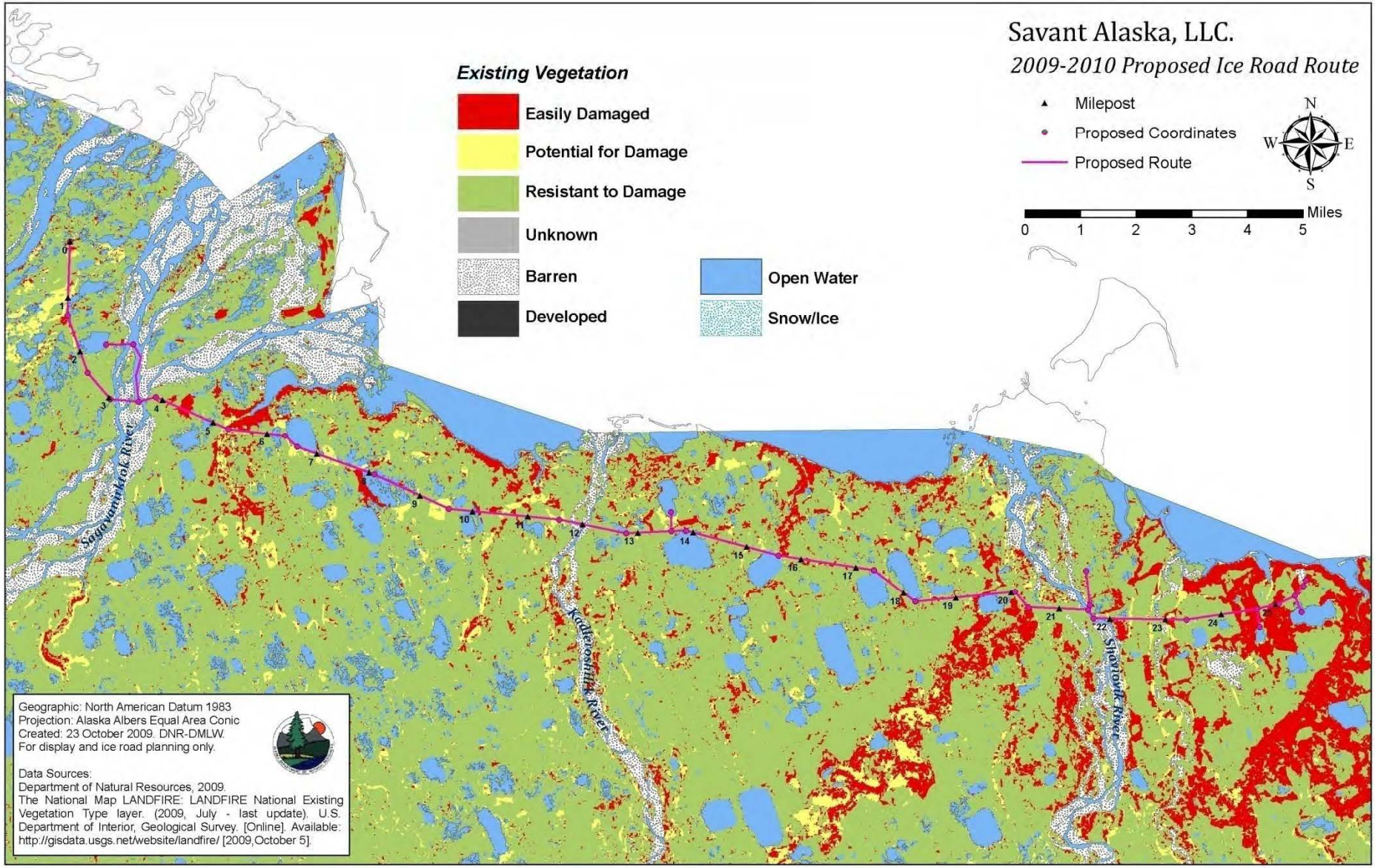
- For multiple pass projects:
  - If SWE ≥ 3.0 inches, approve project.
  - If SWE < 3.0 inches, approve project with increased DNR oversight.

- DNR will continue to monitor snow conditions and impacts of off-road travel projects to determine the most appropriate management standards.

Ice and snow road recommendations

- Define routes during snow-free months
- Pre-packing
- Install thermistors along routes
- Planning
- Snow and ice chip amendments
- Water side-casting method
- Snow fences

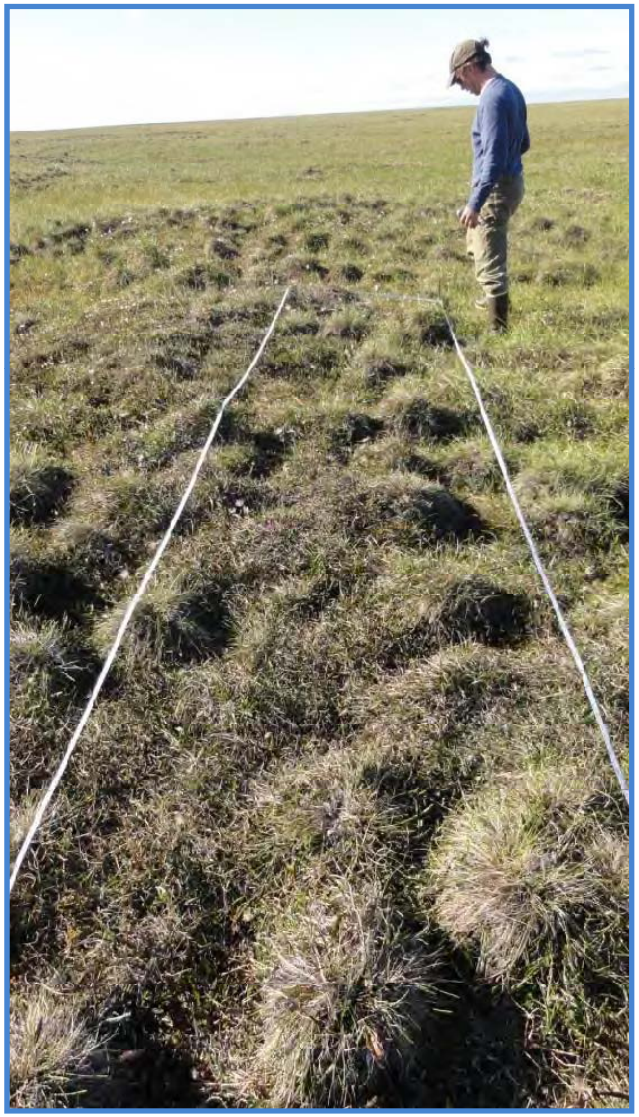
Vegetation mapping for route selection



What we want to avoid: TUNDRA DAMAGE

On Ice Road

Off Ice Road



Tundra damage

- Recognize damage vs. disturbance, but err on the side of caution.
- All incidences of tundra damage must be reported to DNR/DMLW within 72 hours.
- You may be asked to provide an incident report detailing what lead to the damage.
- You may be required to rehabilitate the affected area as determined by DNR.
- Maintain open lines of communication with DNR/DMLW staff.
- Learn from mistakes!

Questions?

DNR/DMLW/Northern Regional Office

451-2740

melissa.head@alaska.gov

April 3, 2013- Grizzly bear at Jennie Creek (KRU)

APPENDIX I

SUMMER AND WINTER TUNDRA TRAVEL PERMITTING – WATER/ICE WITHDRAWALS

Department of Natural Resources

Division of Mining, Land and Water

Water Resources Section

Michael Walton
Natural Resource Manager
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907-269-8609

Henry Brooks
Natural Resource Manager
henry.brooks@alaska.gov
907-269-8641

Water Use Act, 46.15

- Under the Alaska constitution, all surface and subsurface water reserved for common use, except mineral and medicinal water, are subject to appropriation under state law. Alaska follows prior appropriation doctrine.

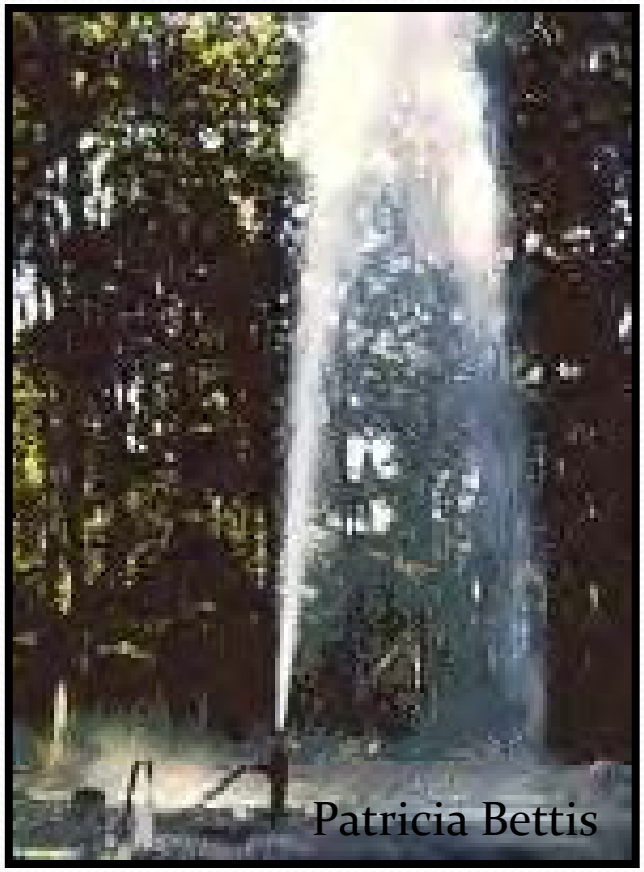
Significant Amount of Water

(11 AAC 93.035) Applies to withdrawals, diversions or impoundments.

- (1) the consumptive use of more than 5,000 gallons per day from a single source in a single day;
- (2) the regular daily or recurring consumptive use of more than 500 gallons per day from a single source for more than 10 days per calendar year;
- (3) the non-consumptive use of more than 30,000 gallons per day (0.05 cubic feet per second) from a single source;
- (4) any water use that may adversely affect the water rights of other appropriators or the public interest.

Management of Water Resources

- Application review, including source data
- Adjudication
- Issuance of authorization or permit-certificate
- Post issuance water use reporting and review



Adjudication Types

- Temporary Water Use Authorization
- Permit to Appropriate Water (not a water right)
- Water Right Certificate of Appropriation (2nd step after permit to appropriate water)
- Certificate of Reservation

Temporary Water Use Authorization (TWUP)

- May be issued for up to a five-year period, including one extension;
- May have up to five separate water sources per TWUP;
- No extension of time allowed after five years;
- No water right or priority is established by a TWUP;
- Permittee will coordinate water withdrawal with other companies using the same source;
- Submit application at least 60-days before first use;
- Organize priority sources on the same application for adjudication efficiency.

Permit to Appropriate Water

- Establishes a provisional priority date for water use;
- Allows for timely development of water source and use;
- May be issued for a specific period of time based on the type of project and quantities of water requested;
- May be extended once, up to the initial permit period.

Certificate of Appropriation

- The water right (A right to the use of the water);
- Conveyed along with title, unless reserved in transaction;
- Continues in effect for as long as water is beneficially used.

Certificate of Reservation (to maintain flow or lake level)

- Purposes for Requesting a Reservation:
  - Protection of Fish and Wildlife Habitat, Migration and Propagation;
  - Recreation and Park Purposes;
  - Navigation and Transportation Purposes;
  - Sanitary and Water Quality Purposes.

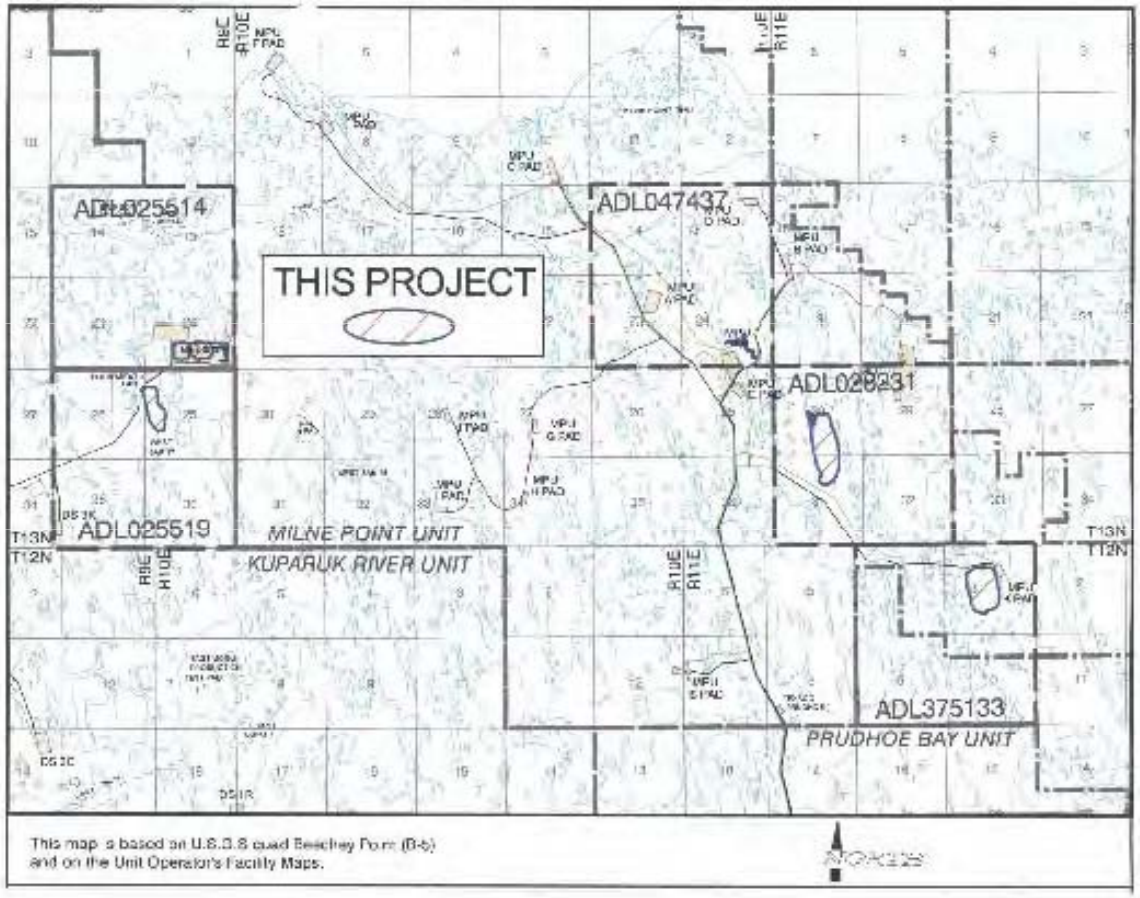
Certificates of Reservation on North Slope: Sag River and Kuparuk River.

Goals of North Slope Permitting

- Management for a sustainable water resource;
- Assurance that each use is:
  - Reasonable and beneficial;
  - Will not interfere with any presently existing legal water rights;
  - Minimizes potential environmental effects;
- Ascertain that unappropriated water is available.

Permitting Process Begins With

- Completed Application along with associated fee
  - Include area map (MTRS)
    - Water Sources
    - Water Use Area



Permitting Process Cont.

- Source Data
  - Lakes & Reservoirs:
    - Depth
    - Surface Area
    - Approximate Total Volume
    - Under Ice Volume
    - Fish Present or Absent (type of fish)
  - River or Streams (Summer Use Only)
    - Flow (cfs)
    - Width & Depth
- Volumes Requested
- Use Time Frames and Purposes

Lake M0812

Other Names: Field Identifier: A0927
Location: 66.35195°N 152.24990°W
USGS Quad Sheet Umiat B-4: T1S R2W, Sec. 12
Habitat: Tundra Lake
Area: 20 acres
Maximum Depth: 7.2 feet
Active Outlet: No
Total Lake Volume: 23.72 million gallons (Aug 1, 2008 date)
Water Volume Under 4 ft of ice: 2.07 million gallons
Water Volume Under 5 ft of ice: 0.34 million gallons
Water Volume Under 7 ft of ice: 0.00 million gallons

Potential Ice Aggregate: *1.3 acres (water depth 4 ft or less)
0.684 million gallons

Maximum Recommended Under-ice Removal: **4.744** million gallons
(20% of lake volume)

Water Chemistry:

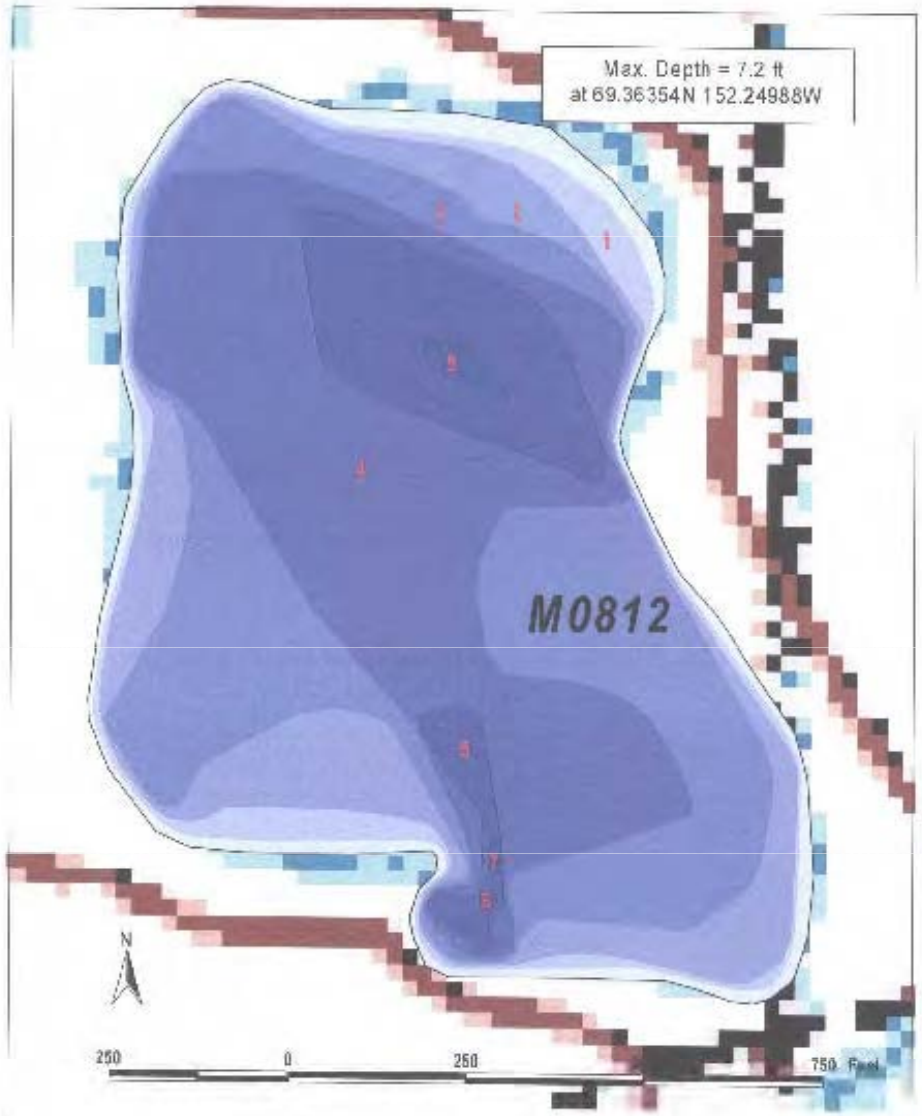
Year of Test	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Total Hardness (CaCO3) (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
2008	3.63	1.72	1.40	1.10	16.1	34.6	4.7	7.81	1 Million

Catch Record:

Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Aug 1 08	4.7	none	0
Minnow trap	Aug 1 08	7.0	none	0
Seine	Aug 1 08	3 hauls	none	0

Bathymetry Studies are important for determining water quantities and available water under ice.

Simple cone method for calculating volume will be used if don't have bathymetry study for a lake source (requires lake surface area and maximum depth).



Depth contours of lake M0812 based on transects surveyed on August 1, 2008 (depth in 1 foot intervals).

Permitting Process Cont.

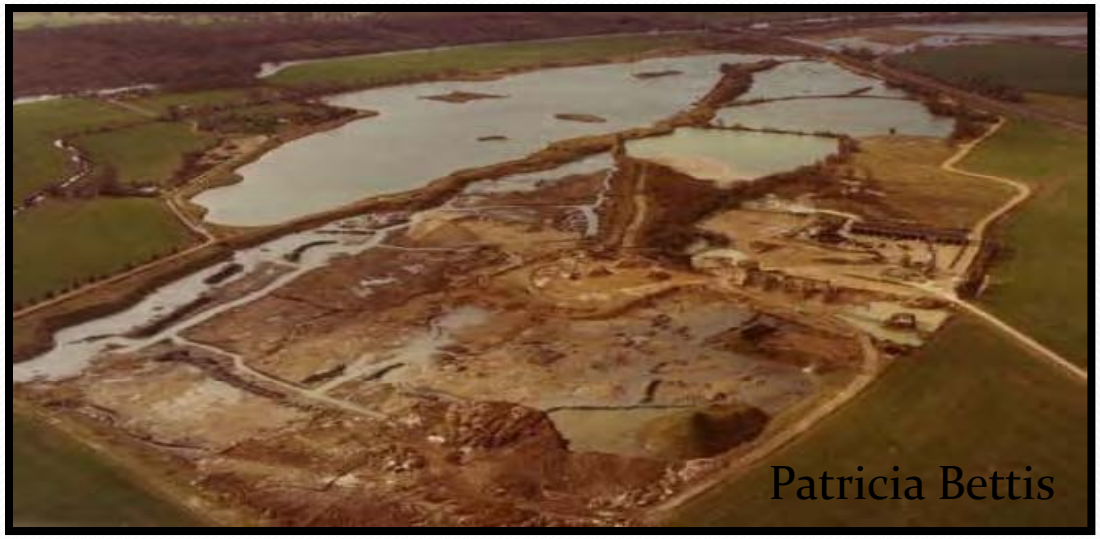
- Review Application Packet
  - Input application into data base
    - Makes searchable to the Public
    - Identifies Multiple Users for the Sources
  - Source with Multiple Users
    - Review the submitted Source Data and Compare to other's Source Data – looking for variations, bathymetry studies, fisheries studies, water quality parameters, etc.
    - Determine if a Water Right is on the Source
- Agency Notice for TWUP Applications
  - Application Packet is sent to:
    - ADF&G Division of Habitat, DNR Division of Oil and Gas, DNR Land Section (NRO), ADEC, North Slope Borough

Winter Permittalbe Volume of Water Limitations

- Fish Bearing Lakes
  - 15 percent of the calculated volume of water under seven feet of ice for lakes deeper than 7 feet that contain species sensitive fish.
  - 30 percent of the calculated volume of water under five feet of ice for those lakes with depths between five and seven feet deep that contain only ninespine stickleback and Alaska blackfish.
- Non-Fish Bearing Lakes/Non-Fish Bearing Reservoirs
  - 20 percent total volume (lake recharge considerations).
  - Up to 100 percent of mine site reservoirs without fish.

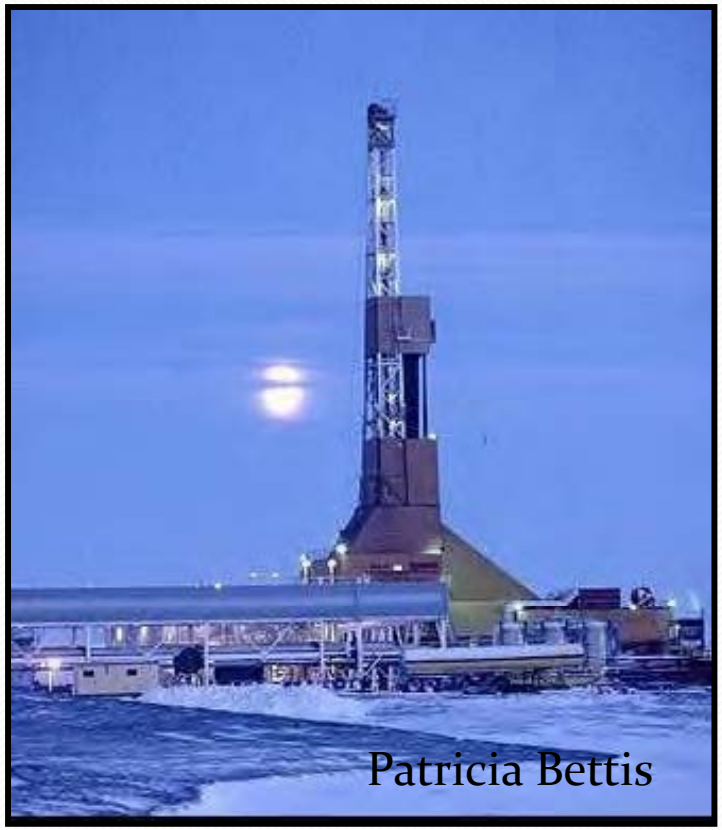
Competing Uses of Water

- Dewatering mine site without fish for gravel extraction.
- Withdrawal of water for beneficial uses, e.g., ice road/pad construction/maintenance, camp supply, etc.

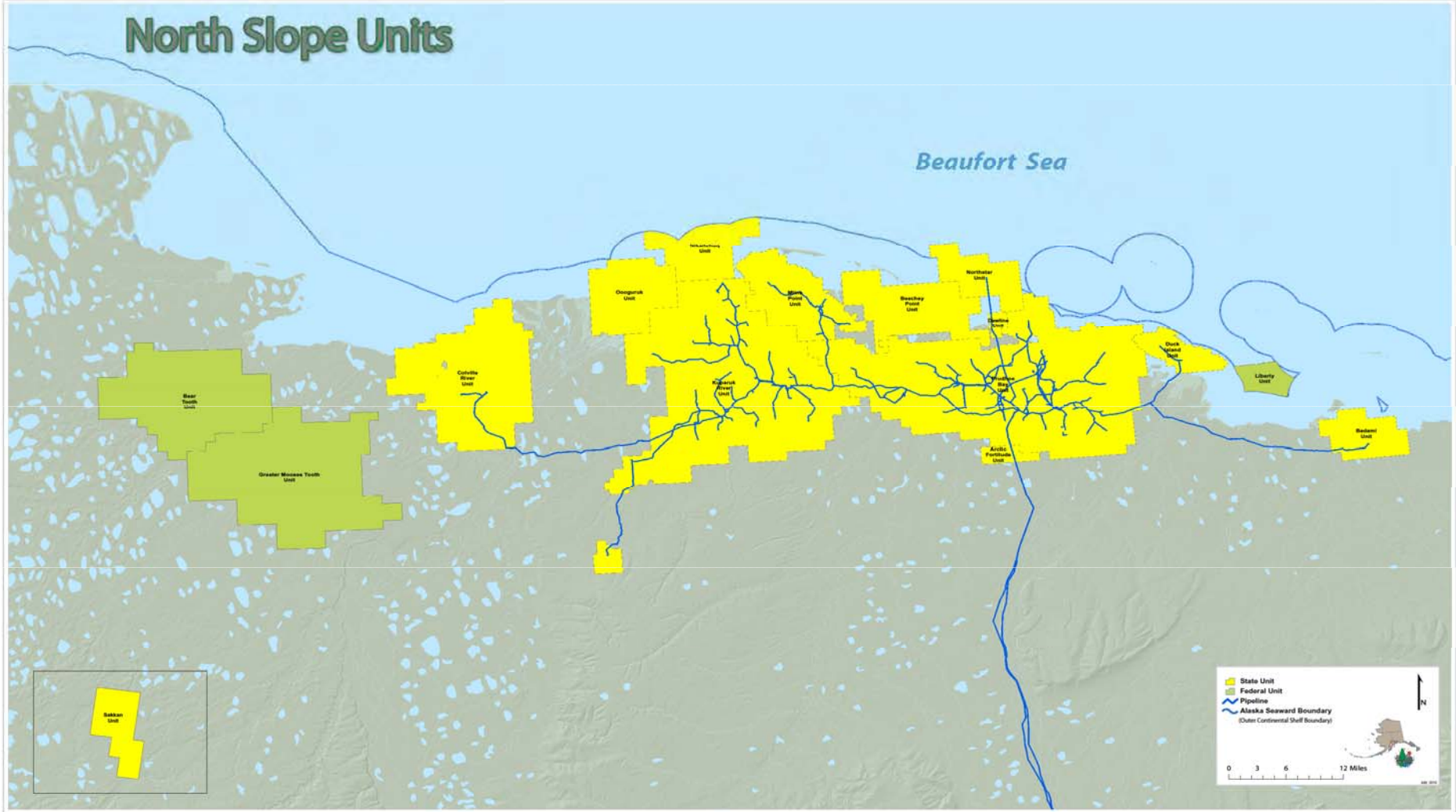


Competitive Uses of Water Cont.

- Drilling and Support
- Enhanced Oil Recovery



North Slope Units



Conservative Management

- Bathymetry Studies
- Snow Surveys & Drainage Basin Studies

By Krissy Plett

Conservative Management Cont.

- Fish Studies
- Water Quality Parameters
  - Dissolved Oxygen
  - Conductivity

Winter Water Withdrawal Colville River Exception

- Conditions
  - Water Chemistry
  - Depth Profiles
  - No Grounding of Ice Over Entire Channel Bottom

http://dnr.alaska.gov/

http://dnr.alaska.gov/mlw/water/wrfact.htm

APPENDIX J

GRAVEL VS. ROADLESS CONSTRUCTION

A L A S K A F R O N T I E R C O N S T R U C T O R S

N A N U Q, I N C.

AFC Alaska Frontier Constructors, INC.

NANUQ INC.

http://www.akfrontier.com

Gravel vs. Roadless Construction

While many well sites from the larger reservoirs such as Prudhoe Bay, Kuparuk, Endicott and Milne Point can be reached on an all weather road system, many new drill sites are roadless and depend on airplanes & helicopters, crew boats & barges and/or ice roads for operational access.

Gravel vs. Roadless Construction

Logistical challenges for Arctic construction include:

- Limited Access
- Weather
- Rules & Regulations to protect the environment
- Best Management Practices Utilized

Gravel vs. Roadless Construction

Areas of Discussion

- Gravel Infrastructure
- Water Transportation
- Helicopter Travel
- Fixed Wing Transportation
- Tundra Travel Vehicles
- Onshore Ice Roads
- Offshore Ice Roads
- Remote Mine Site Development/Gravel Hauling
- Offshore Gravel Islands
- Subsea Pipelines

Gravel Infrastructure

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Gravel Infrastructure

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Gravel Infrastructure

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Water Transportation

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Water Transportation

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NANUQ Inc.

Water Transportation

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Helicopter Travel

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Helicopter Travel

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Fixed Wing Transportation

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Fixed Wing Transportation

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Fixed Wing Transportation

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Fixed Wing Transportation

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NANUQ Inc.

Fixed Wing Transporation

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Tundra Travel Vehicles

Tundra travel

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Tundra Travel Vehicles

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Onshore Ice Roads

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NANUQ INC.

Onshore Ice Roads

Pioneering

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Onshore Ice Roads

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Offshore Ice Roads

Ice Thickening

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Offshore Ice Roads

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Offshore Ice Roads

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Remote Mine Site Development

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Remote Mine Site Development

Gravel Mine Source

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Gravel Hauling over Ice Roads

Separate Ice Roads

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Gravel Hauling over Ice Roads

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NANUQ INC.

Gravel Hauling over Ice Roads

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Offshore Gravel Islands

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Offshore Gravel Islands

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Offshore Gravel Islands

Placing slope protection bags

AFC Alaska Frontier Constructors, INC.

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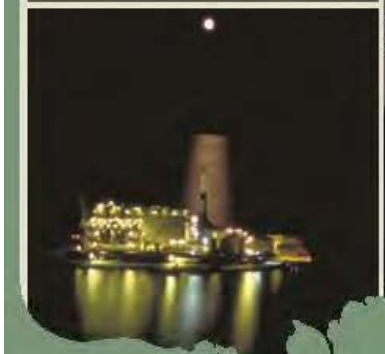
GRAVEL islands



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Subsea Pipelines

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NANUQ INC.

Subsea Pipelines

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Subsea Pipelines

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Subsea Pipelines

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INC.
http://www.akfrontier.com

APPENDIX K

ICE ROADS, ICE PADS, ICE BRIDGES, & ICE AIRSTRIPS

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

Arctic /Cold Regions Oil Pipeline Conference

Eric Wieman
Peak Oilfield Service Company, LLC

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Purpose of Ice Roads
  - Support Exploration, Construction or Resupply
  - Leave little to no lasting impact to the tundra

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Types of Ice Roads
  - Sea Ice or Over Land (Tundra)
  - Remote or In Field (from Gravel)
- Roads, Pads, Bridges and Airstrips can all be constructed using Ice

Completed Ice Road in the NPRA

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Tundra Ice Road
  - Start with Route Planning
    - Routes are dictated by the available water resources
    - Adequate water is required
    - Plan on roughly 1,000,000 gallons per mile
    - Perform cultural survey
    - Avoid rough areas, tussocks, low lying areas, steep banks or side hills
    - Fly the planned route to determine if the route is good and adjust as necessary.
    - Start the permitting process

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Tundra Ice Road
  - Install Thermistors during the summer or fall months
    - Thermistors capture real temperature data up to 12” below surface level
    - Data can be reviewed by DNR to allow site specific access prior to a general tundra opening

Thermistor Pictures supplied by Beaded Stream

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Tundra Ice Road
  - 30 foot minimum width
  - 35 foot is standard on the North Slope
  - Wider roads can be built as required (B-70 Roads – 50 ft)
  - 6 Inches Thick
  - Delineators every 50 feet alternating sides of the road
  - 3 to 5% grade maximum

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Tundra Ice Road
  - Use Forward Looking Infrared Radar (FLIR) to ensure route is clear of polar bear dens
  - Survey Route
    - Install stakes on one side of the road
    - Mark lake access roads
    - Set grade stakes for any river crossings or ice bridges

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Tundra Ice Road
  - Prepack Route
    - Reduces insulating effect of snow
    - Site specific access can be granted with lower temperatures
    - Use summer approved vehicles for prepacking

RD85 Rolligon – Approved for Summer Use on DNR Lands

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Tundra Ice Road
  - Side Cast Water While Pre-packing Route
    - Further reduces insulating effect of snow when compared to regular prepacking
    - Protects the tundra with a layer of ice
    - Allows snow to blow off route or pad
    - Allows even earlier start to construction

RD85 Rolligon – Side Casting Water During Pre-packing

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Tundra Ice Road
  - Pioneering Phase
    - Use Articulated Water Truck (Water Buffalo) & Loader to pack down snow
    - Water snow creating ice layer to protect the tundra for the remainder of the construction activities

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Tundra Ice Road
  - Road building
    - Water trucks used to haul water
    - Rock Trucks & Maxi Trailers used to haul snow & ice chips
    - Grader spreads material

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Tundra Ice Road
  - Use snow or ice chips from permitted lakes

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Tundra Ice Road
  - Use water from permitted lakes
  - Fish screens are approved by Fish and Game
    - 0.25 inch mesh cloth
    - Limit water velocities to less than 0.5 ft per second
  - Track Water and Ice Usage Daily for Submittal

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

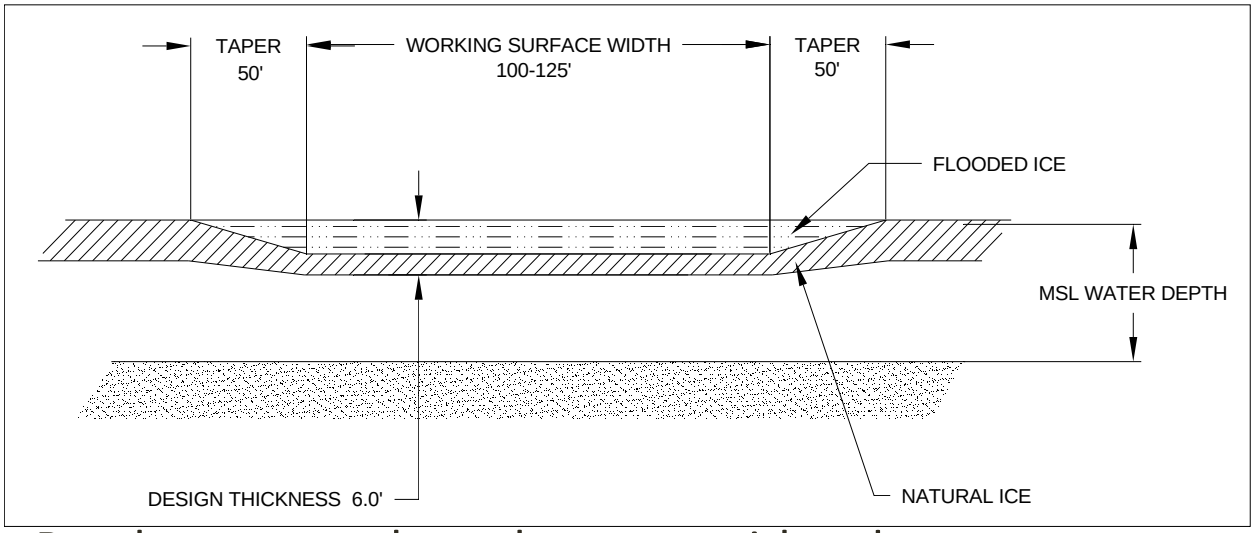
- Tundra Ice Road
  - Final Freshwater Cap is placed with water trucks
  - Delineators are installed
  - Maintenance begins
    - Blade and blower or water trucks

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Sea Ice Roads
  - Type of road is dictated by location
  - Near Shore Roads
    - Shallow water
    - Follow the coast
    - Ground naturally
  - Floating Roads
    - Deeper water
    - Lower maximum design weight

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

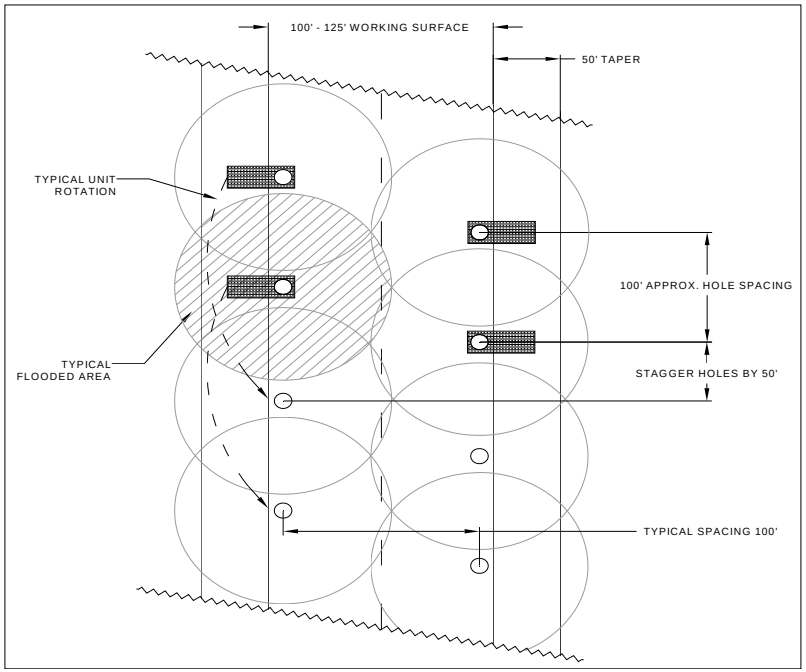
- Floating Sea Ice Roads
  - Follow similar route planning as Tundra Roads
  - Profile Route ensuring there is enough ice to support equipment
  - Standard cross section of floating sea ice road



  - Break up snow along the route with a drag
  - Use pumper units to free flood the route thickening it each day

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Floating Sea Ice Roads
  - Break up snow along the route with a drag
  - Use pumper units to free flood the route thickening it each day
    - Standard flooding plan



Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Floating Sea Ice Roads
  - Approximately 2 inches per day for planning purposes.
  - Continue to pump until to design thickness
  - Install delineators

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

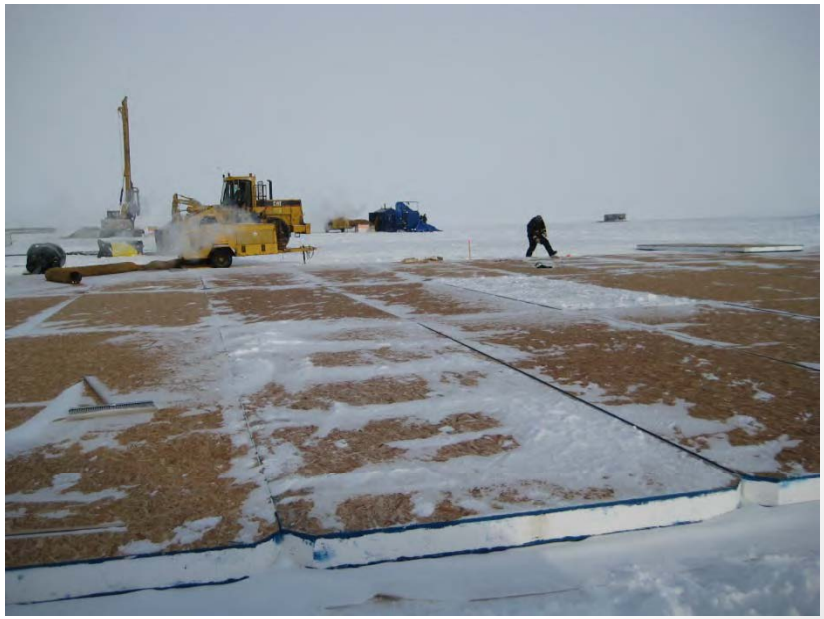
- Near Shore Roads
  - Similar route planning as Tundra Roads
    - Keep adequate space from any shore line bluffs to reduce drifting.
  - Profile Route
  - Clear snow from the route
  - If un-grounded areas are found build up with:
    - Conventional construction
    - Pumping
    - Combination of the two
  - Place freshwater cap
  - Install delineators

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Ice pads
  - Similar Planning as Ice Roads
    - Look for a flat area to build pad
    - Same construction techniques as for ice road construction
  - Standard North Slope Designs
    - 6 inches thick is the minimum
    - Usually 18 to 24 inches under a drill rig
    - 1% to 2% grade across a pad is OK unless under a rig or camp; then the pad needs to be level
      - This reduces the amount of fill if on a side hill

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Over Summer Ice Pads
  - Same techniques as Ice Roads
- Typically minimum of 3 -4 ft thick
- Then install vapor barrier, insulation and rig mats



Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Over Summer Ice Pads
  - Plan on edges of the pad melting
  - Continual monitoring through the summer
- Over Summer Ice Pads are rarely used on the Slope

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Ice Bridges
  - Permits stipulate if the bridge can be grounded or not
    - Does it ground naturally?
  - If Bridge cannot be grounded, the water depth must be deep enough to build up the ice to support the load and still have room for water to pass underneath.
    - Finding the correct ice bridge location can be challenging
  - Construction techniques are similar to roads and pads
    - Conventional construction
    - If permits allow, combination of pumping and conventional construction

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Ice Bridges

Pumping for construction of a Sea Ice Bridge

Conventional Construction to complete the Ice Bridge

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Ice Bridges

Conventional Construction to build Ice Bridge

Completed Ice Bridge 9’x 60’x1300’

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Ice Airstrips
  - Vary considerably depending on the application and location.
    - Wide section of road for emergency flight response
    - 5,000 foot long herc strip with a full light package, comm building and weather observer
  - Can be built on Tundra, Lakes or Sea Ice
    - Construction techniques vary depending on the situation
      - Either conventional construction, pumping or a combination of the two

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Ice Airstrips

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Ice Airstrips

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Ice Road Close Out
  - Lakes are inspected and closed
    - Pump House Removed
    - Snow pile covering hole
  - Delineators Pulled
  - Stream Crossings Cut per approved plan

Ice Roads, Ice Pads, Ice Bridges & Ice Airstrips

- Ice Road Close Out
  - Cut crossings are marked with snow piles on either side of crossings with red dye to mark piles
  - Snow Piles placed at the entrance of the road
  - Route is flown in the summer for stick picking

Thank you for your time

Eric Wieman

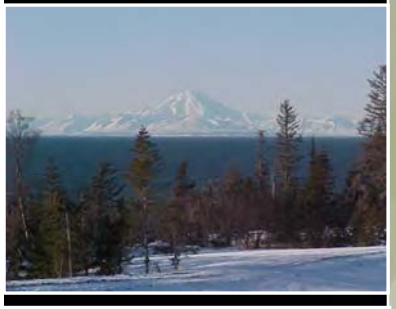
Peak Oilfield Service Company

907-263-7000

eric.wieman@peakalaska.com

APPENDIX L

USE OF OTHER COMPANY PIPELINES – INTERFACING WITH INFRASTRUCTURE



PIONEER
NATURAL RESOURCES ALASKA

Use of Other Company Pipelines – Interfacing with Infrastructure

September 17, 2013

David Hart – Alaska Operations Manager

NYSE: PXD
www.pxd.com

Agenda

PIONEER
NATURAL RESOURCES ALASKA

Pioneer Natural Resources

- Overview

Oooguruk Development

- Oooguruk facilities and operations
- Kuparuk interface and processing

Oooguruk Drill Site (ODS)

Production Processing & Services Agreement (PPSA)

- Fee structure
- Backout
- Measurement
- Conformance

Questions

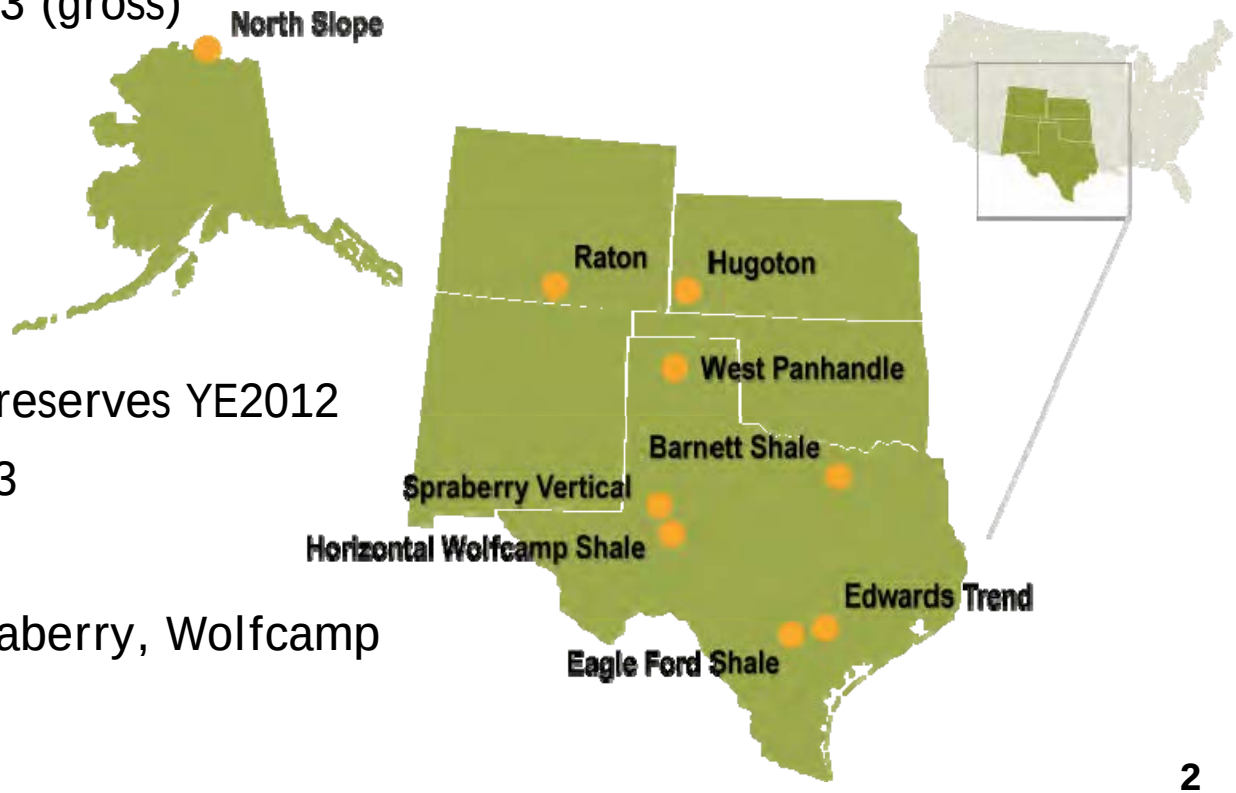
Oooguruk Tie-In Pad (OTP)

Pioneer Natural Resources

PIONEER
NATURAL RESOURCES ALASKA

History

- 1997 merger: Parker & Parsley and Mesa Petroleum
- 2002 Pioneer Natural Resources Alaska, Inc. formed
- 2008 Oooguruk first oil
  - 13 MMBO total produced (gross)
  - 8,000 BO/day 2Q2013 (gross)

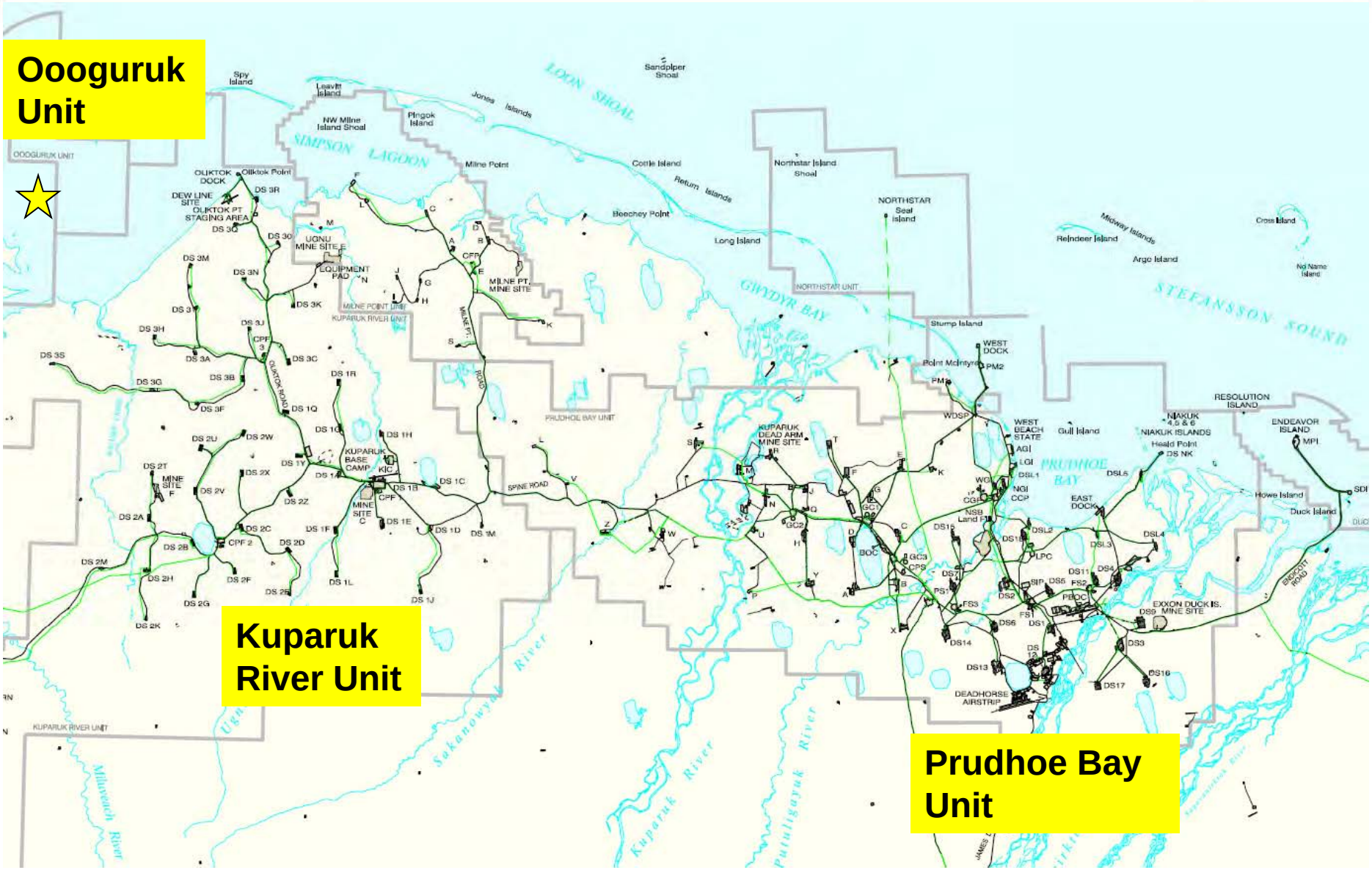


At a glance

- $25 Billion market cap
- 1.1+ Billion BOE proved reserves YE2012
- 176,000 BOE/day 2Q2013
- 10,000+ producing wells
- Eagle Ford, Barnett, Spraberry, Wolfcamp

North Slope Map

PIONEER
NATURAL RESOURCES ALASKA



Oooguruk Transportation Map

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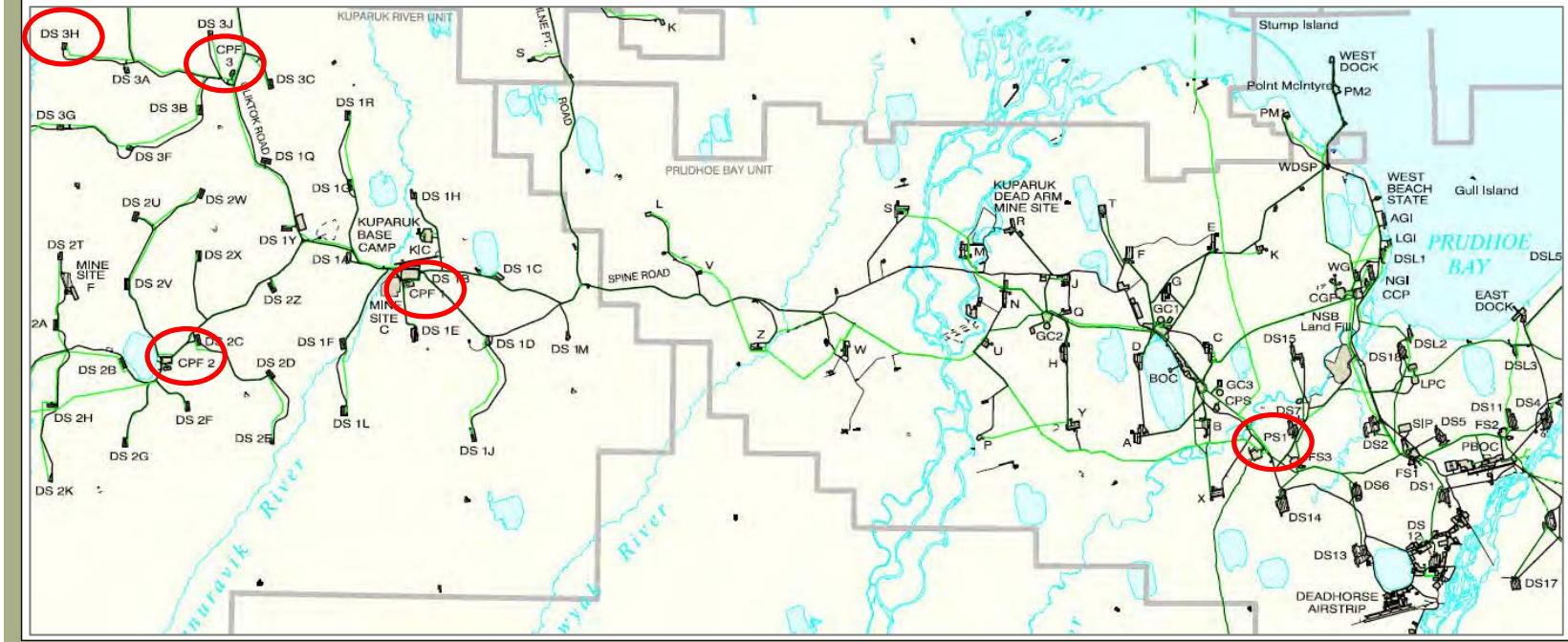
Production Transportation Summary

- ODS Production to OTP for sales metering
- Multiphase delivery to Kuparuk River Unit (KRU) DS3H
- KRU DS3H to CPF3 for partial processing
- KRU CPF3 to CPF1/2 for final processing
- Oil sales via Kuparuk Pipeline and TAPS



OU Offshore Operations - ODS

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NATURAL RESOURCES ALASKA

Oooguruk Drill Site (ODS)

- 104-bed camp and warehouse / shop
- Drilling rig and rig support complex
  - Grind and inject
  - Cementing
  - Mud plant
- 48 wells
  - ESP with gas lift backup
  - Water / gas injection
- Well test meter
- Backup power
- Potable water / sewage treatment
- Helicopter / crew boat / barge landing

Oooguruk Drill Site (ODS)

ODS Tank Farm

OU Onshore Operations - OTP

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NATURAL RESOURCES ALASKA

Oooguruk Tie-in Pad (OTP)

- 56-bed camp and warehouse / shop
- Multiphase metering
- Production heater
- Gas compression
- Power generation
- Helicopter operations

Oooguruk Tie-in Pad (OTP)

OTP Waste Heat Recovery

Kuparuk River Unit (KRU) Operations

PIONEER
NATURAL RESOURCES ALASKA

Central Production Facility 3 (CPF3)

- Gas & liquid separation
- Fuel & lift gas treating, compression and delivery
- Seawater pumping and delivery

Central Production Facilities 1 and 2 (CPF1 / CPF2)

- Final processing of OU production
- Delivery point of OU sales crude to common carrier pipelines (KPL and TAPS)

Seawater Treatment Plant (STP)

- Seawater treating and pumping

KRU Processing Structure

PIONEER
NATURAL RESOURCES ALASKA

OU production delivered to KRU

- Oil, water and gas metered at OTP
- OU fluids shipped to DS3H, CPF3, CPF1/2
- KRU returns gas; OU take or forfeit
- KRU returns water
- Makeup gas and seawater for purchase

Oooguruk Tie-in Pad & KRU Drill Site 3H

OU production to TAPS

- CPF1/2 to TAPS PS1 via Kuparuk Pipeline

Production Processing & Services Agreement (PPSA)

- Processing Fee Structure
- Backout Compensation
- Measurement
- Conformance & Interference

PPSA - Fee Structure

PIONEER
NATURAL RESOURCES ALASKA

Production Processing & Services Agreement (PPSA)

- Facility Use Fee ($ / BO)
- Facility O&M Fee ($ / BO + BW)
- Excess Gas Compression Fee ($ / MCF > “max” GLR)
- Makeup Gas Infrastructure Fee ($ / MCF makeup)
- Makeup Water Fee ($ / BW makeup)
- High Pressure Pump Fee ($ / BW excess)
- CPF3 Fuel Gas Allocation

Kuparuk Pipeline

- CPF1/2 to TAPS PS1

  (Public tariff currently $0.29 / BO)

OTP Power Generation

PPSA – Backout Compensation

PIONEER
NATURAL RESOURCES ALASKA

Backout (compensate for KRU production impacts)

- Per simulator and calculation
- Primary driver is CPF3 gas capacity
  - Fixed capacity; OU gas displaces KRU gas + oil
- Water Injection hydraulics
  - OU water take reduces KRU injection pressure
- Production hydraulics
  - OU production increases KRU system pressure
- KRU maintenance activities
  - Maintenance may reduce processing capacity

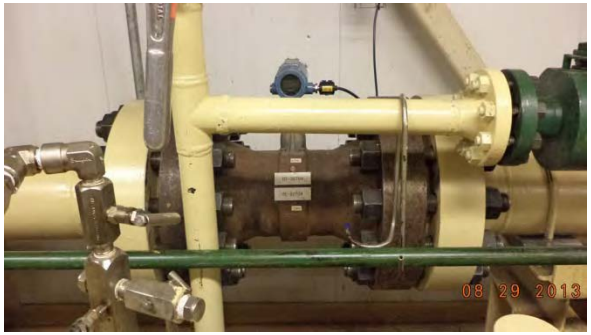
Oooguruk Flowline to ODS

PPSA – Measurement

PIONEER
NATURAL RESOURCES ALASKA

OTP Fluid Measurement (1st multiphase fiscal meter in AK)

- Oil and Water: Schlumberger VX multiphase meter
- Produced Gas: Daniels Junior ultrasonic meter
- Return Gas: Daniels Senior ultrasonic meter
- Return Water: Rosemount vortex meter



Vortex – Return Water (injection)

Multiphase – Sales Oil

Ultrasonic – Return Gas (fuel)

Ultrasonic – Sales Gas

PPSA – Conformance & Interference

PIONEER
NATURAL RESOURCES ALASKA

Conformance

- Solids
- Temperature
- H2S and CO2
- Gas heating value
- Oil gravity
- Chemical / substance limitations

Interference

- Damages reimbursable
  - Rare; increased chemical use (e.g.)
- KRU can shut in Oooguruk production
  - Last resort only

Oooguruk Flowline and OTP

Summary

PIONEER
NATURAL RESOURCES ALASKA

Pipeline and Facility Sharing

- Efficient use of existing infrastructure
  - Avoids duplicate infrastructure
  - Reduces environmental impact
- Improves viability of smaller operators/projects
  - Less capital
  - Shorter schedule
  - Flexible operations
- Benefits infrastructure owner, producer and State of Alaska
  - Requires cooperation and good faith
- Oooguruk / Kuparuk demonstrate 5+ years successful relationship

Oooguruk Tie-In Pad

Questions?

PIONEER
NATURAL RESOURCES ALASKA

APPENDIX M

PIPELINE INSPECTION AND MAINTENANCE

PIPELINE INSPECTION and MAINTENANCE

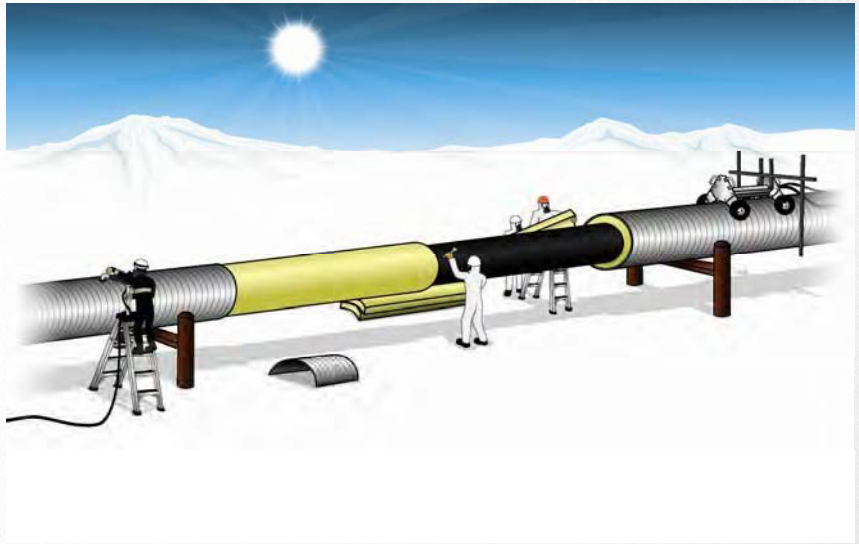
KAKIVIK
ASSET MANAGEMENT

2013 Arctic/Cold Regions Oil Pipeline Conference – September 2013

September 25, 2013

Overview

- Who are Kakivik and CCI Industrial Services?
- Pipeline Operation and Maintenance Issues
  - Monitoring
  - Inspection
  - Maintenance
  - Repair



- Key Principles:
  - Everything gets old!
  - Regular monitoring, exercise and maintenance are critical to long term health

KAKIVIK ASSET MANAGEMENT

Kakivik and CCI Industrial

- Kakivik (est. 1999; 195 ee's)
  - Asset/Infrastructure Integrity Management
    - New construction - QA/QC/NDT
    - Existing infrastructure
      - Inspection
      - Chemical, Coupon/Probe and Lab Services
      - Data integration and management
- CCI Industrial (est. 1989/2010; 245 ee's)
  - Operating & Maintenance (O&M) Services and Labor, including
    - Hazardous Materials Management and Spill Response
    - Corrosion-under-Insulation (CUI) Support and Refurbishment
    - Coatings (Corrosion, Containment and Fire Protection Systems)

Why Maintain, Monitor and Inspect?
(Key Principal #1 – Everything gets old)

- Corporate responsibility – the right thing to do
  - Protection of the environment, people, assets
    - Company Asset & Operating Integrity Programs
    - Process safety
- Regulatory requirements/industry standards
  - US Dept of Transportation (DOT) – Transportation Pipelines; Risk Assessment, Integrity Management, Operator Qualifications
  - AK Dept of Environmental Conservation (ADEC) – Non-DOT lines
  - API 570 – Inspection of Pipelines
  - API 574 – Inspection of Piping System Components

KAKIVIK ASSET MANAGEMENT

Pipeline Corrosion and Damage

- Internal mechanisms
  - Erosion
  - Corrosion – general, localized, preferential weld attack, stress cracking, microbial attack
  - Scaling and solids
- External mechanisms
  - 3rd party damage
  - Wind-induced vibration (WIV)
  - Corrosion-under-Insulation (CUI)

KAKIVIK ASSET MANAGEMENT

How to Maintain, Monitor and Inspect

(Key Principal #2 – Regular monitoring, exercise and maintenance are critical to long term health)

- Somewhat unique for relevant design/service
  - Operation Monitoring - pressures, flows, volumes, chemistry
  - Corrosion Inhibition – chemicals to mitigate corrosion, scale, emulsions, etc.
  - Corrosion Coupons and Probes – valuable indicators
  - Maintenance Pigging – managing water, sludge/wax, corrosion products, bacterial build-up

KAKIVIK ASSET MANAGEMENT

Inspection Methods - Internal

- "Smart Pigging"
  - Internal & external corrosion/erosion, scale, sludge, impacts, manufacturing defects
  - Many vendors, many tools available
    - Geometry – Mechanical Calipers, Combination Mechanical/Electrical
    - Metal Loss – Magnetic Flux (MFL), Ultransonic
    - 3rd Party Damage – Circumferential MFL
    - Cracks, Leaks, Coating Disbondment – Electromagnetic-Acoustic (EMAT)
    - Other Anomalies – Optical Inspections
  - Lots of planning, preparation (of pipe and logistics), flow management, processing time
  - Direct assessment needed to follow-up
  - Data integration requirements – other sources; implications

KAKIVIK ASSET MANAGEMENT

Inspection Methods - External

- External Inspection (for non-piggable lines, verification of "smart pig" findings, and specific areas of concern, etc.)
  - Less invasive, less operational impact, essentially real time results
  - Can look for Internal damage (erosion, corrosion)
    - Linear Array Radiography (from ~ 4 – 8 o'clock)
    - Ultrasonic (UT)
  - Excellent for External Investigation
    - Weld x-rays, Mag Particle, Liquid Penetrant, Visual
  - CUI
    - Rapid: Infrared, Profile Tangential Radiography, Long-range UT
    - Closer Look: RTR4, C-Arm, Ultrasonic, Visual

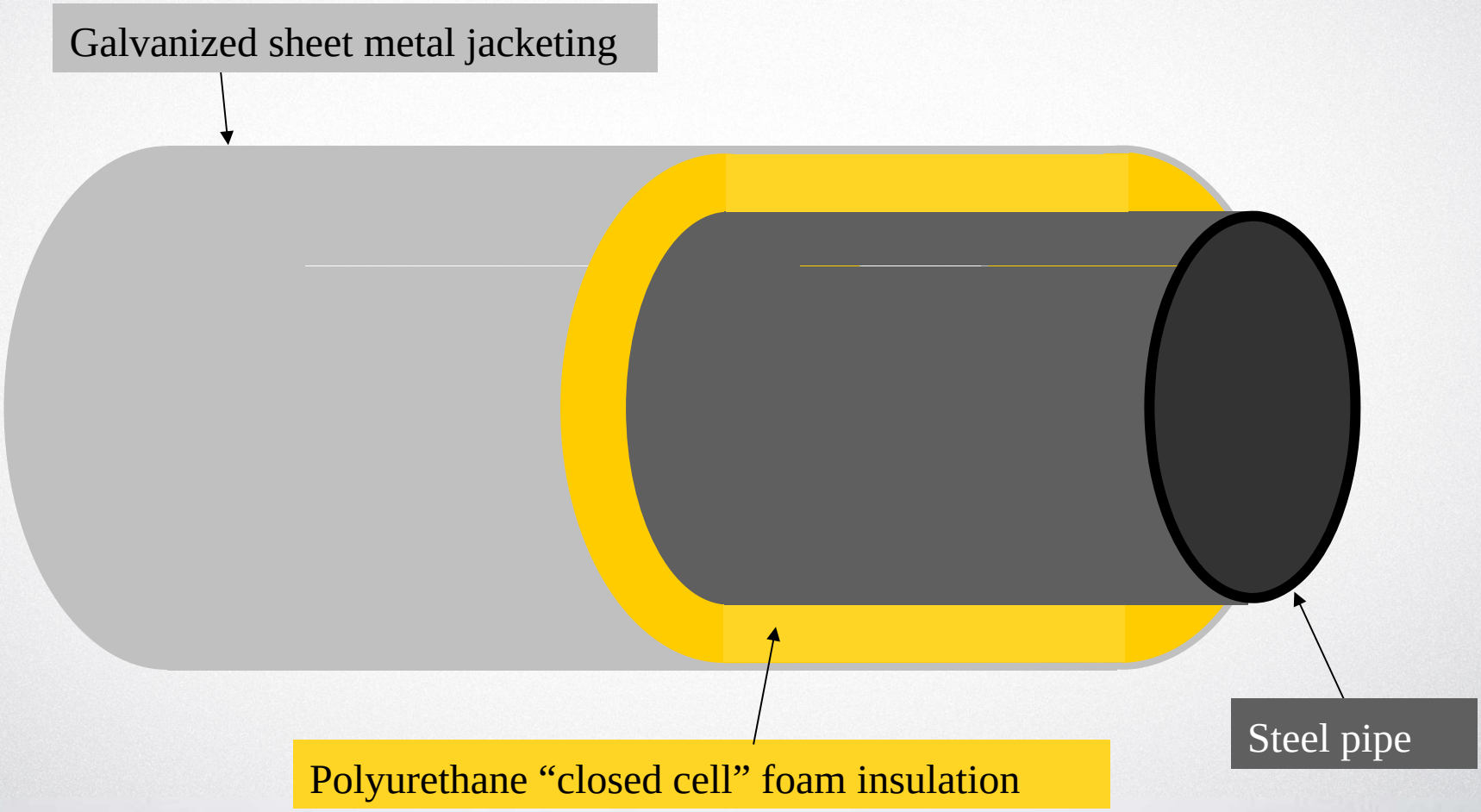
KAKIVIK ASSET MANAGEMENT

Corrosion Under Insulation

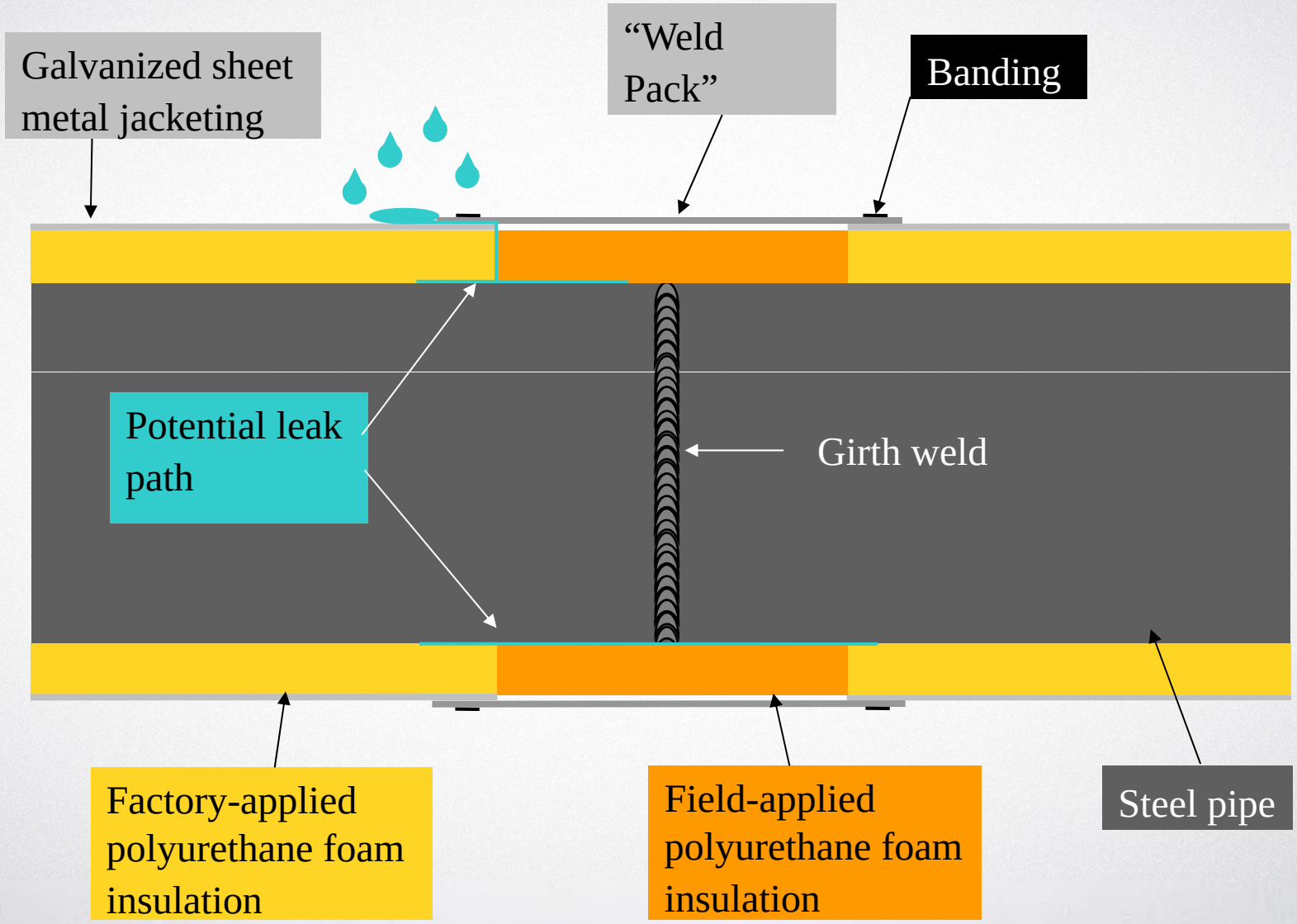
- General corrosion, networking, pitting, stress cracks (SS)
- Affected by:
  - Environment (moisture, coastal (salt), temperature changes)
  - Line Temperature (CS 25-250 deg F; SS 140-400 deg F)
  - Insulation and coating types and jacket integrity
- CUI is best controlled in the design stage:
  - Pipe design
  - Pipe exterior coating
  - Insulation and jacket type
  - Insulation joining/banding systems at welds
- However, all systems are subject to failure, and therefore a CUI inspection program is a must!

KAKIVIK ASSET MANAGEMENT

Insulated pipeline



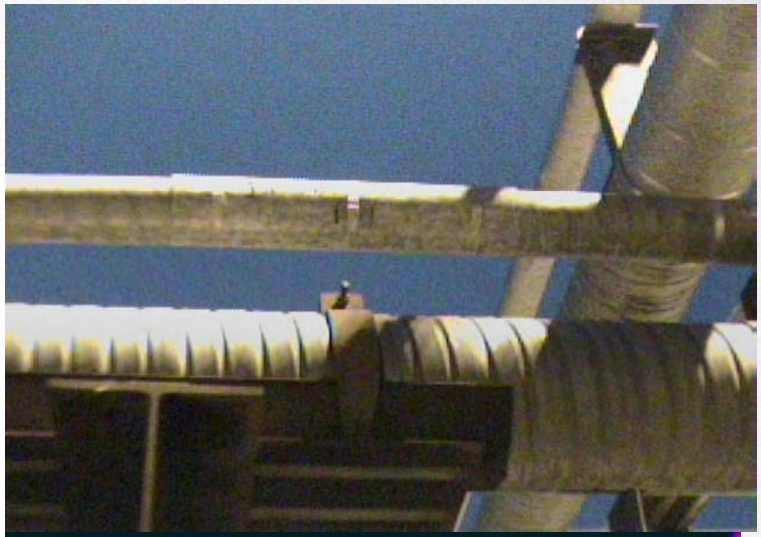
CUI Mechanism



KAKIVIK ASSET MANAGEMENT

Infrared Thermography (IR)

- Rapid scanning technique
- Detect conditions that lead to CUI
- Measure temperature profiles of insulated pipe and piping
- Detect wet insulation
- Not as easy as it looks



Shown: Pipeline with IR indications of heavy water accumulation at the 6 o'clock location

KAKIVIK ASSET MANAGEMENT

CUI Inspection Methodologies

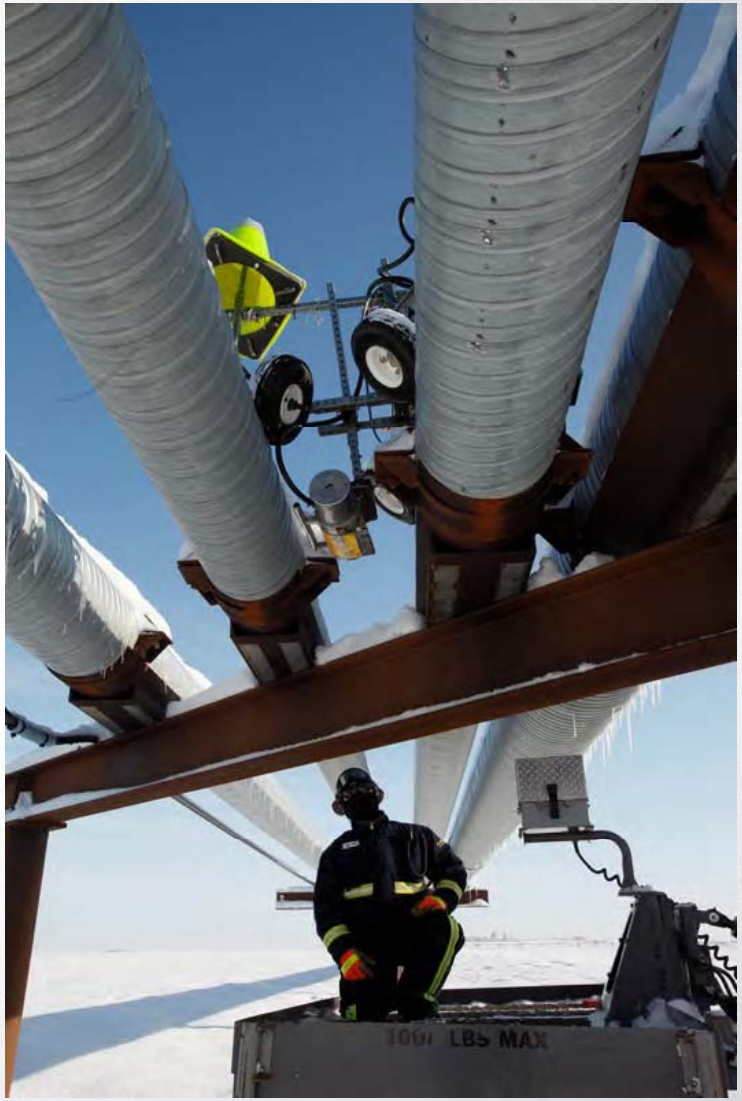
- CUI Inspection Guidelines
  - **API 570** - Piping Inspection Code: In-service Inspection, Repair, and Alteration of Piping Systems
  - **API 574** - Inspection Practices for Piping System Components
  - **ASNT** – American Society of Non-Destructive Testing
- CUI Inspection Methods (other than Smart Pig)
  - Infrared Thermography (IR)
  - Profile (Tangential) Radiography (TRT, ATRT, and C-Arm)
  - Ultrasonic (UT)
  - Long-Range, Guided Wave Ultrasonics (LR UT)
    - For below-grade piping
  - Visual (VT)

KAKIVIK ASSET MANAGEMENT

Automated Tangential Radiography (ATRT)

Shown deployed with KAKIVIK's Wireless SmartCrawler

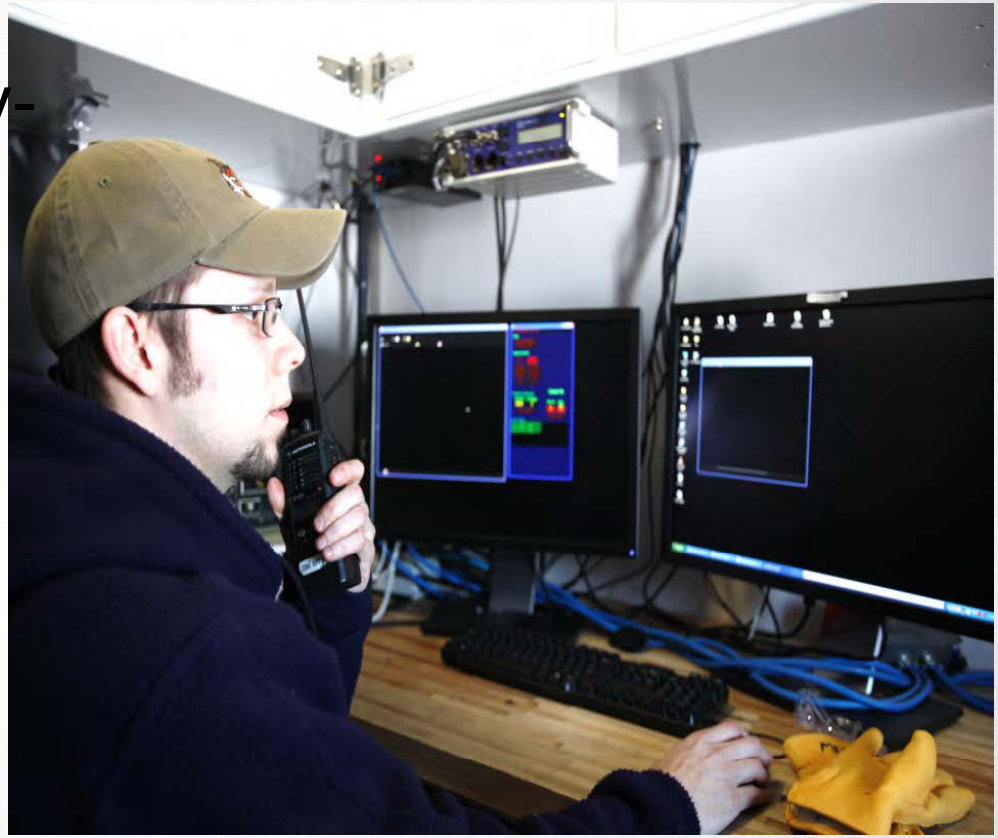
- Highly effective, qualitative real-time, assessment tool
- Ideal for non-piggable pipe
- Kakivik's ATRT can scan ~1,500 feet of straight run, unobstructed pipeline in a single 12-hour shift
- Crawlers often tethered, but wireless (like Kakivik) can be run from up to 2 miles away (line of sight)



KAKIVIK ASSET MANAGEMENT

ATRT Analysis

- Locates external corrosion, corrosion by-product and wet insulation
- Real time
- Interpretation on-site
- Data archived
- NDT follow-up
- Inspection completed before moving



KAKIVIK ASSET MANAGEMENT

C-Arm Radiography & RTR4

- Portable X-ray system
- Real-time, quick, qualitative inspection through insulation
- Good for a variety of geometries and configurations
- Bundle with RTR4 on elbows

KAKIVIK ASSET MANAGEMENT

C-Arm Standard Unit

Advantages

- Real-time video X-ray – full motion 30fps
- Low dose to the operator
- Small exclusion zone
- Fast surveys in confined environments
- Light weight
- Deployable via Rope Access

KAKIVIK ASSET MANAGEMENT

Ultrasonic Testing (UT)

- Determines Remaining Material Thickness
  - External
  - Internal
- Discreet points
- Needed in conjunction with external measurements to assess operating pressure rating impacts

KAKIVIK ASSET MANAGEMENT

Long-Range Ultrasonic Testing

- Used for inspecting below-grade pipe for both internal and external corrosion.
- Gives indication of potential problem, and rough location of first defect
- Must be followed up using other methods (radiography, ultrasonic, visual, etc.); involves excavation

KAKIVIK ASSET MANAGEMENT

Pipeline Maintenance

2013 Arctic/Cold Regions Oil Pipeline Conference.

September 25, 2013

INDUSTRIAL SERVICES, LLC

Subsidiary of Bristol Bay Native Corporation

Types of Maintenance

- Repair of Internal Corrosion
  - Remove Corrosion Product, Monitor
  - Insitu Coating Applications
  - Sleeves, Clock-Springs, Cut-outs

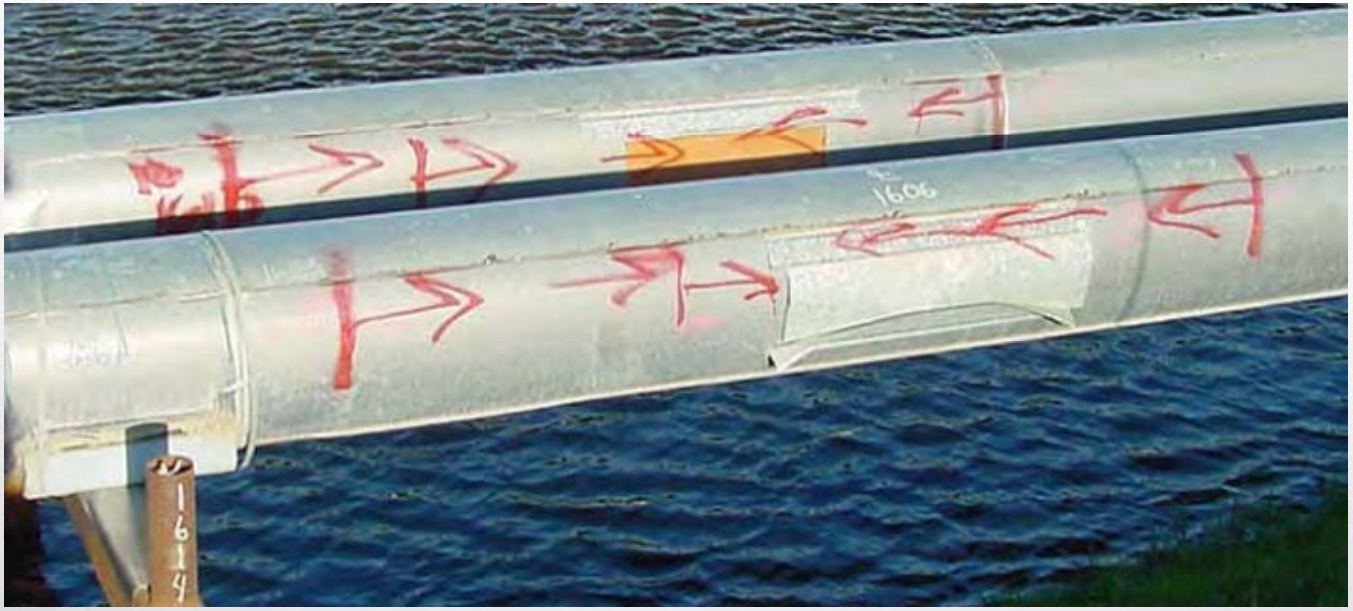
- Wind-Induced Vibration
  - Install Vibration Dampeners

- Damaged Insulation Repair
- Mitigating Corrosion-Under-Insulation
  - Remove Corrosion, Re-insulate and Re-seal
  - Sleeves, Clock-Springs, Cut-outs

INDUSTRIAL SERVICES, LLC
Subsidiary of Bristol Bay Native Corporation

Identify the correct pipe!

- Proper marking of the pipe is essential
- Procedure: External Layout of Well Lines and Flow Lines
- GIS Pipeline Alignment Sheets
- Applicable PID/PLD drawings
- Inspection reference drawings
- Transfer of all markings directly to pipe when jacketing is removed
- Track all activity through multiple databases



INDUSTRIAL SERVICES, LLC
Subsidiary of Bristol Bay Native Corporation

CUI Refurbishment

- Prepare pipe for direct inspection
  - Strip jacketing, insulation and coating
    - Sawsalls, T-Bars, Razor Scrapers, Buffers
    - Avoid nicks, cuts, scratches to pipe surface
- Inspections completed, data analyzed
- Mitigate corrosion, repair pipe
- Re-insulate pipe
  - Denso Tape or sealants, clam shells or “foam-in-place”, re-jacketing

Pipeline Maintenance

Planning, Execution and Access

Alaska Arctic Pipeline Access Options

- Adjacent pipeline access roads, if constructed as such
- Tundra Access (no Spring access allowed)
  - Winter – Tundra travel, ice roads
  - Summer - Specialty tracked vehicles
  - Intention is to always minimize disturbance

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Alaska Tundra Travel Governing Agencies

- ADNR Division of Land
- Bureau of Land Management (BLM) Federal Lands
- North Slope Borough

Permits & Annual Reports Required

- Tundra Travel
- Ice Road Construction
- Land Use

Alaska Tundra Travel Details

- Spring – Tundra Travel is not Allowed
- Summer - Starts July 15th
  - Restricted to “approved vehicles”
  - Rolligons, Argos w/smooth tracks, Hagglunds w/smooth, Tucker Snowcats w/smooth tracks, Kuboda, Polaris Ranger
  - Dynahauls may be “conditionally approved”
- Winter - Dates are weather dependent
  - DNR announces opening
  - Certain vehicle restrictions still apply

Elevated Work Platforms

- Scaffolding
- Temporary work platforms
- Safety/Hazard Mitigations:
  - Manufacturers' instructions, procedures and regulatory, stability on ground
  - Daily Inspection, Permitting and Pre-job Safety
  - Training and Certifications (building, use, inspection)

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Floating work platforms

- For working over water or ice that is too thin
- Sometimes use a “Dock Block” – plastic, floating platform
- Specific hazard analysis required
  - Monitor for hazards under the water
  - Special handling of cables, tubing and cords

Rope Access Systems (IRATA)

- Often a better solution than scaffolding or work platforms
  - For Inspection
  - For Refurbishment
- Considerations
  - Safety
  - Time
  - Cost
- Certified Individuals

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Line Lifts (access to pipe saddles)

- Crib Stacks with Air Bag Systems
  - Shut down or while in operation
  - Based on service, pipe integrity, safety considerations
- Also,
  - Hydraulic jacks
  - Loaders, cranes
  - Beam lifting clamps
- All require mechanical strength evaluations and engineering sign off

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Excavation and Trenching

- For below grade areas (e.g., Road Crossings)
- OSHA Excavation Standards
  - Permitting, Qualified Person
  - Access and egress (confined space?)
  - Demarcation and warning
  - Manage spoils and water

Safe and Clean – the final words

- No one gets hurt
  - Following all regulatory and policy requirements
  - Hazard identification and mitigation
  - Proper training and qualifications
- Key risks
  - Energized systems, including line slugging
  - Working at elevation
  - Power tools, sharp objects, weather considerations
- No leaks or releases (use containment!)
  - Sensitive areas (tundra, wildlife, cultural, etc.)
- Proper planning is essential

INDUSTRIAL SERVICES, LLC

Subsidiary of Bristol Bay Native Corporation

CCI Industrial Services, LLC

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Anchorage, AK 99503-4161

TEL: 907.258.5755
FAX: 907.770.9452

www.cciindustrial.com

APPENDIX N

INTEGRITY MANAGEMENT PROGRAM – AN APPROACH FOR MANAGING STATION FACILITY RISK

Integrity Management Program

An Approach For Managing Station Facility Risk

Brian Yeagley & Eric Coyle

September 18, 2013

Facility Risk Ranking

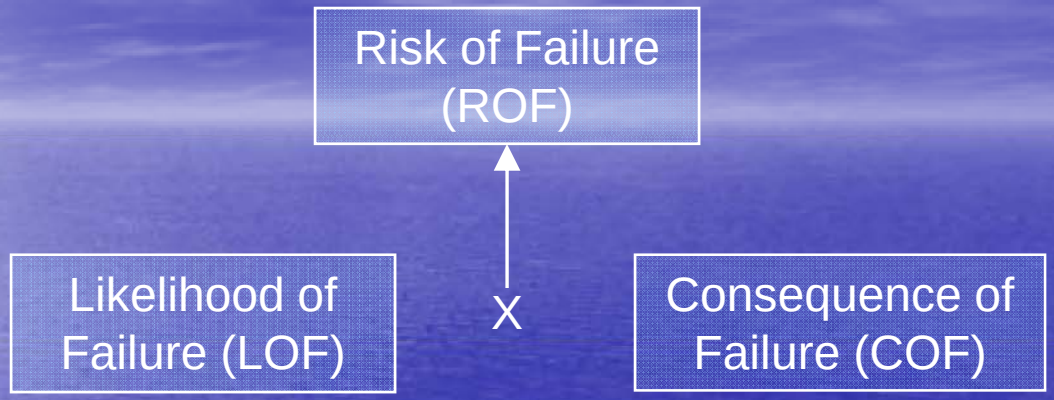
- Brief approach to risk ranking facilities.
- Case study for managing risk for a facility.
- Up-front considerations for starting a risk program.

Risk Ranking Assets

Asset Classes For Risk Ranking:

- **Oil & Gas Pipelines** (gas transmission lines, liquid main lines)
- **Gas Distribution** (DIMP - gas mains, services)
- **Oil & Gas Station Facilities** (high level risk ranking of regulator, compressor, or pump stations)
- **Oil & Gas Facilities Systems** (algorithms for gathering, production, terminals, process, refineries, in-plant utilities)
    1. Piping Systems
    2. Above Ground Storage Tanks
    3. Rotating Equipment
    4. Pressure Vessels

Risk Algorithm



Risk Of Failure → Product of Likelihood & Consequence

Algorithm Components

1. Threat Exposure
2. Consequence of Failure (HCA/non-HCA)
3. Threat Resistance
4. Threat Mitigation

Likelihood of Failure

- Function of 9 threats (standard algorithm)
  - External Corrosion (EC)
  - Internal Corrosion (IC)
  - Stress Corrosion Cracking (SCC)
  - Third Party Damage (TP)
  - Weather & Outside (Natural) Forces (WOF)
  - Equipment Failure (EQ)
  - Manufacturing (MFG)
  - Construction Practices (CONS)
  - Operations (Human Error) (OPS)
  - **Other Asset Specific (e.g. ice plug/hydrates, fatigue)**
- Each Threat Has:
  - Exposure Index
  - Mitigation Index
  - Resistance Index

Likelihood of Failure

- Definitions:
  - Exposure - Likelihood of force or failure mechanism reaching the pipe/facility when no mitigation is applied.
  - Mitigation - Actions that keep the force or failure mechanism off the facility.
  - Resistance - The systems ability to resist a force or failure mechanism applied to the pipe/facility.

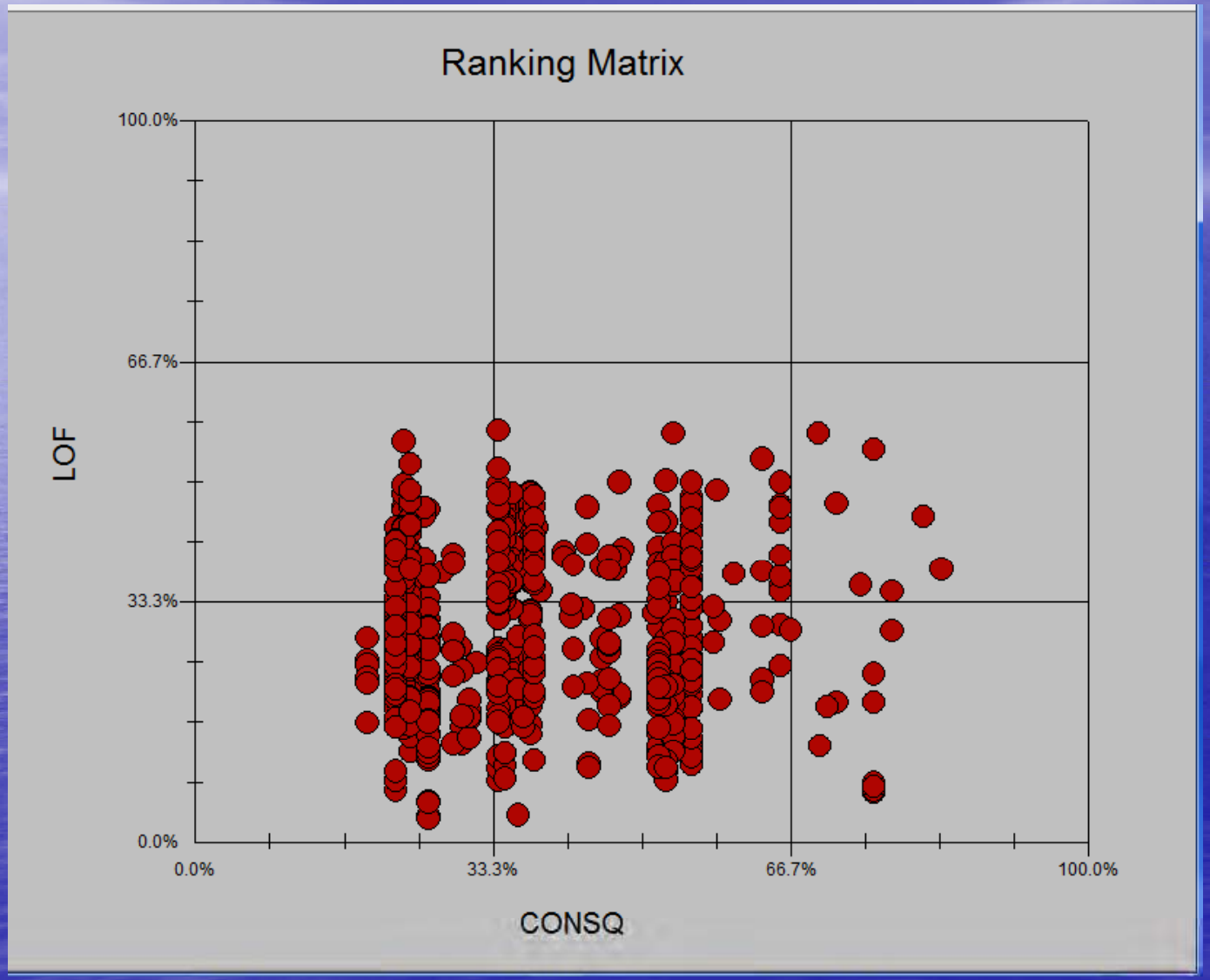
Likelihood of Failure

- The Math:
  - LOF = 1 – [(1-EC) * (1-IC) * (1-SCC) * (1-MFG) * (1-CONS) * (1-EQ) * (1-TP) * (1-IO) * (1-WOF)]
- What it means:
  - Uses Muhlbauer's "OR Gate"
  - LOF is the likelihood of failure from the "EC Threat" OR the "IC Threat" OR "SCC Threat" OR the "MFG Threat"…….

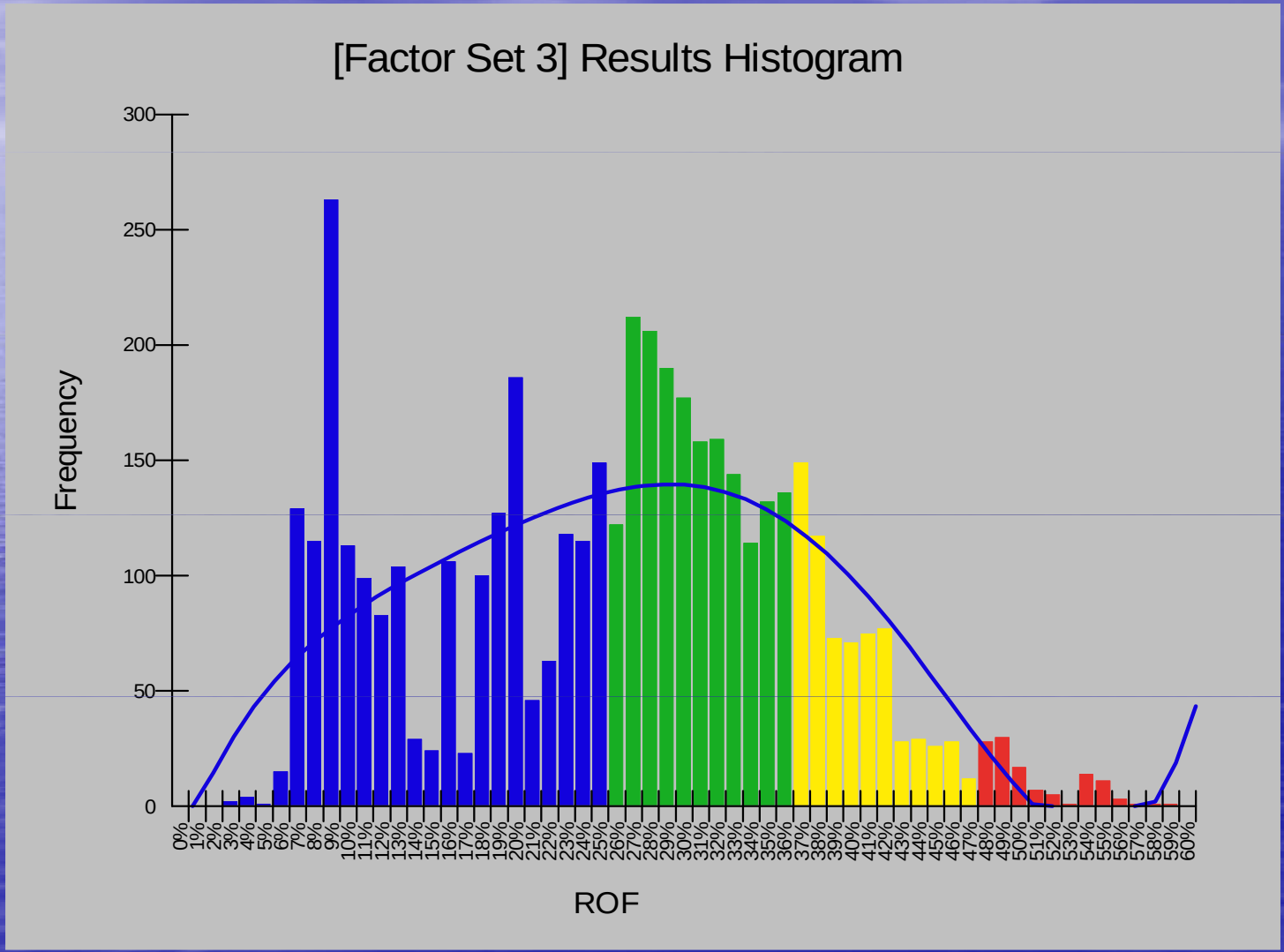
Individual Threat Scores

- The Math
  - EC = (Exposure) * (1 – Mitigation) * (1- Resistance)
- What It means
  - The EC threat score used in the LOF calculation is the remaining threat after mitigation and resistance. OR, the non-mitigated and non-resistant portion of the exposure from a threat.

ROF Ranking Matrix



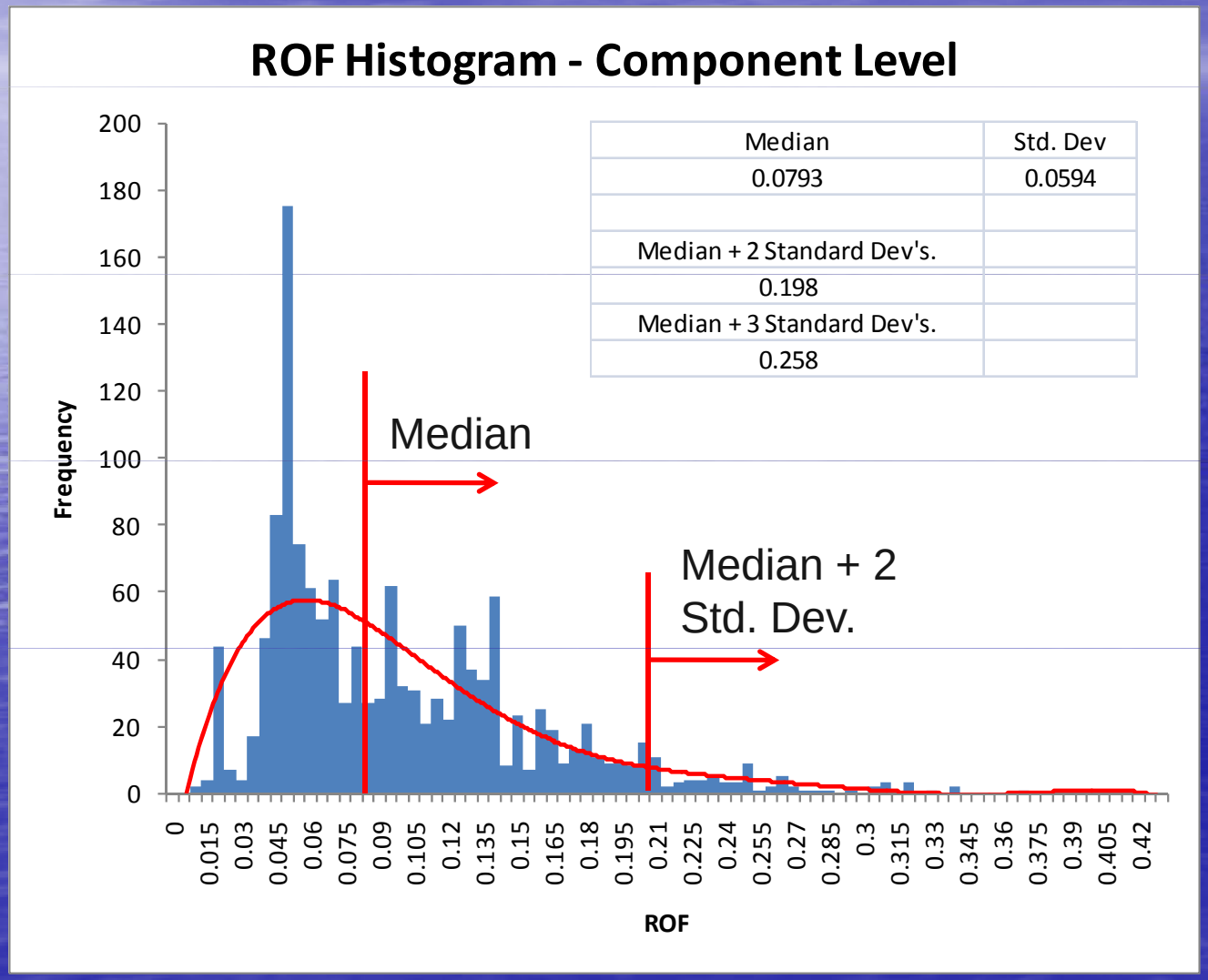
Component ROF Histogram



Risk Ranking Results & Approach

- Max ROF per component
- Results broken into 4 tiers (1 = High, 4 = Low)
- Validation of Risk Ranking Results by comparing with Operations' SME view of risk

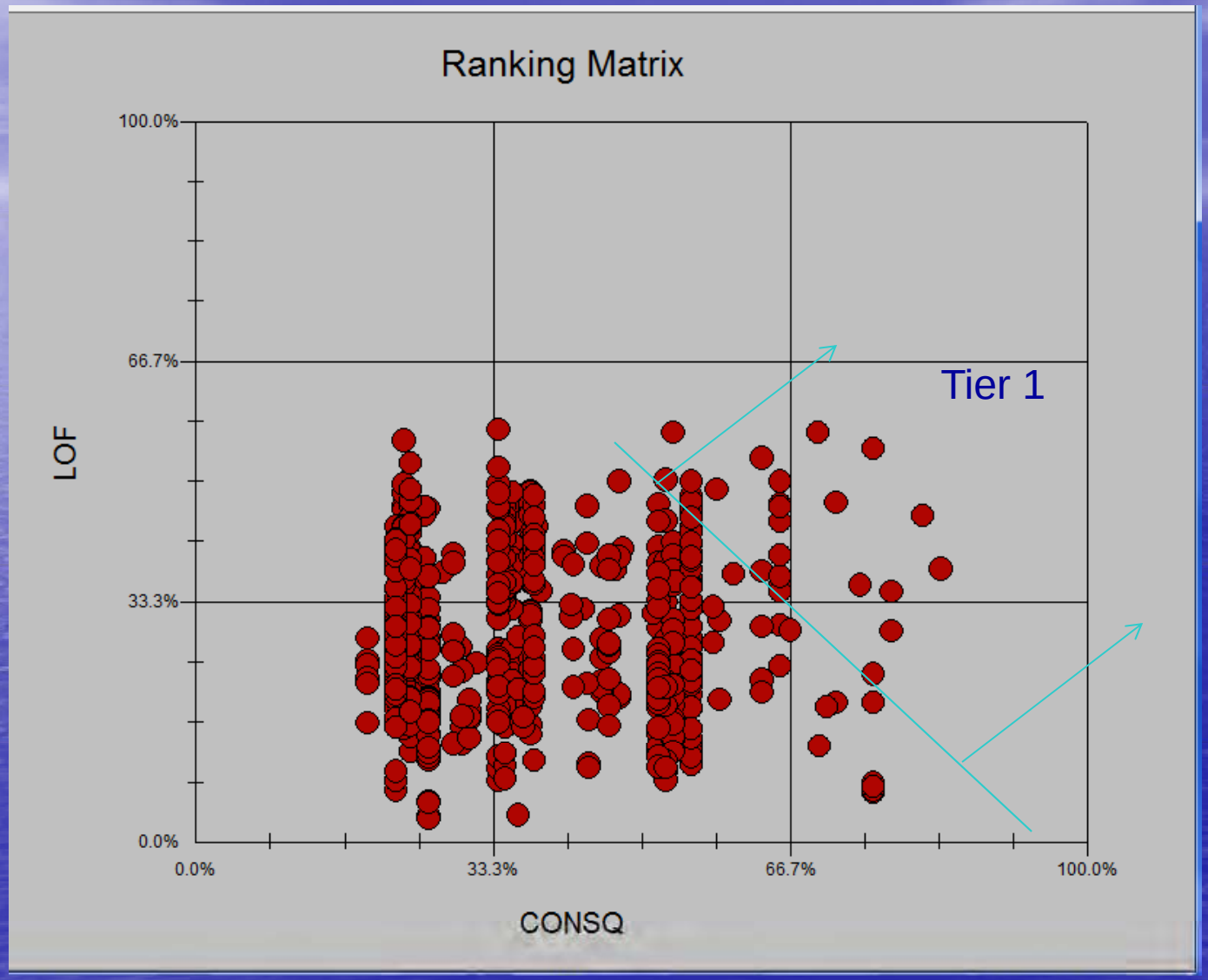
Component ROF Histogram



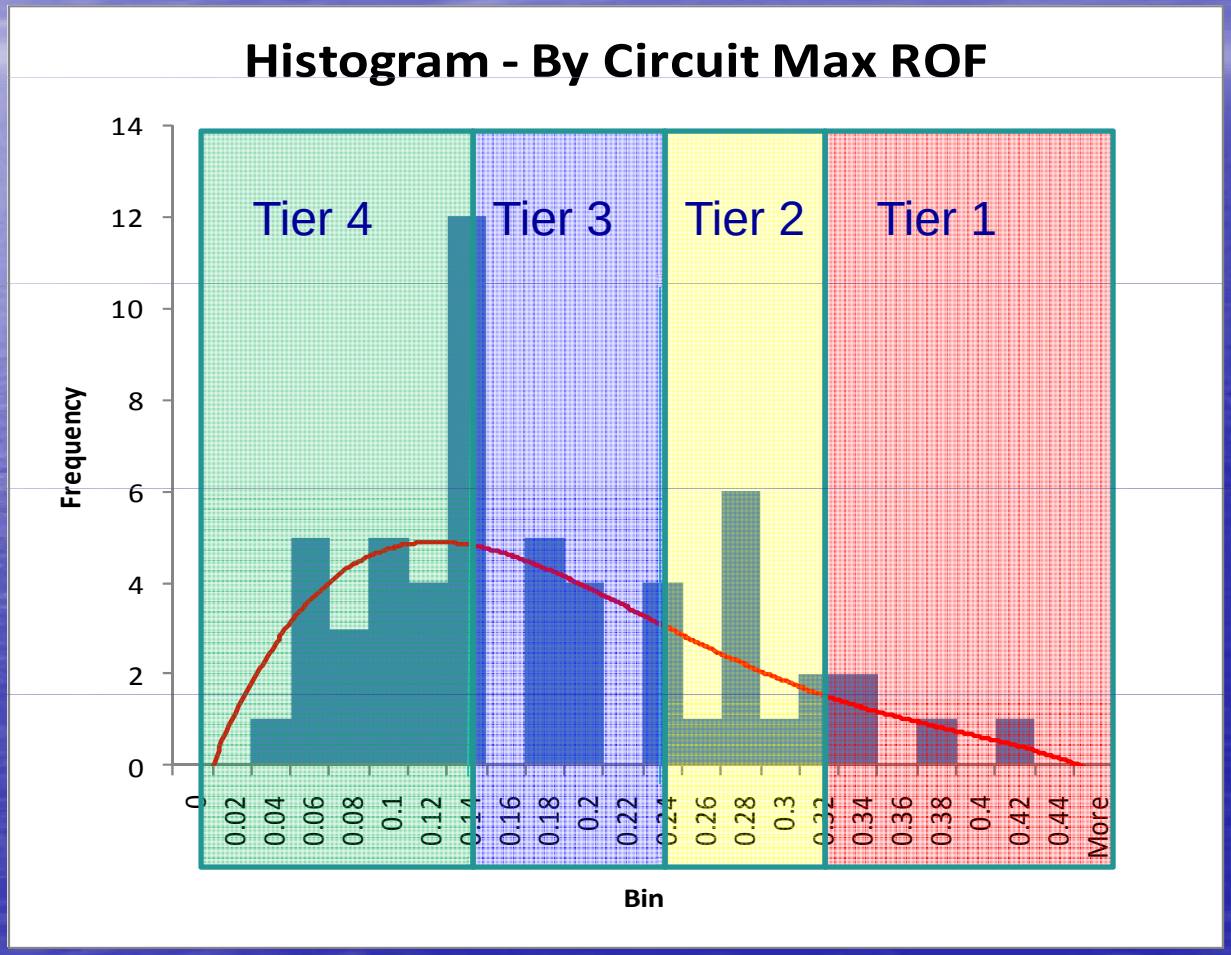
Tier Determination Methodology

- Suggest Tiers Based on Statistical Measures:
  - Tier 1 → > Median + 2 Std. Dev.(σ)
  - Tier 2 → > Median + 1*σ < Median + 2*σ
  - Tier 3 → > Median < Median + 1*σ
  - Tier 4 → < Median

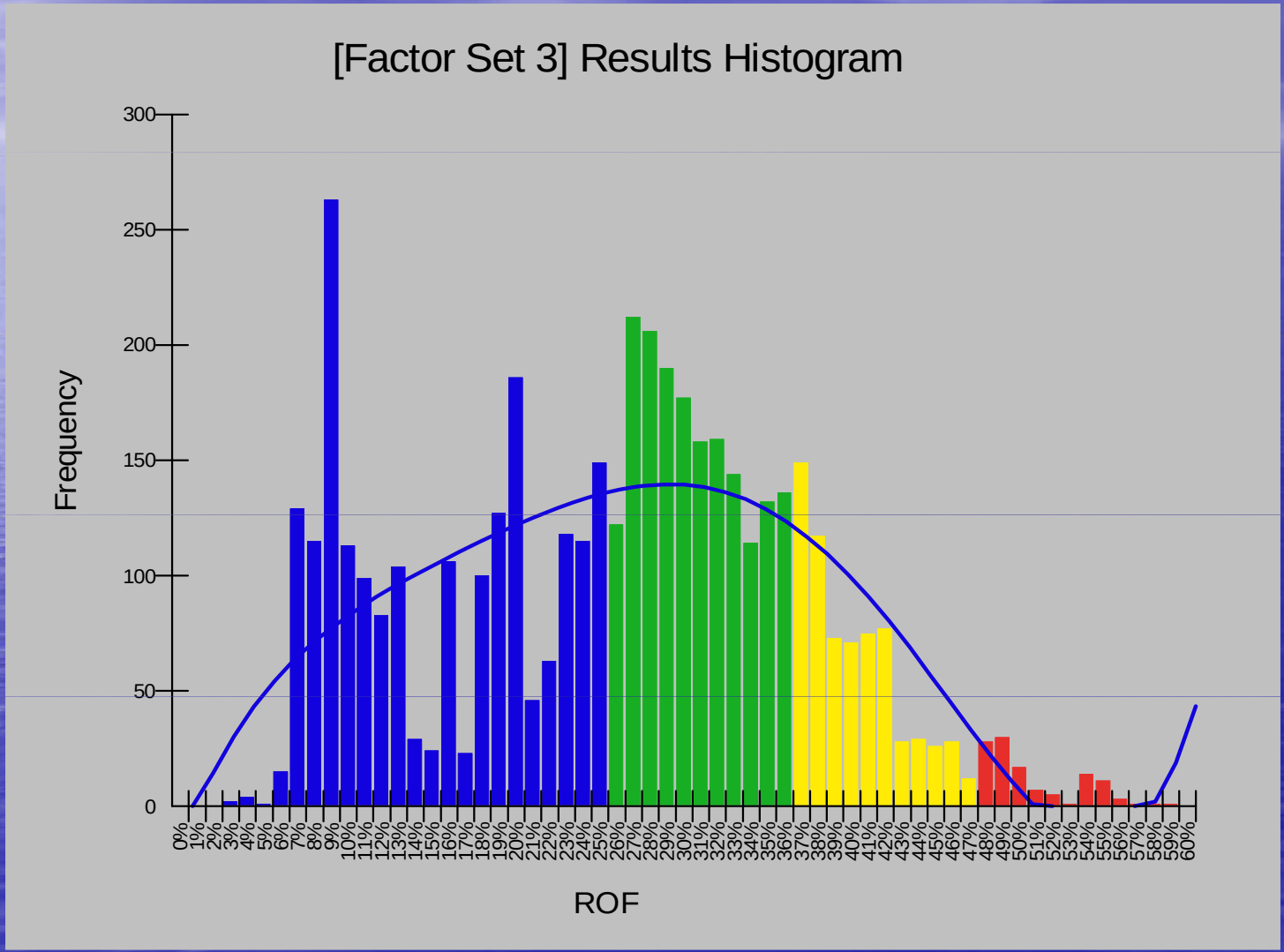
Ranking Matrix



Suggested Tier Determination



Component ROF Histogram



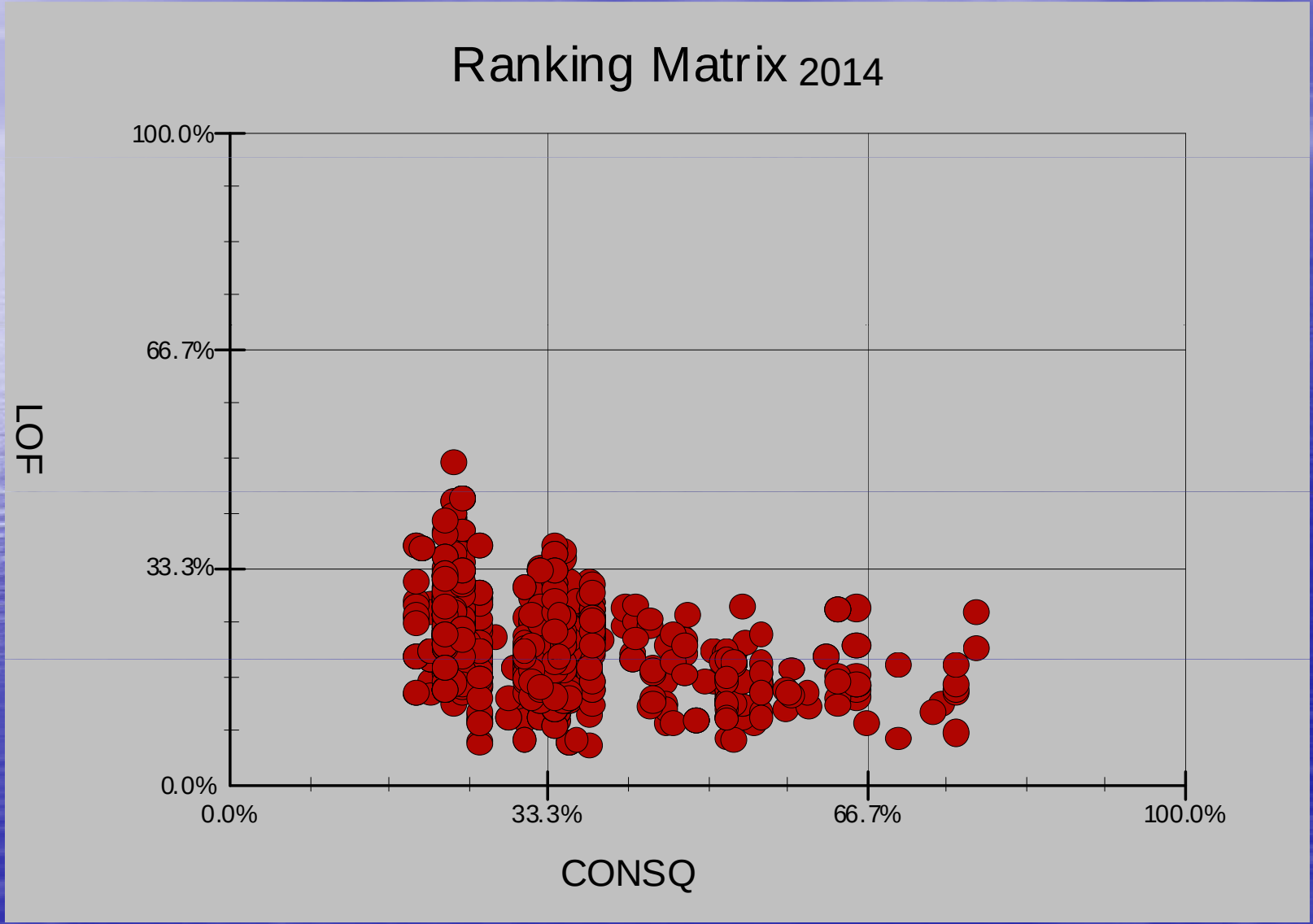
Prevention & Mitigation Plan

Inspection Criteria by Circuit			
TIER	Inspection	ROF Criteria	Frequency
1	100%	> Med + 1SD	Annual
2	100%	> Median	2 Year
3	50%	> Median	3 Year
4	25%	< Median	5 Year

- Reduce Risk of Failure by implementing mitigation strategies.
- Base number of P&MMs on risk metrics and criticality (Tier group 1, 2, 3, or 4).
- All Tiers will have some suggested P&MMs.
- Additional Prevention and Mitigation Measures?

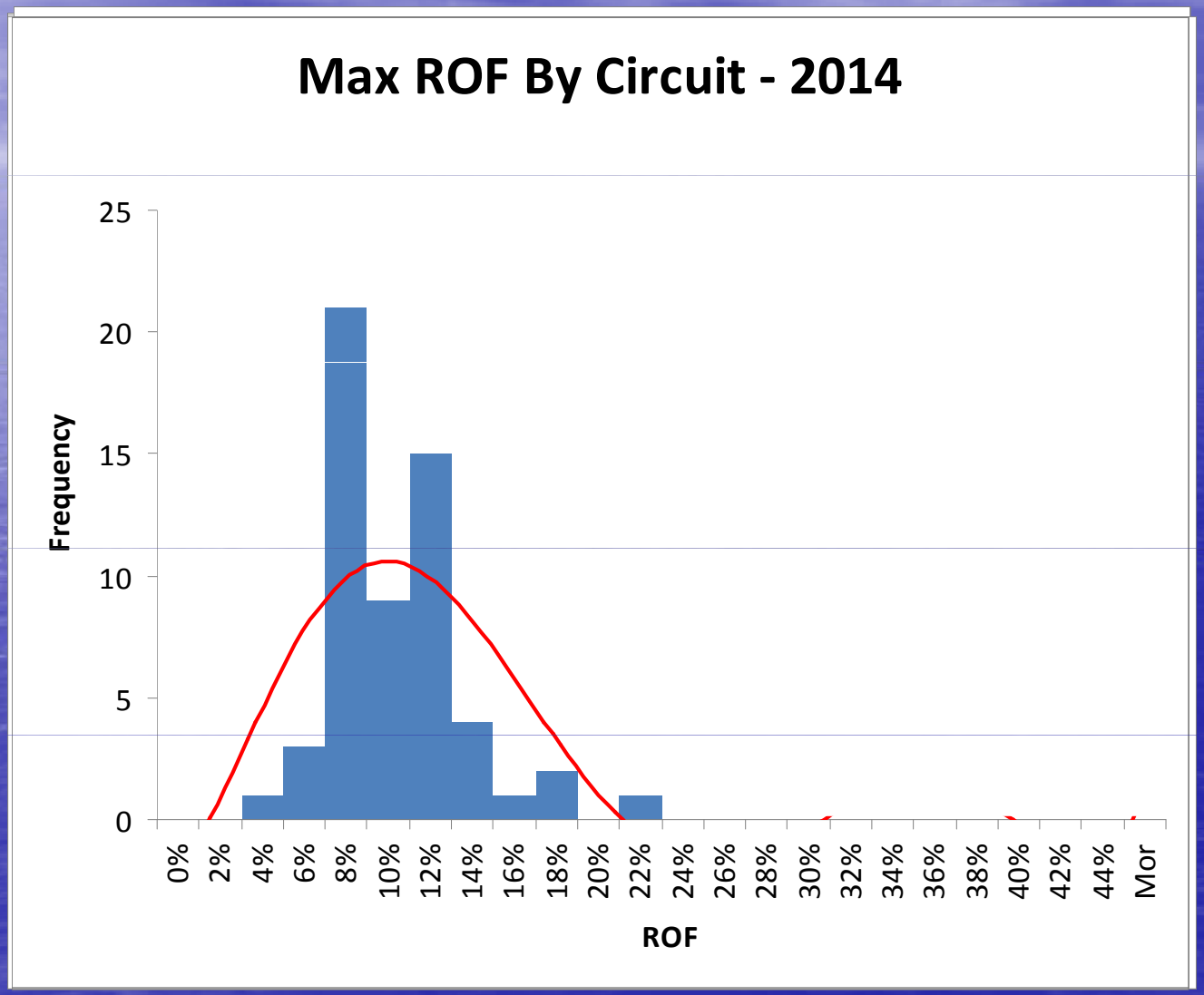
Change in Risk over time (5 yr)

Ranking Matrix



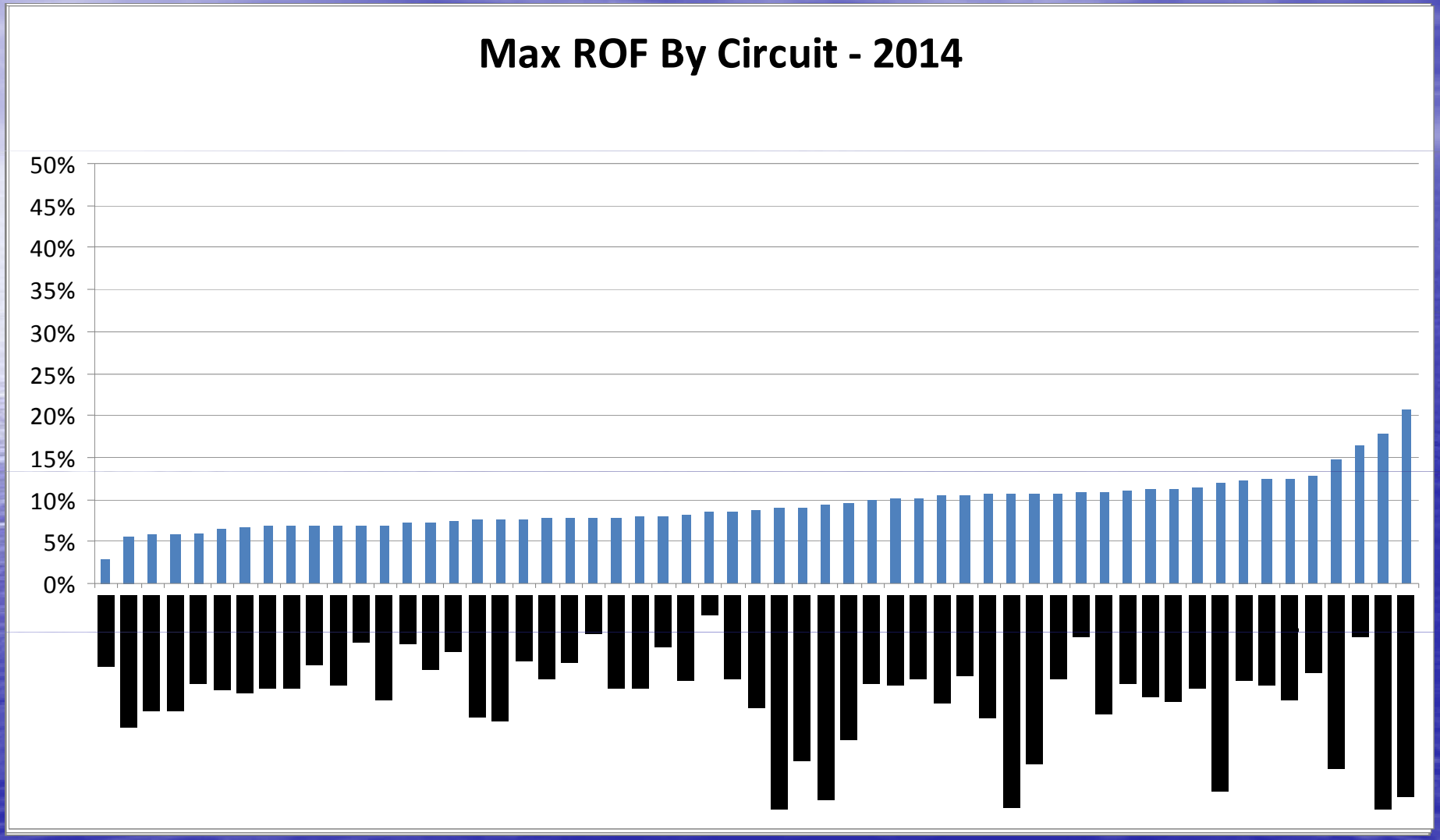
Change in Risk over time (5 yr)

Histogram



Change in Risk over time (5 yr)

Max ROF By Circuit



Up Front Planning (new or updated)

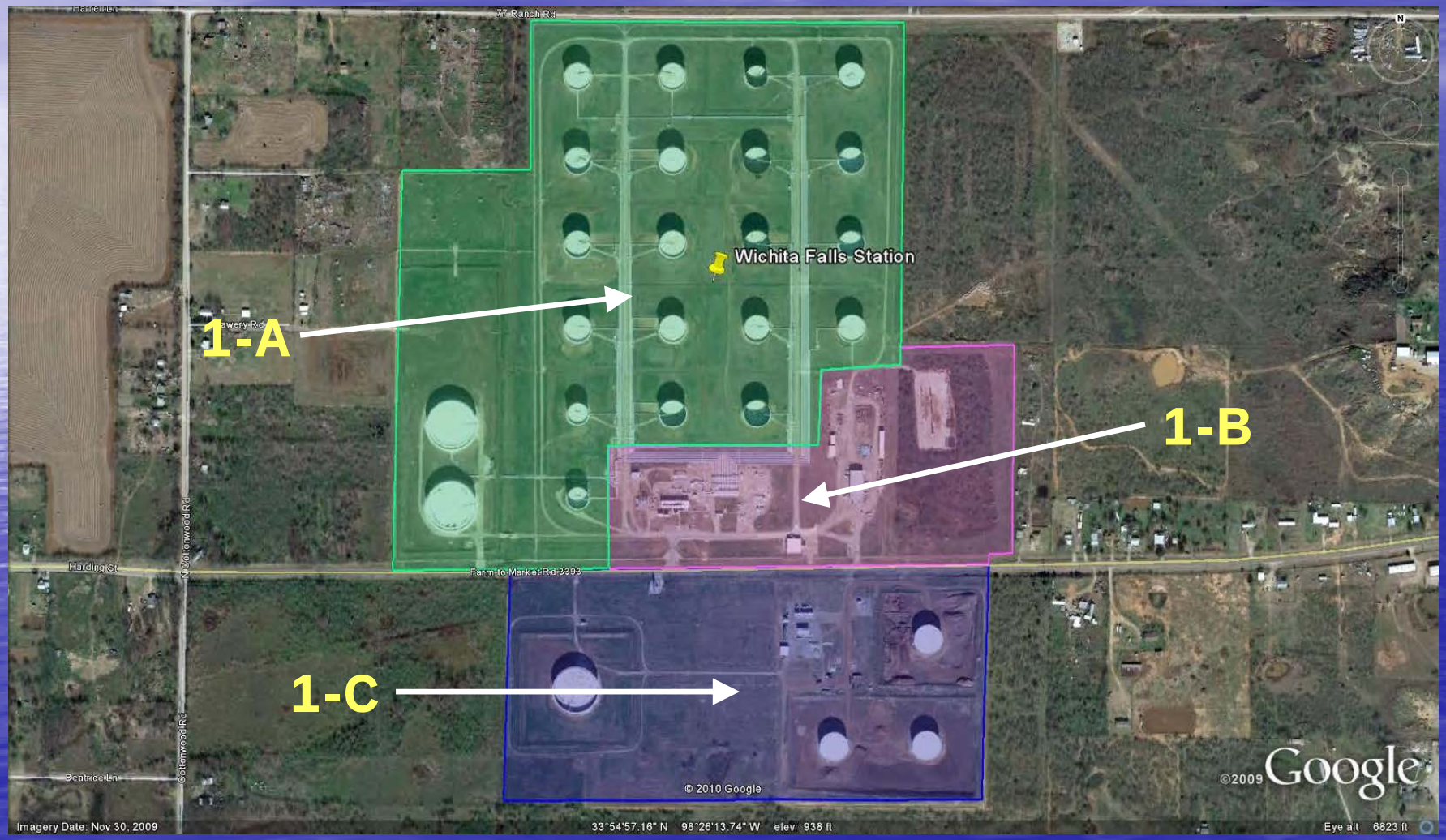
- What are the anticipated threats?
- How will the mechanical integrity be managed?
  - Assessment methods?
  - Preventive & Mitigative Measures?
- How does the facility design impact the ability to assess the asset?
- What level will risk results be calculated?
  - Facility A vs. B?
  - Equipment circuit C vs. D?
  - Pipe E vs. F?

The “Component”

- Lowest level at which ROF will be calculated.
- Level at which data will be managed
- Think of it as “dynamic segmentation” for non-stationed assets
- Multiple components can be aggregated for risk analysis.

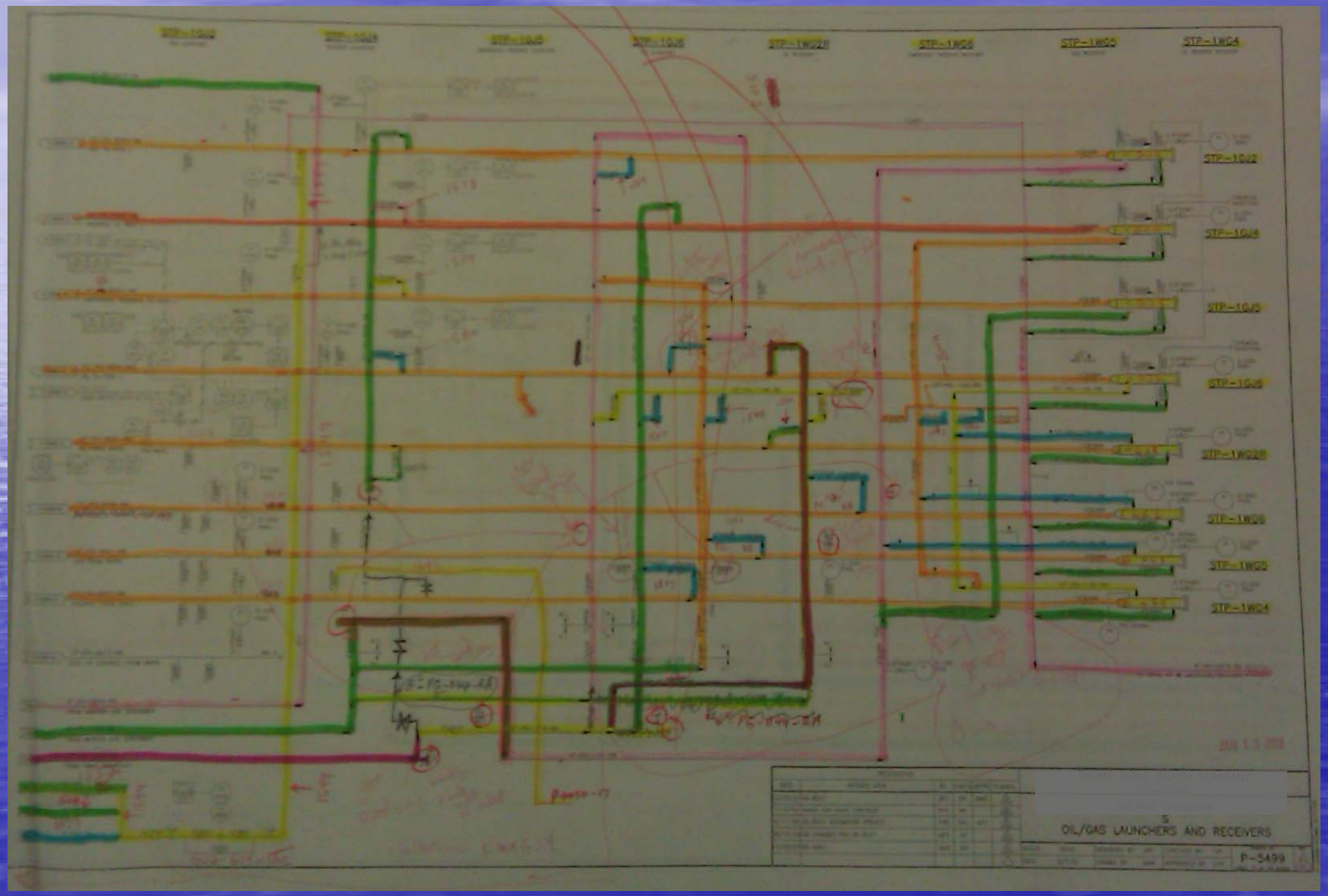
Station Facilities – Whole or Partial

Station Facilities – Tank Farm vs. Refinery or Pump Station



Identify Components

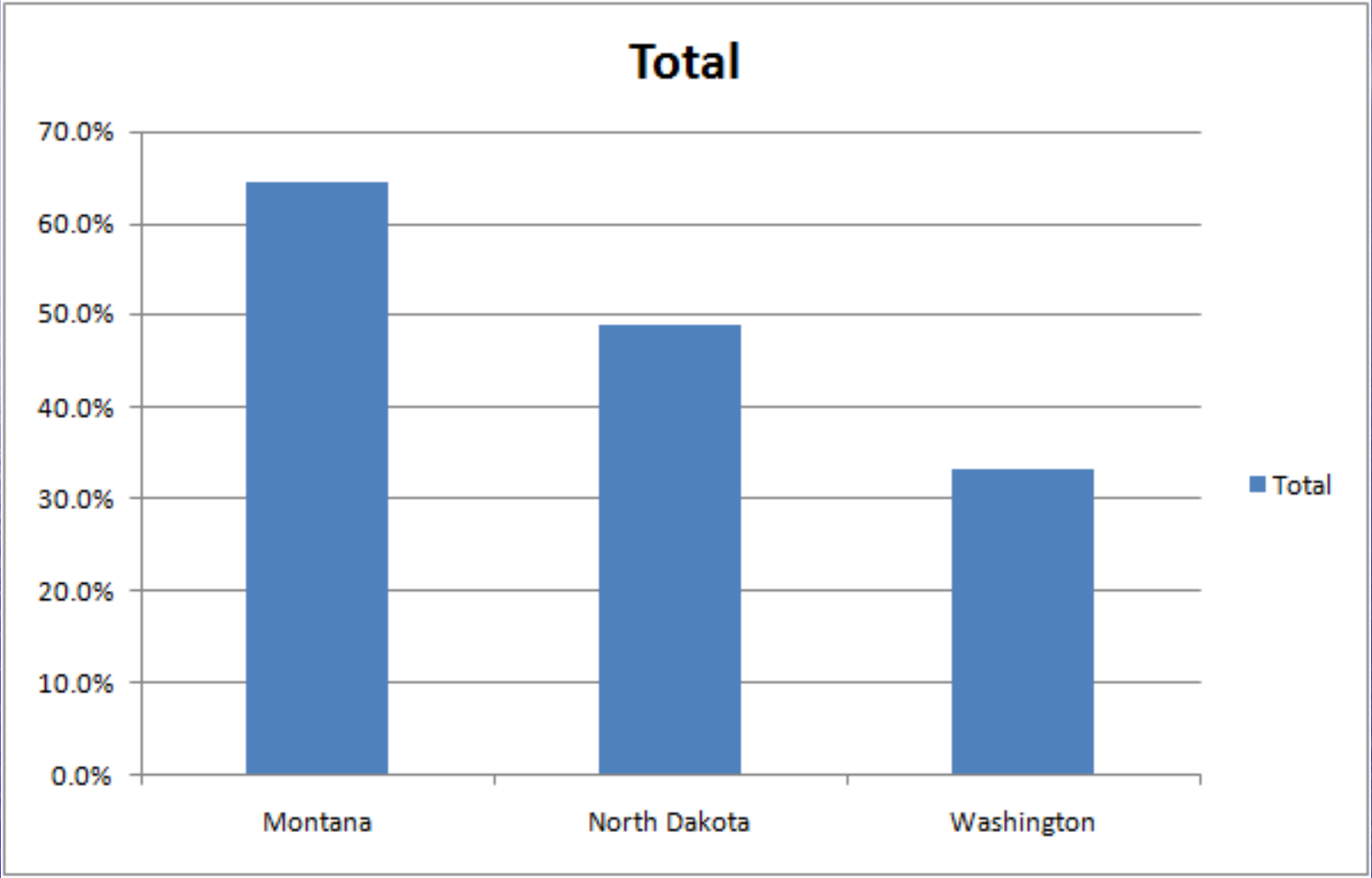
Grouping by function



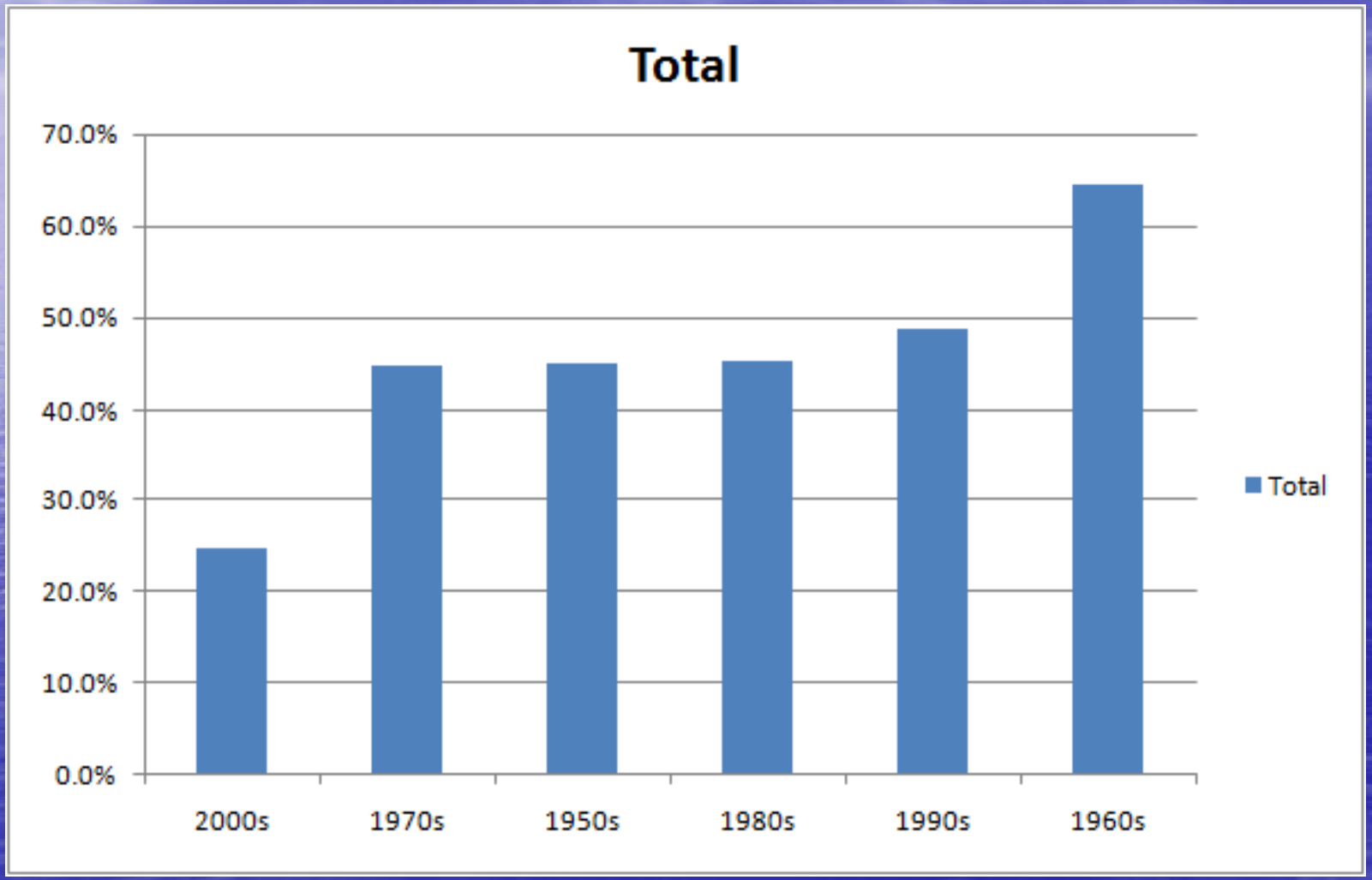
Identify Components – Piping Systems, AST Model, Rotating Equipment & Pressure Vessels

Alternate Risk Analysis: Facilities Systems – (1) Piping Systems, (2) AST Model, (3) Rotating Equipment & (4) Pressure Vessels. Phased approach to implementation: Station Facilities to Facility Systems.

Component Details



Component Details



APPENDIX O

PIPELINE RISK ASSESSMENT: THE ESSENTIAL ELEMENTS

Pipeline Risk Assessment: The Essential Elements

Sept 2013

MANAGING RISK

Bellingham, WA 1999

Appomattox, VA 2008

San Bruno, CA 2010

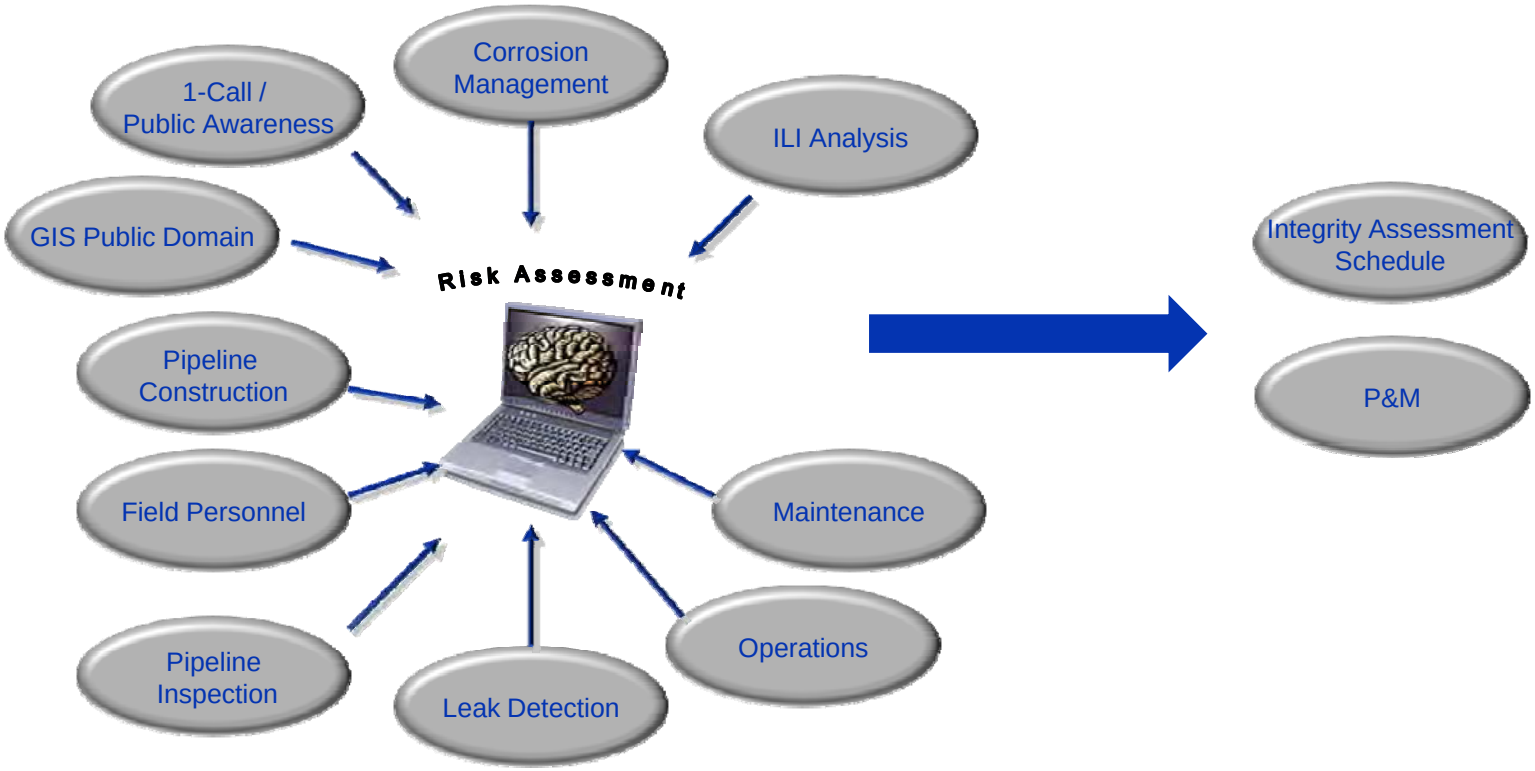
Kalamazoo River, MI 2010

Carlsbad, NM 2000

Mayflower, AR 2013

Background

RA is the Centerpiece of IMP



PL RA Methodologies

Qualitative
Quantitative
Semi-quantitative

ASME B31.8s
- Subject Matter Experts
- Relative Assessments
- Scenario Assessments
- Probabilistic Assessments

Probabilistic
Mechanistic
Deterministic

QRA
PRA
Indexing
Scoring

	Index/Score
depth cover	shallow = 8 pts
wrinkle bend	yes = 6 pts
coating condition	fair = 3 pts
soil	moderate = 4 pts

Hearsay

- Common Complaints:

  "We've been waiting for two years to start generating risk results we can trust"

  "We have a risk assessment, but we can't use the results for anything"

  "We purchased a sophisticated off-the-shelf solution, but we're not really sure how it calculates risk"

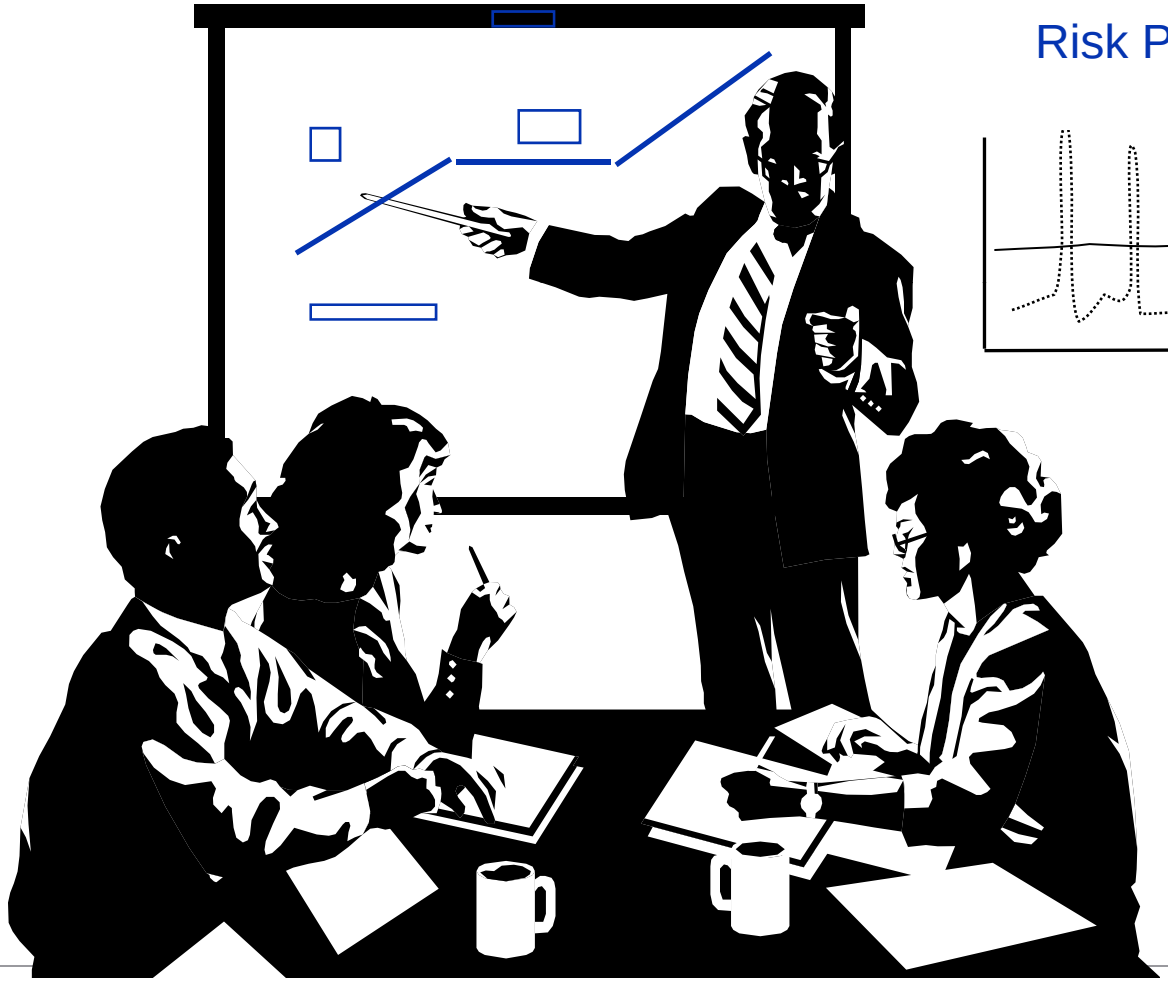
  "Our risk assessment methodology was developed internally ages ago, how do we know if it's still acceptable?"

Inspecting a Risk Assessment

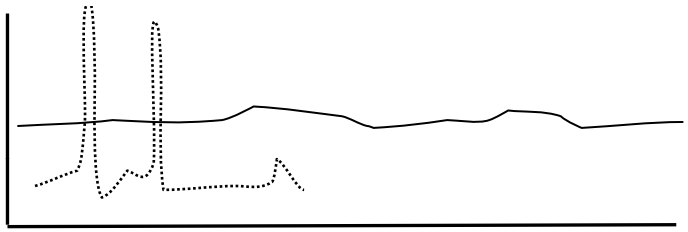
Judging a Risk Assessment

- “Technically justifiable . . .”
- “Logical, structured, and documented….”
- “Assurance of completeness…”
- “…incorporates sufficient resolution…”
- “Appropriate application of risk factors….”
- “Explicitly accounts for…” and combines PoF and CoF factors
- “Process to validate results…”
- P&M based on risk analyses

Passing the ‘Map Point’ Test



Risk Profiles



IMP Objectives vs RA Techniques

Objectives

(a) prioritization of pipelines/segments for scheduling integrity assessments and mitigating action

(b) assessment of the benefits derived from mitigating action

(c) determination of the most effective mitigation measures for the identified threats

(d) assessment of the integrity impact from modified inspection intervals

(e) assessment of the use of or need for alternative inspection methodologies

(f) more effective resource allocation

Techniques

- ~~Subject Matter Experts~~
- ~~Relative Assessments~~
- ~~Scenario Assessments~~
- Probabilistic Assessments

Numbers Needed

- Failure rate estimates for each threat on each PL segment
- Mitigation effectiveness for each contemplated measure
- Time to Failure (TTF) estimates *(time-dep threats)*

PHMSA Concerns

U.S. Department of Transportation
Pipeline and Hazardous Materials
Safety Administration

Inspections Identify Weaknesses in Risk Analysis

- Current challenge is for industry to develop
  - More rigorous quantitative risk analyses
  - More investigative approach
  - Engineering critical assessment
  - Robust approach for P&M measures
    - Technically sound risk-based criteria

U.S. Department of Transportation
Pipeline and Hazardous Materials
Safety Administration

Recent Events Illustrate Weaknesses in Risk Analysis

- Effective risk analysis might have prevented or mitigated recent high consequence accidents
- Weaknesses include inadequate:
  - Knowledge of pipeline risk characteristics
  - Processes to analyze interactive threats
  - Evaluation of way to reduce or mitigate consequences
  - Process to select P&M measures
    - Lack of objective, systematic approach

U.S. Department of Transportation
Pipeline and Hazardous Materials
Safety Administration

Limitations of Simple Index Models

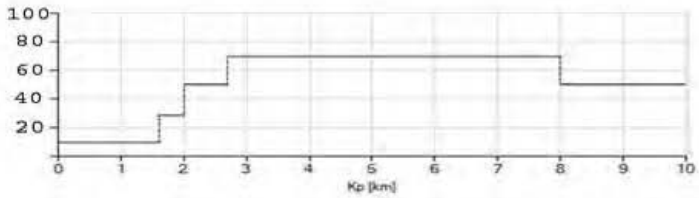
- Ineffective analysis of complex risk factor interactions
- Output not useful for identifying previously unrecognized threats/risks
- Not proven as adequate basis for evaluating P&M measures
- Poor capability to identify risk drivers
- Uncertainties (due to quantifying risk scores based on opinion) are not appropriately considered

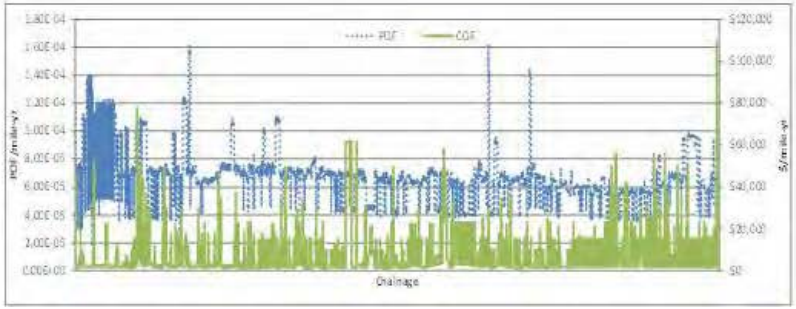
U.S. Department of Transportation
Pipeline and Hazardous Materials
Safety Administration

PHMSA Risk Assessment Concerns

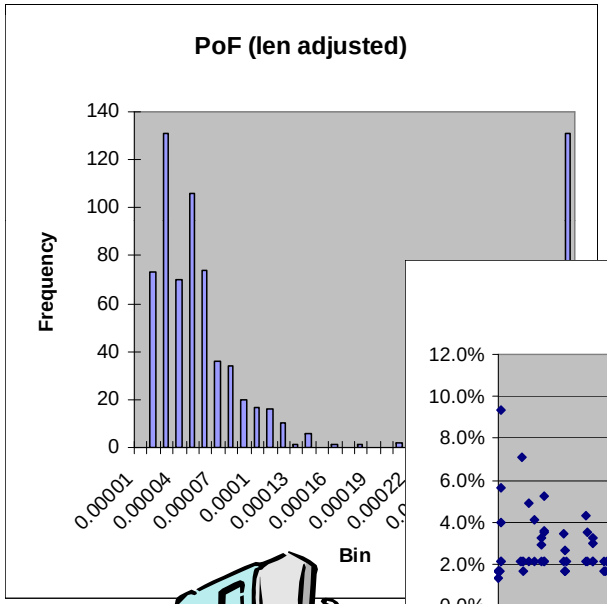
- Weaknesses of Simple Relative Index Models
- Records (Availability and Quality of Data)
- Data Integration
- Interacting Threats
- Vintage/Legacy Pipe
- Connection to Real Decision-Making
- Uncertainties

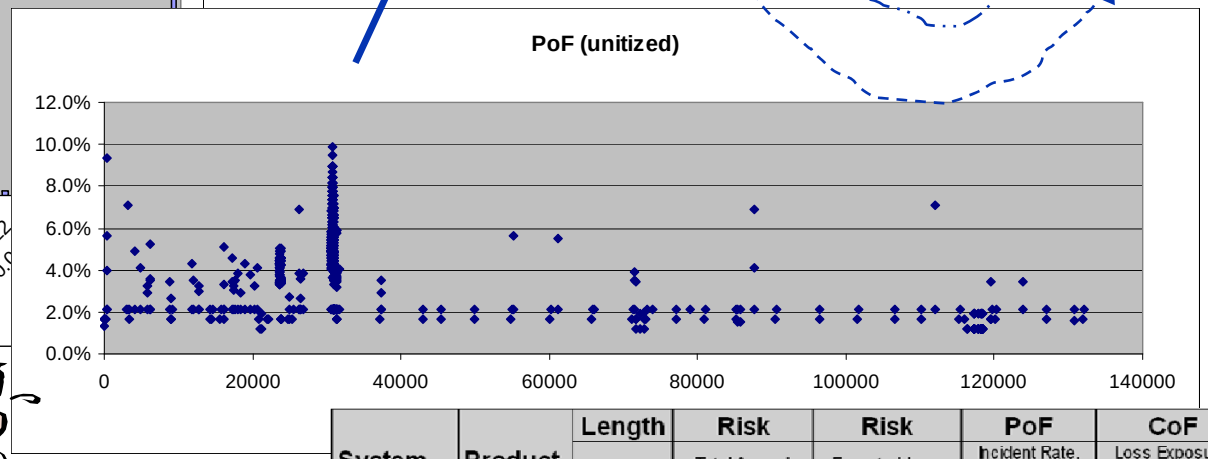
Risk Assessment Maturity

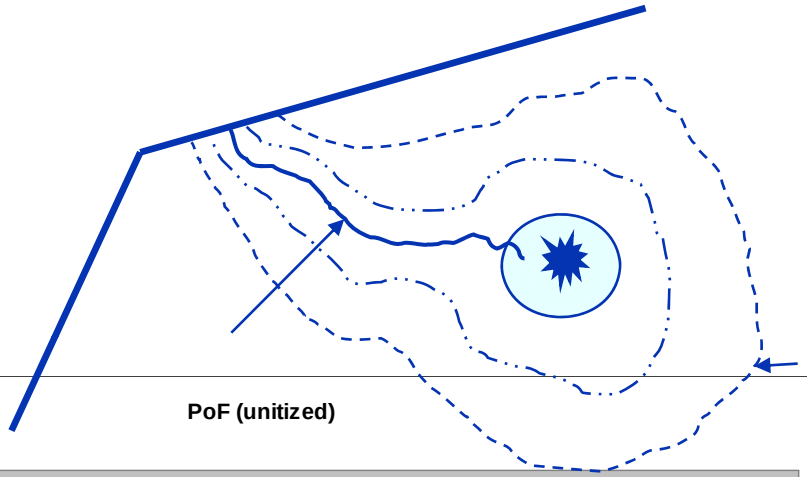


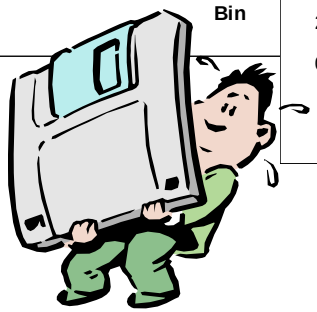


Modern Pipeline Risk Assessment









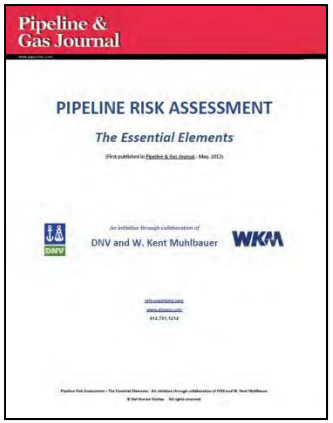
System	Product	Length	Risk	Risk	PoF	CoF
		miles	Total Annual Exposure	Expected Loss $/mi-yr	Incident Rate, failures per mi-yr	Loss Exposure, Probability-weighted $/failure
Elvira	gasoline	120	$ 142,080	$ 1,184	0.001	$ 1,184,000
Scaramonga	crude oil	408	$ 342,720	$ 840	0.0015	$ 560,000
Perseus	natural gas	23	$ 33,810	$ 1,470	0.007	$ 210,000

Essential Elements

Essential Elements

- The Essential Elements are meant to
  - Be common sense ingredients that make risk assessment meaningful, objective, and acceptable to all stakeholders
  - Be concise yet flexible, allowing tailored solutions to situation-specific concerns
  - Avoid need for ‘one-size fits all’ mandates
  - Lead to *smarter risk assessment*

- The elements are meant to supplement, not replace, guidance, recommended practice, and regulations already in place


Pipeline & Gas Journal

PIPELINE RISK ASSESSMENT

The Essential Elements

DNV and W. Kent Muhlbauer

The Essential Elements

Measurements in Verifiable Units

Proper Probability of Failure Assessment

Characterization of Potential Consequences

Full Integration of Pipeline Knowledge

Sufficient Granularity

Bias Management

Profiles of Risk

Proper Aggregation

Measure in Verifiable Units

- Must include a definition of “Failure”
- Must produce *verifiable* estimates of PoF and CoF in commonly used measurement units
- PoF must capture effects of length and time
- Must be free from intermediate schemes (scoring, point assignments, etc)

“Measure in verifiable units” keeps the process transparent by expressing risk elements in understandable terms that can be calibrated to reality

Absolute Risk Values

Measure in Verifiable Units

Frequency of consequence

- Temporally
- Spatially

•Incidents per mile-year

•fatalities per mile-year

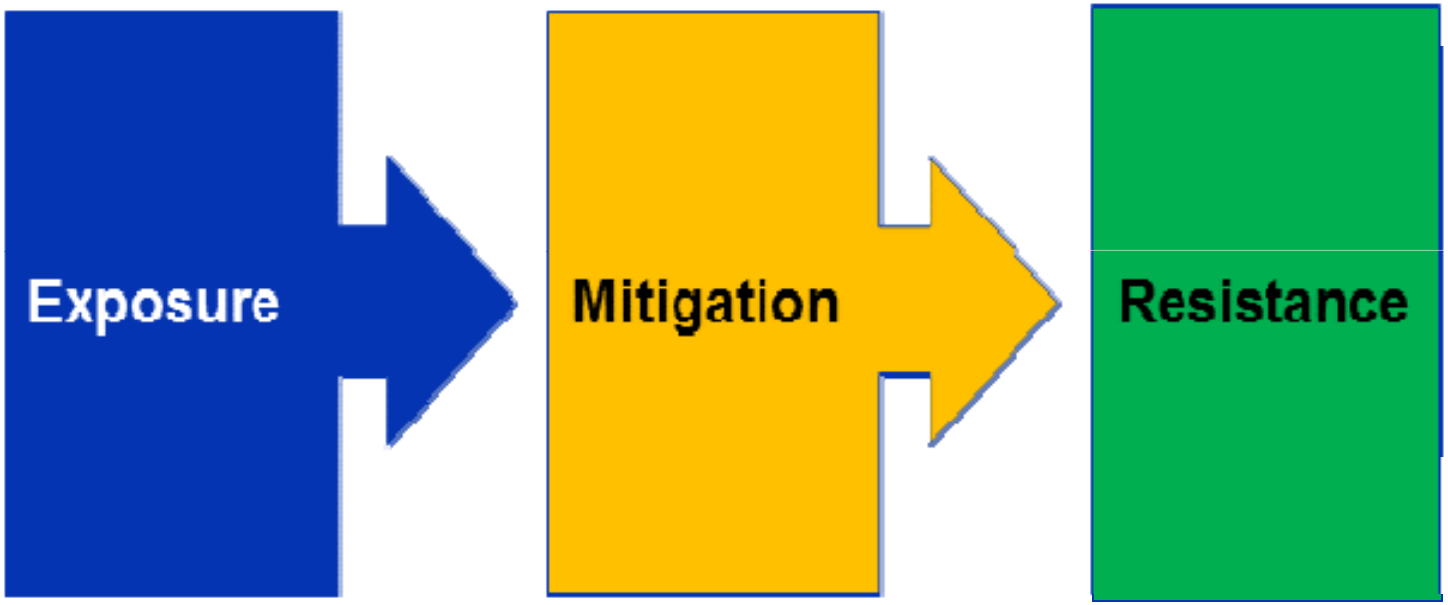
•dollars per km-decade

conseq prob

Probability of Failure Grounded in Engineering Principles

- All plausible failure mechanisms must be included in the assessment of PoF
- Each failure mechanism must have the following elements independently measured:
  - Exposure
  - Mitigation
  - Resistance
- For each time dependent failure mechanism, a theoretical remaining life estimate must be produced

PoF: Critical Aspects



Probability of Damage or Failure—Simple Math

- Probability of Damage (PoD) = exposure x (1 - mitigation)

- Probability of Failure (PoF) = PoD x (1- resistance)

  {PoF = exposure x (1 - mitigation) x (1 - resistance)}

- PoF (time-dependent) = 1 / TTF

  = exposure * (1 – mitigation) / resistance *(example only)*

Exposure
Mitigation } PoD
Resistance } PoF

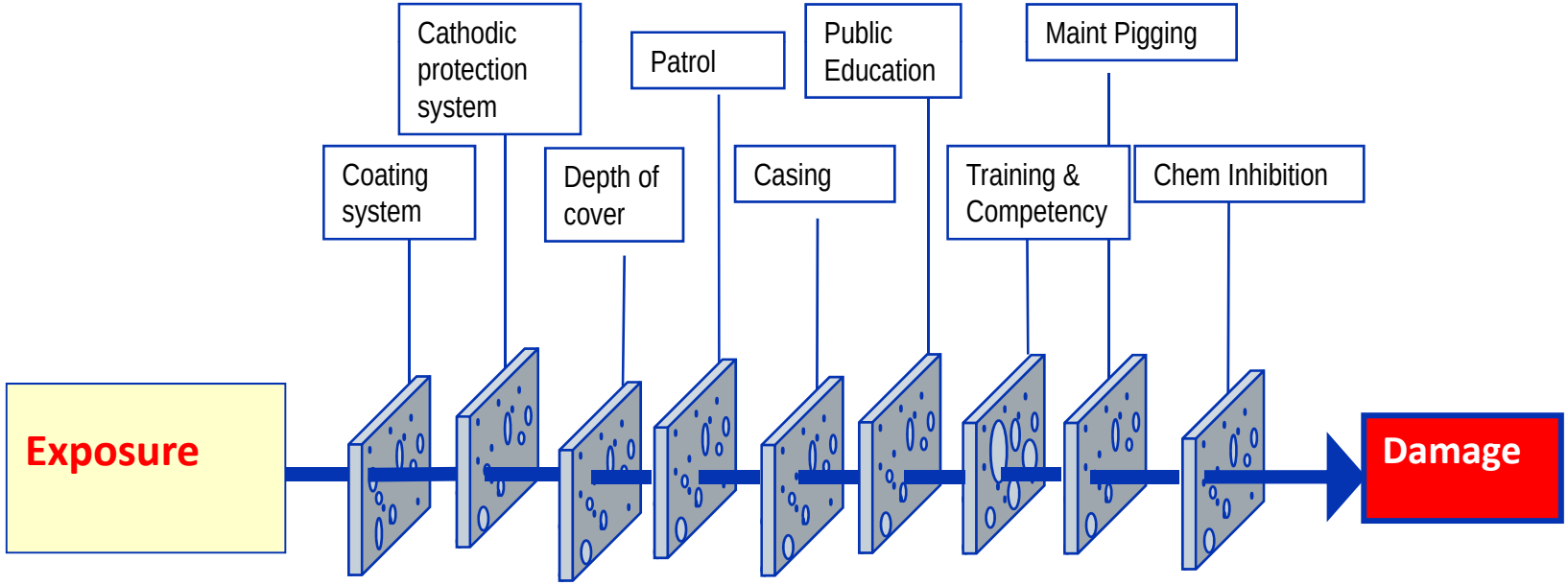
Estimating Threat Exposure

Probability of Failure Grounded in Engineering Principles

- Events per mile-year (km-yr) for time independent mechanism
  - third party
  - incorrect operations
  - weather & land movements
- MPY (mm/yr) for degradation mechanisms
  - Ext corr
  - Int corr
  - Cracking (EAC / fatigue)

Estimating Mitigation Measure Effectiveness

Strong, single measure
Or
Accumulation of lesser measures



Anomaly Characterization

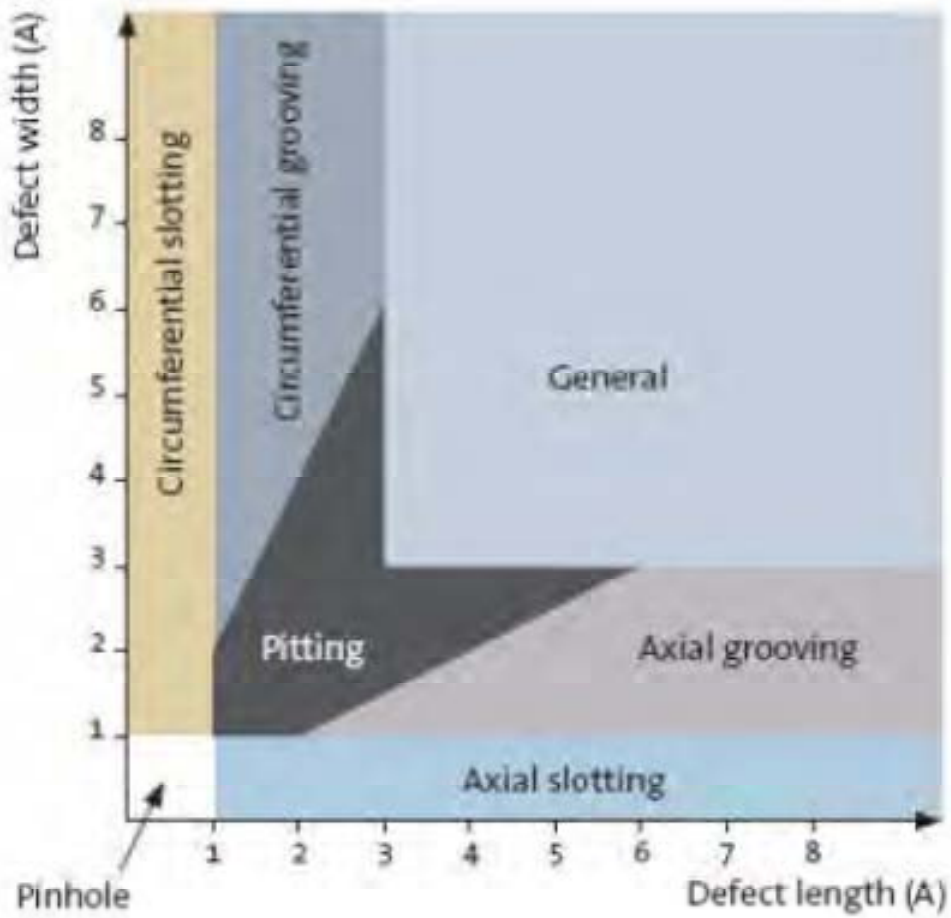


Figure 8. POF Specification graph

Pipe Resistance Issues

Probability of Failure Grounded in Engineering Principles

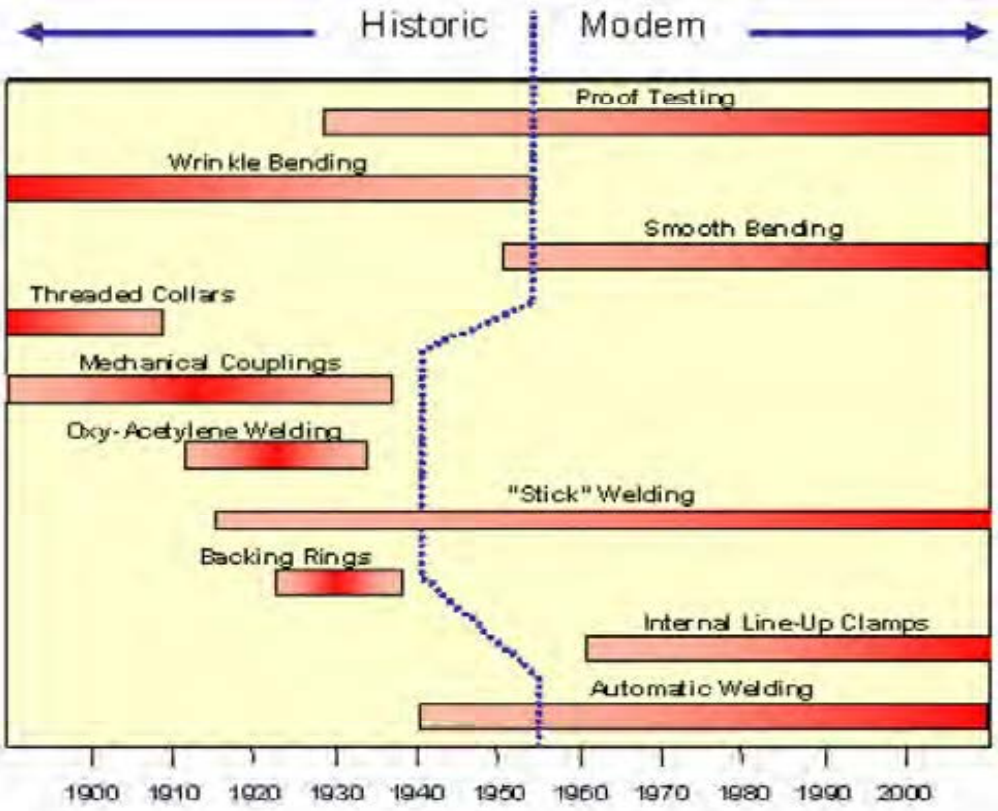
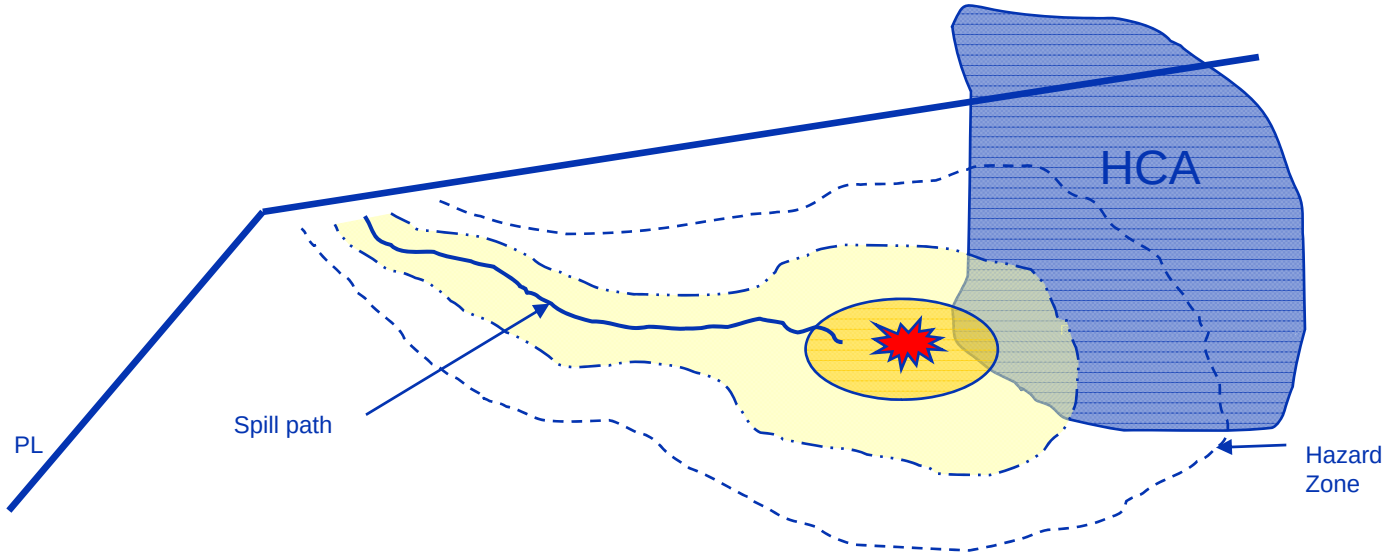


Figure G-1. Pipeline construction practices

Fully Characterize Consequence of Failure

- Must identify and acknowledge the full range of possible consequence scenarios
- Must consider ‘most probable’ and ‘worst case’ scenarios



Integrate Pipeline Knowledge

- The assessment must include complete, appropriate, and transparent use of all available information
- ‘Appropriate’ when model uses info as would an SME

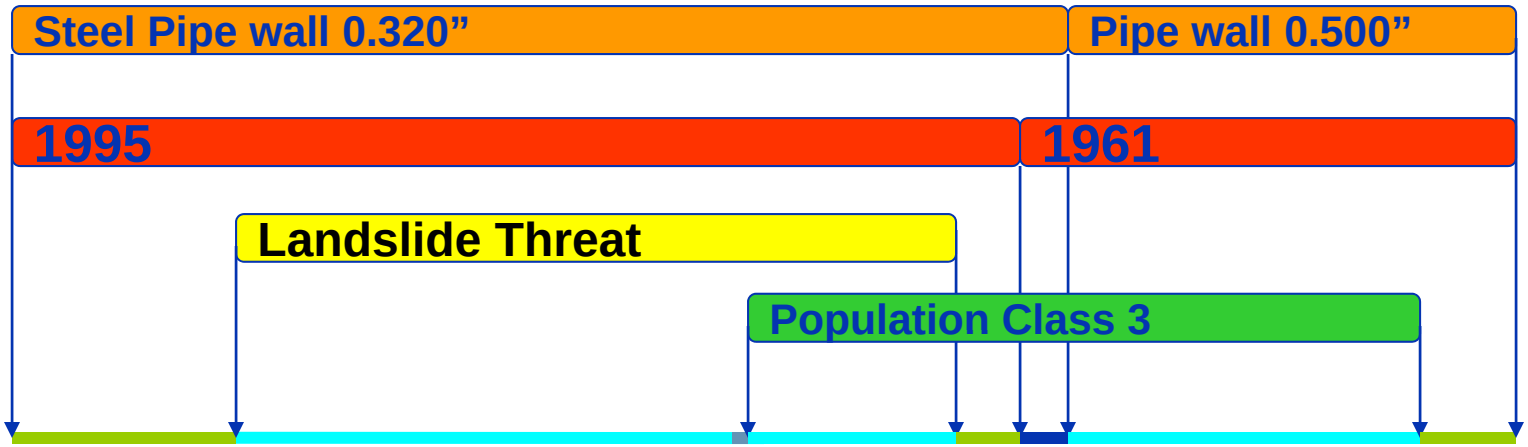
Incorporate Sufficient Granularity

- Risk assessment must divide the pipeline into segments where risks are unchanging
- Compromises involving the use of averages or extremes can significantly weaken the analysis and are to be avoided

Dynamic Segmentation

Incorporate Sufficient Granularity

Due to the numerous and constantly-varying factors effecting the risk to the pipeline, proper analysis will require at least 10-20 segments per mile*



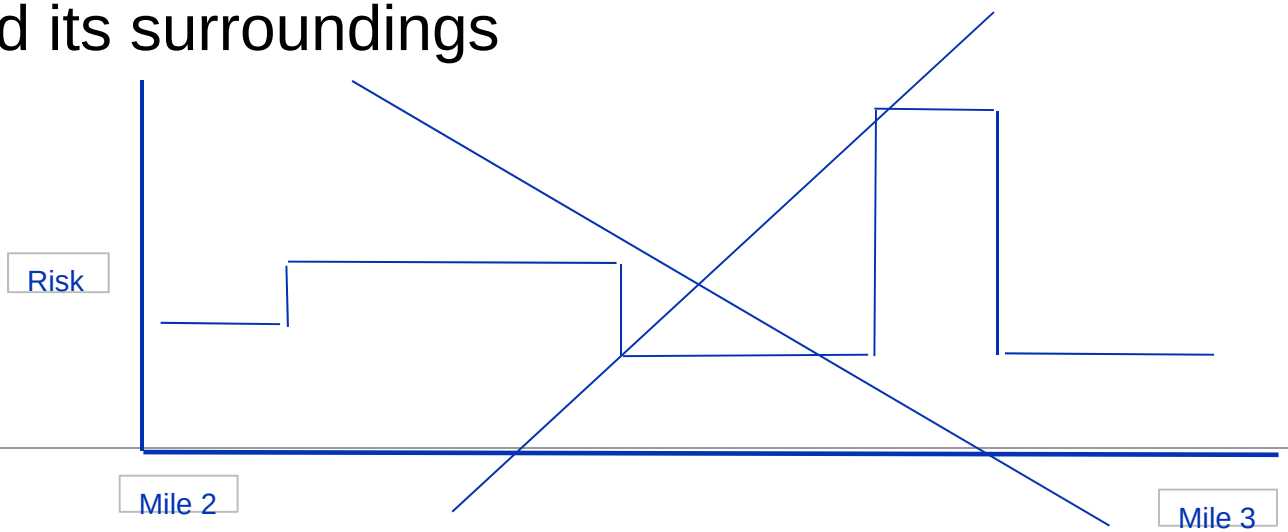
*thousands of segments per mile is not unusual today

Control the Bias

- Risk assessment must state the level of conservatism employed in all of its components
- Assessment must be free of inappropriate bias that tends to force incorrect conclusions

Profile the Risk Reality

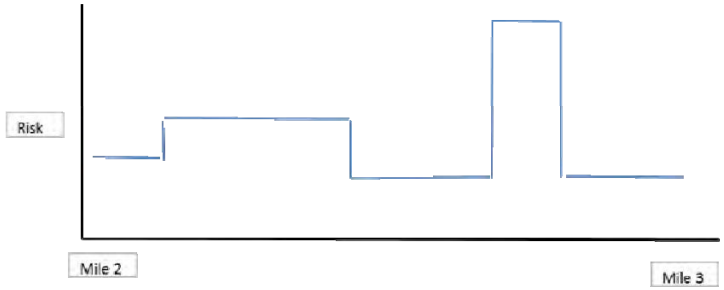
- The risk assessment must be performed at all points along the pipeline
- Must produce a continuous profile of changing risks along the entire pipeline
- Profile must reflect the changing characteristics of the pipe and its surroundings

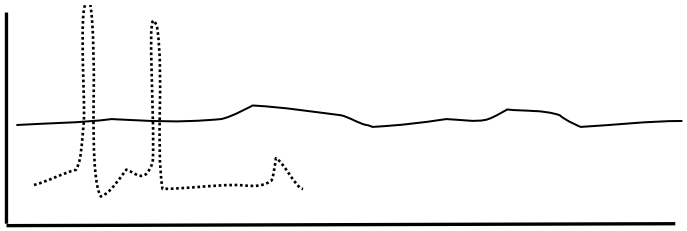


ProperAggregation

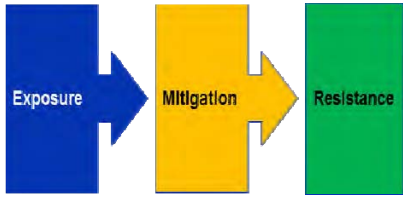
- Proper process for aggregation of the risks from multiple pipeline segments must be included
- Summarization of the risks from multiple segments must avoid simple statistics or weighted statistics that mask the actual risks

Easy to Spot (and Correct!) Methodology Weaknesses



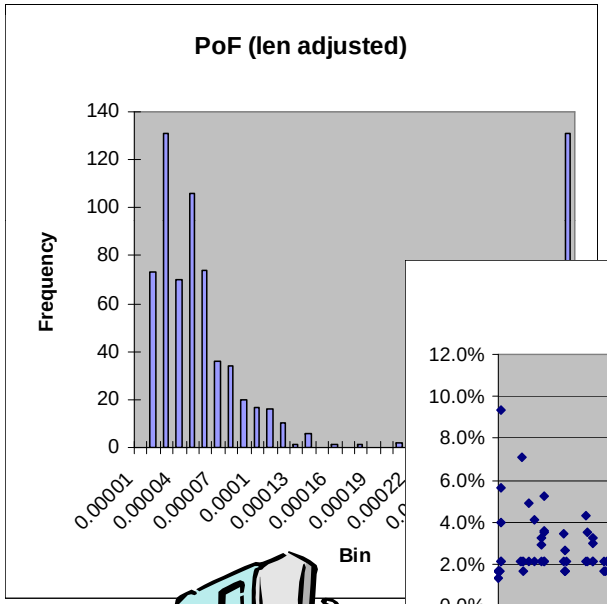


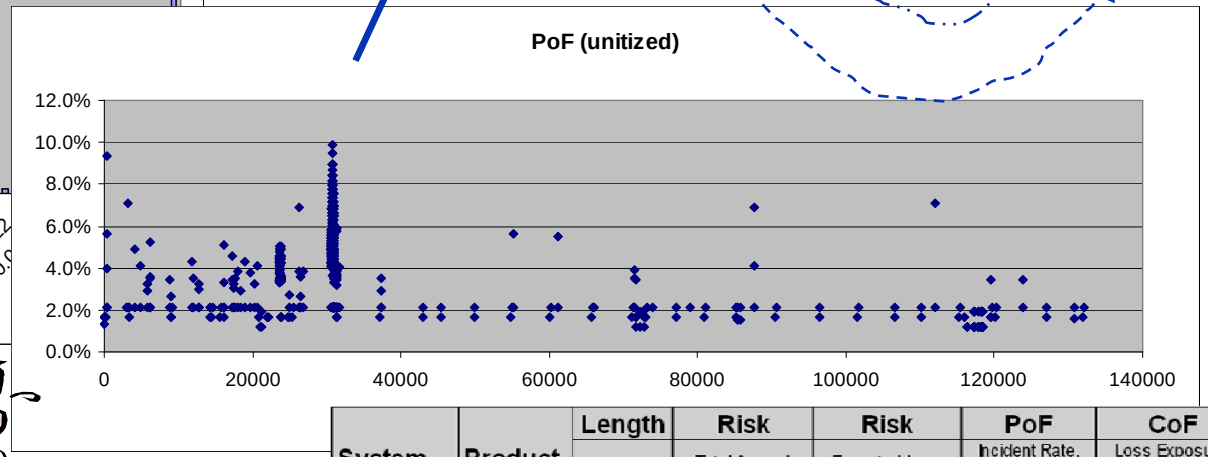
	Index/Score
depth cover	shallow = 8 pts
wrinkle bend	yes = 6 pts
coating condition	fair = 3 pts
soil	moderate = 4 pts

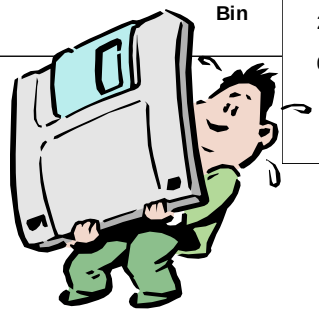


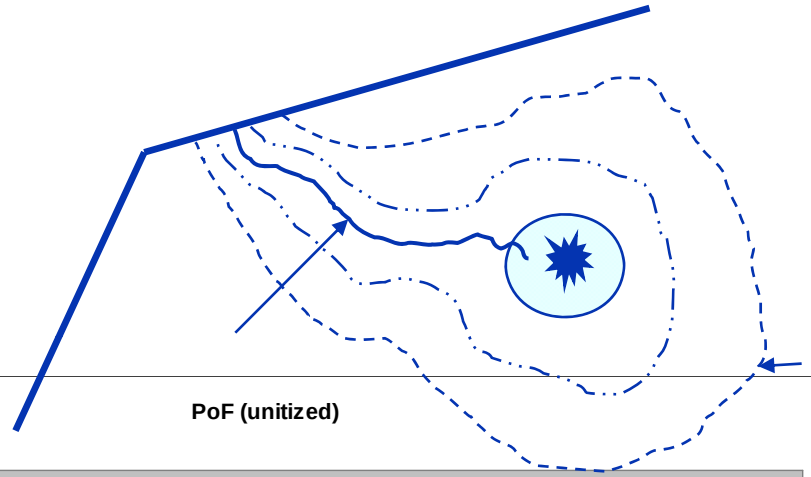
Concluding Remarks

Modern PL RA: A Critical Process









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The Essential Elements

Measurements in Verifiable Units

Proper Probability of Failure Assessment

Characterization of Potential Consequences

Full Integration of Pipeline Knowledge

Sufficient Granularity

Bias Management

Profiles of Risk

Proper Aggregation

Application of EE's—benefits realized

- Efficient and transparent risk modeling
- Accurate, verifiable, and complete results
- Improved understanding of actual risk
- Risk-based input to guide integrity decision-making: *true risk management*
- Optimized resource allocation leading to higher levels of public safety
- Appropriate level of standardization facilitating smoother regulatory audits
  - Does not stifle creativity
  - Does not dictate all aspects of the process
  - Avoids need for (high-overhead) prescriptive documentation
- Expectations of regulators, the public, and operators fulfilled

Hawthorne Effect

"Anything that is studied, improves."

Robust RA to generate enormously more useful information

Safeguarding life, property and the environment

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MANAGING RISK DNV

APPENDIX P

STRUCTURAL DESIGN

ADEC 2013 ARCTIC/COLD REGIONS OIL PIPELINE CONFERENCE

Presentation 3

STRUCTURAL DESIGN

Session 4

Aboveground Pipeline Concerns

Presented by:

Paul Wallis, PE, SE, MLSE

Baker

Structural Design of Cross-Country Pipeline Support Assemblies

Structural Design of Pipeline Support Assemblies

Cross-Country Pipeline Support Nomenclature

Principal Design Issues

Pipeline-Specific Design VS. Pipeline Support Assembly Design

Design Environment

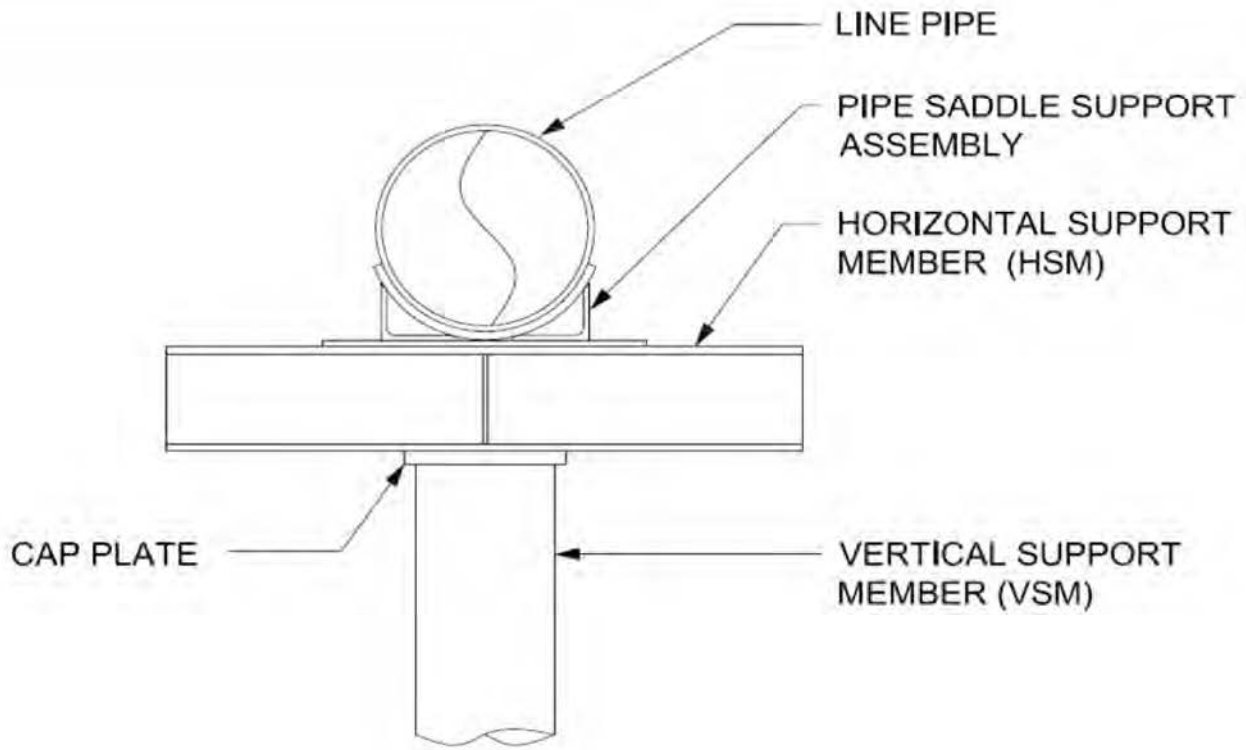
Cross-Country Pipeline Support Nomenclature

Common Industry Terminology

- Racks, Bents, Pipe Supports, Support Assemblies
- Vertical Support Members (VSM), columns, piles
- Horizontal Support Members (HSM), beams, cross-beams, cross members
- Saddles, Saddle Assemblies, Pipe Supports
- Design Depth, Install Depth, Pile Tip Depth
- Stickup Height, Top of Steel Elevation

Cross-Country Pipeline Support Nomenclature

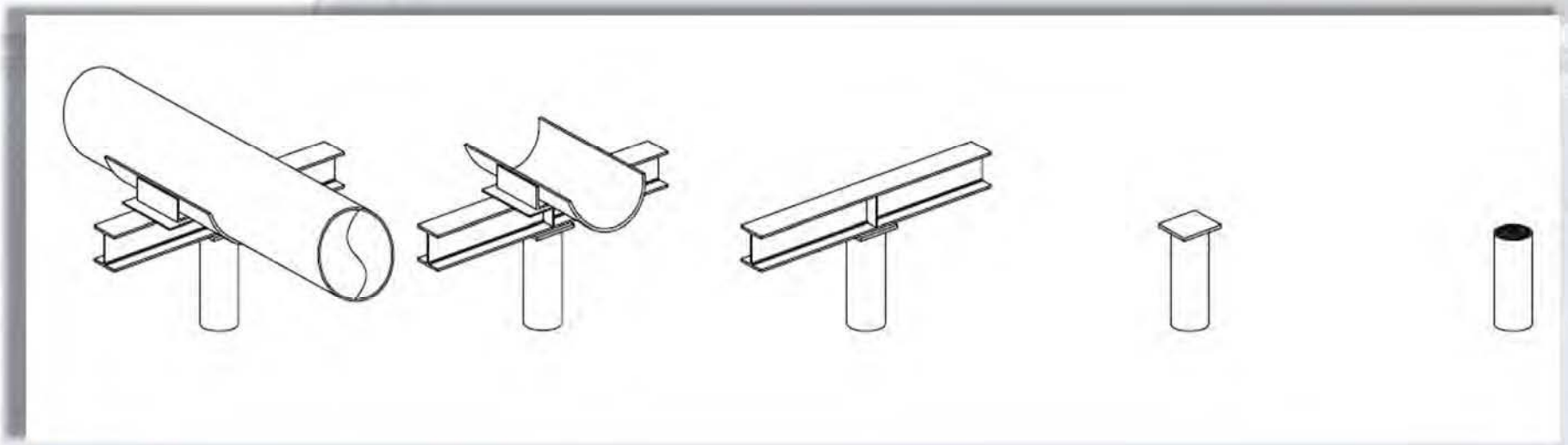
Typical Pipeline Support Assembly:



SECTION (nts)

Cross-Country Pipeline Support Nomenclature

Deconstructing a Typical Pipeline Support Assembly:



Cross-Country Pipeline Support Nomenclature

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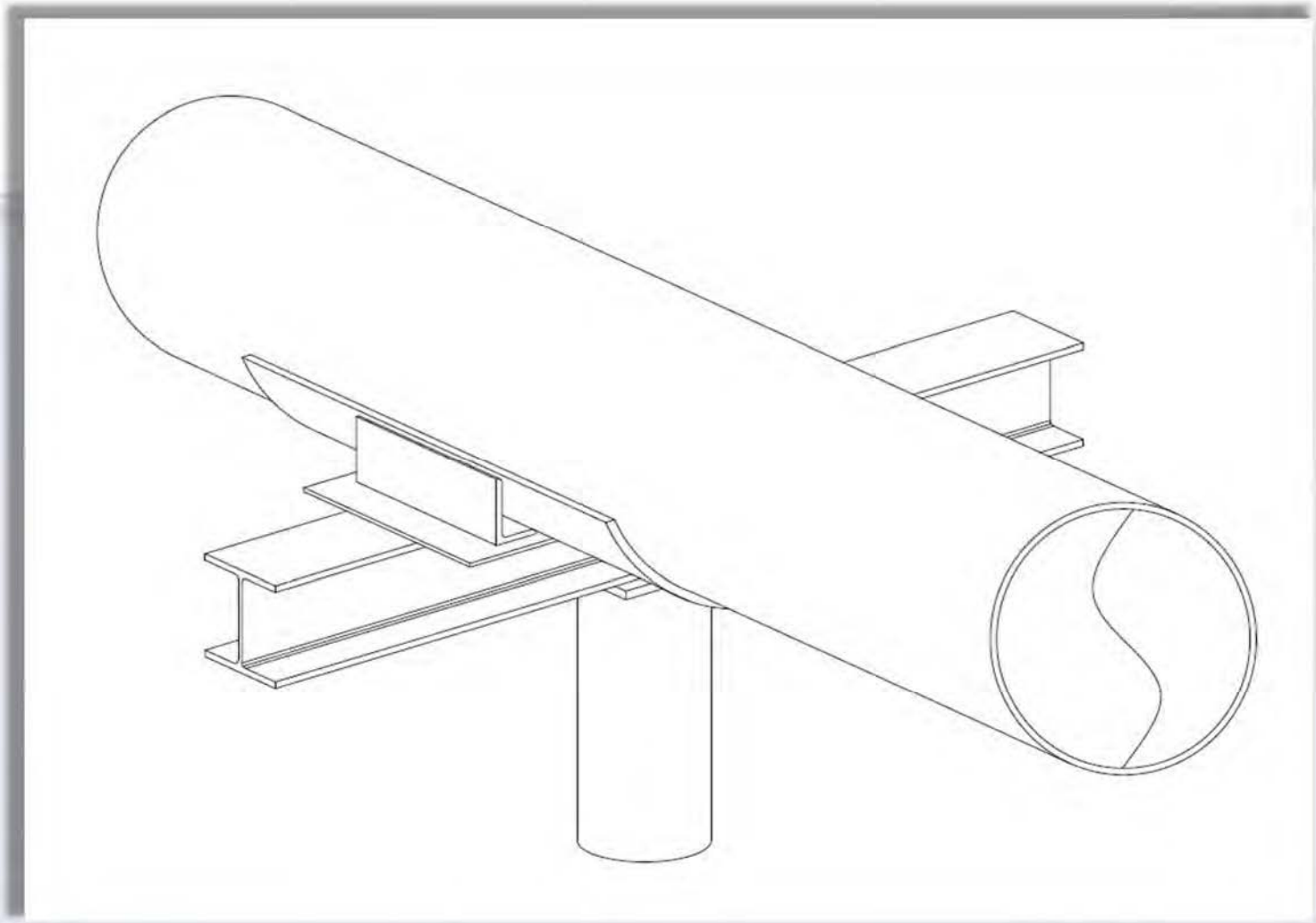

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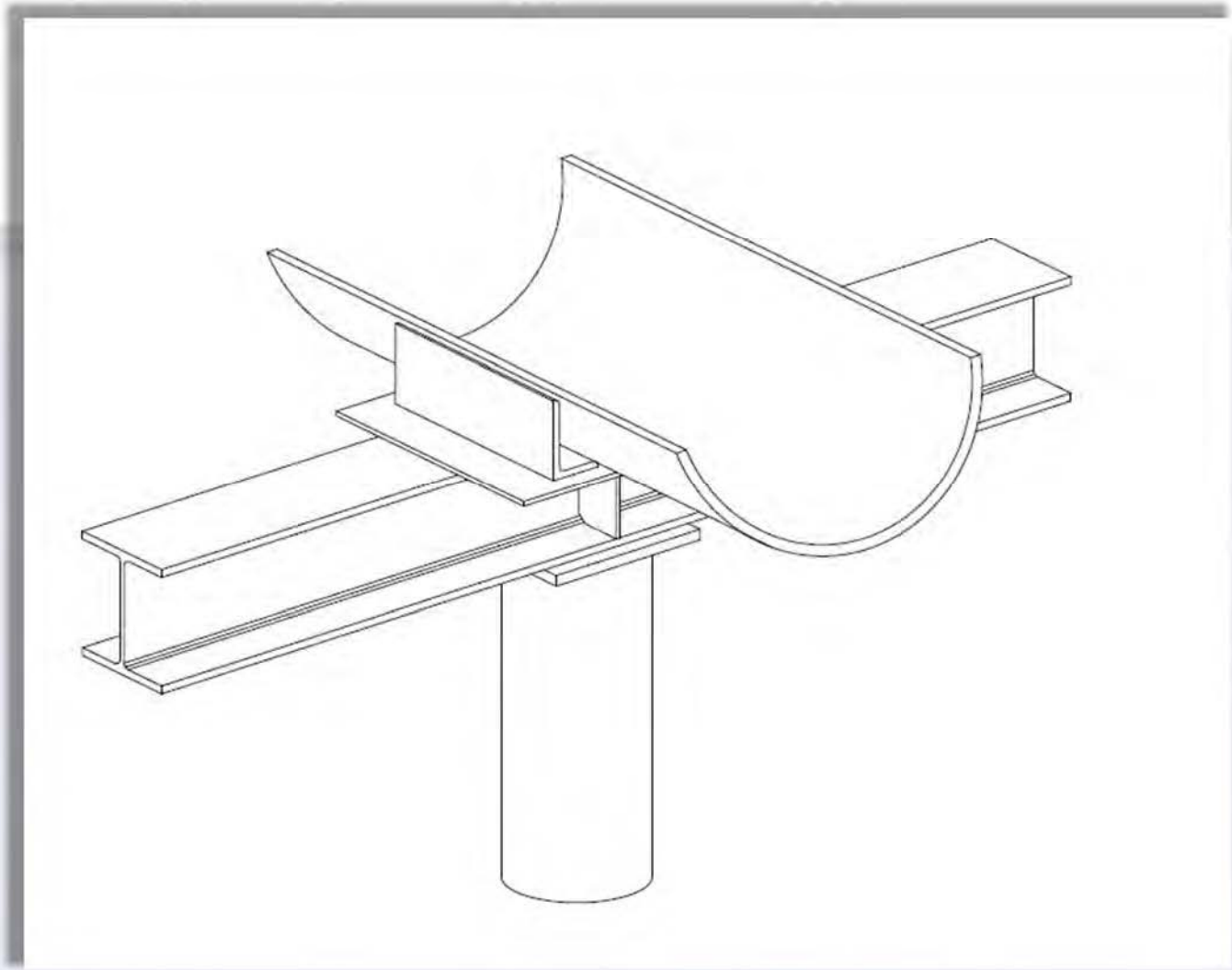

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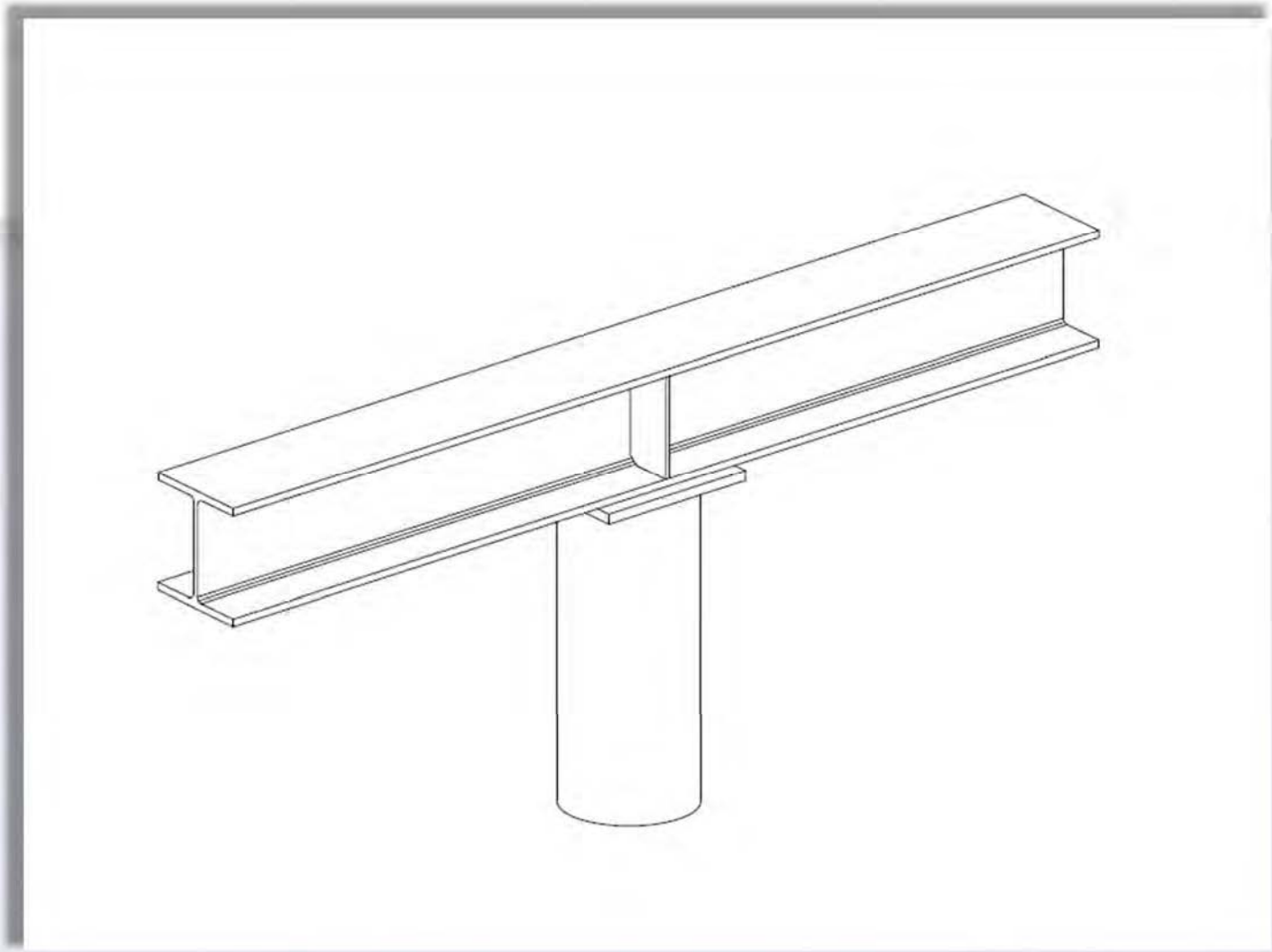

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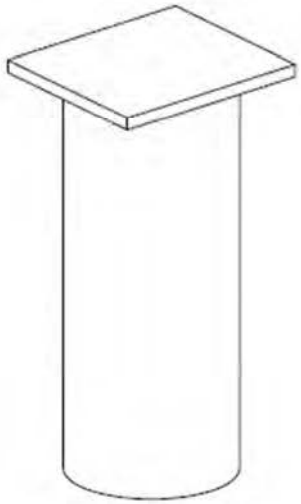

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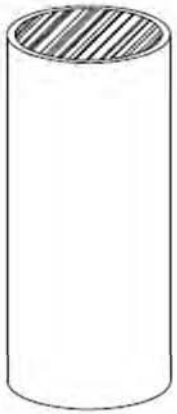
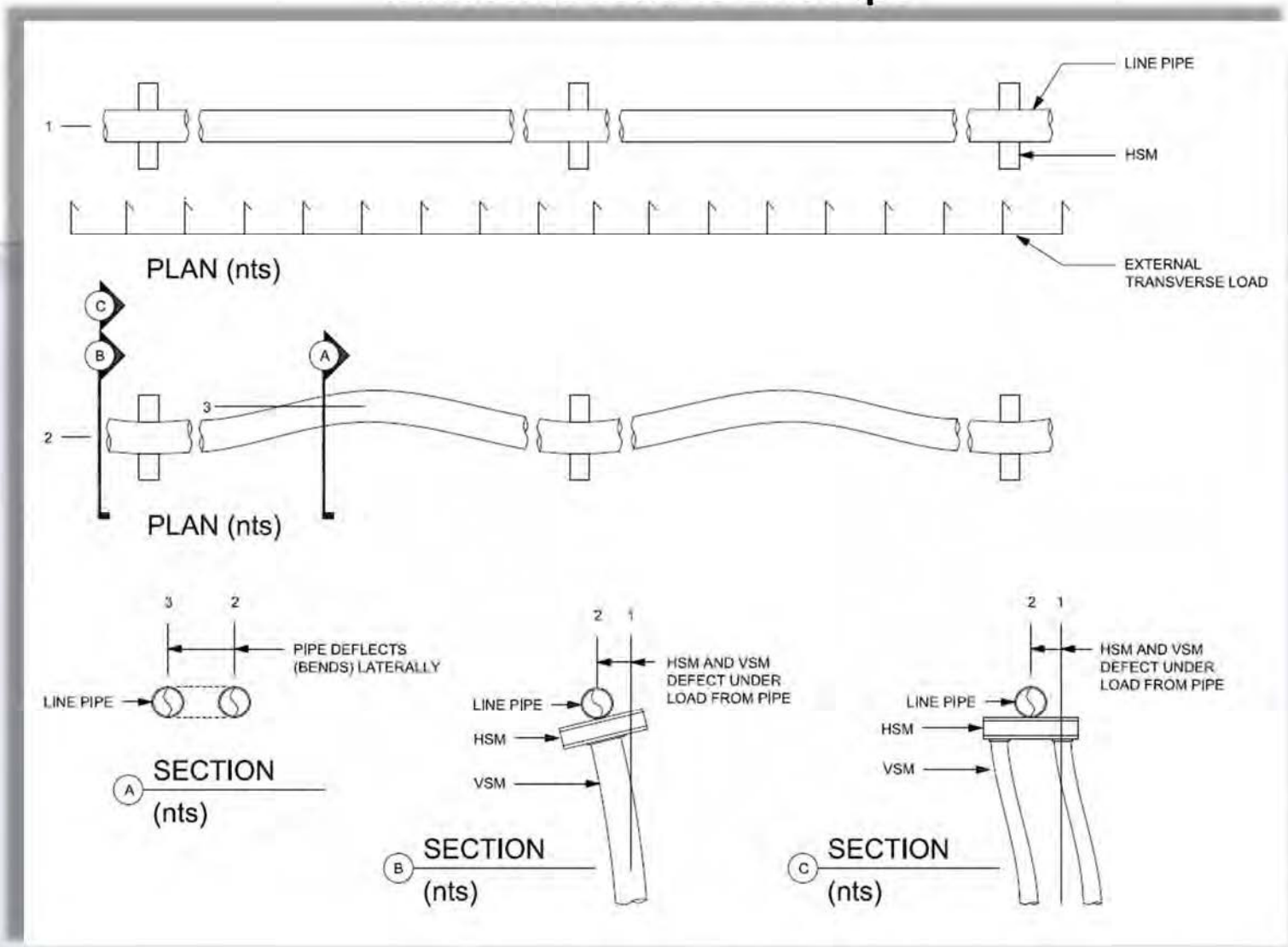


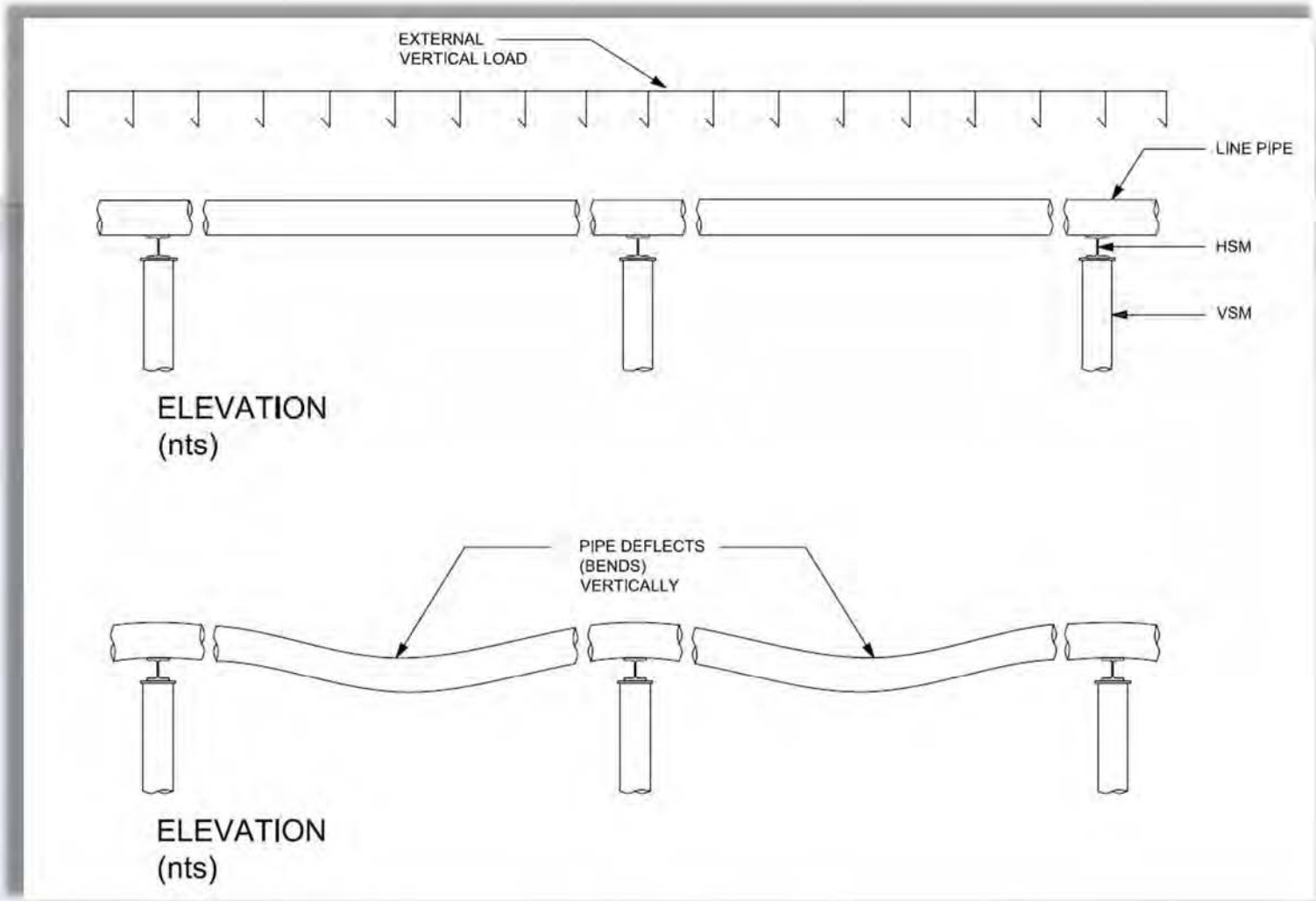
Pipeline-Specific Design VS. Pipeline Support Assembly Design

Transverse Load to Line Pipe



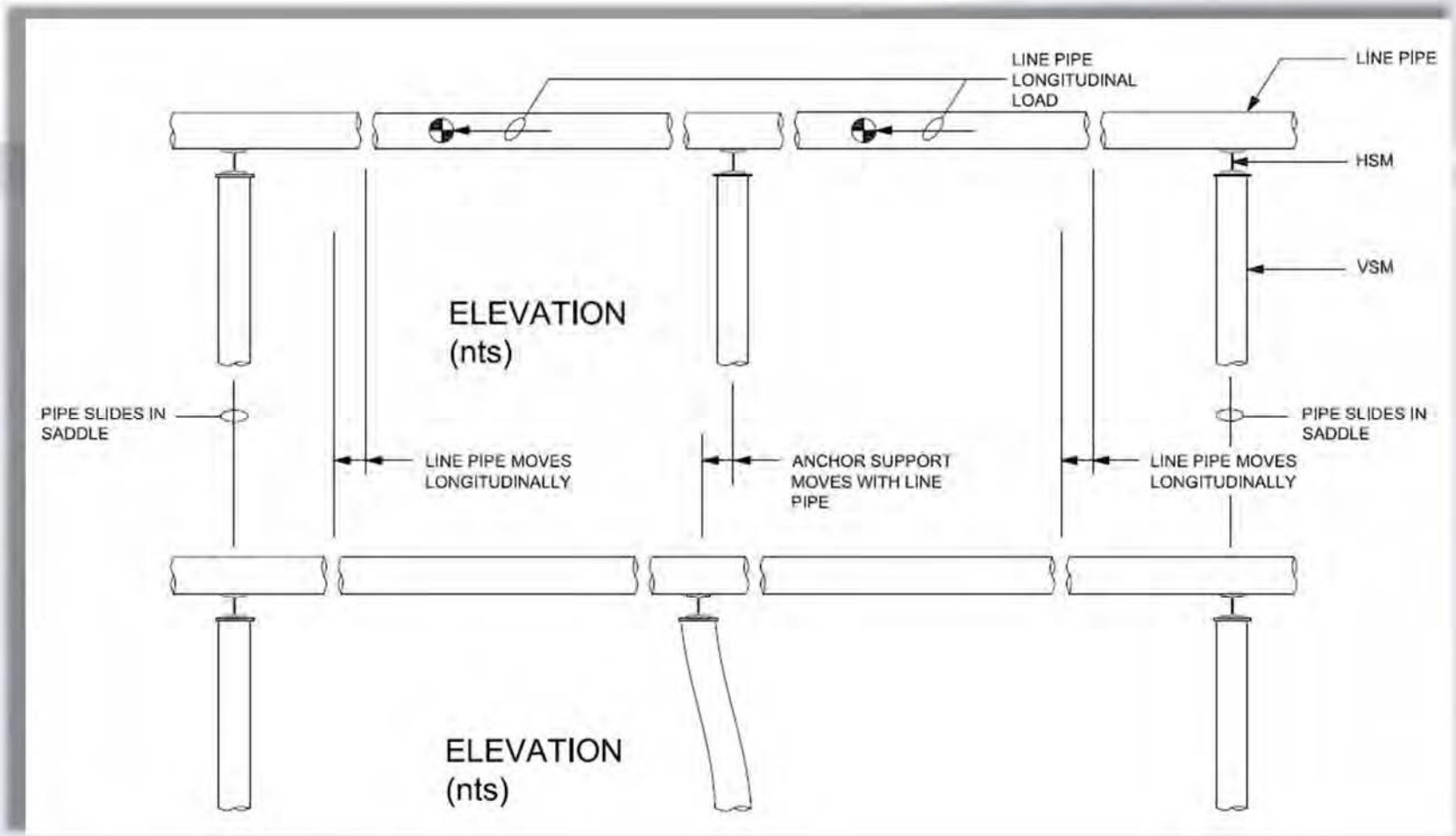
Pipeline-Specific Design VS. Pipeline Support Assembly Design

Vertical Load to Line Pipe



Pipeline-Specific Design VS. Pipeline Support Assembly Design

Longitudinal Load to Line Pipe



Above- Grade Conditions

Transient Environment Loads

- WIND
- EARTHQUAKE
- SNOW
- ICE

Transient Environment Loads

WIND

a. Pseudo-Static Design Considerations

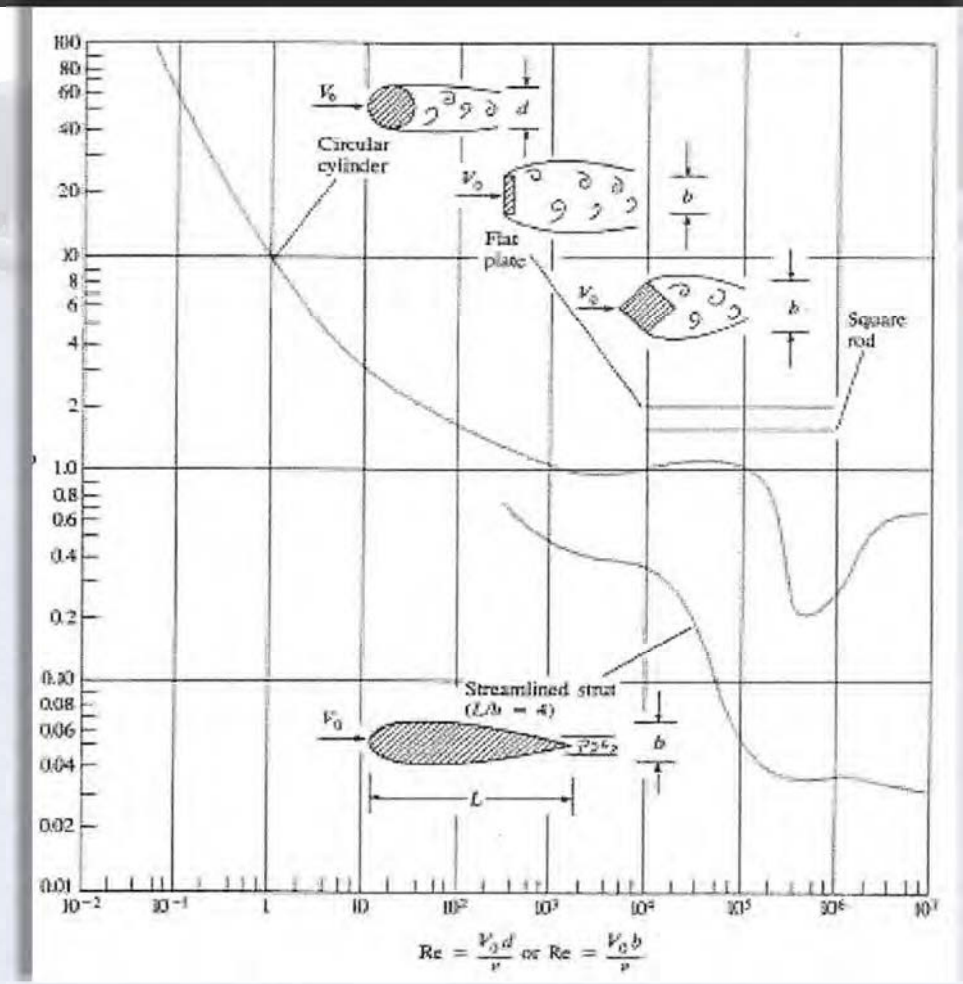
Ordinary Limit States Design

b. Dynamic Design Considerations

Wind-Induced Vibrations

Transient Environment Loads

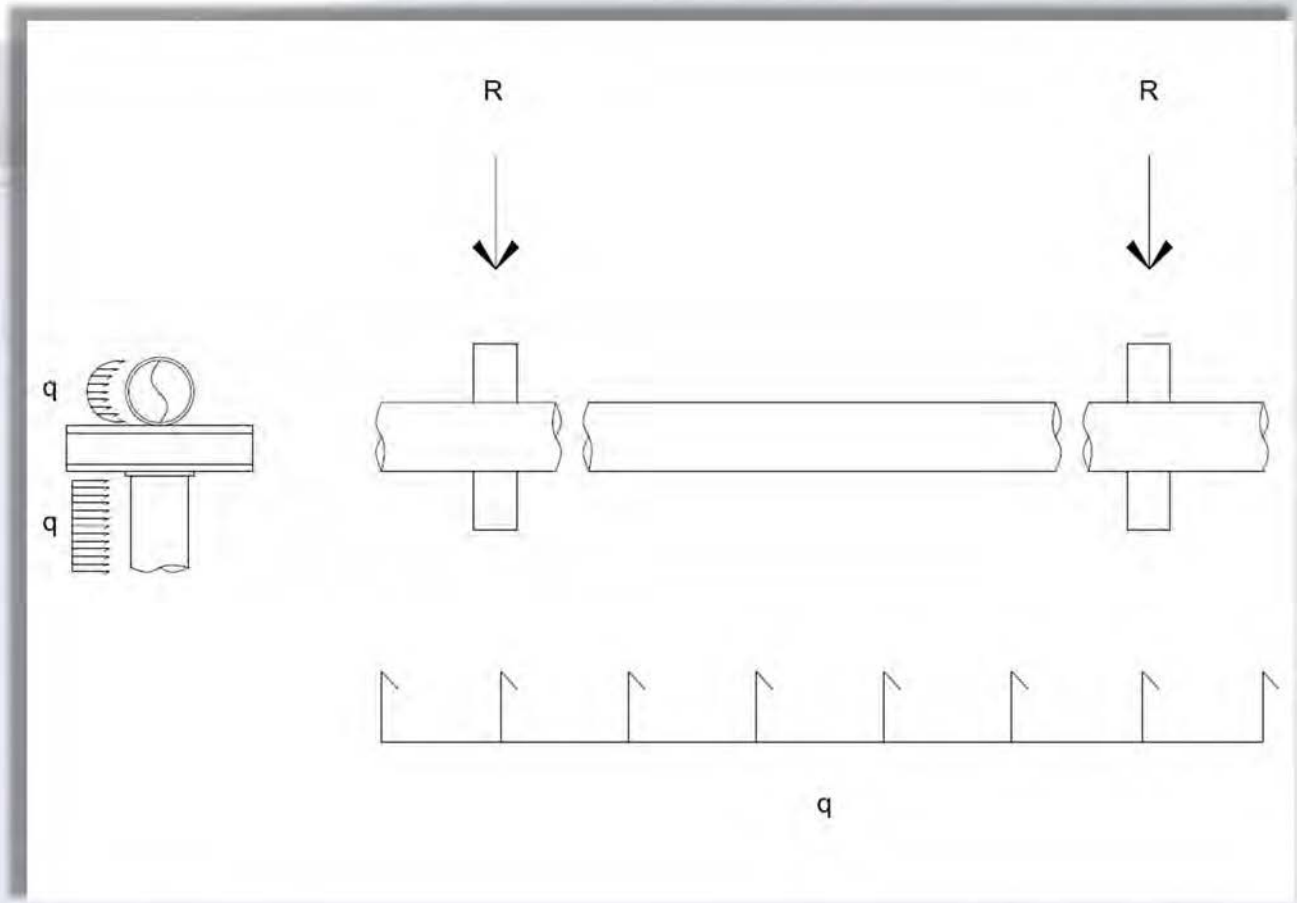
WIND



Reproduced from Engineering Fluid Mechanics, 5th Ed. (Roberson/Crowe; Wiley, 1993)

Transient Environment Loads

WIND



Transient Environment Loads

EARTHQUAKE

a. Pseudo-Static Design Considerations

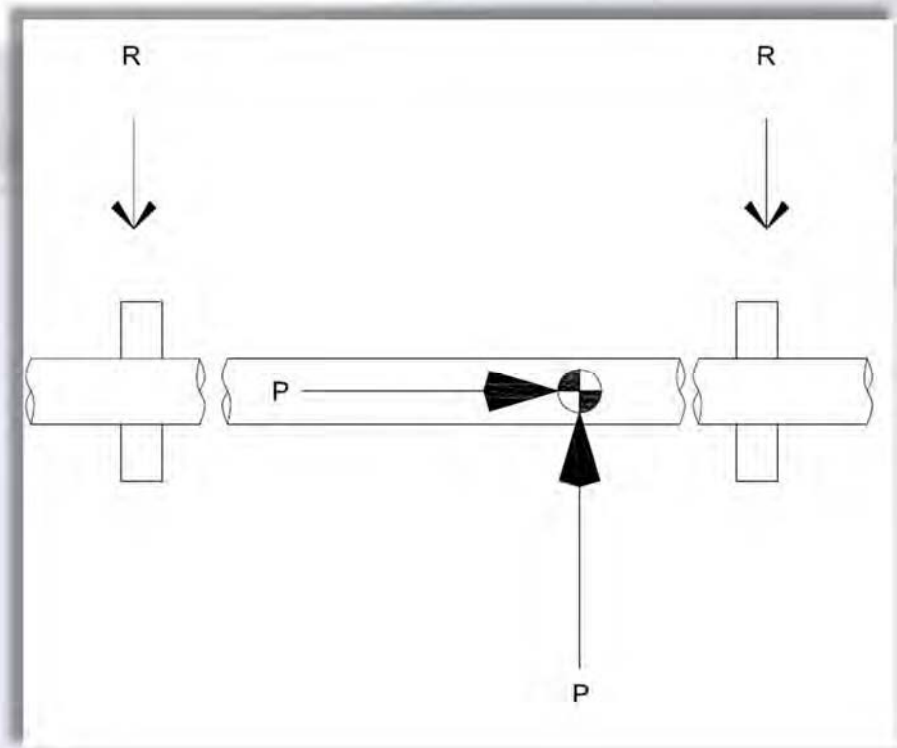
Ordinary Limit States Design

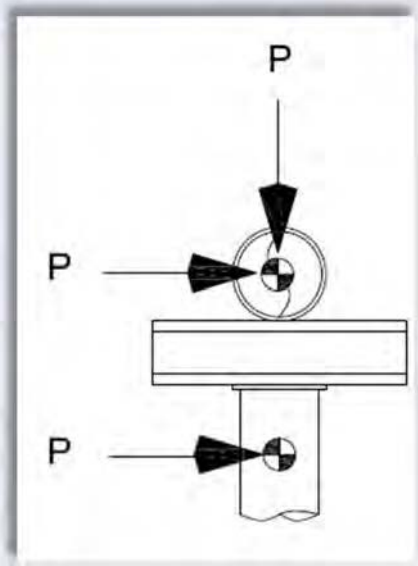
b. Dynamic Design Considerations

Low-Temperature Material Response

Transient Environment Loads

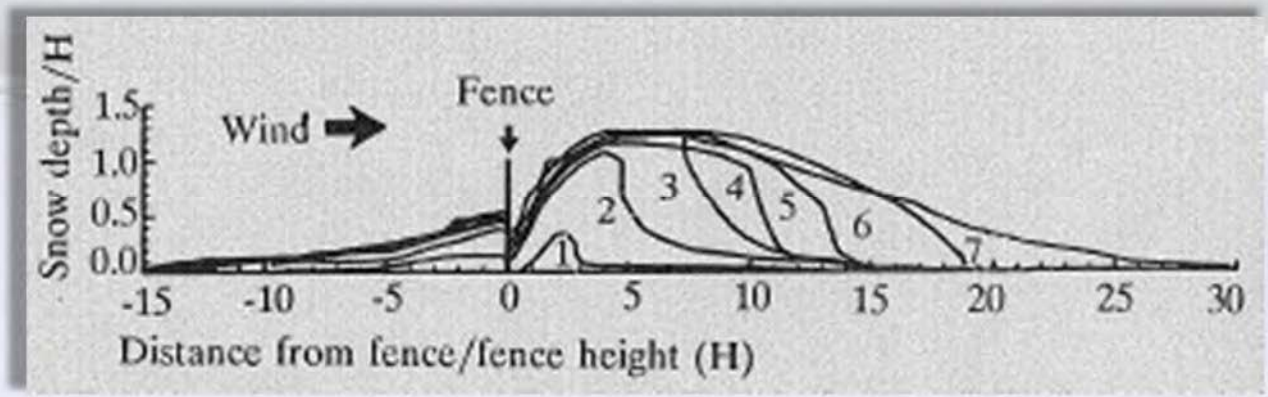
EARTHQUAKE



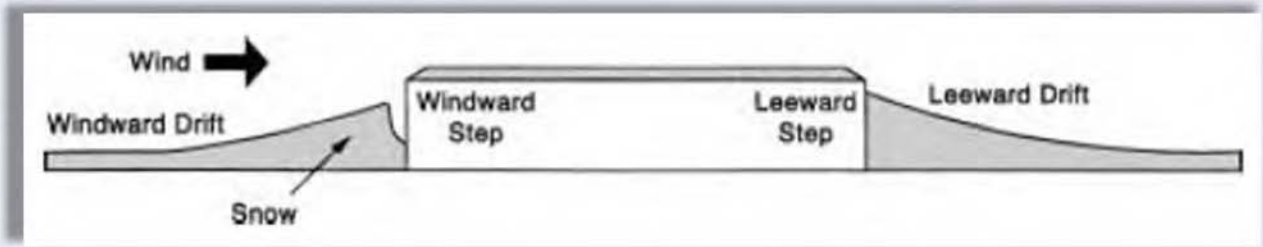


Transient Environment Loads

SNOW



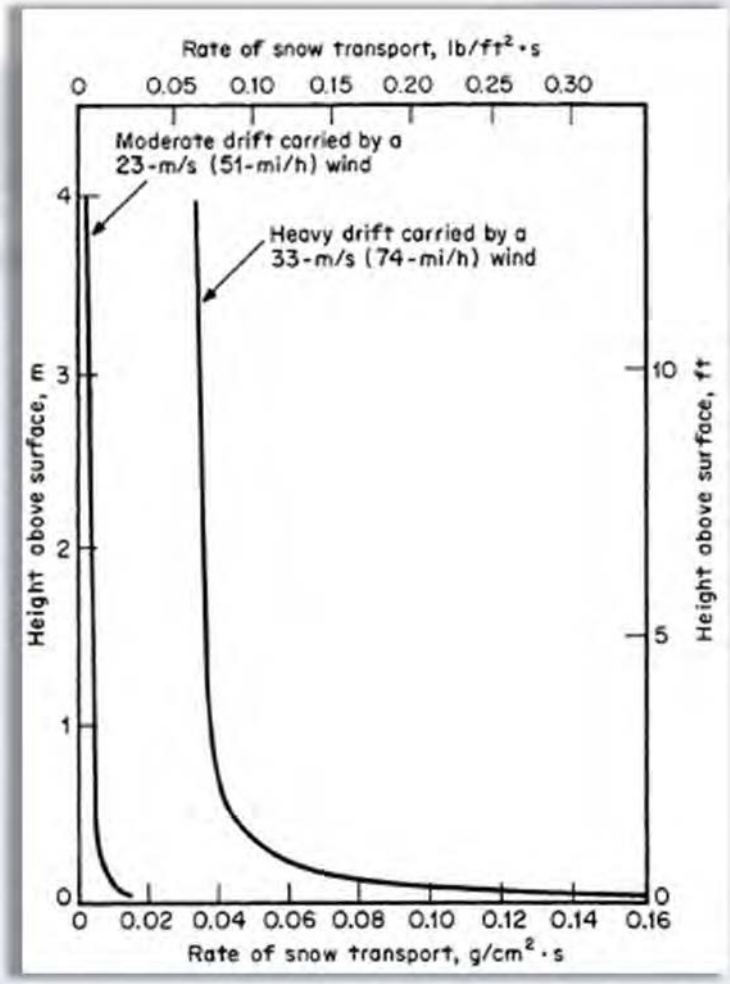
Reproduced from SHRP-H-320. (USDOT / FHWA, 1991)



Reproduced from ASCE 7-05. (American Society of Civil Engineers; 2005)

Transient Environment Loads

SNOW



Reproduced from Cold Region Structural Engineering (Eranti/Lee; McGraw-Hill, 1986)

Transient Environment Loads

SNOW

Transient Environment Loads

SNOW

Transient Environment Loads

ICE

a. Atmospheric Icing

b. Floe Ice

Transient Environment Loads

a. Atmospheric Icing

ICE

Transient Environment Loads

a. Atmospheric Icing

ICE

Transient Environment Loads

b. Floe Ice

ICE

Transient Environment Loads

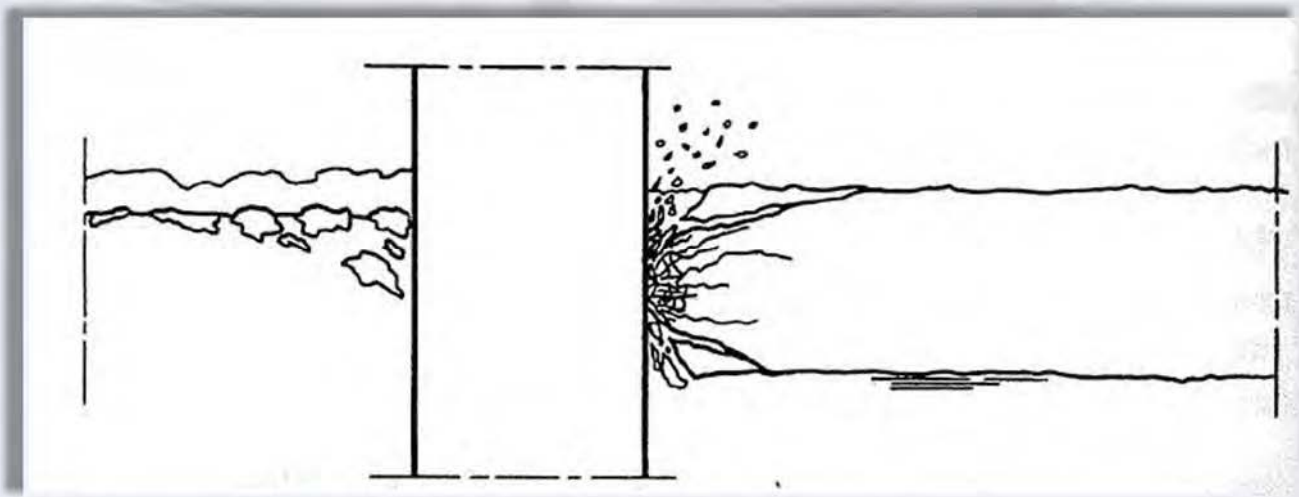
b. Floe Ice

ICE

Transient Environment Loads

b. Floe Ice

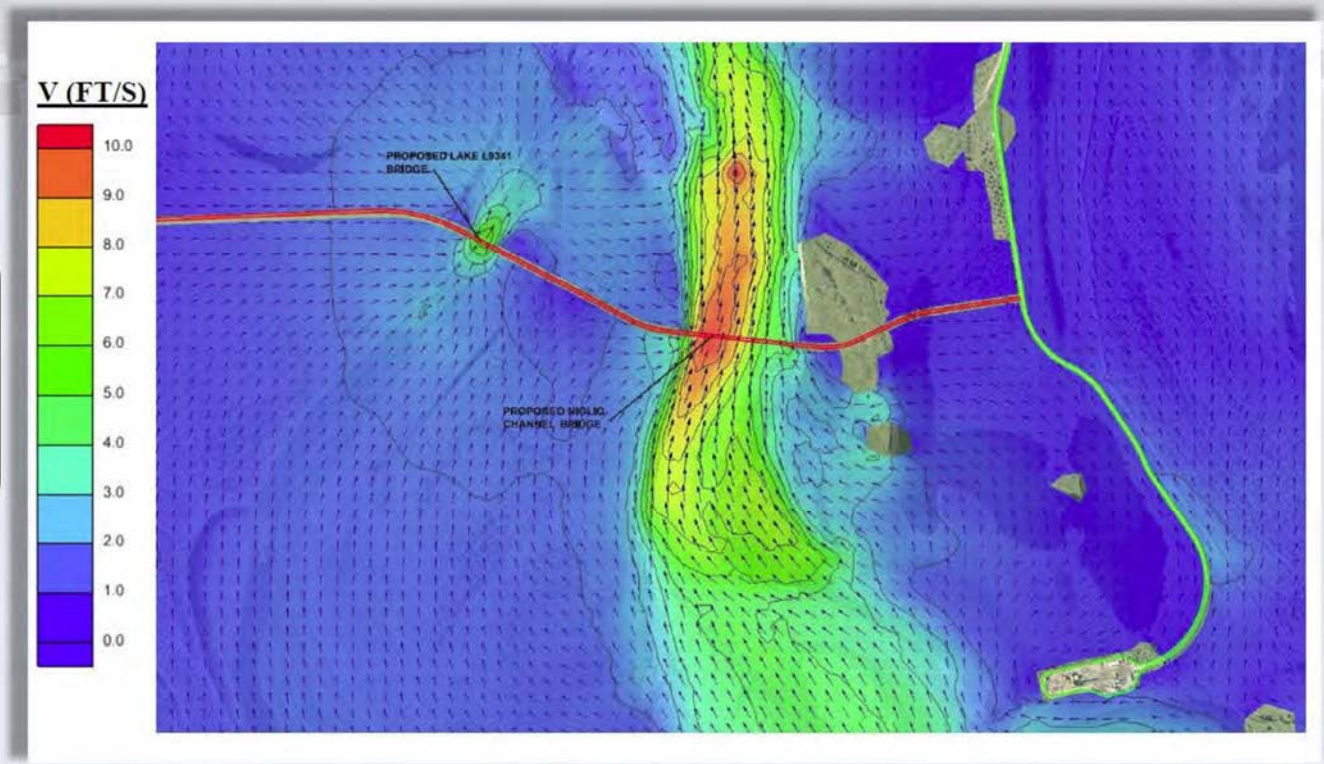
ICE



Transient Environment Loads

b. Floe Ice

ICE



Principal Design Issues

Principal Design Issues

a. Line Pipe Influences on Support Assembly Design

- Size, Wall Thickness, Contents Density, Operating Temperatures of Line Pipes
- Number of Line Pipes in a Given Alignment
- Alignment of Pipelines, Existing Line Pipes

b. Soil Structure Interaction

- VSM Settlement, Sinking Supports
- VSM Jacking, Frost-Jacking
- Differential Settlement

c. Pipeline Support Assembly Structural Design

- Project-Specific Design Requirements
- Detailed Structural Design Principals
- Special Design Considerations
- Practical Design Considerations

Principal Design Issues

a. Line Pipe Influences on Support Assembly Design

I. **Size, Wall Thickness, Contents Density, Operating Temperatures of Line Pipes**

1. Effects on Support Assembly Spacing

ii. **ii. Number of Line Pipes in a Given Alignment**

1. Effects on VSM Configuration

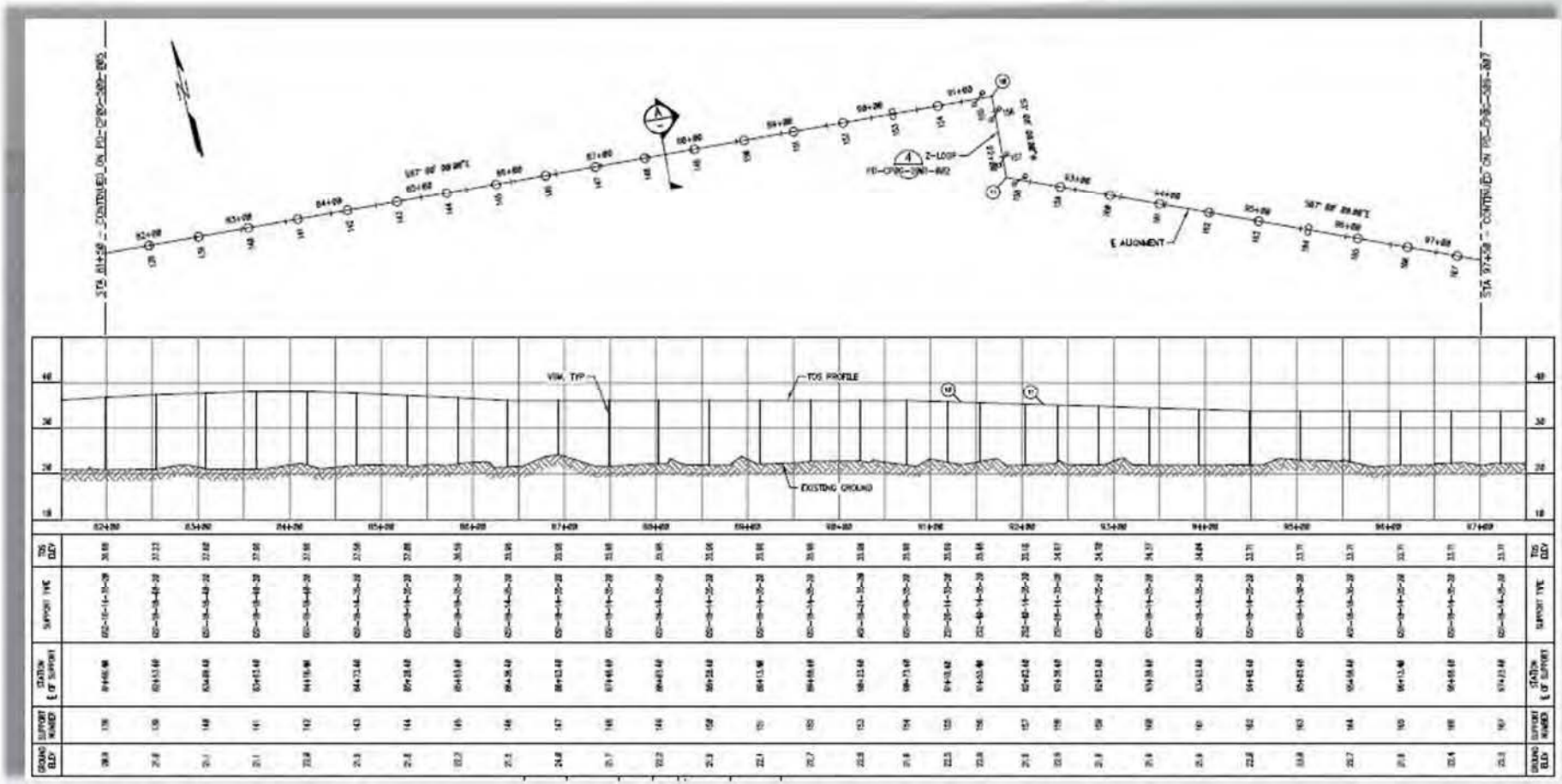
a. Actual Installed VS. Future Line Pipes

iii. **Alignment of Pipelines, Existing Line Pipes**

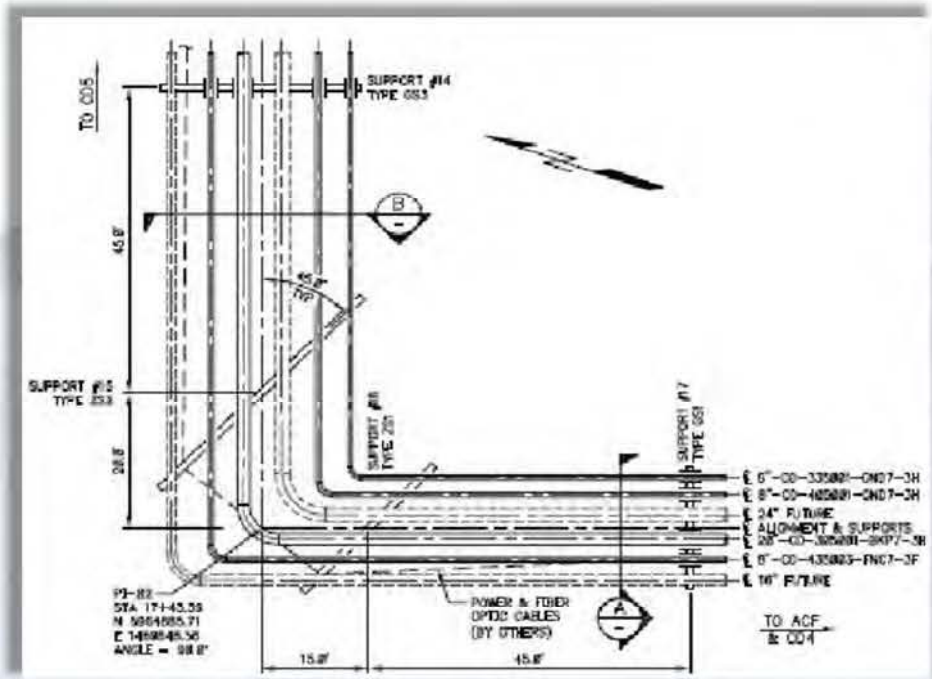
1. Vertical alignment, Horizontal Alignment

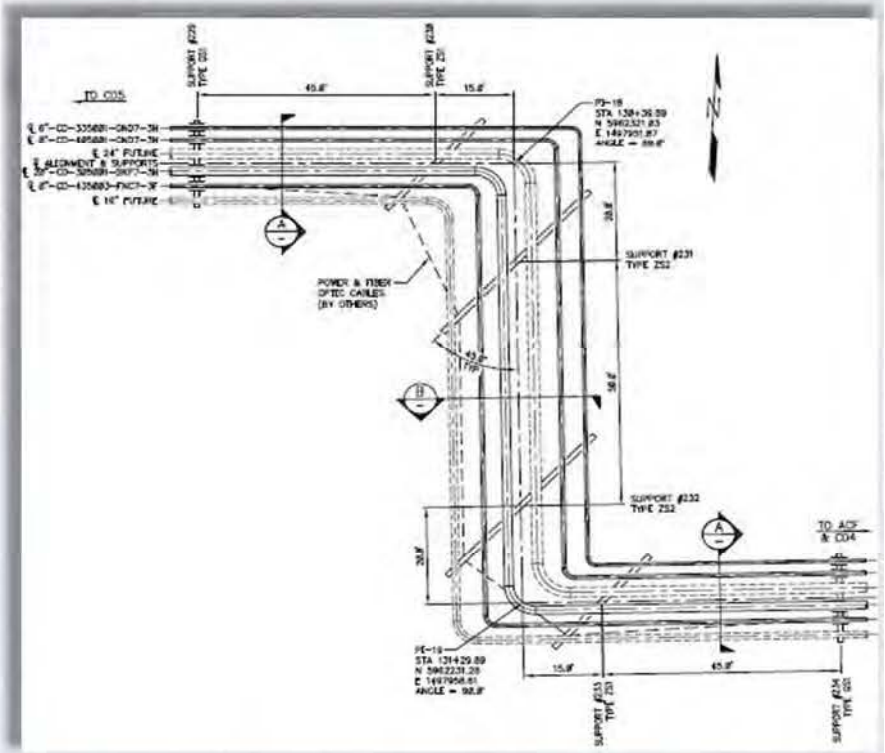
2. Tie-In to Existing Pipelines; Impacts on Geometry

Pipeline Alignment

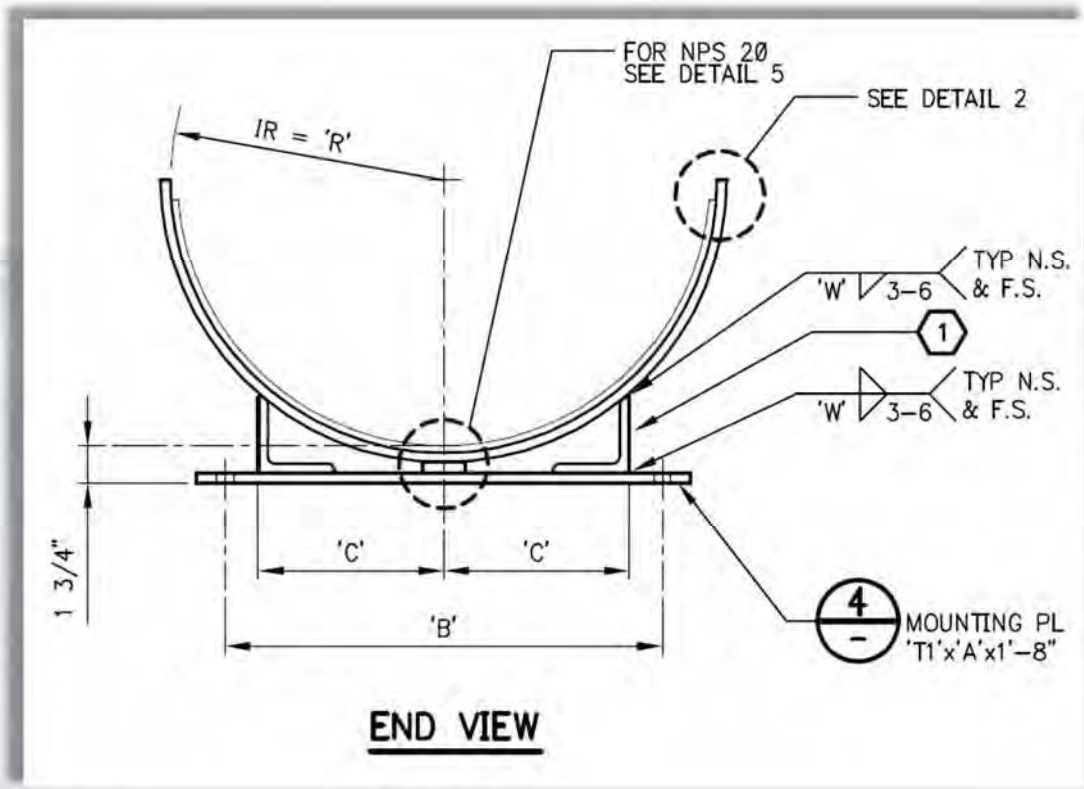


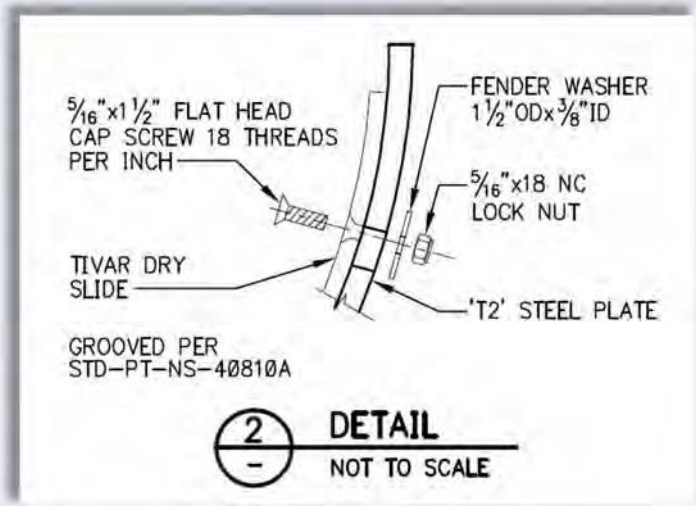
Expansion Loops



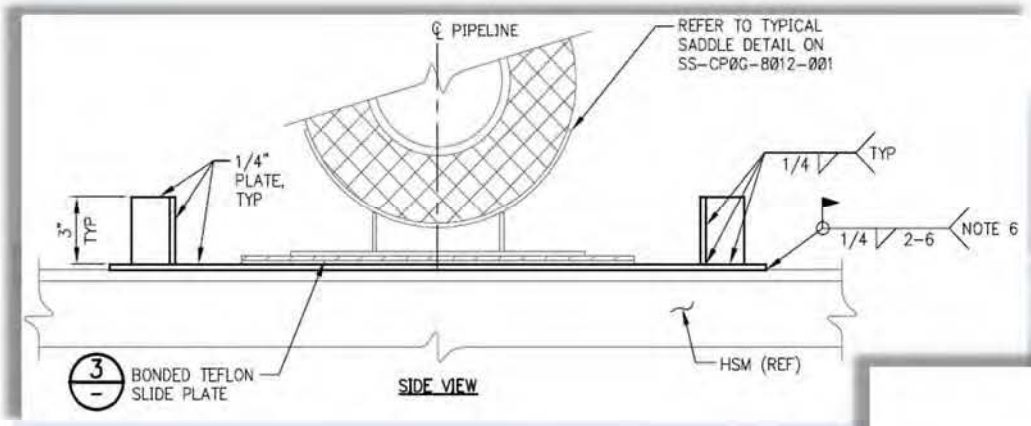


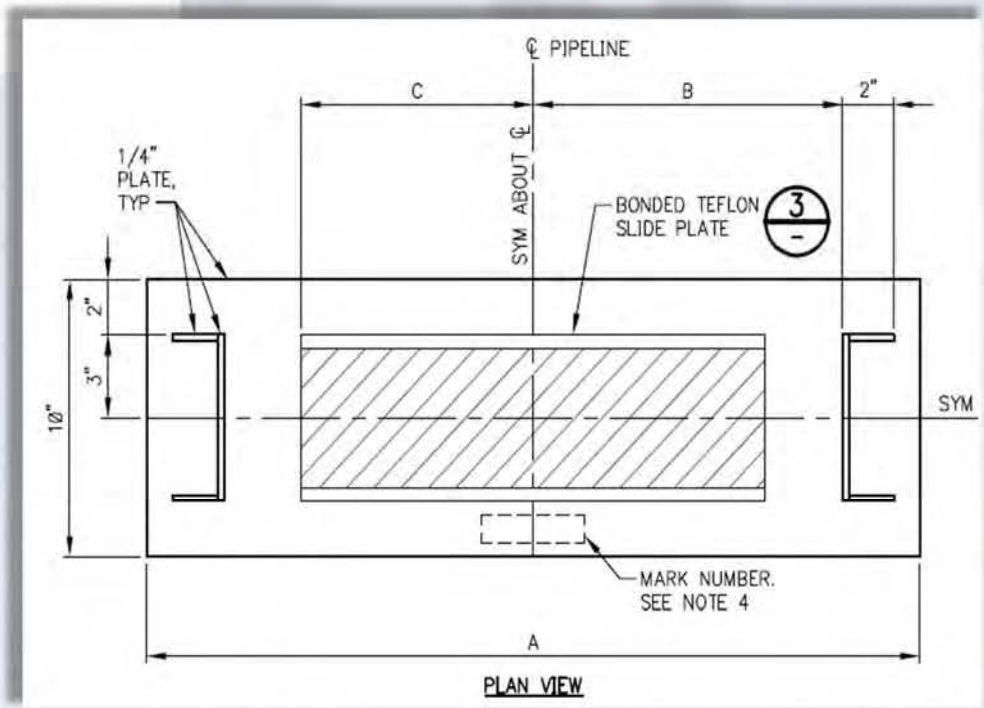
Saddle Assembly Types



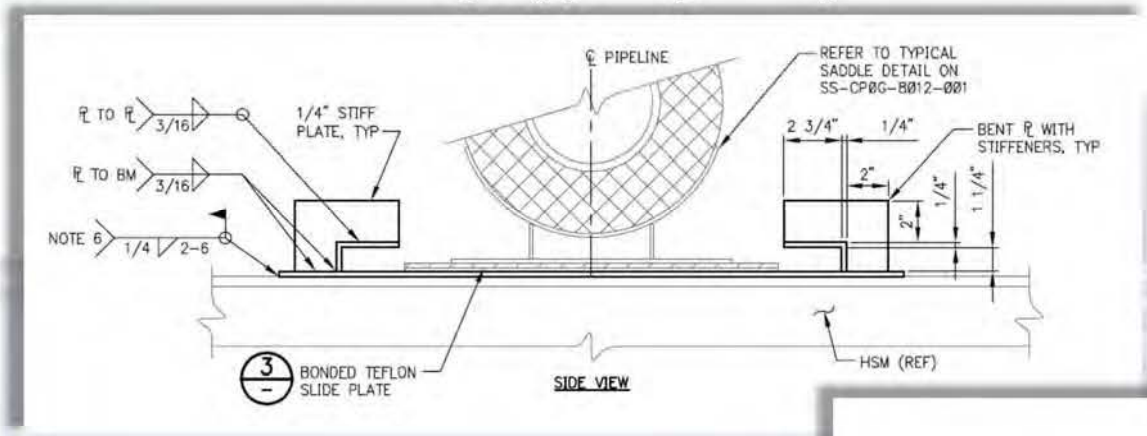


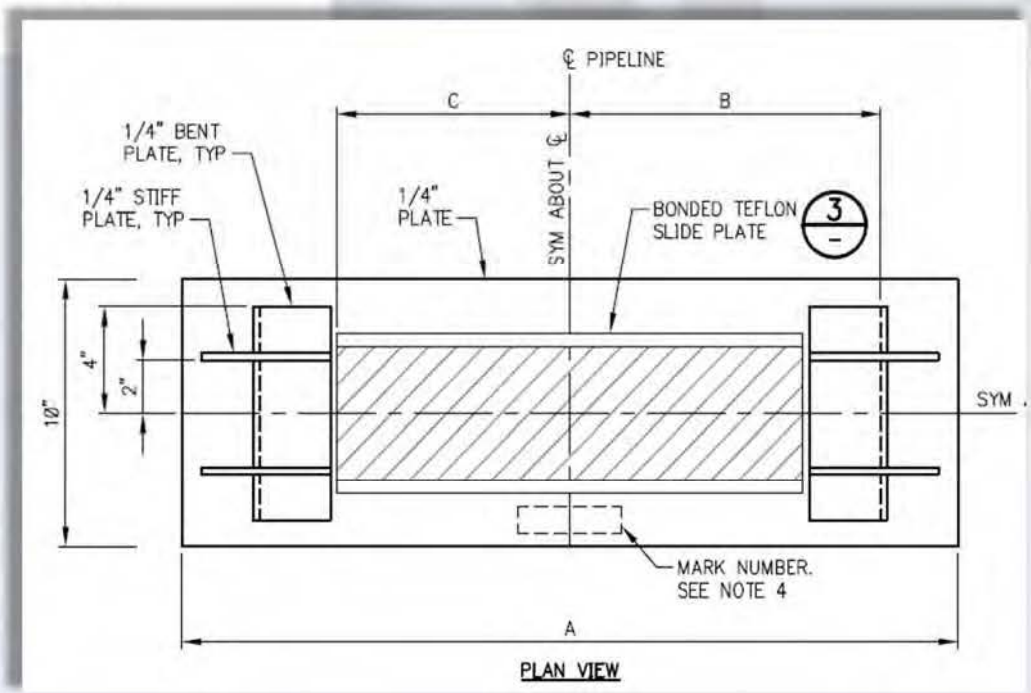
Saddle Assembly Types (cont.)



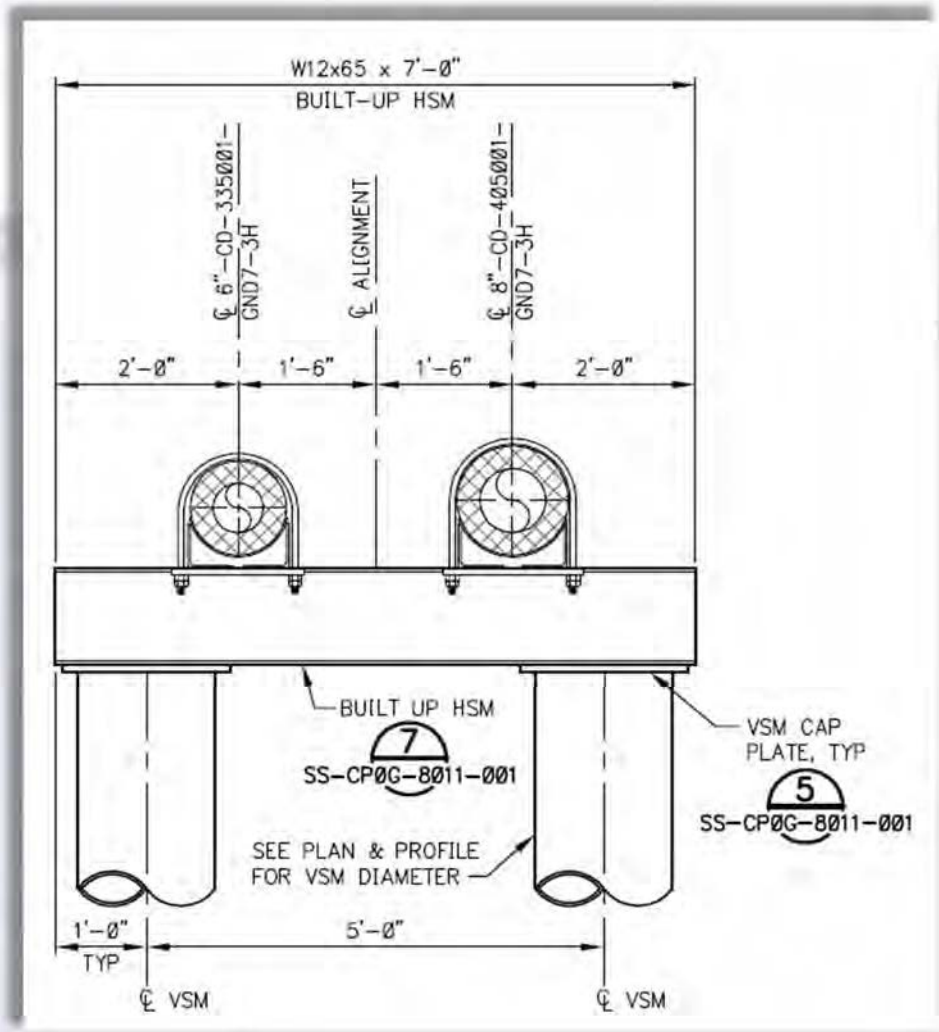


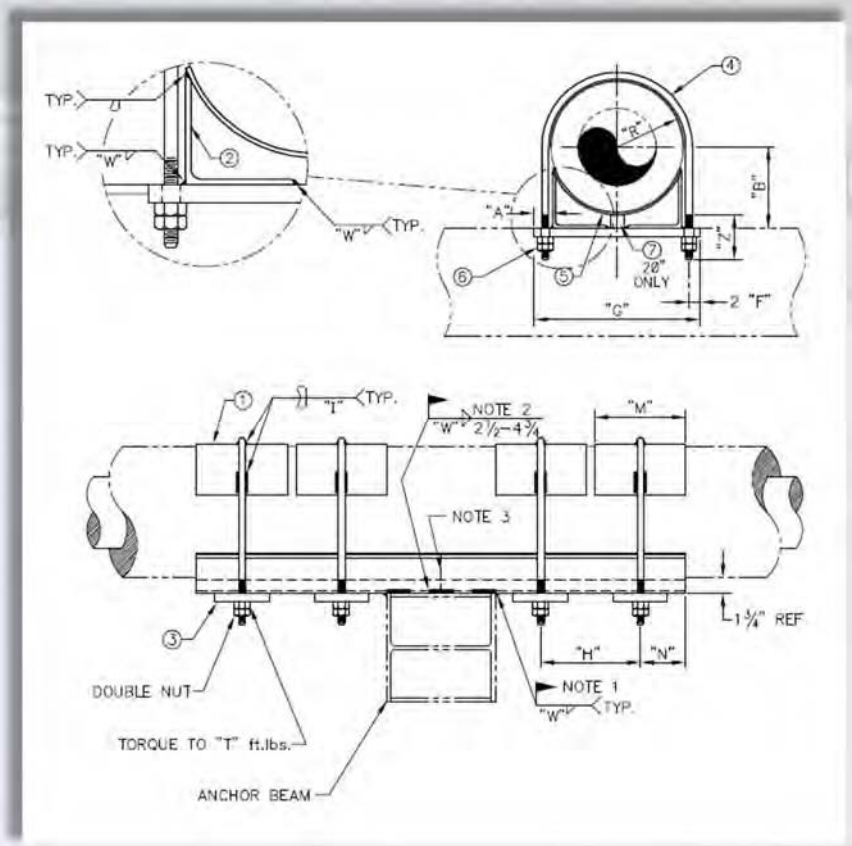
Saddle Assembly Types (cont.)



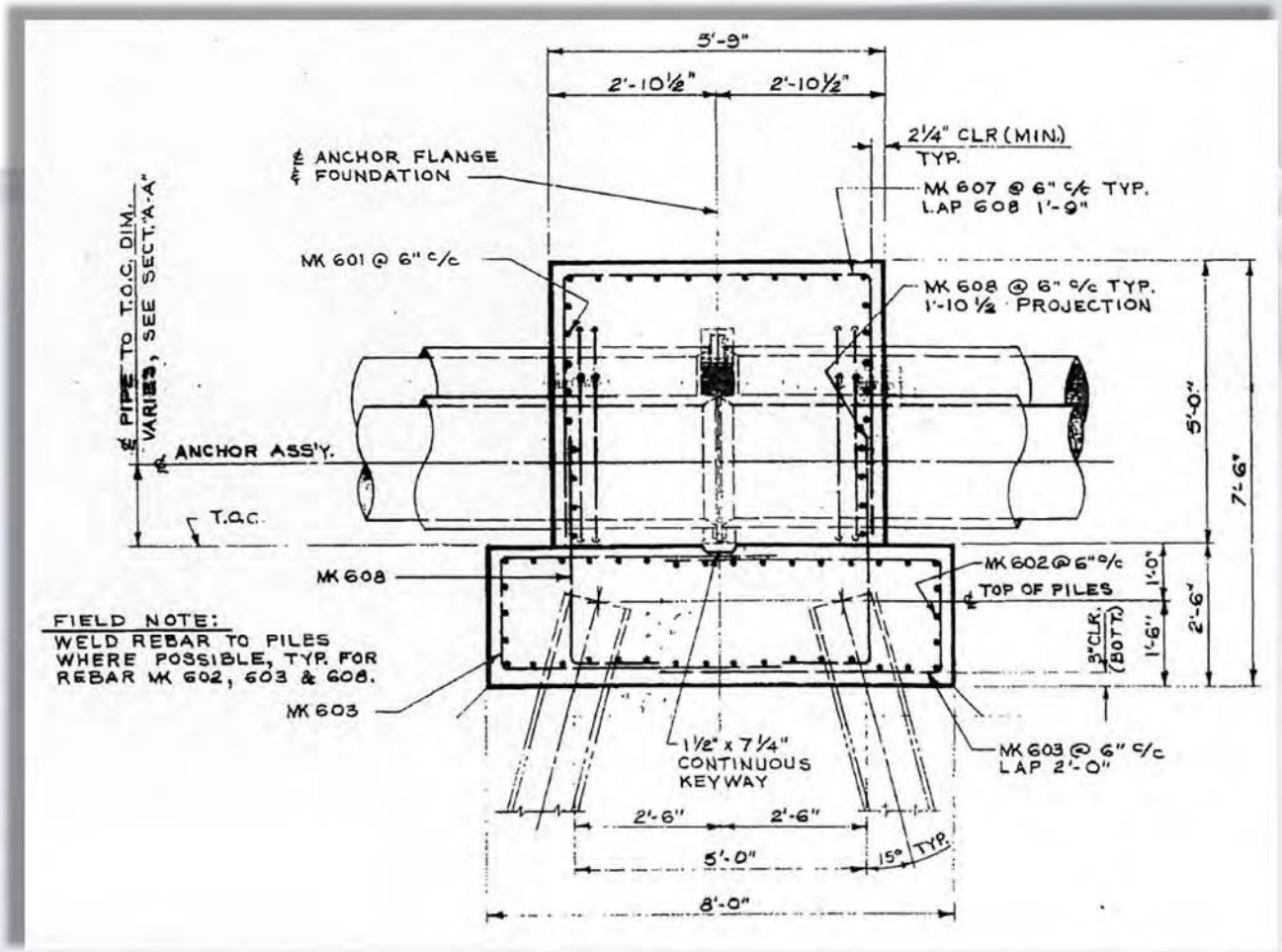


Pipeline Anchors





Pipeline Anchors (cont.)



I. VSM MOVEMENT

1. Vertical Settlement

2. Lateral Creep / Rotation

b. Soil Structure Interaction

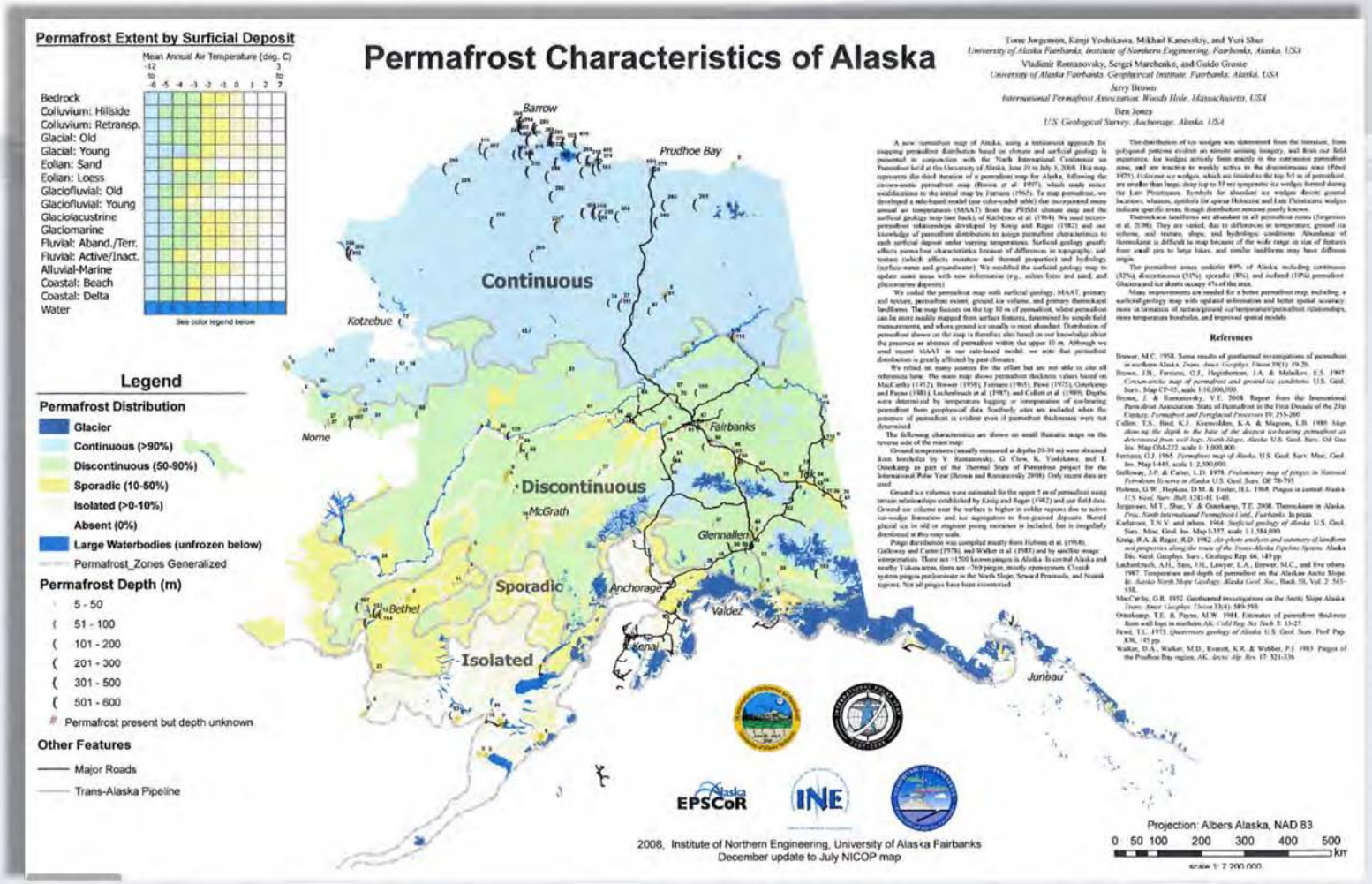
ii. Pile Heave / Frost-Jacking

iii. Differential Settlement

Principal Design Issues

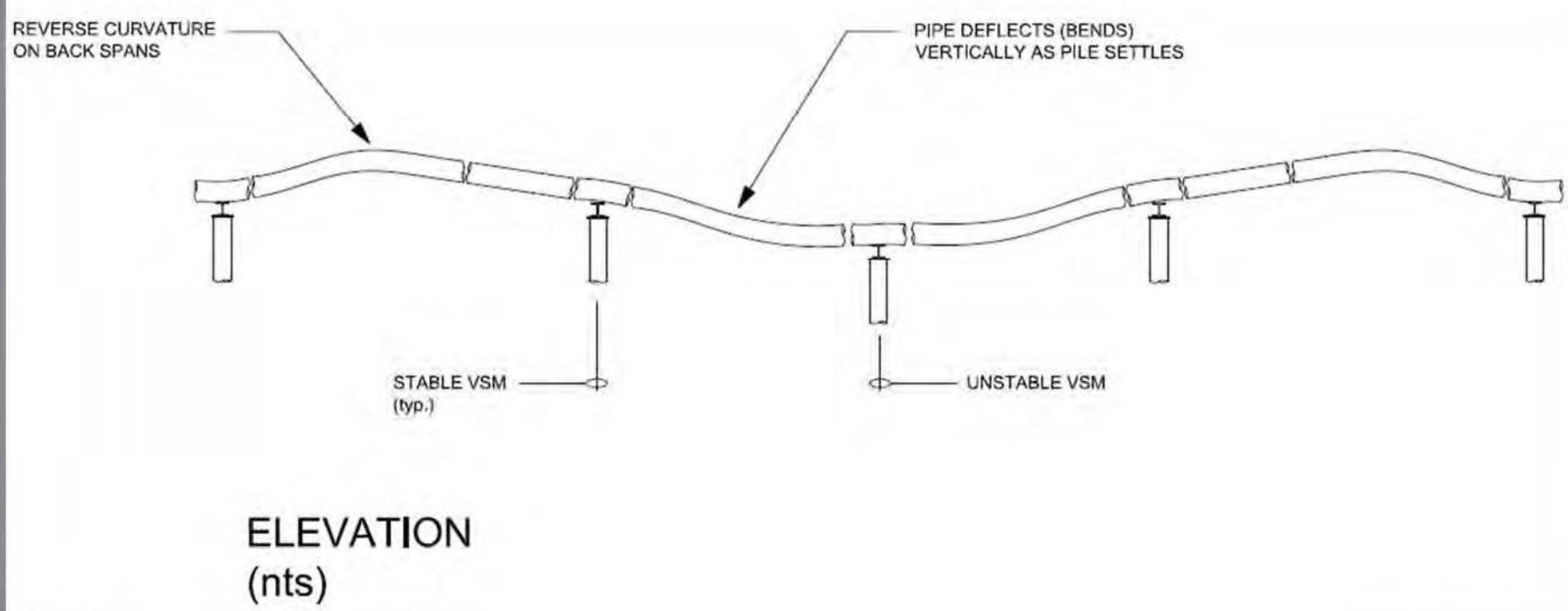
b. Soil – Structure Interaction

Permafrost



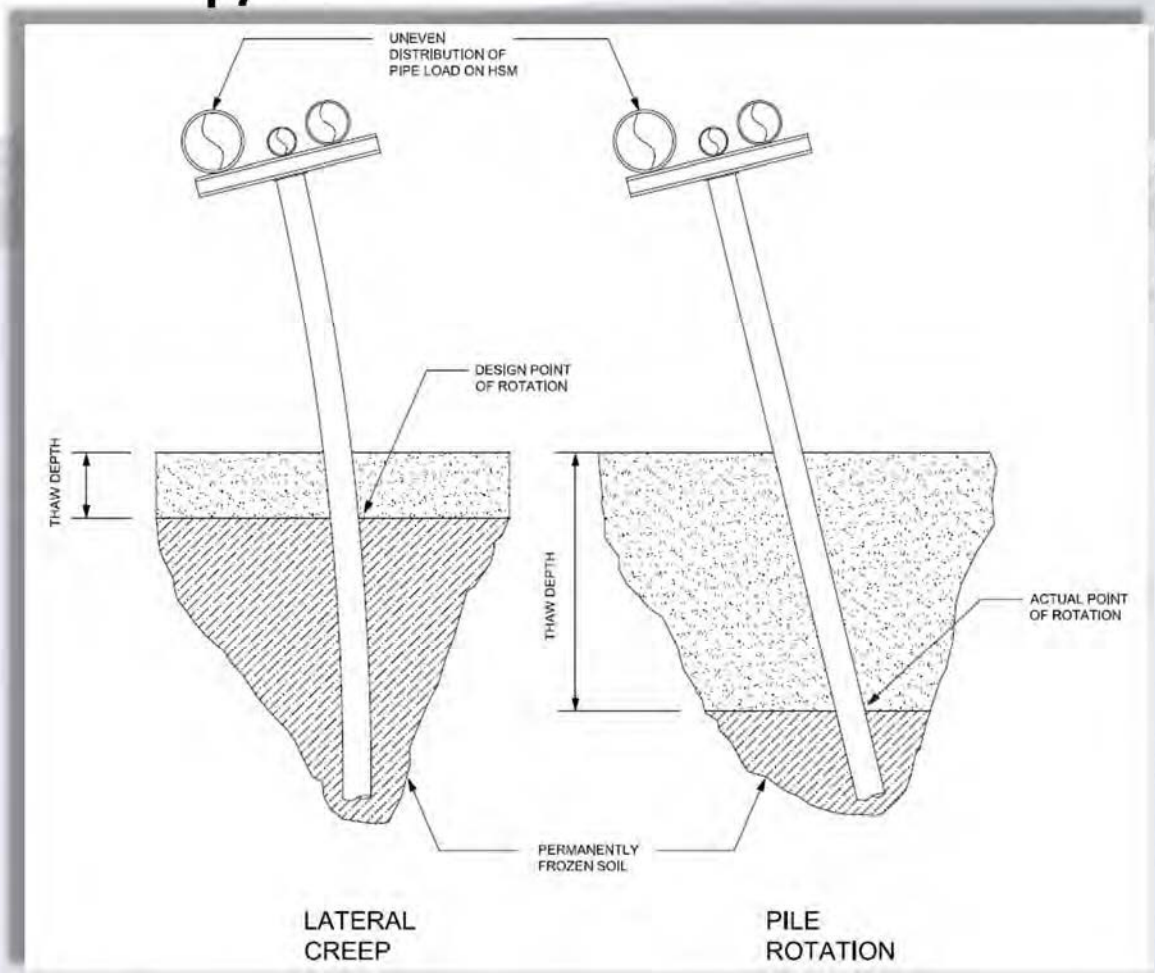
b. Soil – Structure Interaction

VSM Vertical Settlement



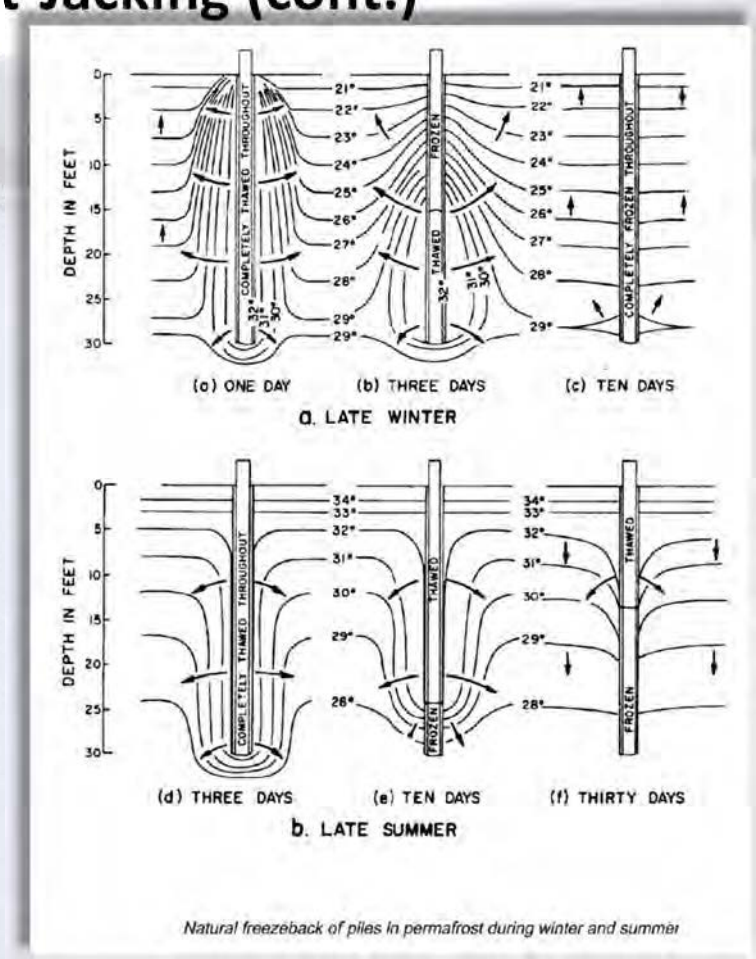
b. Soil – Structure Interaction

VSM Lateral Creep/Rotation



b. Soil – Structure Interaction

Pile Heave / Frost-Jacking (cont.)

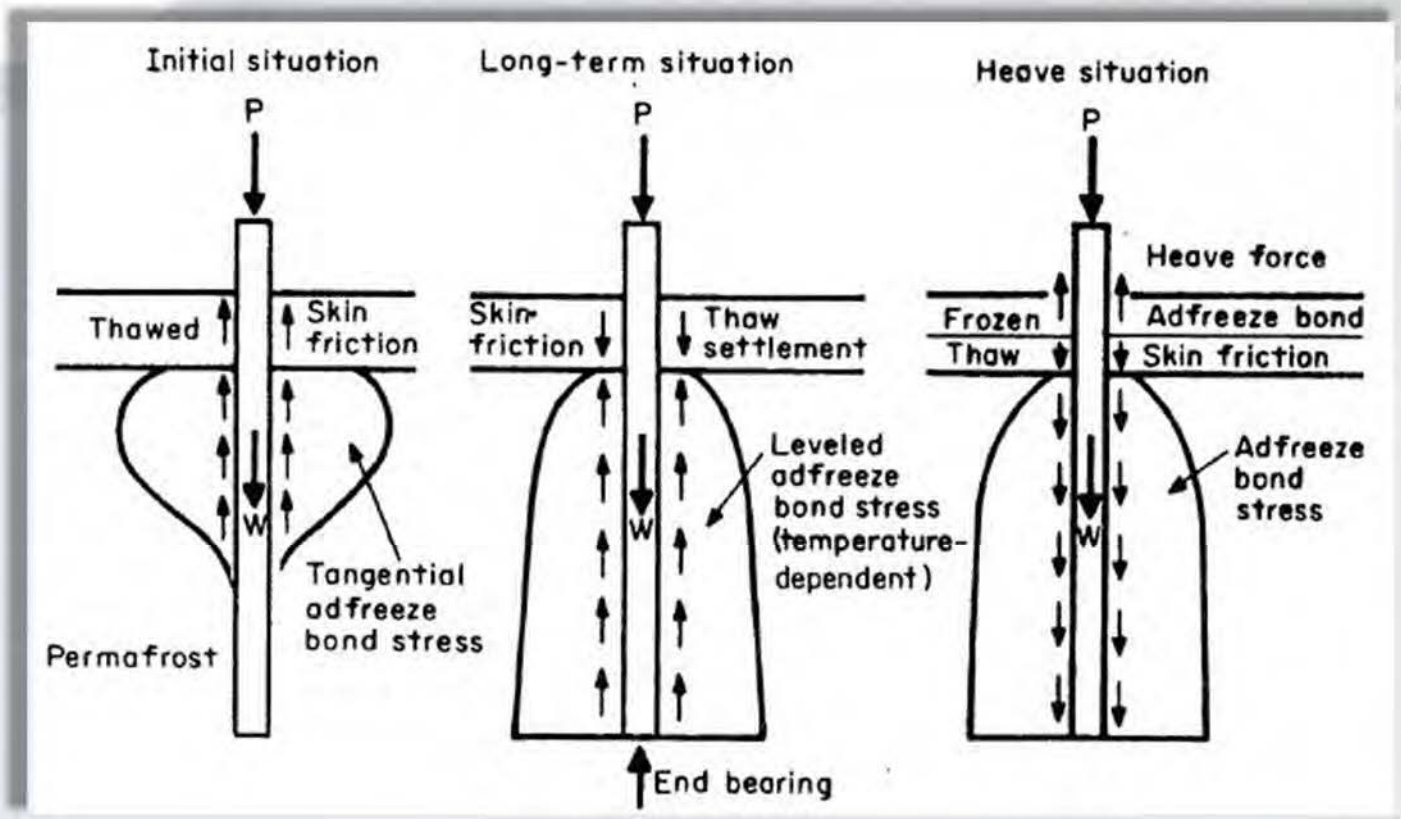


Natural freezeback of piles in permafrost during winter and summer

Reproduced from Cold Region Structural Engineering (Eranti/Lee; McGraw-Hill, 1986)

b. Soil – Structure Interaction

Pile Heave / Frost-Jacking (cont.)



Reproduced from Cold Region Structural Engineering (Eranti/Lee; McGraw-Hill, 1986)

b. Soil – Structure Interaction

Differential Settlement

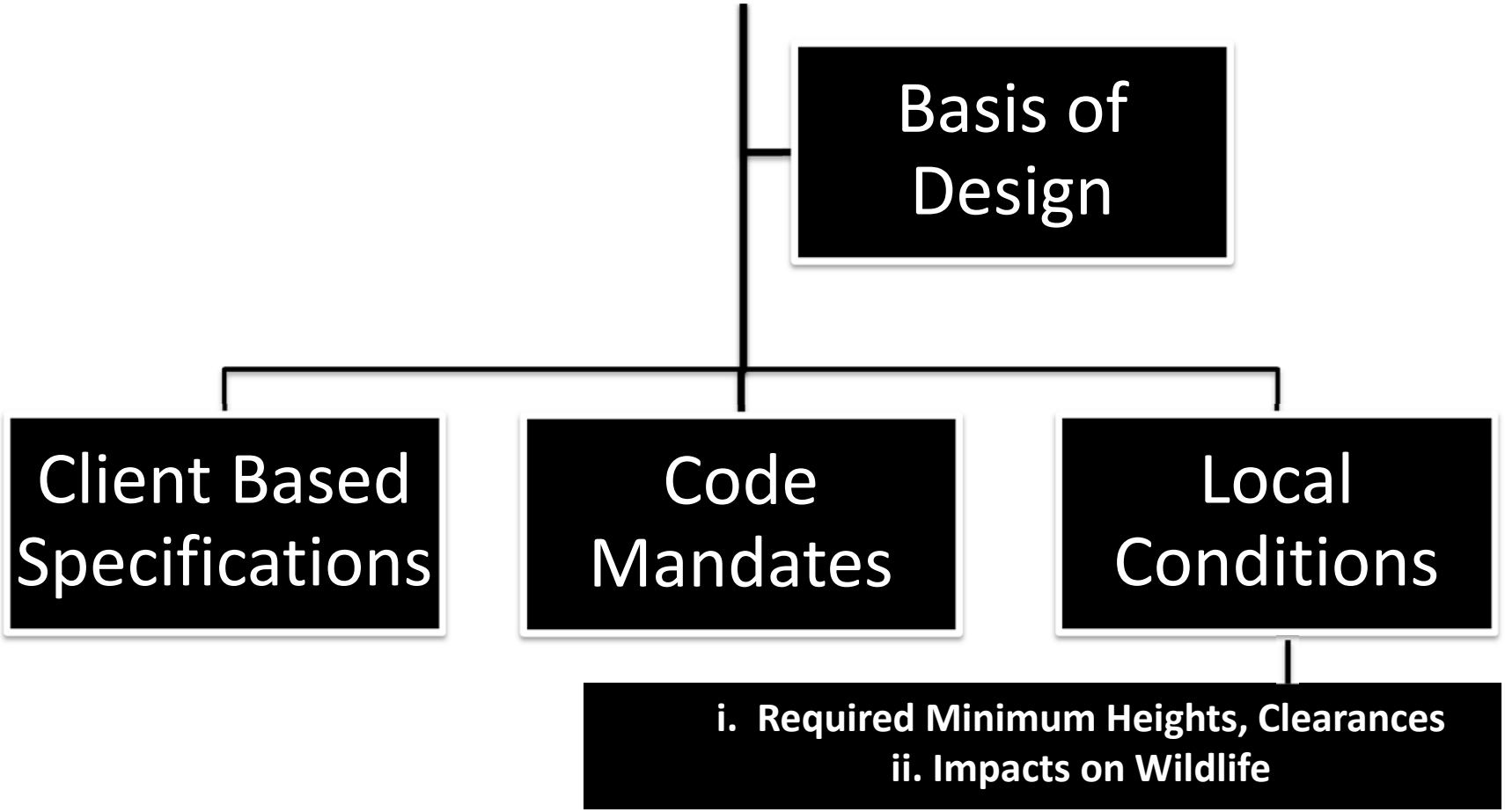
Principal Design Issues

- **Project-Specific Design Requirements**
  1. Basis of Design
- **Detailed Structural Design Principals**
  1. Limit States
- **Special Design Considerations**
  1. Durability
- **Practical Design Considerations**
  1. Constructability
  2. Cost

c. Pipeline Support Assembly Structural Design

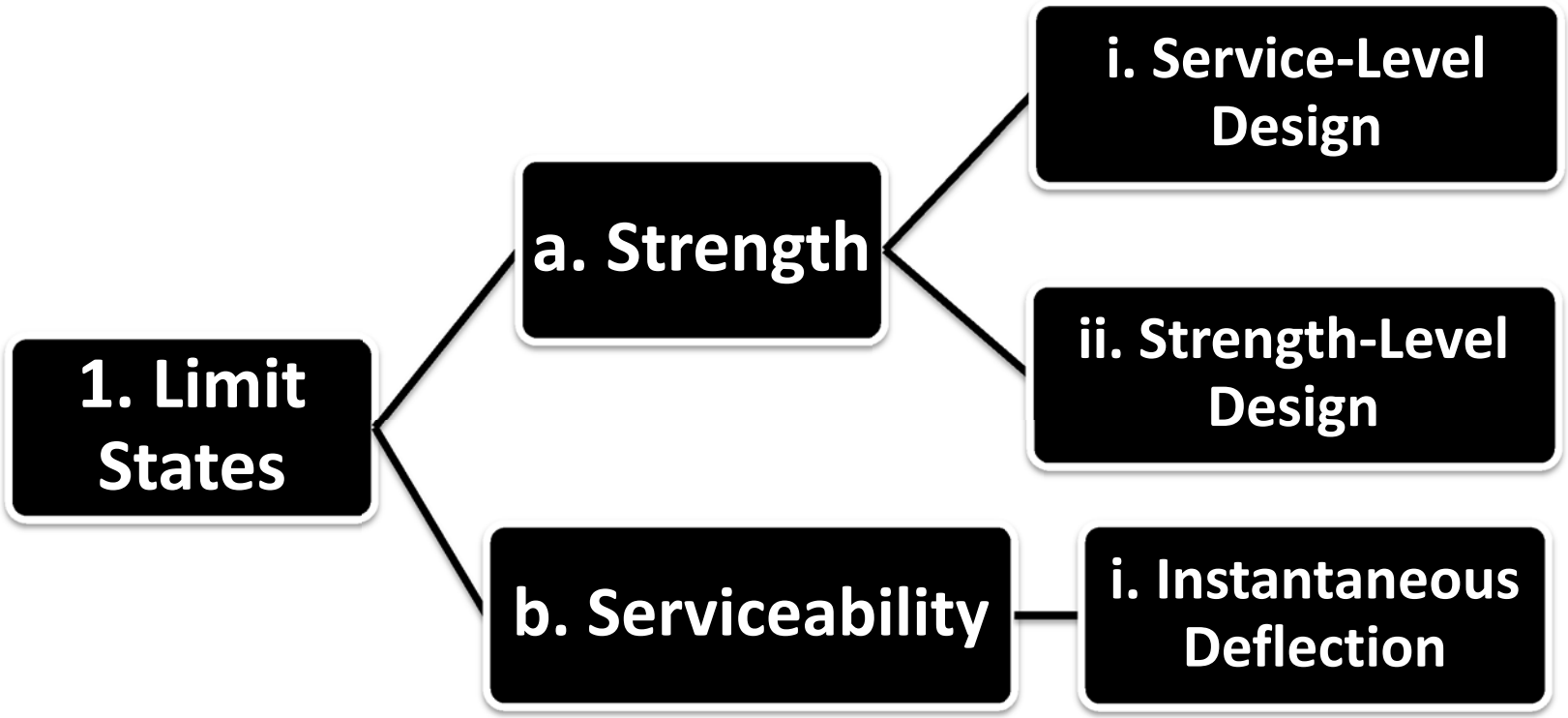
c. Pipeline Support Assembly Structural Design

i. Project-Specific Design Requirements



c. Pipeline Support Assembly Structural Design

ii. Detailed Structural Design Principals



c. Pipeline Support Assembly Structural Design

LIMIT STATES, DEFINED:

- A limit state shall be considered a condition in which, once the acceptable boundaries of that state have been exceeded, some structural system or component of the system becomes unfit for its ordinary or intended use.

- Such a condition exists when either:

  (a) the performance of a structural system or component is considered unsatisfactory, for reasons other than life-safety (i.e. a "serviceability" limit state; such as excessive deflection, or vibration of an element), or

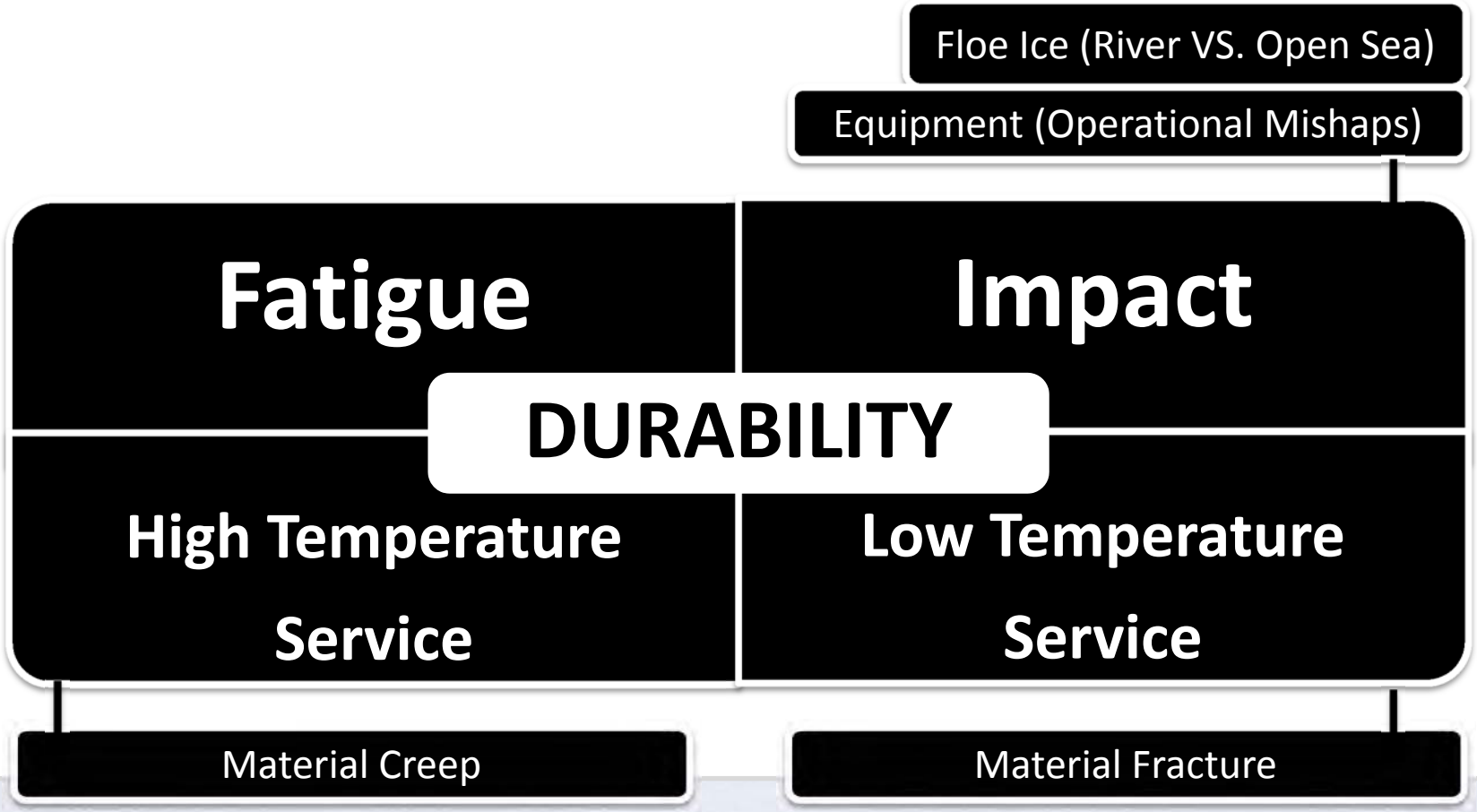
  (b) the performance of a structural system or component is considered unsatisfactory for life-safety reasons (i.e. a "strength" limit state; such as when loading of an element unreasonably approaches the ultimate resistance capacity of that element).

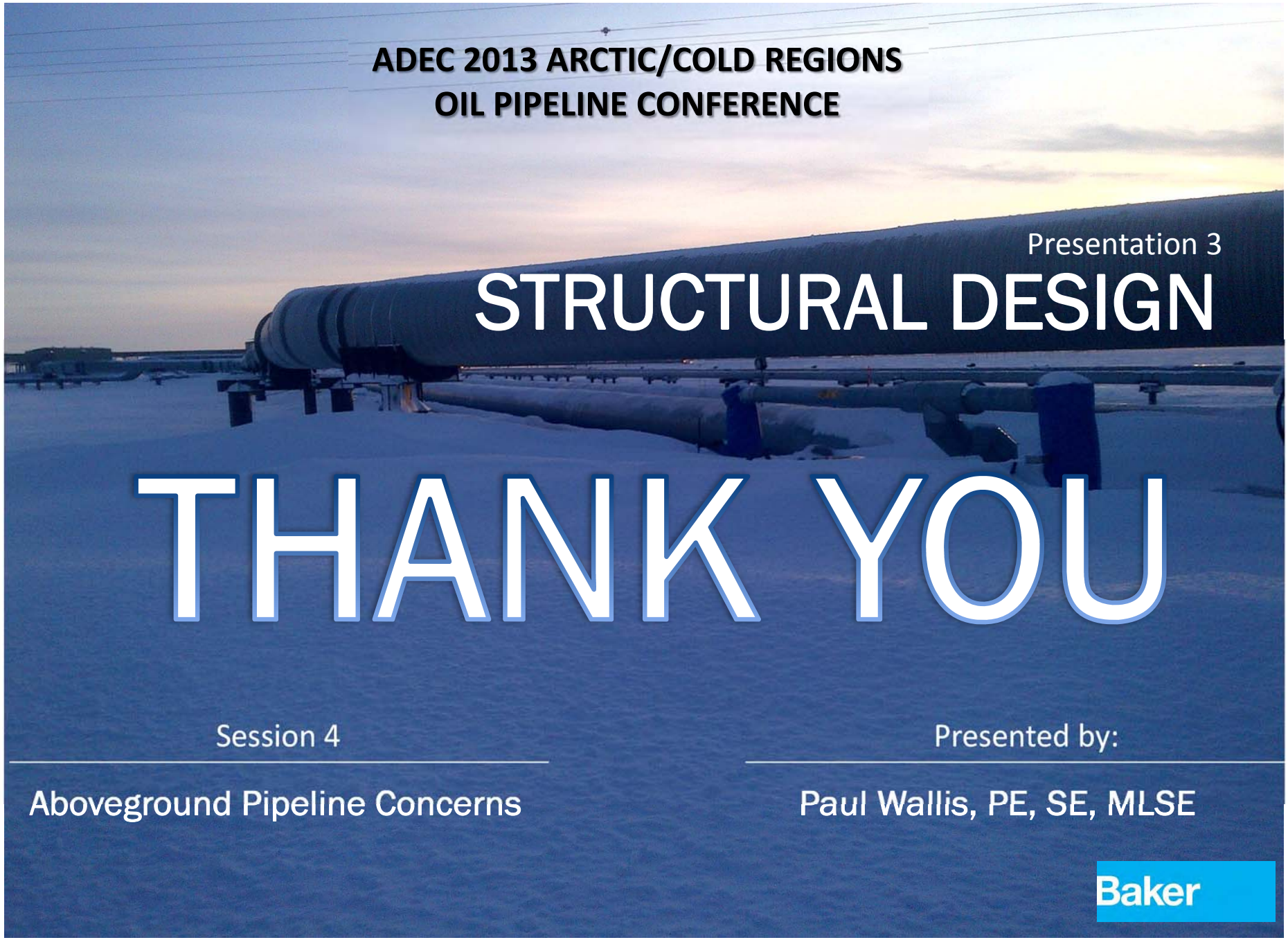
- Both strength and serviceability limit states shall be investigated in the design of all structural systems and components, according to reasonable standards of care.

- The limit states for each structural system and component shall have uniquely developed and well-accepted factors of safety associated with their designs; which will be dependent on properties of the materials, and on the specific code or specification which governs the design of those materials.

c. Pipeline Support Assembly Structural Design

iii.Special Design Considerations





ADEC 2013 ARCTIC/COLD REGIONS OIL PIPELINE CONFERENCE

Presentation 3

STRUCTURAL DESIGN

THANK YOU

Session 4

Aboveground Pipeline Concerns

Presented by:

Paul Wallis, PE, SE, MLSE

Baker

APPENDIX Q

LIMIT STATES DESIGN OF ARCTIC PIPELINES

ExxonMobil Development

Limit States Design of Arctic Pipelines

Alaska Department of Environmental Conservation

2013 Arctic/Cold Regions

Oil Pipeline Conference

Robert Appleby, Mike Cook

ExxonMobil Development Company

EM Pipeline Development Experience

ExxonMobil Development

- ExxonMobil (EM) has designed/built challenging pipelines for 40+ yrs
  - TransAlaska Pipeline (TAPS), Mobile Bay, Chad, Sakhalin I, Papua New Guinea (PNG)
- As TAPS designer, EM-led project team developed heat pipe vertical support member concept enabling 'warm' pipeline to operate without impacting permafrost

EM Pipeline Development Experience

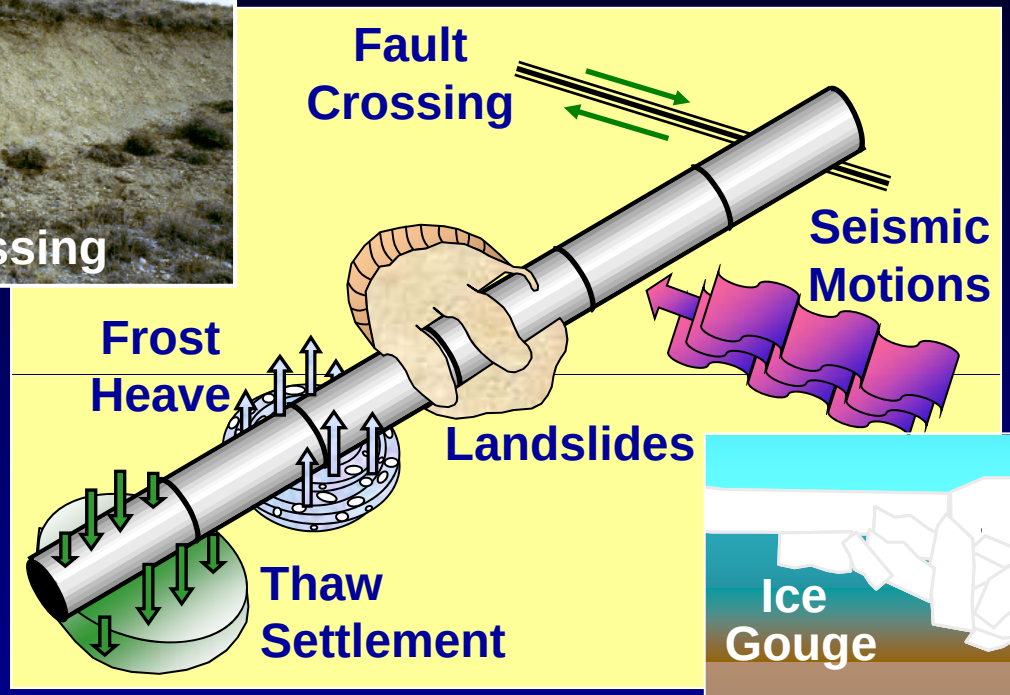
ExxonMobil Development

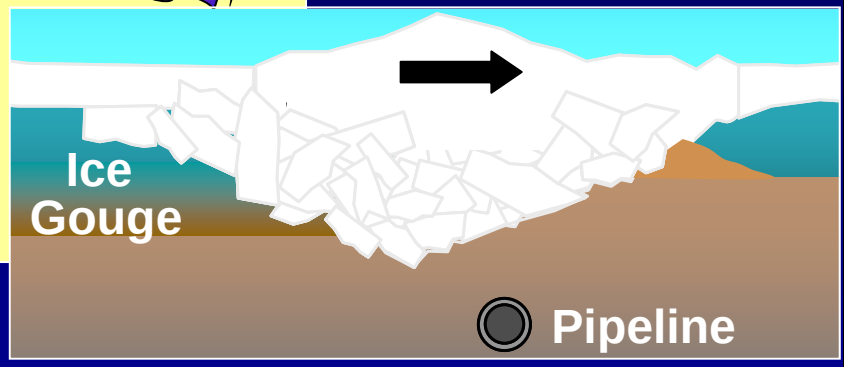
- In 80s/90s, EM focused on HPHT pipelines in both US & UK
- Since 2000, EM and partners have designed buried chilled gas pipelines in permafrost, and executed projects in Sakhalin (seismic, ice gouging), in PNG (mountainous, seismically active), and now Point Thomson
- EM and partners have also designed and installed deepwater pipelines in W. Africa and Gulf of Mexico

Today's presentation highlights considerations for pipelines where ground deformations may be significant

Potential Causes of Pipe Deformation Once In-Service

ExxonMobil Development



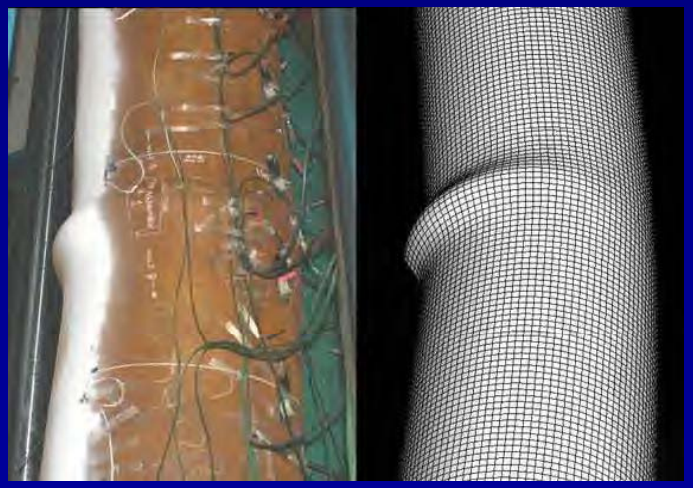


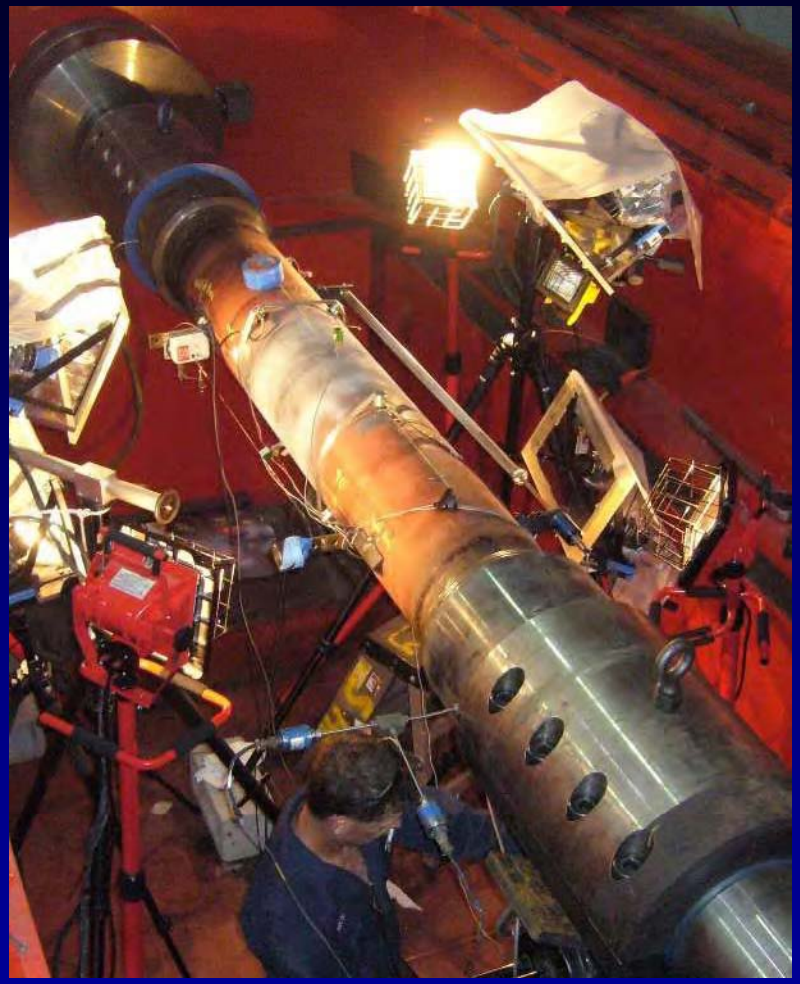
- Short sections of pipelines in arctic or seismic regions may be subjected to deformations that induce longitudinal strain above yield
- To accommodate, designer must understand mechanisms and magnitudes of potential deformation and how much strain both pipe and welds can withstand without loss of containment

Limit State Design for Arctic Pipelines

ExxonMobil Development

- Arctic pipelines may be subjected to strains caused by ground deformation or movement of supports
- Failure modes of interest: buckling and tensile fracture of welds with imperfections
- Susceptibility to each failure mode addressed by quantifying demand and capacity
- Strain-based design: Complementary to conventional design with capacity and demand for longitudinal loads characterized as a function of applied strains





Primary Limit States of Interest

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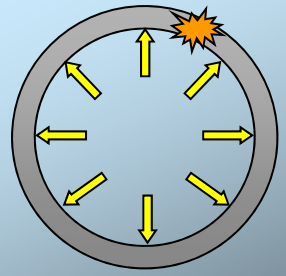
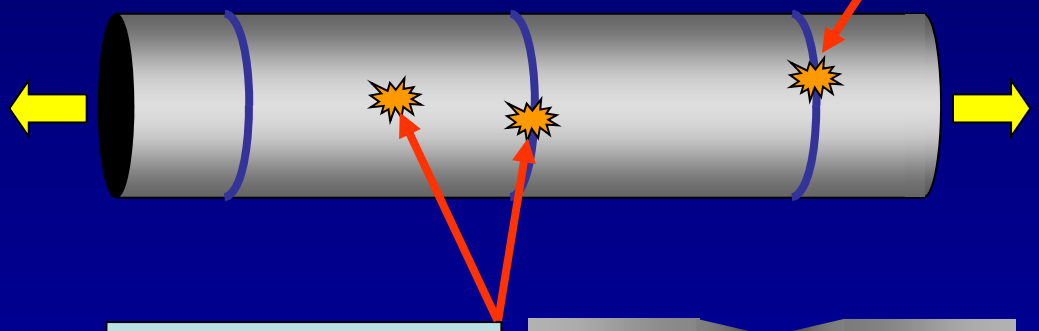
Conventional

Internal Pressure Failure Mode

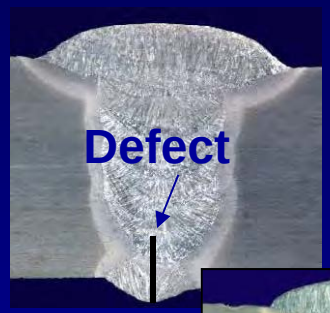


Strain-Based Design Failure Modes



Ductile Fracture at weld

Example of failure in full-scale pressurized test with machined defect



Plastic Collapse in weld or base pipe

Other limit states also considered, including buckling

Designing for Large Deformation (Strain-based Design Limit States)

ExxonMobil Development

Consistent Design Goal: no release of contents to environment

- **First step is to set minimum wall thickness using conventional design approach (limiting hoop stress to 72% (or 80%) of SMYS). Wall thickness may be further increased to ensure adequate strain capacity if extreme deformations occur at isolated pipeline sections**
- **For sections of pipeline potentially subjected to large deformation, it is necessary to ensure that the maximum longitudinal strain demand (how much strain a section of pipeline could be subjected to) is less than the longitudinal strain capacity (how much strain a section of pipeline can take without loss of containment) with adequate safety margin**
- **Strain demand estimated based using large displacement non-linear pipe-soil interaction model with representative stress-strain properties of pipe and load-displacement properties of soil**
- **Strain capacity derived from finite element models of pipe-weld system based on extensive full-scale pressurized tests using comprehensive set of small-scale material property tests, then ultimately verified by limited full-scale pressurized testing with project pipe**
- **Monitoring pipeline deformation during operations often required**

Design Process for Large Deformations

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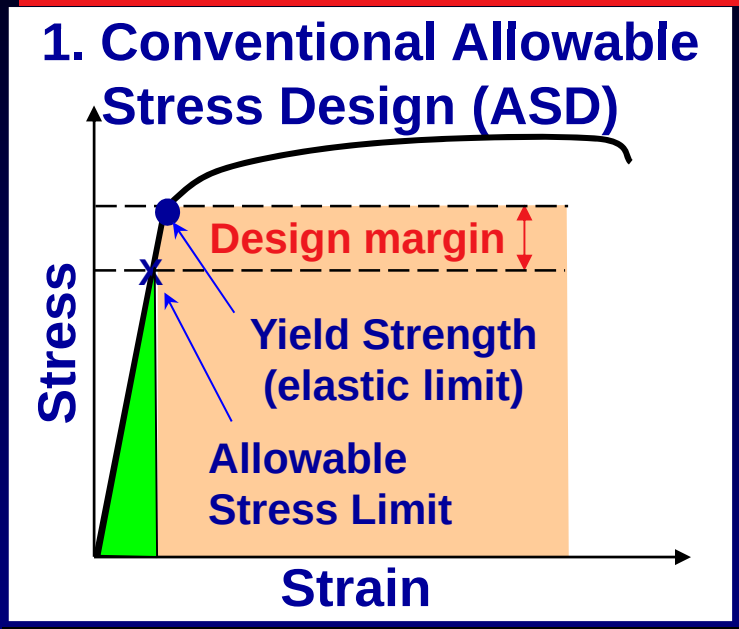
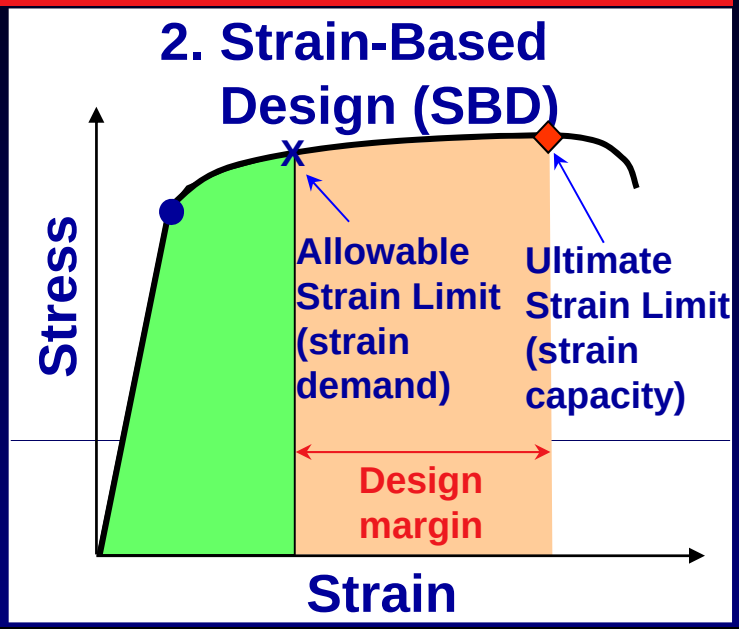


If Pipe Subjected to Large Deformation



Allowable Stress Design		Strain-Based Design
• Stress due to internal and external pressure loads • Loads impact entire pipeline	Primary Considerations	• Longitudinal strain caused by deformation from ground movement • Infrequent; isolated to short segments of the pipeline
• Avoid pipe yielding	Focus	• Avoid tensile rupture and compressive wrinkling/buckling
• Limit hoop stress to fraction of yield strength • Limit combined stress to fraction of yield strength	Design Criteria	• Limit longitudinal tensile strain demand to fraction of strain capacity • Limit longitudinal compressive strain to avoid local buckling

Simplified Strain-Based Design Process

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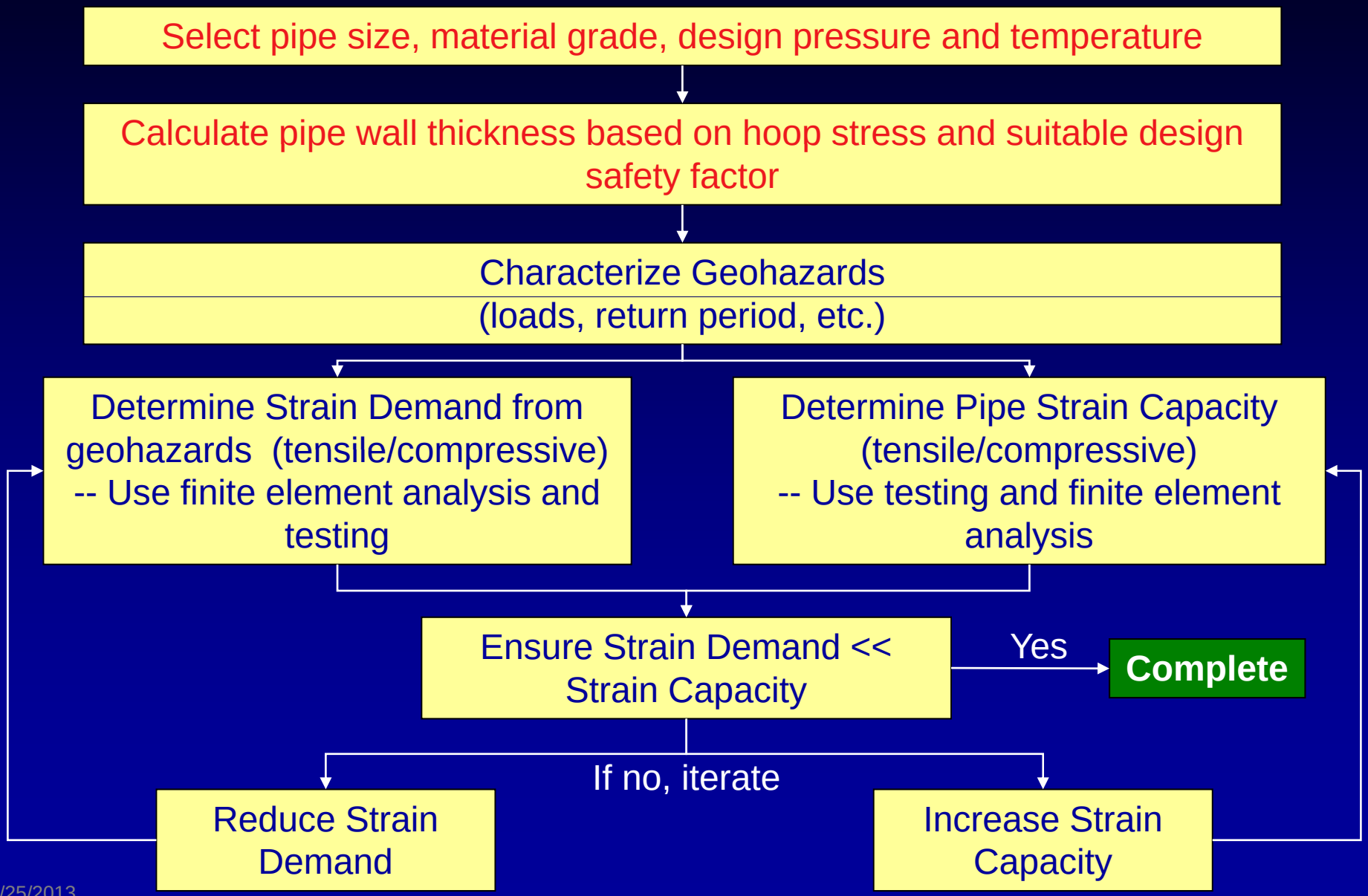

Example: Buried Onshore Arctic Pipeline

ExxonMobil Development

- **For gas pipelines buried in permafrost**
  - Route data important and expensive to obtain
  - Temperature of ground and pipe contents important
  - Significant pipe/soil relative displacement possible
    - + Frost heave - pipe moves up as ice forms
    - + Thaw settlement - pipe moves down as ice melts
- **Heave & settlement displacement-controlled loads**
  - Evaluate using strain-based design if long. strain >.5%
  - Deformation monitoring/maintenance during operation
- **Construction and maintenance**
  - Winter construction often preferred
  - Permafrost can complicate access, ROW preparation, ditching, backfill, and restoration
  - Remote locations create logistics challenges
- **Significant arctic pipeline experience exists**
  - TAPS, TAPS Fuel Gas Line, Norman Wells, Ikhil, Northstar, North Slope, Yamal pipelines

Implications on Codes and Standards

ExxonMobil Development

- **Strain-based design (SBD) limit states are an evolving technology with no uniformly adopted codified approach**
- **Designing for large ground deformations relatively complex and dependent on local conditions and pipeline design and operating parameters**
- **Approaches for estimating longitudinal strain capacity have been developed. Full-scale validation using pressurized tests in various stages of completeness. Codification of these approaches beginning**
- **Value in both deterministic and probabilistic approaches to ensure design integrity**
- **Pipelines likely to be subjected to large ground deformation will require more rigorous monitoring to ensure design integrity**

As strain-based design matures, continuing upgrade of industry standards to more fully address SBD warranted

Codes and Standards Work Status

ExxonMobil Development

- Current ASME B31.4 and B31.8 Codes have included references for the use of strain limits since 2003
  - Only functional guidelines provided
  - Maximum strain limited to 2%
  - No design factors identified
  - Active project within B31.8 to develop more specific guidance for Strain-Based Design
- Canadian code (Z662) provides a non-mandatory approach in Annex C, Limit State Design
  - Provides design principles and factors
- ISO 13623: next revision anticipated to expand guidance for strain-based design construction and operation of pipelines
- API 1104 considering strain-based ECA guidance for welds
- API, DNV, and others provide some additional guidance but there is no single “go-to” authority

Codes and Standards – Technical Focus (1)

ExxonMobil Development

- Codes and Standards activities leverage technical considerations addressed by Industry strain-based design projects, including
  - Distinction between SBD requirements for installation and operation
  - Differences when pipeline configuration controlled by imposed displacements or limited by geometric constraints
  - Estimating tensile strain capacity needs to consider:
    - Pipeline geometry (D/t) & Weld imperfection geometry
    - Pipe and girth weld material properties
    - Internal pipeline pressure
  - Estimating compressive strain capacity needs to consider:
    - Pipe geometry (D/t) and imperfections (e.g. ovality)
    - Pipe material properties
    - Presence of girth welds and field bends

Codes and Standards – Technical Focus (2)

ExxonMobil Development

- **Codes and Standards activities leverage technical considerations addressed by Industry strain-based design projects, including**
  - **Impact of longitudinal pipe properties on both strain demand and strain capacity**
  - **Relevant material properties for strain-based design**
    - **Pipe longitudinal yield and tensile strengths**
    - **Uniform elongation and yield to tensile ratio**
    - **Material aging e.g. heating with coating application**
    - **Predictable plastic deformation**
    - **Overmatched welds to avoid strain concentrations**
  - **Sufficient small and large scale testing to ensure adequate margin between strain capacity and strain demand**
  - **Integrity management considerations for SBD pipelines**

Summary and Conclusions

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- Designing pipelines for challenging environments requires careful focus and thorough engineering to ensure design achieves long-term integrity requirements
- SBD methods are being used to meet integrity requirements when pipelines may be subjected to large ground deformations
- Operators implementing SBD technology must recognize that additional design and integrity management requirements are necessary to ensure operational integrity
- US and International Codes and Standards are actively addressing SBD design, installation and operation of onshore and offshore pipelines

APPENDIX R

ABOVEGROUND PIPELINE CONCERNS: WIND-INDUCED VIBRATION (WIV)

Aboveground Pipeline Concerns: Wind-Induced Vibration (WIV)

by

J. D. Hart, P.E., Ph.D.

President

SSD, Inc.

September 18, 2013

Main Discussion Items

- Overview of Pipeline WIV
- North Slope WIV History
- Overview of Current WIV Design Practice
  - Pipeline Structural Dynamics
  - Pipeline Aerodynamics
  - Wind Speed & Direction Statistics
  - Synthesis
  - WIV Mitigation
  - WIV Monitoring

Overview of Pipeline WIV

Overview of Pipeline WIV

- Alaskan North Slope Experiences Steady Arctic Winds Over Flat Topography
- Vortex Shedding Occurs on Aboveground Pipelines
- Sustained, Well-Organized Vortex Shedding Can Lead to Vertical (Cross-Flow) Pipeline Oscillations
- Main Concern is High Cycle Fatigue Damage at Pipeline Girth Welds

Overview of Pipeline WIV

- Pipelines that are Most WIV Susceptible:
  - Smaller Diameter
  - Longer Span Lengths
  - Lighter Contents
  - More Perpendicular to Prevailing Winds
  - Exterior Lines on the “Leading Edge” of Rack

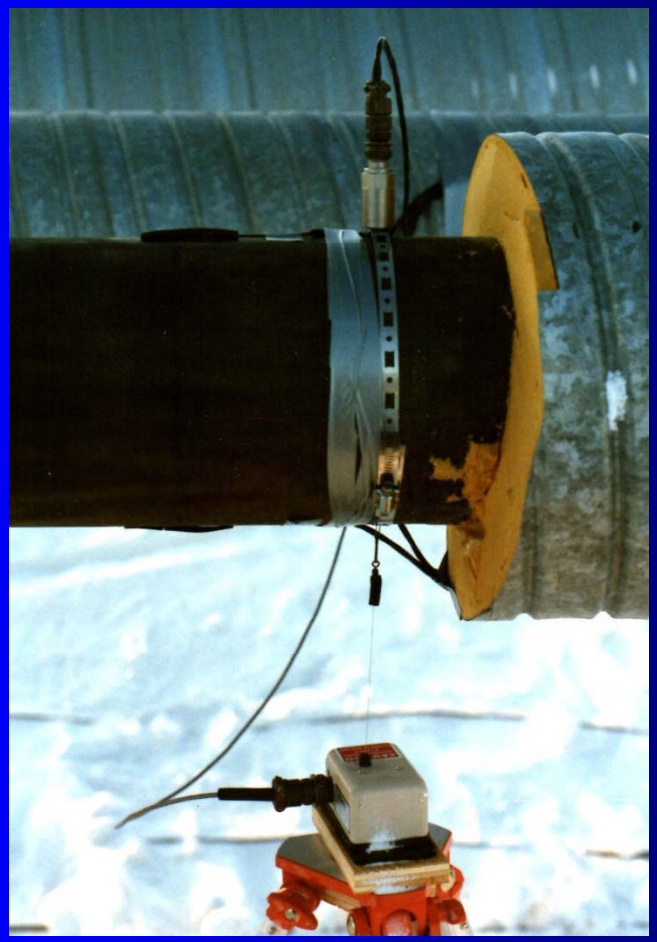
North Slope WIV History

North Slope WIV History

- **Analytical WIV Studies - Multi-Year Program Initiated 1988:**
  - Pipeline Structural Dynamics & Aerodynamics
  - Wind Speed & Direction Statistics
  - WIV Mitigation
- **Experimental Studies:**
  - Fall 1988: Basic Instrumentation on 8-inch Line
  - Lab Testing of Prototype Pipeline Vibration Dampers (PVDs)
  - Early 1990's: Field Trials of Aerodynamic & Structural Mitigation Methods on 8-inch Line
  - 2000: 12-inch and 14-inch Lines Different Azimuth Orientations, with/without PVD Mitigation

Multi-Span Array of Accelerometers,

Displacement Transducers and Strain Gages & Anemometers

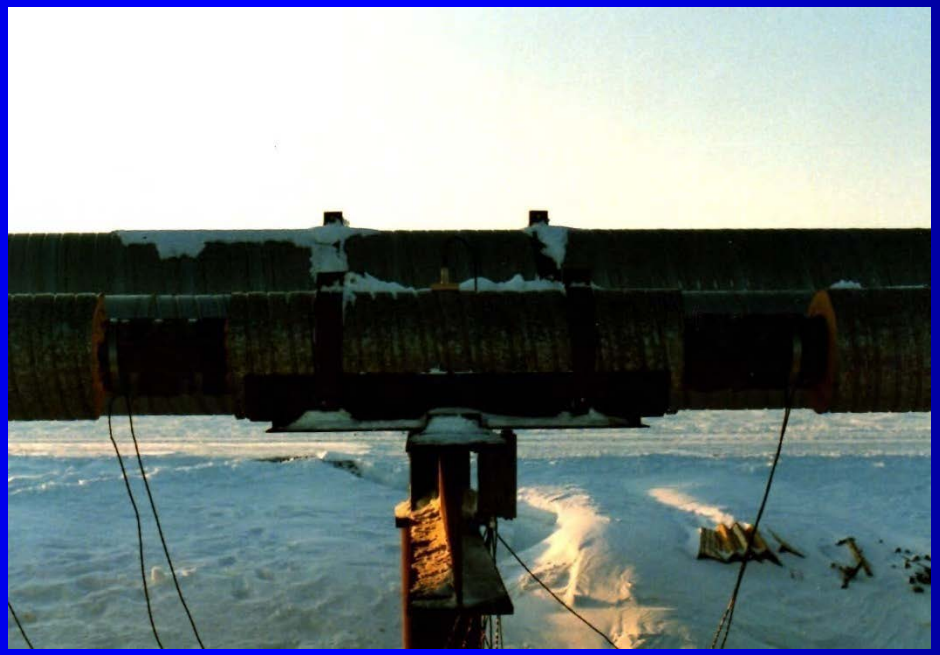


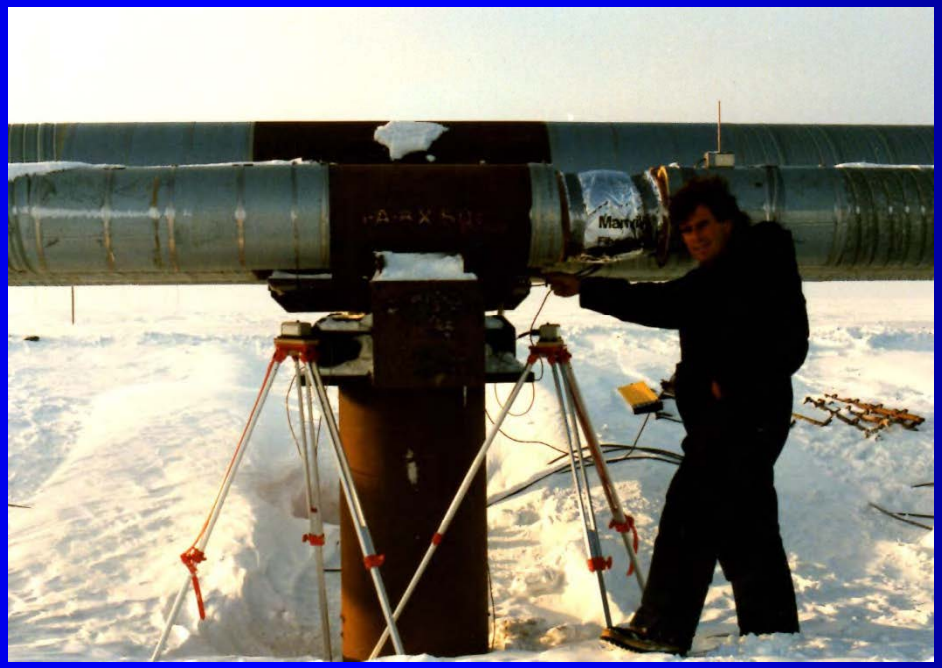
Accelerometers

Displacement Transducers

Strain Gages

Instrumentation at/near Supports and Anchor





Prototype PVDs

North Slope WIV History

Pipeline Vibration Dampers (PVDs):

- Implementation of PVDs:
  - *Use Triple Tuning for Broad-Banded Mitigation*
  - *Focus on Primary Modes, Dampers at Mid-Span Locations*
- Wide-Spread Installation of PVDs Across North Slope (Estimated > 30,000 Installed)
- Overall Assessment of PVDs:
  - *Well-Accepted by Field Personnel & Review Agencies*
  - *Proven Technology*
  - *Main Drawbacks: Under Pipe Clearance, Shorter Life*

North Slope WIV History

Tuned Vibration Absorbers (TVAs):

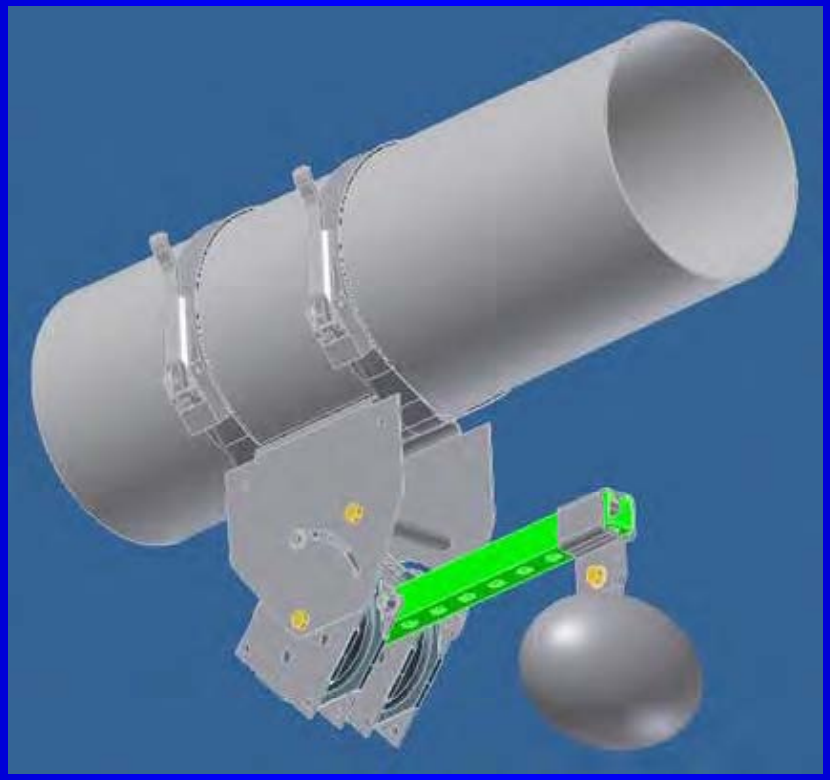
- Development, Lab and Field Testing of Top-of-Pipe Tuned Vibration Absorbers (TVAs)
  - *Avoid Under Pipe Clearance Restrictions, Longer Life*
- Lab & Field Tests Show that TVAs Outperform PVDs
- Routine Implementation of TVAs for New Pipelines
- Development of Below-Pipe TVAs
- Development of Hybrid TVAs (TVA with PVD Weight)

Top of Pipe TVAs

Below Pipe TVAs

LORD Corporation

Hybrid TVAs



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Overview of Current WIV Design Practice

Overview of Current WIV Design Practice

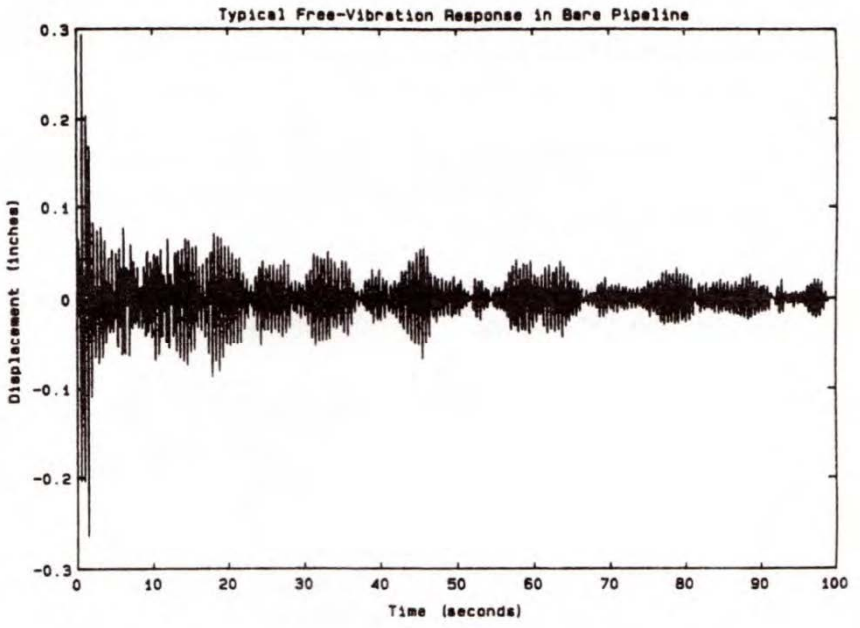
- New & Existing Pipelines can be Evaluated for WIV & Mitigation if Required
- Typical Design Evaluation Considers:
  - Pipeline Structural Dynamics
  - Pipeline Aerodynamics
  - Wind Speed & Direction Statistics
  - Synthesis
  - WIV Mitigation
  - WIV Monitoring

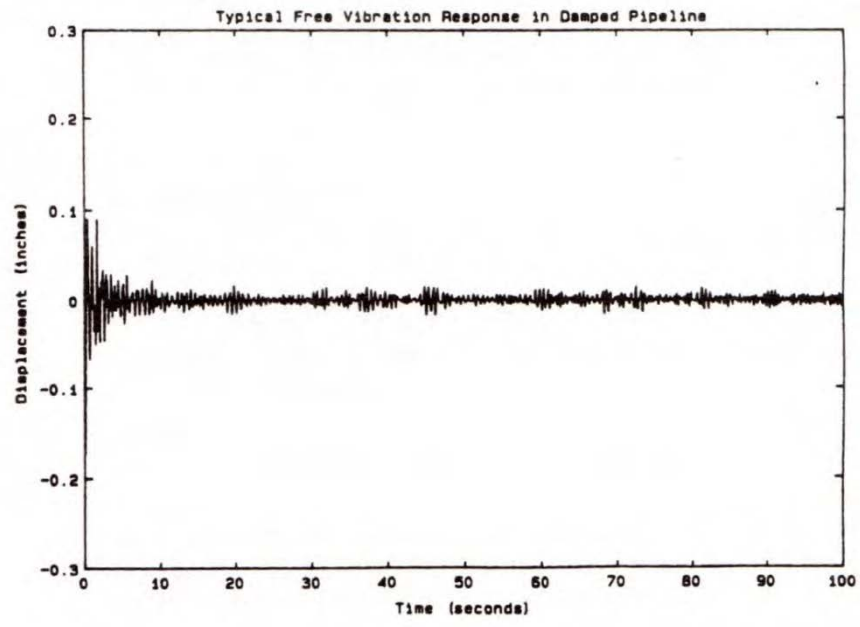
Pipeline Structural Dynamics

Mode Shapes, Frequencies, Damping Ratio

- Key Parameters: Diameter, Span Length, Density of Contents, Wall Thickness, Location of Pipe on HSM Rack
- Dynamics Well-Defined by Field "Pluck" Testing
- Typical Unmitigated Damping Ratios $\xi < 0.5\%$ of Critical
- Generic Configurations:
  - *Typical Cross-Country Pipeline Geometry (Long Straight Runs & Expansion Loops)*
  - *Repeated Span Length in Straight Runs*
- Multi-Span Finite Element Modeling:
  - *Modal Analysis for Mode shapes, Frequencies and Modal Stresses (Eigenvalues)*

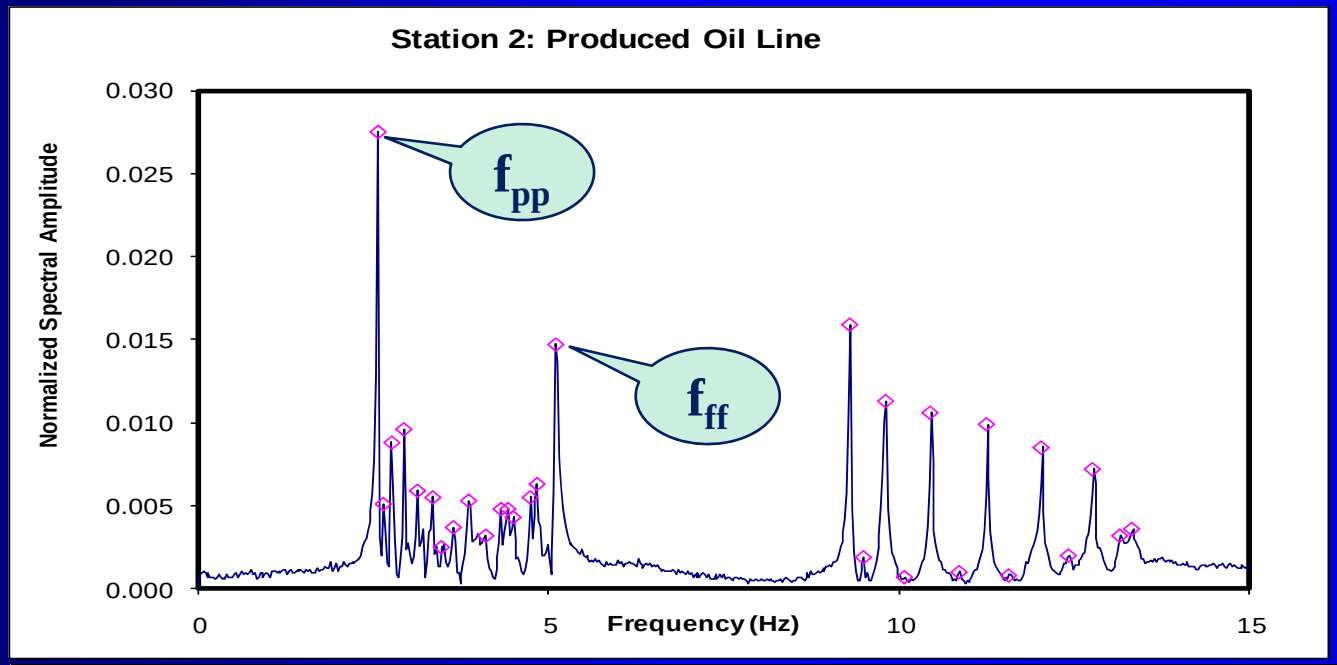
Pluck Testing

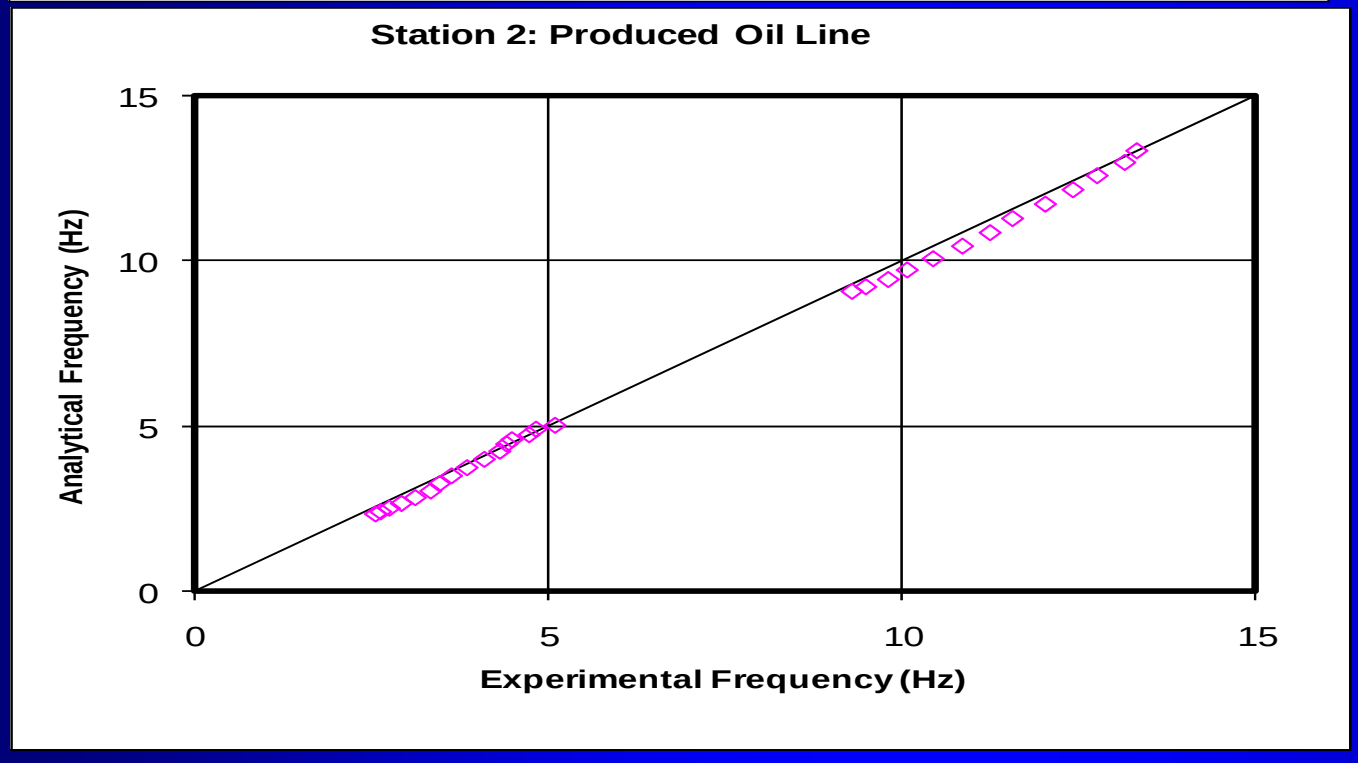




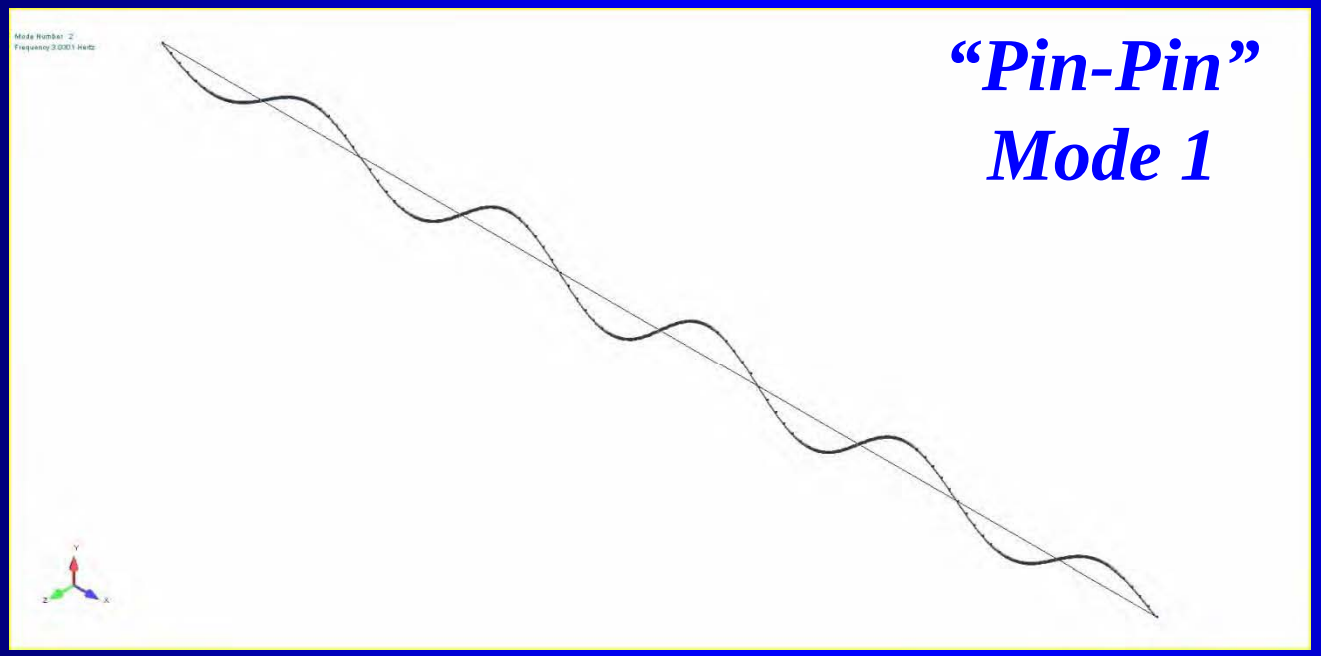
Free-Vibration Decay from Pluck Tests:

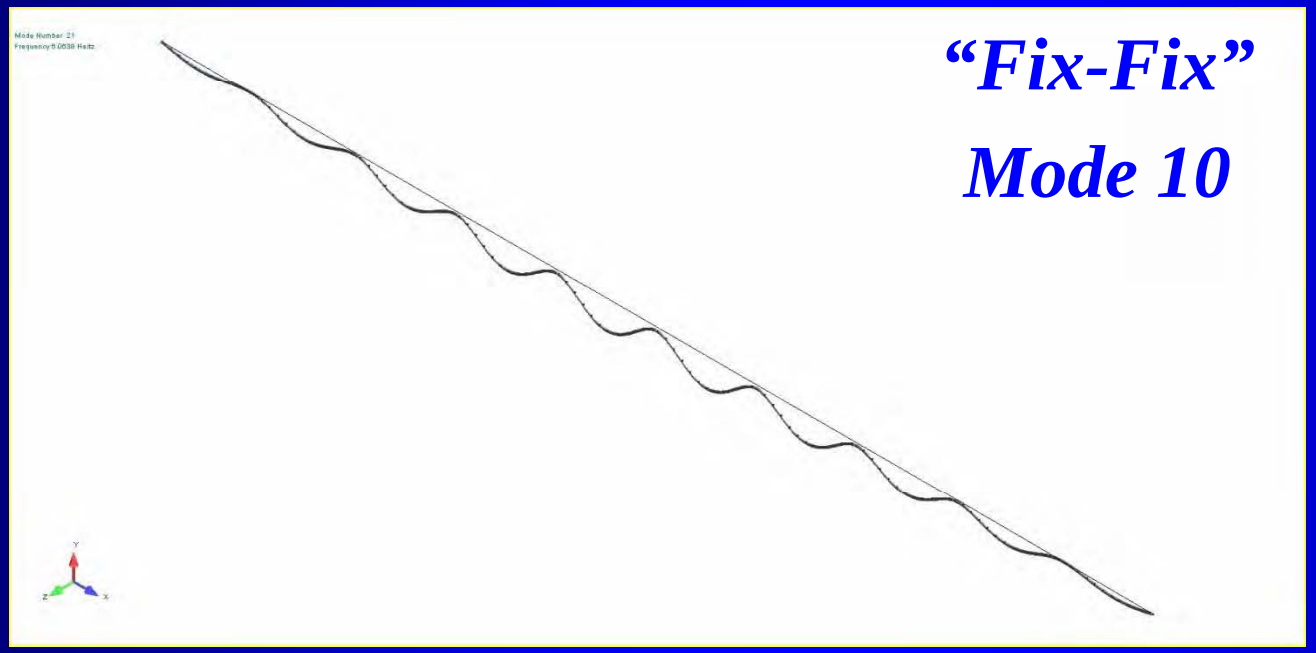
- *Without PVDs*
- *With PVDs*





Sample Results from System Identification: Modal Analysis for Primary and Secondary Modes)





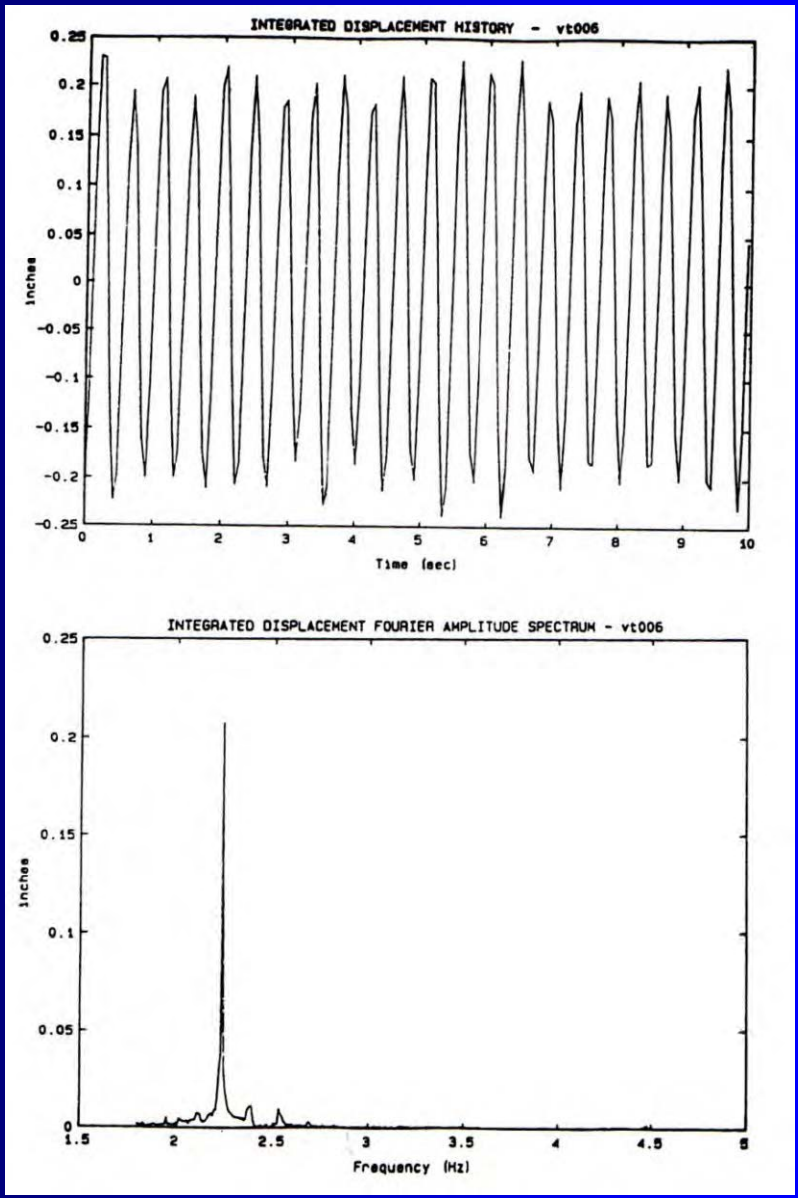
Primary Mode Shapes in 10 Span Pipeline Model

Pipeline Aerodynamics

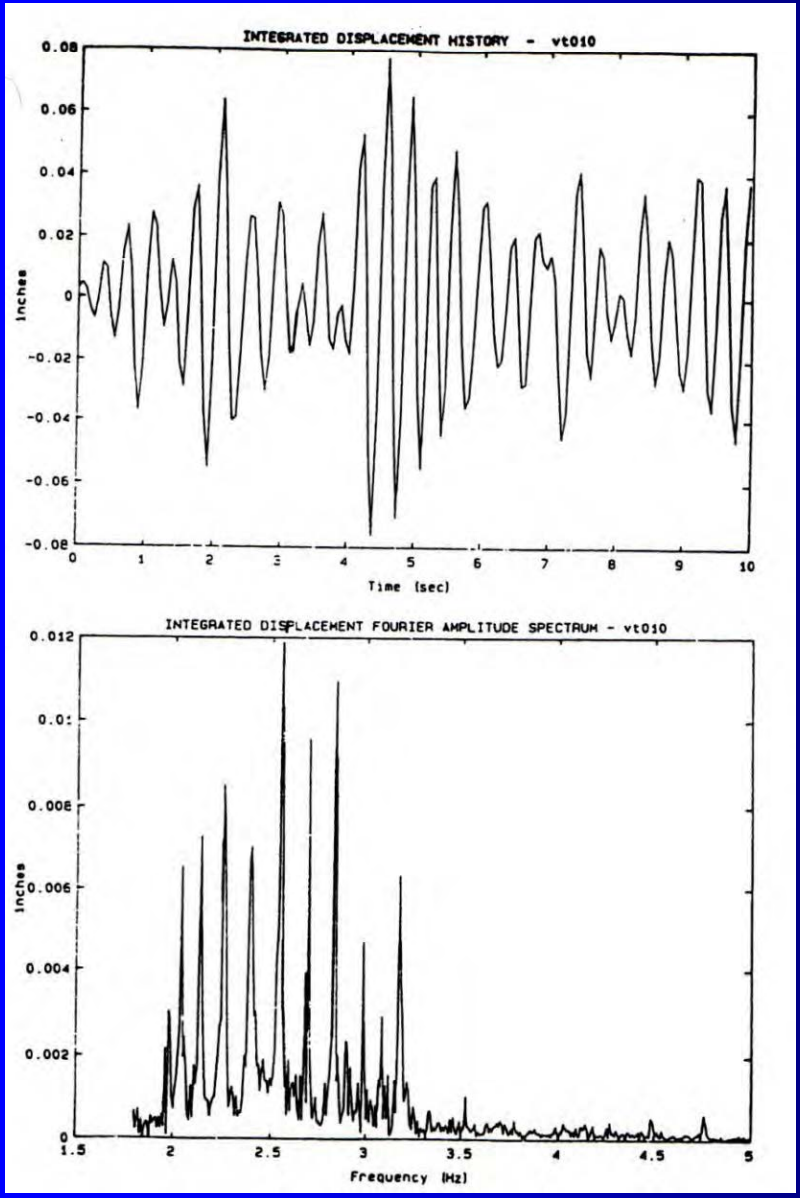
Vortex Shedding Excitation

- Fluctuating Lift Force Depends on:
  - Reynolds Number Regime
    - *Narrow-Banded vs. Broad-Banded Excitation*
  - Turbulence Intensity of Incoming Flow
    - *Upwind Topography, Drifting*
  - Surface Roughness

Narrow-Banded WIV



Broad-Banded WIV

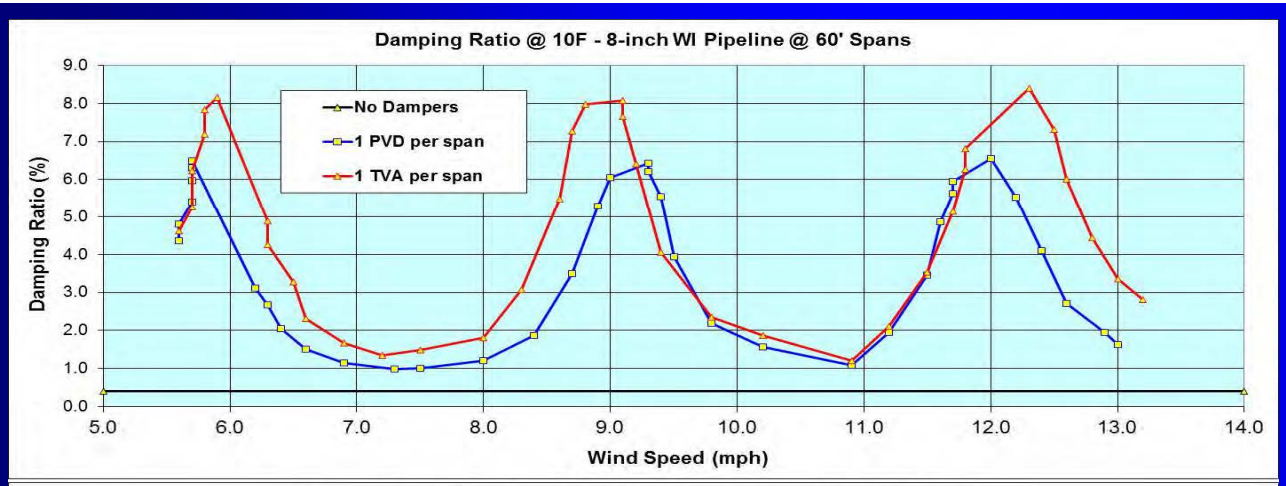


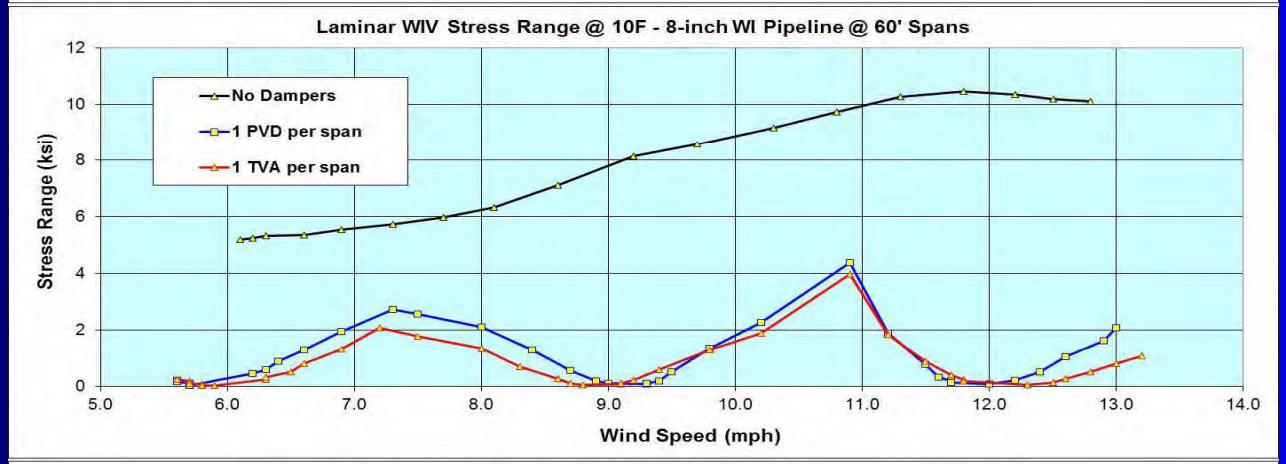
Pipeline Aerodynamics: *WIV Analysis with **EXTRA***

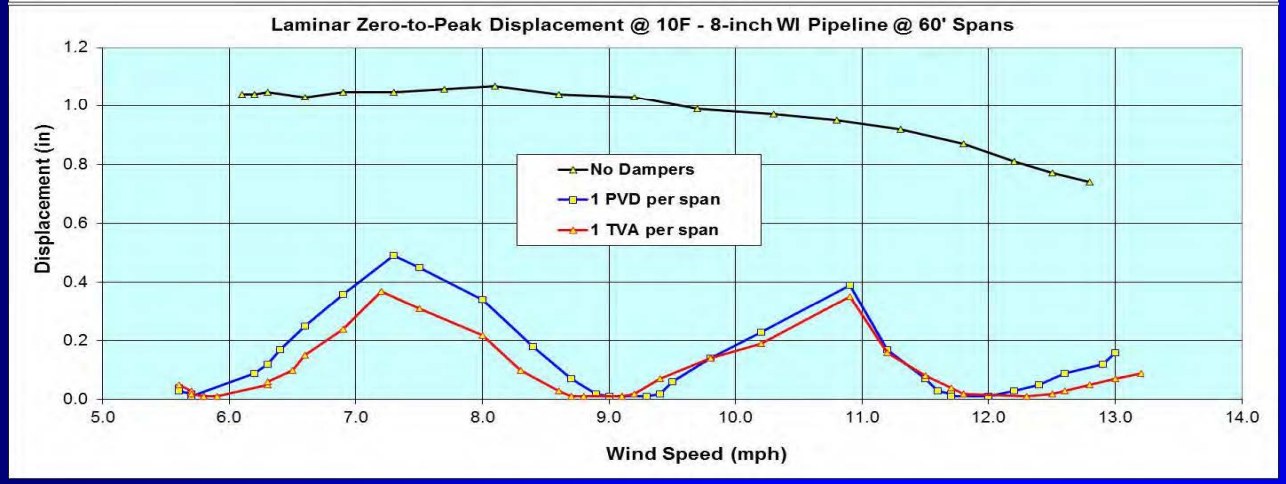
- Program Operates on Mode Shapes from Multi-Span Finite Element Models
- Considers Laminar and Turbulent Incoming (Free-Stream) Wind Conditions
- Assumes Constant Strouhal Number (S=0.2) Relating Vortex Shedding Frequency f_s to Projected Diameter D and Perpendicular Wind Speed U: $\mathbf{f_s = S \cdot U/D}$
- Fluctuating Lift Coefficient Depends on Reynolds Number: $\mathbf{Re = U \cdot D/\nu}$ (ν= kinematic viscosity)

Pipeline Aerodynamics: *WIV Analysis with **EXTRA***

- Predicts Maximum Pipe Displacement and Stress Range Under Resonant, Uni-Modal Conditions Due to Narrow-Banded Vortex Shedding
- Wind Speed & Reynolds Number Range for Each Mode
- Results Valid for Modes with Re Below Critical Value (200,000 Turbulent, 280,000 Laminar)
- Flow Characteristics at High Re Not Well Understood - EXTRA Attempts to Capture Some of the Observed Experimental Data at High Re.

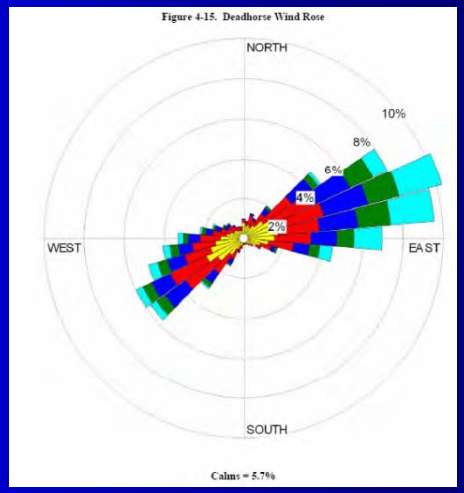






EXTRA Results: Un-damped vs. PVDs vs. TVAs

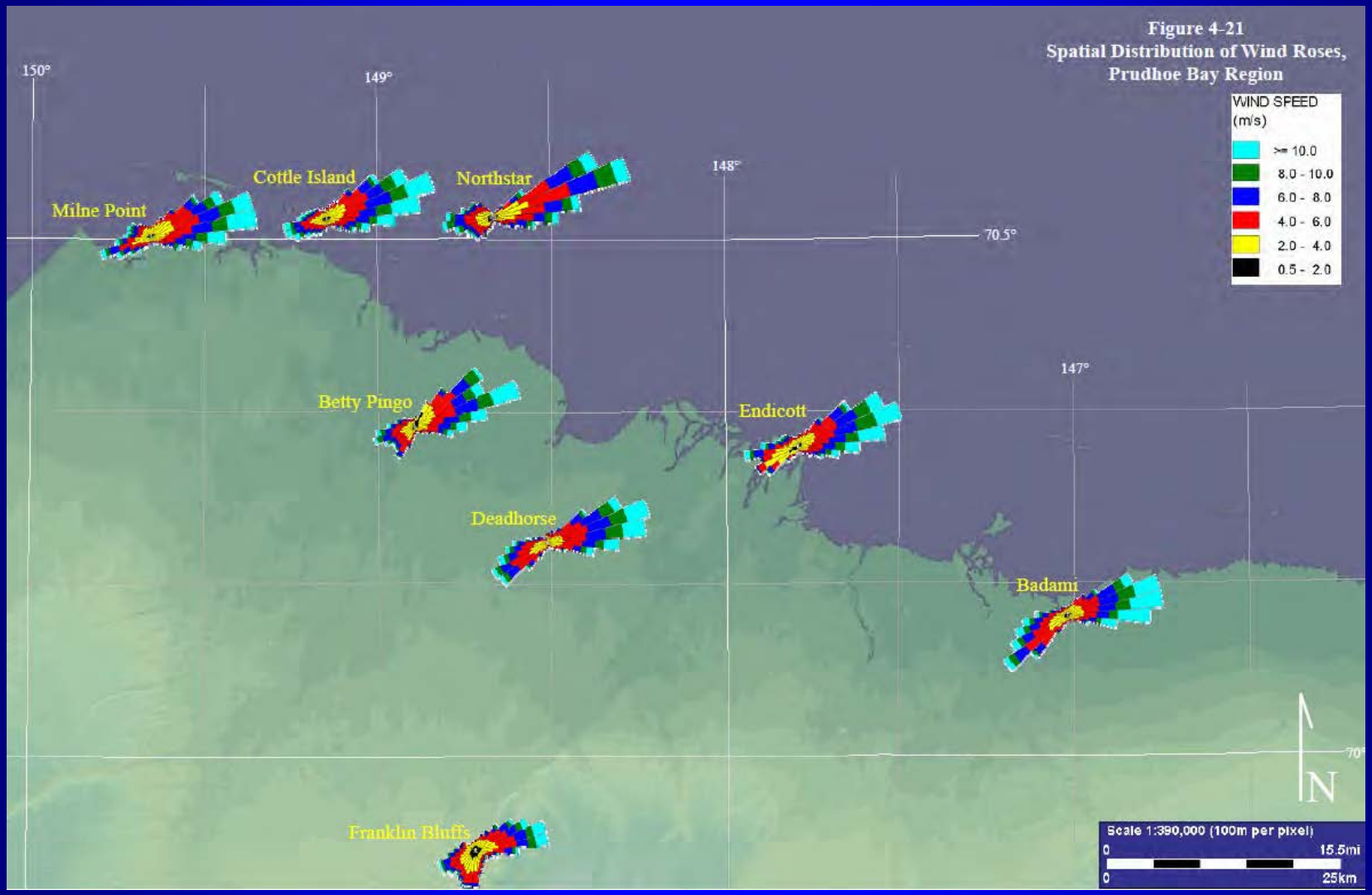
Wind Speed & Direction Statistics



- Characterized with a Wind Rose
  - *Bins of Wind Speed Range*
  - *Bins of Wind Direction Range*
- Used to Estimate WIV Susceptibility Ranking Based on Pipeline Segment Orientation
- Use North Slope Data from MMS at Multiple Stations Across North Slope:

  "Nearshore Beaufort Sea Meteorological Monitoring and Data Synthesis Project" (OCS Study MMS 2007-011)

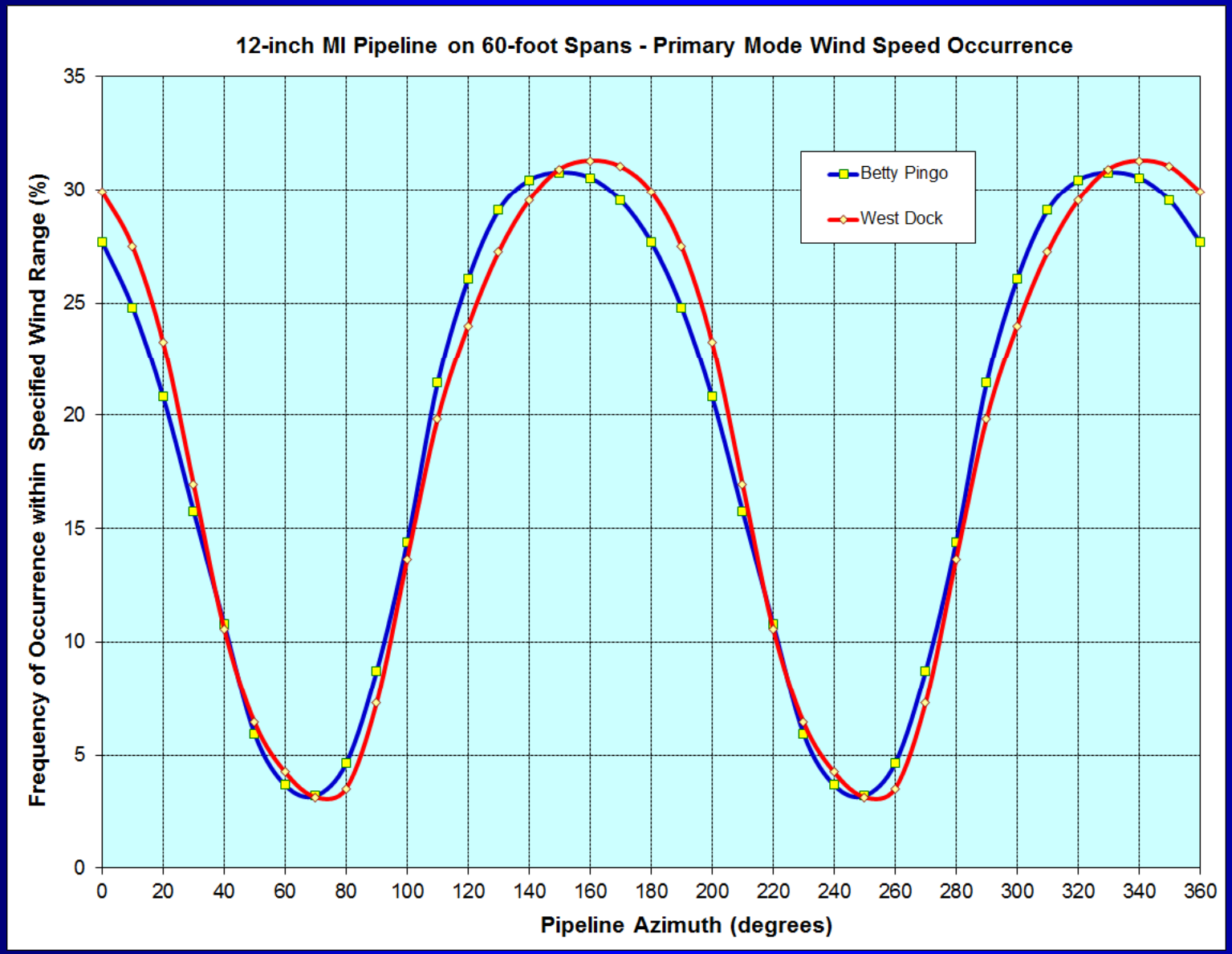
Wind Roses Prudhoe Bay Region



Wind Speed & Direction Statistics

- Perform Various Operations on the Data:
  - *Adjust for Height*
  - *Perpendicular Wind Speed Distribution vs. Azimuth*
- Compare Data from Various Weather Stations
- Use Data from Nearest Station to Characterize Effect of Pipeline Orientation:
  - *WIV Exposure Plots: % Perpendicular Wind Observations Within a Selected Wind Speed Range as Function of Pipeline Azimuth*
  - *Rank Pipeline Segment Orientations Based on Relative WIV Exposure*

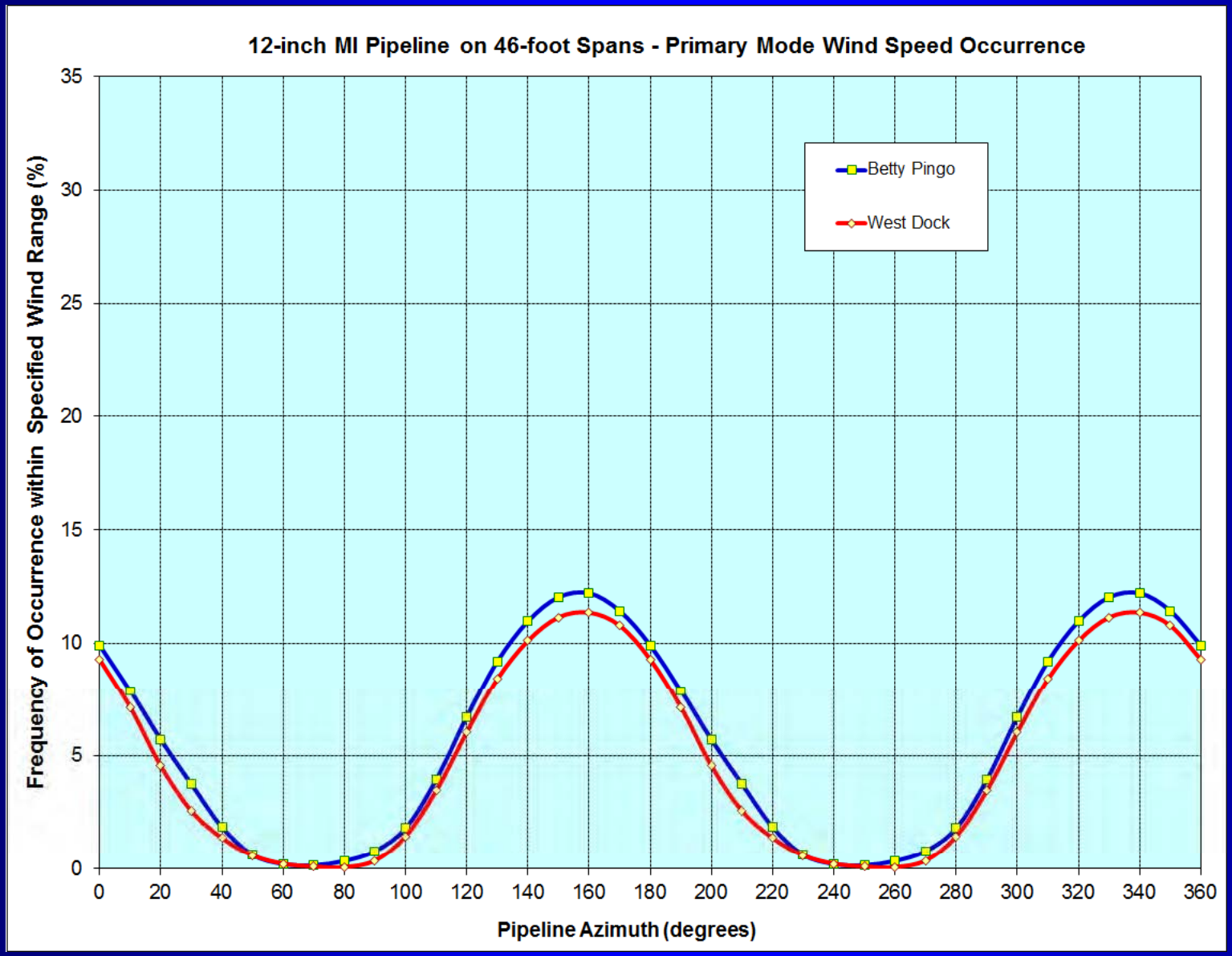
Illustration of Results



12-inch Line on 60-foot Spans

Primary Mode Wind Speed Range ≈11-23 mph

Illustration of Results



12-inch Line on 46-foot Spans

Primary Mode Wind Speed Range ≈19-36 mph

Synthesis

- Design Recommendations Based on:
  - Predicted WIV Displacement/Stress Levels
  - % Modes with Sub-critical Reynolds Numbers
  - Azimuth Orientation of the Subject Line
  - Leading Edge vs. Shielded Position on HSM
  - Previous Experience with Similar Lines
  - Previous WIV Observations for Subject Line
  - Importance of Subject Line

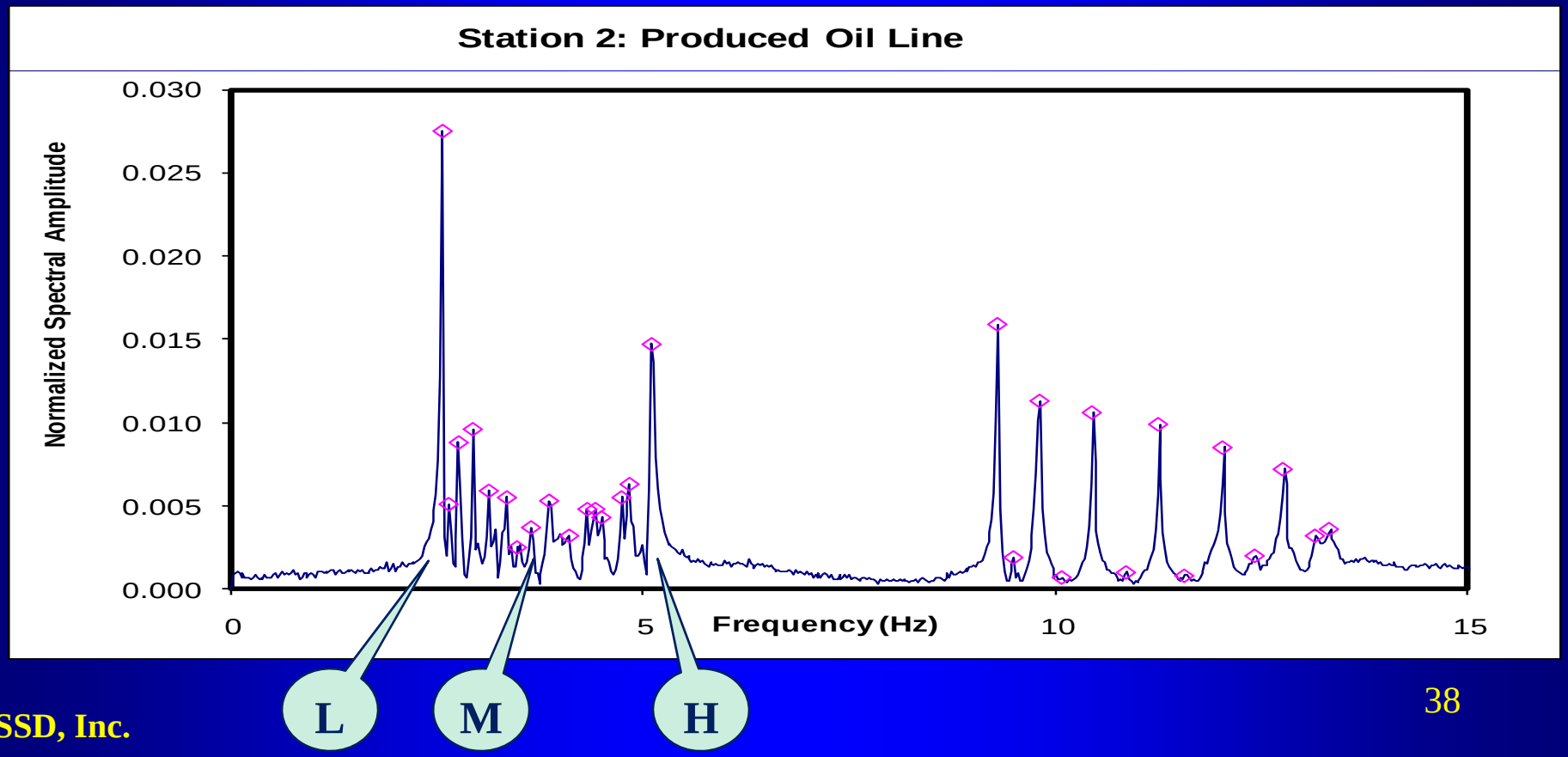
WIV Mitigation

- Auxiliary Mass Dampers (PVDs & TVAs) Provide Best Structural Solution – Increase Effective Damping Ratio Due to Relative Motion Across Elastomer (Hysteresis)
- PVDs Proven by Lab and Field Testing
- TVAs Proven to Outperform PVDs

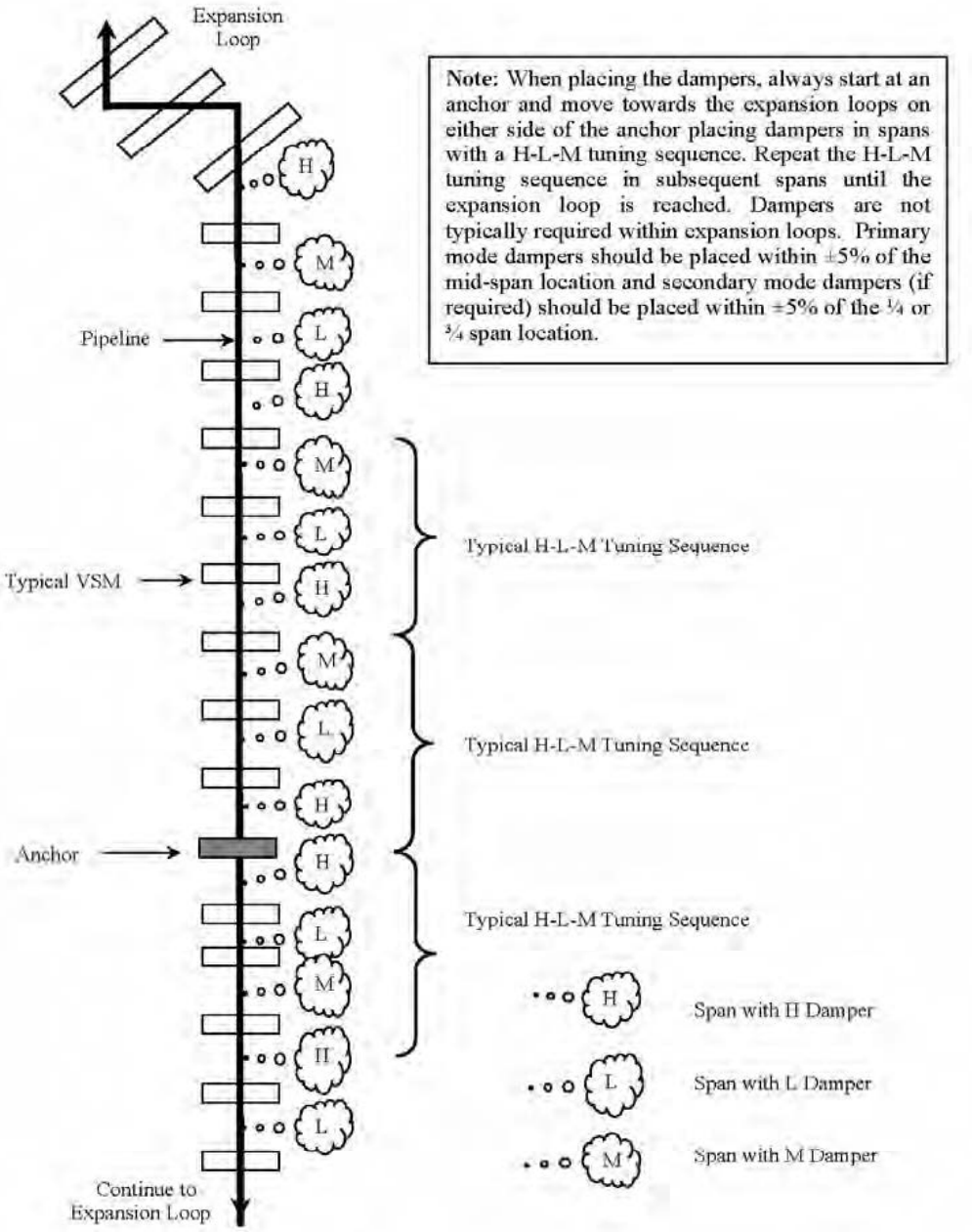
PVDs & TVAs

WIV Mitigation

- Use Triple Tuning and H-L-M Placement Pattern
- Broad-Banded Mitigation
- Spatially Distributed



Standard H-L-M Damper Placement Pattern

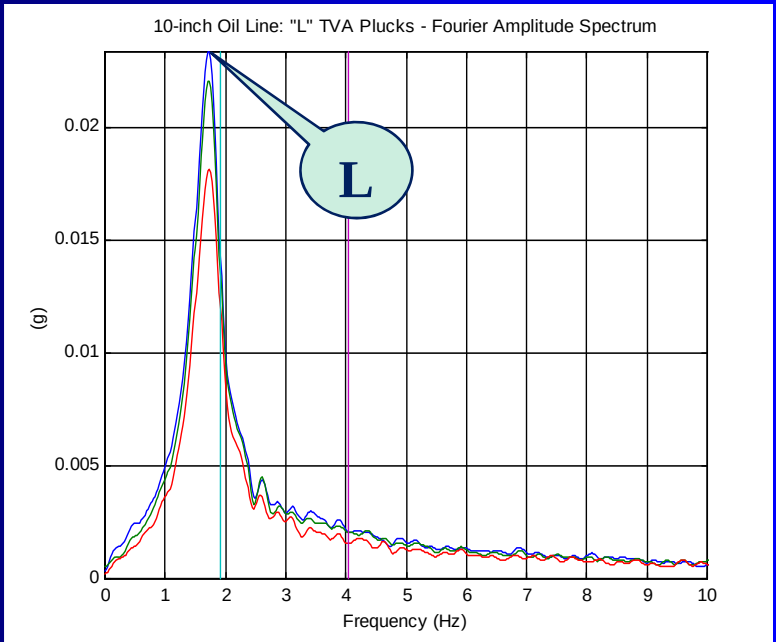


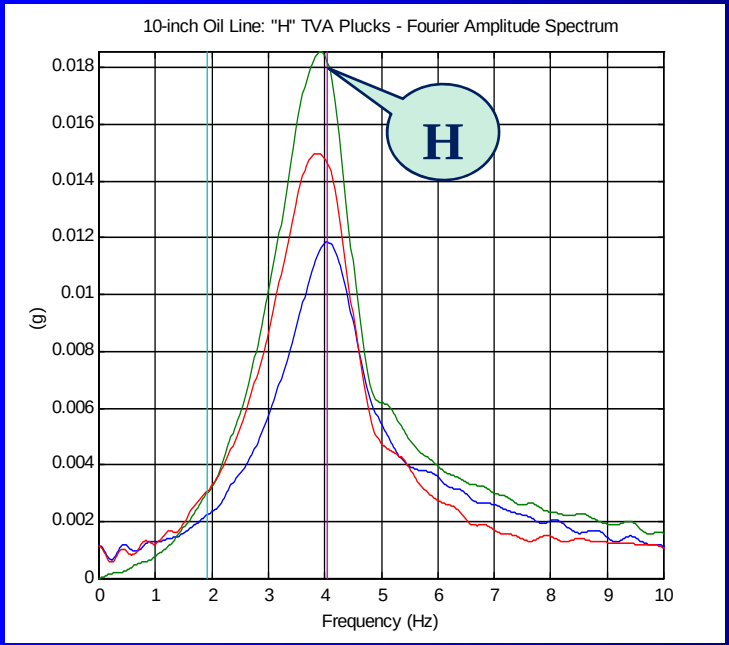
Note: When placing the dampers, always start at an anchor and move towards the expansion loops on either side of the anchor placing dampers in spans with a H-L-M tuning sequence. Repeat the H-L-M tuning sequence in subsequent spans until the expansion loop is reached. Dampers are not typically required within expansion loops. Primary mode dampers should be placed within ±5% of the mid-span location and secondary mode dampers (if required) should be placed within ±5% of the ¼ or ¾ span location.

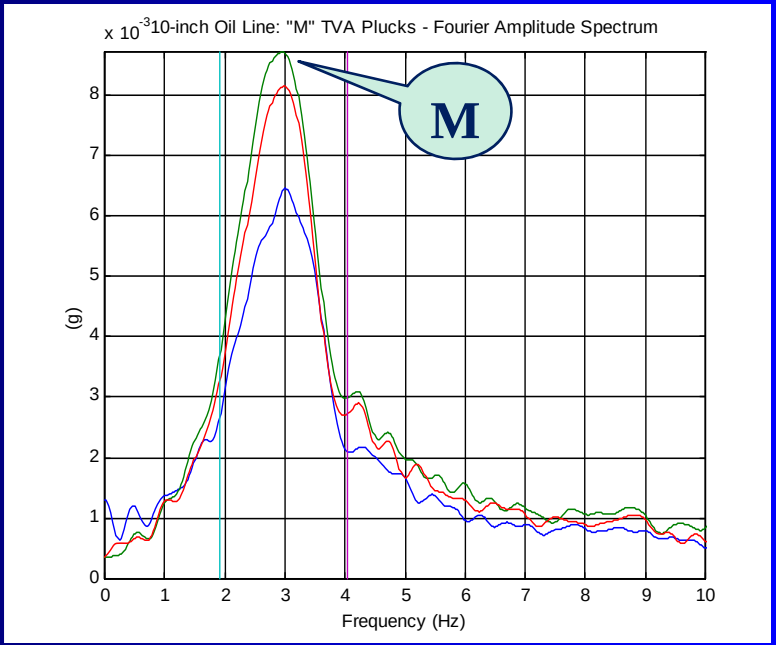
Schematic of Tuned Vibration Absorber Layout

TVA Pluck Tests – Field Verification of Tuning

10-inch Diameter Oil and Gas Pipelines







TVA Pluck Test Results

WIV Mitigation

- Client Decision on Segments to Mitigate:
  - *May not be Practicable to Mitigate all Segments of a Given Pipeline*
  - *Use WIV Susceptibility Ranking Table or Other Criteria to Guide Mitigation Strategy*

WIV Monitoring

- Recommend Monitoring/Visual Observation for Unmitigated Pipeline Segments
  - *Observations During Security Patrols*
  - *Walking Speed Surveys*
  - *Scratch Posts (Displacement Range)*
- Additional Training for Field WIV Observations:
  - *Note Line Name/Number, Date/Time, Location*
  - *Measure Peak to Peak Motion in Multiple Spans*
  - *Estimate Frequency (Timed Cycle Counting)*
  - *Take Video*

WIV Monitoring Scratch Post

WIV Monitoring

- Response to Observed WIV:
  - Review Available Observation Data
    - Be Aware of "Optical Illusion"
  - Use Date/Time to Obtain Wind Speed/Direction Data
  - Estimate Stress Range "*S*" Using Modal Stress
  - Evaluate/Screen Stress Levels
  - Mitigate or Continue Monitoring

Thank You!

APPENDIX S

CORROSION UNDER INSULATION PREVENTION AND INSPECTION

Corrosion Under Insulation

Prevention and Inspection

CUI Definition

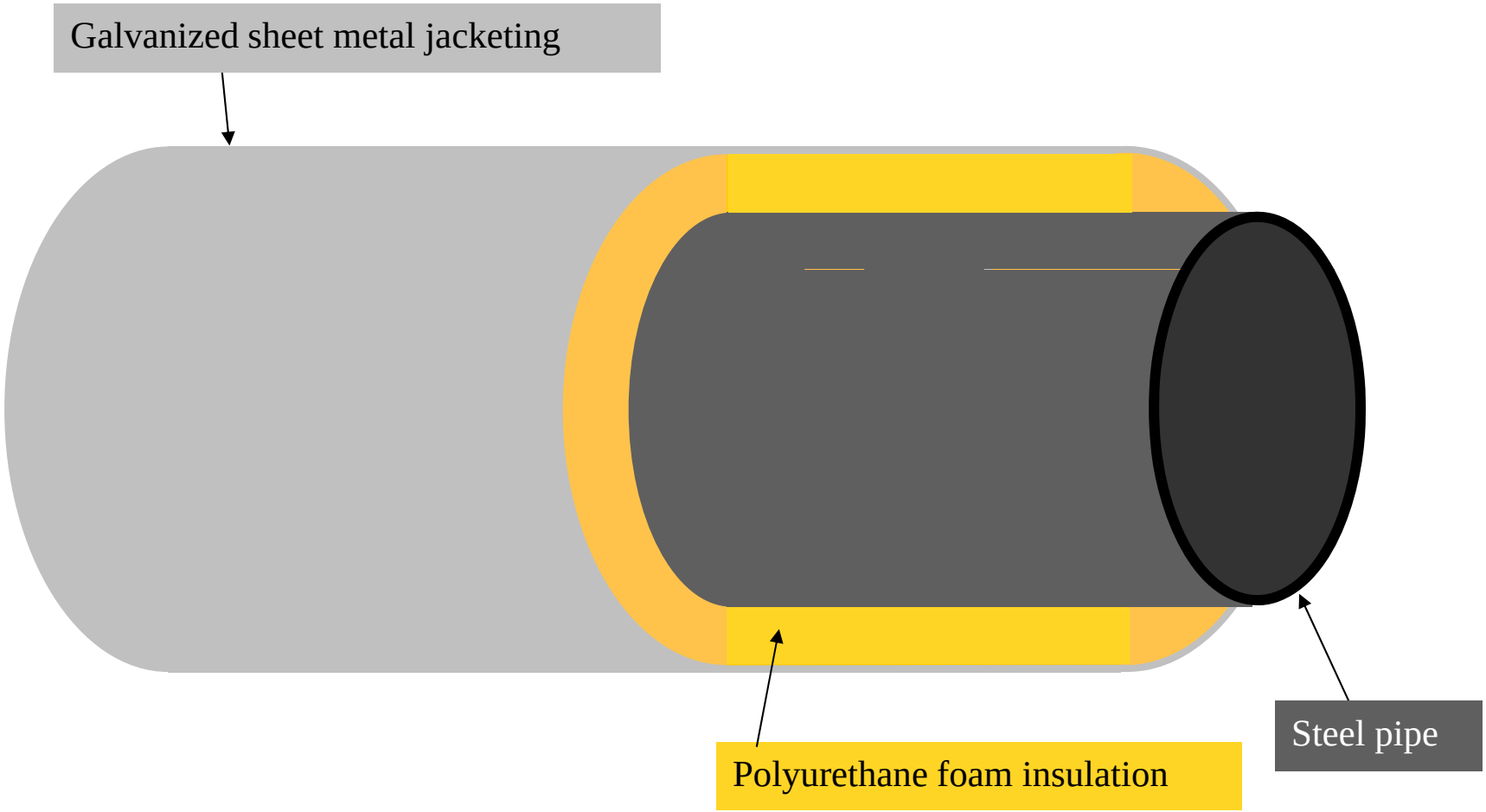
Corrosion Under Insulation (CUI)

- Corrosion that occurs under insulation in the presence of water and oxygen
- The corrosion rate may be accelerated by the presence of other species, such as chlorides (from insulation or marine environments)

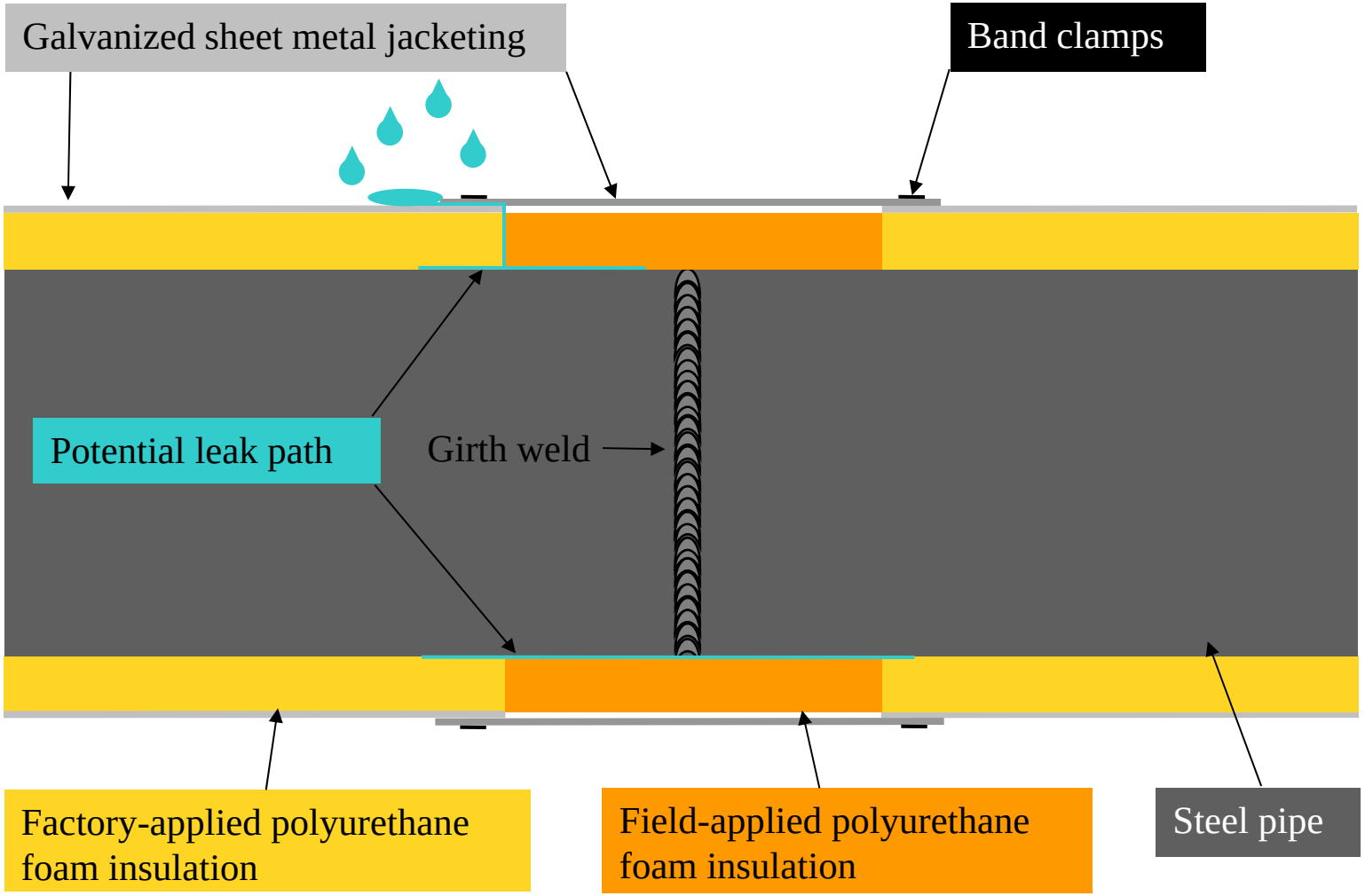
Corrosion Under Insulation

- Affects
  - piping
  - tanks
  - vessels
- Carbon steel
  - susceptible between 25°F and 350°F
  - susceptible above 350°F in intermittent service
  - general corrosion
  - pitting
- Stainless steel
  - susceptible between 140°F and 400°F
  - pitting
  - stress corrosion cracking

Insulation System



Schematic of Water Ingress



Saturation of Insulation

WATER ENTRY POINT AT BUCKLE

DIFFUSION PROFILE THROUGH
"CLOSED CELL FOAM" INSULATION

CUI Example

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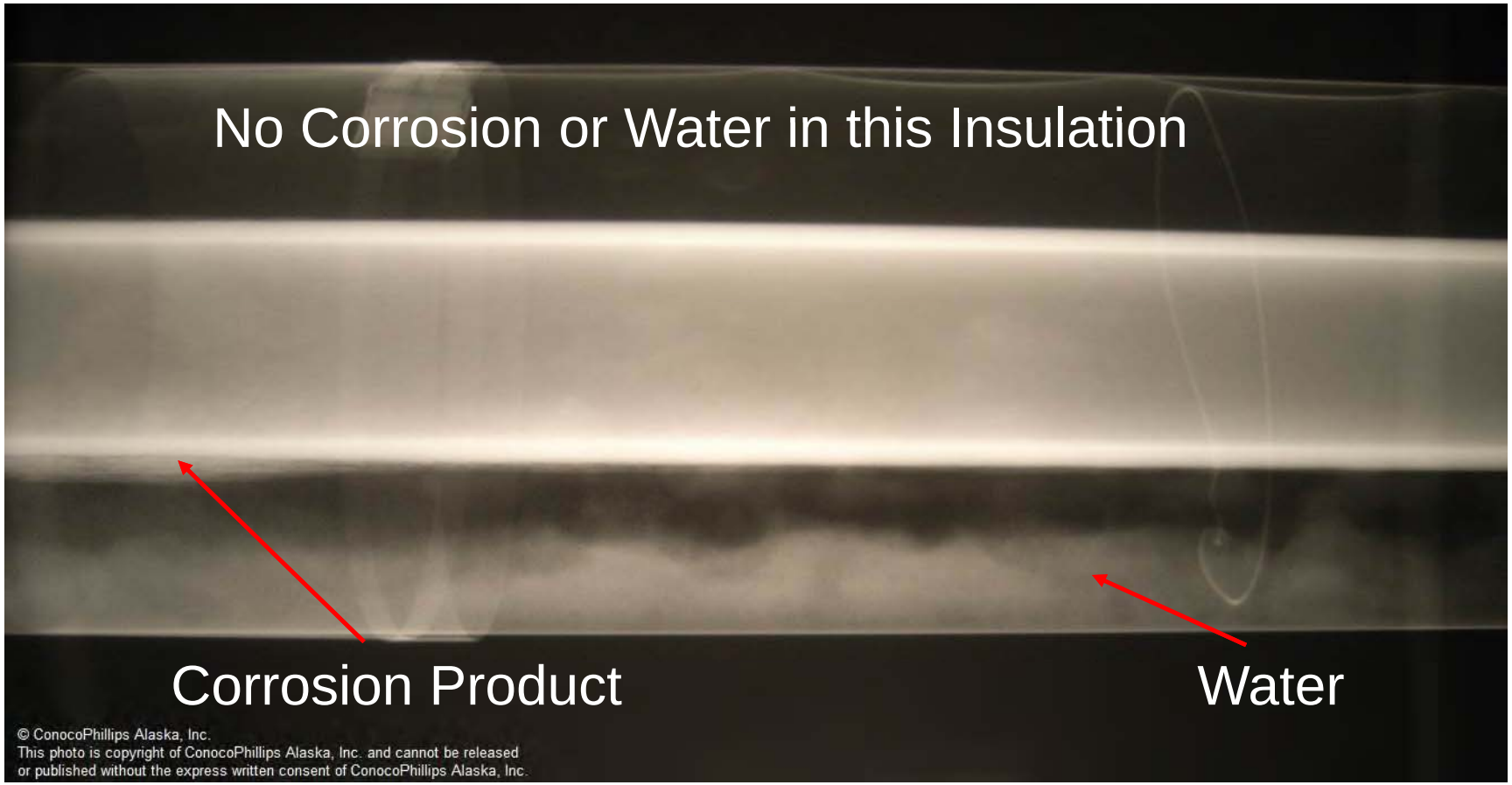
CUI Inspection Technologies

- In Line Inspection (smart pigging)
  - Full coverage quantitative inspection for corrosion
  - Does not identify wet insulation
- Automated Tangential Radiographic Testing (ATRT)
  - Motorized Crawler with real time imaging
  - Detects wet insulation and corrosion at the 6 o'clock position
- Tangential Radiographic Testing (TRT) with C-Arm
  - Handheld real time imaging
- Manual Radiographic Testing (RT)
  - Film exposure
- Infrared Thermography (IR)
  - Rapid screening for wet insulation
- Long-Range Ultrasonic Testing (LRUT)
  - Screening technique for below-grade pipe

RT: Water and Corrosion



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ATRT

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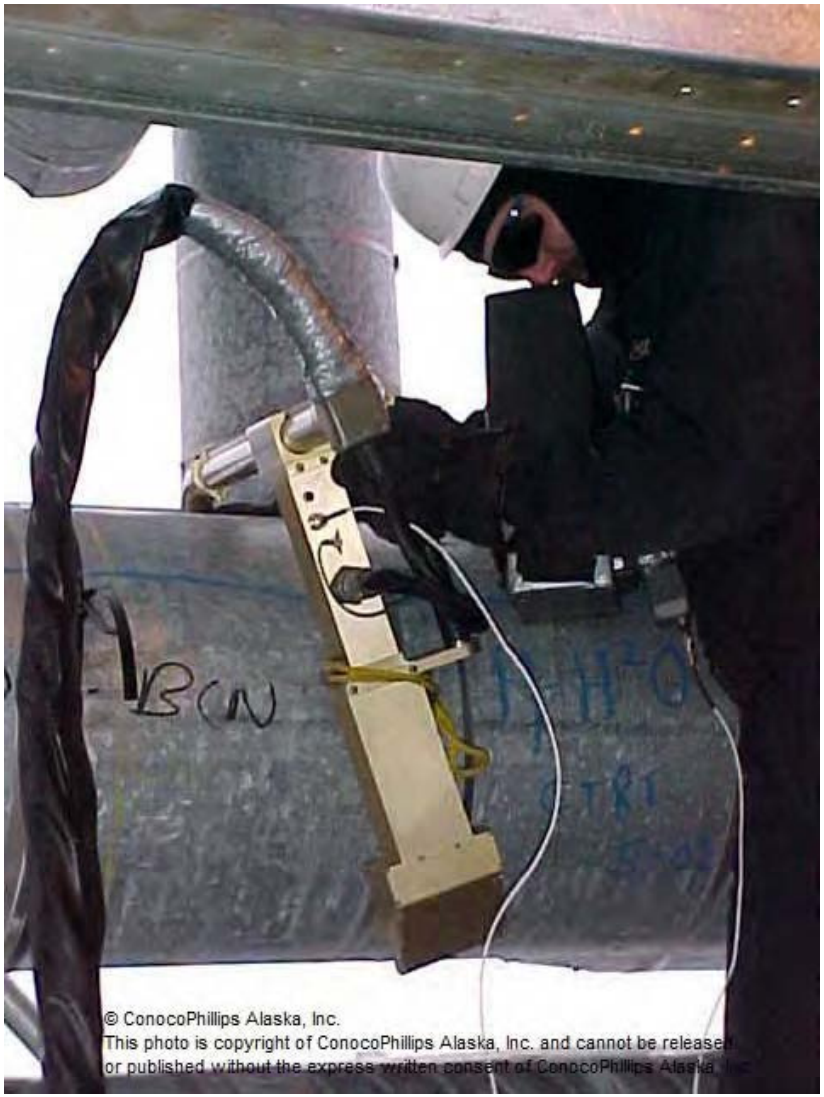
C-Arm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Manual TRT

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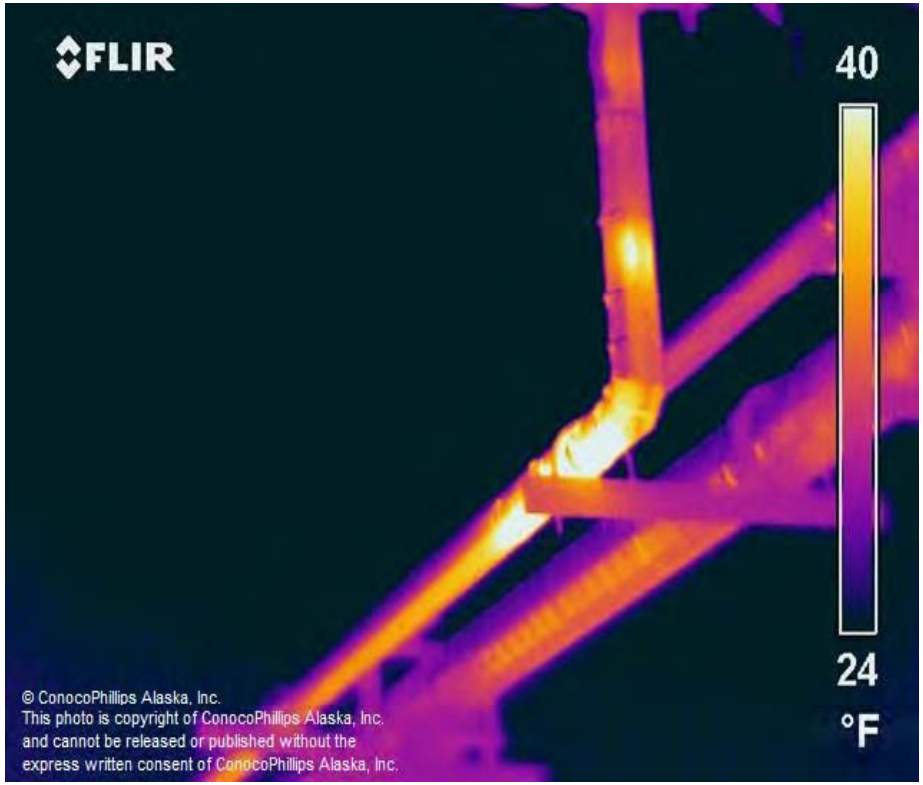
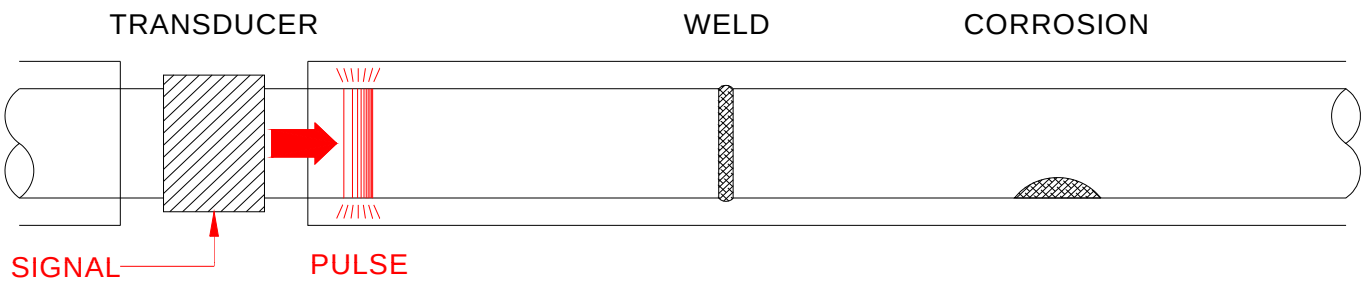
In Line Inspection

Infrared Thermography

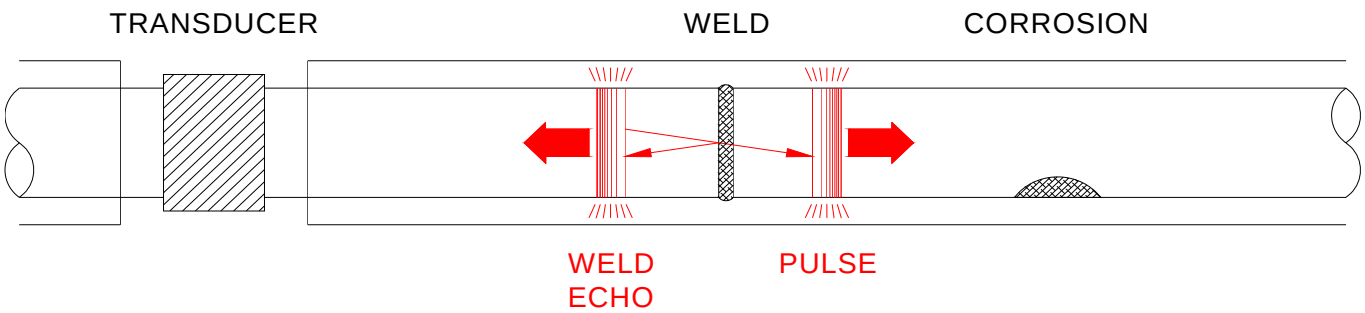


Long-Range UT Inspection

A. TRANSDUCERS GENERATE A PULSE OF ULTRASOUND.

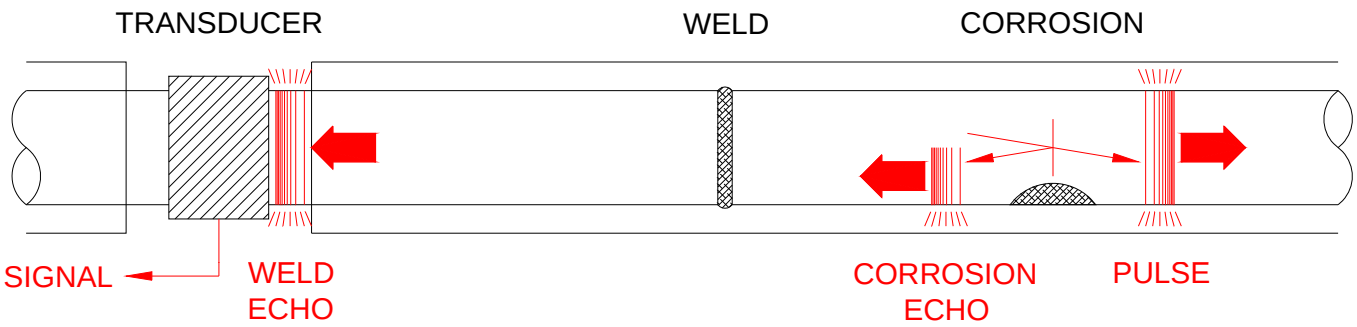


B. WELD PRODUCES A SYMMETRIC ECHO;
PULSE CONTINUES ON.

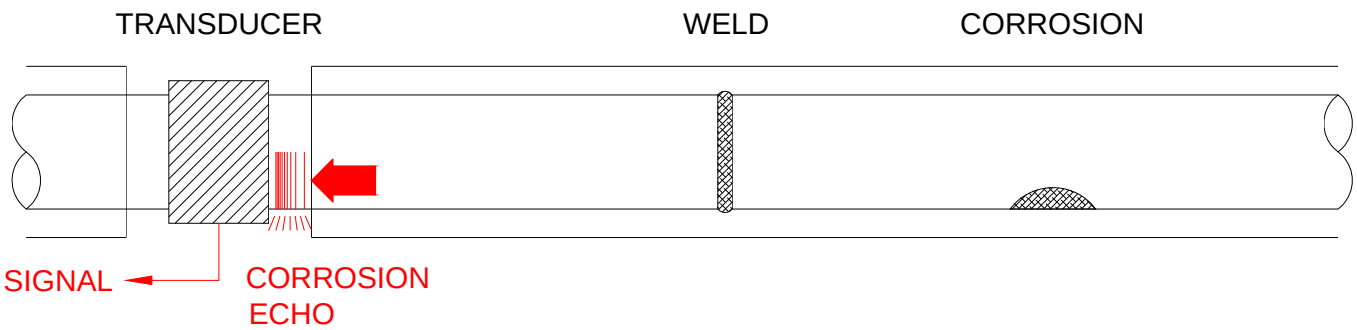


Long-Range UT Inspection

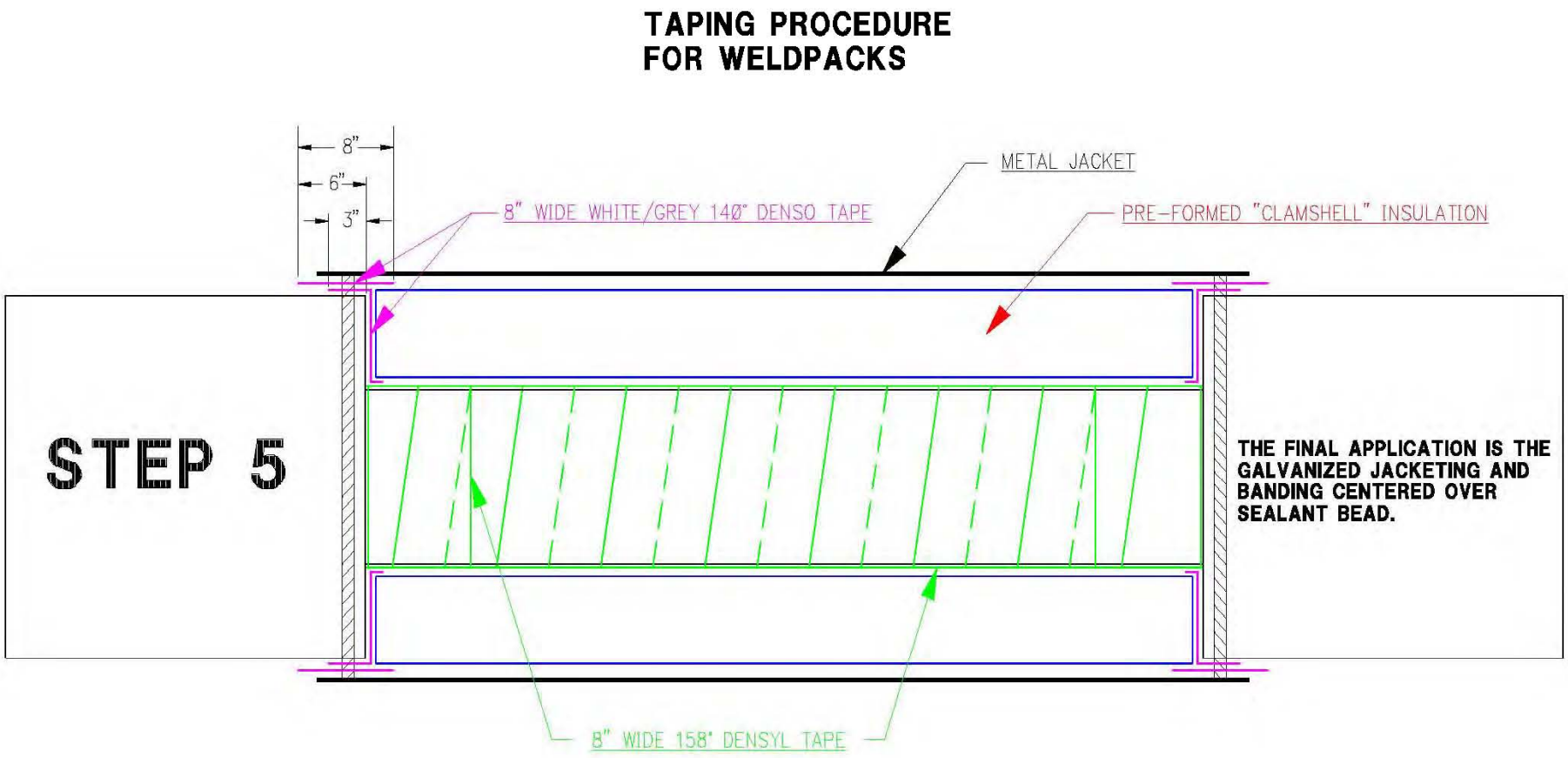
C. WELD ECHO DETECTED;
CORROSION PRODUCES AN ASYMMETRIC ECHO.



D. CORROSION ECHO DETECTED.



CUI Mitigation Techniques



Insulation Refurbishment (Denso)

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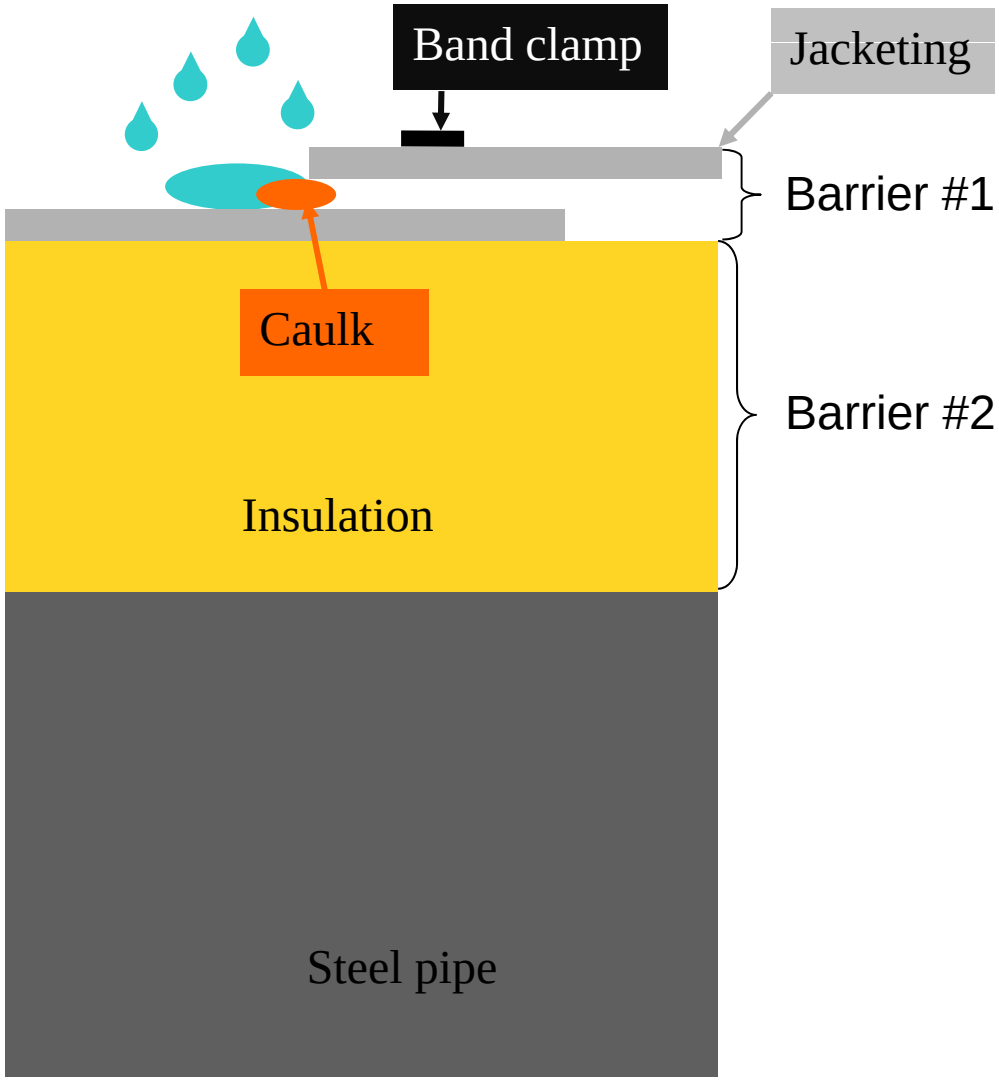
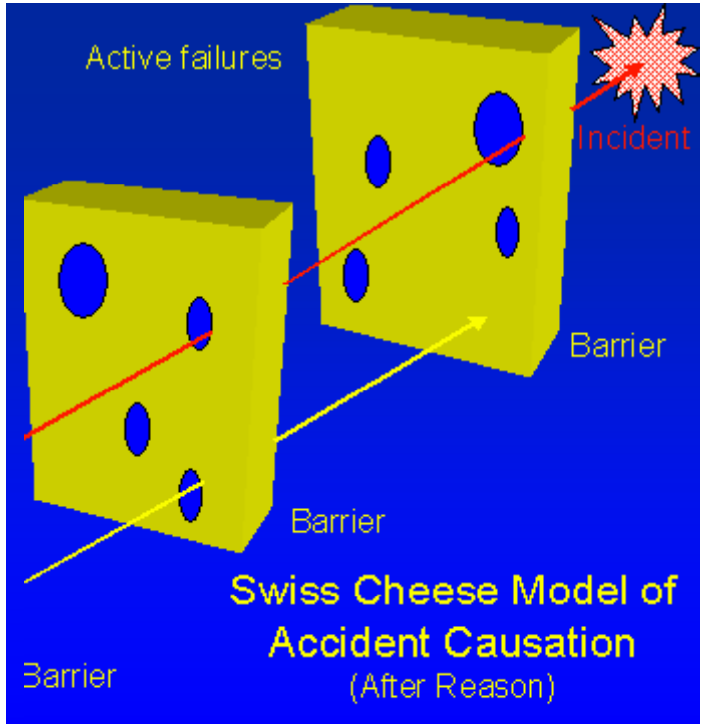
Corrosion Under Insulation

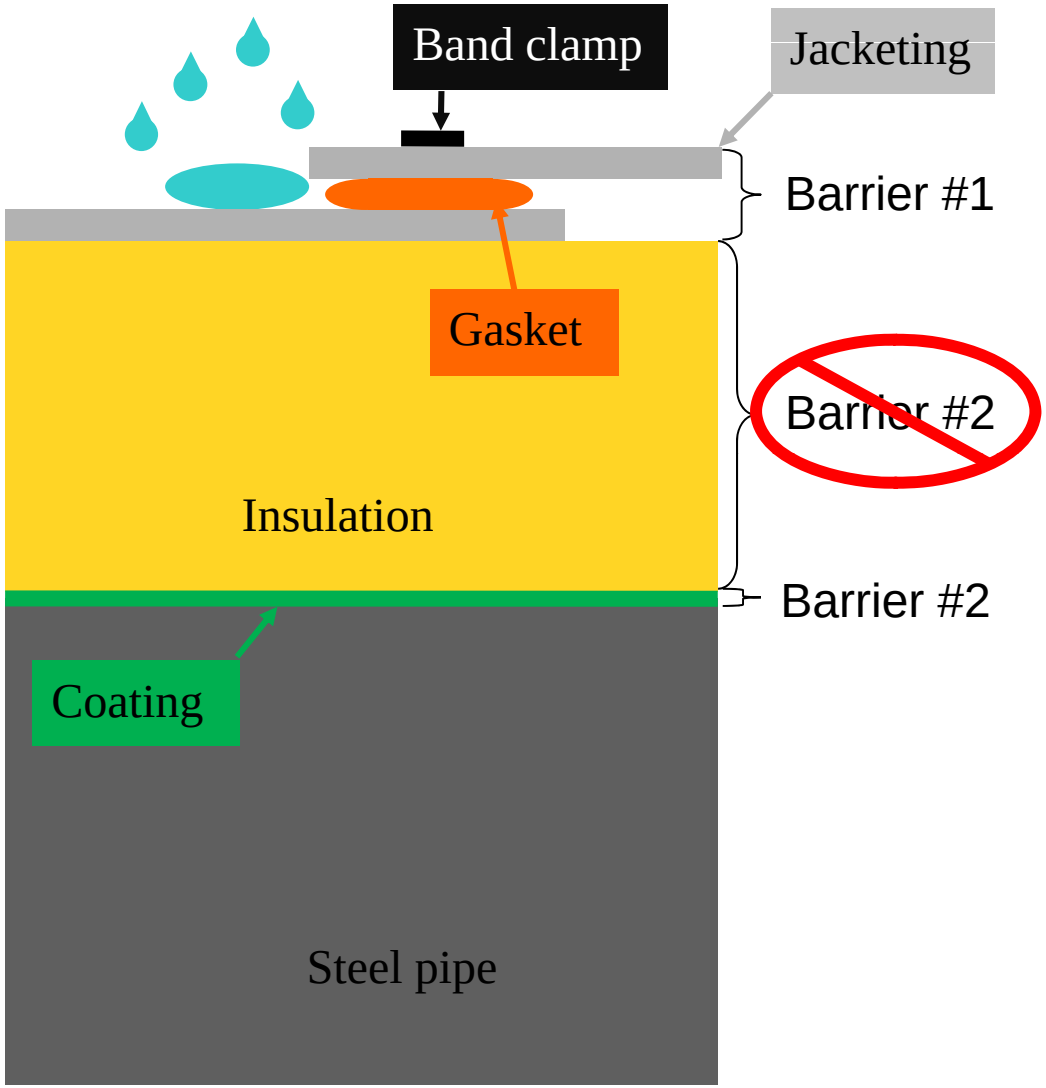
- Can be prevented by:
  - coating under insulation
  - sealing jacket to prevent water ingress
  - use insulation with corrosion inhibitor
- CUI is best controlled in the design stage.
- Do not rely on inspection and maintenance to control corrosion under insulation!!!!

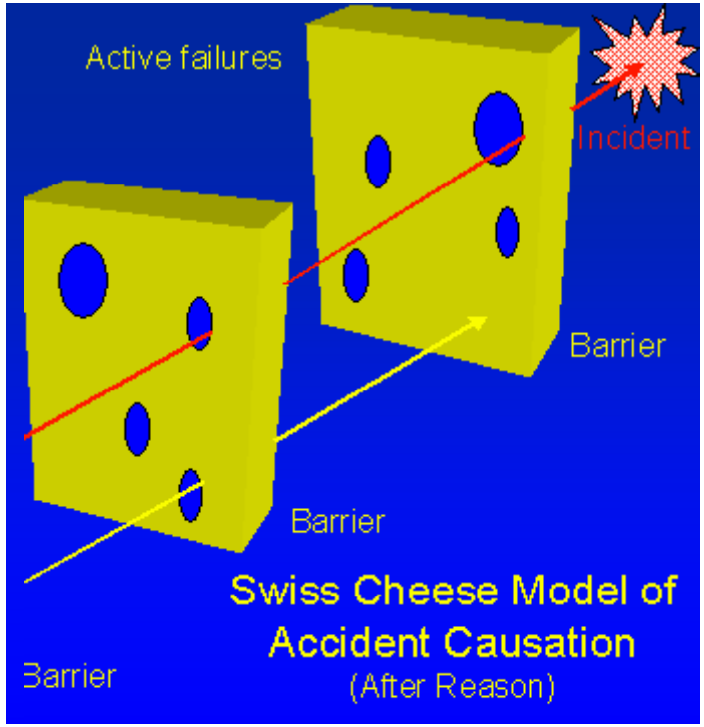
Minimizing the leak path



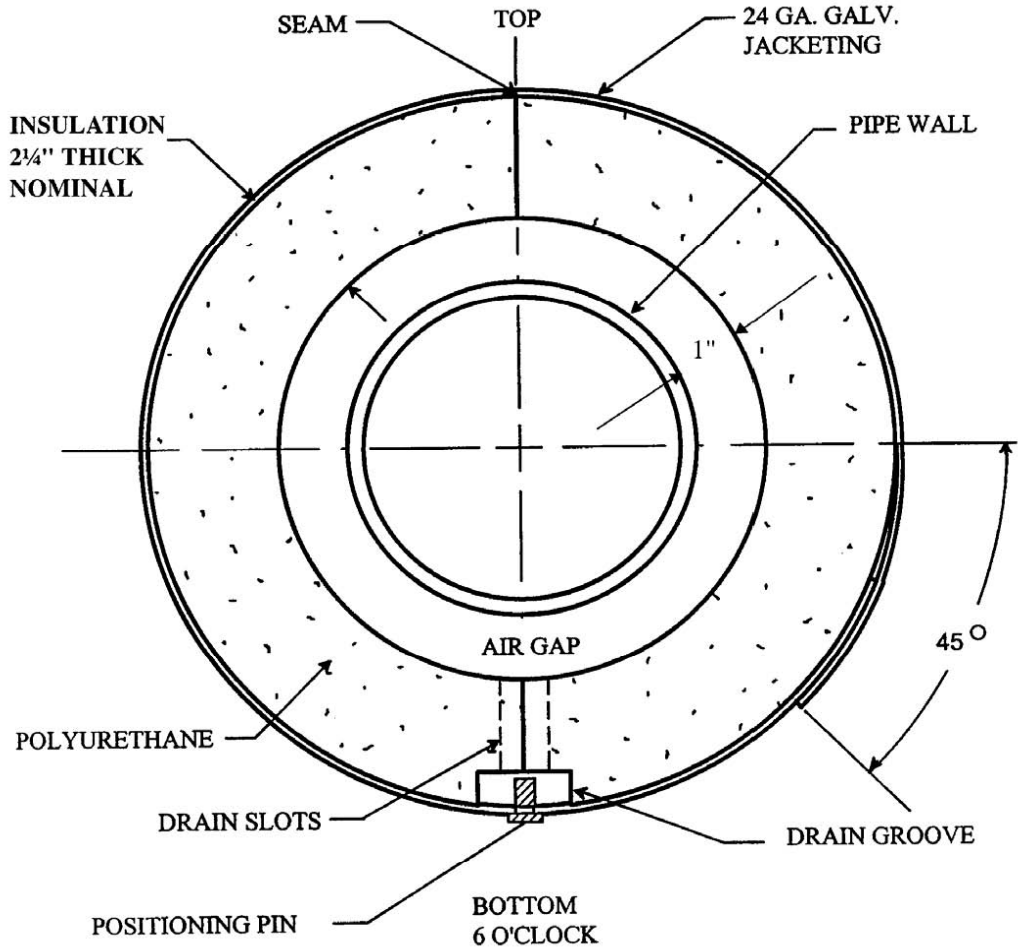


Minimizing the leak path





New Field-Applied Insulation Design



This cross section is for insulation joints that do not fall in pipeline support saddles.
Tape coating is not shown in this cross section but is required.

New Saddle Design

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Corrosion Under Insulation

- CUI is the largest part of our asset integrity program
- Best controlled in design stage
  - Inspection still necessary

Thank you!

APPENDIX T

GEOTHERMAL DESIGN OF WARM PIPELINES IN THAW UNSTABLE PERMAFROST AND CHILLED PIPELINES IN FROST-HEAVING SOILS

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Alaska Department of Environmental Conservation
2013 Arctic/Cold Regions Oil Pipeline Conference

September 17-19, 2013

Geothermal Design of Warm Pipelines in Thaw Unstable Permafrost and Chilled Pipelines in Frost-Heaving Soils

Beez Hazen, P.E.
Northern Engineering & Scientific
Anchorage, Alaska

beez@northern-engineering.com

Presentation Outline

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Thaw Settlement, Pipelines and Right-of-Way

- Material Properties
- Long-Term CRREL / Linell Field Experiment
- Predictions of Pipeline Thaw Settlement

Pipeline Frost Heave

- Material Properties
- Full-Scale Test Sites
- Comparisons between Measured and Predicted Frost Heave and Frost-Bulb Growth

Buried Utility Pipes

- Configurations, Predictions
- Comparisons Between Measured and Predicted

Pipeline Thaw Settlement

Clearing trees and disturbance of vegetation along a pipeline ROW will change the surface energy balance, likely leading to an increase in ground surface temperature.

In permafrost areas that will increase the seasonal thaw depth (active layer depth). If soil is thaw unstable, the increase in thaw depth will cause thaw consolidation and surface settlement.

In warm permafrost areas the increase in surface temperature can cause a continuing increase in thaw depth and surface thaw settlement. Operating the pipeline continuously below freezing will prevent settlement of the pipeline, but the ROW will still settle.

Thaw Settlement Testing, US Army Cold Regions Research and Engineering Laboratory's (CRREL's) Alaska Field Station near Fairbanks, Alaska

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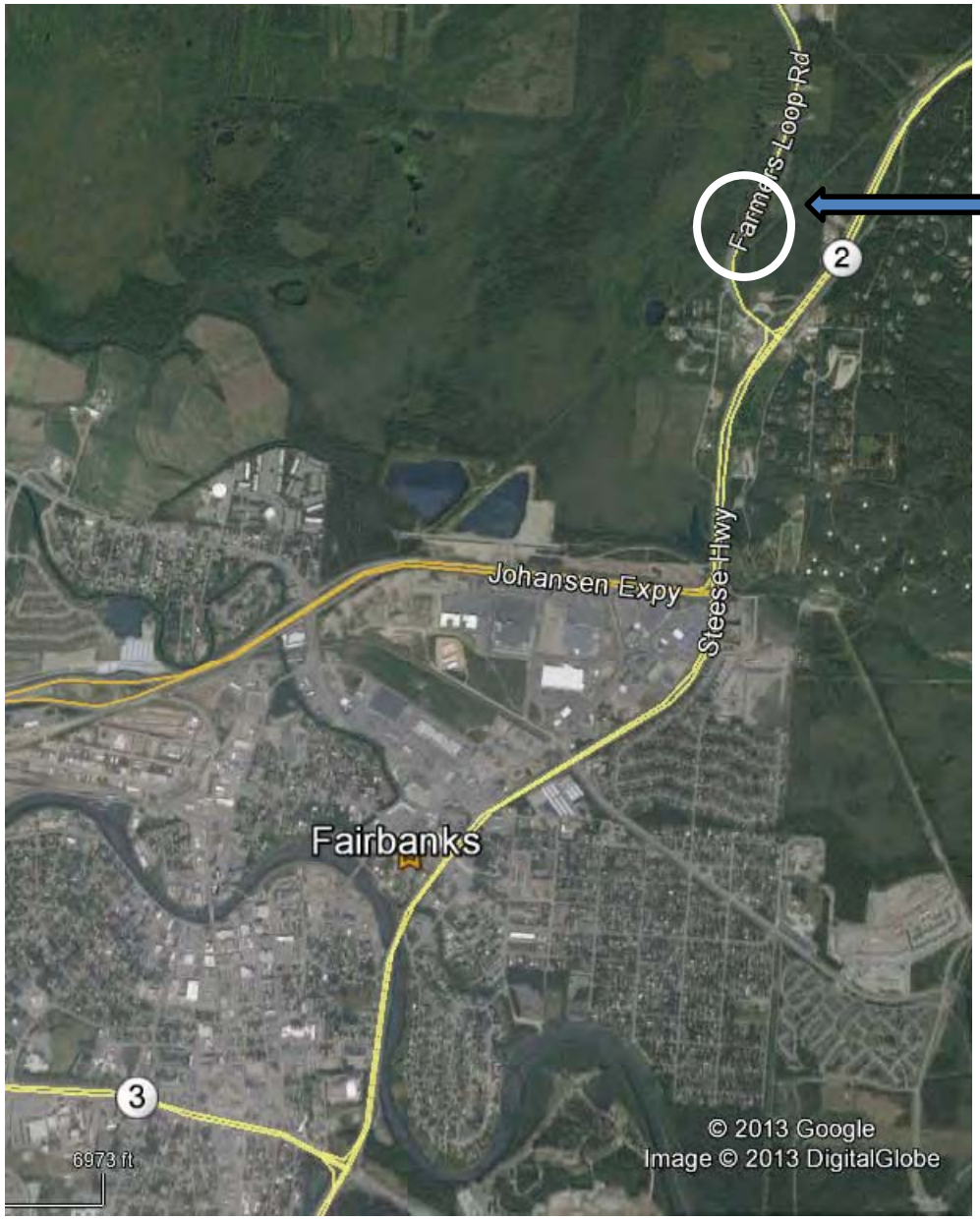

CRREL's Alaska Field Station

Linell, K.A., 1973, "Long-Term Effects of Vegetative Cover on Permafrost Stability in an Area of Discontinuous Permafrost," Second International Conference on Permafrost, 1973.

Thaw Settlement Testing, US Army Cold Regions Research and Engineering Laboratory's (CRREL's) Alaska Field Station near Fairbanks, Alaska

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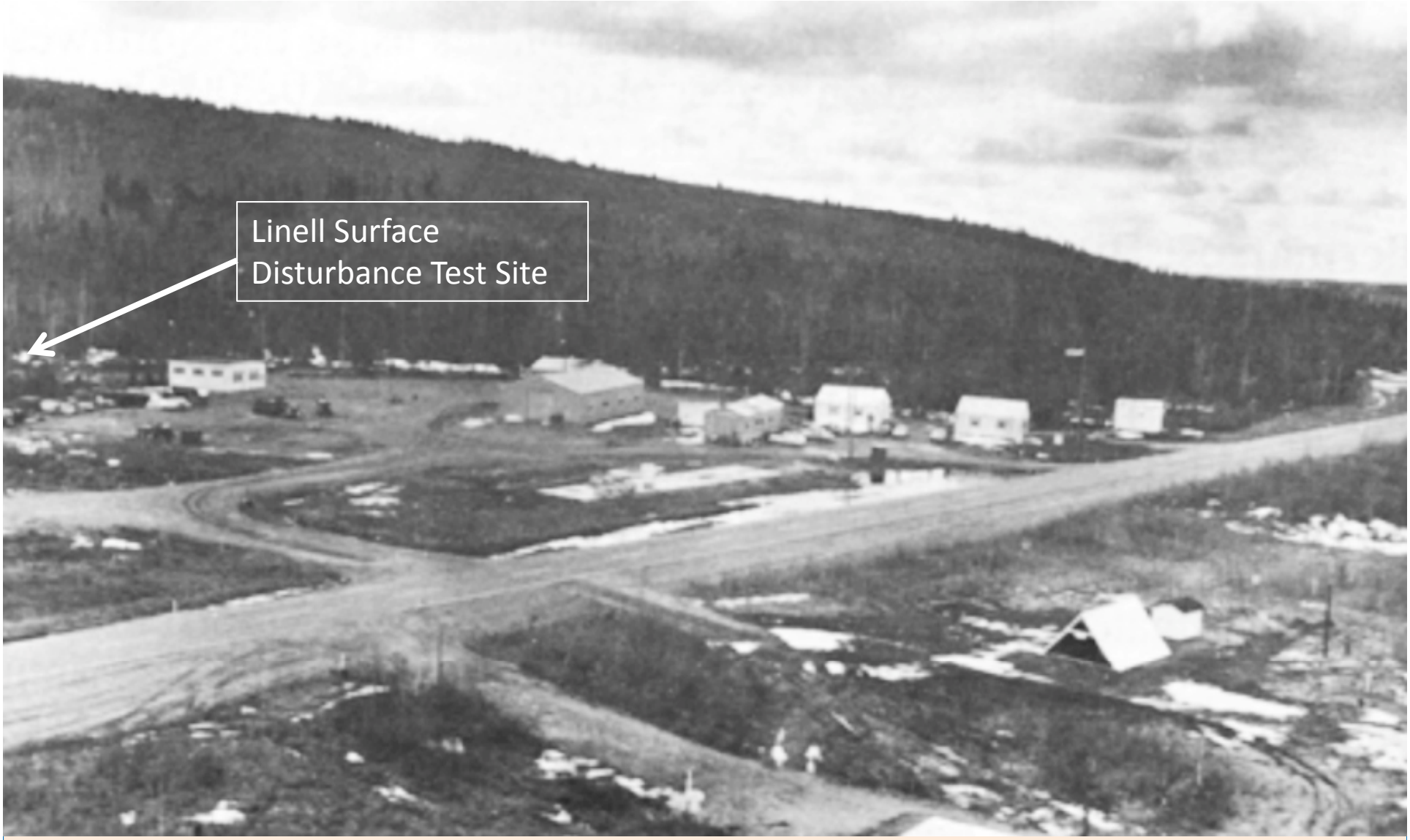

CRREL's First 25 Years (1961-1986)

Thaw Settlement Testing, US Army Cold Regions Research and Engineering Laboratory's (CRREL's) Alaska Field Station near Fairbanks, Alaska

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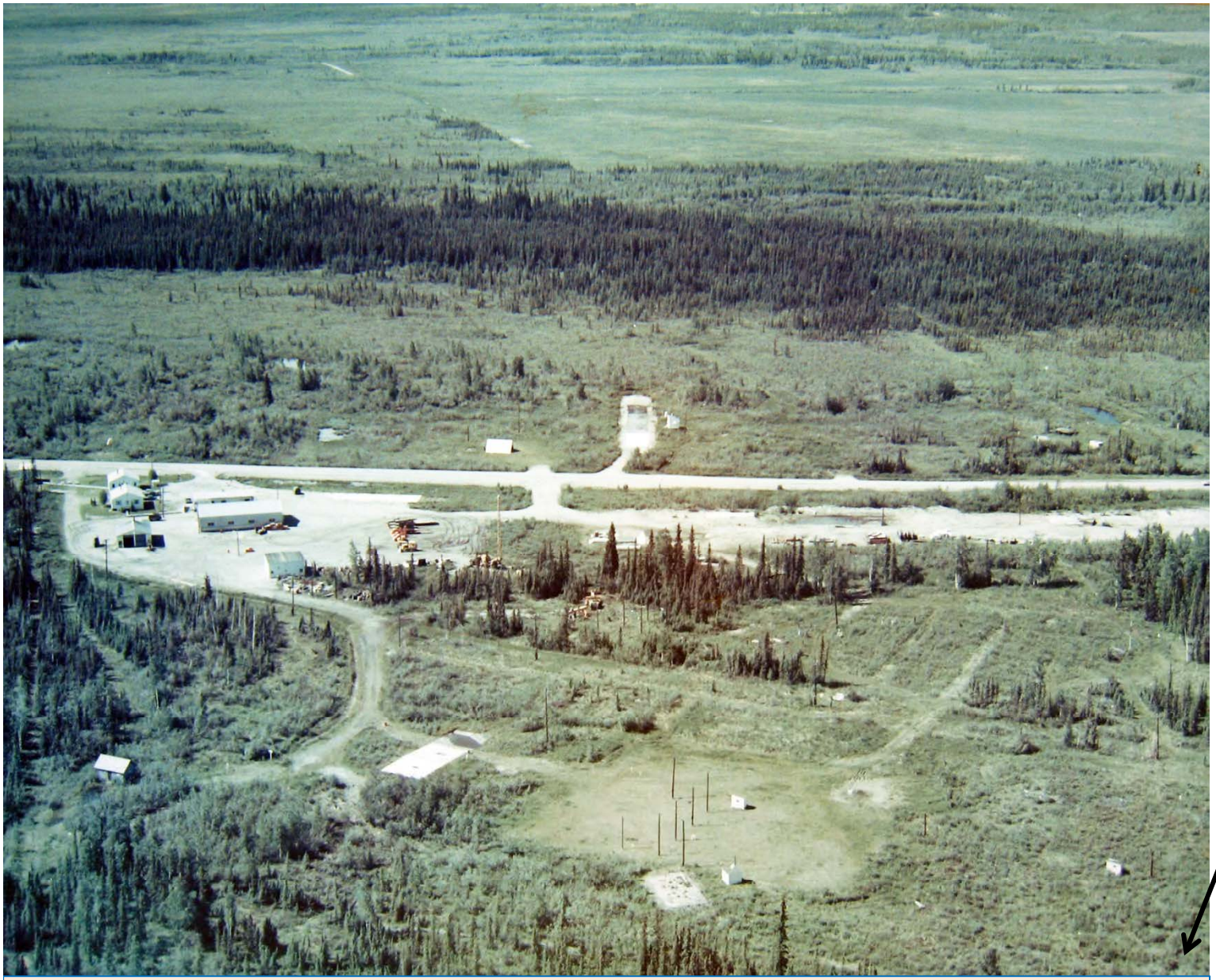

"Rear View, USA TSC Field Station, Fairbanks, Alaska, 1968". Photo by T. Marler

Linell Surface Disturbance Test Site

ANGTS' Heat Pipe Test Site at Linell's Cleared and Stripped Test Area

nes

ANGTS Heat Pipe Test Site, Section C (cleared, stripped) of Linell Test Area

Linell Field Experiment to Measure the Effect of Surface Disturbance on Permafrost Thaw Depths

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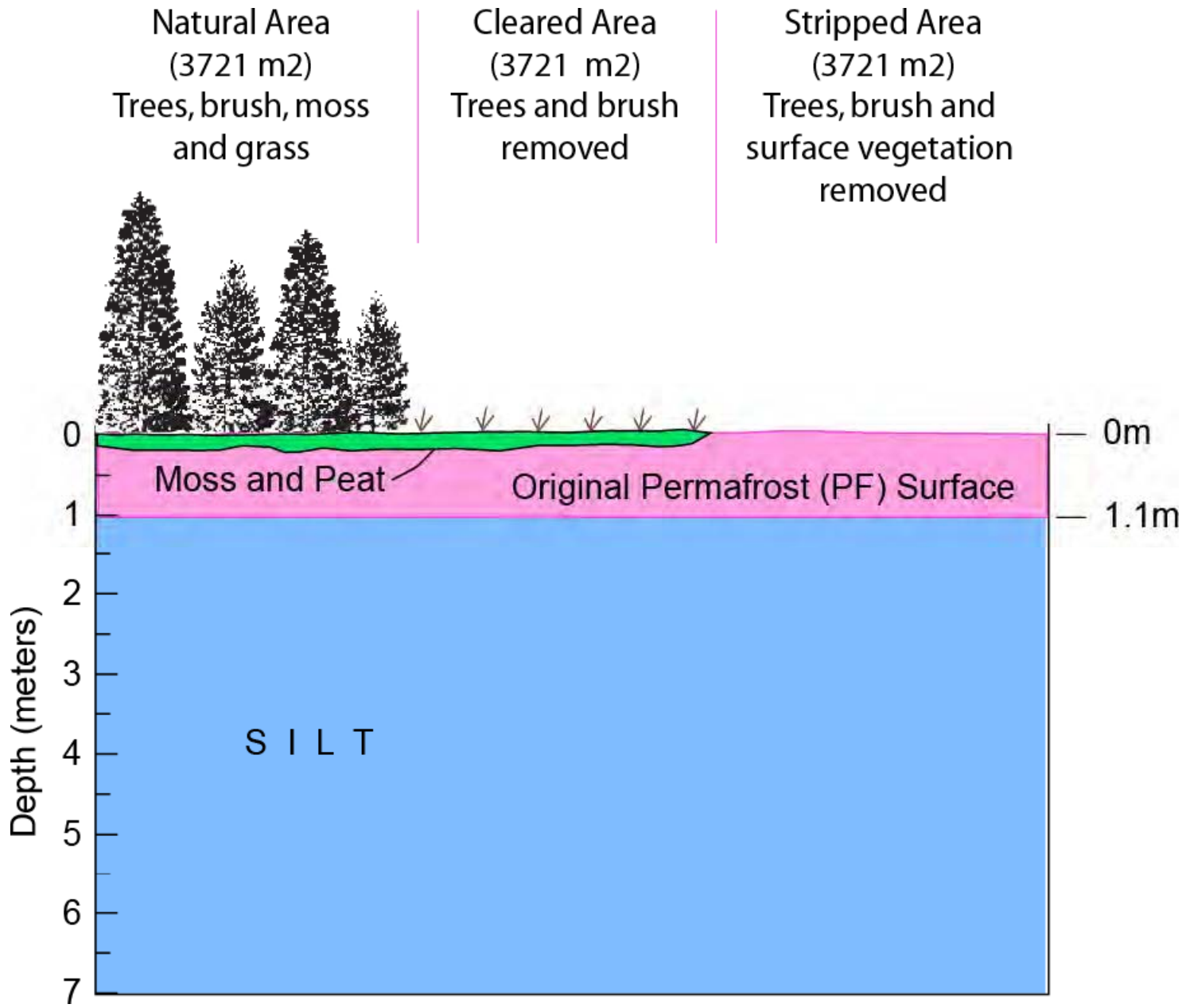

Linell Field Experiment to Measure the Effect of Surface Disturbance on Permafrost Thaw Depths

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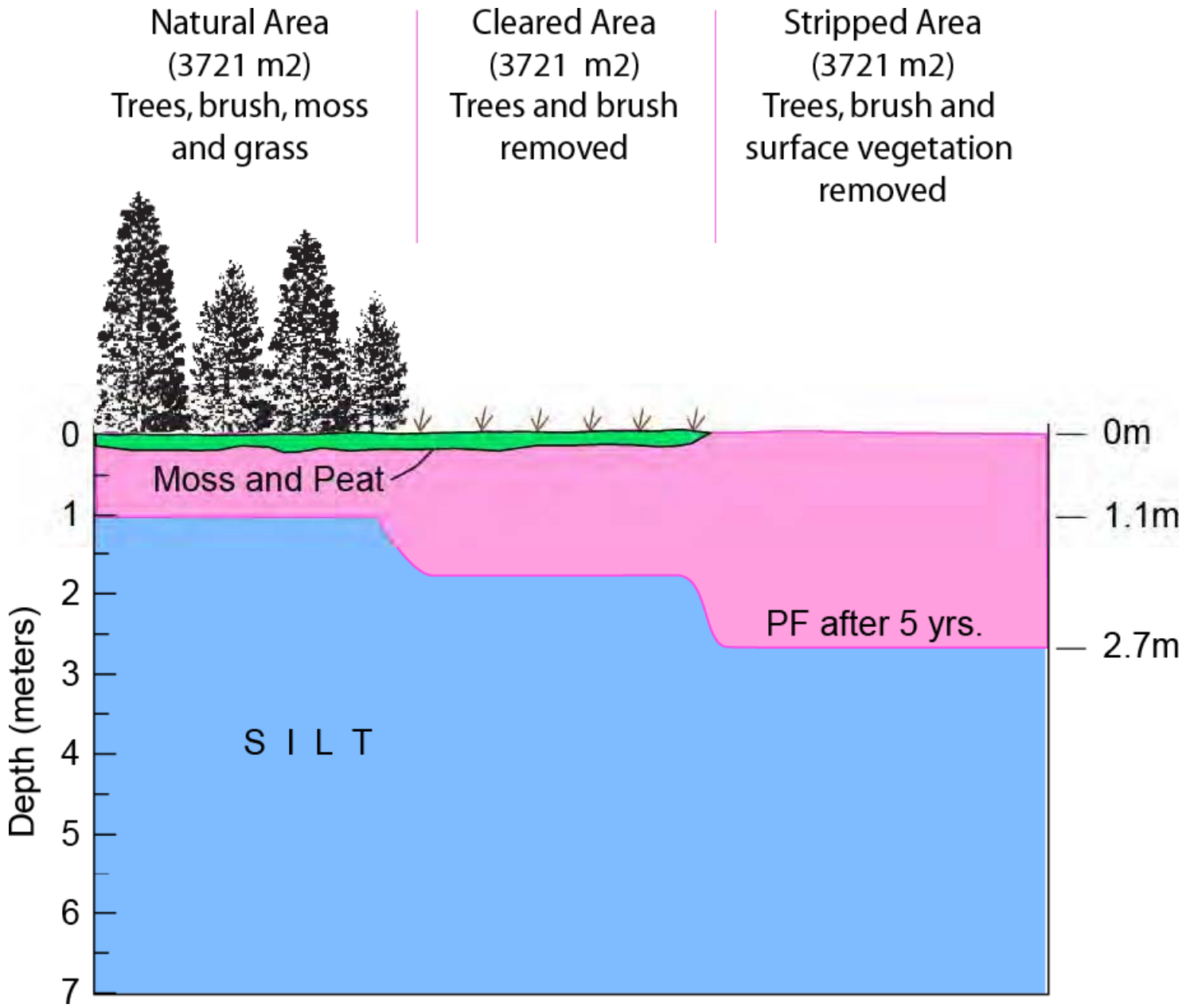

Linell Field Experiment to Measure the Effect of Surface Disturbance on Permafrost Thaw Depths

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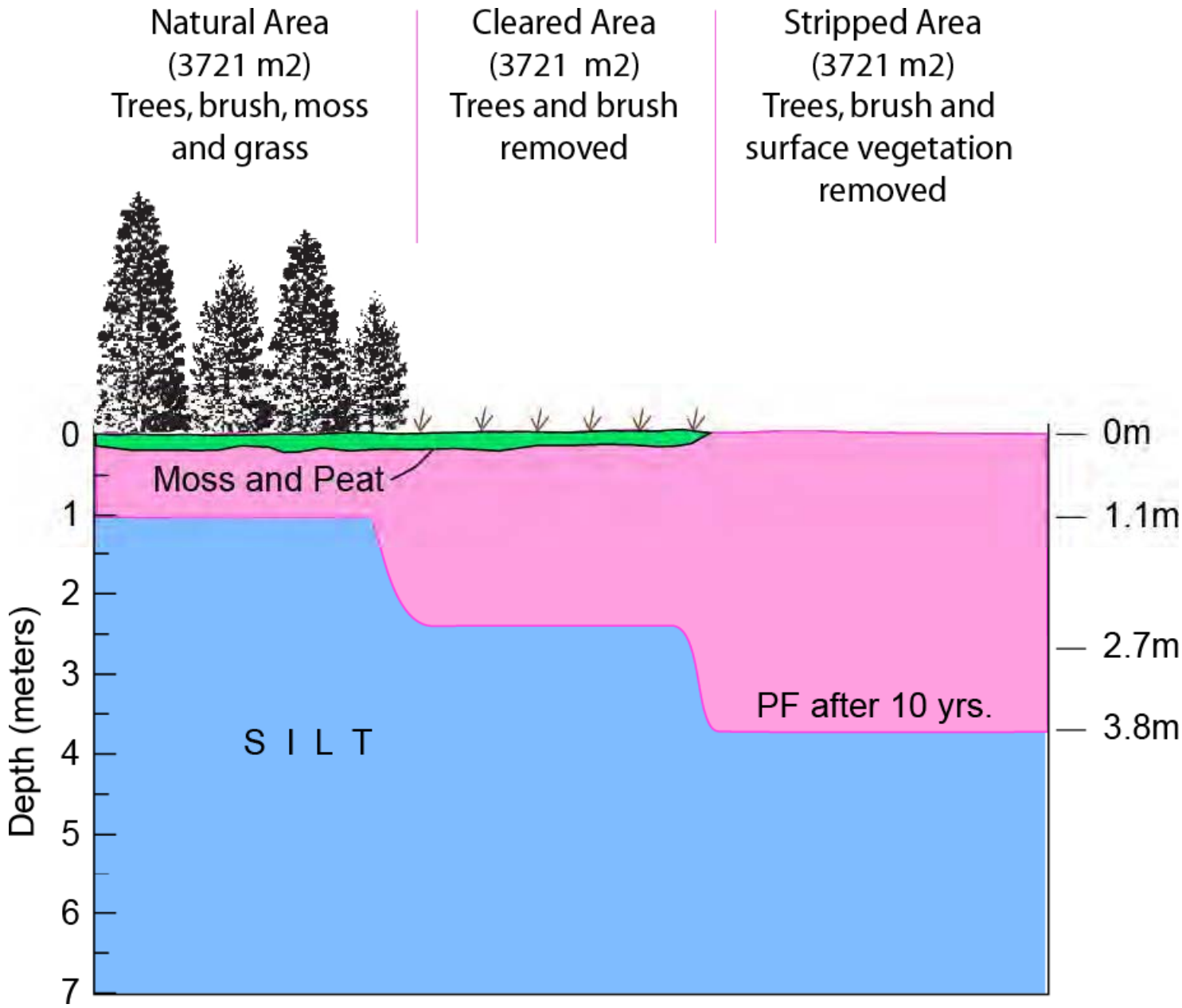

Linell Field Experiment to Measure the Effect of Surface Disturbance on Permafrost Thaw Depths

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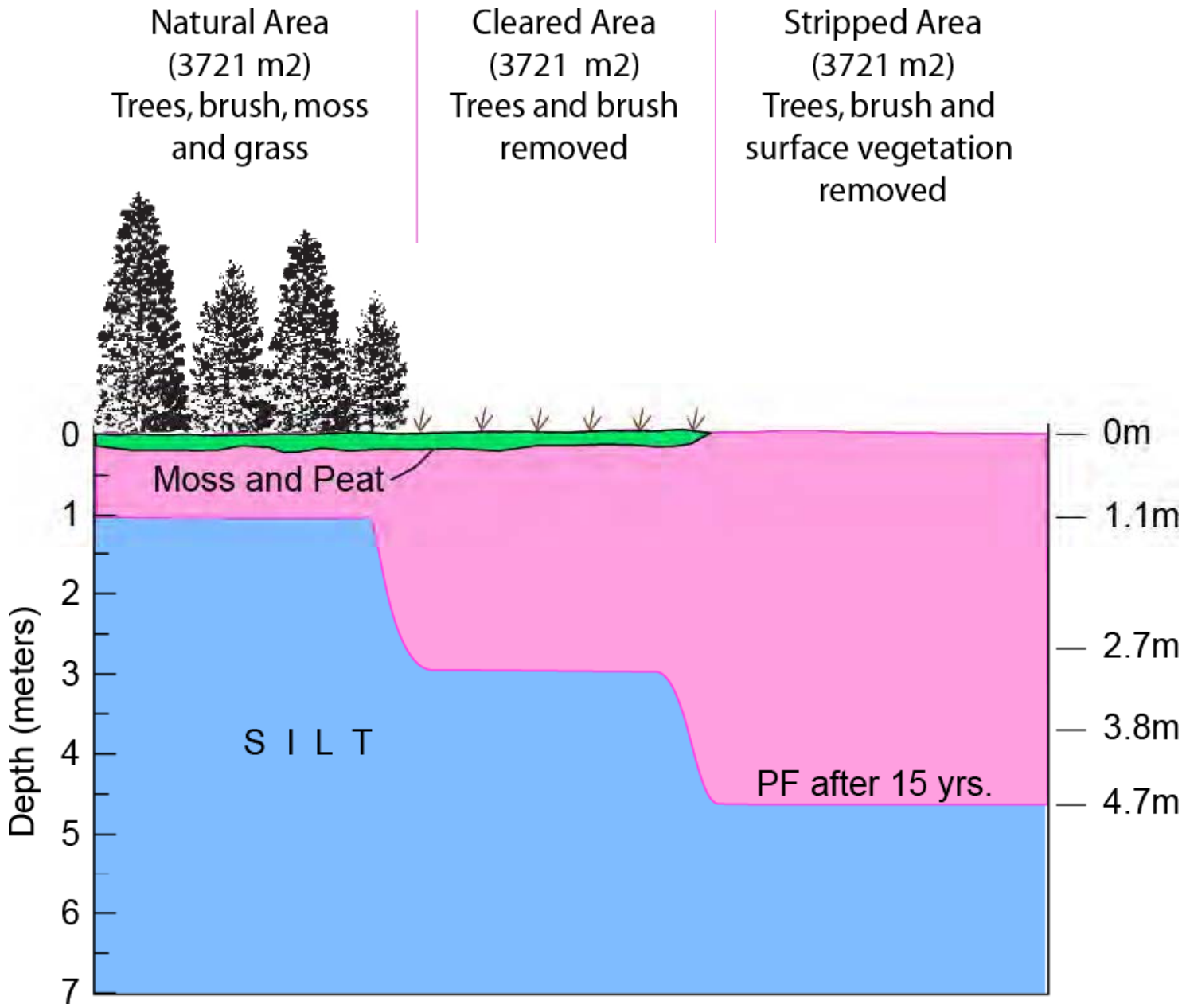

Linell Field Experiment to Measure the Effect of Surface Disturbance on Permafrost Thaw Depths

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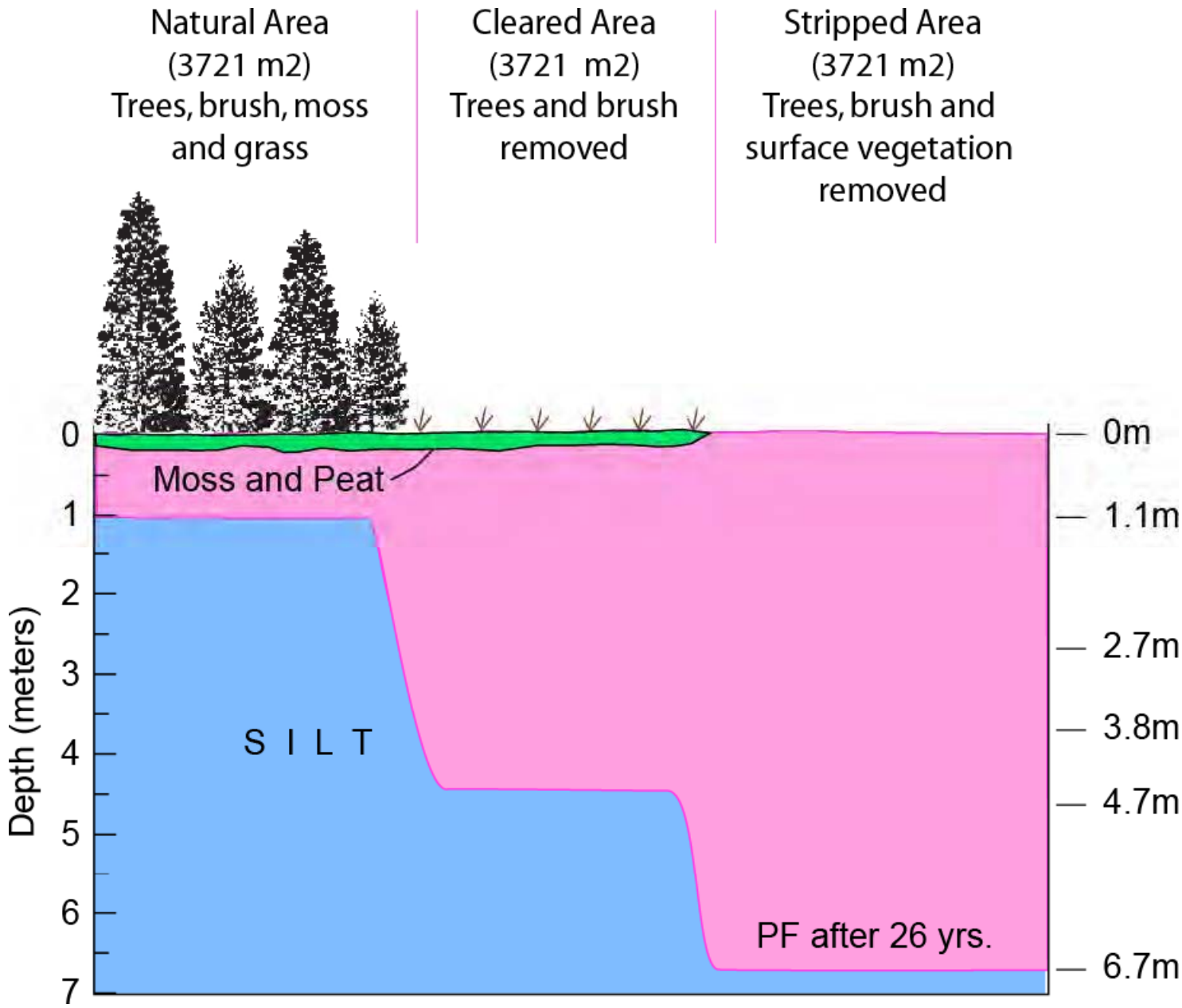

Linell Field Experiment to Measure the Effect of Surface Disturbance on Permafrost Thaw Depths

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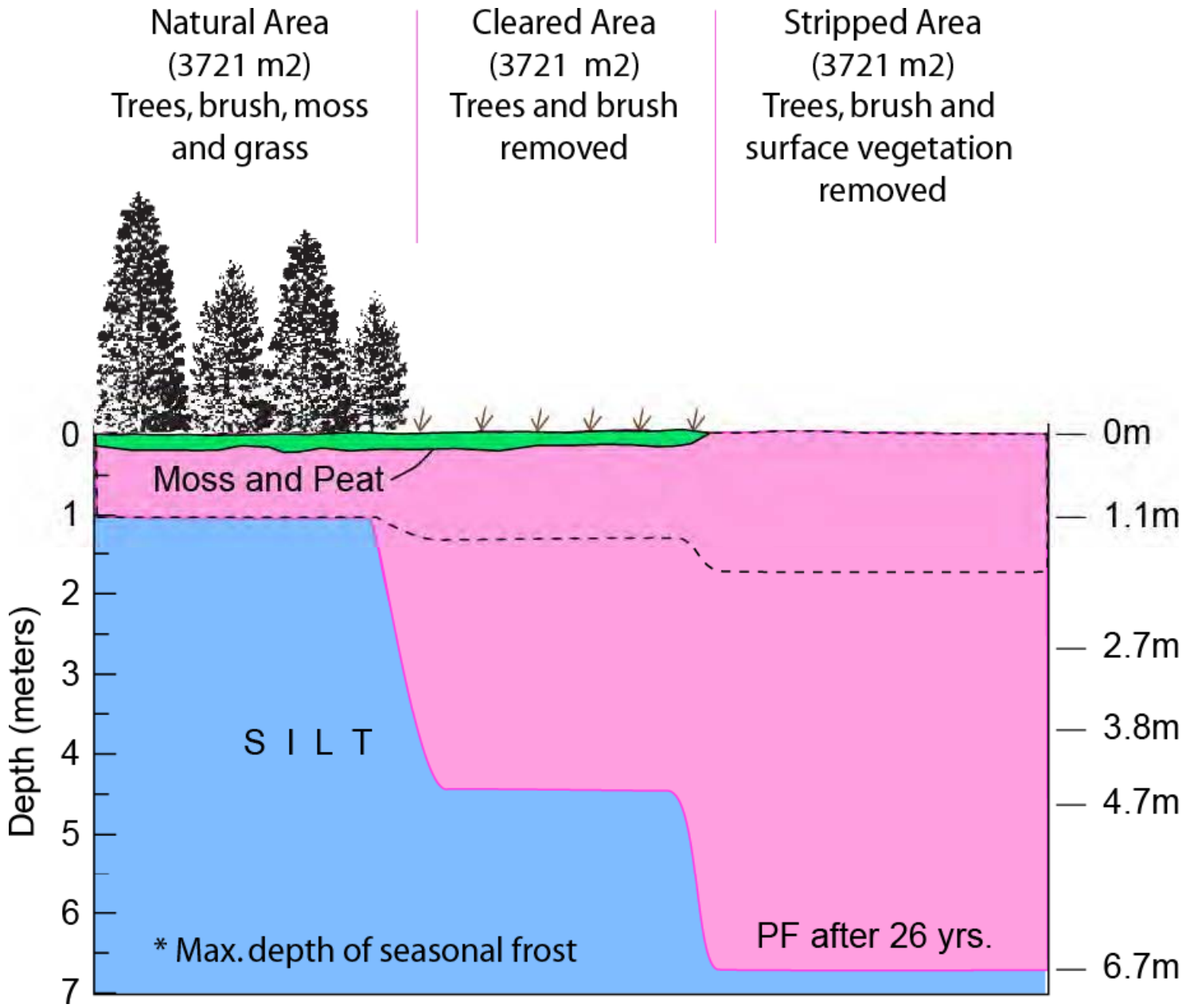

Linell Field Experiment to Measure the Effect of Surface Disturbance on Permafrost Thaw Depths

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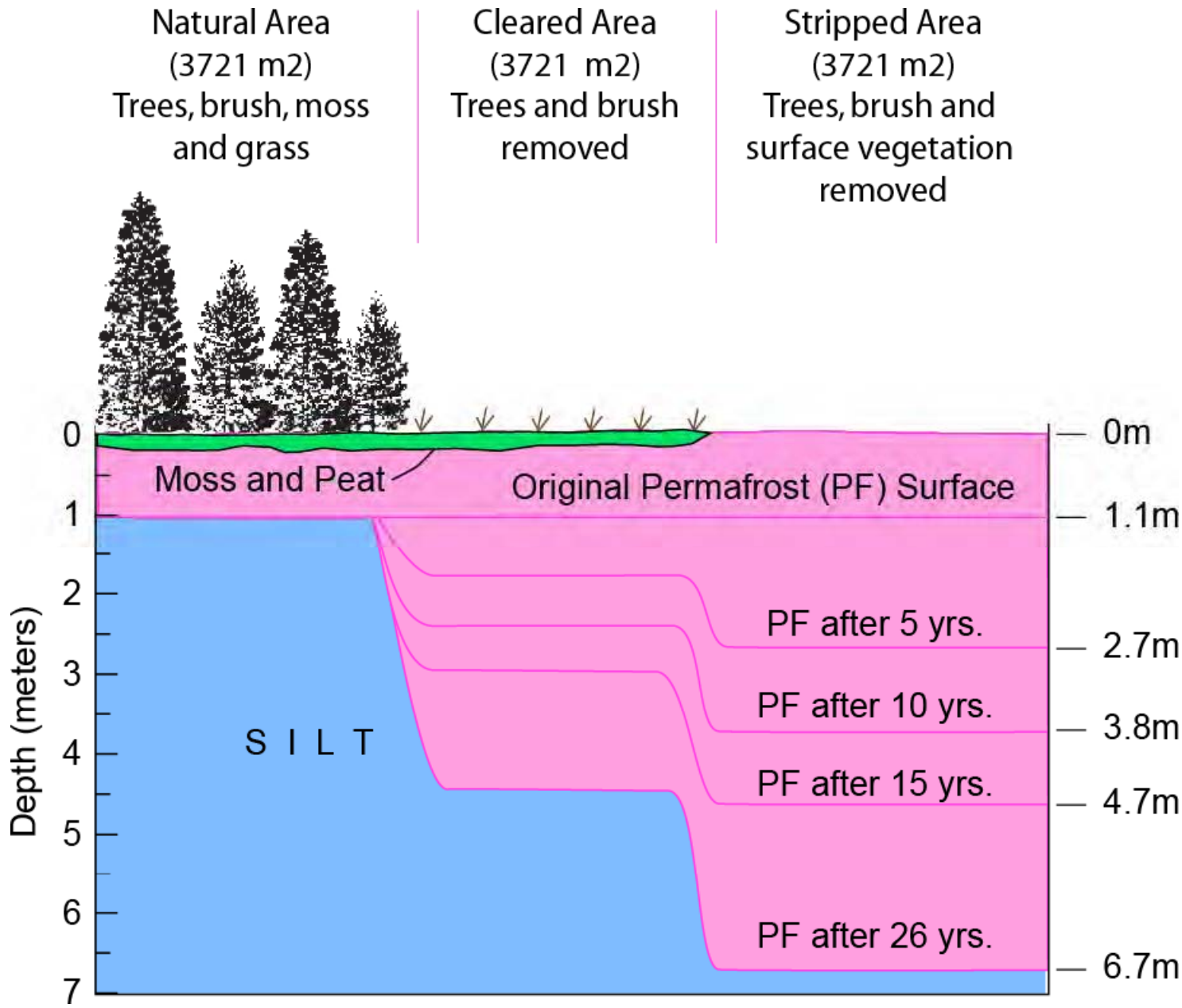

Linell Field Experiment to Measure the Effect of Surface Disturbance on Permafrost Thaw Depths
Comparisons of Measured and Predicted Thaw Depths

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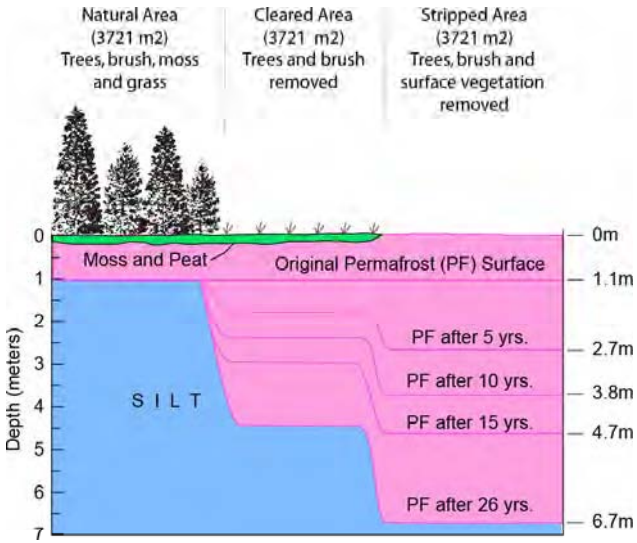
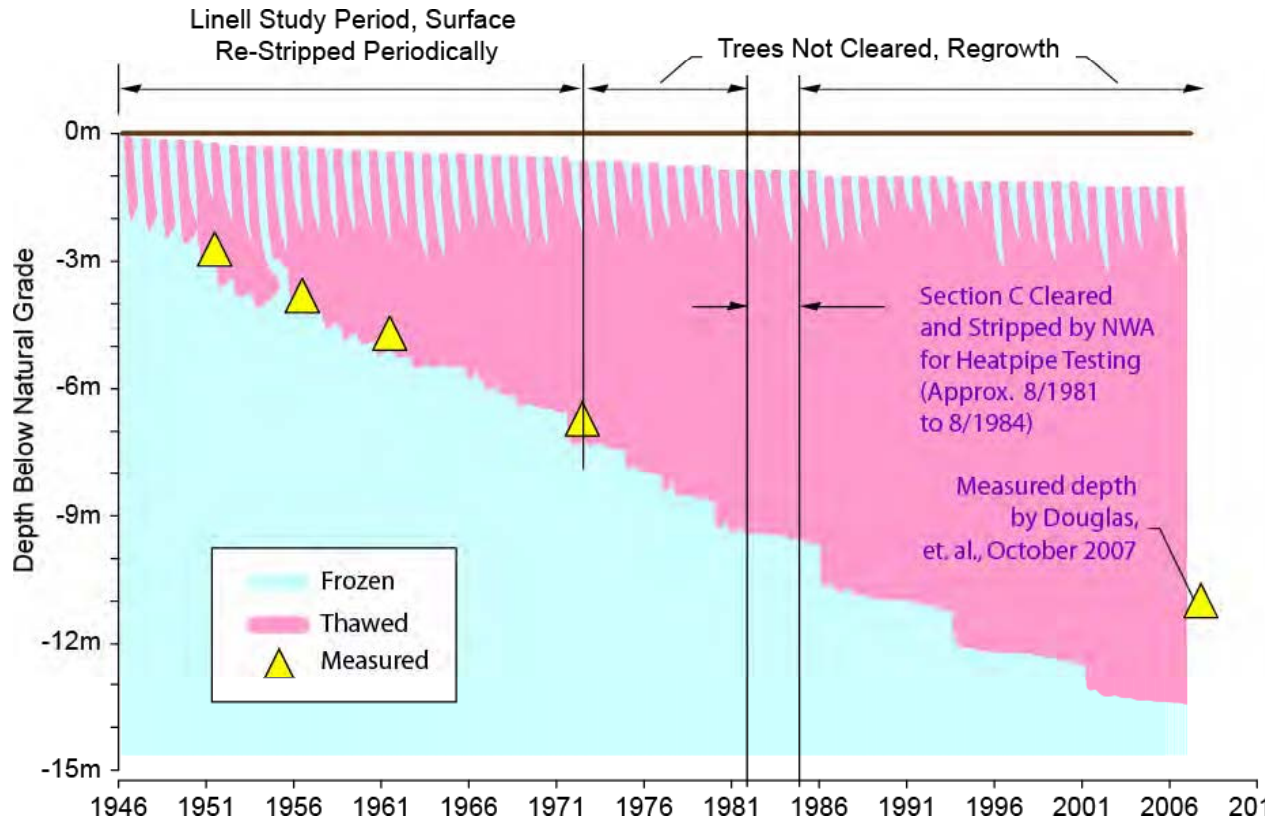
Linell's Data



Model Predictions using day-by-day ambient temperatures and snow depths. Calibration of surface energy balance parameters



Calculation of Thaw Strain of Frozen Soil

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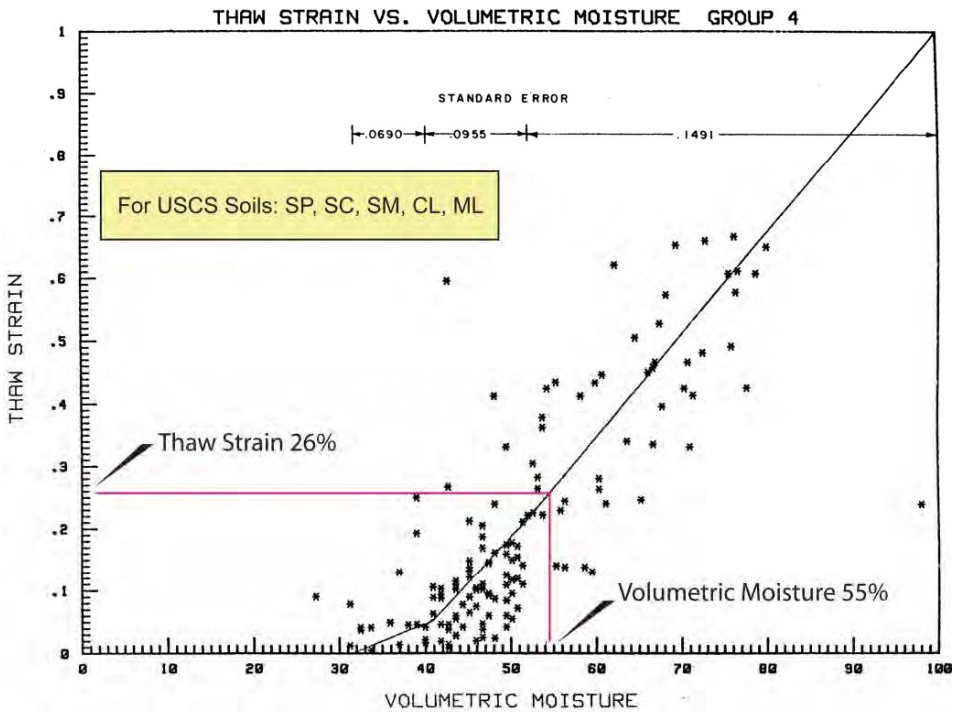
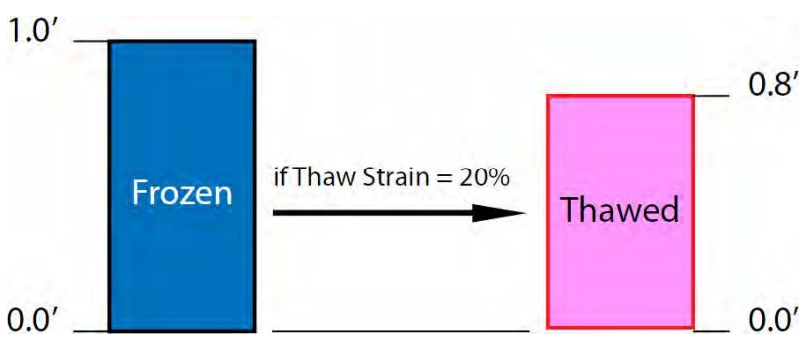
Thaw Strain Equation Developed by Foothills Pipeline





Thaw Strain Equation Developed by the Trans Alaska Pipeline System

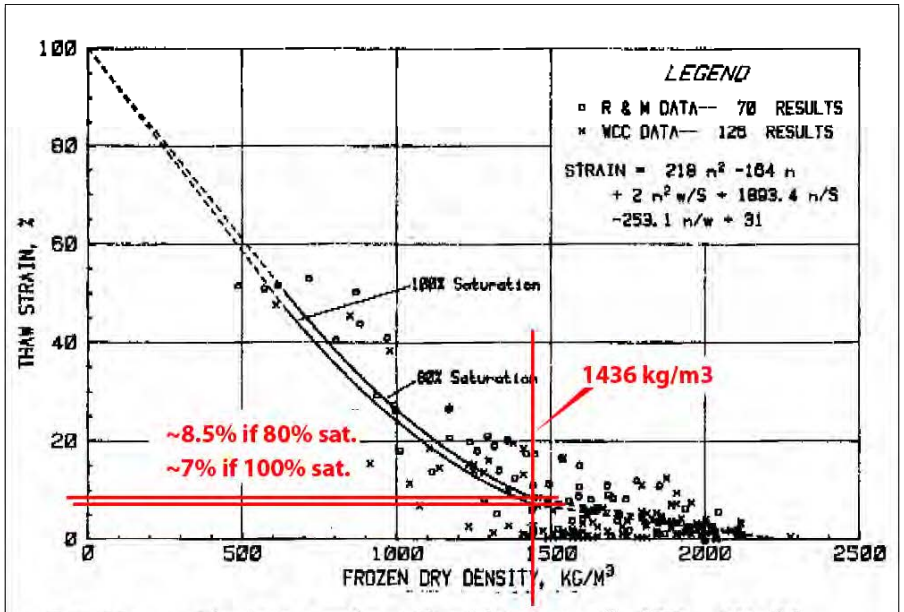


FIGURE 6 Thaw strain of silty sand (SM, SM-SC,

"**Thaw Strain Data and Thaw Settlement Predictions for Alaskan Soils**", Nelson, Luscher, Rooney, and Stramler, 4th Int'l Permafrost Conference

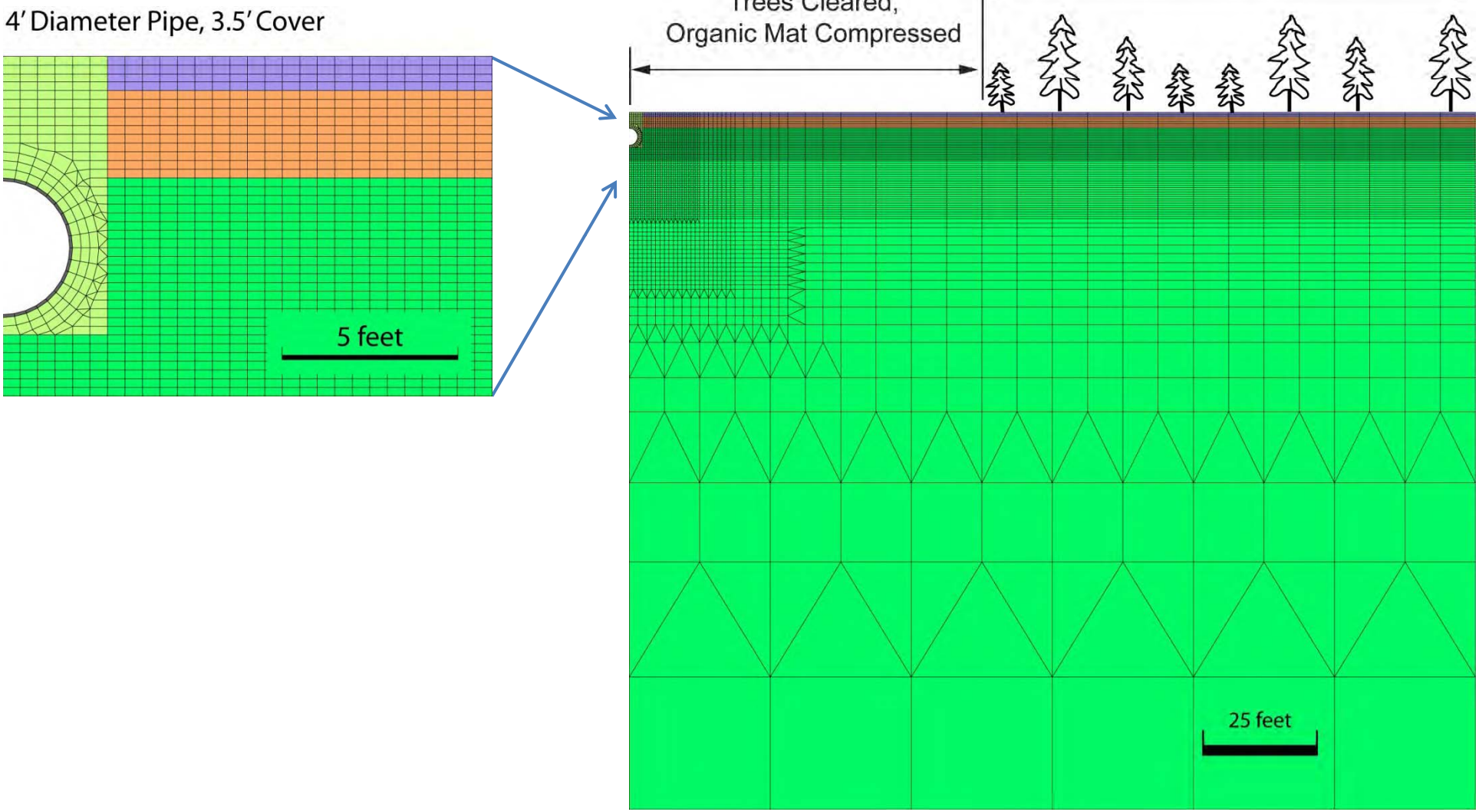
"**Alaska Highway Gas Pipeline Project (Yukon Section) - Alberta. Thaw settlement design approach**", Hanna, Saunders, Lem & Carlson, 4th International Permafrost Conference.

Finite-Element Model Representation of Pipeline and ROW

nes

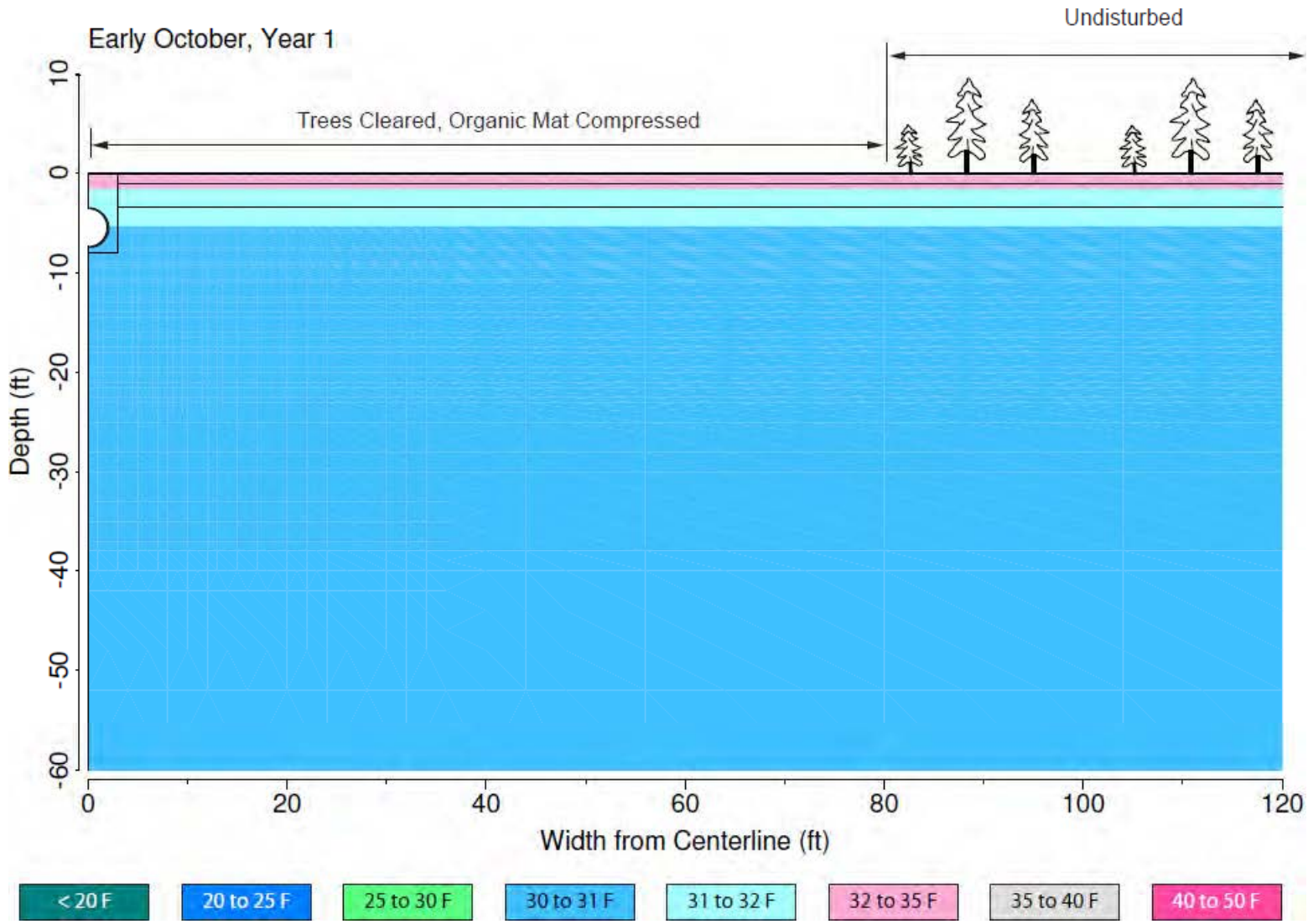
Close-Up of Pipe and Trench

Full Width and Depth of TQUEST grid



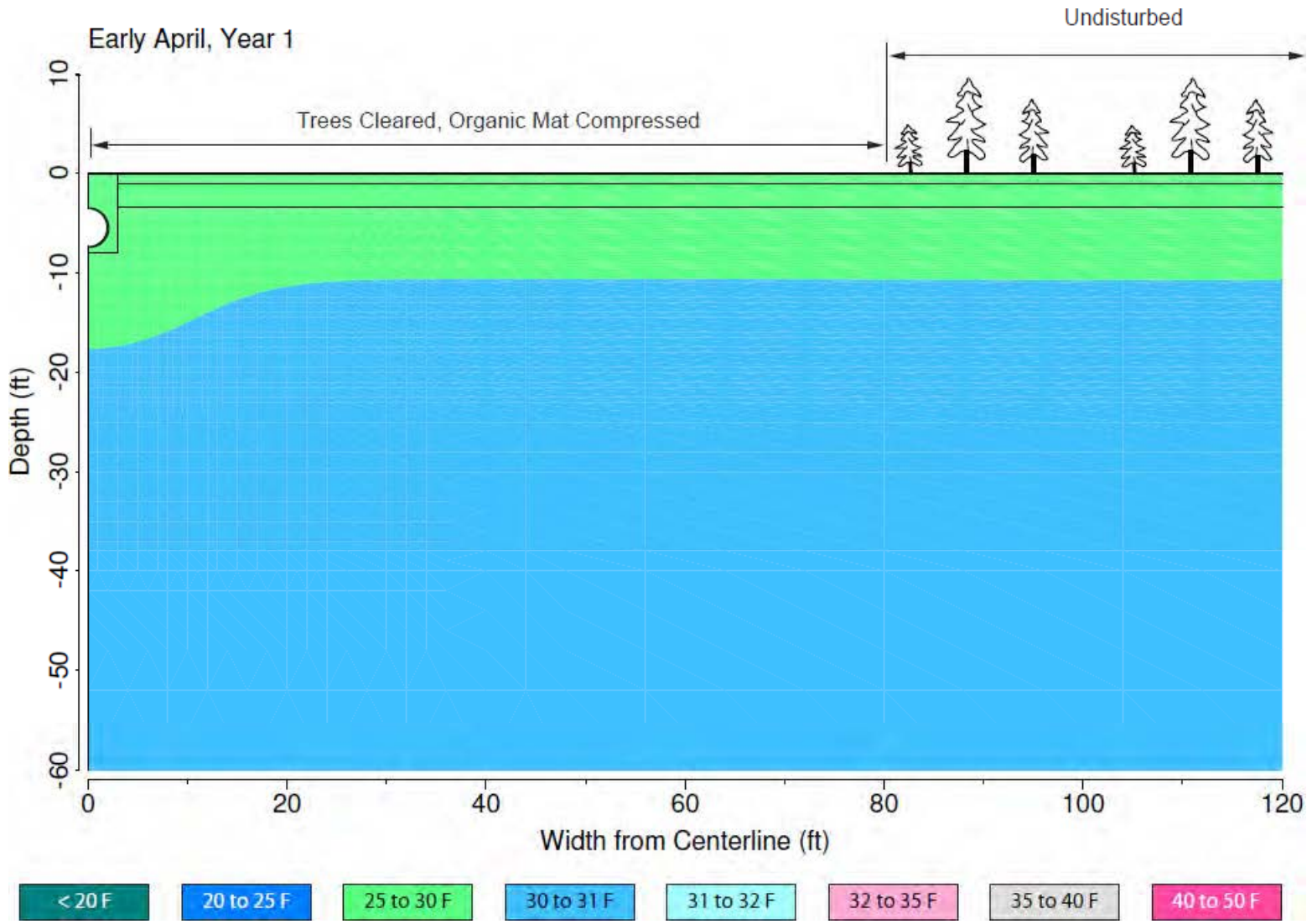
Dormant Pipe, Recently Cleared (not Stripped) ROW. Warm, Thaw-Unstable Permafrost (1 of 8).

nes



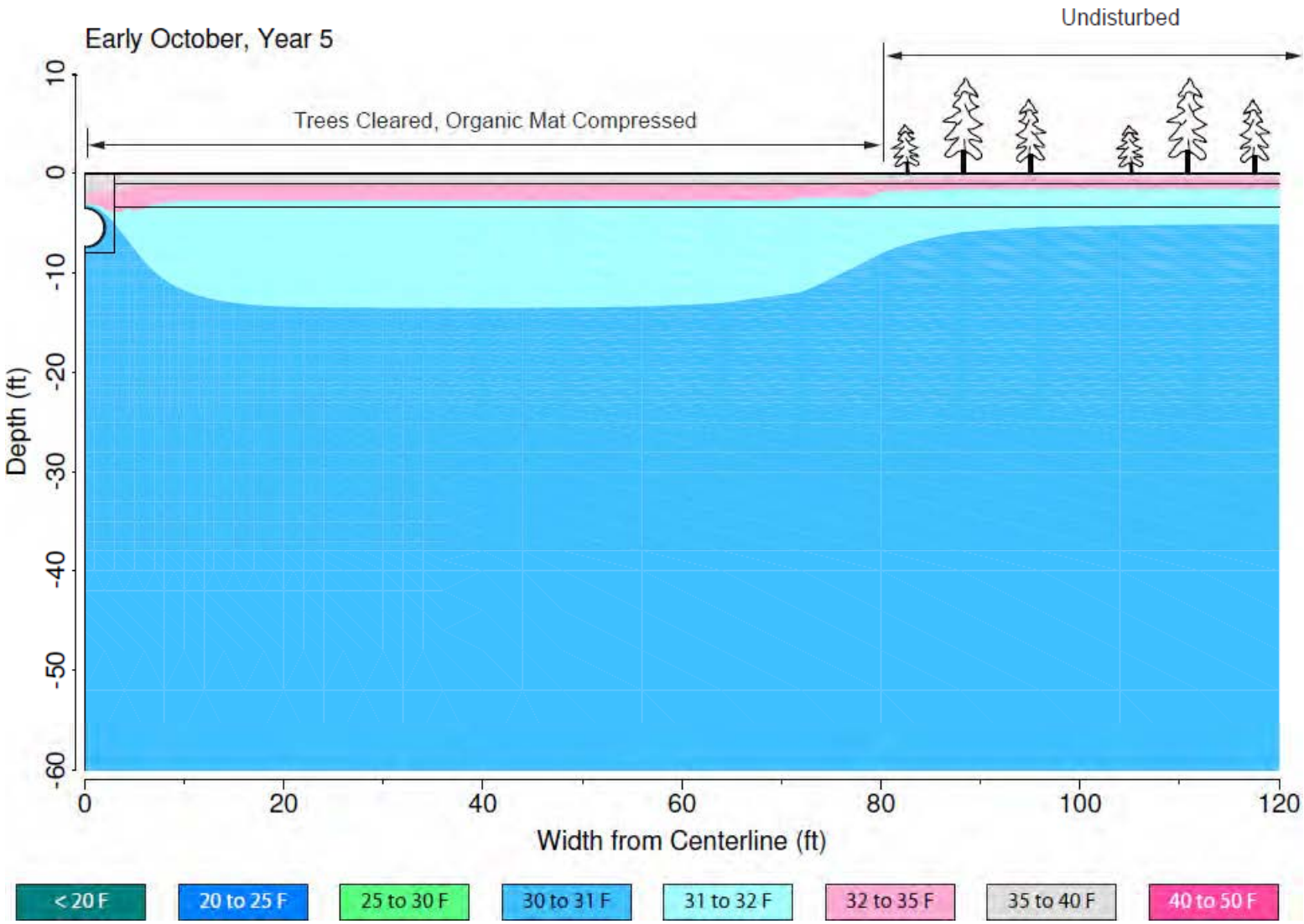
Dormant Pipe, Recently Cleared (not Stripped) ROW. Warm, Thaw-Unstable Permafrost (2 of 8).

nes



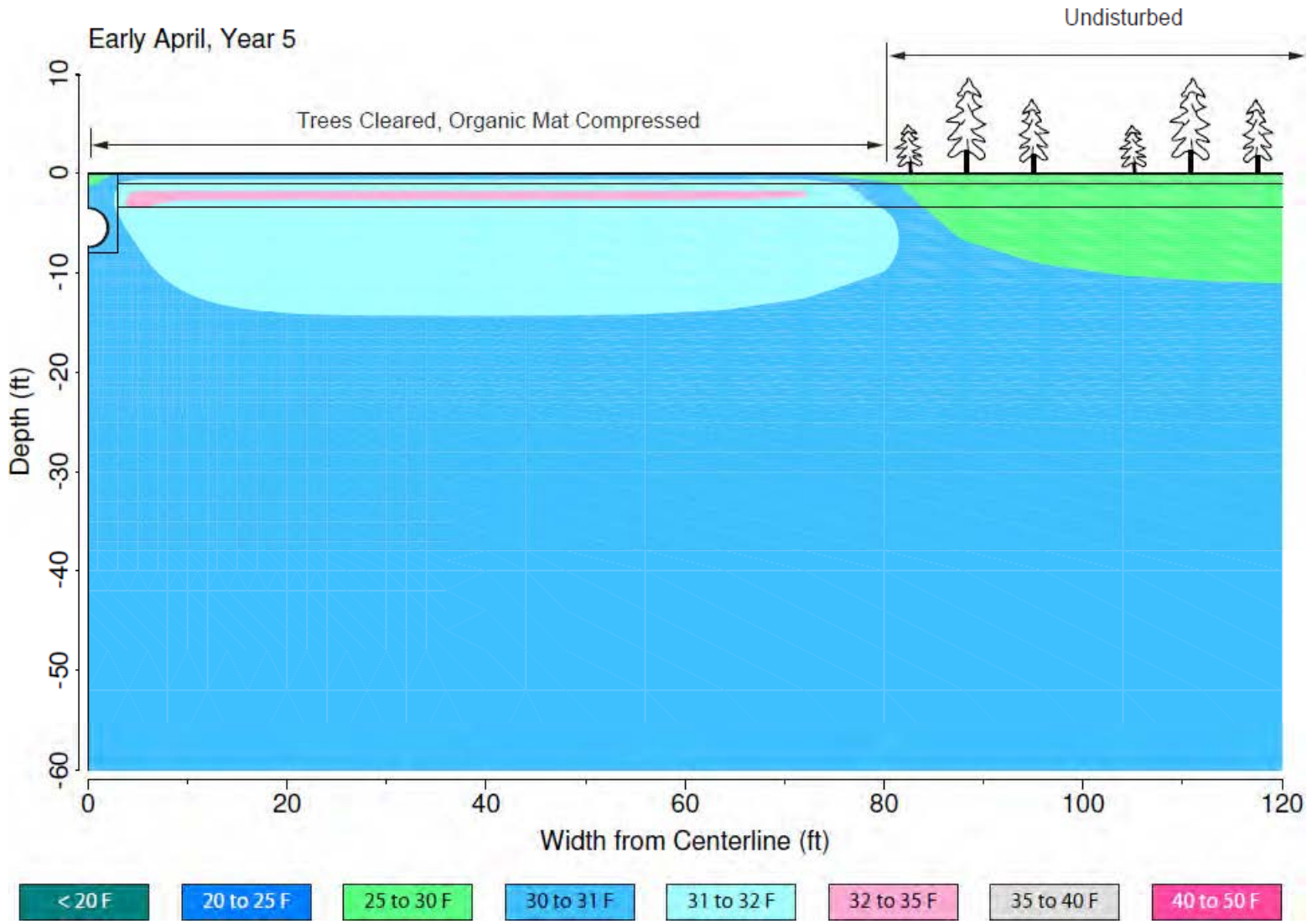
Dormant Pipe, Recently Cleared (not Stripped) ROW. Warm, Thaw-Unstable Permafrost (3 of 8).

nes



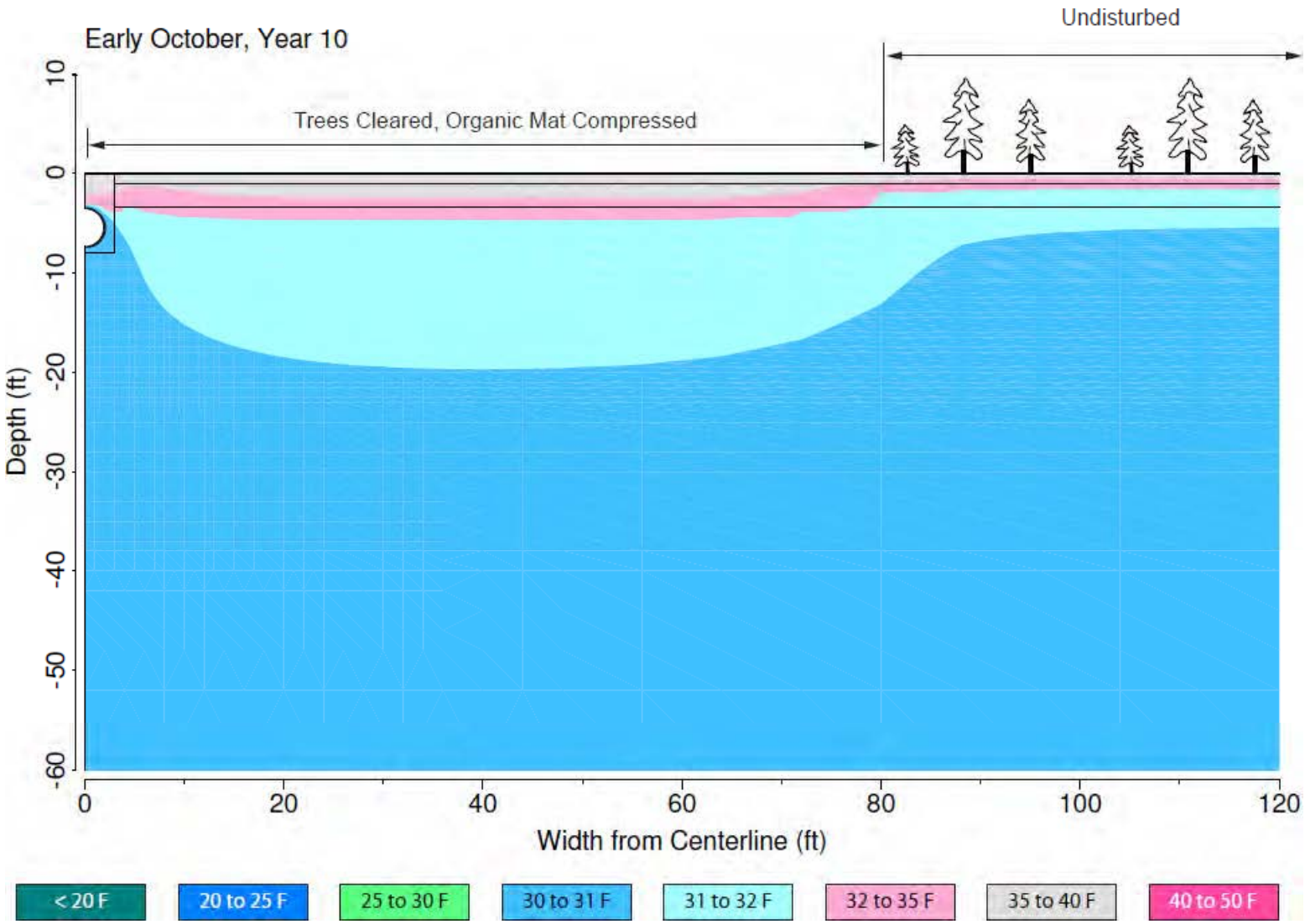
Dormant Pipe, Recently Cleared (not Stripped) ROW. Warm, Thaw-Unstable Permafrost (4 of 8).

nes



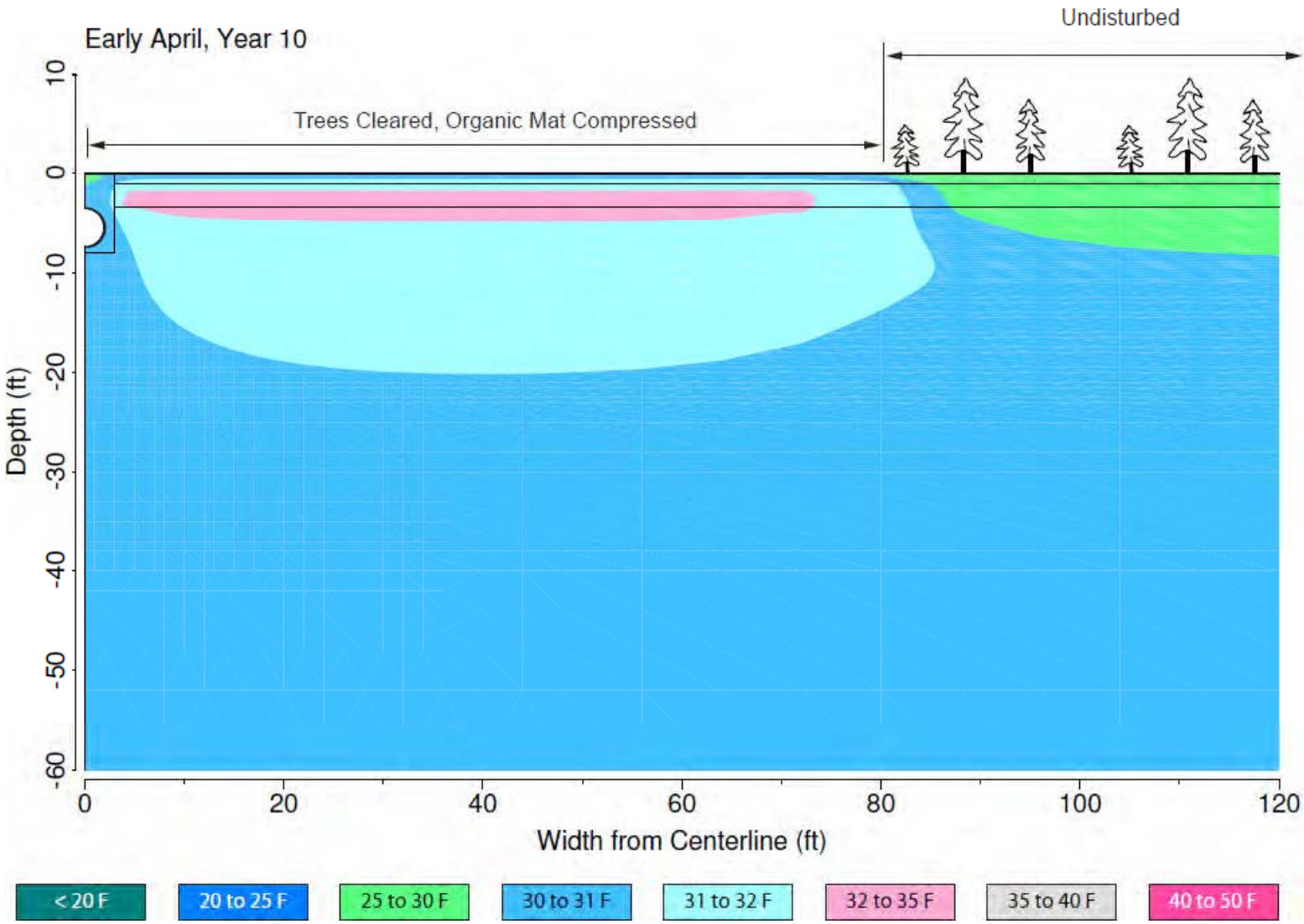
Dormant Pipe, Recently Cleared (not Stripped) ROW. Warm, Thaw-Unstable Permafrost (5 of 8).

nes



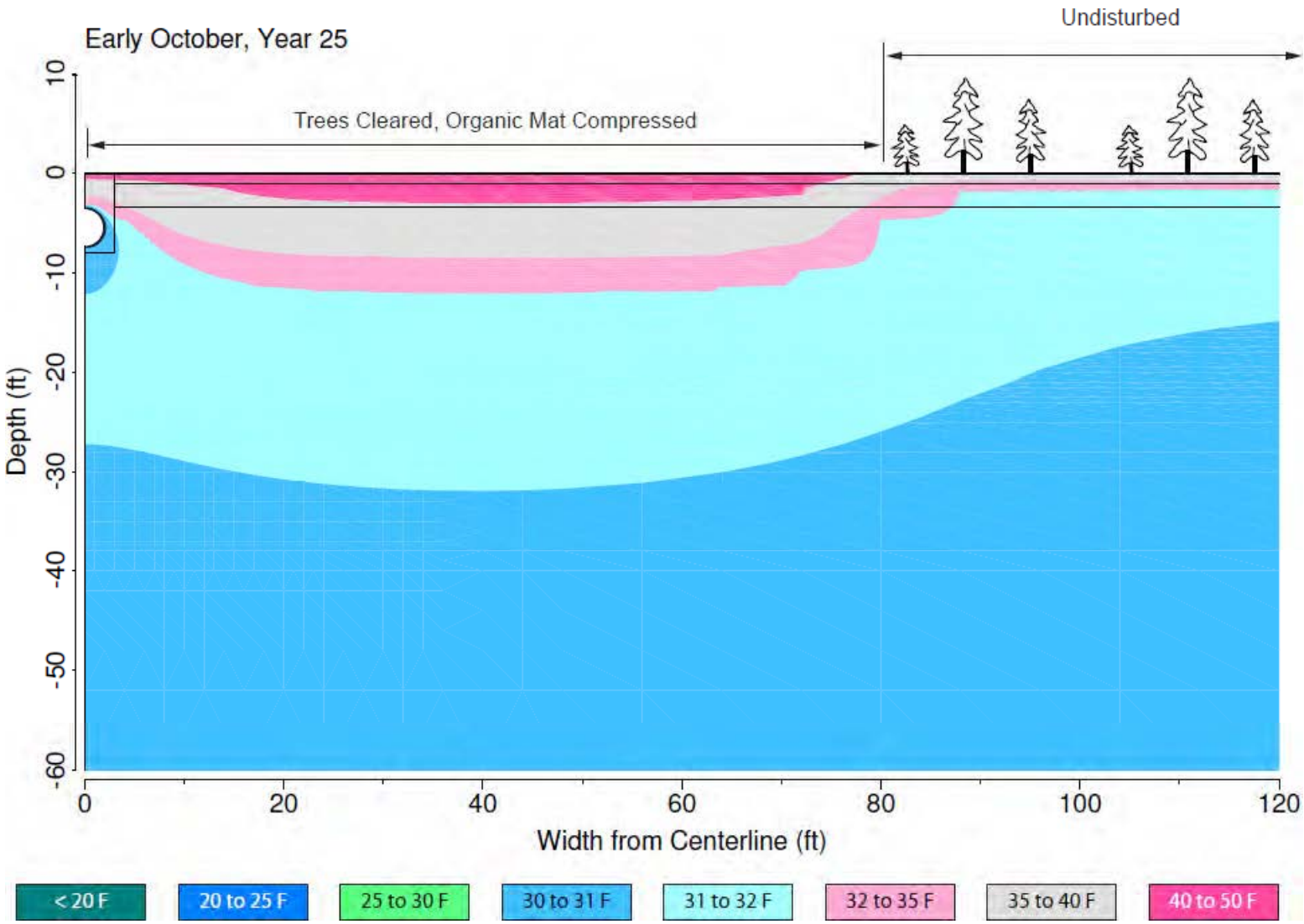
Dormant Pipe, Recently Cleared (not Stripped) ROW. Warm, Thaw-Unstable Permafrost (6 of 8).

nes



Dormant Pipe, Recently Cleared (not Stripped) ROW. Warm, Thaw-Unstable Permafrost (7 of 8).

nes



Dormant Pipe, Recently Cleared (not Stripped) ROW. Warm, Thaw-Unstable Permafrost (8 of 8).

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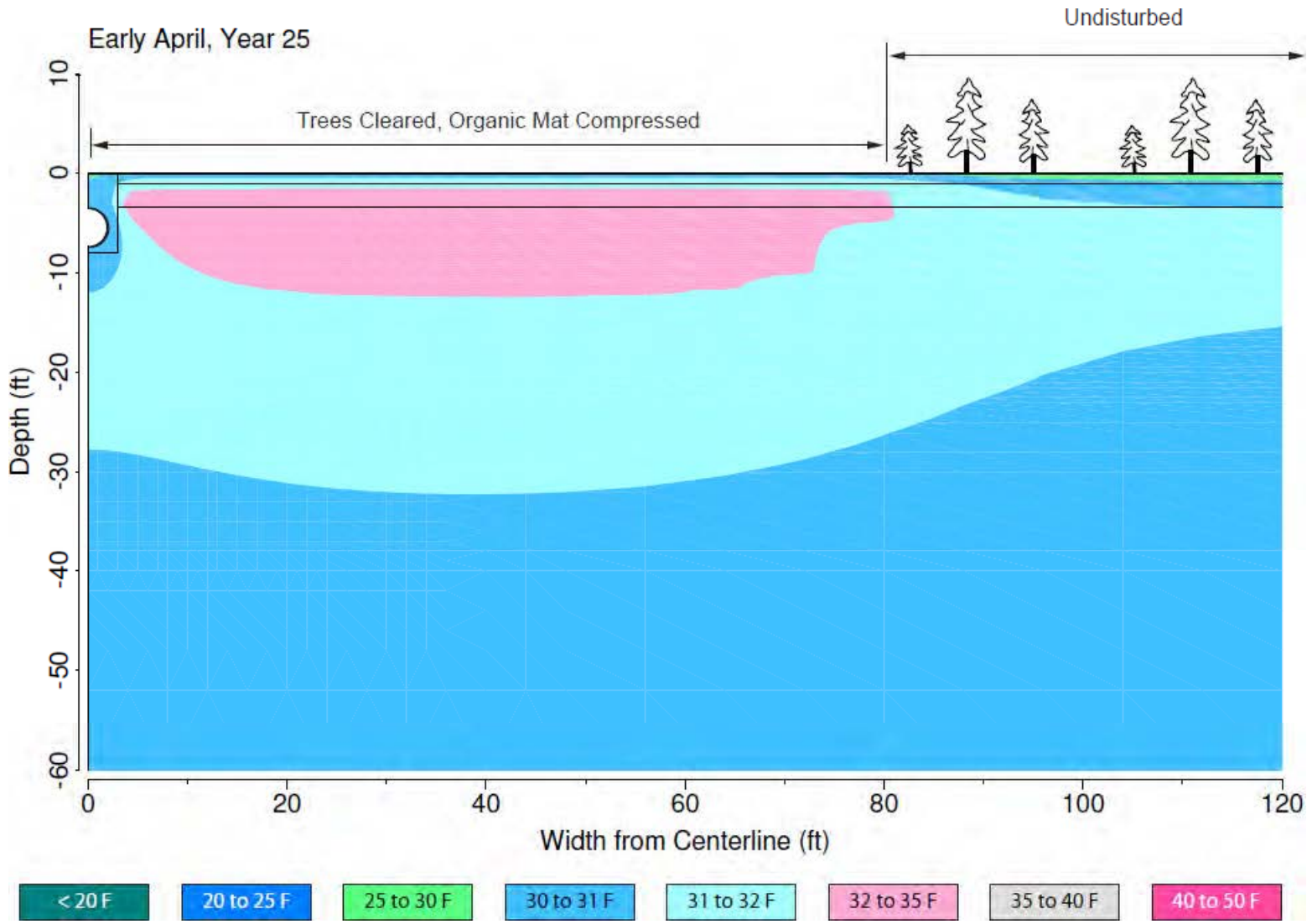
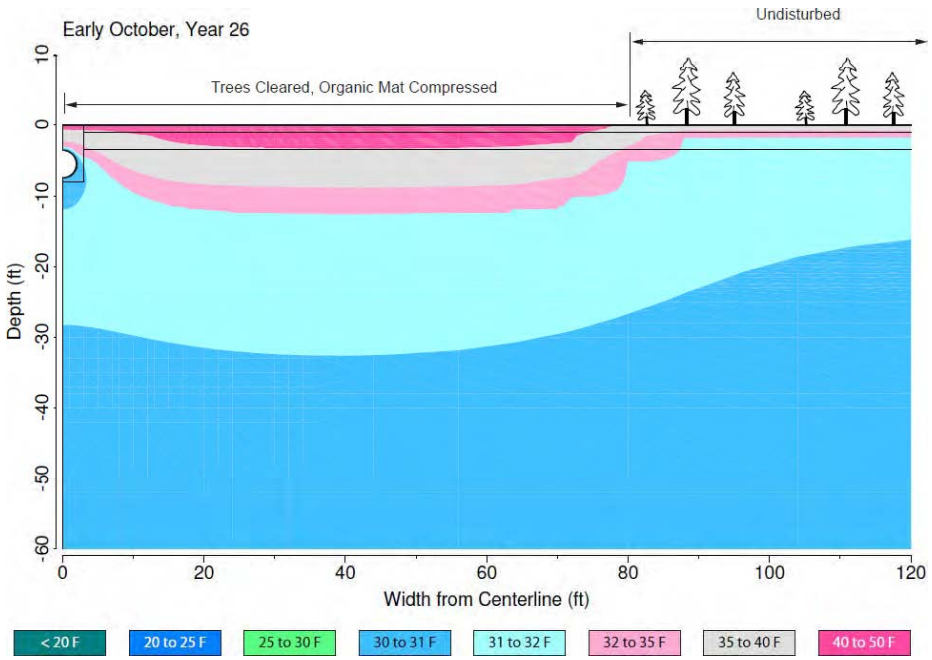


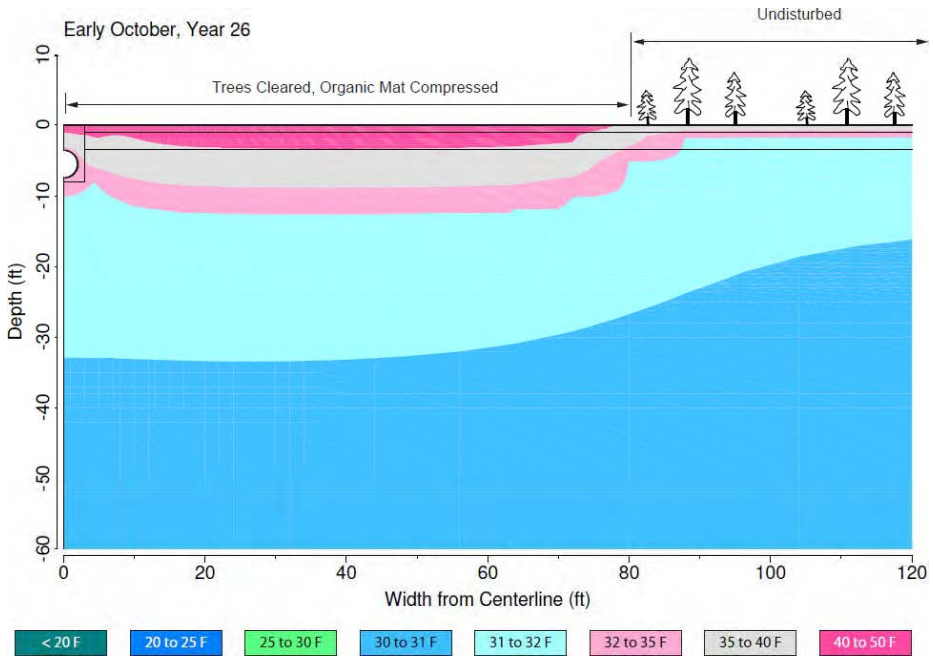
Comparisons of Predicted Temperature Contours, Constant versus Cycled Gas Temperature

nes

Pipe 30 °F, Constantly



Pipe average 31.5 °F, Cyclic



Summary, Thaw Settlement

nes

Good agreement between measured and predicted thaw depths for undisturbed, cleared but not stripped and cleared and stripped areas.

- Based upon comparisons for Linell's test site near Fairbanks, Alaska.

Good, empirical data to calculate thaw strain for a wide range of soil properties and types.

- Laboratory tests and fitted equations developed for TAPS
- Laboratory tests and fitted equations developed by Foothills Pipeline (Yukon)

Potential benefit to cycle pipeline temperatures to cause the Pipeline to settle at approximately the same rate as the ROW.

- In warm permafrost, if trees are cleared in the ROW permafrost will likely begin to thaw. If thaw-unstable the cleared ROW will settle. If the pipeline operates below freezing continuously it will likely preserve underlying permafrost and the pipeline will not settle along with the ROW.

Pipeline Frost Heave

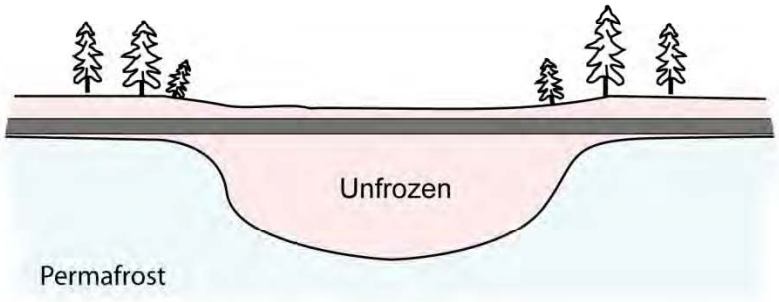
Where a chilled pipeline passes through unfrozen soils it will create a frost bulb. If soil under the pipeline is frost-susceptible water will be drawn to the freezing front.

Freezing of this water and pore water may cause the pipeline to heave upward due to the volume increase in water when it freezes. Soil must be unfrozen, frost-susceptible and ground water must be available.

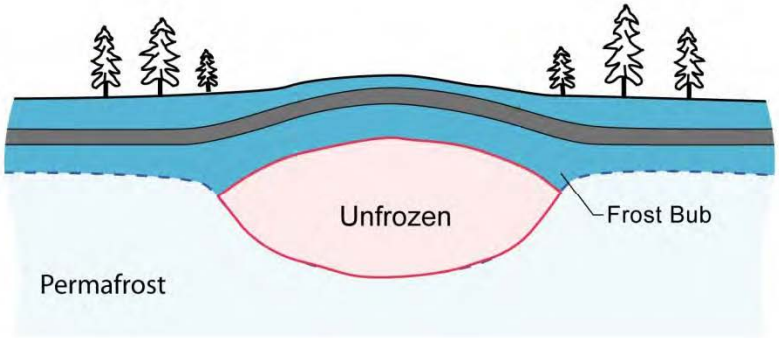
Idealized Representation of Differential Frost Heave

nes

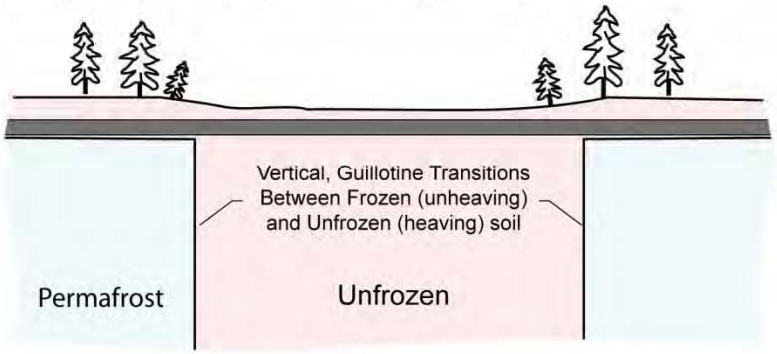
Idealization of Field Conditions, Short-Span Unfrozen Segment, Before Chilled Gas Flow



Idealization of Field Conditions, Differential Heaving Caused By Chilled Gas Flow

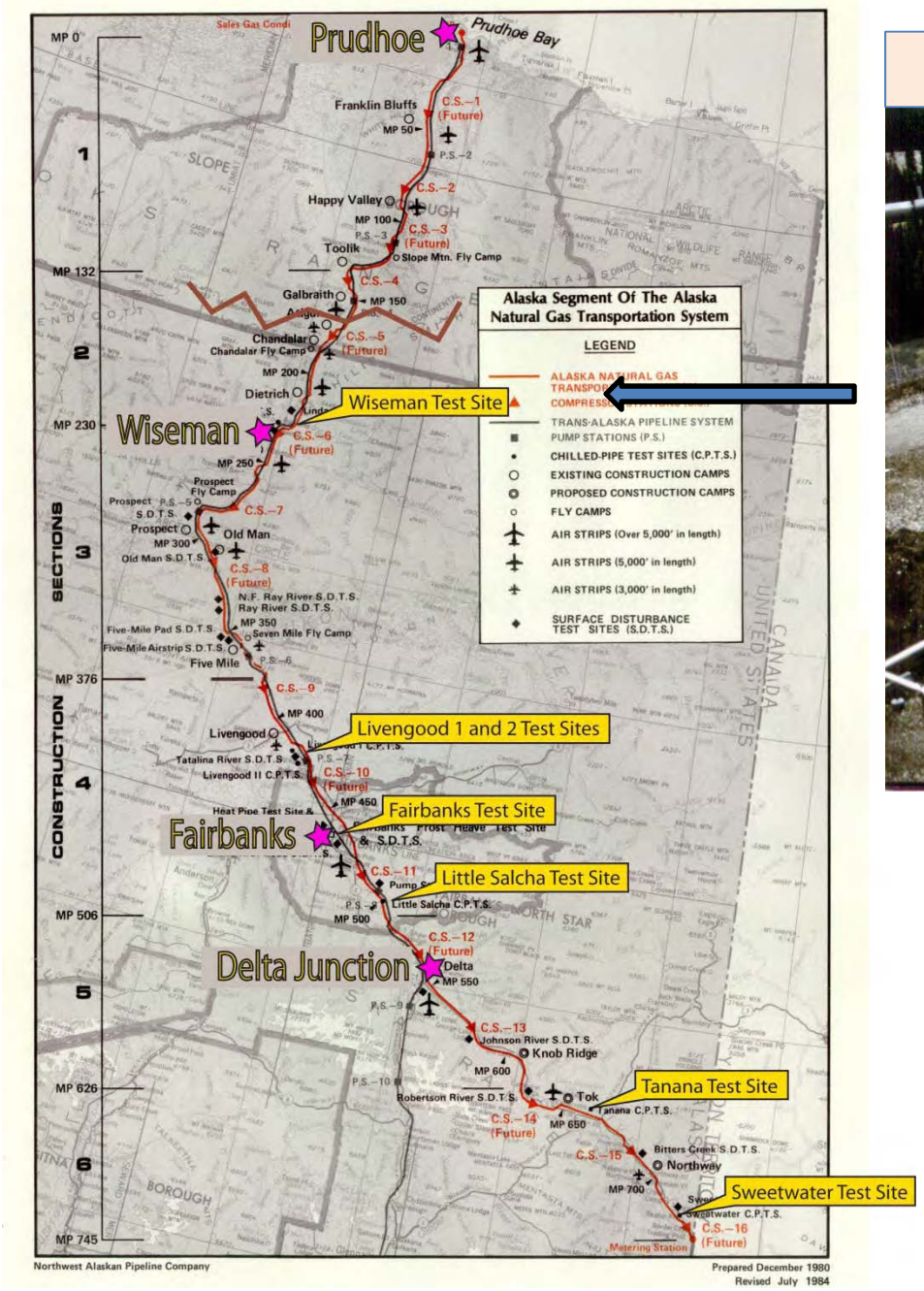


Idealization, Vertical Transitions for Frost Heave Predictions Before Chilled Gas Flow



Alaska Natural Gas Transportation System (ANGTS) System Map, Alaska

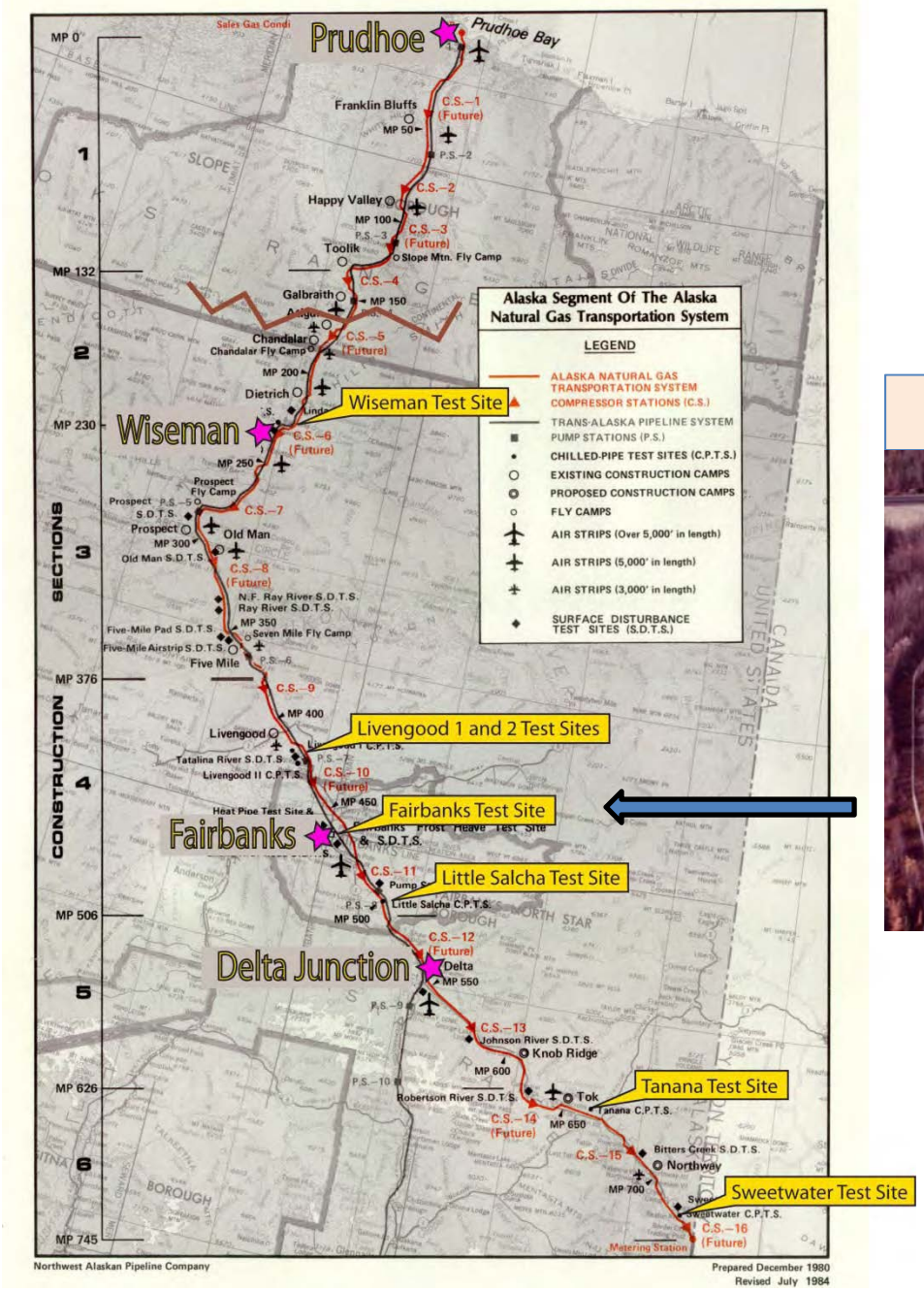
nes



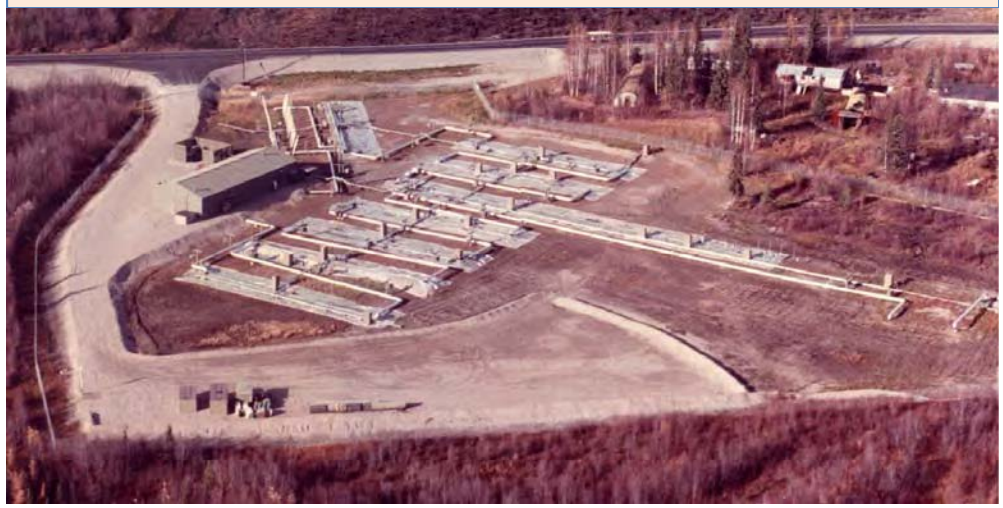
Wiseman Test Site

Alaska Natural Gas Transportation System (ANGTS) System Map, Alaska

nes



Fairbanks Test Site



Alaska Natural Gas Transportation System (ANGTS) System Map, Alaska

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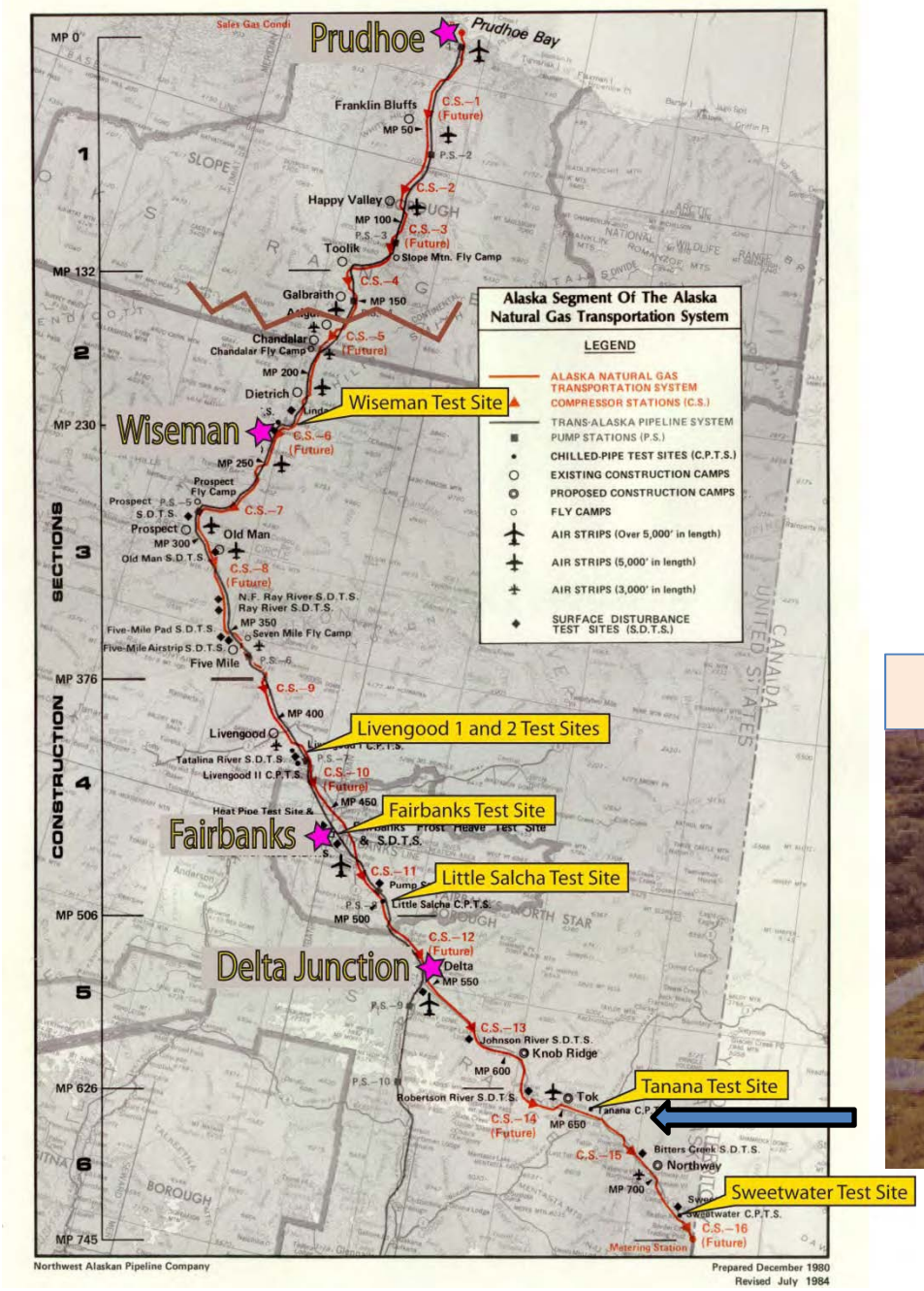
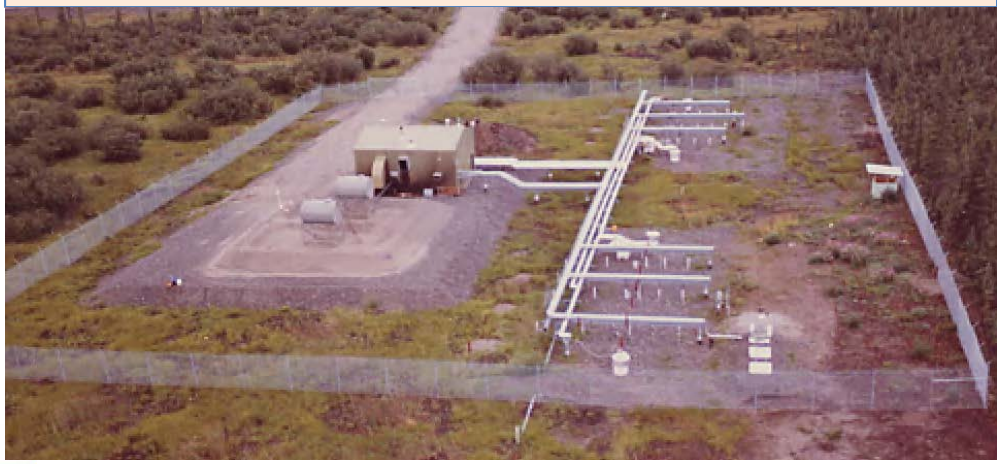


Tanana Test Site



Fairbanks Frost Heave Test Site (before startup, September 1979)

nes

Photo courtesy of Fred Crory, CRREL

Fairbanks Full-Scale Frost Heave Test Facility

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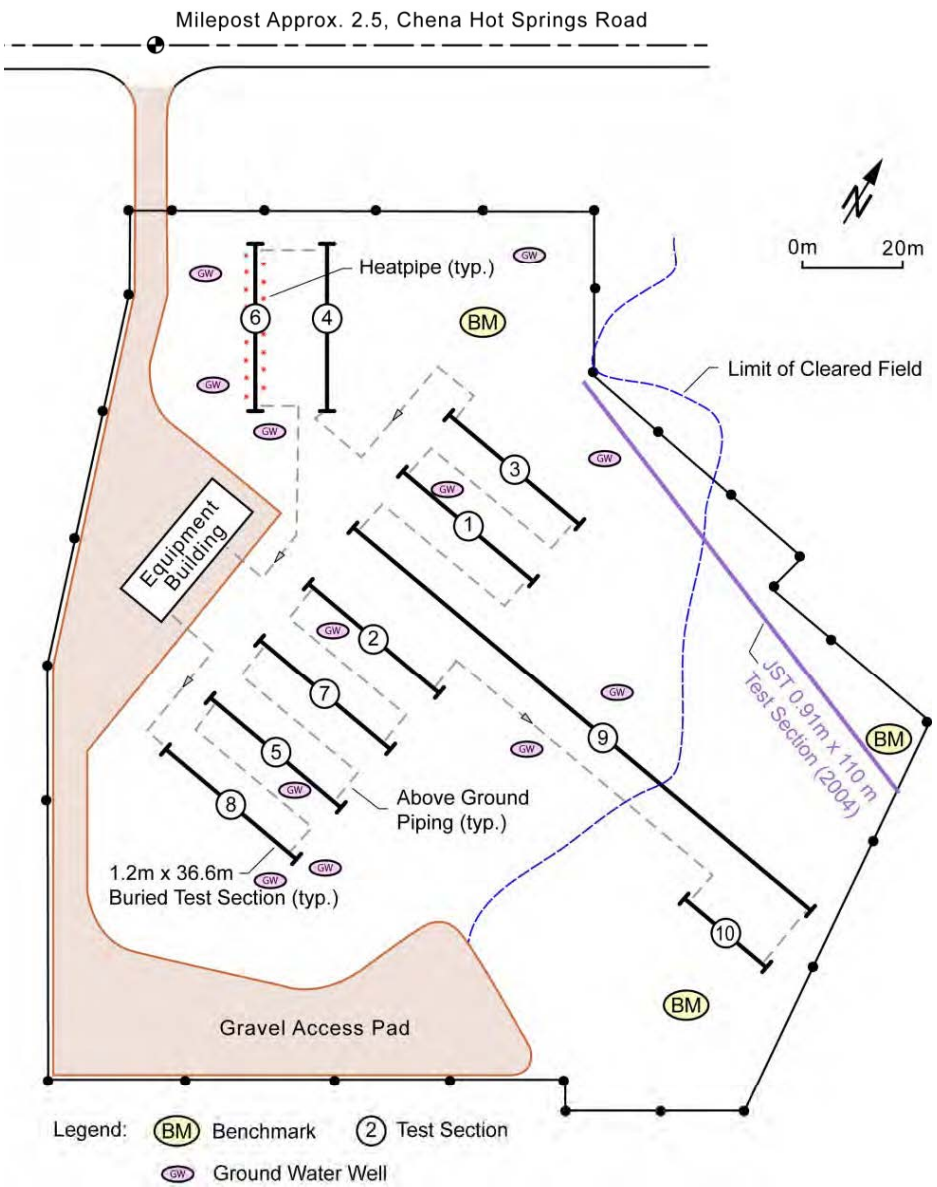

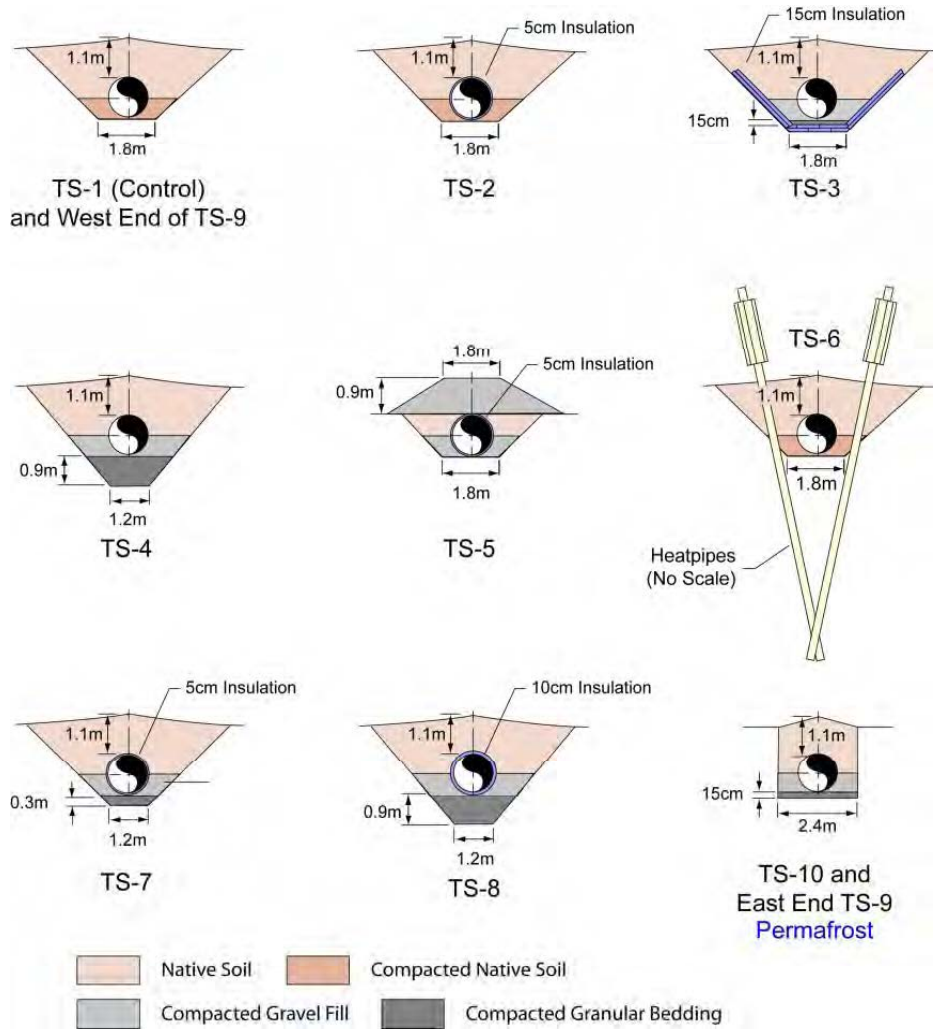

Typical Instrumentation, Fairbanks Frost Heave Test Site

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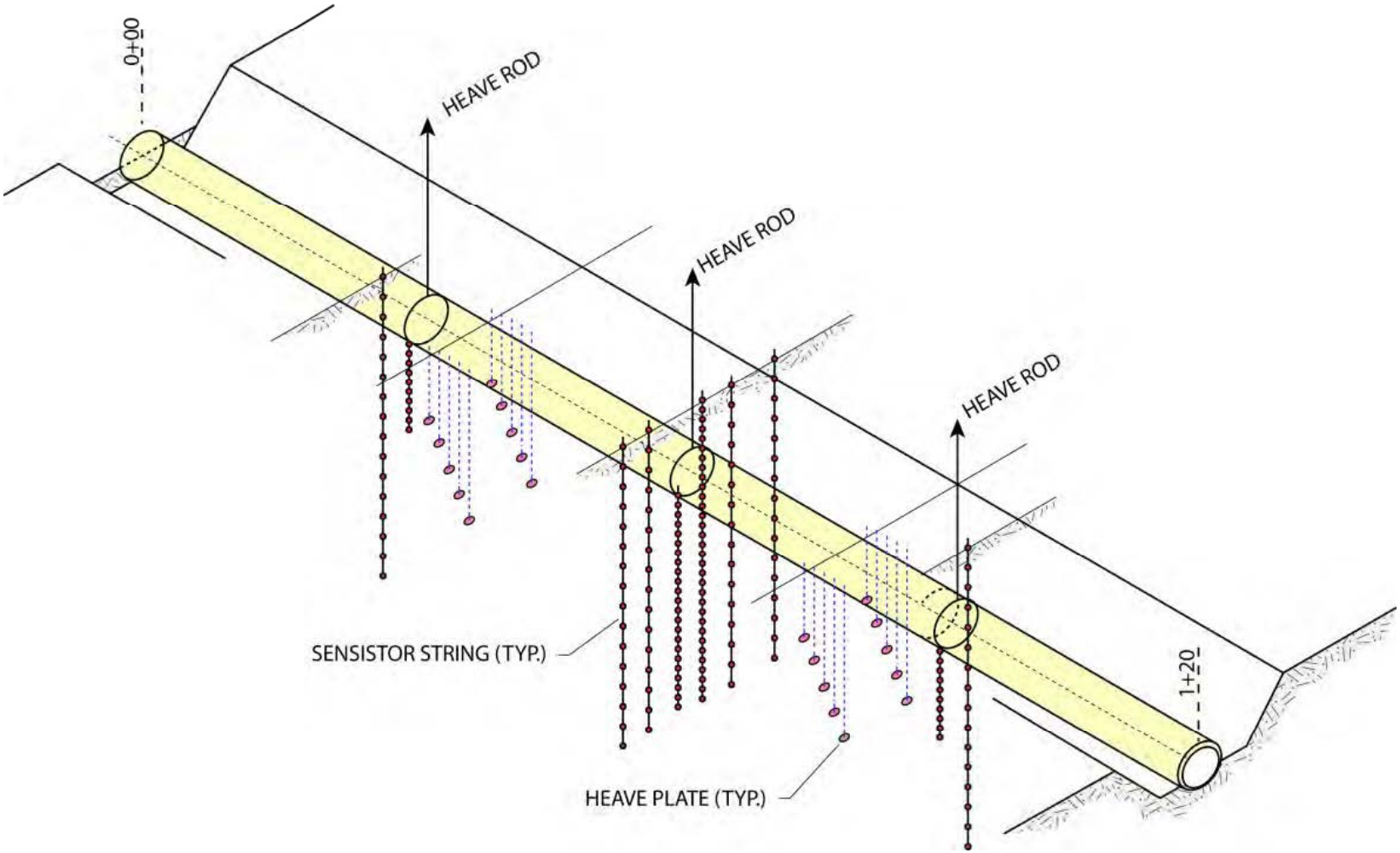

Differential Frost Heave, Fairbanks Test Site

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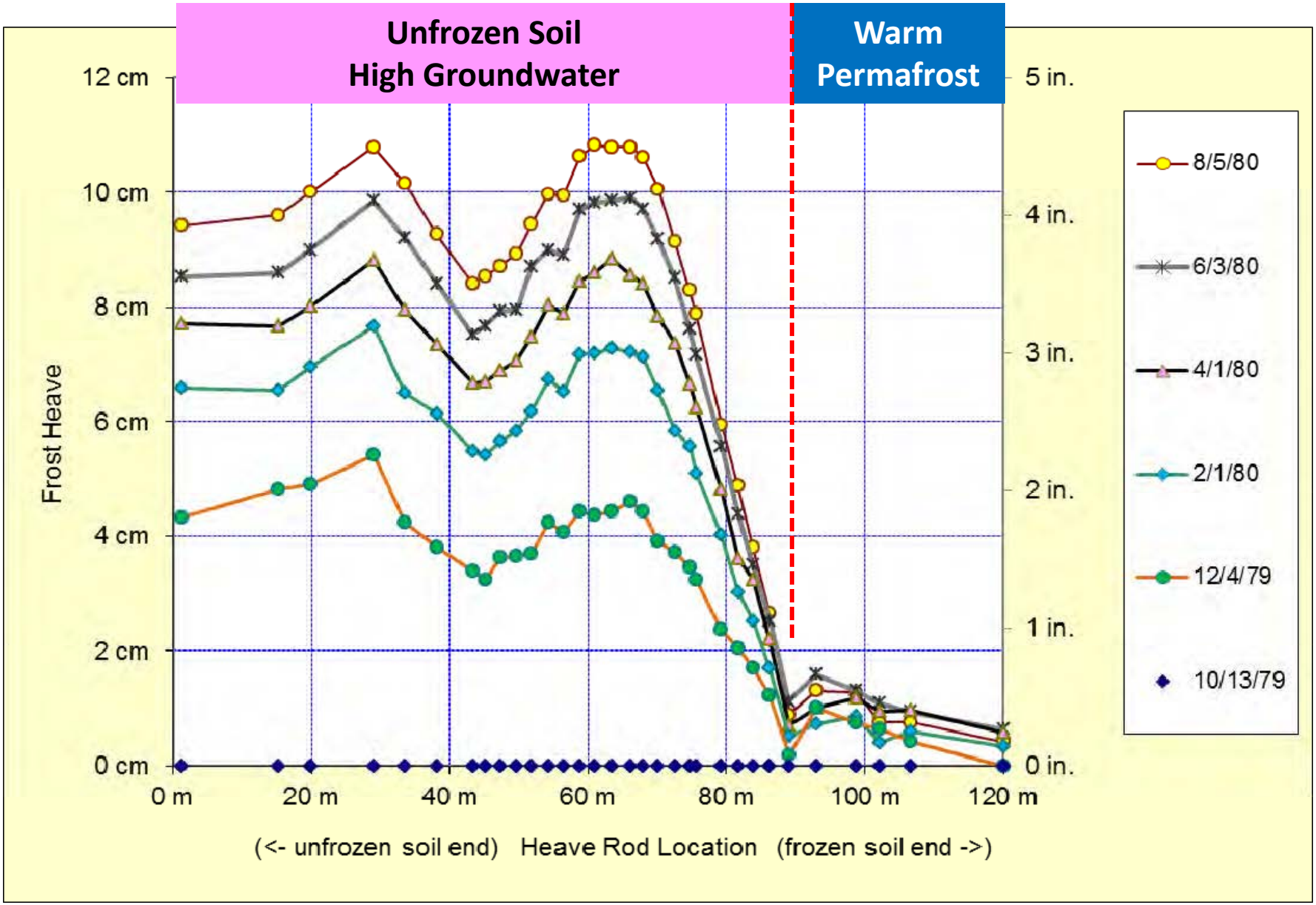
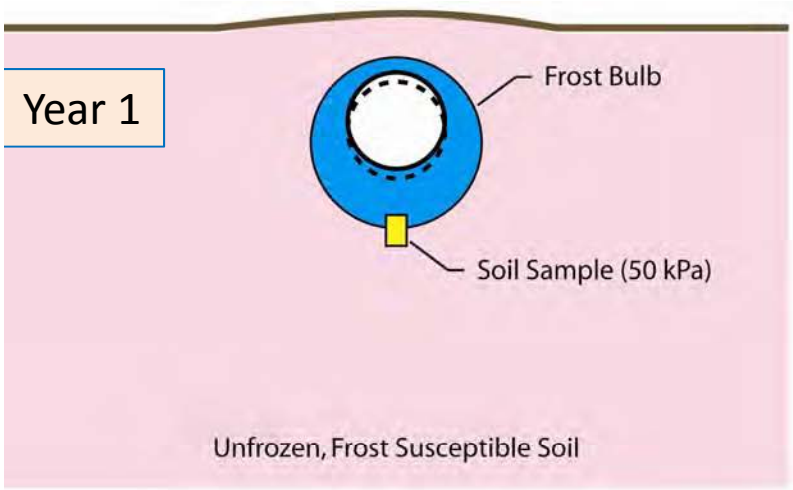
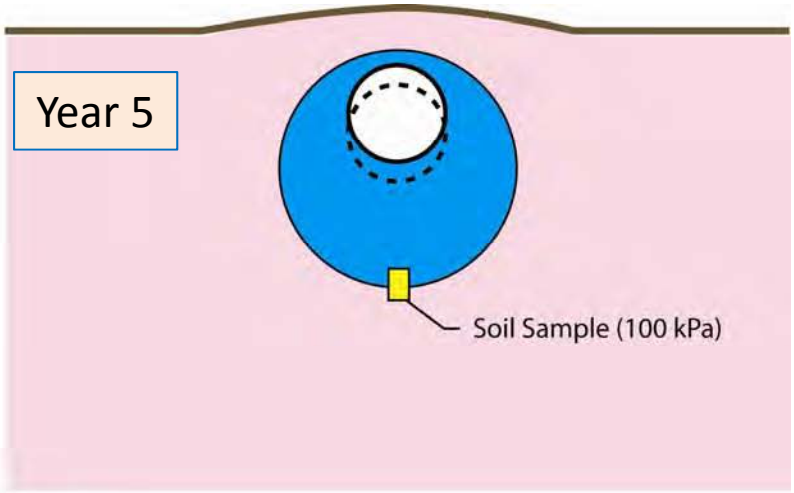


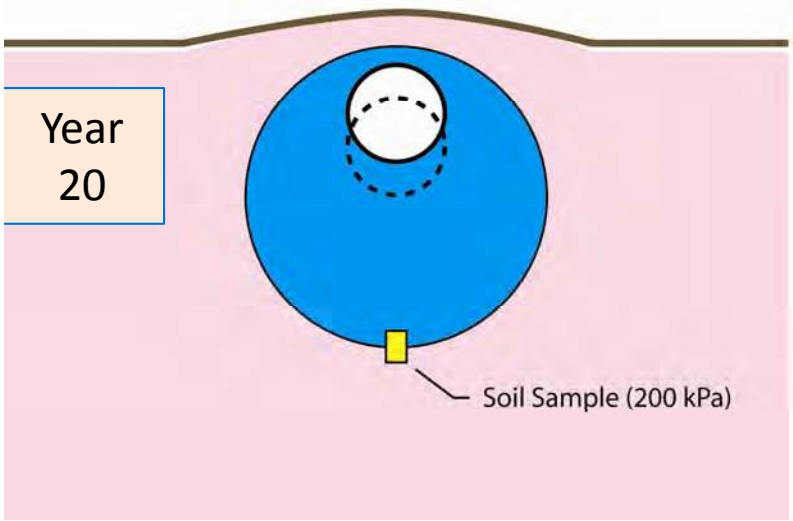
Hazen, Isaacs & Myrick, GEO2010, Calgary, September 2010

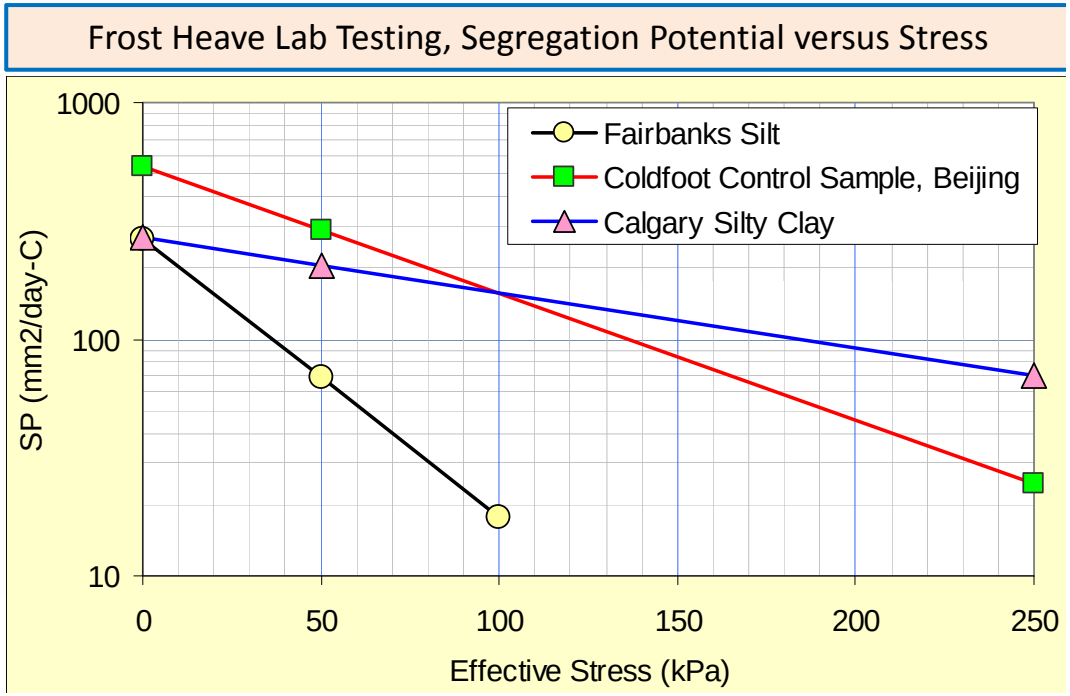
Frost Bulb Growth, Laboratory Testing for Frost Heave Segregation Potential

nes



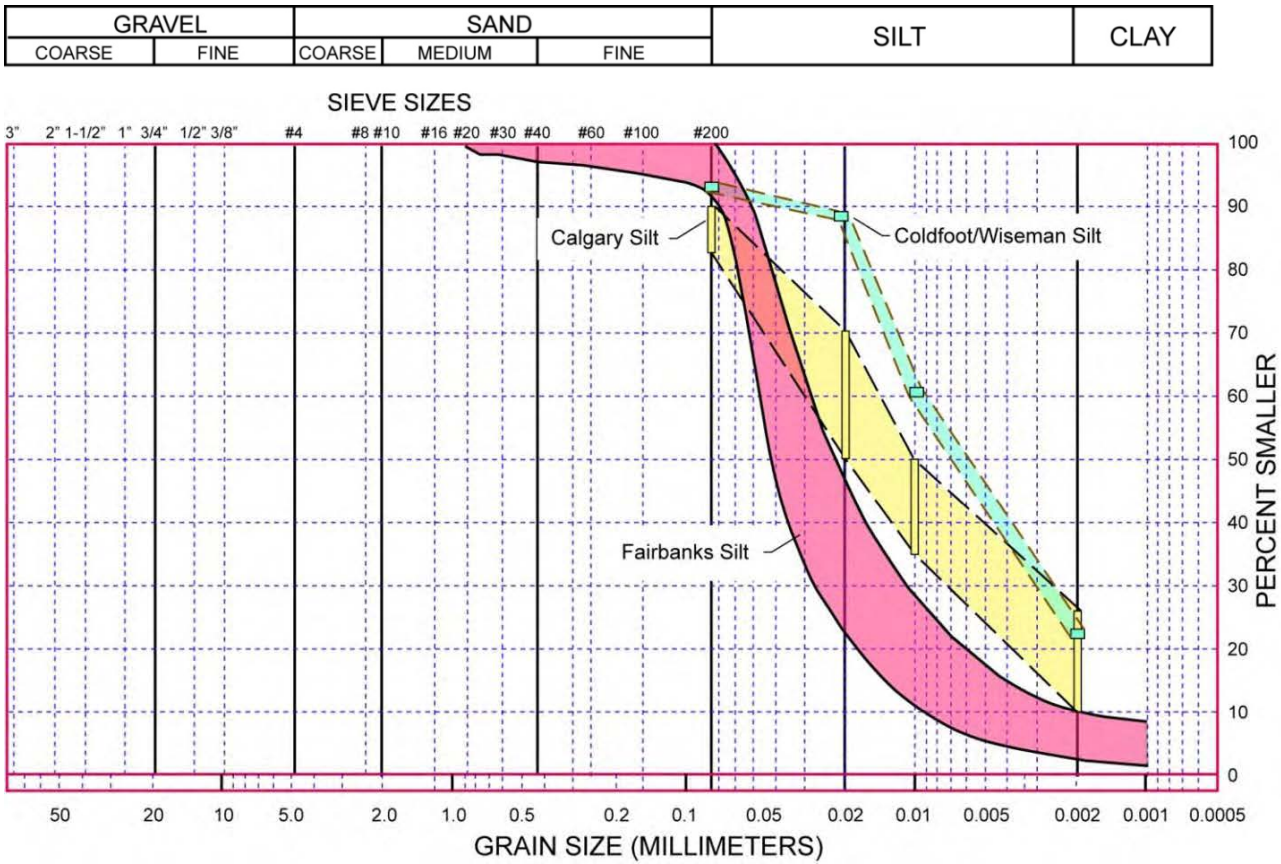


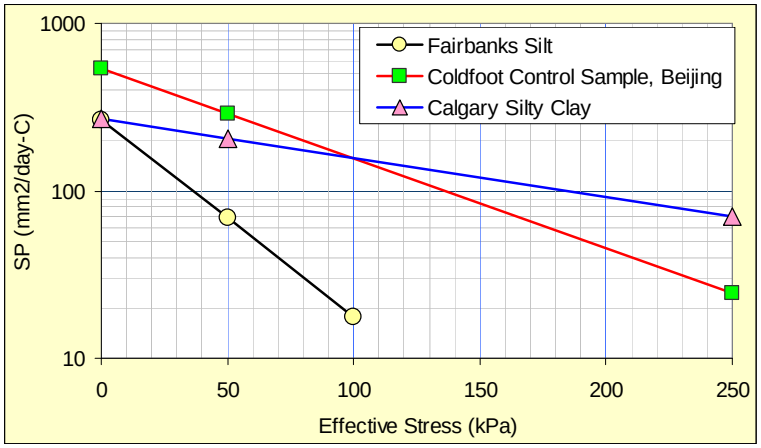




Comparison of Grain Sizes for Coldfoot/Wiseman, Calgary and Fairbanks Silt

nes





Hazen, Isaacs & Myrick, GEO2010, Calgary, September 2010

Frost Bulb Growth, Laboratory Testing for Frost Heave Segregation Potential

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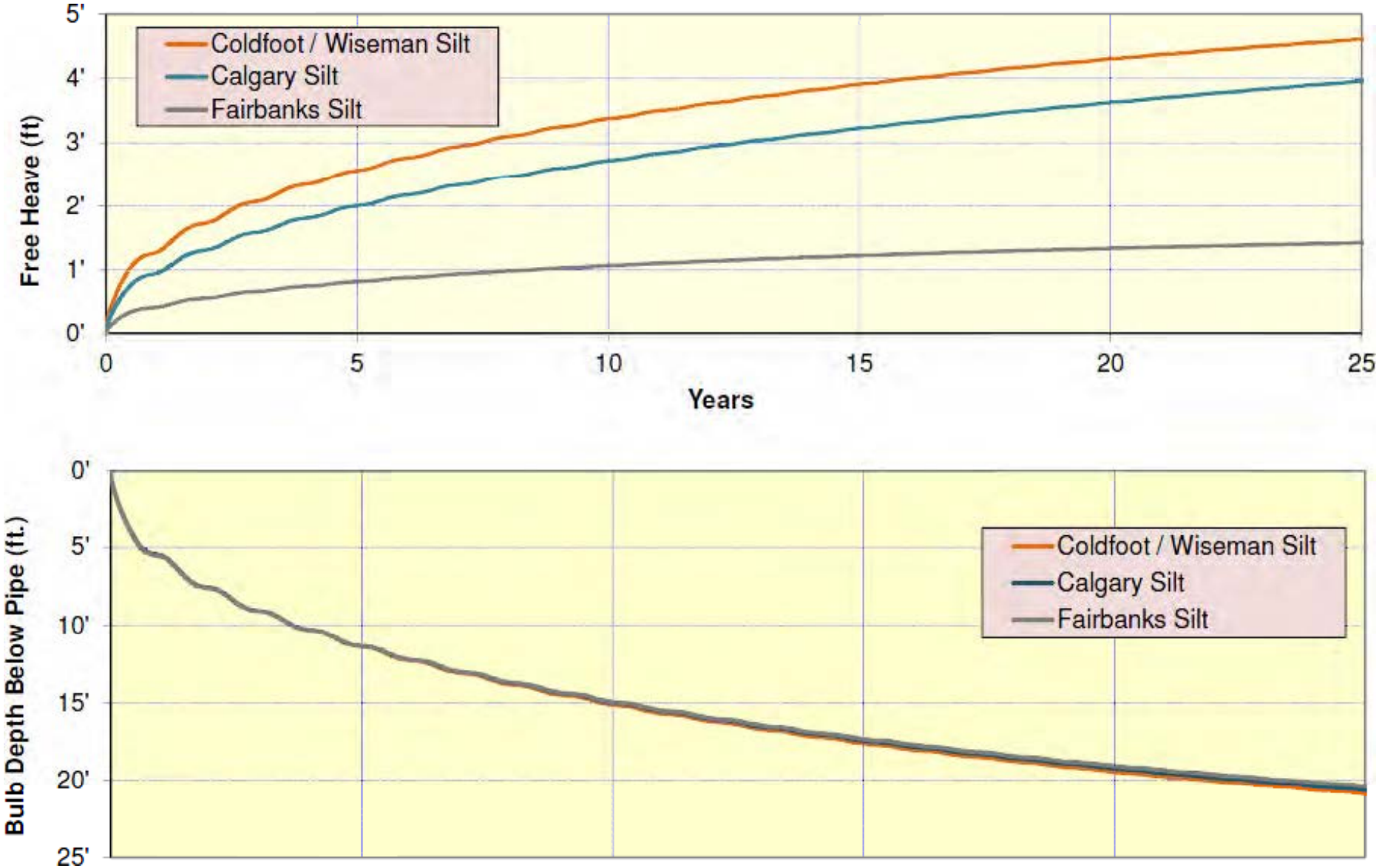

Pipeline Frost Heave, Fairbanks Frost Heave Test Site, Control Test Section

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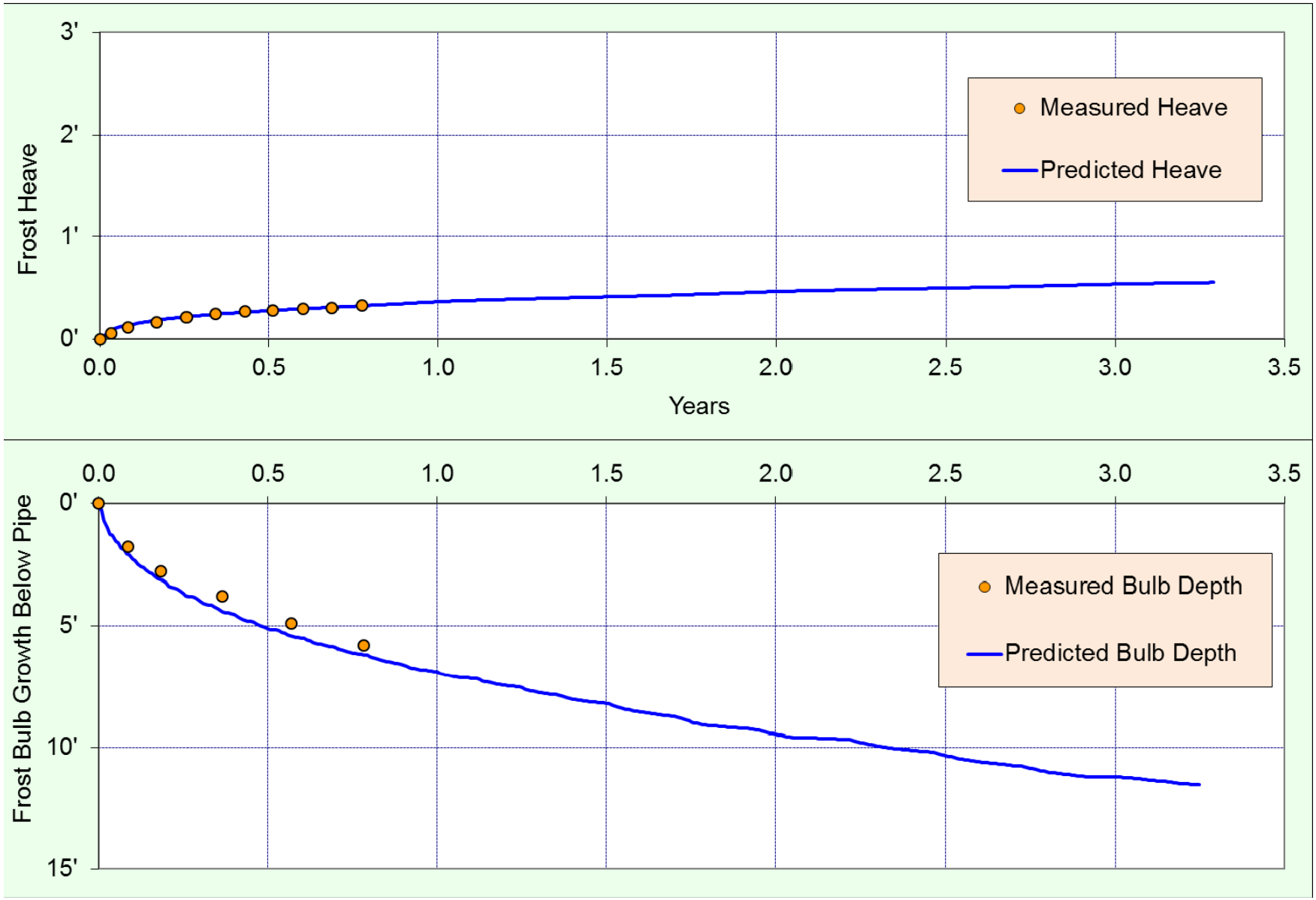

Hazen, Isaacs & Myrick, GEO2010, Calgary, September 2010

Pipeline Frost Heave, Calgary Frost Heave Test Site, Control Test Section

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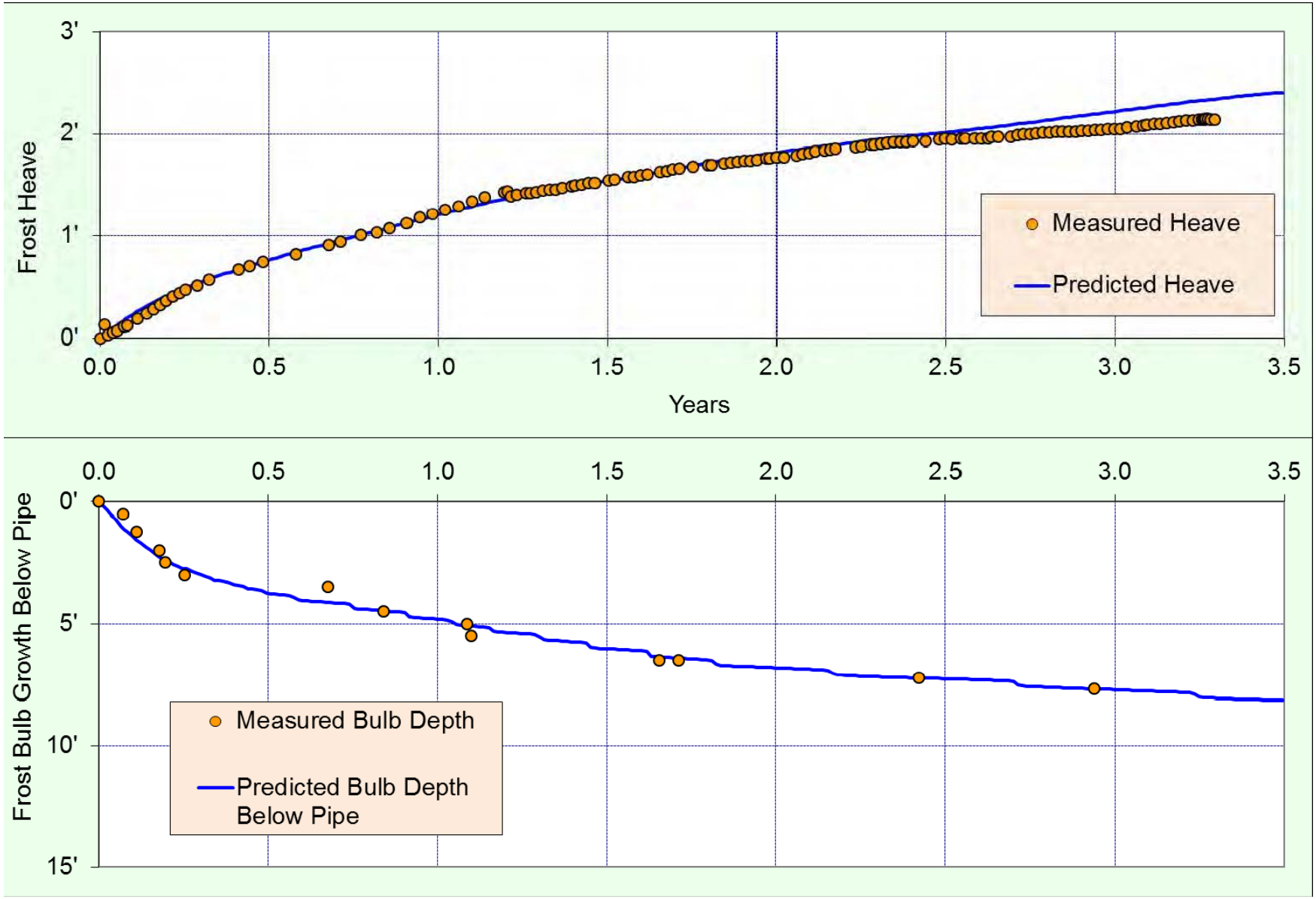


"**Analysis of Data from the Calgary Frost Heave Test Facility**" by LEC Engineering (Lorne Carlson) for Energy, Mines and Resources Canada, open file number 84-26, July 1984

Frost Heave, Summary

nes

Good understanding of Pipeline Frost Heave

- Full-Scale Test Sites
- Which soils heave (soil types, pressure dependency, permafrost doesn't heave)

Refined Computer Models for Predicting Pipeline Frost Heave

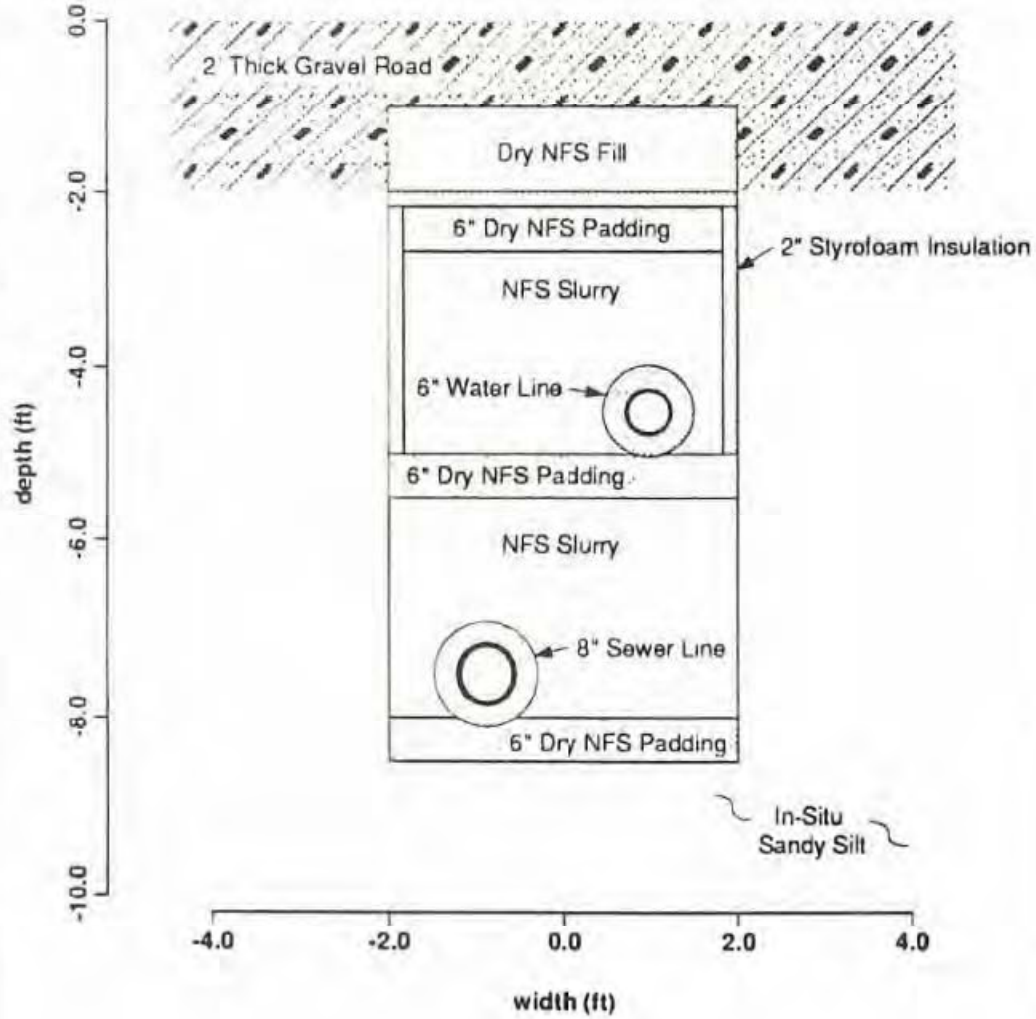
- Integration with Pipeline Flow Gas Hydraulics Model
- Integration with Pipeline Stress Analysis Models
- Advantages of Gas Temperature Cycling
- Influence of Pipeline Upon Others (Roads, Utilities, existing Pipelines)

Very good progress developing equations to predict frost heave from conventional soils tests

Buried Utility Pipes

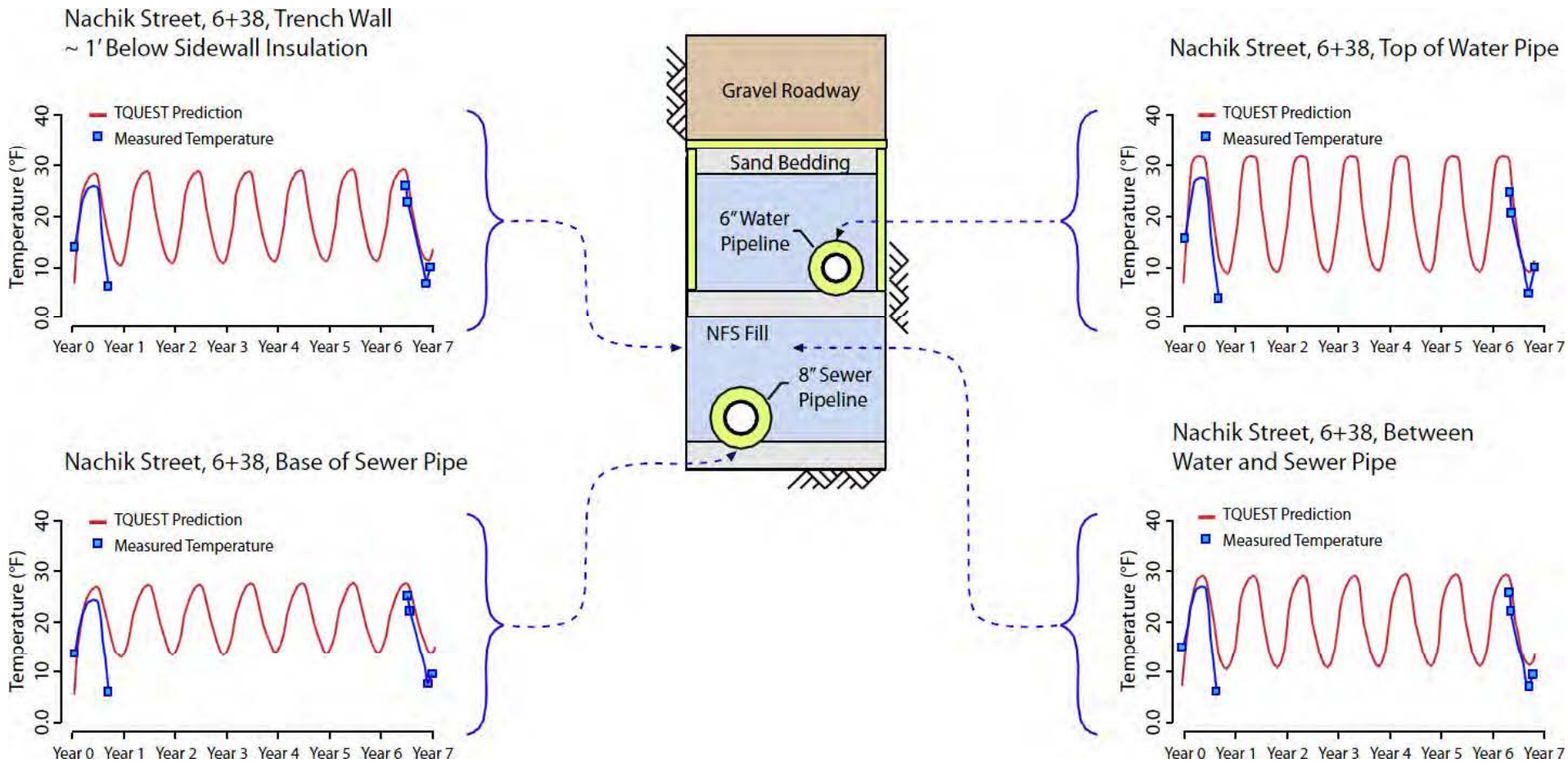
Thanks to
Richard Reich, P.E. General Manager Umiaq and
Charlotte Brower, North Slope Borough Mayor
for granting permission to show NSB Direct-Bury Utility Data

Figure 4.2-2
Nachik Street Cross-Section



Barrow Alaska Direct Bury Utility System, Comparisons Between Measured and Predicted Temperatures (1 of 2)

nes



Barrow Alaska Direct Bury Utility System, Comparisons Between Measured and Predicted Temperatures (2 of 2)

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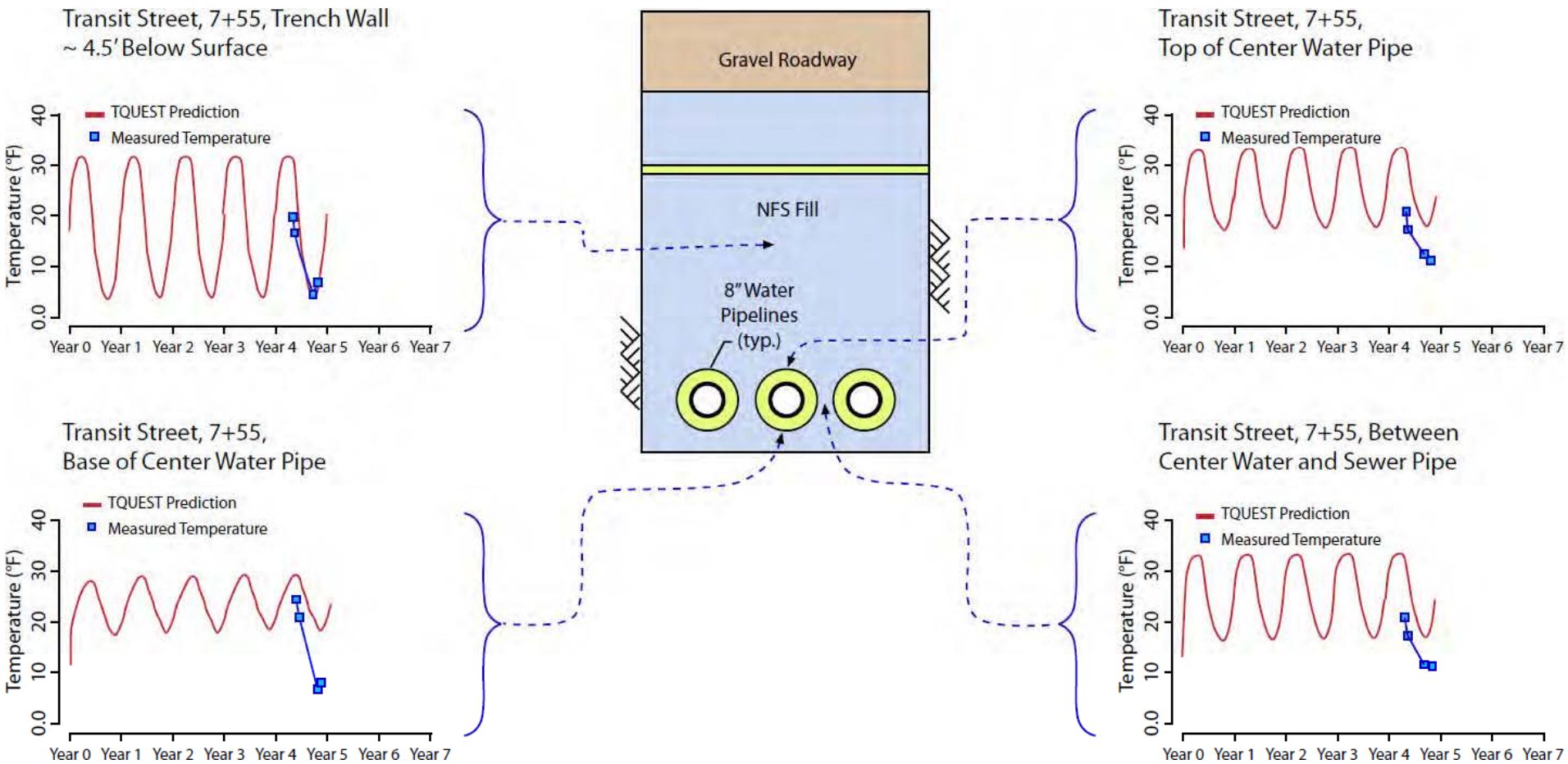

One of Many Designs for Insulated, Fluid Heat Traced Utility Pipes

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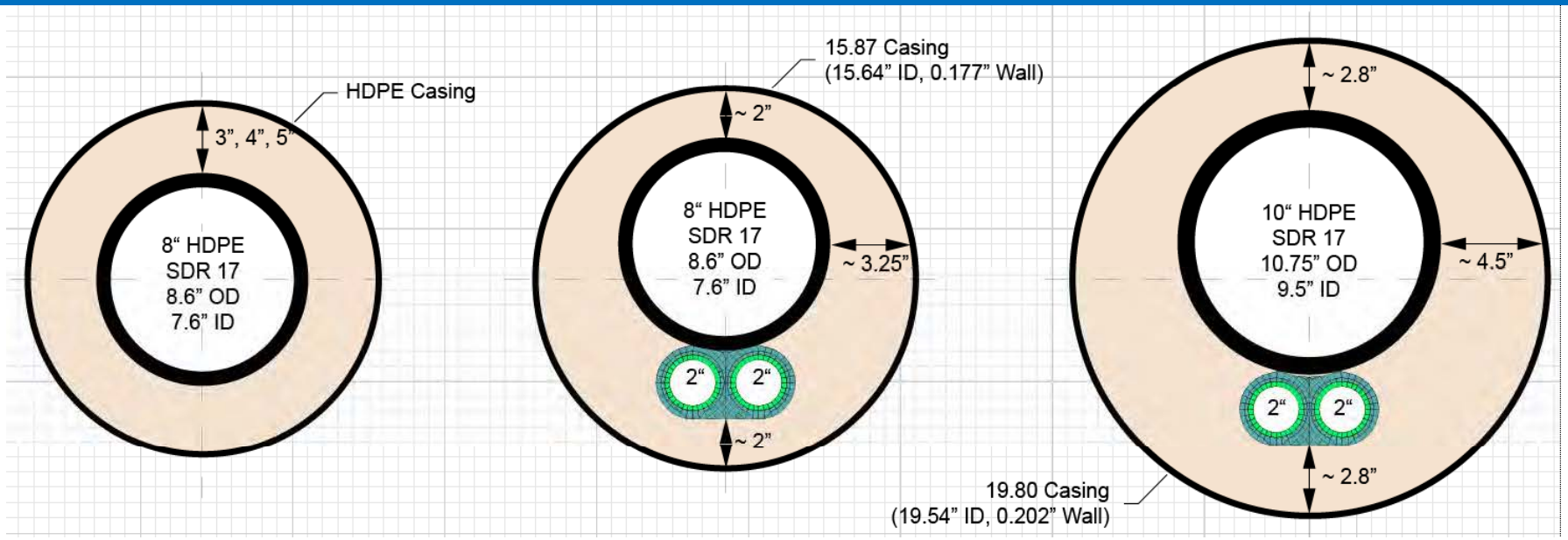

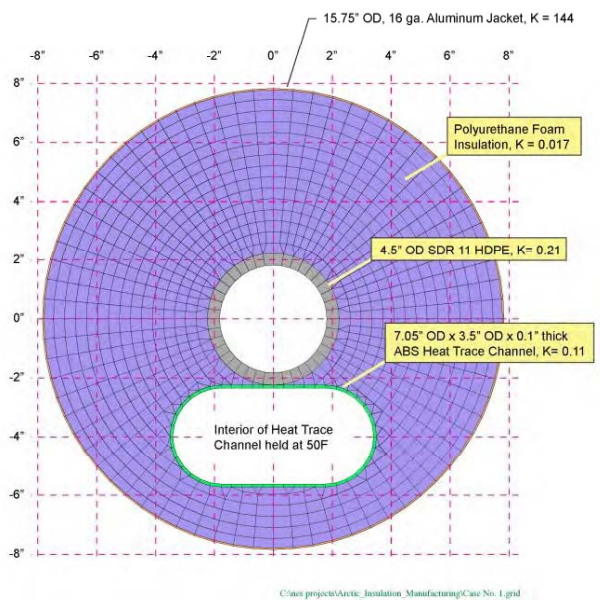

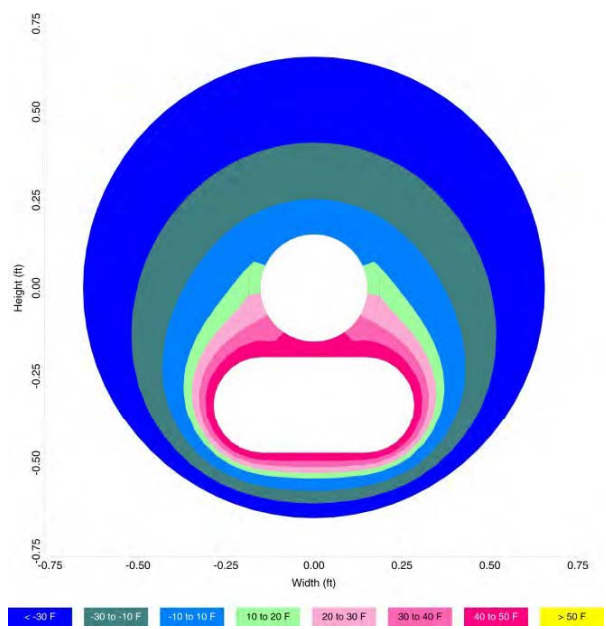

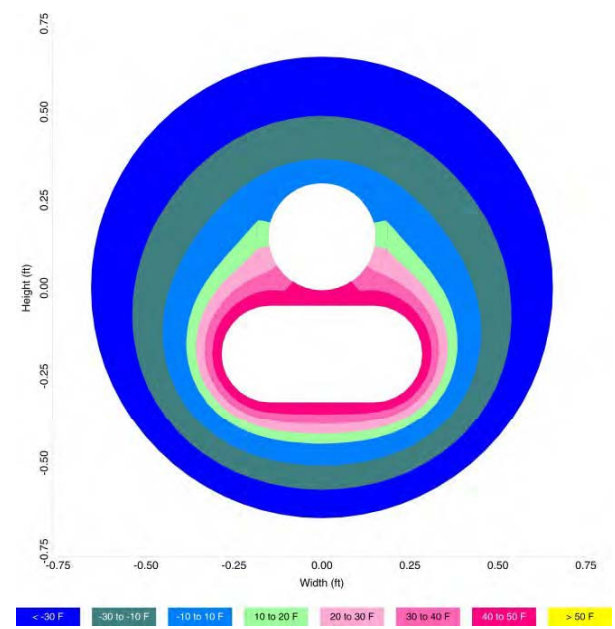

One of Many Designs for Insulated, Electric Heat Traced Utility Pipes

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Oops

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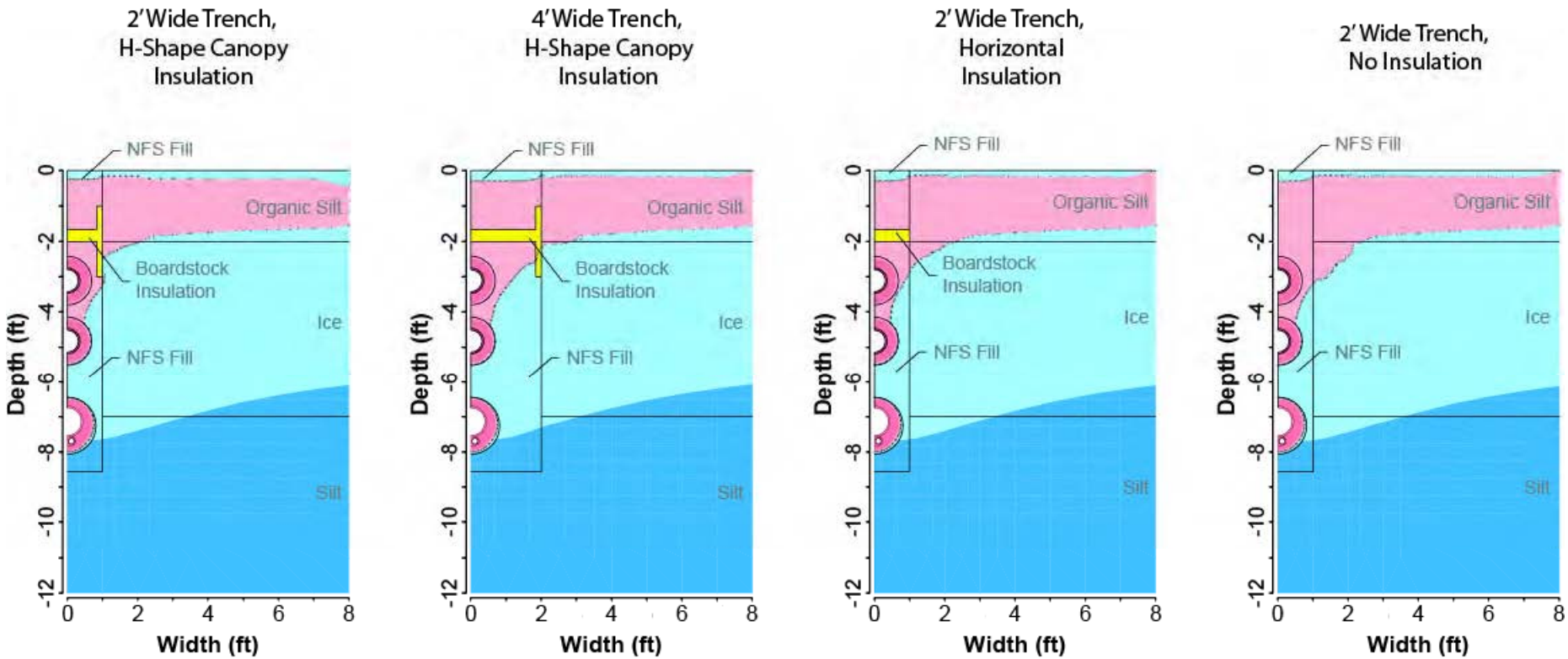


Contour Legend

- 20 to 28 °F
- 28 to 32 °F
- 32 to 35 °F
- > 35 °F

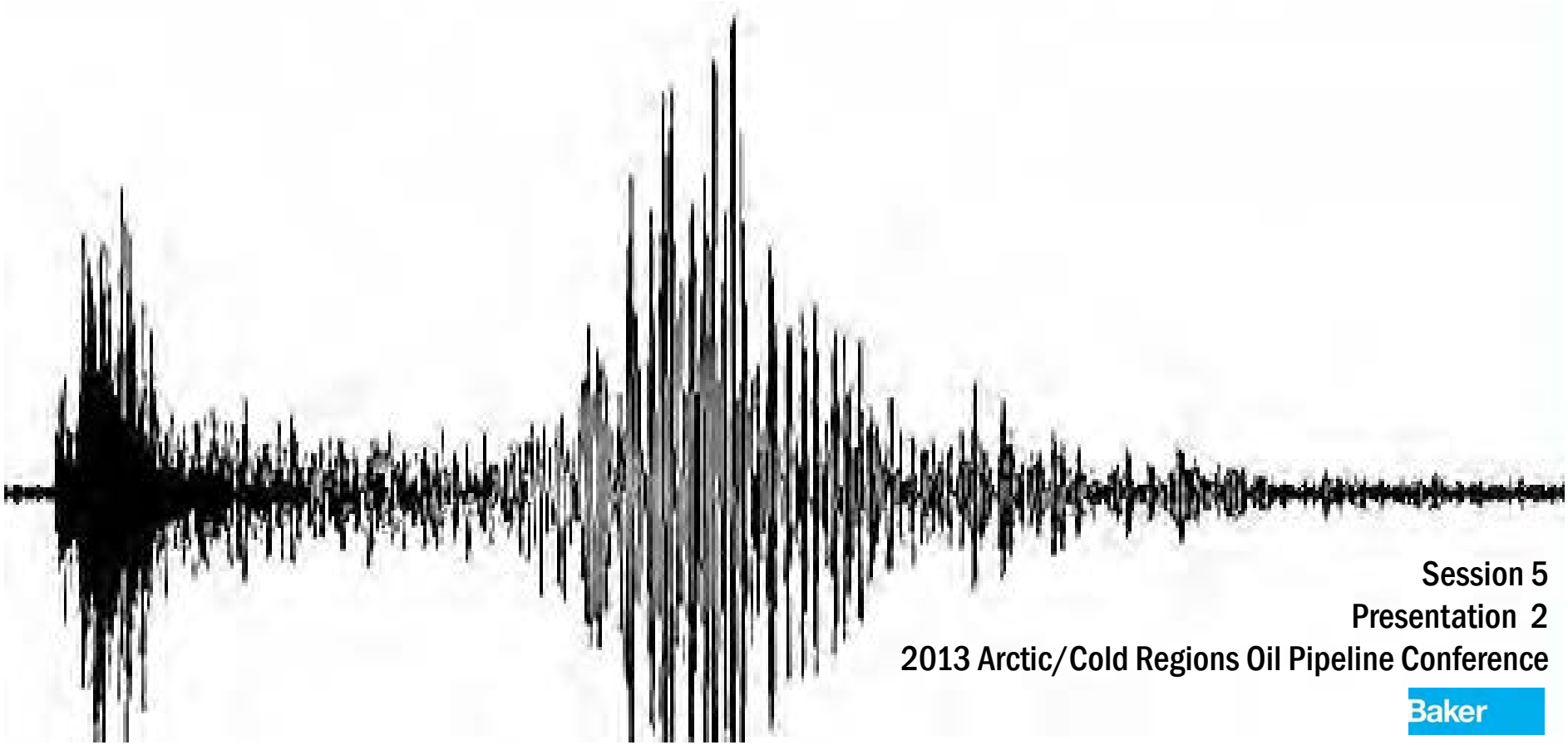
Thanks !

APPENDIX U

DESIGN FOR GROUND MOTION EFFECTS ON BURIED PIPELINES

DESIGN FOR GROUND MOTION EFFECTS ON BURIED PIPELINES

Presented by: Toby Lovelace



Session 5
Presentation 2
2013 Arctic/Cold Regions Oil Pipeline Conference

Baker

Objectives

a) Overview of seismic basics

b) Description of seismic hazards

c) Consequences of damage in an earthquake event

d) Background on seismic design of buried pipelines

e) Design for seismic wave propagation

f) Design for permanent ground displacement

g) Performance of buried pipelines in earthquakes

h) Conclusion

SEISMIC BASICS

- TECTONICS
- EARTHQUAKE WAVES
- EARTHQUAKE MAGNITUDE

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TECTONICS

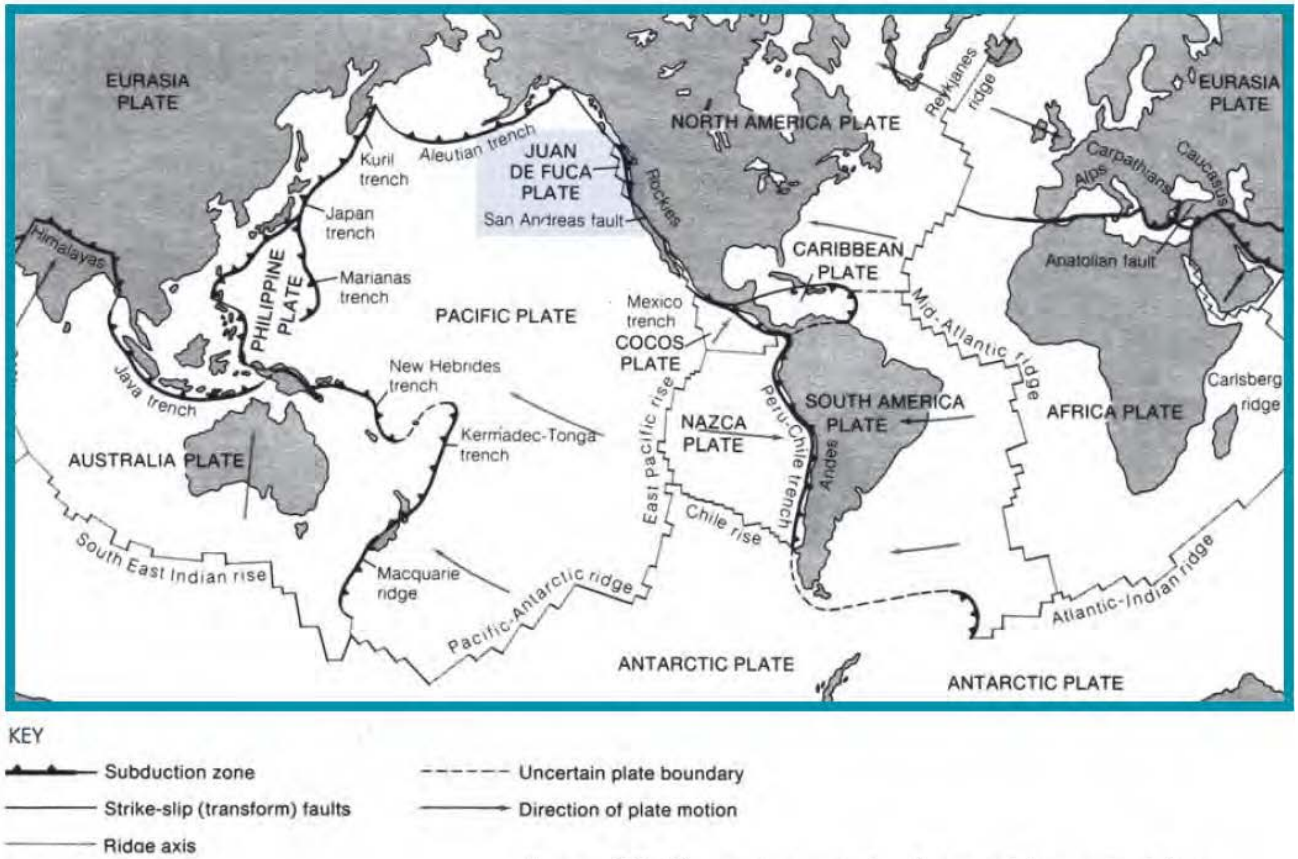


Figure 2-2: The major tectonic plates, midoceanic ridges, trenches and transform faults.

SOURCE: BRUCE A. BOLT, *NUCLEAR EXPLOSIONS AND EARTHQUAKES: THE PARTED VEIL* (SAN FRANCISCO: W. H. FREEMAN AND COMPANY. COPYRIGHT 1976

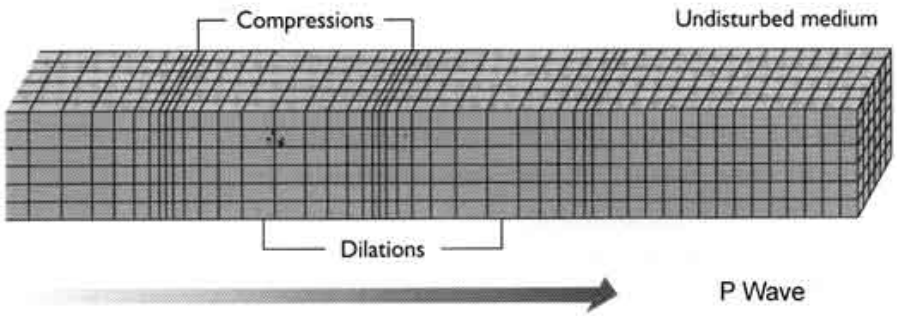
a) Tectonic plates

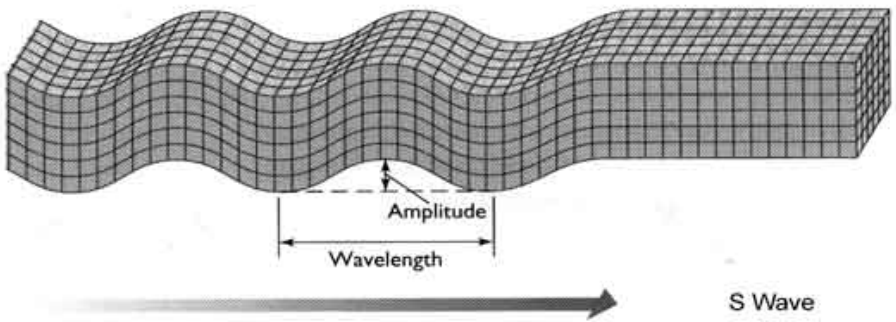
b) Subduction Zones

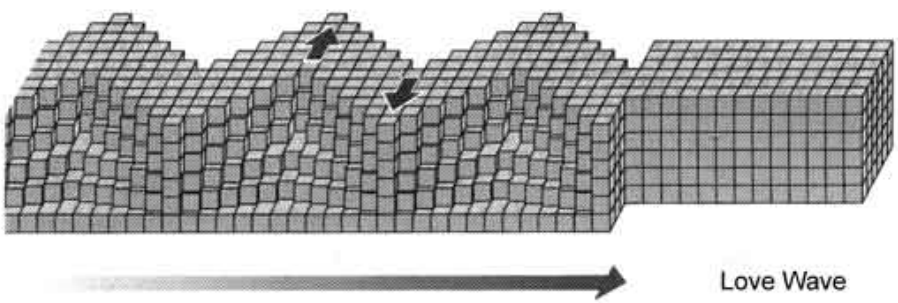
c) Interplate

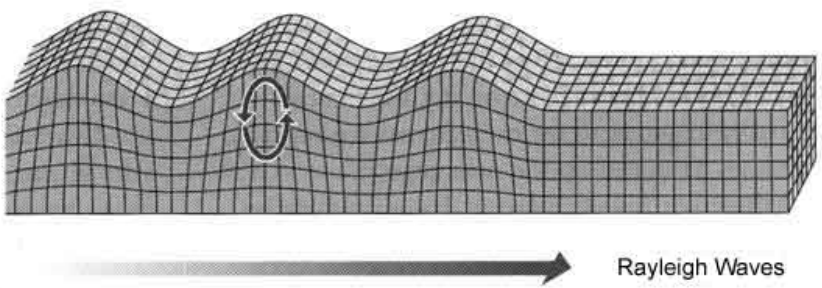
d) Intraplate

EARTHQUAKE WAVES









EARTHQUAKE MAGNITUDE

a) Richter magnitude (M_L)

   1) Logarithmic scale of seismic wave amplitude

   2) Amplifies waves with periods from 0.5 to 1.5 sec.

b) Surface wave magnitude (M_S)

   1) Based on amplitude of surface waves with a period of 20 sec.

c) Moment magnitude (M_W)

   1) Directly based on forces over the area of fault rupture

   2) Logarithmic scale of the Seismic Moment:

      - Shear modulus of rock formation
      - Area of rupture along fault
      - Average displacement

Variance in Magnitude

Table 2-1: Magnitudes of some great earthquakes

Date	Region	M_s	M_w
January 9, 1905	Mongolia	8.25	8.4
January 31, 1906	Ecuador	8.6	8.8
April 18, 1906	San Francisco	8.25	7.9
January 3, 1911	Turkestan	8.4	7.7
December 16, 1920	Kansu, China	8.5	7.8
May 22, 1960	Chile	8.3	9.5
March 28, 1964	Alaska	8.4	9.2
October 17, 1966	Peru	7.5	8.1
August 11, 1969	Kurile Islands	7.8	8.2
October 3, 1974	Peru	7.6	8.1
July 27, 1976	China	8.0	7.5

Table Excerpt

Source: Federal Emergency Management Agency FEMA 454 Designing for Earthquakes; A Manual for Architects

SEISMIC HAZARDS

- Differential fault movement and ground rupture
- Ground Shaking
- Liquefaction
- Landslides
- Tsunamis or seiches

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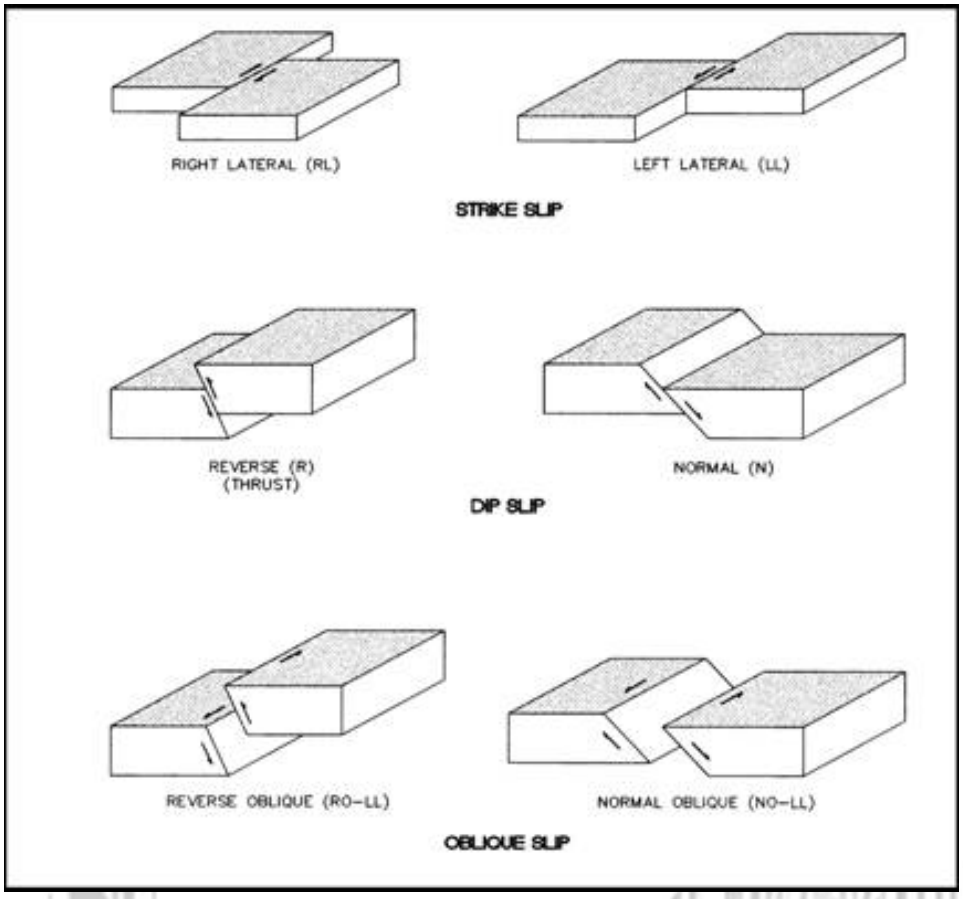
DIFFERENTIAL FAULT MOVEMENT AND GROUND RUPTURE



a) Occurs above faults

b) Dip – angle of fault surface to horizontal plane

c) Strike-slip / transform

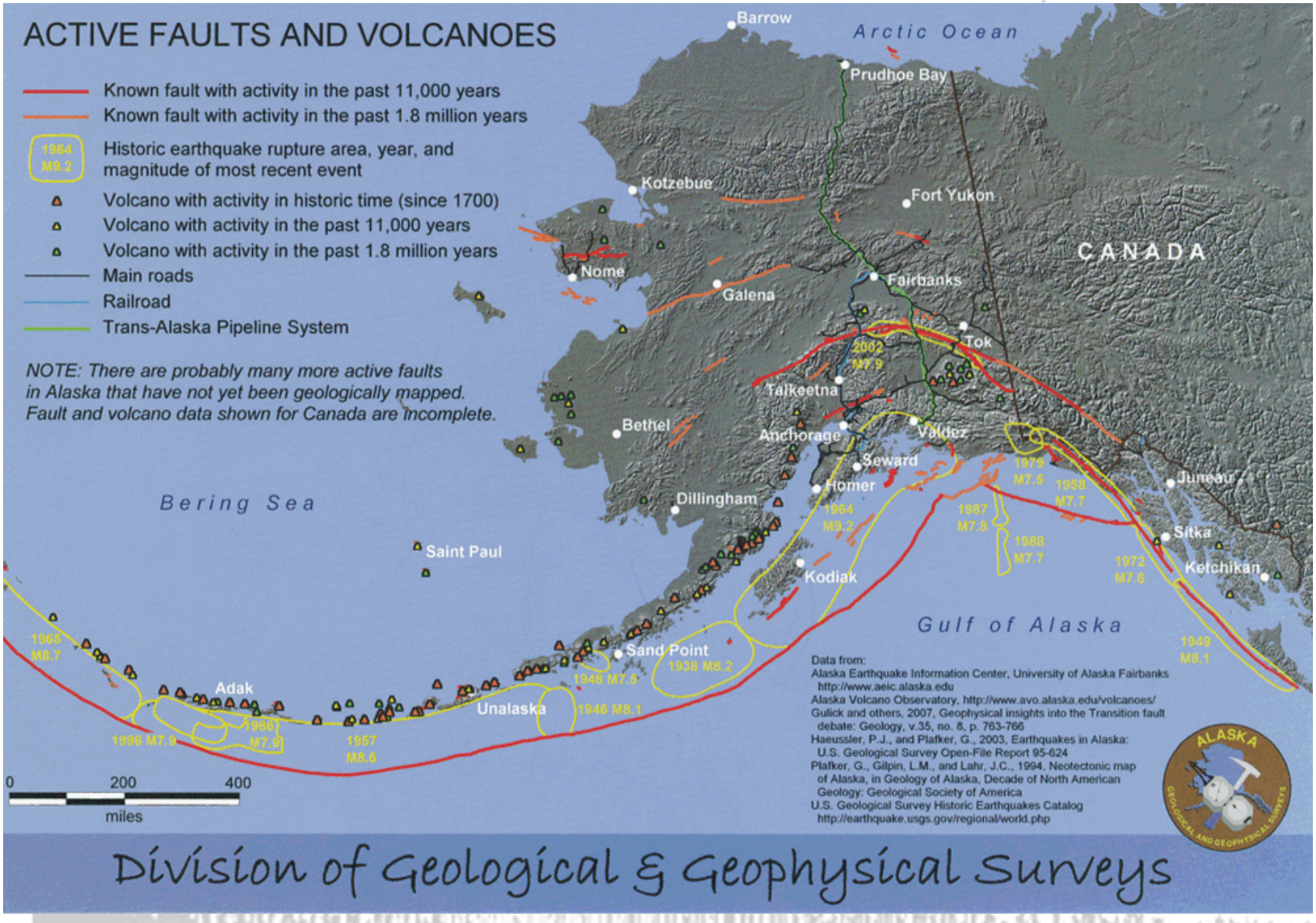
   1) 1999 Izmit, Turkey

   2) 2002 Denali, Alaska

d) Dip-slip

   1) 1994 Northridge (reverse)

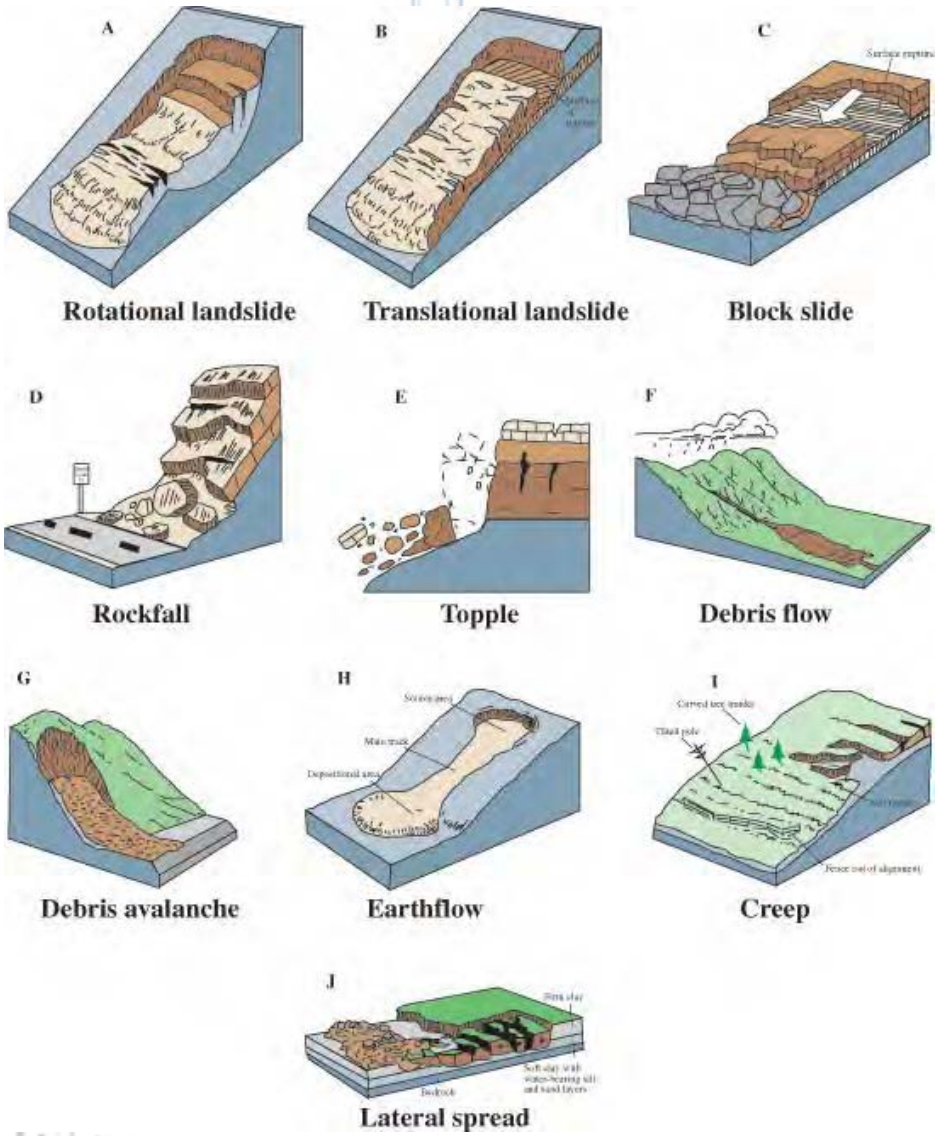
KNOWN FAULT LINES IN ALASKA



LIQUEFACTION

a) Lateral spread: horizontal movement of surface soil due to liquefaction of underlying deposits
b) Flow failures: displacement of liquefied soil carrying blocks of intact earth
c) Loss of bearing: liquefaction of bearing soil causing deformation of structures or embankments
d) Subsidence: liquefied soil ejected through sand boils, etc. causing a loss of volume and resultant subsidence
e) Buoyancy: pipeline floats in liquefied soil

LANDSLIDES



Source: US Geological Survey

Fact Sheet 2004-3072; Landslide Types and Processes

CONSEQUENCES OF DAMAGE IN AN EARTHQUAKE EVENT

a. Economic consequences due to loss of services and product

b. Safety/Environmental

   i. Harm to facility personnel
   ii. Harm to general public
   iii. Damage to the environment

c. Interruption to vital delivery: Lifelines

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Consequences

Interruption to vital delivery: Lifelines

Operations are essential to maintain public safety and well being.

Examples:

1. **Hospitals**
2. **Emergency aid centers**
3. **Other utilities: heat, electricity, water pumping, etc.**

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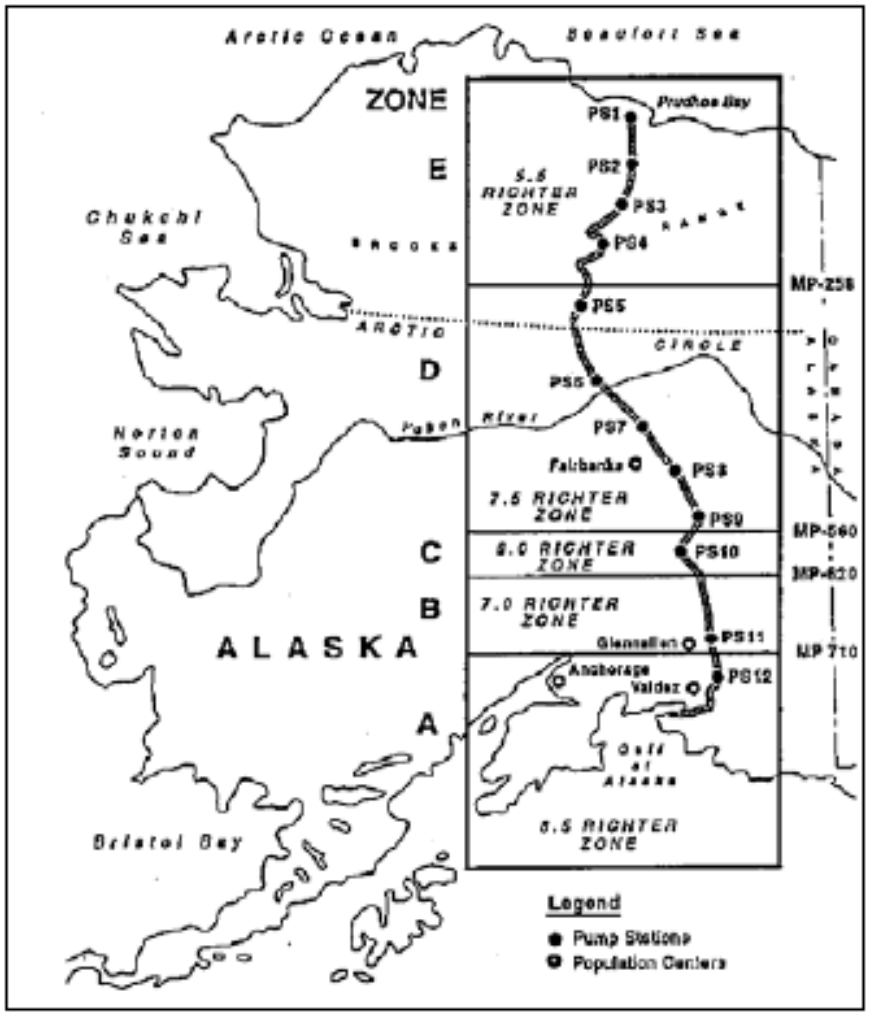
BACKGROUND ON SEISMIC DESIGN OF BURIED PIPELINES

a. Nathan M. Newmark (1967) research on wave propagation in soil and rock
b. Trans-Alaska Pipeline Design Basis (1973): developed by Newark, Dr. Bruce Bolt and others.
c. Guidelines for the Seismic Design of Oil and Gas Pipeline Systems: ASCE Committee on Gas and Liquid Fuel Lifelines (ASCE 1984)
d. Guidelines for the Design of Buried Steel Pipe: American Lifelines Alliance (ALA 2001)

Trans-Alaska Pipeline Design



a. State of the art seismic design for it's time
b. Methodology similar to what is used today
c. Approximately half of 800-mile length is buried
d. Standard trench design validated for a condition of 2 ft. differential movement
e. Avoidance of areas with unstable slopes in vicinity of faults
f. Above ground construction at fault crossings

1984 Guidelines for the Seismic Design of Oil and Gas Pipeline Systems (ASCE 1984)

a. Guidance for seismic design of most major components of pipeline systems, based on state-of-the-practice at the time.

b. Buried pipelines:

1) Description and quantification of seismic hazards
2) Design criteria considerations
3) Differential ground movement effects
4) Wave propagation effects
5) Operation and maintenance considerations

2001 Guidelines for the Design of Buried Steel Pipe (ALA 2001)

a. Seismic guidance:
   a. Seismic wave propagation (quantified)
   b. Differential ground movement (qualitative)
   c. Soil spring determination (quantified)
b. Other: internal pressure, earth loads, live loads, buoyancy, thermal expansion, movement at bends, etc.

DESIGN FOR SEISMIC WAVE PROPAGATION

a. From "Guidelines for the Design of Buried Steel Pipe", American Lifelines Alliance, July 2001

b. Results in longitudinal axial strain; parallel to pipe axis

c. Flexural strains from ground curvature typically are neglected

d. Resultant strain is limited by friction at the pipe/soil interface

$$\varepsilon_a \leq \frac{T_u \lambda}{4AE}$$

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Design for Seismic Wave Propagation

Formula (Newmark):

$$\varepsilon_a = \frac{V_g}{\alpha C_s}$$

Where:

Vg = peak ground velocity generated by ground shaking

Cs = apparent propagation velocity for seismic waves (conservatively assumed to be 2 km/s)

α = 2.0 for Cs associated with shear waves, 1.0 otherwise

1. If only peak ground acceleration values are known, table 11.1 may be used to determine peak ground velocity
2. Peak ground acceleration values are available from the USGS http://earthquake.usgs.gov/hazards/products/ak/2007/data

Shear wave vs. Surface waves (next slide)

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Design for Seismic Wave Propagation

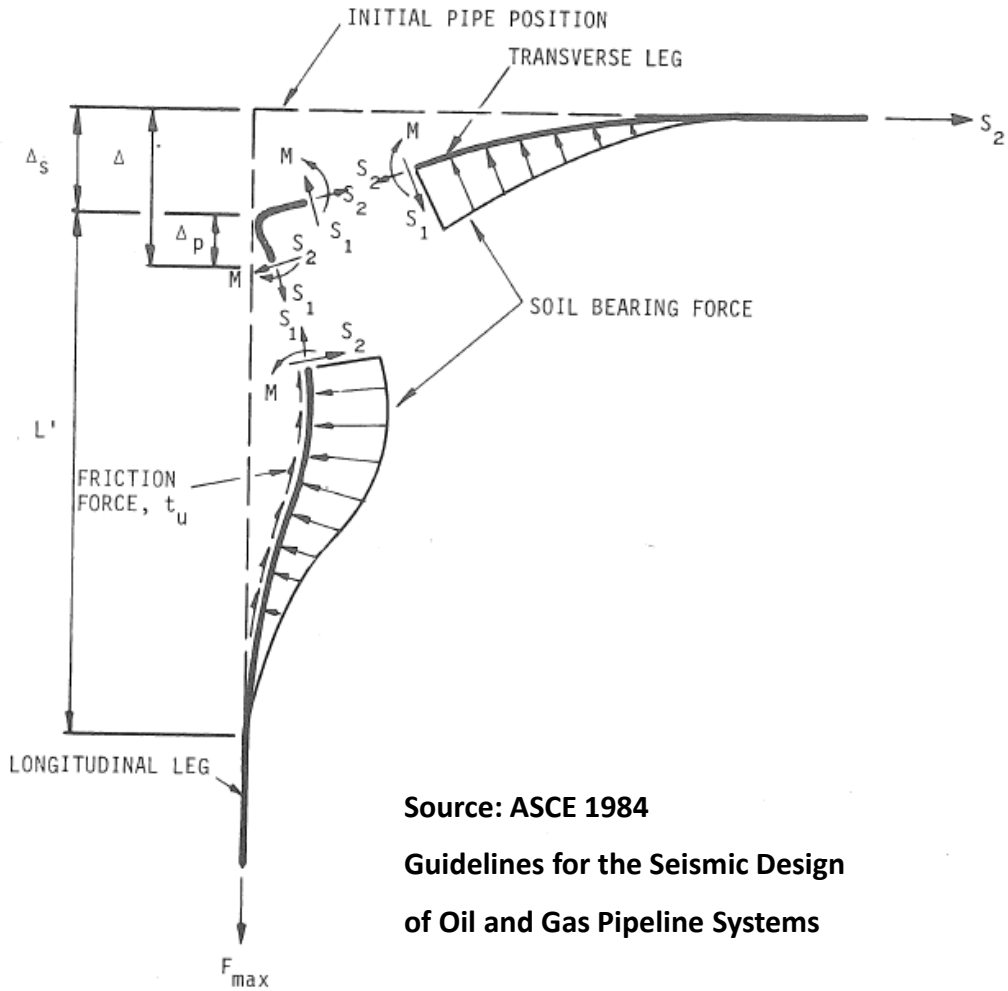
Shear waves vs. Surface waves

a. Peak ground velocities are associated with types of seismic waves, determined by a seismic assessment
b. Peak ground velocity in Newmark equation is usually associated with shear waves
c. The effect of surface waves should be considered, especially for sites within sedimentary basins.
d. Surface waves tend to increase in proportion to shear waves at distances greater than 20 km. from earthquake source.

Design for Seismic Wave Propagation

Effects at Bends

- ASCE 1984 provides guidance
- Rigid bend analysis (very conservative)
- Flexible bend analysis
- Computer solutions (FEA)



Source: ASCE 1984 Guidelines for the Seismic Design of Oil and Gas Pipeline Systems

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DESIGN FOR PERMANENT GROUND DISPLACEMENT

a. Due to liquefaction, differential fault movement or ground rupture

b. Fault Considerations:

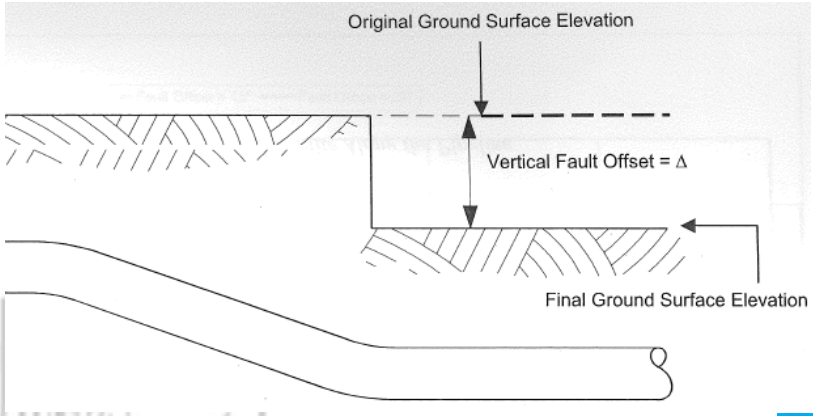
   a. Amount and type of ground surface displacement

   b. geometry of fault, type of fault, recurrence interval, etc.

c. Liquefaction considerations:

   a. Geotechnical investigation

   b. In-situ and laboratory methods



Source: American Lifelines Alliance Guidelines for the Design of Buried Steel Pipe

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Design for Permanent Ground Displacement

a. Factors affecting pipeline performance at fault crossings
   1) Depth of burial
   2) Trench configuration
   3) Amount of fault movement
   4) Pipeline-fault crossing angle
   5) Soil properties
   6) Effective unanchored lengths

b. Other fault crossing modes
   1) Placement of pipeline in above-ground berm
   2) Placement in oversize ditch with compressible backfill
   3) Encasement in oversize conduit or culvert
   4) Above ground sliding pipeline supports

Design for Permanent Ground Displacement

a. Both axial and bending effects must be considered

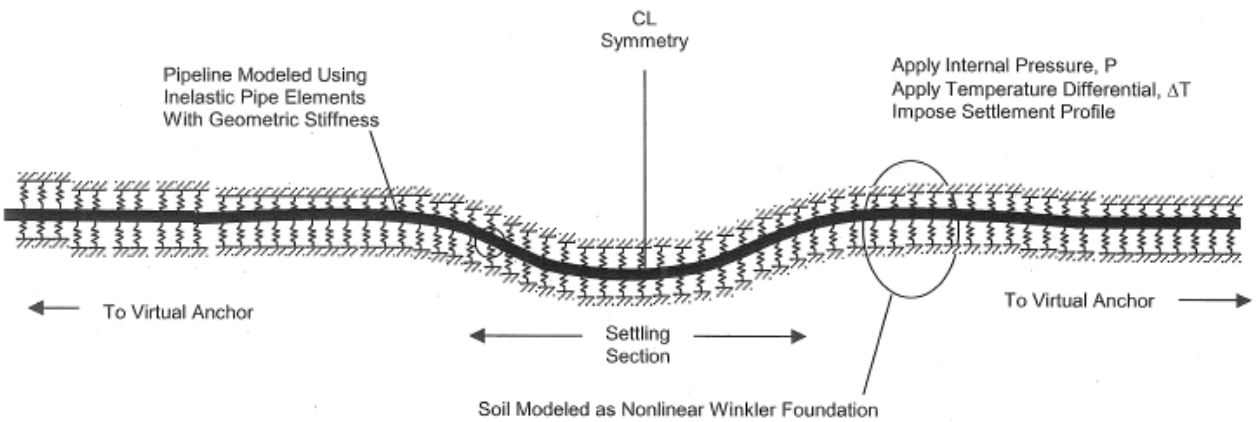
b. Best evaluated using finite element analysis

   a. EX: AutoPIPE (elastic range)

   b. EX: PIPLIN (inelastic range)

c. "Guidelines for the Design of Buried Steel Pipe"

   Appendix B – for determining soil spring values



Source: American Lifelines Alliance Guidelines for the Design of Buried Steel Pipe

PERFORMANCE OF BURIED PIPELINES IN EARTHQUAKES

"The performance record of large diameter oil and gas transmission pipeline subjected to earthquakes generally has been satisfactory."

~ *Guidelines for the Seismic Design of Oil and Gas Pipeline Systems (1984)*

a. **Modern construction methods are key.**
b. **Failures have typically been caused by large ground deformation, landslides, liquefaction or ground failure**
c. **Past earthquakes: 1971 San Fernando Earthquake (CA), 1994 Northridge Earthquake (CA), 2002 Denali Fault Earthquake (AK)**

1971 San Fernando Earthquake

Southern California Gas Company

a) **Damage and shut-down of 4 transmission lines:**

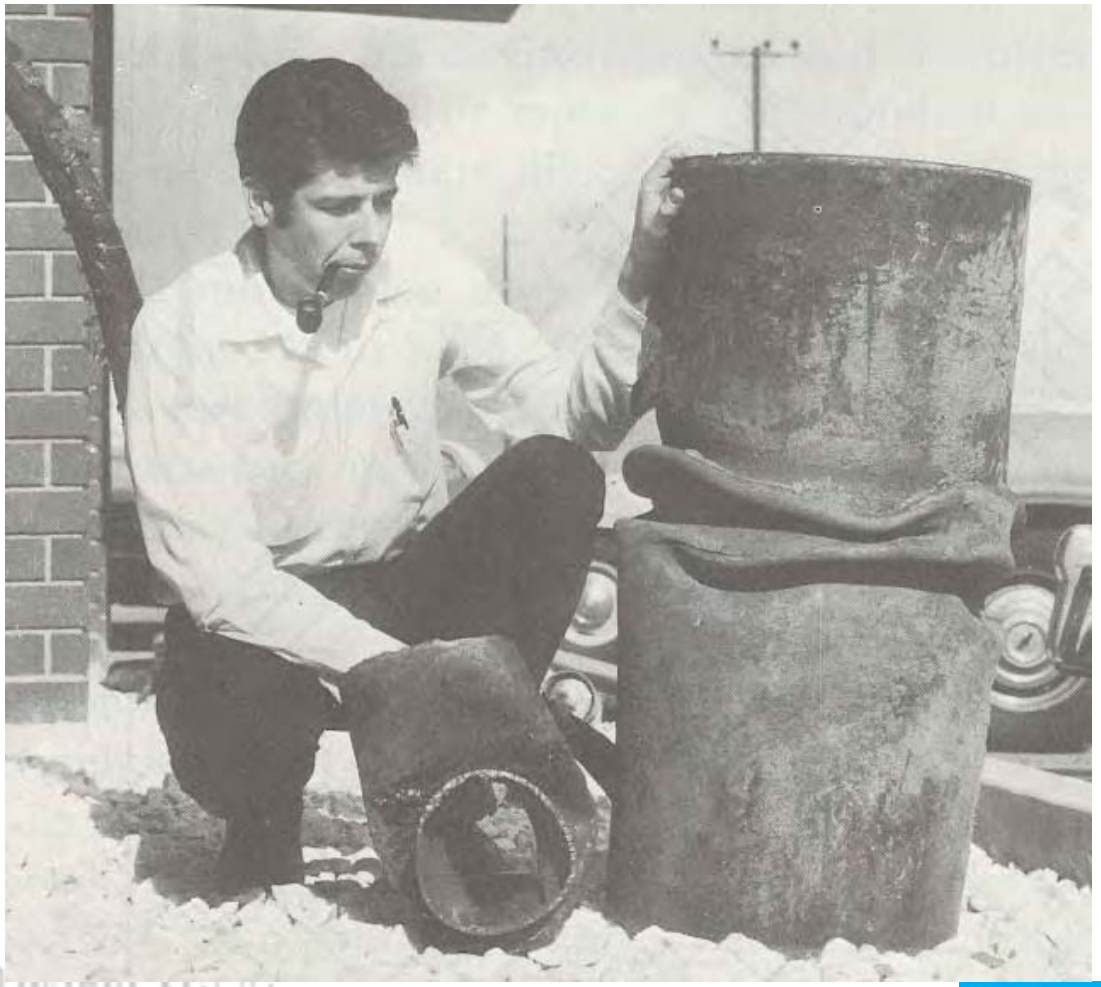
   1. **68 total breaks were repaired. 12-26 inches in diameter, welded steel construction**
   2. **Resulted in loss of gas supply to distribution systems in San Fernando – Sylmar area**
      - i. **~ 2 days to repair/restore services**
      - ii. **~ 17,000 customers affected**

1971 San Fernando Earthquake

iii. Greatest damage to a 16-inch transmission line between Clampitt Junction and San Fernando

a) 52 separate breaks in 6 miles section

b) Buckled under compressive forces



Source: US Department of Commerce, National Oceanic and Atmospheric Administration.
San Fernando Earthquake of February 9, 1971 Vol. II

1994 Northridge Earthquake

Southern California Gas Company

a. **Distribution Pipelines: 12” diameter and smaller, low pressure (<60psi)**
   1) **394 repairs to piping with evidence of corrosion**
   2) **197 repairs in piping with no corrosion observed**

1994 Northridge Earthquake

Southern California Gas Company

b. Transmission Pipelines: 8” to 36” diameter, 150 psi and greater

1) 2 repairs at locations of corrosion

2) 35 non-corrosion related repairs, 27 at cracked/ruptured girth welds in pre-1932 pipelines

i. Line 1001, constructed in 1925 and operated at 245 psi. 25 breaks at oxy-acetylene girth welds.

ii. Fire ignited by downed power line near Fillmore

1994 Northridge Earthquake

Southern California Gas Company

c. Rupture at an over-bend, triggered by landslide in Line 104 inside storage field. Pipeline constructed in 1941, operated at 200psi.

FIGURE 4-21 Local Landslide in Sandstone and Overlying Soil at the Aliso Canyon Gas Storage Facility

Source: National Center for Earthquake Engineering Research, State University of New York at Buffalo. Technical Report NCEER-94-005

2002 Denali Fault Earthquake

Trans-Alaska Pipeline System. Approximately half of 800-mile length is buried

a. **Magnitude 7.9 with peak ground accelerations of 0.34 g**

b. **Moderate lateral spread movements in areas close to Denali Fault Crossing**

c. **Liquefaction of subsurface deposits along the buried pipeline alignment**

2002 Denali Fault Earthquake

c. **Liquefaction of subsurface deposits along the buried pipeline alignment**

- **High groundwater areas of floodplains; esp. Delta River & Phelan Creek ~30 km south of Denali Fault**

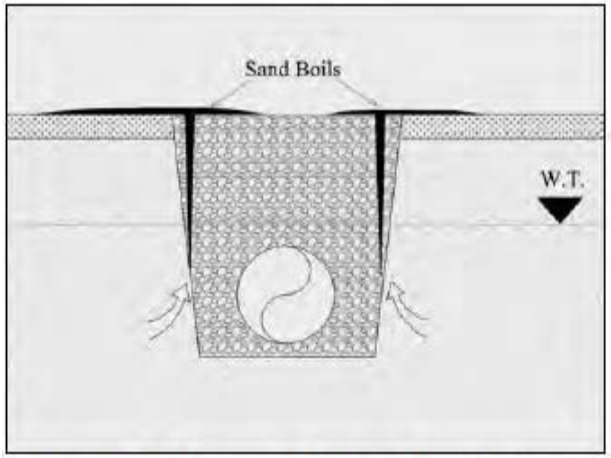


Figure 5. Diagram of typical liquefaction event

Figure 3. Surface evidence of liquefaction near Remote Gate Valve 91. south of Denali Fault.

Figure 4. Surface evidence of liquefaction in the Delta River floodplain.

Source: Conference Proceedings; ASCE 6th US Conference and Workshop on Lifeline Earthquake Engineering

Assessment of the Below-Ground Trans-Alaska Pipeline Following the Magnitude 7.9 Denali Fault Earthquake

2002 Denali Fault Earthquake

Other observations and findings

a. **Buried pipeline met all performance expectations associated with earthquake.**

b. **Below ground portion inspected by in-line inspection (ILI) "smart-pigs"**

   1) **~137 mile segment from Pump Stations 9 to 11**

   2) **Changes in curvature from May 2000 (previous smart-pig data) to December 2002 (post-earthquake) were noted.**

   3) **In each case, the change in curvature resulted in a lower strain state.**

   4) **Areas of liquefaction allowed pipe to "relax" in ditch during the shaking**

c. **Above ground fault crossing likely reduced the amount of damage and repair**

d. **Avoidance of unstable slopes effectively avoided damage from landslides and ground settlement**

CONCLUSION

a. Oil and gas pipelines are “lifelines” of importance in an earthquake event.

b. Seismic considerations are an important component of buried pipeline design.

c. Pipeline route should give consideration to locations of known seismic hazards such as fault lines, unstable slopes, landslides, etc.

d. Below ground pipelines designed for seismic wave propagation, effects at bends, and differential ground movements.

e. Modern construction methods and welding are keys to performance in earthquake events.

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APPENDIX V

PIPELINE STRAIN-BASED DESIGN AND ASSESSMENT

Session 5: Presentation 3 – Design State of Practice for Strain Based Design

Company Name: Michael Baker Corporation
Speaker: Paul Carson
Co-author: Keith Meyer
Website URL: http://www.mbakercorp.com/

Appropriately designed pipelines subjected to significant ground deformation can accommodate longitudinal bending loads that induce tension and/or compression loads well beyond yield without impacting pressure containment. Strain-based design and assessment (SBDA) approaches for evaluating and ensuring pipeline integrity for such potential pipeline hazards are being safely used today for both offshore and onshore pipelines – the approach is particularly suitable for arctic pipeline loadings such as thaw settlement and frost heave. SBDA approaches place an increased emphasis on identifying the limiting conditions for strain development, i.e., the limit states, and the pipeline properties that contribute to a quantitative evaluation of these limit states. At its core, SBDA focuses the problem of ensuring pipeline integrity when subjected to significant ground displacement on estimating two entities: the longitudinal bending strain that is likely to occur in the pipe due to a route hazard, i.e., the strain demand, and the potential of the pipeline to safely accommodate this demand, i.e., the strain capacity. Furthermore, given the uncertainties inherent in both sets of calculations, to ensure safety it is imperative that strain capacity is well in excess of strain demand so this evaluation is also part of the SBDA assessment process. This presentation will outline the basis and current state-of-art for SBDA, including how it works in tandem with conventional stress-based design along with a synopsis of some past projects that have employed SBDA principles.

APPENDIX W

LESSONS LEARNED FROM TEN YEARS OF TUNDRA RESTORATION ON THREE EXPERIMENTAL GAS PIPELINE TRENCHING SITES IN ALASKA

Lessons Learned from Ten Years of Tundra Restoration on Three Experimental Gas Pipeline Trenching Sites in Alaska

Bill Streever （BPXA）

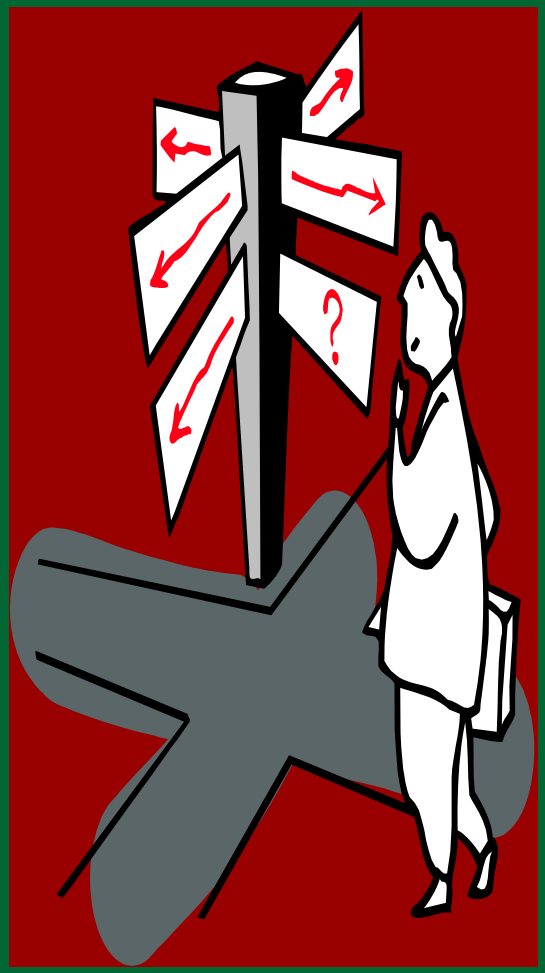
Janet Kidd （ABR）

Tim Cater （ABR）

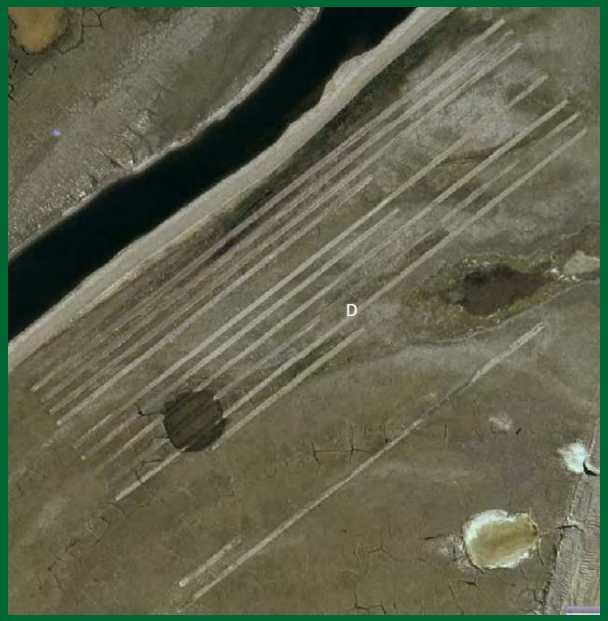
Lorene Lynn （HDR）

Where we're going . . .

- The sites: background
- The nature of permafrost
- What happened?
- What did we learn?
- Way forward



The Sites: Background



3 Sites:

Each Different,

Each the Same

- ~37 acres (~4 acres trenches)
- Built winter 2002

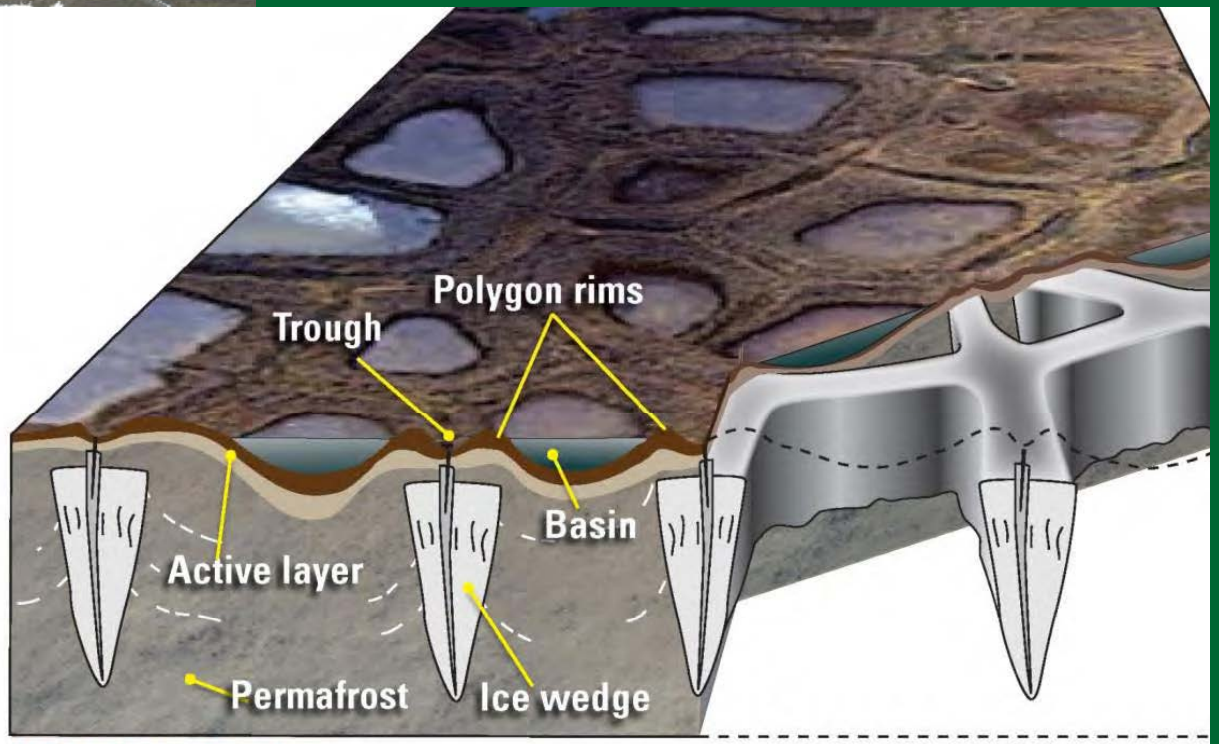
The Sites: Background

The Sites: Background

The Sites: Background

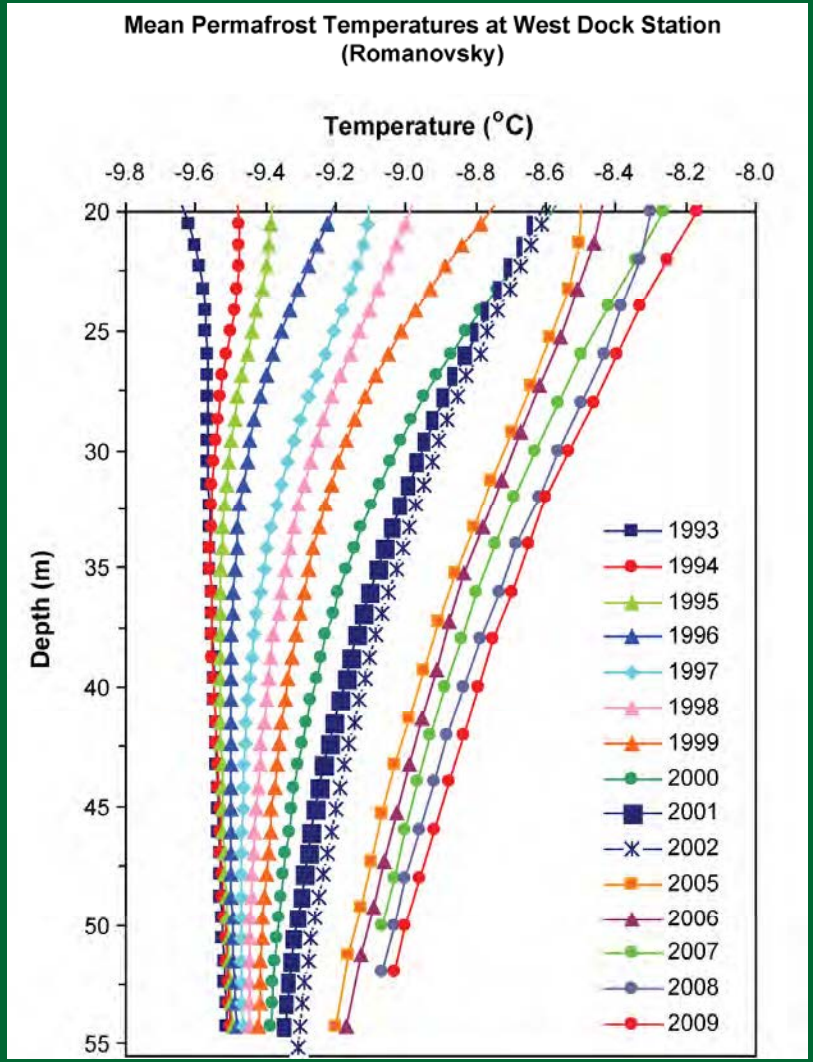
The Nature of Permafrost

The Nature of Permafrost



US Fish and Wildlife Service figure

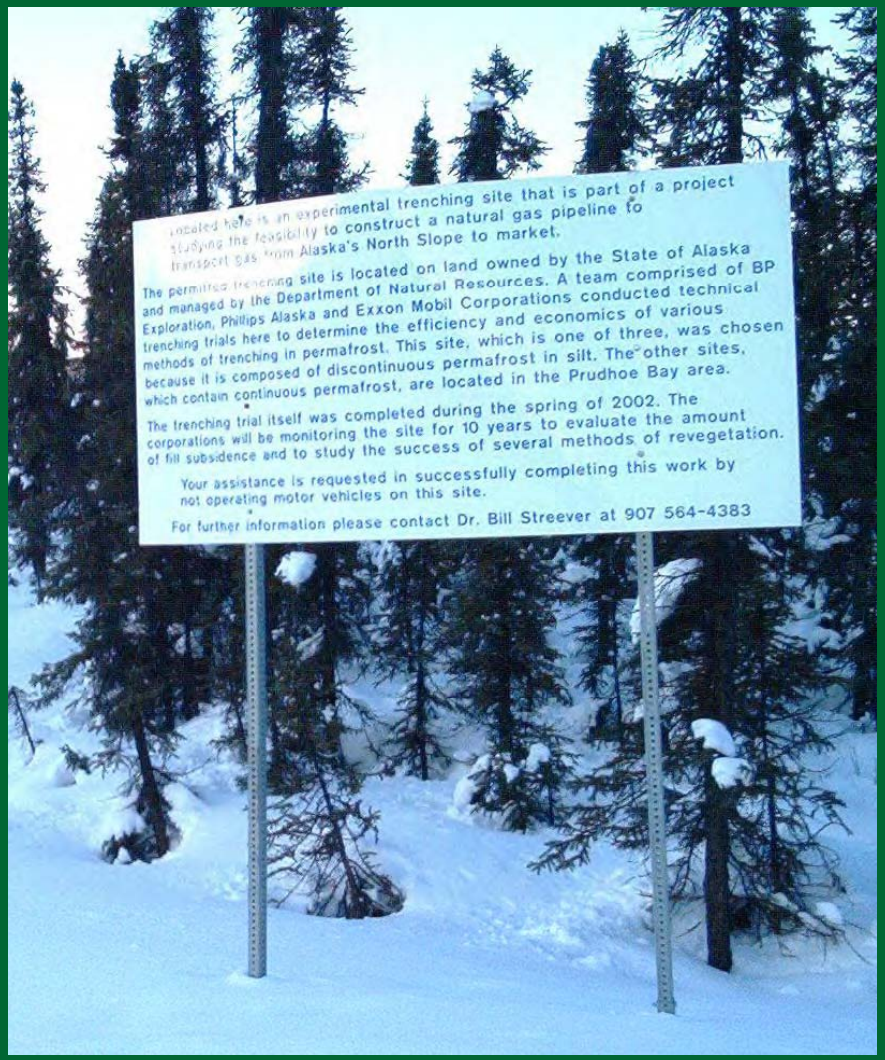
The Nature of Permafrost



What Happened？
（Washington Creek）

What Happened？

（Washington Creek）



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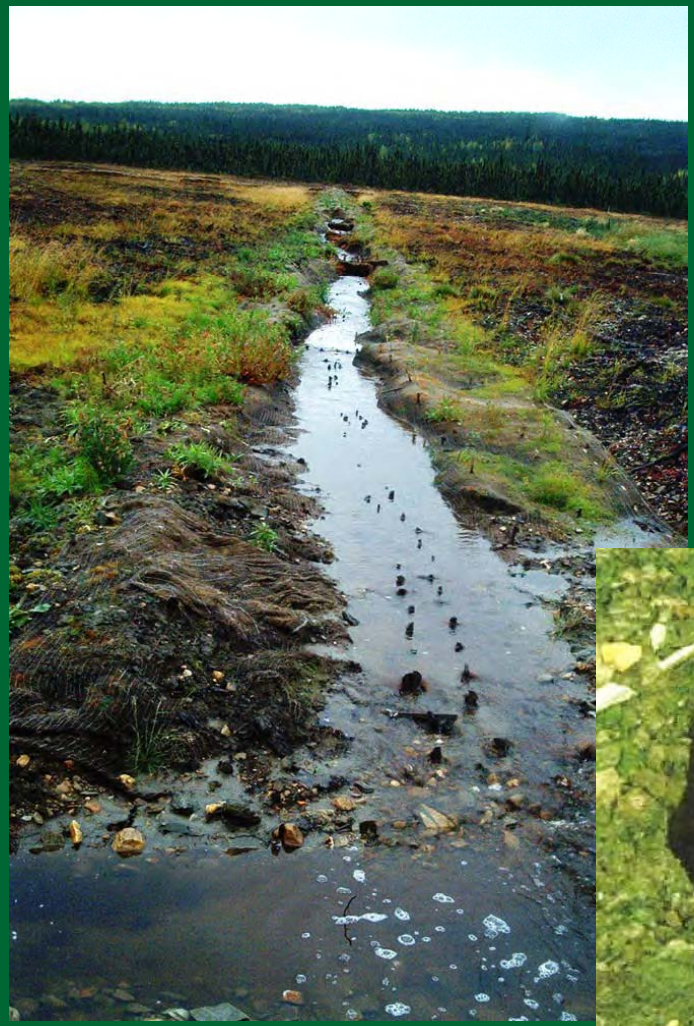

What Happened?

What Happened？

（Washington Creek）

What Happened？
（Washington Creek）

What Happened？
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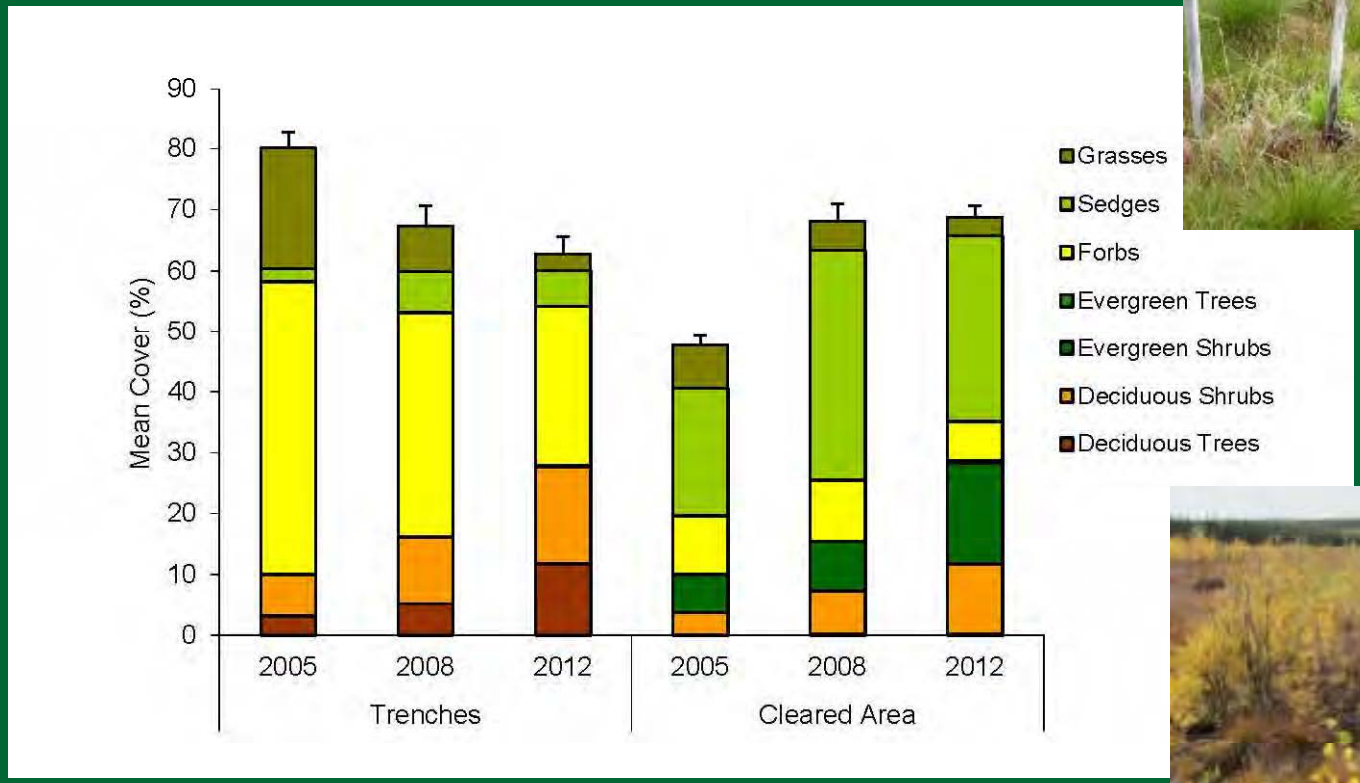
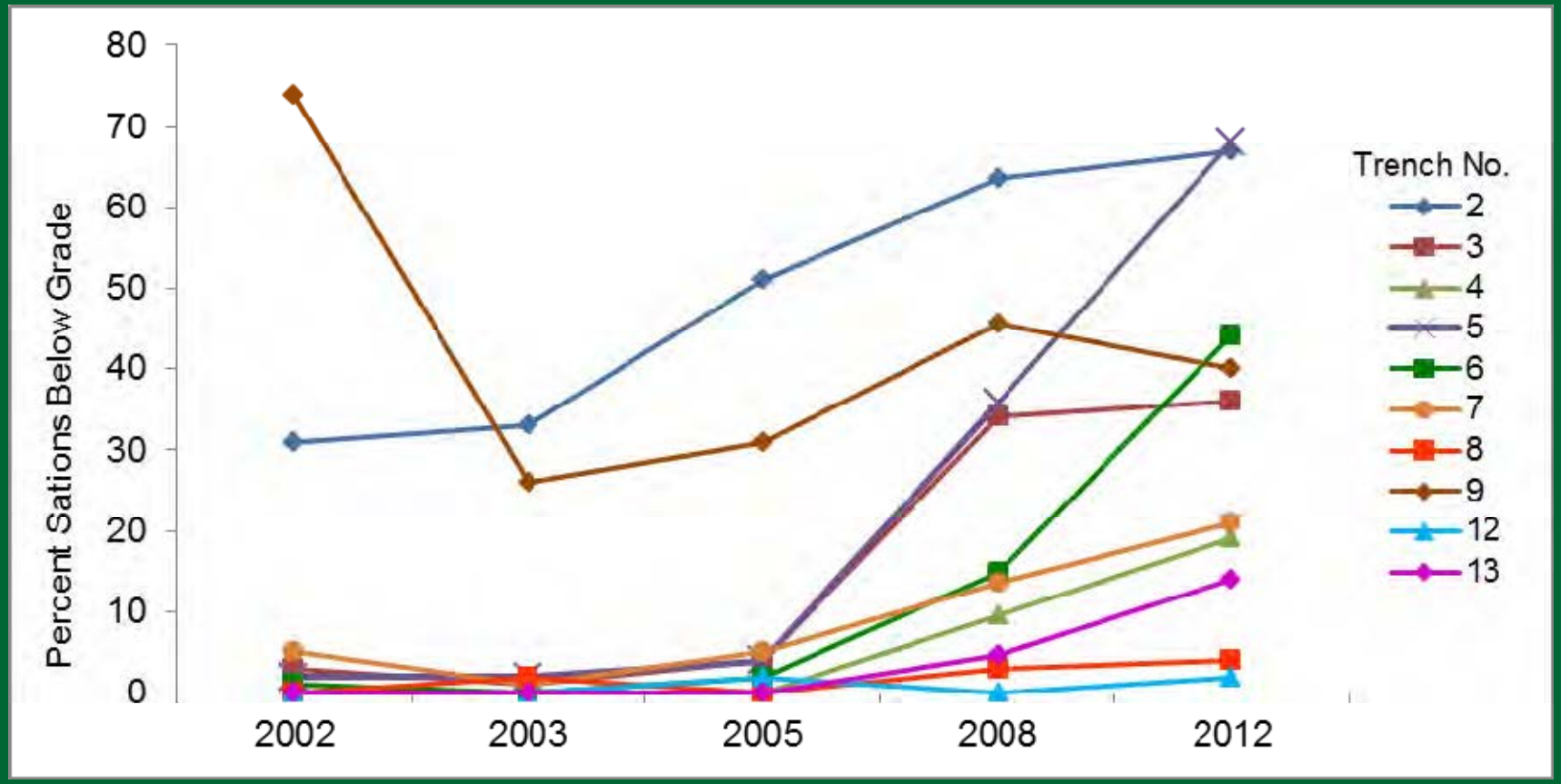


What Happened？
（Washington Creek）



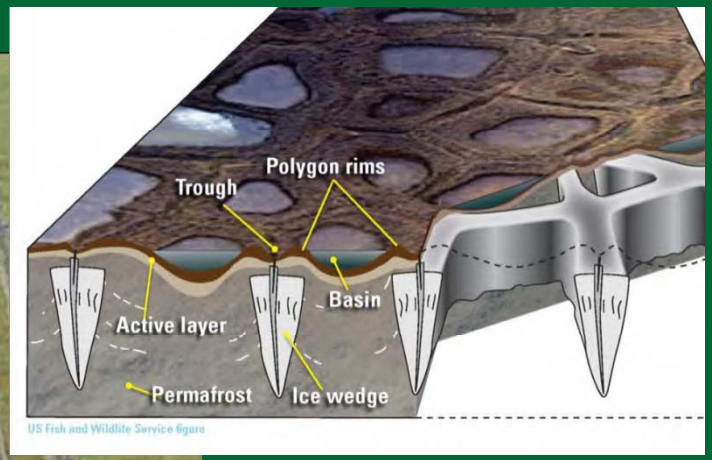
What Happened？
（Washington Creek）

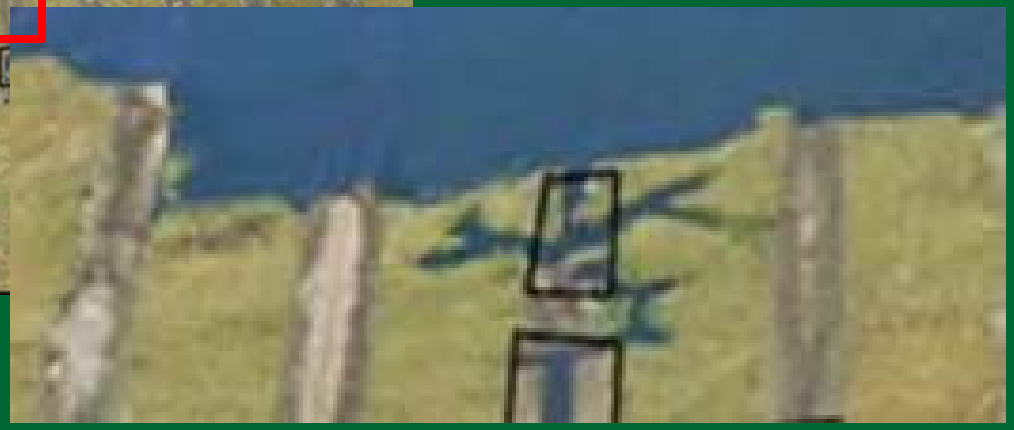
What Happened？

（MS3）

What Happened？

（MS3）





What Happened？

（MS3）

What Happened？

（MS3）

What Happened？

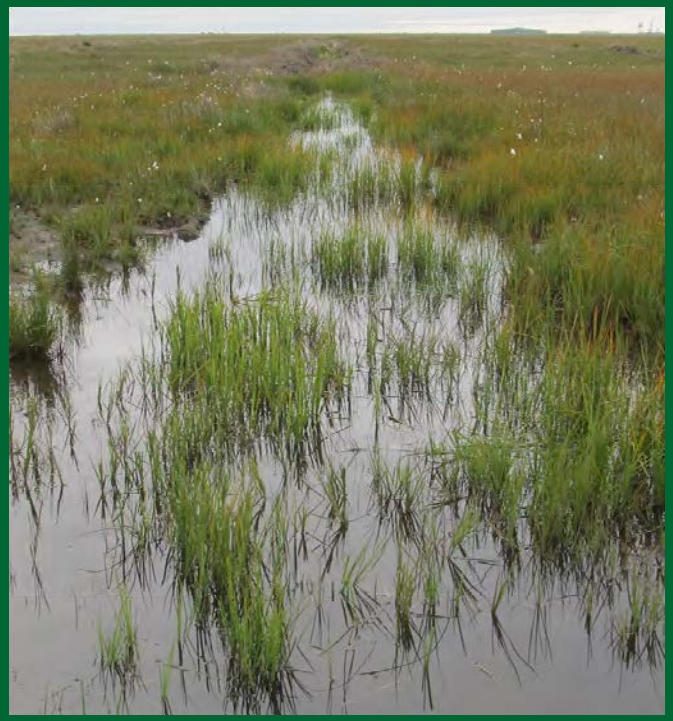
（MS3）

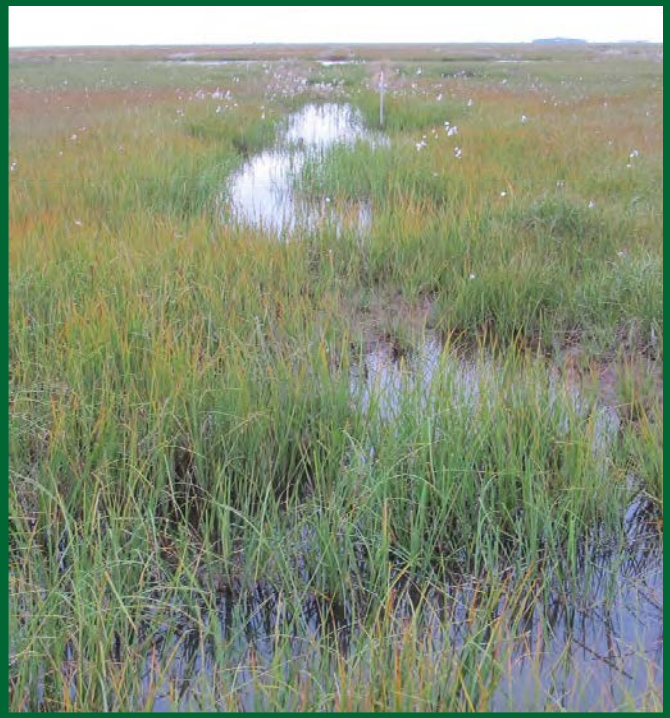
What Happened？
（MS3）

Trench subsidence 2011 to 2012.

What Happened？

（MS3）





Sedges colonizing subsided trenches.

What Happened？

（MS3）

What Happened?

（Put 23）

Lessons Learned
（Washington Creek）

- Mounding not complete solution
- Expect erosion （short and long term）
- Inspect, inspect, inspect
- Think twice about seeding
- Consider removing duff
- Work closely with agencies

What Happened?
(Washington Creek)

- Consider contractor availability
- Methods development needed
- Access is critical
- Public outreach
- Systematic reporting
- Innovate as you go

Thanks !

Rehabilitation Site Type
Abandoned Pads
Spill Sites
Trenching
Abandoned Airstrips
Other
Northstar
Beaufort Sea
Milne Point
Kuparuk River
Prudhoe Bay
Endicott
Deadhorse
Badami & Red Dog #1 (See Insert)
Badami

APPENDIX X

RIVER CROSSINGS – WHAT HAVE WE LEARNED IN 40 YEARS?

Alaska Department of
Environmental Conservation

Alaska DEC Oil Pipeline Conference

September 18, 2013
Anchorage, Alaska

River Crossings
What Have We Learned In 40 Years

WIM M. VELDMAN
Consulting Inc.
www.wimveldman.com

Wim M. Veldman, M.Sc., FEIC, P.Eng.

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 → Scour = Pipe Depth
- **SCOUR**
  - Bank Erosion → 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

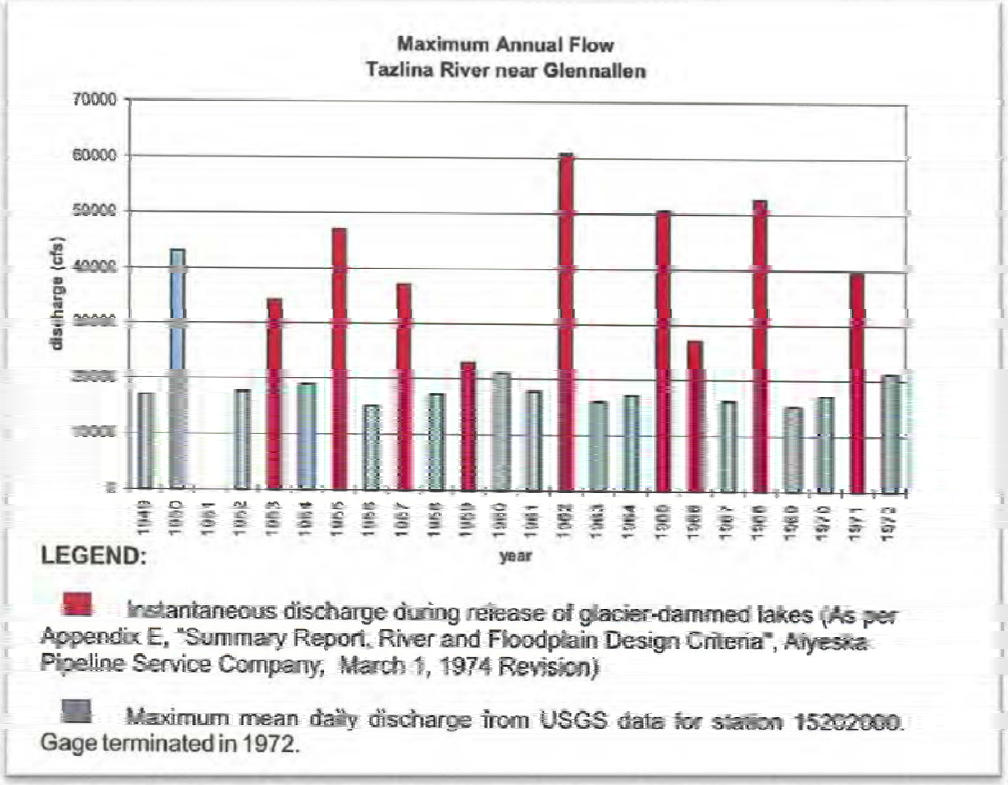
FLOW
GLACIER DAMMED LAKE RELEASES

- **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)

Tazlina River

GLACIER DAMMED LAKE RELEASES

- **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

AUFEIS (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 IFS

- **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

	Low	Medium	High
Streamflow			
Peak	X	X	
Low	X		
Water Level			
Open Water	X	X	
Ice	X	X	
Bed Scour			
General		X	X
Local			X
Bank Erosion			X

Quantitative vs. Qualitative Analysis

DESIGN – RELATIVE IMPORTANCE ELEVATED CROSSINGS

	Low	Medium	High
Streamflow			
Peak			X
Low	X	-	-
Water Level			
Open Water			X
Ice			X
Bed Scour			
General		X	
Local			X
Bank Erosion		X →	X

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

CONSTRUCTON TECHNIQUES

Frozen “dry” ditch

Open cut, wet ditch.

Flow Isolation- Pipe Flume

Flow Isolation-Pumping

OTHER CONSTRUCTION TECHNIQUES

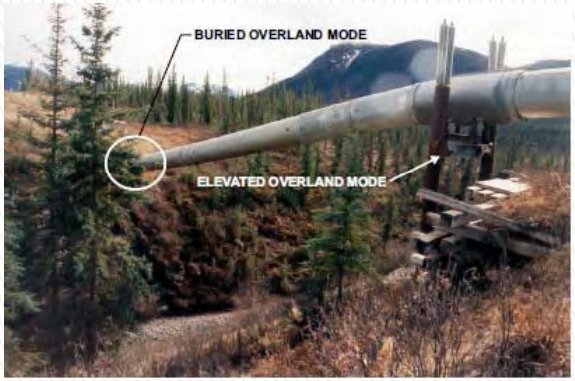
Open Cut – Sauerman Dragline

HDD

Bore

Flow Isolation - Superflumes

ELEVATED CROSSINGS



Free span of pipe

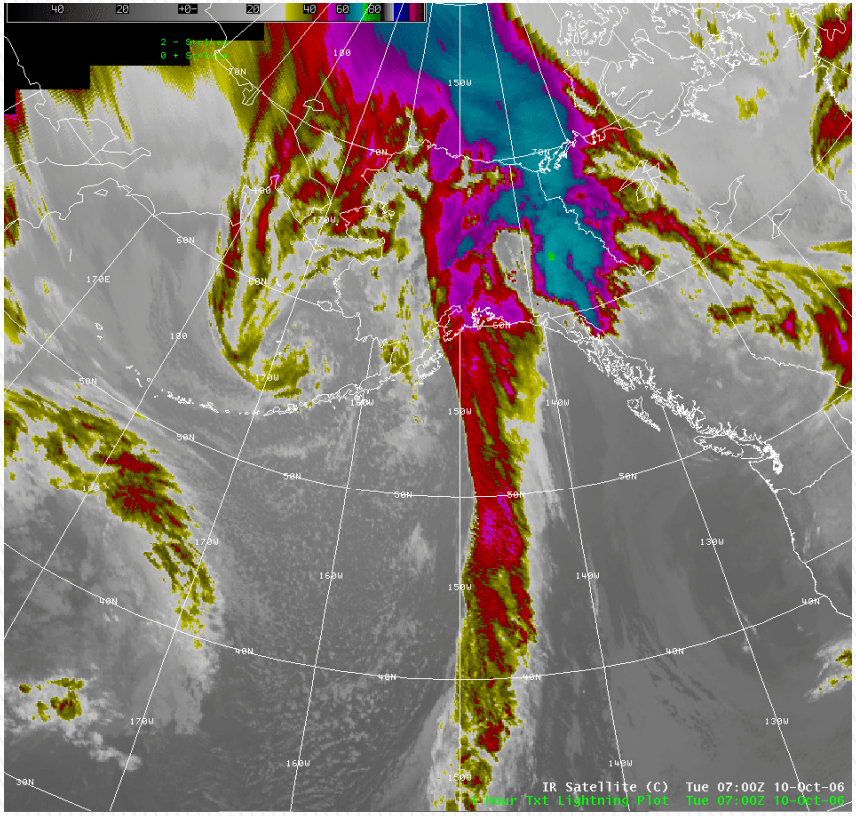
Pile Supports

Girder Bridge

Suspension Bridge

OPERATIONAL MONITORING

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



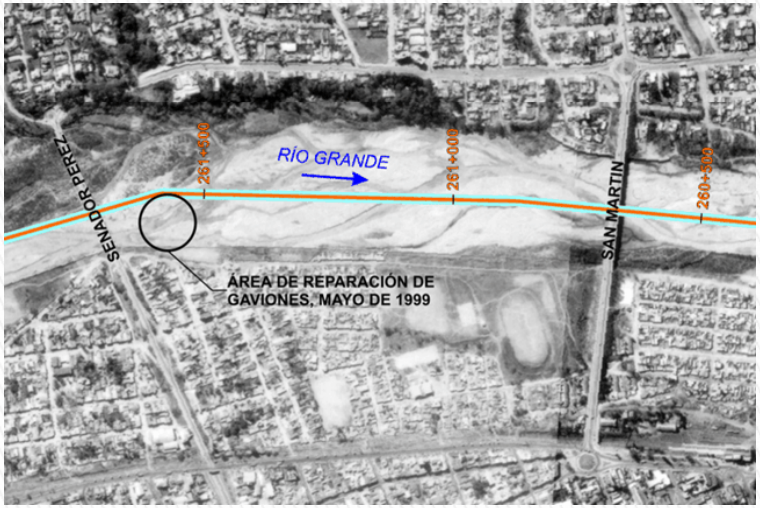
LESSON #1

Adapt to Conditions

LESSON #2

Schedule for 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

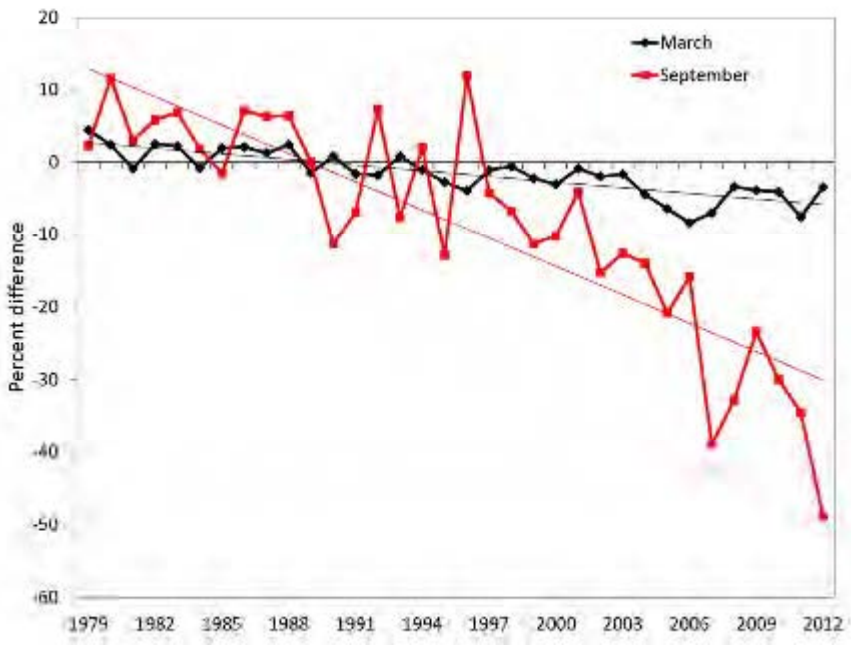
APPENDIX Y

YEAR-LONG UPWARD LOOKING SONAR MOORING MEASUREMENTS OF SEA ICE KEEL DISTRIBUTIONS: IMPLICATIONS FOR ICE GOUGING

Year-Long Upward Looking Sonar Mooring Measurements of Sea Ice Keel Distributions: Implications for Ice Gouging

Ed Ross
ASL Environmental Sciences

Arctic Ice: The Long-term Trend



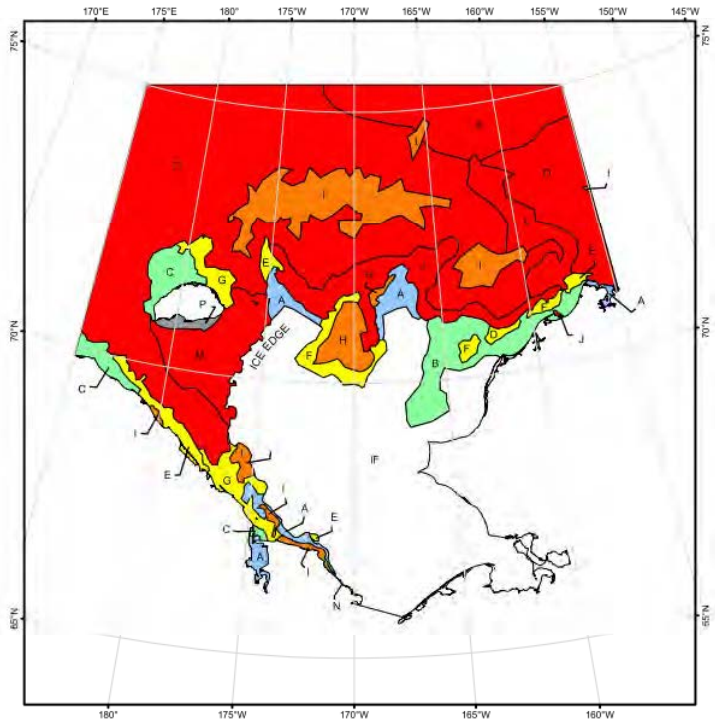
Source: www.arctic.noaa.gov

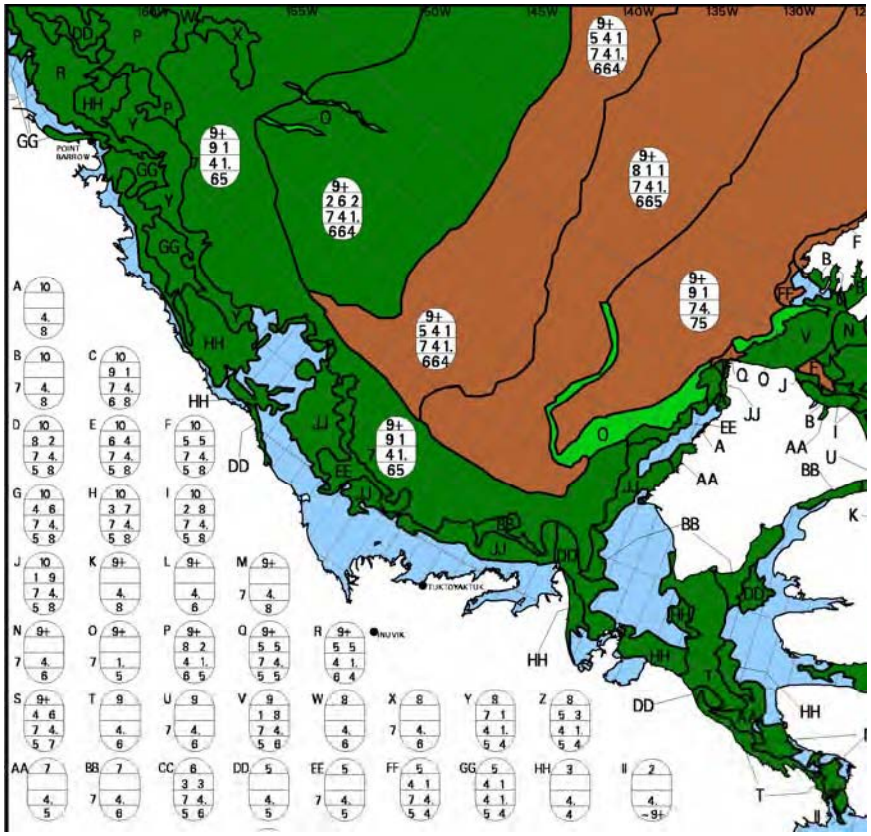
Sea ice extent trends:

March (max) -2.6% per decade

Sept (min) -13.0% per decade

Arctic Ice: Interannual and Regional Variation

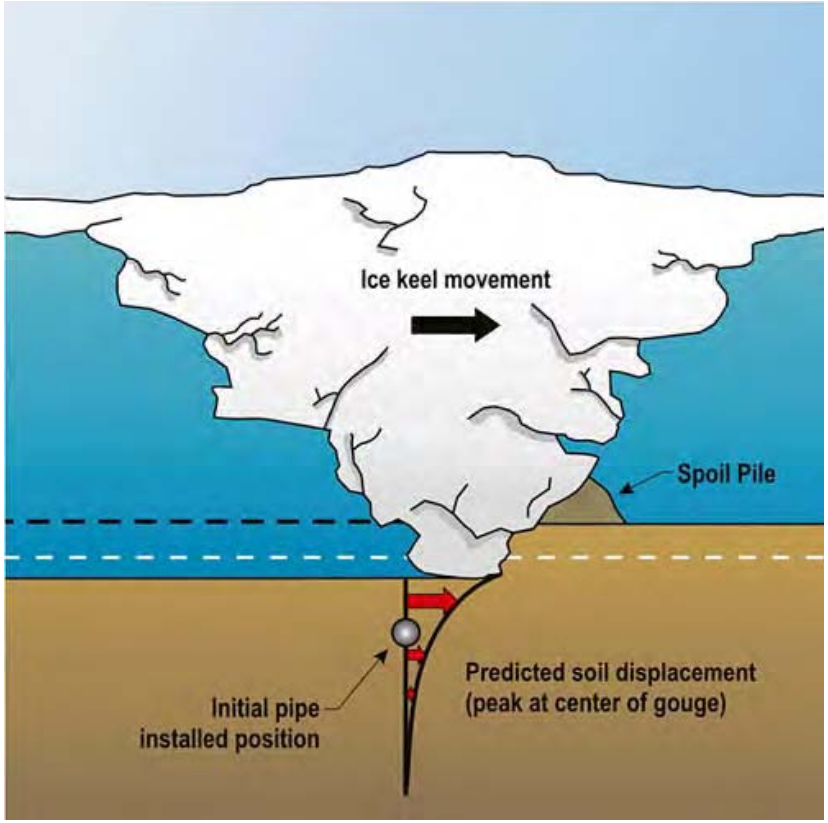




Ice Gouging

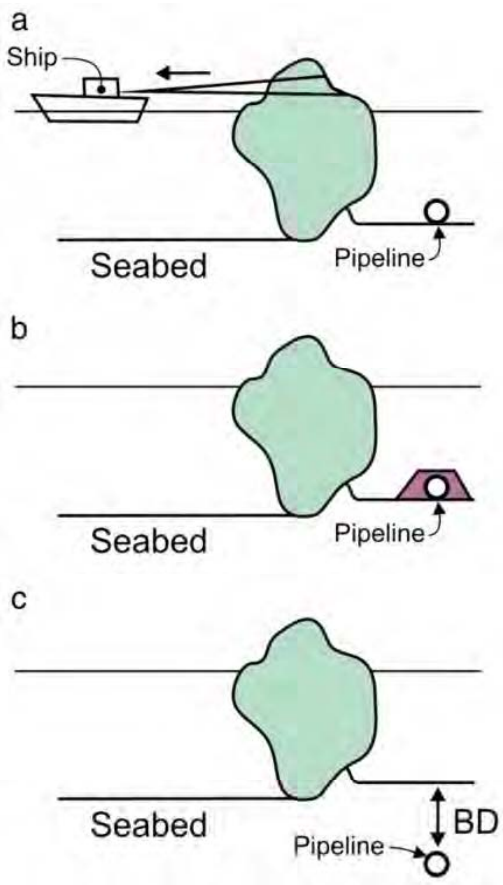
Three main actors in Arctic offshore pipeline design:

- Pipeline
- Seabed
- Ice



Source: www.intoceansys.co.uk

Ice Gouging Mitigation Strategies



Towing

Shielding

Burial

Source: Barrette, P. (2011). "Offshore pipeline protection against seabed gouging by ice: An overview." Cold Regions Science and Technology **69**(1): 3-20.

What parameters are relevant to engineering design against ice gouging constraints?

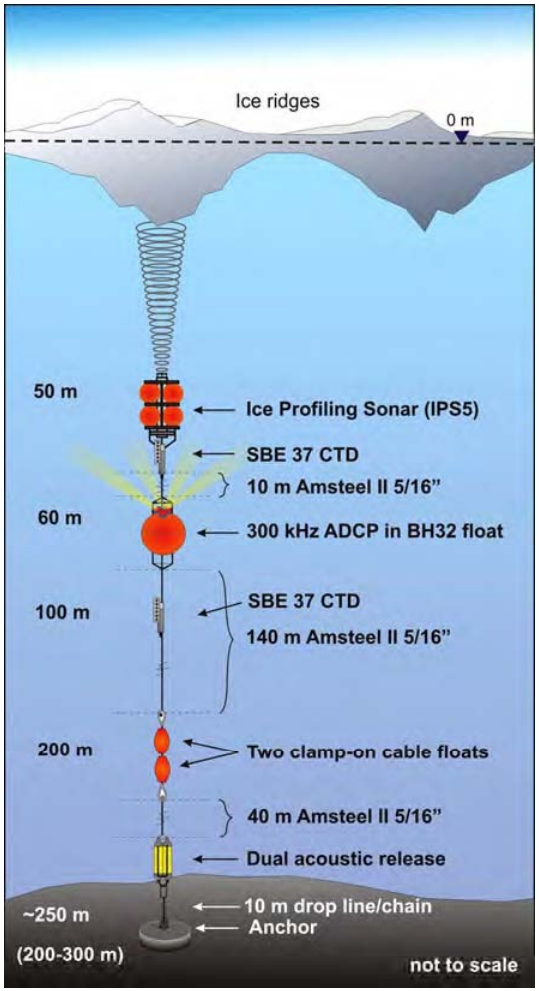
- Ice draft
- Ice keel geometry
- Velocity
- Momentum

Upward Looking Sonar

Upward Looking Sonar History

Source: www.subguru.com

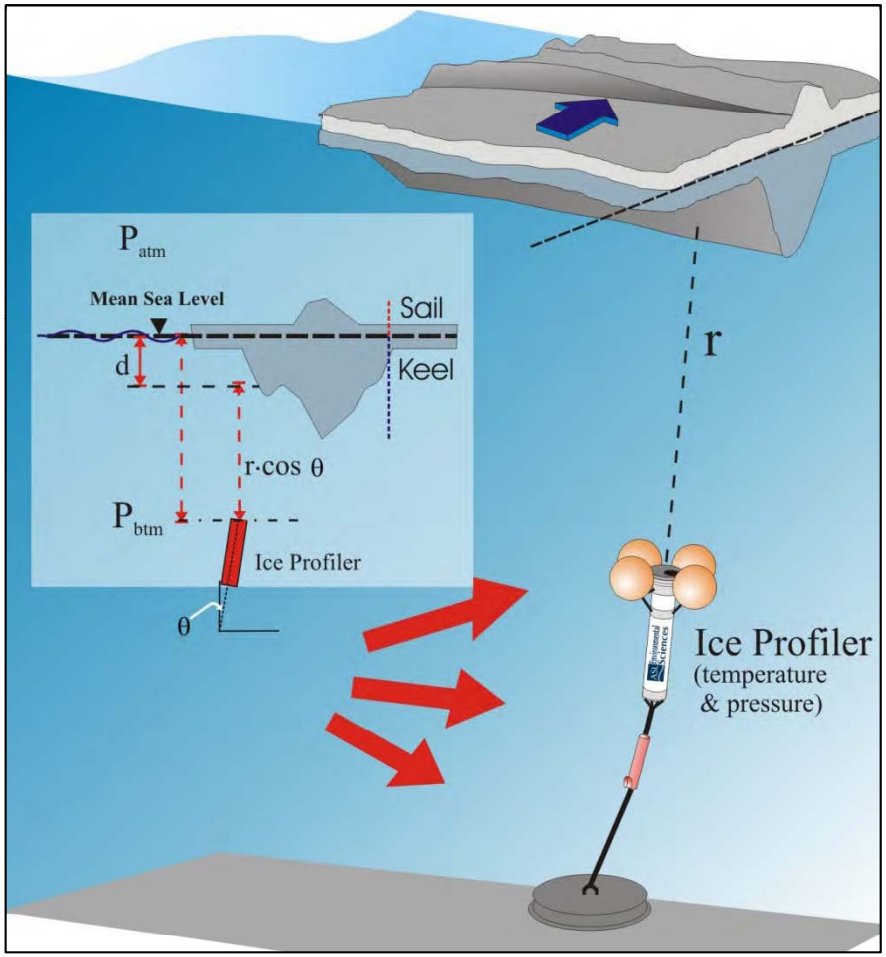
Modern Upward Looking Sonar



Ice Profiling Sonar (IPS)

- Key performance statistics
  - range resolution: ~2 cm
  - sampling rate: up to 2 Hz
  - number of targets per ping: 5
  - storage and power capacity leading to 1-3 year deployments
- When co-deployed with ADCP, 1 m horizontal resolution

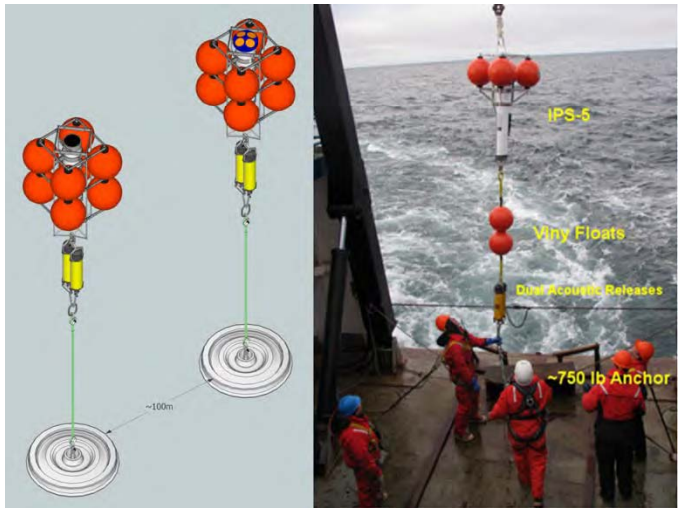
Ice Draft From IPS Sensors



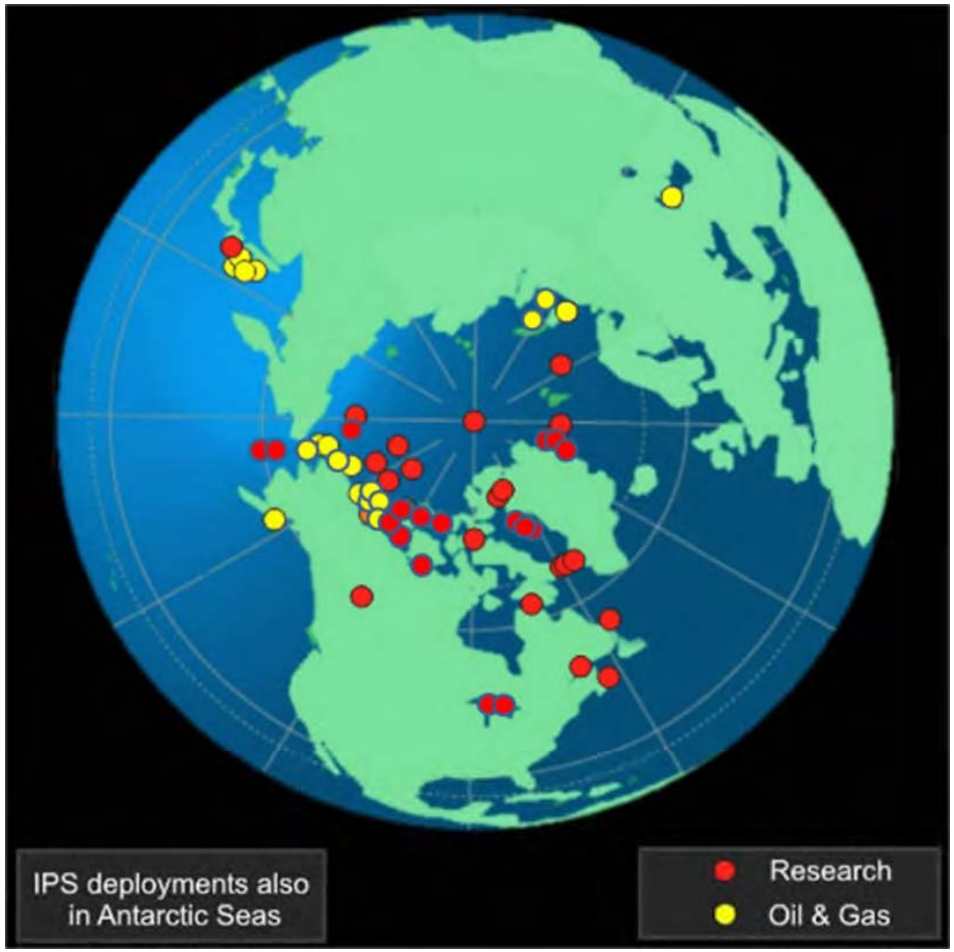
Ice draft determined to within ± 5 cm

Other IPS Configurations

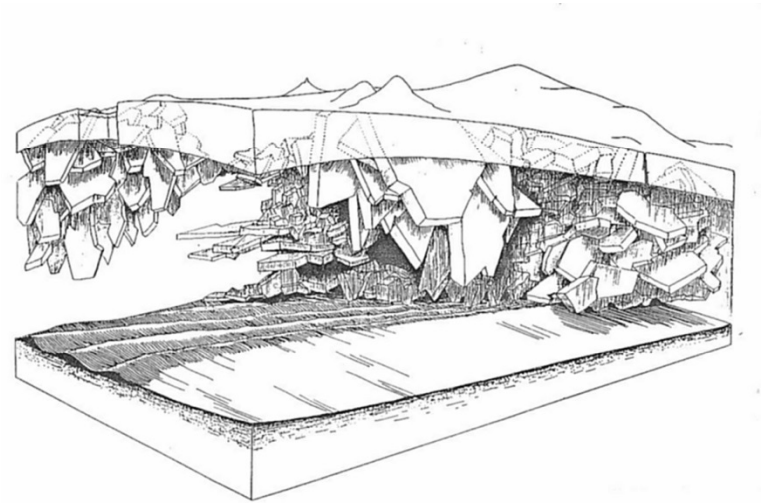
- SWIP, e.g. Peace River (BC Hydro)
- Tethered realtime, e.g. Confederation Bridge (Public Works and Government Services Canada), Cambridge Bay (Ocean Networks Canada)



IPS Deployments



Ice Feature Detection

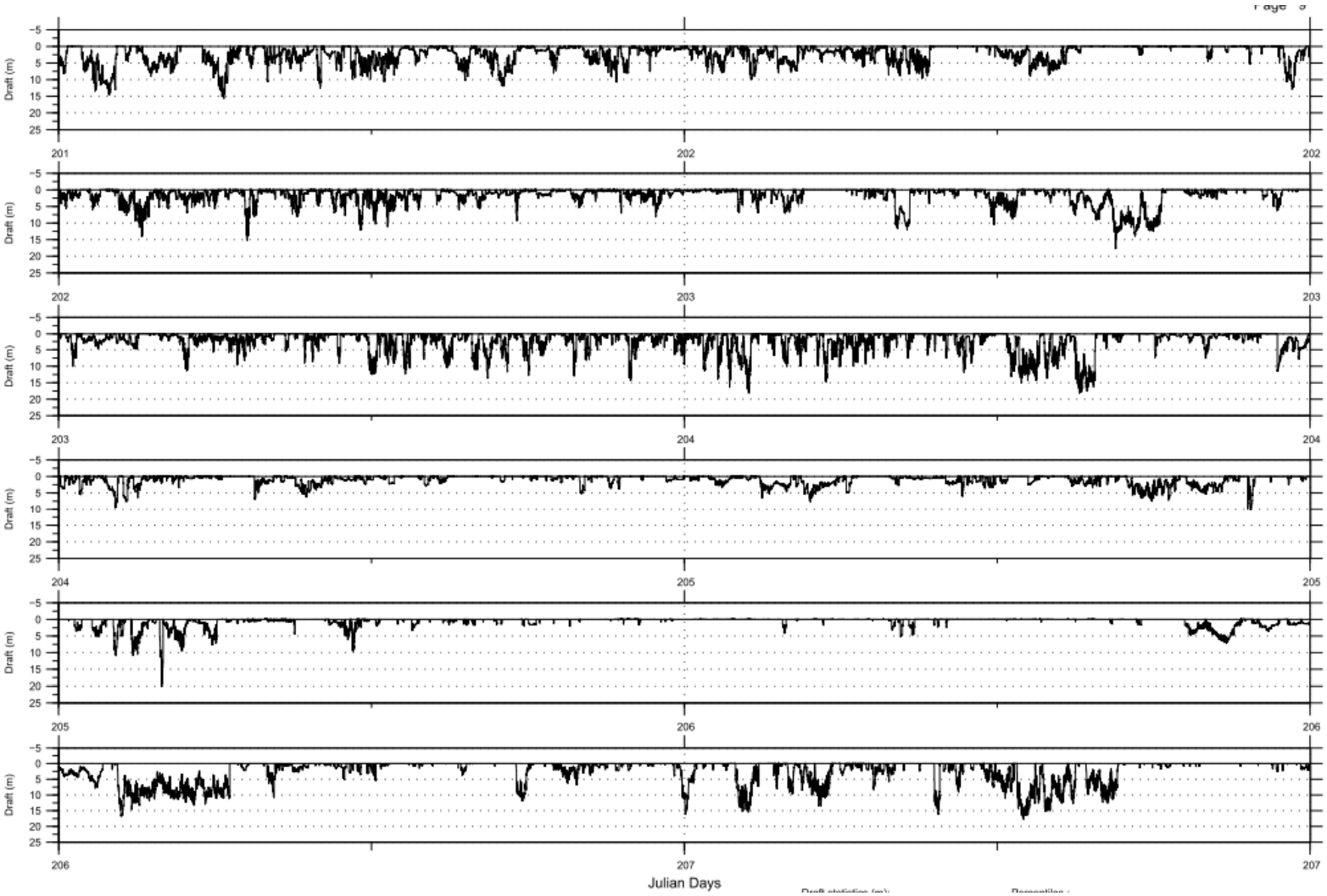


Source: www.engr.mun.ca

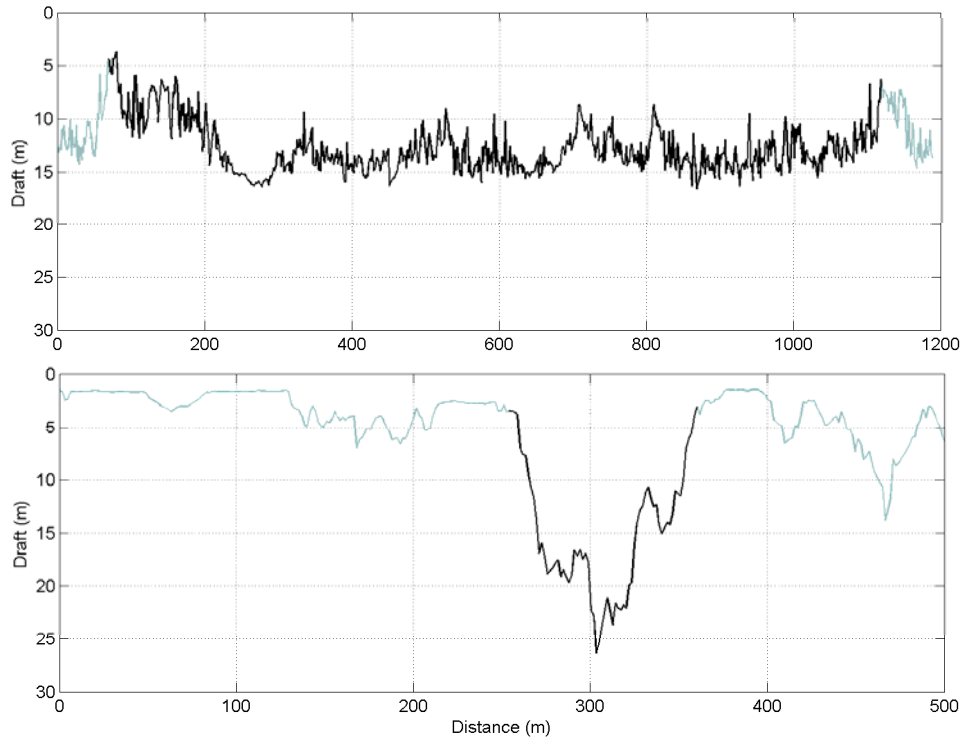
Source: www.arctic.noaa.gov

Source: H. Melling

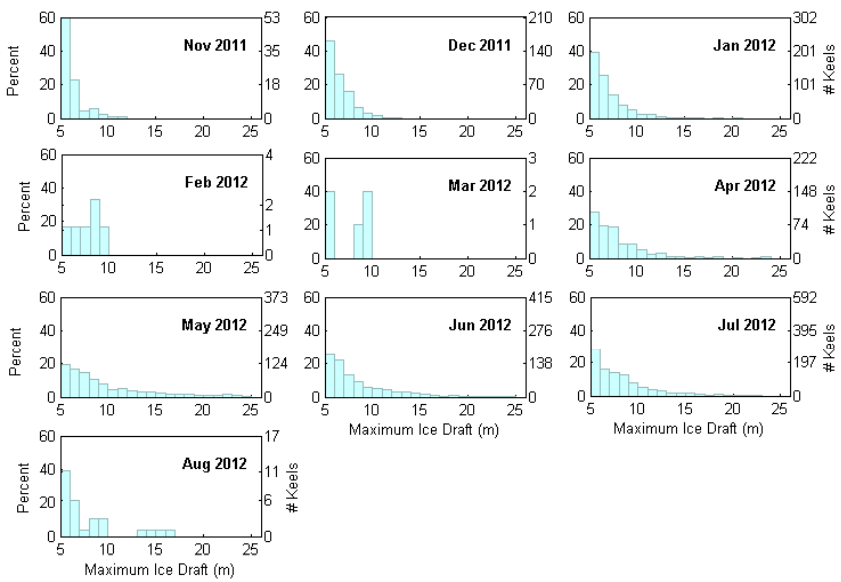
Ice Profile Data

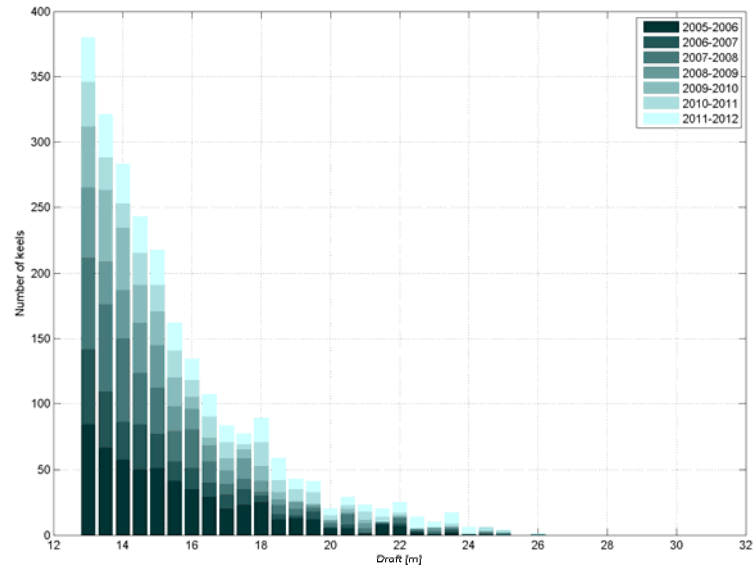


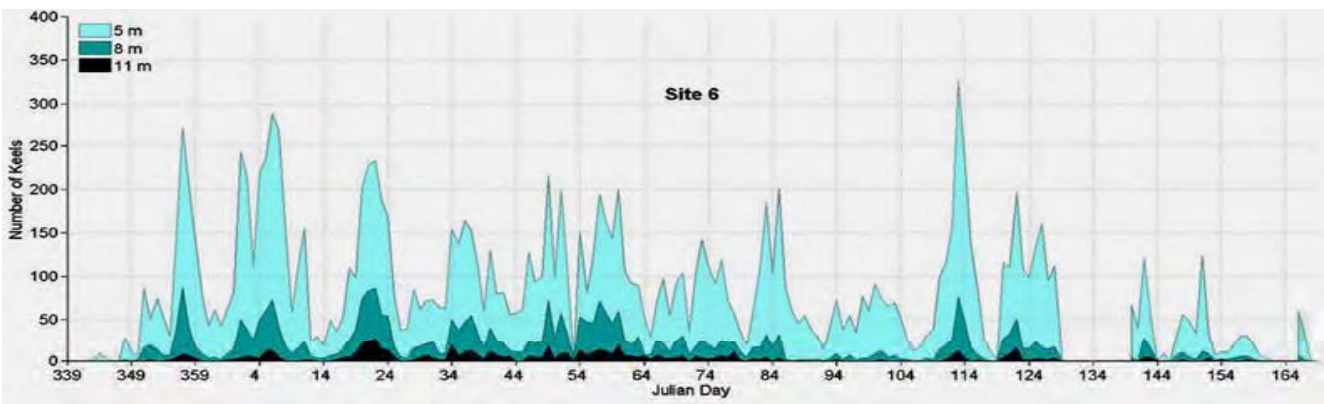
Ice Feature Database



Ice Feature Database - Statistics



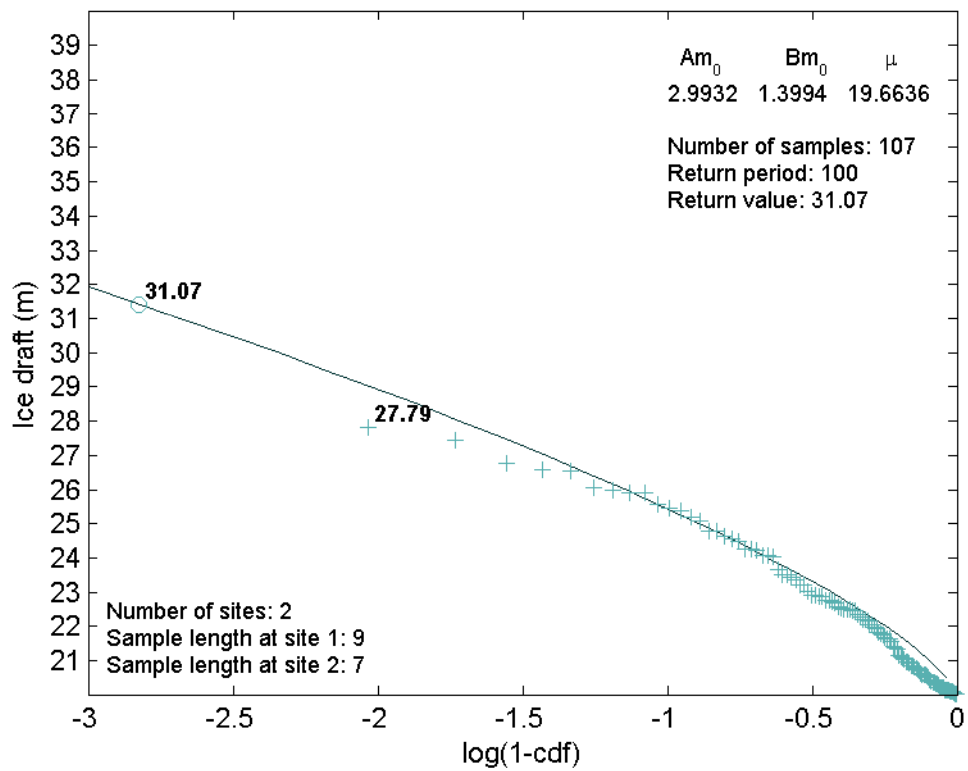




Ice Feature Database – Extremal Analysis

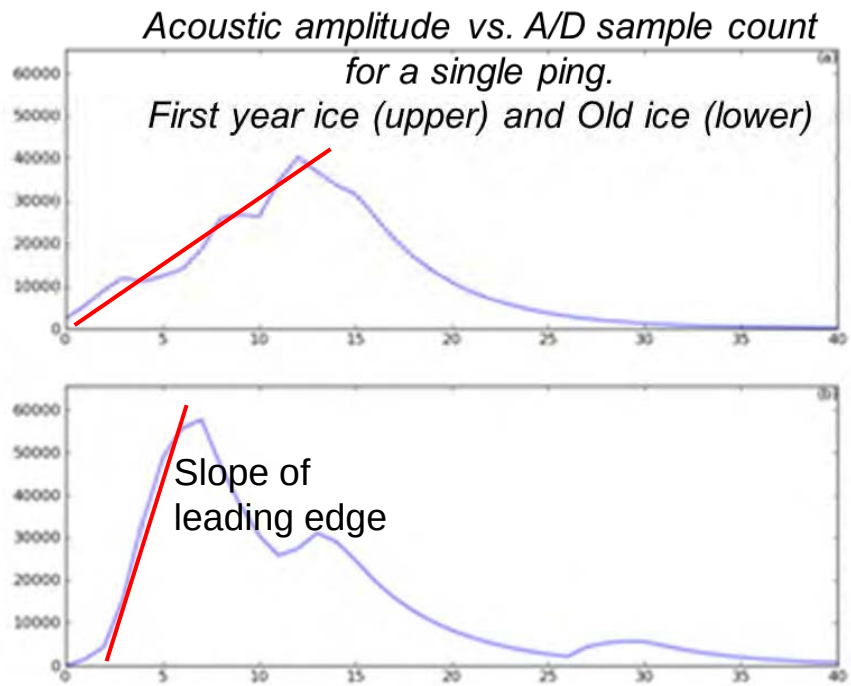
- Peak over threshold selection
- Weibull distribution

$$E(x) = 1 - e^{-\left(\frac{x-\mu}{a}\right)^b}$$



Stage of Development

- Distinguish between first-year and multi-year ice



Conclusions

- Long-term trend of decreasing ice extent but, large regional and temporal variations in ice concentration, thickness, composition, and dynamics
- Upward looking sonar –> ice characterization
- Identification of individual hazardous features -> ice feature statistics and return values

APPENDIX Z

OFFSHORE OIL PIPELINE LEAK DETECTION TECHNOLOGIES FOR ARCTIC/COLD REGIONS

INTECSEA
WorleyParsons Group

Alaska DEC

Offshore Oil Pipeline Leak Detection Technologies for Arctic/Cold Regions

Prem Thodi, PhD
Engineering Specialist, INTECSEA, WorleyParsons

ADEC Arctic/Cold Regions Oil Pipeline Conference,17-19 Sept. 2013

EcoNomics

Outline

- Introduction
- Key regulations
- Arctic pipeline leak detection challenges
- Existing leak detection technologies
  - Internal / Primary / CPM systems
  - External / Secondary systems
  - Periodic leak testing systems
- Fiber Optic Cable DTS and DAS
- Principle of operation, installation and maintenance challenges
- Key technology gaps
- INTECSEA experience with Leak Detection Systems (LDS)
- Summary and conclusions

Courtesy: www.telegraph.co.uk (03 Jun 2010)

Courtesy: www.offshoreenergytoday.com (19 Dec 2011)

Introduction

- 25% of world's remaining oil & gas reserves are expected to be in Arctic
- Demand for oil and gas will continue to drive Arctic development
- Unique Arctic environment presents technical challenges
- Reliable Arctic operational strategies are needed to reduce risk
- Rapid and reliable leak detection is an important aspect of safe and economic hydrocarbon development in the offshore Arctic/cold regions

Arctic Pipeline Leakage – Potential Causes & Consequences

Causes

- High bending strain due to ground movement, ice gouging, strudel scour, etc.
- Pipeline connections, valves, fittings, etc.
- Structural degradations – Corrosion, erosion
- Structural degradations – Fatigue cracking
- Other issues – Span, VIV, buckling, rupture

Consequences

- Safety
- Environmental
- Shutdown
- Cleanup cost
- Negative reputation

Structural Degradation - Corrosion

Structural Degradation – Cracking

Key Regulations

- Alaska State Regulations (18 AAC 75)
  - Single phase pipeline – should have a LDS that can continuously detect the daily discharge of at least 1% of daily throughput and flow verification through a CPM (Computational Pipeline Monitoring) system at least once every 24 hours. The CPM system must be designed and operated in accordance with API 1130 guidelines
  - Multiphase flowline – completely contain entire circumference of flowline, and annulus if PIP, with a leak detection system approved by the department. Or, have in-place a preventative maintenance program that ensures the continued operational reliability of components affecting quality, safety and pollution prevention
  - The leak detection system selection should be based on Best Available and Safest Technology (BAST) evaluation
  - Operator shall ensure that the flow must be completely stopped within an hour after the detection of a leakage

Key Regulations

- Federal Regulations (49 CFR 195, 30 CFR 250)
  - Pipelines located in High Consequence Areas (HCA) must have a leak detection system (LDS) approved by the department
  - An operator's LDS evaluation must consider the following factors: length and size of the pipeline, type of product carried, the pipeline's proximity to the HCA, the swiftness of leak detection, location of nearest response personnel, leak history, and risk assessment
  - The regional supervisor may require either an input-to-output volumetric comparison alarm system or a LDS on a federally-regulated pipeline
  - On hazardous liquid pipeline systems transporting single phase oil, a new CPM system should be considered
  - If a CPM system is installed, it must be designed and operated in accordance with API RP 1130 guidelines

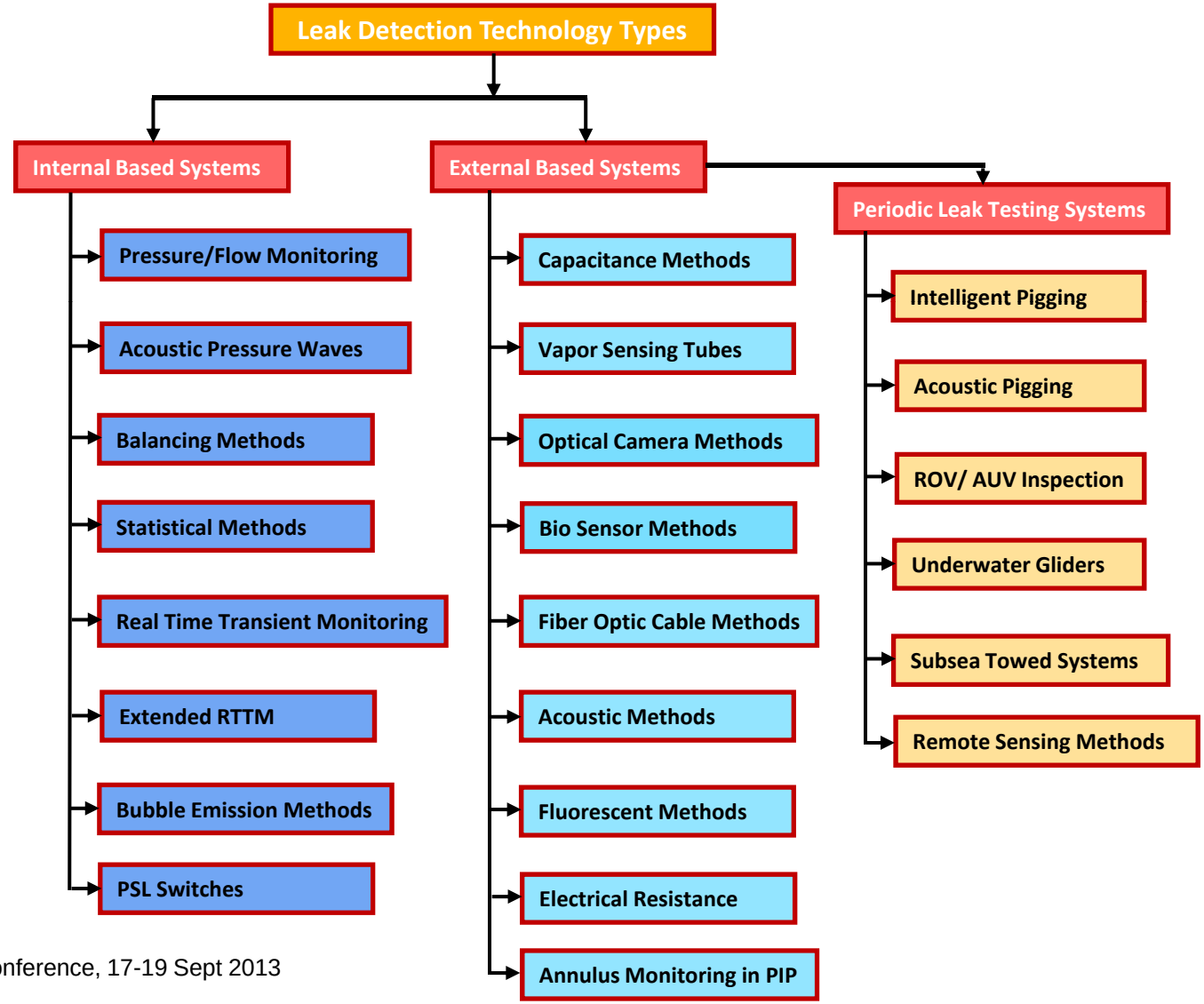
Preferred LDS Attributes

- Sensitivity – should be able to detect large and small leaks
- Detection time – small leaks in hours and large leaks in seconds/minutes
- False alarms – sufficiently discerning to avoid false alarms
- Installation and operation – robust to survive installation and long term operation in Arctic buried/unburied condition
- Minimum impact on production line operation from outage/reduced flows
- Detectability in single phase and multiphase flow conditions
- Accommodates operating conditions and fluid types
- Proven / promising track record of technology or inherently simplistic or fail-safe design
- Commercially available
- Leak location identification and leak rate quantification capability are preferred, though not mandatory

Arctic/Cold Region Oil Pipeline Leak Detection Challenges

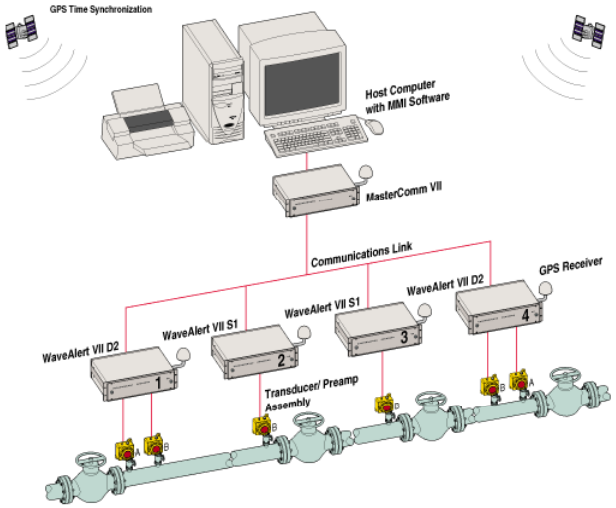
- Buried pipelines conveying multiphase flows
- Open water and seasonal ice cover
- Installation and maintenance challenges
- Subsea equipment and power requirements
- Operational management using SCADA
- Remote performance monitoring and control
- Likelihood of false alarms
- Uncertain minimum thresholds of detection
- Background noise reduction
- Uncertain operational reliability
- Temperature and slack line issues

Existing & Emerging Pipeline Leak Detection Technologies

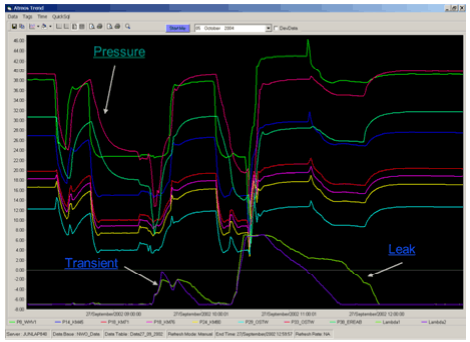


Internal Leak Detection Systems

- Utilize field sensor data to monitor pressure, temperature, density, flow rate, contamination, sonic velocity, product data at interfaces
  - Mass balance system
  - Volume balance system
  - Pressure monitoring system
  - Acoustic pressure wave monitoring
  - Real-time transient monitoring (RTTM)
  - Extended RTTM
- Infer commodity release by computation
- Install-able along with pipeline and SCADA
- Use acquired data to determine leakage



Wave Alert System (Courtesy: Acoustic Systems Inc.)



Atmos Pipe (Courtesy: ATMOS Intl.)

Pros and Cons of Internal Leak Detection Systems

- Internal leak detection systems can detect large leaks
- Easy installation and maintenance
- Limited ability to detect small, chronic leaks (sub 1% leak)
- Limited capability to locate leaks accurately
- Leak detection capability reduces with operations, like:
  - Startup & Shutdown
  - Valve closures
  - Transient flow
  - Multiphase flow
- Prone to false alarms
- Cannot use under low-flow or non-flow conditions

Pressure **P**oint **A**nalysis (Courtesy: EFA Technologies)

Mass Balance Systems

Suitable for	Single Phase Oil / Multiphase flow pipelines
Type of Installation	Permanent
Type of Monitoring	Continuous
Advantages	• Can detect large pipeline leaks • Well established and matured technology • It is able to detect leaks in transient flow conditions less accurately
Disadvantages	• Cannot detect small chronic leaks (i.e. sub 1% leaks) • Cannot locate leaks • Prone to false alarms and reported poor performance in transient flow conditions • Not intended for use under low-flow or no-flow conditions • Accurate multiphase leak detection is challenging

Pressure Monitoring Systems

Suitable for	Single Phase Oil / Multiphase flow pipelines
Type of Installation	Permanent
Type of Monitoring	Continuous
Advantages	• Well established and matured technology, Pressure Switch Low (PSL) and statistical LDS alarms are the most common type of pipeline leak detection systems • Can be easily integrated into pipeline SCADA • Can detect large pipeline leaks
Disadvantages	• Cannot detect small chronic leaks (i.e. sub 1% leaks) • Prone to false alarms and reported poor performance in transient conditions • Limited ability to locate leaks • Potentially requires intermediate monitoring points • Not intended for use under low-flow or no-flow conditions • Multiphase flowline leak detection is challenging

Acoustic Monitoring Systems

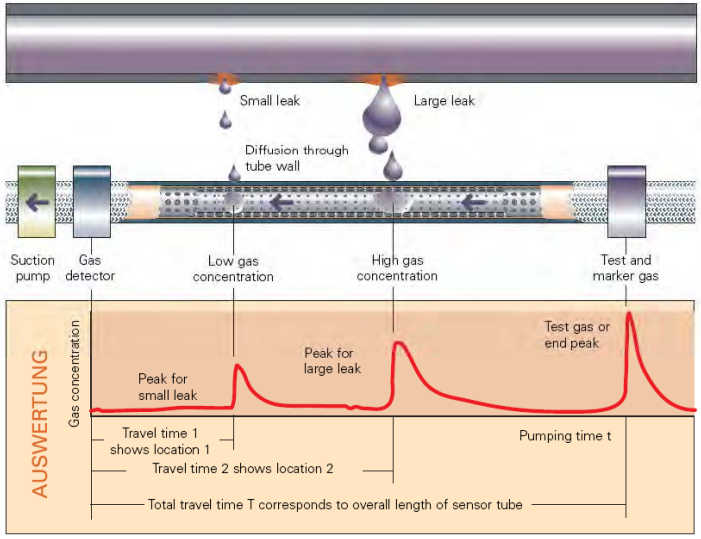
Suitable for	Single Phase / Multiphase flow pipelines
Type of Installation	Permanent
Type of Monitoring	Continuous
Advantages	• Quick leak detection • Good for large leak detection • Can detect location of leak (multiphase is around 100-200m) • Simplified sensor and software set-up with minimal calibration
Disadvantages	• Background noise severely affects leak detection capability for small leaks • Difficult for multiphase flow • Prone to false alarms • No leak detection capability once the leak-noise misses the sensor • Challenging for small leak detection on long pipelines

Real Time Transient Monitoring

Suitable for	Single Phase Oil / Multiphase flow pipelines
Type of Installation	Permanent
Type of Monitoring	Continuous
Advantages	• Very accurate for steady state conditions • Can detect small leaks (as low as 1% of flow) • Good for long oil transport pipelines • RTTM Software algorithm are designed for leak location
Disadvantages	• Extensive instrumentation is required (for measuring pressure, temperature, flow rate, density, etc.) • Unsteady flow creates errors (or, false alarms) • Calibration or loss of data could cause missed leaks or false alarms • Sensitivity reduces with ultra long pipelines

External Leak Detection Systems

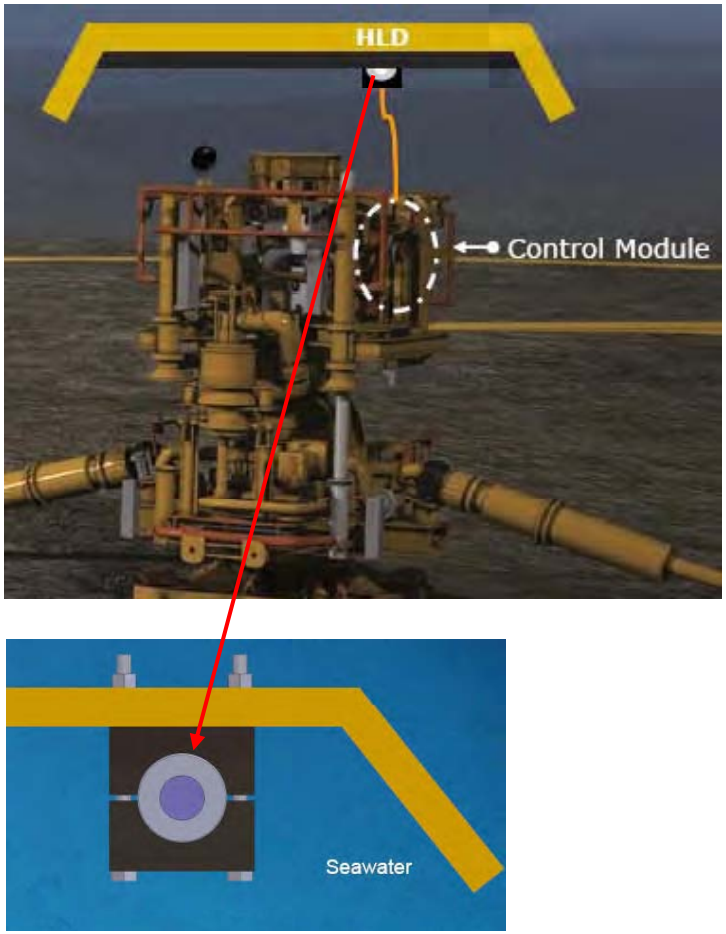
- Measures physical properties (temperature, acoustics, presence of oil particle, capacitance) around the pipelines
- Can be fixed on to pipelines or kept adjacent to pipelines
- Can be easily integrated into pipelines SCADA
  - Hydrocarbon Vapor Sensors
  - Capacitance Sensors
  - Vacuum Annulus Monitoring Sensors
  - Temperature Differential Sensors
  - Fiber Optic Cable Sensors
  - Remote Sensors
  - Acoustic Sensors
  - Fluorescence & Optical Technologies



Vapor Sensor (Courtesy: Areva NP GmbH)

Pros and Cons of External Leak Detection Systems

- Can detect small, chronic leaks
- Can locate small leaks accurately
- Can be used for continuous leak monitoring
- Dependent on diffusing material to the sensor
- Difficulty in quantifying size and rate of small leaks
- Requirement of permanent installations
- Requirement of leaking fluid-sensor contact
- Requirement of differential pressures
- False alarms
- Installation and maintenance difficulties



Hydrocarbon Vapor Sensing Tubes

Suitable for	Single Phase Oil / Multiphase flow pipelines and equipment monitoring
Type of Installation	Permanent
Type of Monitoring	Continuous monitoring
Advantages	• 30 years of service history, used in river crossing pipeline, onshore and offshore Arctic buried pipeline leak detection • Capable of detecting small chronic leaks (0.1m3/hr gas) • Leak location accuracy is approx. 0.5% of total length • System is readily available • Discerning gas leak is rapid • Can work under low flow conditions • Well established technology, less unknowns
Disadvantages	• Length limitation is 15 kilometres • Slow detection. Detection time is determined by air circulation frequency, normally 12 or 24 hours • Additional protection required (e.g. perforated conduits) • Handling, installation and maintenance are difficult • Sensor pickup all incidents along the pipeline • Difficult to retrofit • Only detects leaks that evolve into the sensing tube

Vacuum Annulus Monitoring (for Pipe-In-Pipe, PIP) System

Suitable for	Single Phase / Multiphase flow pipelines
Type of Installation	Permanent (applicable only on PIP lines)
Type of Monitoring	Continuous monitoring
Advantages	• Sensitive to small leaks • Quick leak detection for small leaks to large leaks • Minimizes false alarms due to pressure increases caused by temperature fluctuations • Installable and maintainable • Cost effective • Provides continuous monitoring during various flow conditions • Monitoring is not affected by flowline fluid type
Disadvantages	• Cannot detect the exact location of leakage • Vacuum pump/gauges require a heated environment • Challenging to install and repair at intermediate bulkheads • Moderately increased risk of annulus failure due to additional pressure sensor fitting • Additional communication link is needed

Fiber Optic Cable Sensors

Suitable for	Single Phase Oil / Multiphase flow pipelines
Type of Installation	Permanent
Type of Monitoring	Continuous monitoring
Advantages	• Does not require shutdown for calibration • Can work under low flow conditions • Can detect very small leaks accurately (sub 1% leaks) • Can locate leaks very accurately • Can be used on seabed as well as in buried conditions • Can use optical communications, no data link is needed • No subsea power requirements • Not subjected to electrical/electromagnetic interferences • Can be used on long pipelines for continuous monitoring • Can also detect geohazards and third party interventions
Disadvantages	• Multiple interrogator units may be required for long (>50km) pipelines • Increased installation cost for sensor and interrogator system • Needs enhancement in technology readiness level

Periodic Leak Detection Systems

- Not a continuous (24x7) leak monitoring system
- Can be used for periodic leak testing, or when a leak is suspected
  - Intelligent pigging
  - Acoustic pigging
  - ROV/AUV/Overflight inspection
  - Underwater gliders
  - Underwater towed systems
- Buried pipeline leak detection capability is uncertain
- Need support vessel for periodic ROV operation

Courtesy: COLMAR ALD mounted on ROV

Courtesy: NAXYS SALD (Left) and ALVD (Right)

Periodic Monitoring Options: Intelligent Pigging

Suitable for	Single Phase Oil / Multiphase flow pipelines
Type of Application	Intermittent Running
Type of Monitoring	Periodic
Advantages	• Accurately detects leaks • Sensitive to small leaks • Can simultaneously check for internal corrosion, scale/wax build up, etc. • Can be run during normal operations
Disadvantages	• Not a continuous (24x7) leak monitoring system • Requires a pig launcher and receiver for operation • Cannot instantaneously detect leaks, substantial volume of fluid may be released before detection • Ability to detect very small leak (sub 1% leak) is uncertain in transient conditions or multiphase flow conditions

Periodic Monitoring Options: Acoustic Pigging

Suitable for	Single Phase / Multiphase flow pipelines
Type of Application	Intermittent Running
Type of Monitoring	Periodic
Advantages	• Relatively high leak detection sensitivity • Ability to detect pin hole sized leaks of less than 0.15L/min • Can locate leaks very accurately (within 3 m) • Can be used in long, buried pipelines • Smaller than the pipe diameter so no concern in getting stuck • Acoustic receivers can transmit data in real-time.
Disadvantages	• No continuous monitoring, cannot instantaneously detect leaks • Periodic testing – needs to be run during normal operation • Prone to false alarms • Cleaning pig noise may reduce leak detection sensitivity

Fiber Optic Cable Distributed Sensing Systems

- Distributed Temperature Sensing (DTS)
- Oil leakage leads to local rise in temperature
- Gas leakage leads to local cooling
- Raman band systems
- Brillouin band systems
- FOC itself acts as the sensor and data link

- Distributed Acoustic Sensing (DAS)
- Acts as a hydrophone
- Captures acoustic signature (i.e. vibration) generated by leaking fluid
- Noise separations
- Rayleigh band systems
- No need to contact fluid with FOC sensors

Fiber Optic Cable DTS - Raman & Brillouin Principle of Operation

Raman DTS System

- Raman DTS is intensity-based
- Hydrocarbon leakage is capable of modifying surrounding temperature by 0.2 to 0.3 deg. C
- Thermally activated vibrational modes of sensor results in low-intensity, inelastic backscattering
- The temperature information is gathered by measuring light signal powers scattered at the Stokes and anti-Stokes wave lengths, and by evaluating the ratio:
- $\frac{P_{anti-Stokes}}{P_{Stokes}} \sim exp\left(-\frac{h\Delta v}{kT}\right)$

where, h is the Planck's constant, Δv is the frequency difference between the incident and the backscattered signals, k is the Boltzmann constant, and T is the temp.

Brillouin DTS System

- Converts temperature effects on cable into frequency shifts of backscattered light
- Insensitive to the fiber attenuation changes over time and distance
- Thermally excited acoustic modes results in a frequency shift
- $\nu_B = \frac{2nV_A}{\lambda}$

where ν_B is the Brillouin frequency shift, V_A is the acoustic velocity, and λ is incident wavelength. The acoustic velocity:

- $V_a = \sqrt{\frac{K}{\rho}}$

where K is the bulk modulus and ρ is the density. The density of material ρ, is temperature dependent as a result of thermal expansion, so the peak frequency of interaction is observed to change with temp.

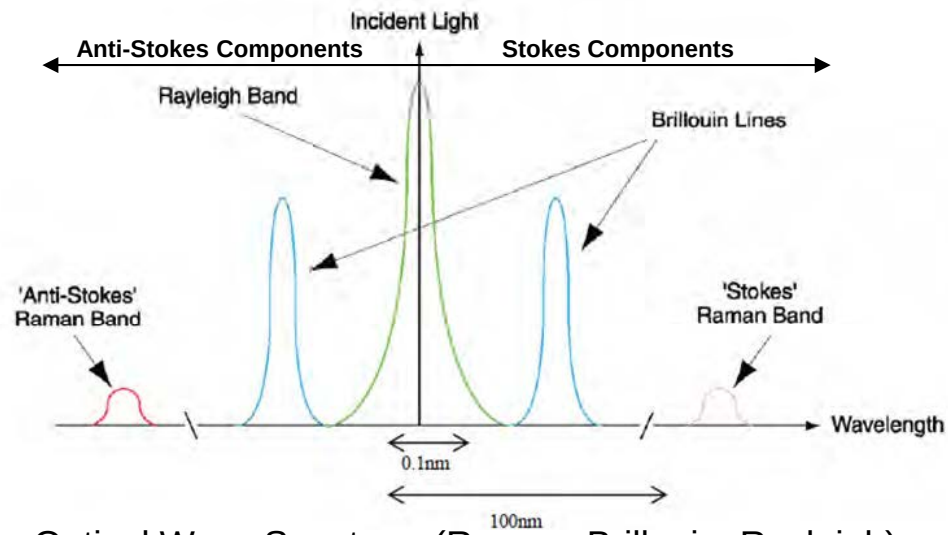
Fiber Optic Cable Rayleigh DAS Principle of Operation

- Measures minute strain effects on FOC DAS sensor
- Strain is caused by acoustic vibrations arising from leaking source
- When a short pulse of light is emitted, a proportion of the outgoing signal is scattered back to source due to impurities or defects in fiber microstructure
- The acoustic waves modulates the backscattered signal. The degree of contact between the acoustic wave and the cable determines the level of backscatter modulation, which can be used to recreate the acoustic field
- FOC pick up the acoustic signals, and when a distinguishable sound signature is detected, an alarm is triggered
- The timescale of detection, t' can be converted to distance scale, z:

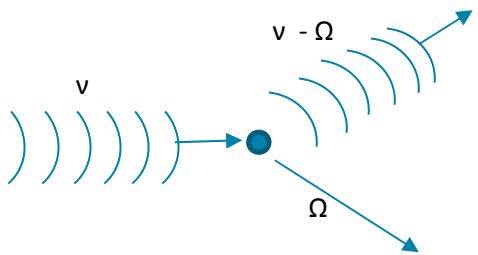
$$z = \frac{v_g t'}{2}$$

where z denotes the leak location, v_g is the signal group velocity, and $t' = 2t$ (because of round trip propagation)

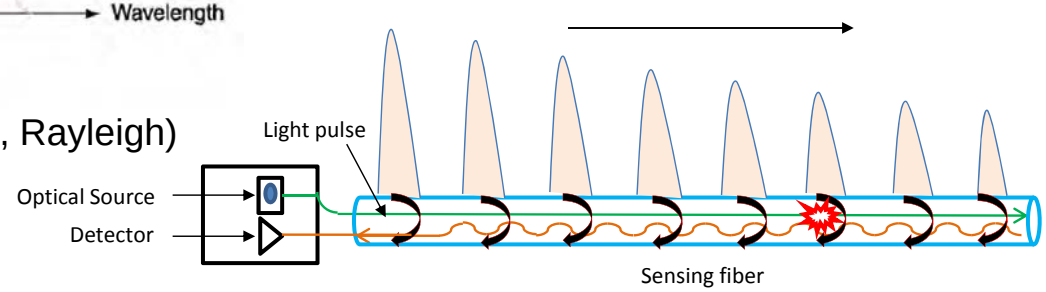
OTDR Principle for Distributed Sensing Systems

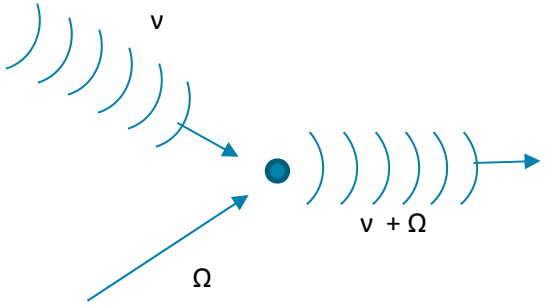


Optical Wave Spectrum (Raman, Brillouin, Rayleigh)

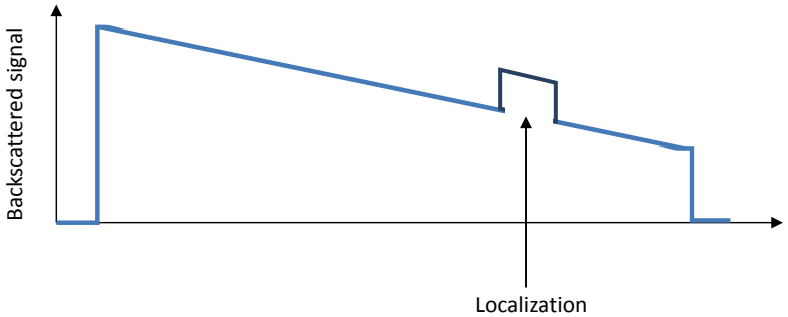


Stokes Component



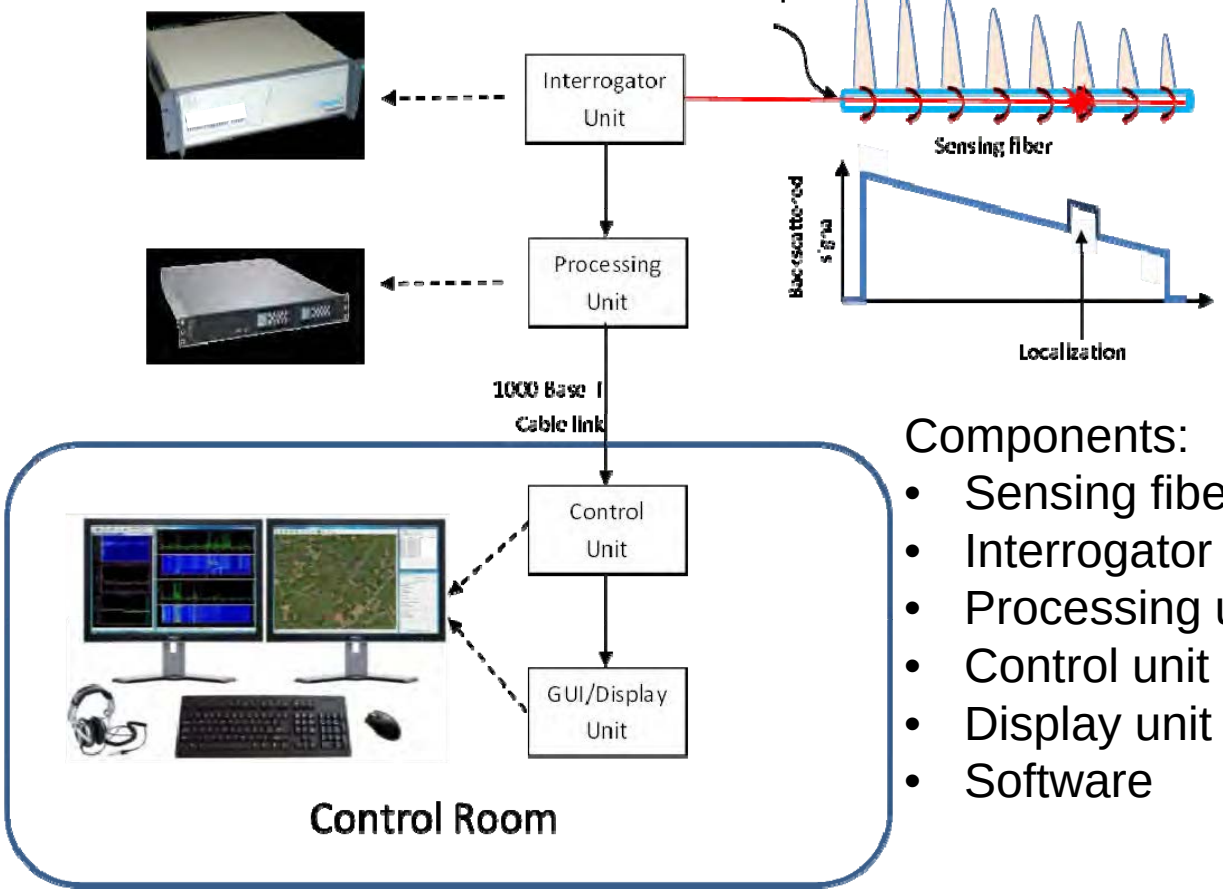


Anti-Stokes Component



Principle of Optical Time Domain Reflectometer

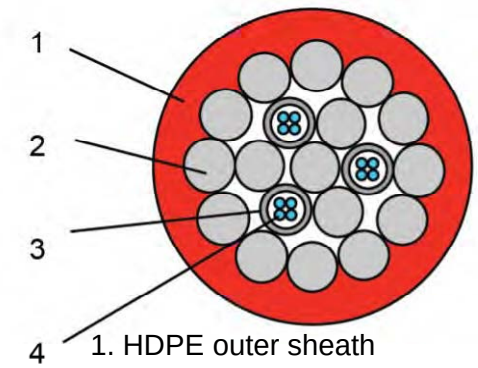
FOC Distributed Sensing System Components



Components:

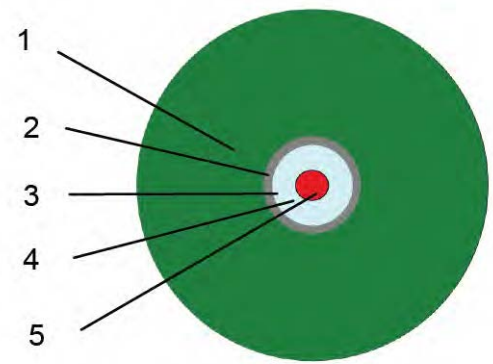
- Sensing fiber
- Interrogator unit
- Processing unit
- Control unit
- Display unit
- Software

Typical DTS Cable



1. HDPE outer sheath
2. Galfan high strength steel wire
3. Gel-filled metal loose tube SS 316L
4. Bend insensitive optical fibers

Typical DAS Cable

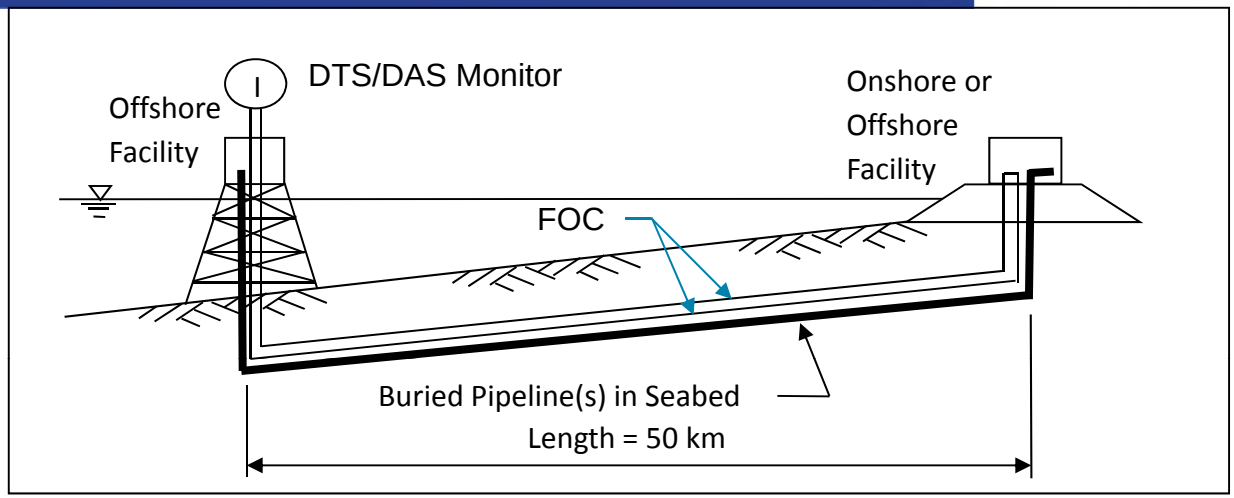


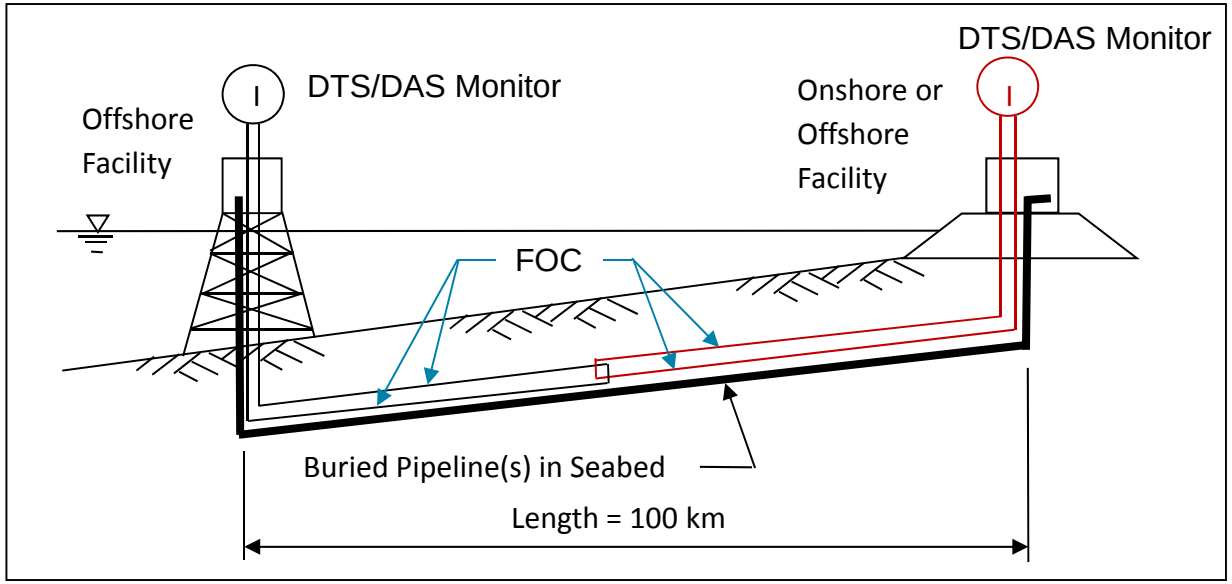
1. PA Outer sheath
2. Stainless steel 316 L metal tube
3. Inner interlocking system
4. Multilayer acoustic coupling layer
5. Bend insensitive optical fiber

FOC DTS/DAS Installation & Maintenance Challenges

- DTS cable need to be in close proximity to the pipeline
- Optimum location of DTS and DAS cables
- Shielding of acoustic leak signal from the DAS cable
- Impact of trench and backfill on cable
- Need to pass over lay vessel rollers / trenching equipment
- DTS installation temperature in the Arctic
- Lay barge reconfiguration requirements
- Limitations of cable splices offshore / onshore
- Installation and maintenance of subsea (marinized) repeaters

Leak Detection Strategy for Long Arctic/Cold Region Pipelines





Technology Status (TRL/TRC)

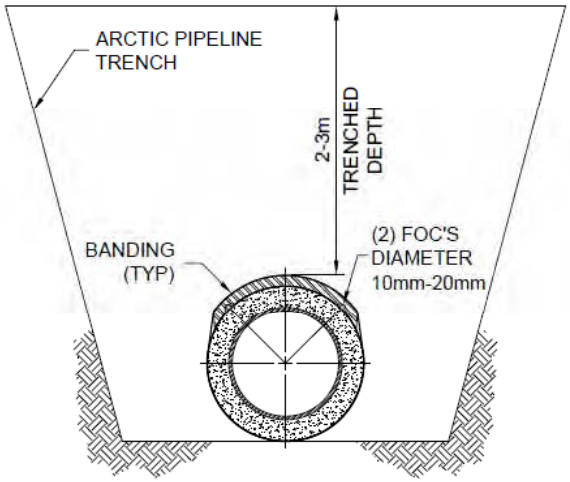
Technology Readiness Levels (TRL)

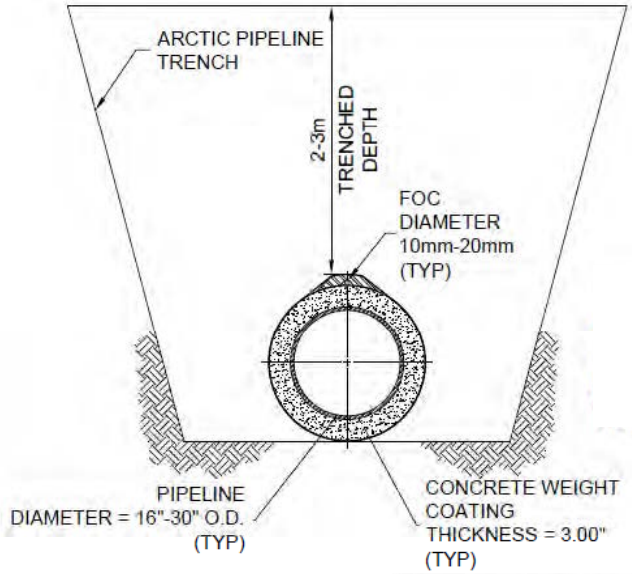
Major Components	Technology Readiness Level		Key Points (API RP 17N)
	DAS	DTS	
Interrogator Unit Processing Unit Control Unit Sensing Fiber Optic Cable	3	3	Concept proved, prototype tested in lab for performance, functionality, reliability. Pre-production system Arctic environmental test not yet performed.

Technology Risk Categorization (TRC)

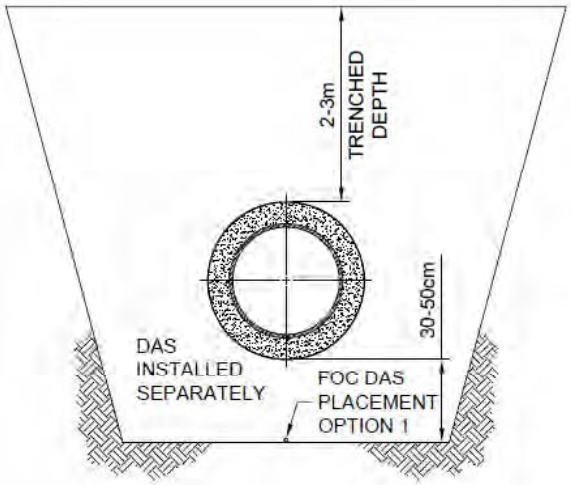
DTS & DAS	Reliability	Technology	Architecture/ Configuration	Operating Environment	Organizational Scale/Complexity	Overall Risk
Risk Category	High (B)	High (B)	High (B)	Very High (A)	High (B)	Very High (A)
Key Points	False Alarms MTBF Installability	Long Length Installability	New Application	Arctic LDS Uncertainty	Relatively New Team	

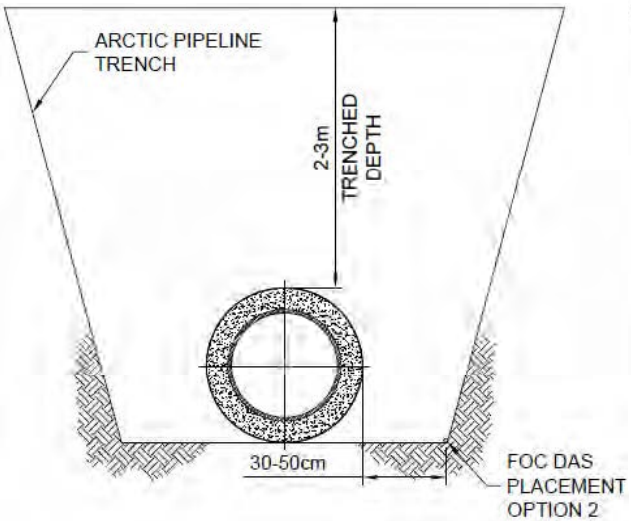
Potential Positioning for FOC DTS & DAS Cables

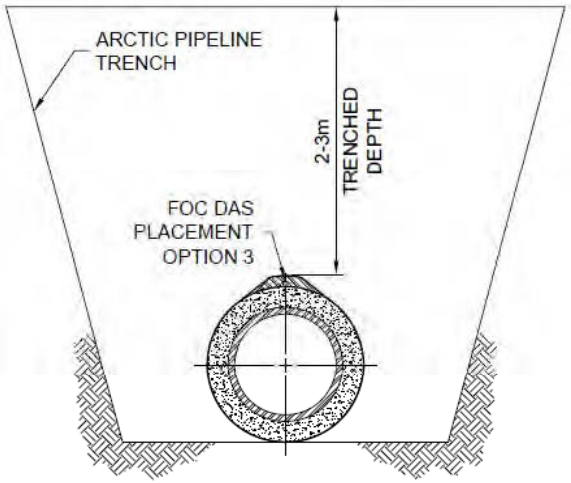




Potential Positions for DTS Cable







Potential Positions for DAS Cable

Technology Gaps

- False alarm reduction
- Reliability of systems
- Minimum thresholds of detection
- Long pipeline application
- Cable positioning
- Inadequate technology status
- Lack of Arctic subsea experience
- System life expectancy
- Interrogator installation and repair
- Leak size quantification difficulty

Northstar Pipeline (BP Alaska)

Oooguruk Pipeline
(Pioneer Natural Resources)

INTECSEA Experience with Leak Detection Systems

Beaufort Sea Pipeline Projects:

BPXA Northstar (installed 2000)

- Oil Transmission lines: EFA LeakNet, PSL, LEOS, over flights
- Gas transmission lines: Mass balance, PSL, over flights

Pioneer Oooguruk (installed 2007)

- 3 Phase Production flowline: PIP annulus monitoring, PSL, over flights
- Water injection flowline: Mass Balance, PSL, over flights
- Gas Injection Flowline: Mass Balance, PSL, over flights
- Seabed erosion: Distributed temperature sensing (DTS)

Eni Nikaitchuq (installed 2009)

- 3 Phase Production flow line: PIP annulus monitoring, PSL, over flights
- Water injection flowline: Mass Balance, PSL, over flights
- Gas Injection Flowline: Mass Balance, PSL, over flights
- Seabed erosion: Distributed temperature sensing (DTS)

Oooguruk Flowline Bundle Fiber Optic LDS

Summary & Conclusions

- Pipelines are designed to safely transport hydrocarbons
- Leaks in the Arctic can have severe safety, economical and environmental consequences
- Existing leak detection technologies:
  - Internal / Primary / CPM systems
  - External / Secondary systems – focusing on FOC DTS and DAS
  - Periodic Leak Testing systems
- FOC DTS and DAS operating principles, applicability, advantages, limitations, installation and maintenance considerations are discussed for Arctic leak detection
- Key technology gaps identified
- JIP on FOC DTS/DAS testing

INTECSEA
WorleyParsons Group

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APPENDIX AA

SUBSEA ARCTIC PIPELINES - DESIGN AND CONSTRUCTION CHALLENGES

INTECSEA
WorleyParsons Group

Alaska DEC

Subsea Arctic Pipelines

Design and Construction Challenges

2013 ARCTIC/COLD REGIONS OIL PIPELINE CONFERENCE

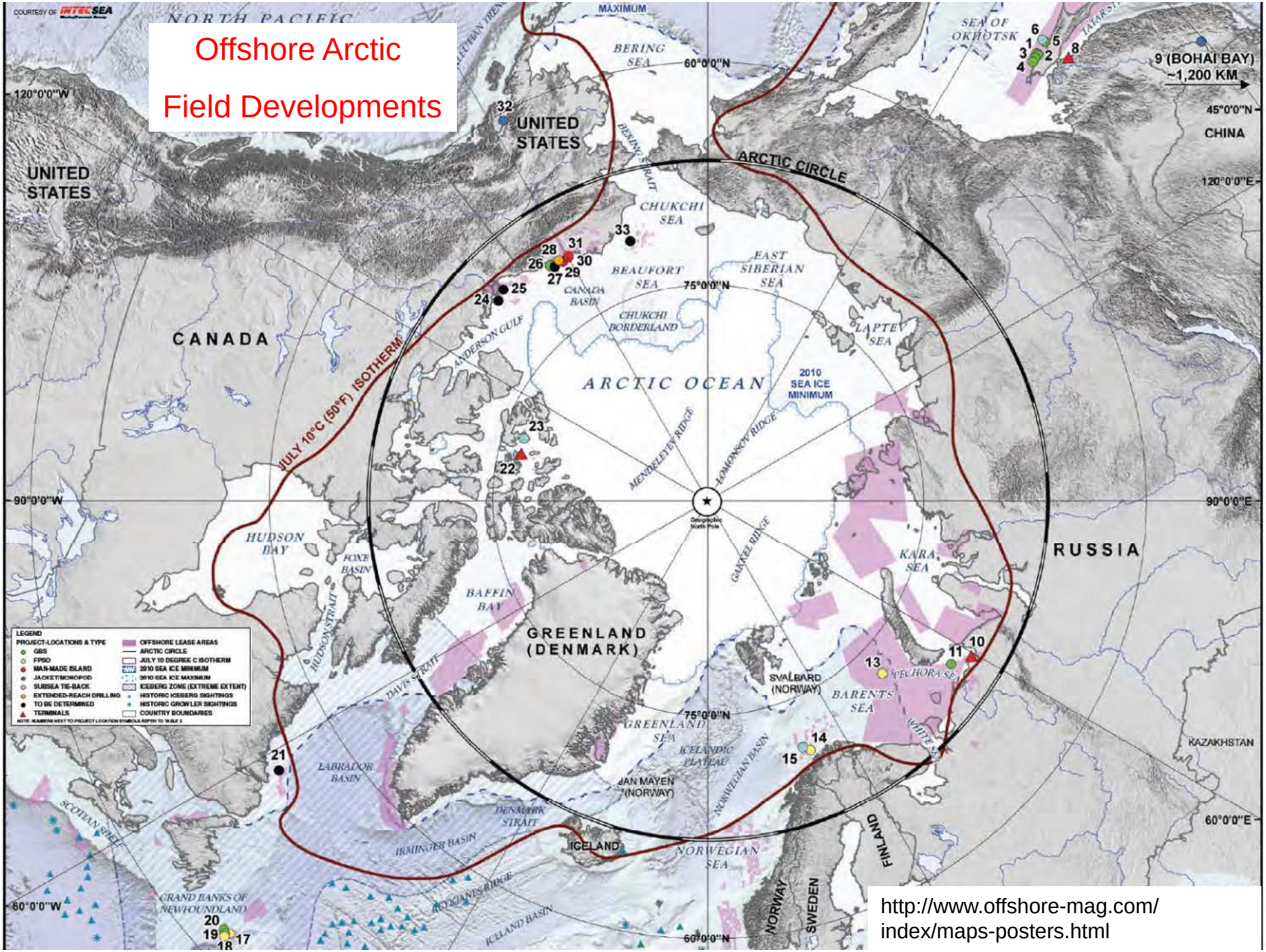
Craig Young – INTECSEA Houston
Anchorage, 19-September-2013

EcoNomics

What are Subsea Arctic Pipelines?

- Most common definition of "Arctic" is area north of the Arctic Circle (66º 33' North Latitude)
- A more functional definition includes marine pipelines with Arctic loading and operating conditions:
  - Sea ice
  - Permafrost
  - Remote locations
  - Sensitive physical and social environments
- This definition includes the Arctic Ocean and areas with seasonal sea ice such as:
  - Barents Sea
  - Offshore Greenland / Newfoundland
  - Sakhalin Island
  - Northern Caspian Sea

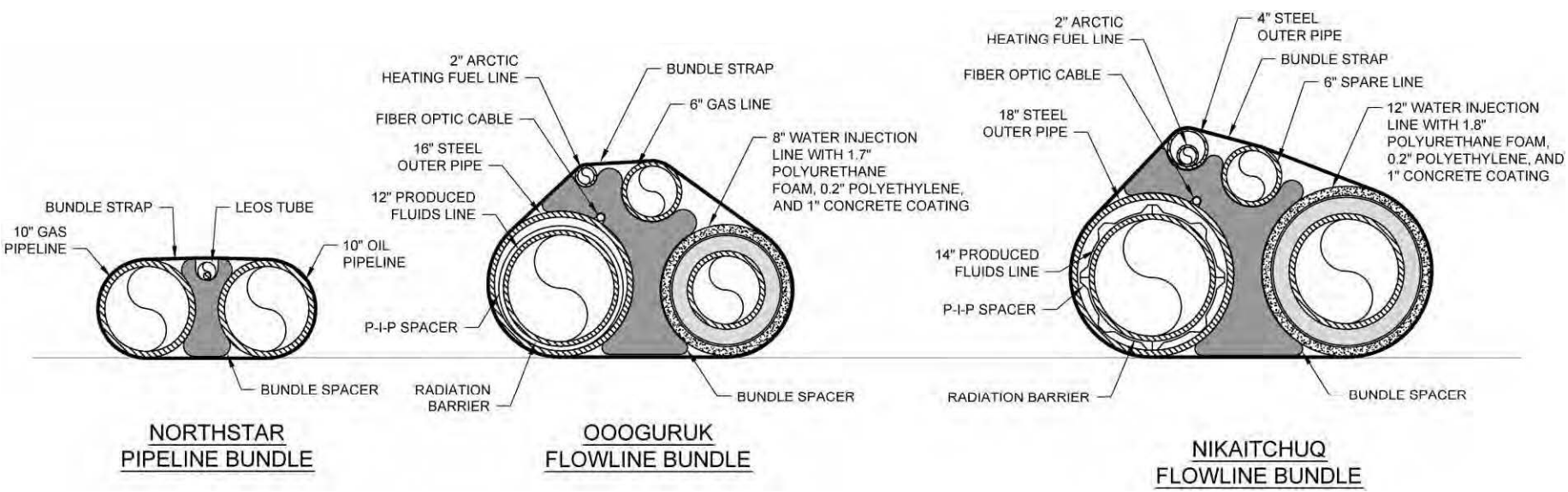
Offshore Arctic Field Developments



http://www.offshore-mag.com/index/maps-posters.html

Beaufort Sea Pipelines

- Beaufort Sea Subsea Pipelines Currently in Operation
  - BPXA Northstar installed in the winter of 2000
  - Pioneer Oooguruk installed in the winter of 2007
  - Eni Nikaitchuq installed in winter of 2009
- Other Developments being evaluated

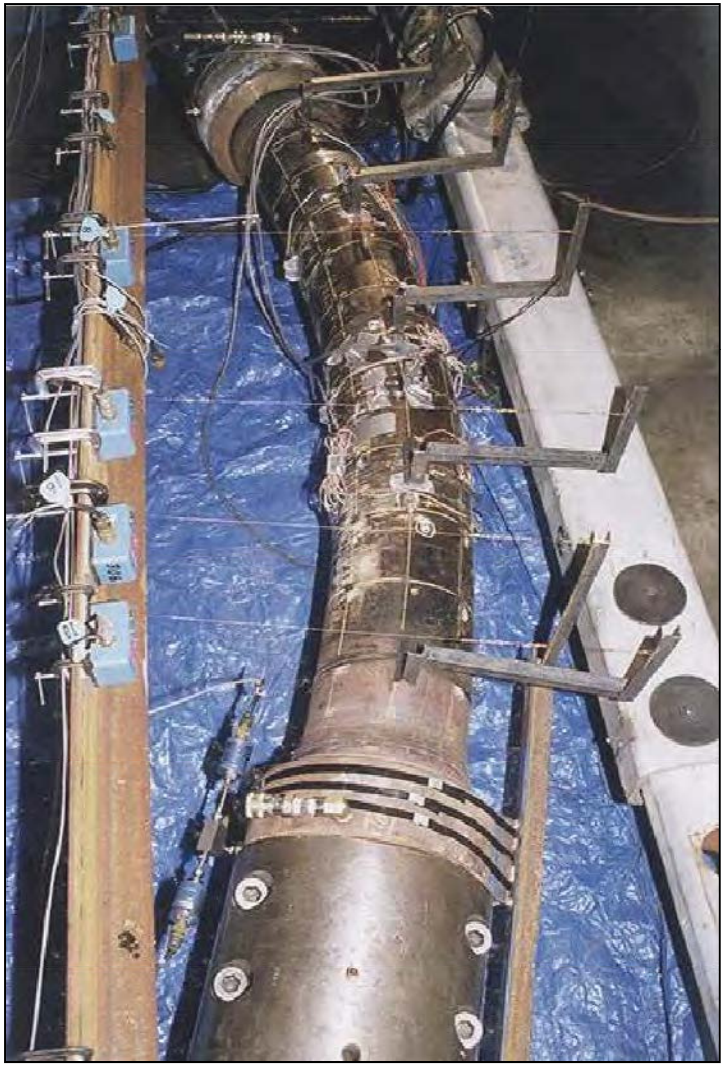


Ref.: Lanan, et al., OTC 2001; OTC 2008; ATC 2011

Pipeline Design

Design Codes & Limit State Design

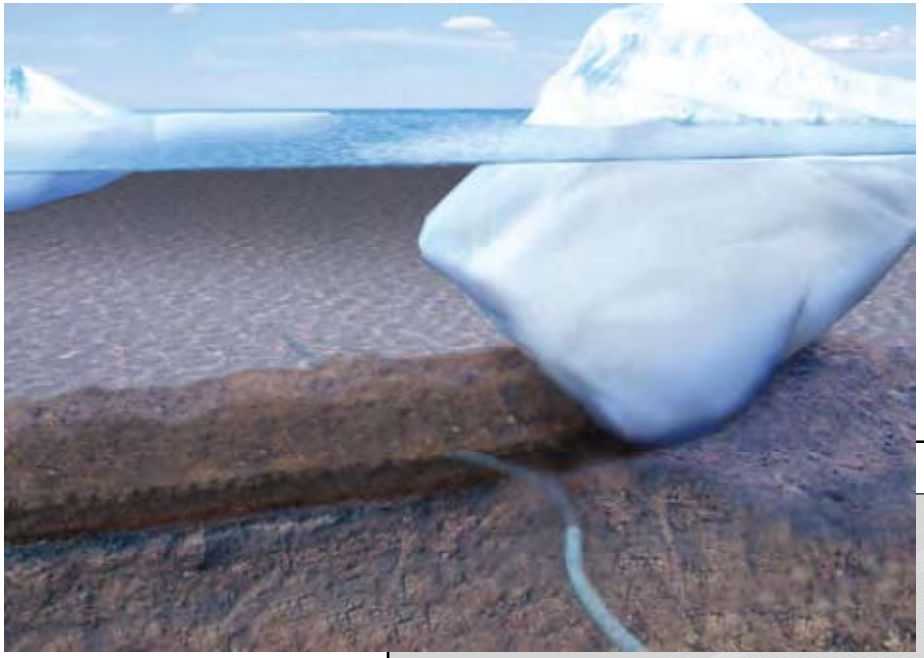
- API RP1111, Design, Construction, Operation and Maintenance of Offshore Hydrocarbon Pipelines (Limit State Design)
- ASME/ANSI B31.4, Flowline Transportation Systems for Liquid Hydrocarbons and Other Liquids
- ASME/ANSI B31.8, Gas Transmission and Distribution Piping Systems
- DNV OS-F101, Submarine Pipeline Systems
- US DOI and US DOT regulations
- ISO 19906, Offshore Arctic Structures
- Other conventional pipeline design codes, standards and regulations
- Limit State Design
  - Ultimate Limit States
  - Serviceability Limit States
  - Bending strain limits



Primary Ice Loading Conditions

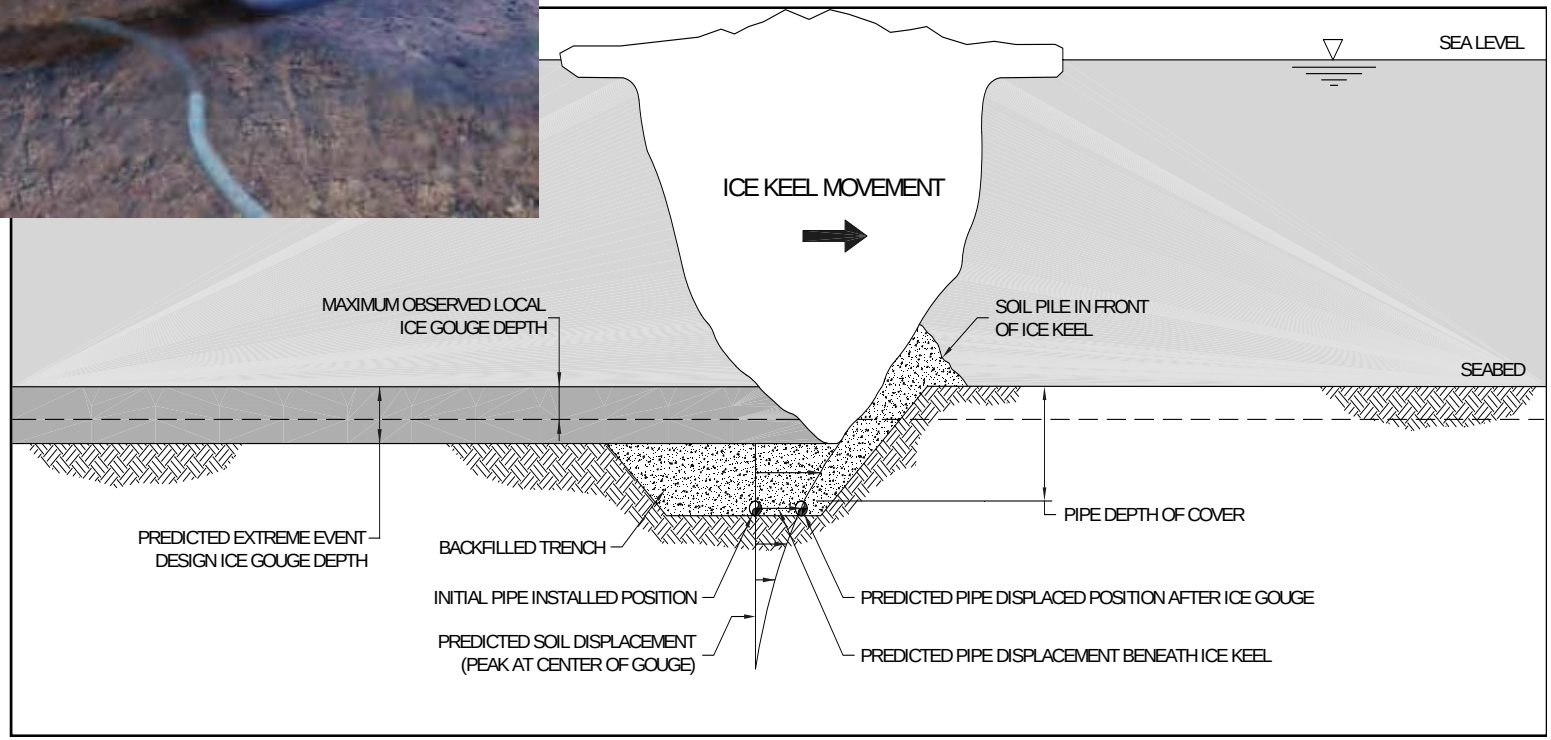
- Ice gouge loading
- Sub-gouge seabed soil deformations
- Ice keel-soil-pipe interaction
- Native seabed versus trench backfill soil effects
- Trench configuration effects
- Limiting gouge depths
- Iceberg loading
- Ice wallowing
- Ice-pipe contact

Ice Scour/Gouging



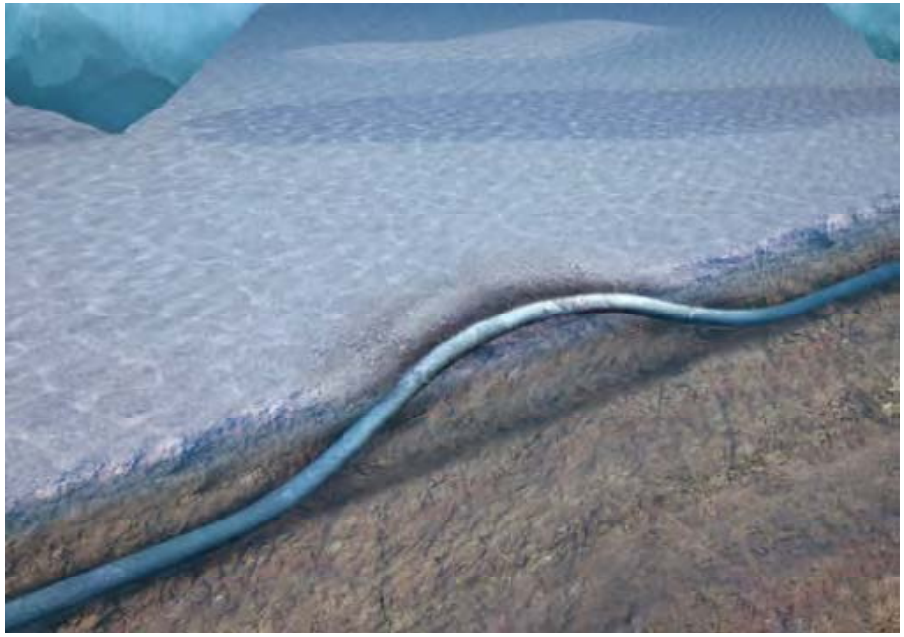
Ice Gouge Characteristics

- Gouge depth, width, orientation, frequency
- Ice gouge depth distribution statistics
- Gouge depth versus water depth trends



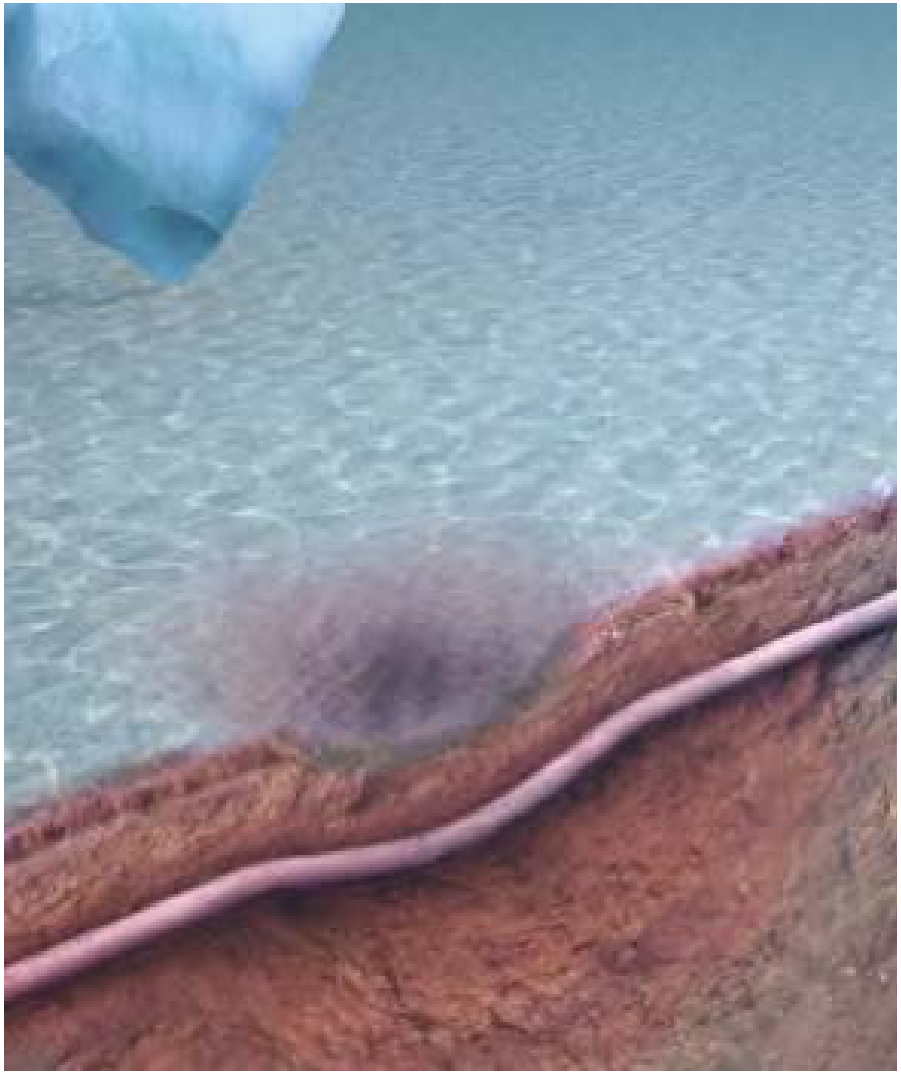
Upheaval Buckling

- Trenched and backfilled pipelines for ice keel protection
- Potentially low pipeline installation temperatures
- Warm pipelines for heat conservation
- Pipeline vertical stability under increased operational temperature and pressure
- Consequential ice loading after buckling
- Pipe prop height design criteria
- As-built assessment of pipe vertical profile
- Monitor for temperature anomalies to detect potential pipe upward movement



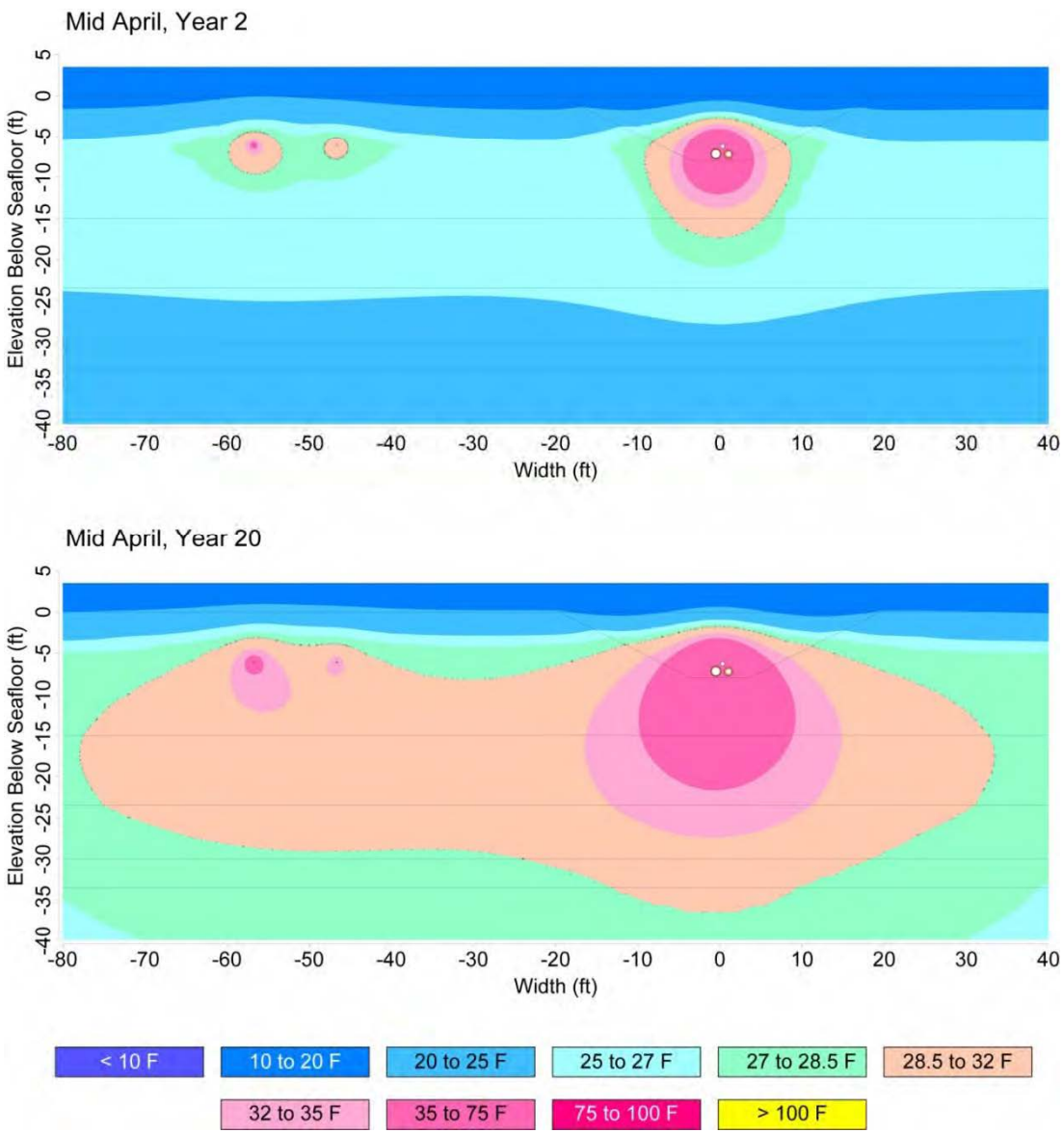
Permafrost Thaw Settlement

- Seabed Permafrost
  - Permafrost definition (soil below 0° C for 2 or more years) adjusted for offshore pipeline design
  - Thaw consolidation of ice rich, thaw sensitive permafrost
  - Primarily a concern in shallow water/shore approach
  - Thaw bulb growth
  - Differential thaw settlement
  - Shallow gas and gas hydrates



Flowline Bundle Thaw Bulb Growth

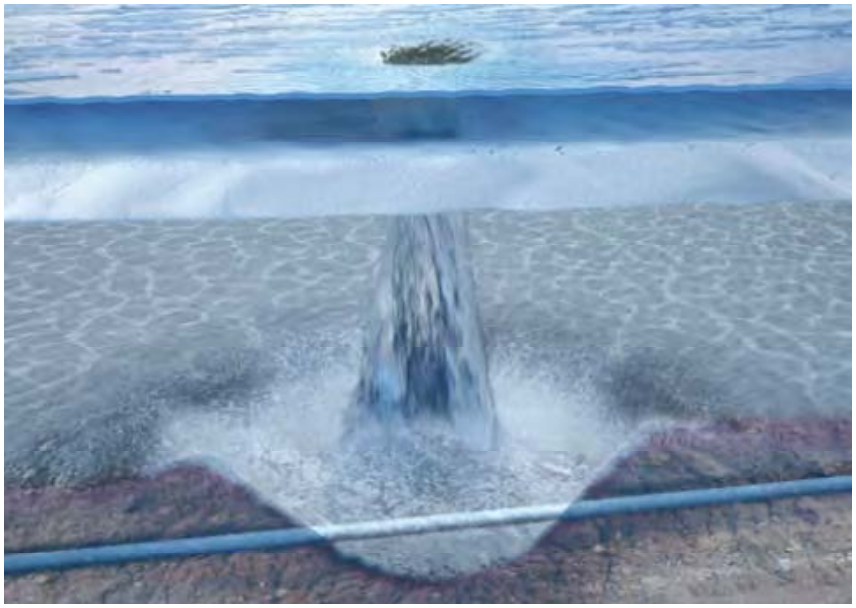
- Thaw sensitive permafrost vs. thaw stable permafrost
- Progressive thaw bulb growth
  - Computer model predictions of thaw bulb growth
  - Monitor soil temperatures
  - Monitor thaw settlement
  - Monitor pipeline movements and bending strains
- Thaw settlement limiting measures
  - Thermal insulation
  - Thaw-stable bedding material
  - Thermal siphons

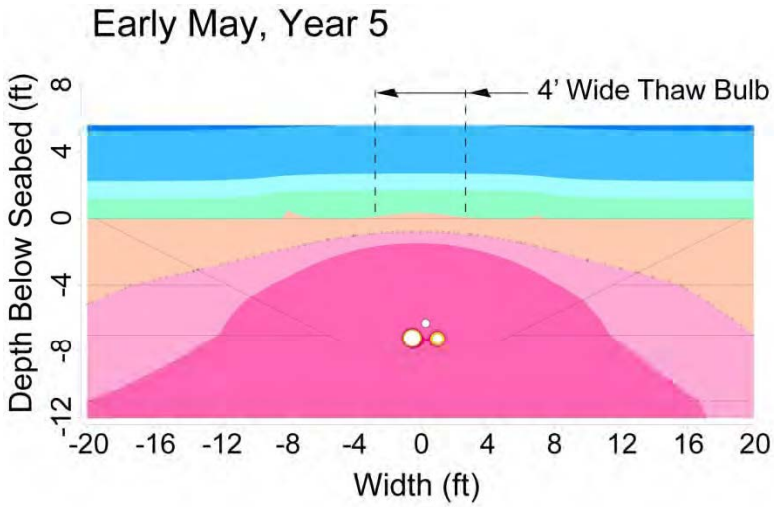


Ref. Northern Engineering & Scientific

Strudel Scour

- Springtime river overflood of sea ice causing seabed erosion
  - River overflood onto natural sea ice sheet
  - Generally near shore/shallow water
  - Pipeline spanning and loads
  - Strudel induced upheaval buckling
  - Ice thinning above warm pipelines
  - Electrical power cable and umbilical heat input



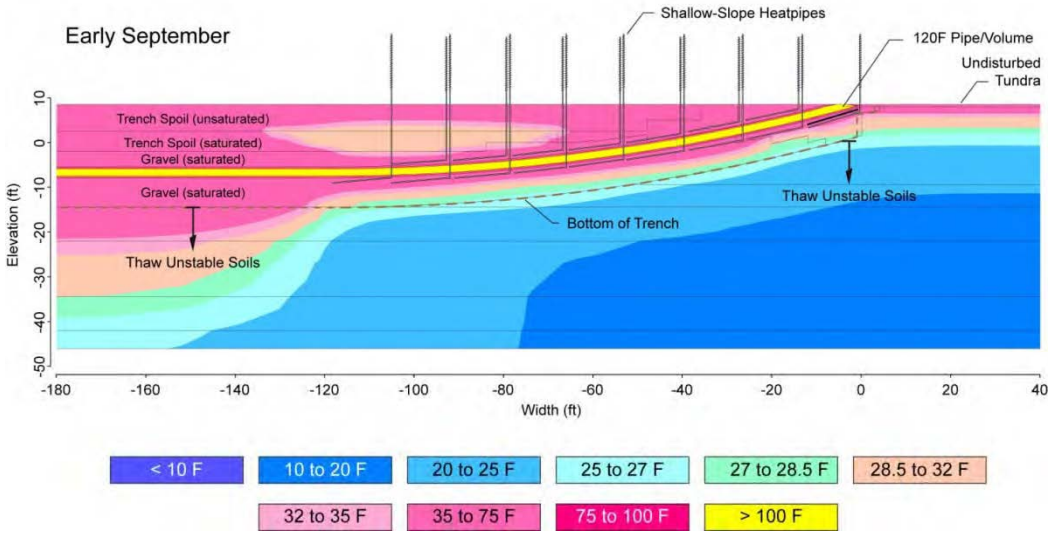


Pipeline Design

- Pipe-in-Pipe
  - Premium thermal insulation
  - Leak detection
  - Secondary containment*
  - Construction challenges
  - Consideration of appropriate failure modes
- Bundling
  - Open bundles
  - Closed bundles
    - Construction challenges
- Thick-Walled Pipe
  - Low D/t to increase bending strain capacity

Tie-ins & Shore Approaches

- Shoreline Ice Ride-Up & Erosion
  - Coastline and islands subject to ice movement during freeze-up and break-up
  - Sheet ice rides up beach until the sliding resistance overcomes the driving force
  - Shoreline pile-up also created by offshore bending failure of ice sheet and rafting/stacking of failed ice blocks
  - Ride-up peak may be located at the waterline or onshore
  - Onshore facilities must have setback distance (ride up and coastal erosion)
- Permafrost
  - Ice Lenses
  - Geothermal Design



Construction

Summer vs. Winter

- Summer
  - Trenching (pre-trenching or post-trenching)
  - Environmental and permitting constraints
  - Short construction season
  - Logistical support (remote)
  - Pre-trench with dredge (cutter suction dredge, trailing suction hopper dredge, mechanical excavation dredge)
  - Pre-dredged trench requirements
  - Trench backfilling with dredge spoils
  - US “Jones Act” dredge limitations
  - Post-trenching equipment (jet sled, plow, mechanical trencher)
  - Post-excavated trench backfilling
- Winter (near shore)
  - Contracting strategy
  - Procurement and logistics
  - Arctic materials specifications
  - Inflexible project schedule deadlines
  - Mobilization/demobilization requirements
  - Camp and utilities requirements
  - Winter tundra travel season for site access
  - Offshore ice road construction (grounded or floating)
  - Bundled flowlines
  - High ΔT for winter construction
  - Expansion of trench excavation spoils
  - Backfill soil thaw consolidation
  - Water depth limitation for conventional trenching equipment

Winter Construction from the Ice

- General Subsea Pipeline Construction Steps:
  - Ice thickening
  - Ice cutting and slotting
  - Trench excavation
  - Pipeline make up
  - Pipeline bundling and staging
  - Bundle installation
  - Trench backfilling

Ice Thickening

- Methods
  - Surface Flooding
  - Ice Chips

- Challenges
  - Sufficient thickness
  - Grounded vs. floating ice
  - Temperature constraints

Ice Slotting and Trenching

- Trenching Issues to consider:
  - Trench side slopes and undermined ice
  - Dry trench in shallow water
  - Trench bottom roughness
  - Over excavation to account for slumping
  - Accurate survey
  - Unexpected permafrost
  - Slumping under the pipelay spread
  - Long reach backhoes

Makeup and Bundling

- Insulated line installation temperatures
- Welding challenges
- Sequencing of operations
- Bundle assembly

Pipeline Installation

- Flowline Bundle Installation Issues:
  - Flowline bundle weight
    - Loads on floating ice
    - Horizontal offset distance may require more supports or beam support
  - Trench side slopes and undermined ice
  - Ice movement
  - Bundle roll (use flat bottom roller supports)
  - Route curves
  - Long route, single season

Pipeline Backfilling

- Backfilling Issues to consider:
  - Spoil expansion and placement
  - Storage location
  - Gravel backfill or bags over props
  - Strudel scours
  - Frozen backfill

Summer Trenching

- Summer Trenching and Backfilling
  - Pre-trench with dredge (cutter suction dredge, trailing suction hopper dredge, mechanical excavation dredge)
  - Pre-dredged trench requirements
  - Trench backfilling with dredge spoils
  - US “Jones Act” dredge limitations
  - Post-trenching equipment (jet sled, plow, mechanical trencher)
  - Post-excavated trench backfilling

Summer Installation

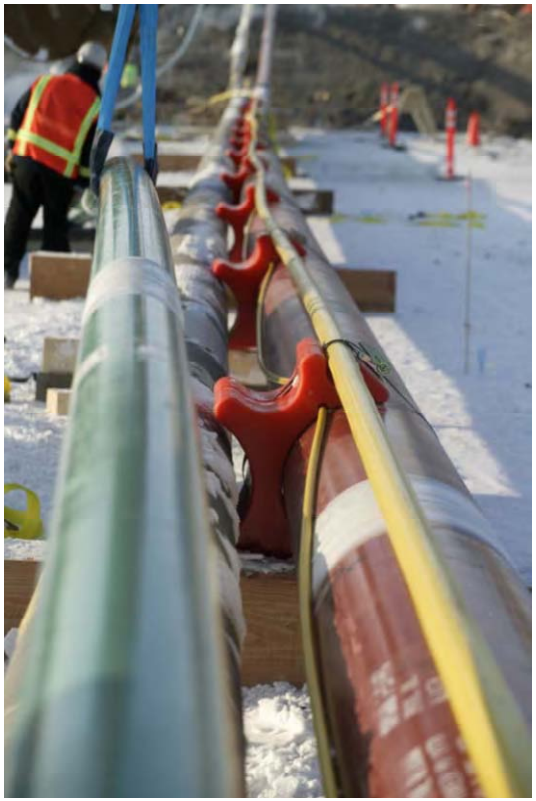
- Summer Installation Methods
  - S-lay (conventional, locally assembled laybarge, alternative configurations)
  - Reeling (large, small diameter lines)
  - J-lay pipelay vessel (ice class)
  - Towing / pulling methods (surface tow, bottom pull, etc.)
  - Horizontal Directional Drilling (HDD)

MRTS "Defender" Pipeline Laybarge

Operations, Maintenance and Repair

Leak Detection

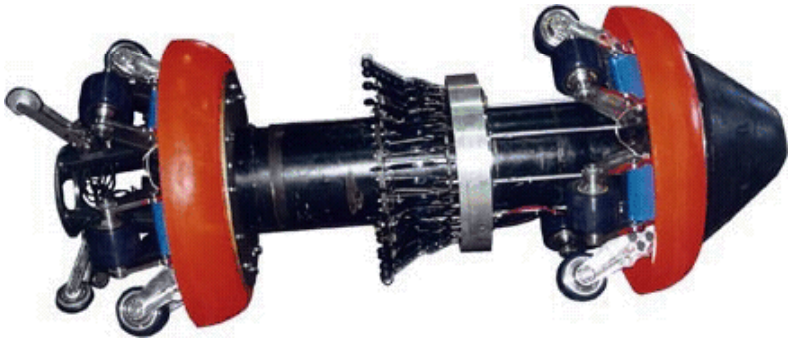
- Preferred Subsea Leak Detection System Features
  - Continuous operation
  - Rapid detection of sub-1% leaks
  - Independent of flow conditions
  - Cost-effective, constructible & installable
  - Minimal false alarms
  - Long (>15 miles) pipeline coverage without intermediate power requirements
  - Winter sea ice season operations
  - Proven performance in Arctic conditions



- Pipeline Leak Detection Systems
  - Conventional flow-based pipeline monitoring systems (mass balance, transient pressure wave, acoustic detection)
  - Airborne and marine surveillance
  - External monitoring systems (FO cables, LEOS, point source monitors)
  - Remote sensing systems (airborne infra-red, radar, satellite, visual, smell)
  - Other systems based on pipeline configuration

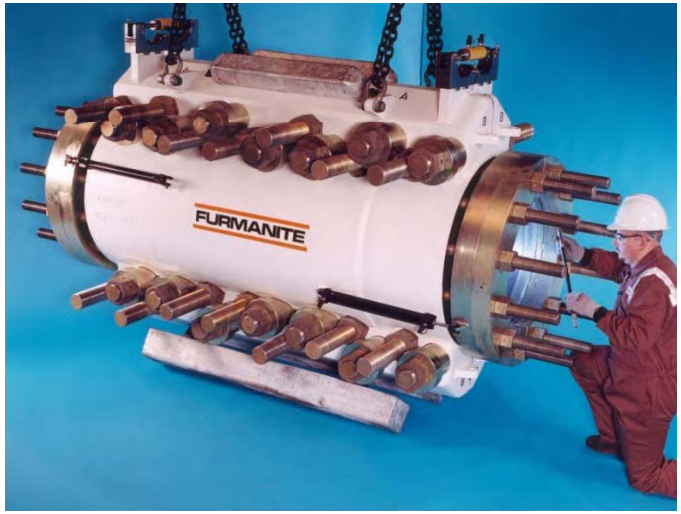
Surveys/Monitoring/Pigging

- In Line Inspection
  - Caliper pigging
  - Wall thickness measurement pigging
  - 3-D geometry survey pigging
- Site Inspections
  - Structure tie-in and shore approach inspections
  - Remote valve stations
  - Cathodic protection (CP) potential survey
- Seabed Surveys
  - Coastal erosion
  - Seabed erosion
  - Ice gouges & strudel scours
  - Trench backfill/replenishment



Repair Options

- Summer access
- Winter access
- Freeze-up and break-up periods
- Damage assessment
- Minor repair
- Major repair



Summary and Conclusions

- Limited pipeline industry experience with offshore arctic conditions
- Many unique design, construction and operational aspects of offshore arctic pipeline engineering
- All aspects of an offshore arctic pipeline must be successfully engineered in order to provide a fully functional pipeline system
- Safe design, construction and operation of offshore arctic pipelines have been demonstrated
- Additional research needed on specific engineering subjects
- Arctic pipeline ice loading conditions
- Gouge formation & limiting depth for 1st year sea ice
- Ice-soil-pipe interactions
- Pipeline bending strain limitations
- Strudel scour effects on pipelines
- Subsea field development technology
- Leak detection and real-time pipeline monitoring technologies
- Deep trenching and backfilling methods
- Effects of climate change

INTECSEA

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APPENDIX BB

INSPECTION OF DIFFICULT-TO-INSPECT PIPELINES: KINDER MORGAN CANADA'S EXPERIENCE

Inspection of Difficult-to-Inspect Pipelines: Kinder Morgan Canada's Experience

Nelson Tonui,
Technical Services Department,
Kinder Morgan Canada

Overview

- Kinder Morgan Canada's Unpiggable Pipelines Inspection Program
- Inspection tools and technologies used
  - Applications
  - Results and Challenges
  - Lessons Learned
- Conclusion

Definition

- Piggable Pipelines:
  - Lines that can be internally inspected using conventional unidirectional ILI tools. Process of Pigging
- Unpiggable Pipelines: = Difficult-to-Inspect
  - Lines that cannot be pigged EASILY
  - Can be pigged with a little more effort

Background

- Unpiggable pipe segments in KMC system are found in the facility locations- tank farms, terminals and pump stations
- KMC developed a Facility Piping Inspection Program
- The main drivers of this program:
  - Need to assure integrity
  - Regulatory compliance - FIMP
- Main threat – Metal Loss

Facility Piping Inspection Program

Key Statistics	
Program Initiated	2003
System wide Implementation	2010
Inspected to date	>30%
Tools & Technologies used	>5 types
Success rate (for ILI tools)	>50%
Investment (from 2010) $$$	>3,$$$,$$$

Characteristics of Facility Piping

- Limited access on one or both ends of the pipes
- Some are dual diameter
- Multiple bends with unknown radii
- Presence of un-barred tees, off-takes and branches
- No permanent launch and receive traps
- Low flow and low pressure conditions
- Some lines experience intermittent services

Line Selection

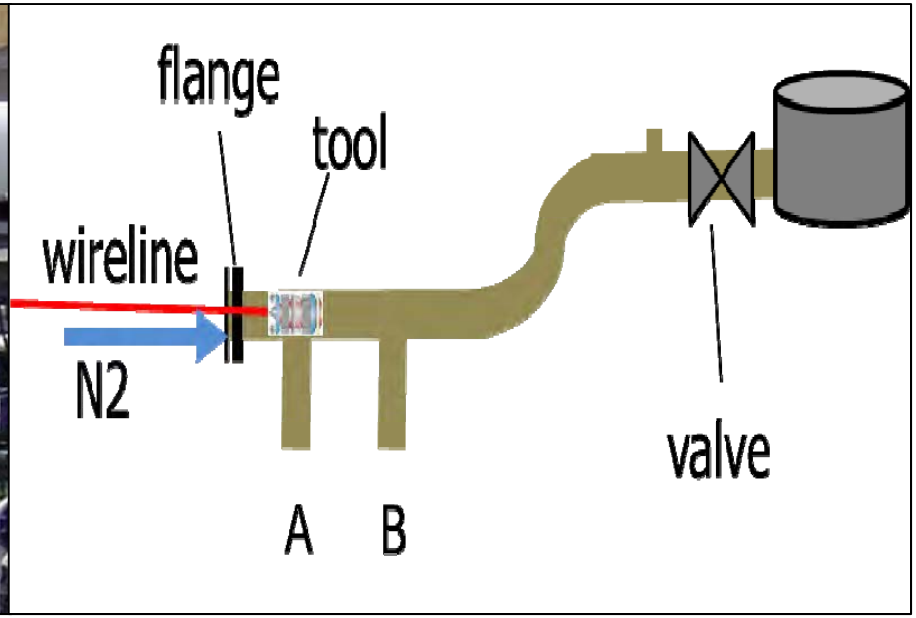
- Previously, a qualitative risk analysis approach was used to rank lines in terms of susceptibility to corrosion
  - Age, Usage Frequency, Product and Length
- Currently, we use a semi-quantitative risk analysis model based on the API 353 Std to rank lines according to risk
  - Age, WT, Length, Product, Service, CP
- Other considerations include budget, locations, service history (similar services)

Inspection Technologies and Tools

- More than five types of tools and technologies have be used for inspection
- Tool consideration:
  - Accessibility of the pipe- one or two points
  - Cost and budgetary allocation
  - Tool characteristics (UT vs. MFL) and
  - Availability in the required sizes

1. Tethered ILI Tool

- Tethered ILI needs one point of entry
- Tethered ILI was attempted on three NPS 20 lines in one of KMC Terminals in 2010
- No pipe modification was required = cheaper



Tethered ILI - Line #1

- A gauge tool was run before the ILI tool
- It became increasingly difficult to move the tool a few feet after launch
- The run was eventually stopped 200ft from the launch when the pressure approached 30 psig
- The tool moved backwards when pressure was bled off
- There was little or no tension on the wireline for the first part of the retraction.

Tethered ILI - Line #1

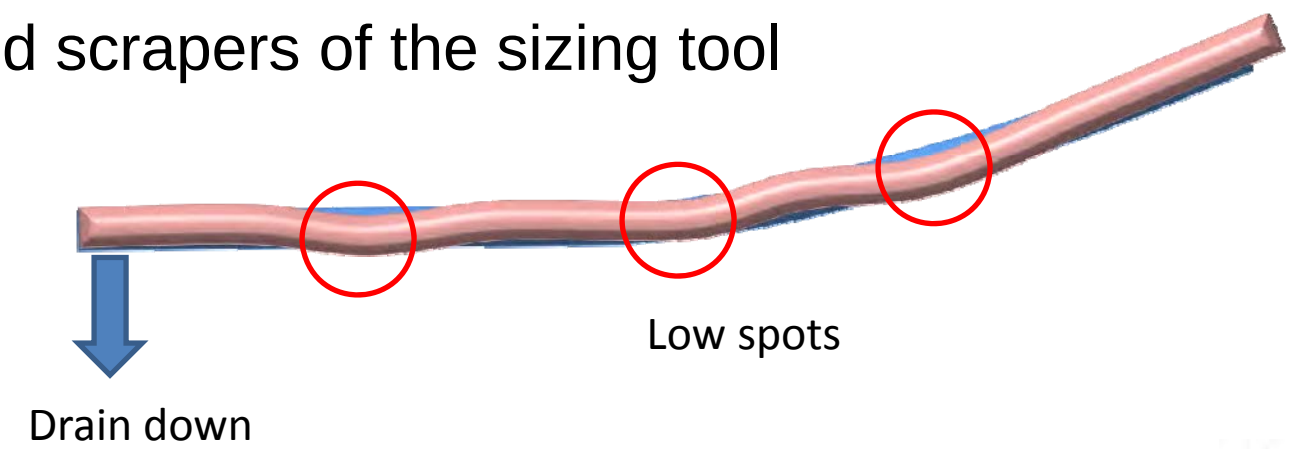
- The wireline tangled and broke
- Pushed from higher position vent and used mechanical puller to retrieve

Damage to the gauge tool blades occurred in both directions

No further inspection was done

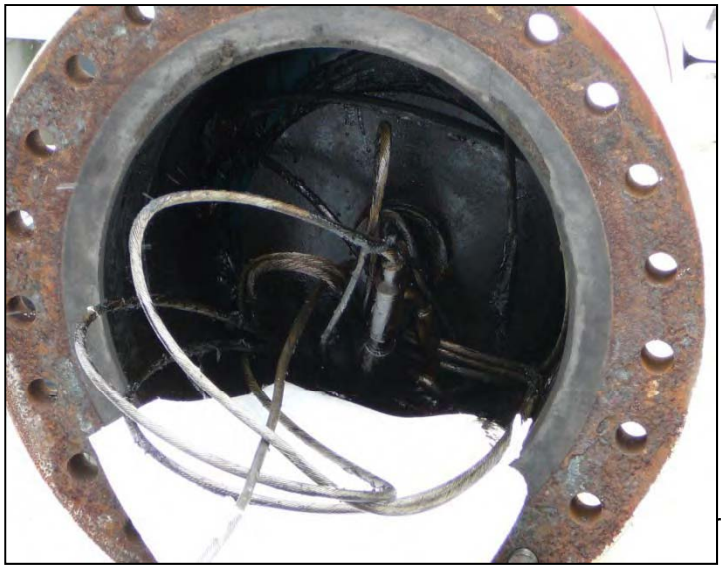
Cause of Failure

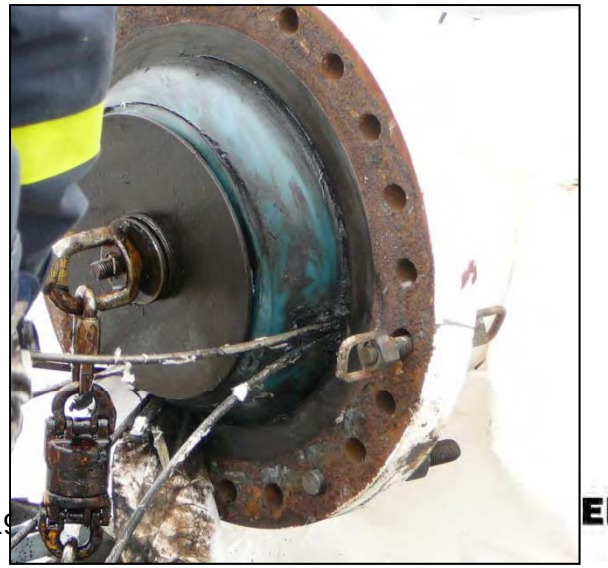
- Incomplete drain down – Led to accumulation of liquid as the gauge tool ahead of the line
- The pressure from this column of liquid pushed the tool backwards when N2 pressure was bled off
- Resulting in the tangling of the wireline around the disks and scrapers of the sizing tool



Tethered ILI - Line #2

- Gauge tool was stopped when the nitrogen pressure required to push it approached 15 psig
- Again the gauge tool moved backwards slightly when the pressure was released
- Wireline was tangled but did not break



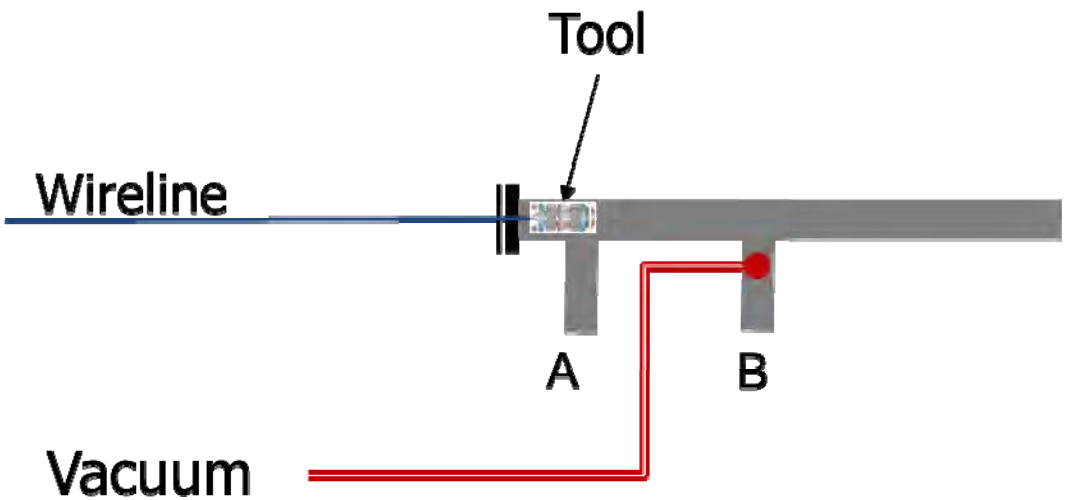


Tethered ILI - Line #2

- Damage to gauge tool blades was only in the backward direction
- Occurred when the tool was pulled back against a coiled wireline.
- Inspection of the line with the tethered ILI tool proceeded for 150 ft
- Partial success - 10% inspected

Tethered ILI - Line #3

- A small vacuum was applied to the low point drain to draw vapors away from the work crew, as the gauge tool was loaded
- Vacuum was isolated and the vent at high point opened to atmosphere

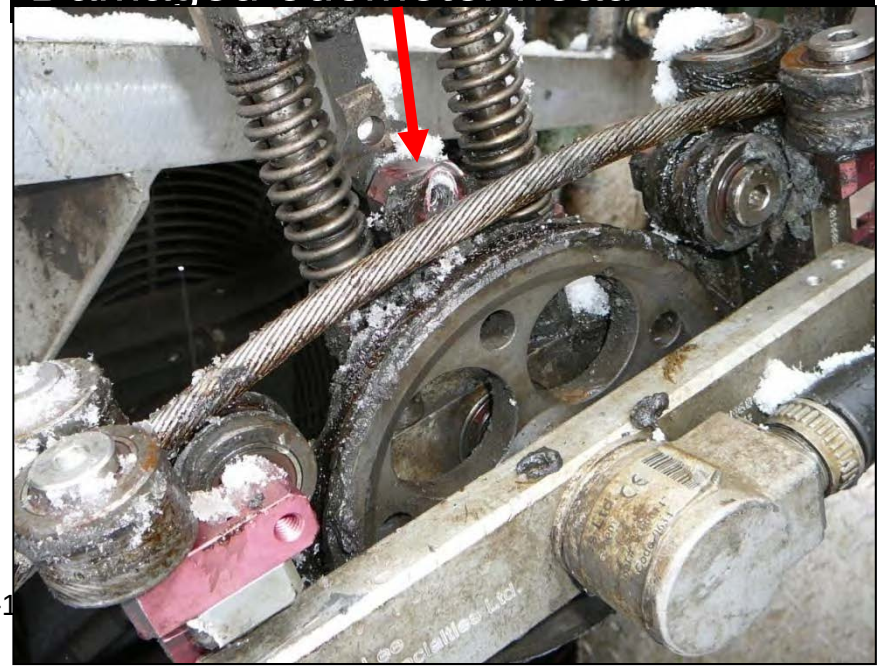


Tethered ILI - Line #3

- When the bar holding the scraper tool in place was removed the tool was sucked in with a lot of force
- The wireline severed and the odometer head was damaged

Broken wireline

Damaged odometer head



Cause of Failure

- Residual vacuum due to inadequate bleeding
- Because of the damage to the wireline equipment and no replacement parts on site, the inspection was called off
- No further inspections were attempted

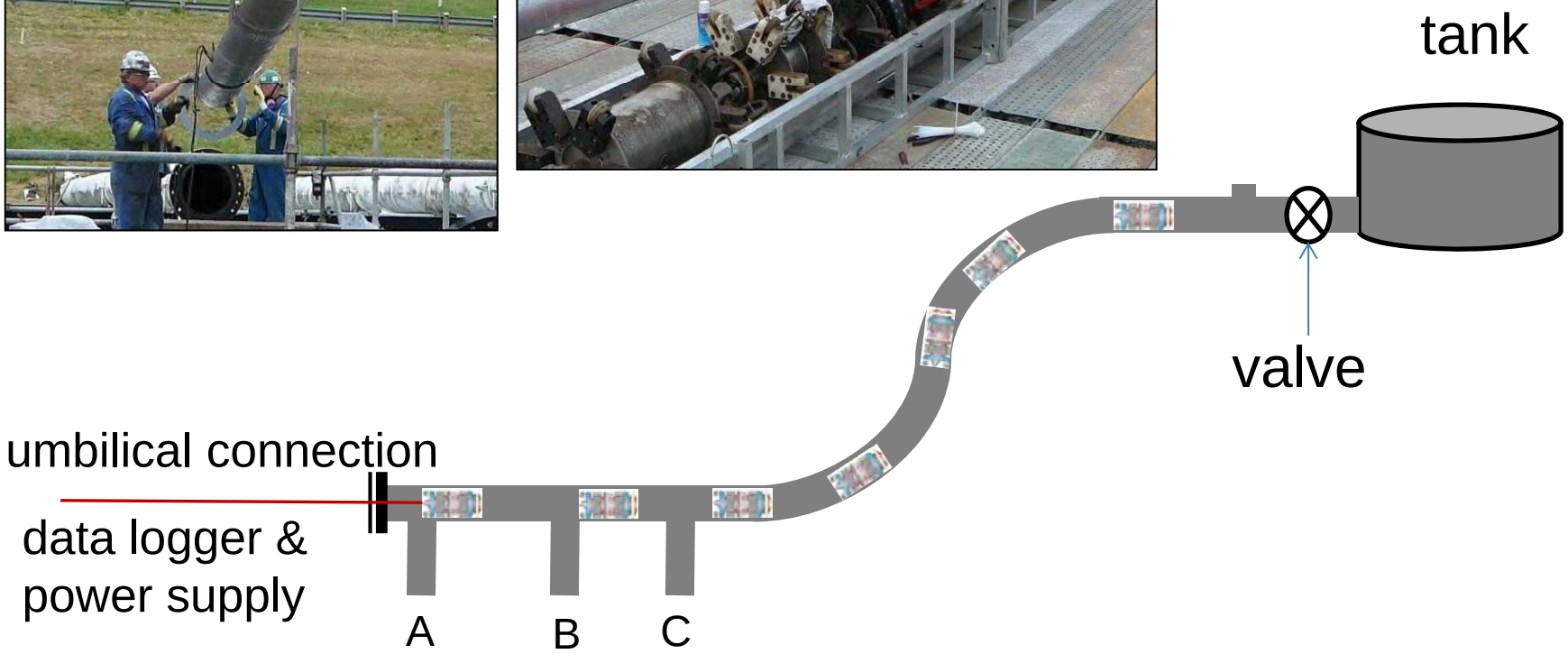
Lessons Learned

- Verify the line profile before pushing a tethered ILI tool. Helps ensure that the line is completely drained
- If possible, predetermine the maximum amount of pressure you need to keep the tool moving.
- Ensure that there is no residual vacuum in the line - provide adequate venting

2. Self Propelled Tool

- Attempted on the two lines previously attempted with Tethered ILI
- An insertion sleeve was used to prevent the tool from getting stuck at the unbarred branch connections

Self Propelled Tool

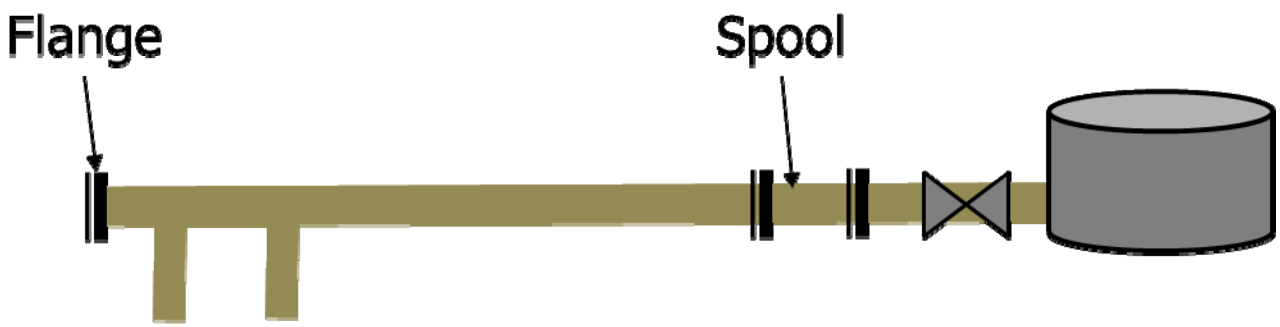


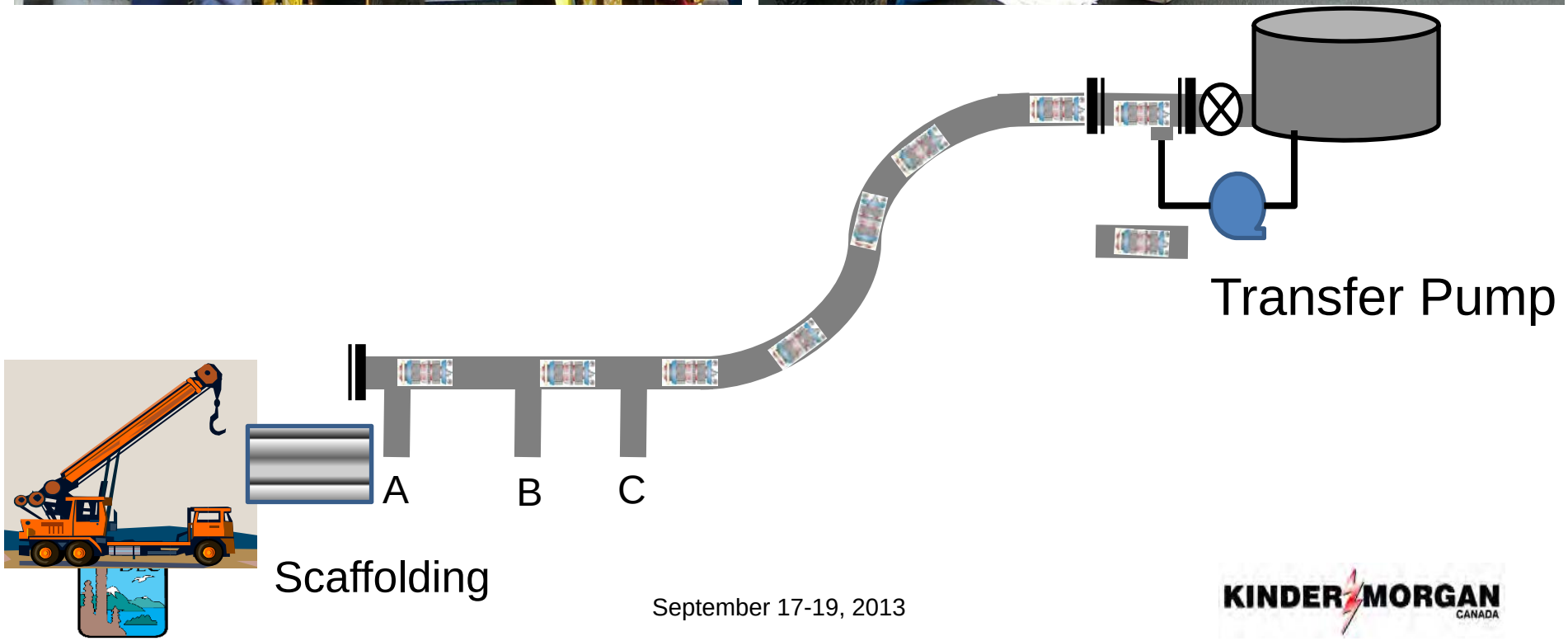
Self Propelled Tool -Results

- Run on two crude oil lines was successful
- Run on one iso-octane line failed
  - lack of lubricity dried out pump seals
  - scale build up damage the tool's onboard pumps
- The tool had to be repaired before using it- less robust
- Use of tool insertion technique significantly increased the chances of success

3. Free-Swimming ILI

- Free-swimming ILI requires two points of access. Tool is launched in one side and is received on the other.
- Free swimming tool was used to inspect two lines in 2011 and one line in 2012
- Access through a spool on the line and a blind flange





KINDER MORGAN CANADA

Results

- 2011 runs in two crude oil lines was a success
- 2012 run in one iso-octane line failed
  - The product was lighter, less viscous and had lower lubricity
  - It by-passed the tool in the tight bends

Results

- The tool got stuck three times and after days of attempts to free it, the line was cut to free the tool
- Root Cause Analysis: Combination of low flow and product physical properties

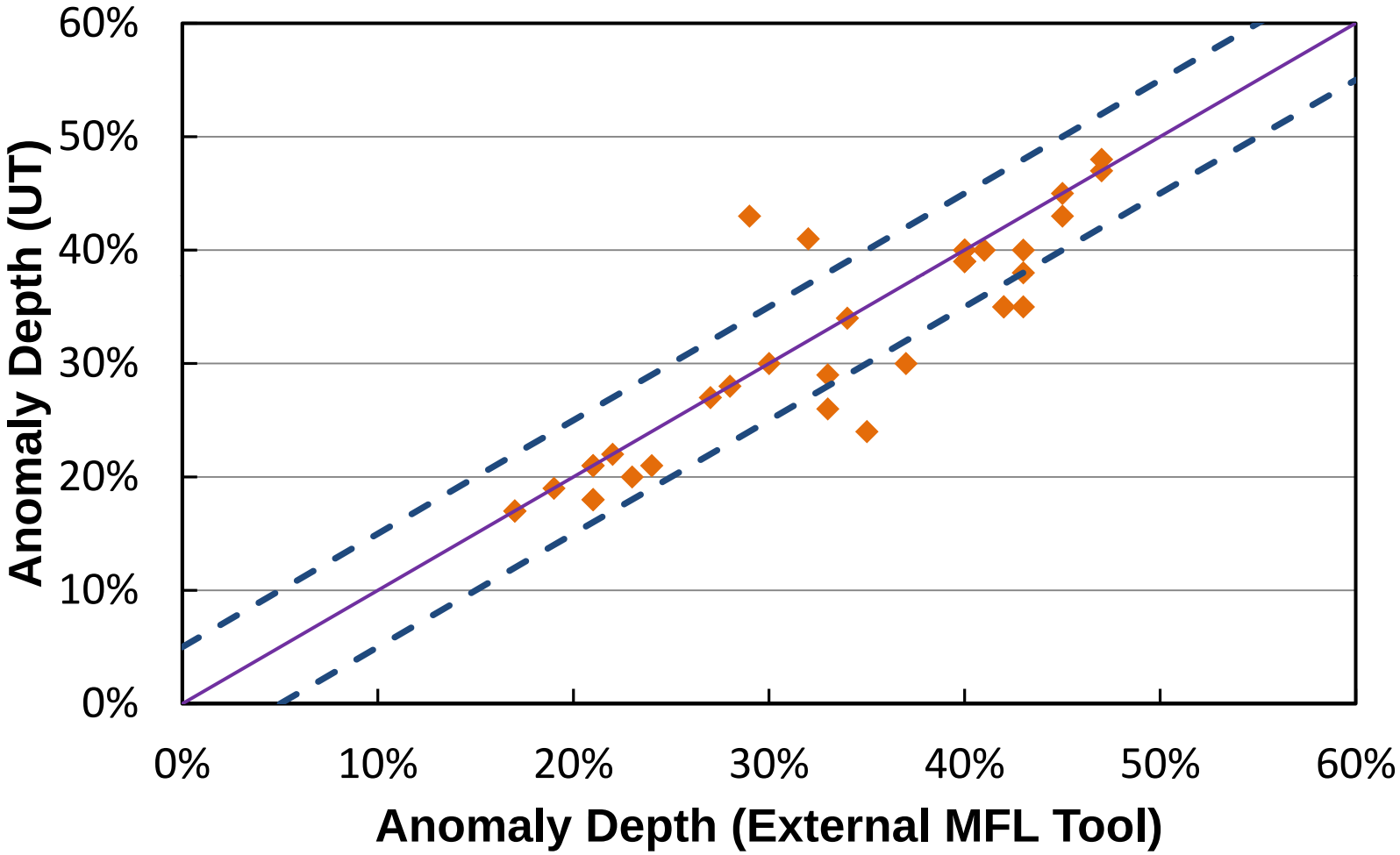
Lessons Learned

- Consider the physical properties of the product in the pipeline and how it will affect the tool run.
- This knowledge helps in estimating required pumping pressure, flow rates and tool speed
- Detailed tool tracking is essential

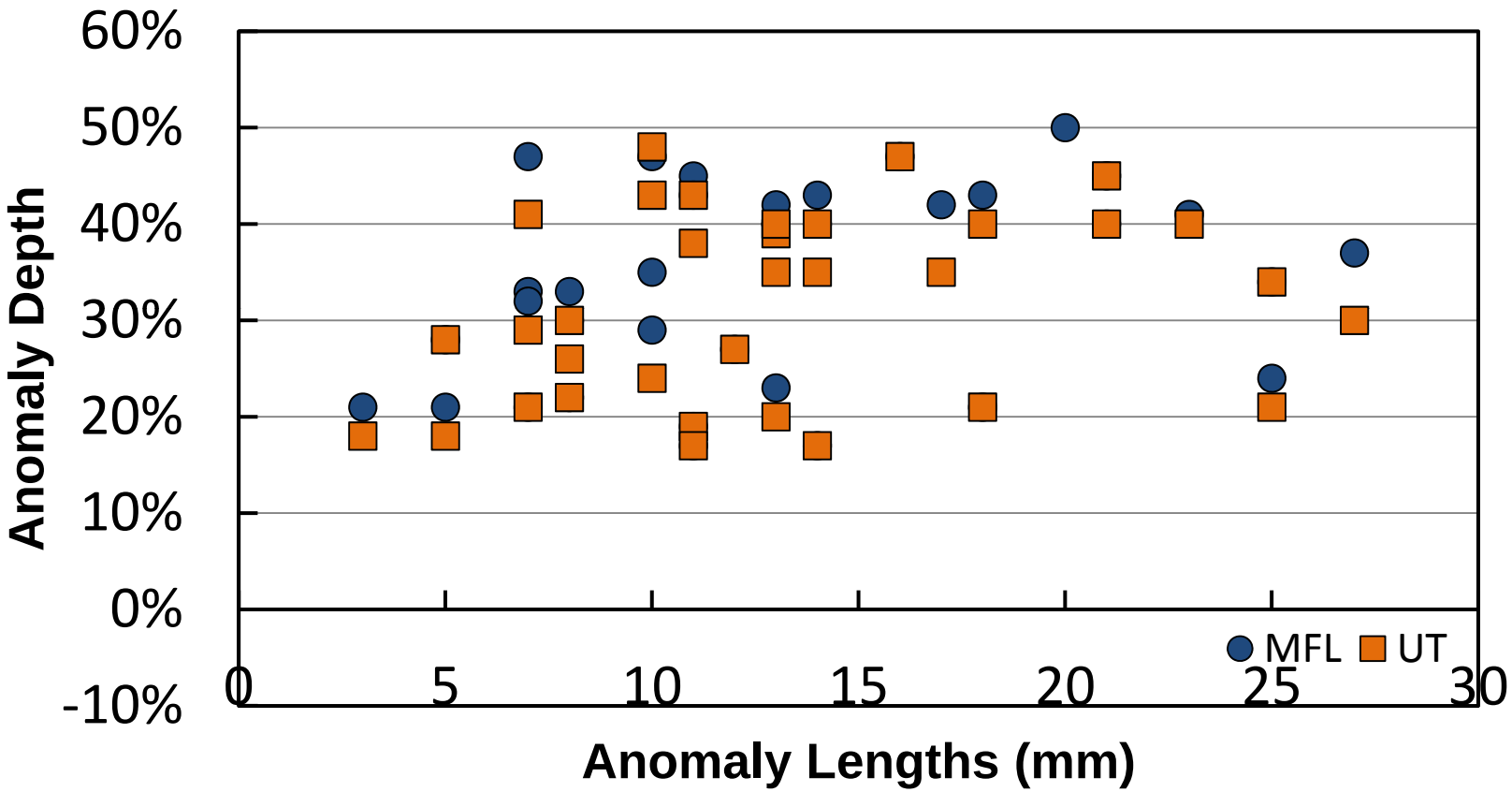
4. External MFL Technology

- This technology was been used to inspect above ground pipes, underground pipes at exposed locations and pipe cut outs
- Easy to run and relatively cheap

Results/Validation

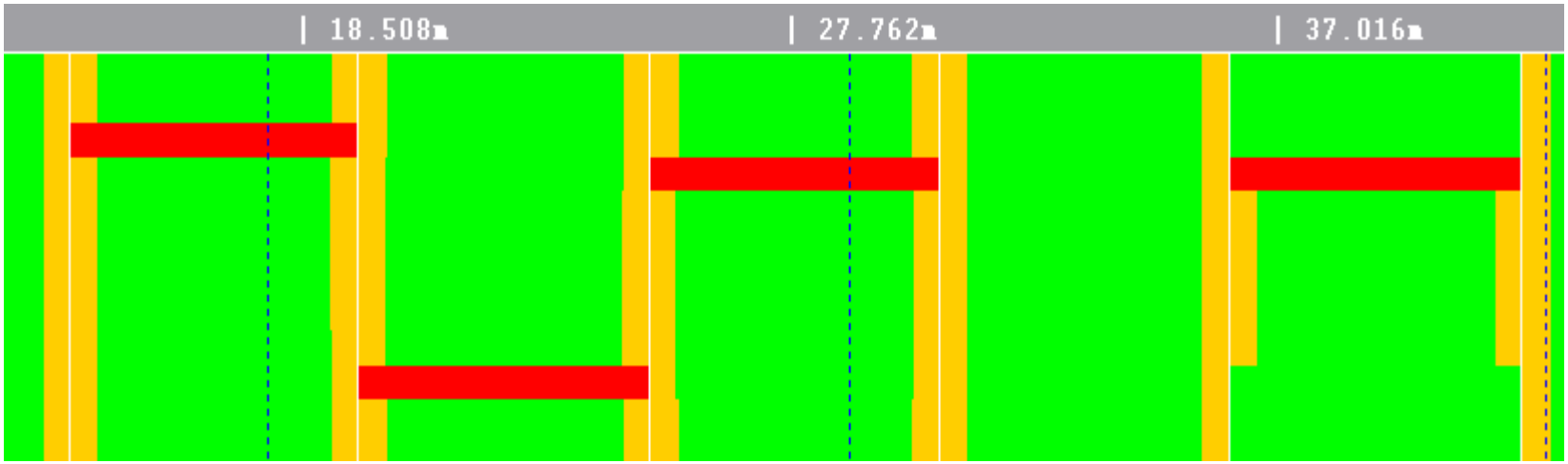


Anomaly Depth vs. Length



External MFL- Limitations

- Incomplete coverage- need to move the equipment around supports and obstacles



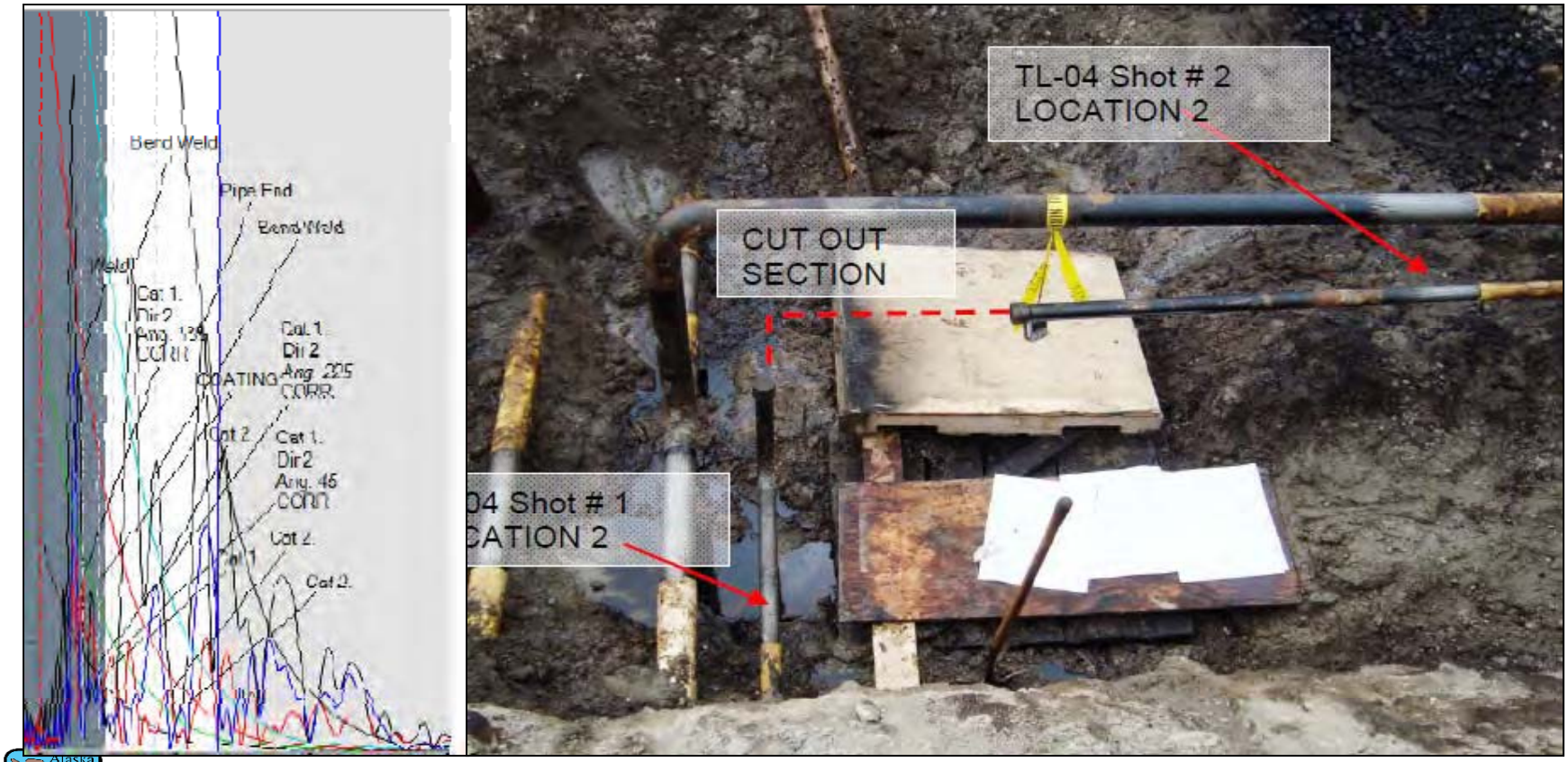
- Typically require removal of some types of coatings

5. Guided Wave Inspection

- This inspection has been used as a screening tool
- Inspection can be done while the line is in-service
- Used to inspect u/g facility piping in 2011
- The pipe was expose pipe a few locations

Results

- Accurately located through wall corrosion on a NPS 2 drain line



Guided Wave -Limitations

- Dependent on coating conditions- heavy coating like coal tar prevent sound wave from reaching very far
- Affected by the presence of bends, welds and branches
- Doesn’t differentiate between internal and external corrosion

Conclusion

- There is no single tool that is suitable for all unpiggable pipe segments- each one is unique in its own way
- Know your line. Know your line.
- Proper technology and tool selection is key to a successful inspection
- Be prepared to go an extra mile in order to be successful
- Tool runs in unpiggable pipe segments require extensive planning and hazard assessments by properly trained personnel

Thank You

Comments and Questions

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APPENDIX CC

DESIGN CHALLENGES OF ARCTIC PIPELINES – TECHNOLOGY GAPS AND ADVANCED ANALYSIS SOLUTIONS

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2013 Arctic / Cold Regions Oil Pipeline Conference

Design Challenges of Arctic Pipelines – Technology Gaps and Advanced Analysis Solutions

Basel Abdalla, PhD, PE, CEng

Anchorage, Alaska

17 – 19 September, 2013

Our Position in Wood Group

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Engineering

Wood Group PSN

Operations, Maintenance & Modifications

Gas Turbine Services

Repair & Overhaul of:
- Turbines
- Generators / Motors
- Pumps/Controls

Engineering: 7,000+ employees

Wood Group Kenny
- Subsea Systems
- Offshore Pipelines
- Onshore Pipelines
- Risers & Moorings
- Renewable Energy
- Integrity Management
- Advanced Engineering
- Software
- Technology Development

2,200 employees

Mustang Engineering
- Facilities Engineering
- Topsides Detail Design
- Deepwater Structures
- Gas Plant Design
- Project Management

Alliance Engineering
- Front End Engineering
- Project Management
- Process Facilities & Structures
- Lightweight Topsides

IMV
- SAGD Process
- Project Mgmt
- Process Facilities

Energeticos
- Oil & Gas, Petrochemical
- Engineering & PM

Wood Group
- 34,000 employees
- 50 countries
- $5.5bn revenue

Wood Group Kenny Organisation Chart

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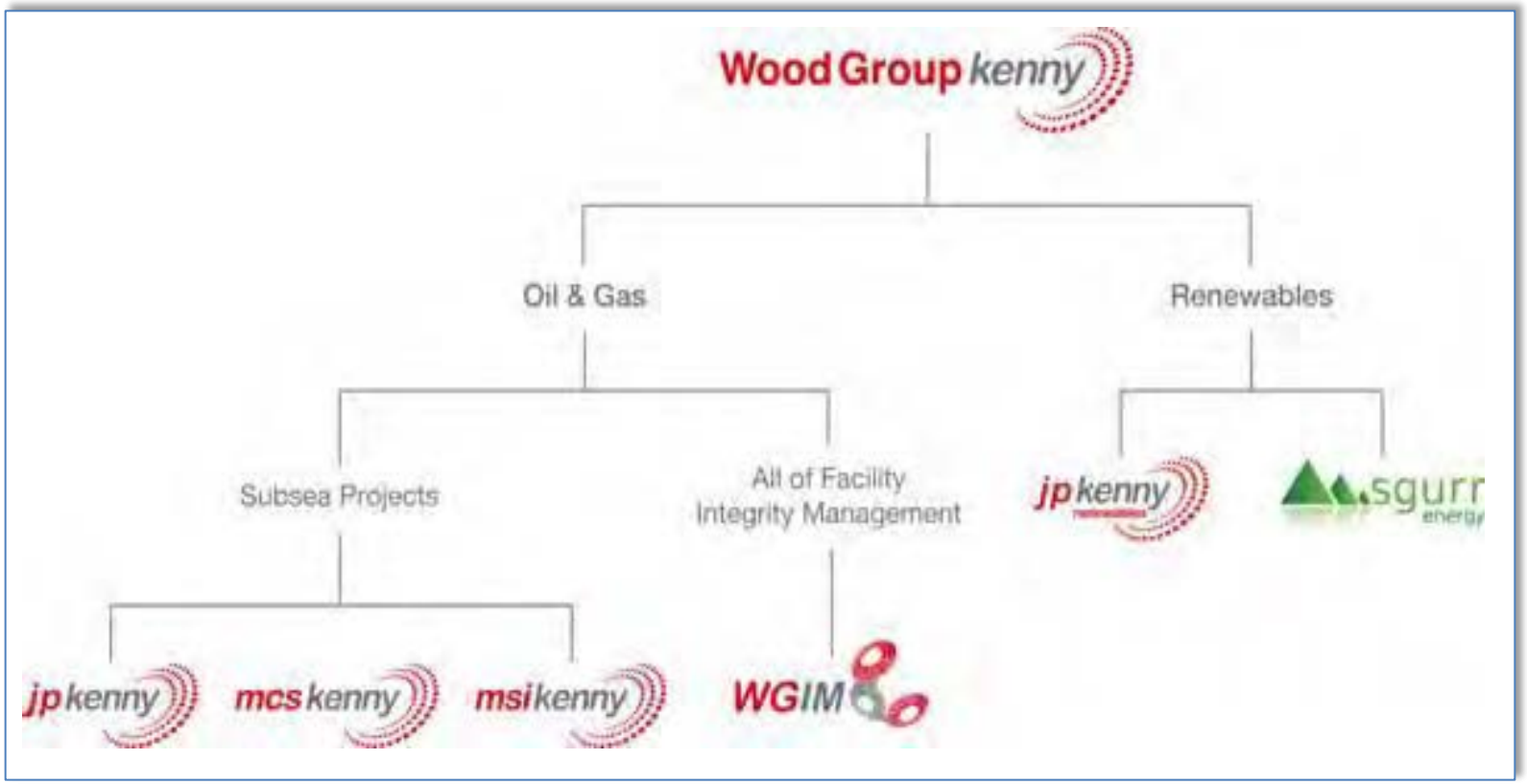

"Discipline Excellence with Integrated Capability"

Our People & Global Reach

Wood Group kenny

Wood Group Kenny
2,200 people
Oil & Gas: 14 offices worldwide

"The world's largest solution independent provider of engineering and management services for subsea systems, onshore and offshore pipelines and associated marine facilities."

Outline

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- Introduction
- Arctic Challenges
- Arctic Pipeline Design Challenges and FEA Solutions
  - Ice Gouging
  - Permafrost Thawing
  - Frost Heave
- Closing Remarks

Introduction: Arctic Resource Potential

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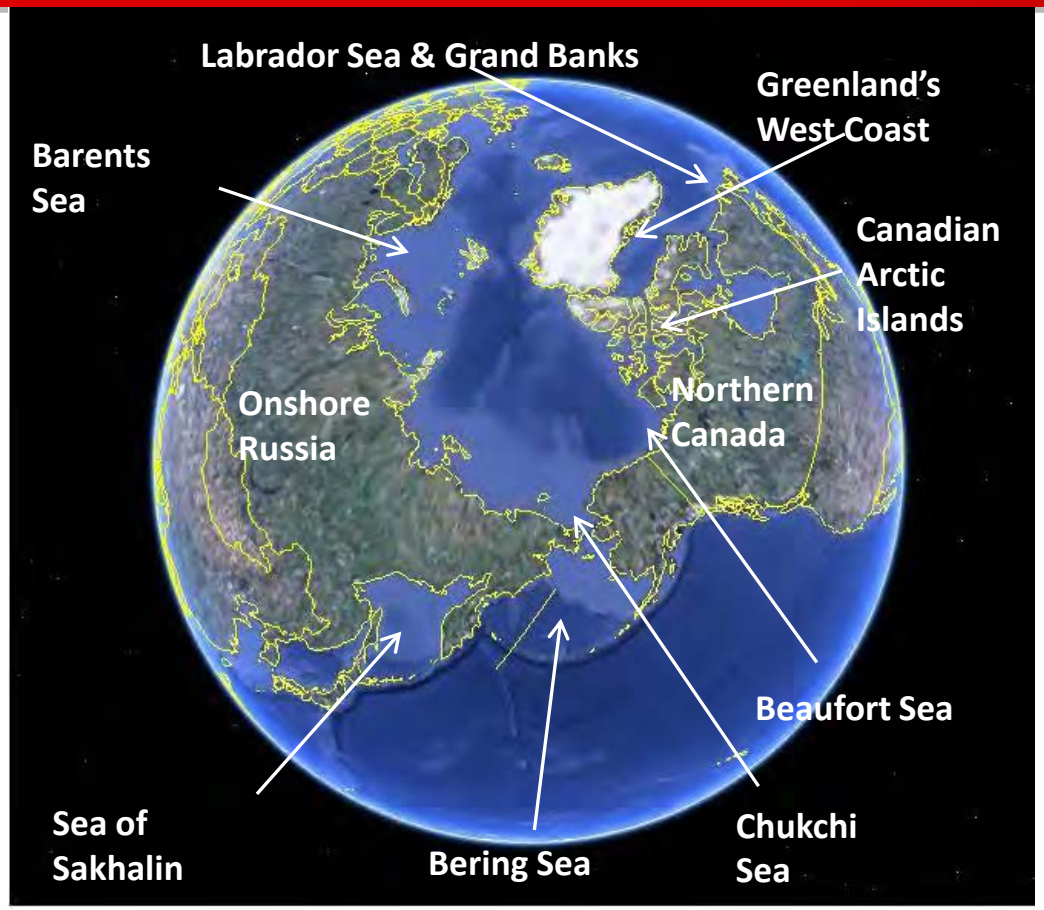
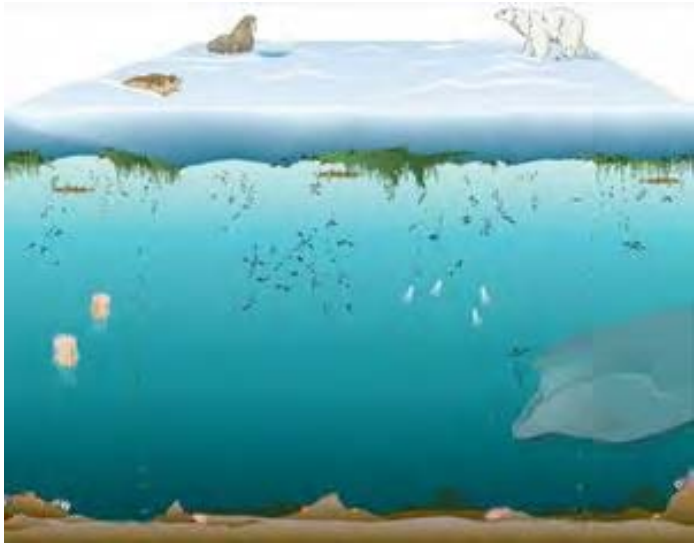


- Increasing Oil & Gas Consumption Worldwide
- Development in Oil Prices
- Decrease of Production in Several of the World's Biggest Fields
- 22% of World Reserves (USGS, 2008)
- Demand for New Opportunities
- Arctic Challenges in Designing Pipelines for Harsh Environments

Producing commercially profitable ventures is expensive and challenging!!

Arctic Challenges



Arctic Challenges: The Reality

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- Pack Ice, Ice Ridges, Icebergs
- Soil conditions
- Harsh weather/extreme cold
- Limited access/supply lines
- High cost, high risk, long lead-times

Arctic Challenges - General

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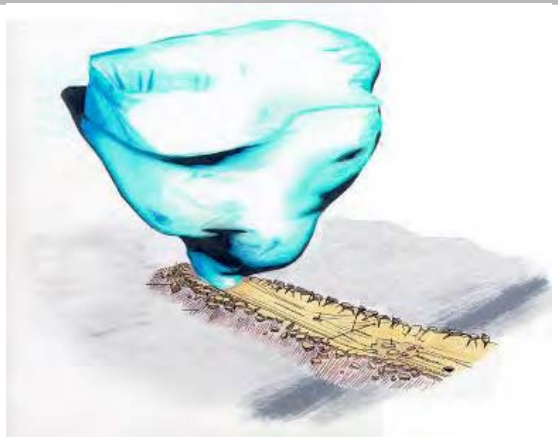

General Arctic Challenges

- Location Related
- Climate Related
- Nature of Arctic
- Environment Related

Arctic Challenges (1 of 4)

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Geographic Location (Remoteness and Darkness)

- Human Safety
- Working Conditions
- Communications
- Emergency Response
- Logistics
- Equipment Reliability
- Limited Time for Construction Activities

Arctic Challenges (2 of 4)

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Climate Conditions & Ice Coverage

- Construction and Installation
- Operation and Maintenance
- Extreme Low Winter Temp.
- Flow Assurance
- Ice Gouging
- Ice Mechanics
- Strudel Scour
- Localized High Pipeline Strain
- Permafrost thaw
- New Materials

http://www.fedre.org/

Arctic Challenges (3 of 4)

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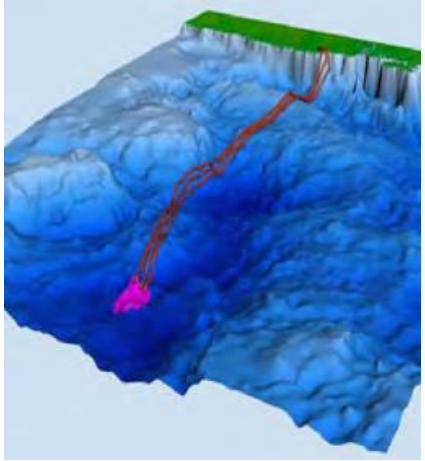

Nature of Arctic

- Large Fields
- Flow Assurance
- High Maintenance
- Power Transmitting
- Shore Approach Facilities
- Ultra Long Distances
- High Reliability
- Complex Control Systems
- Power Distribution
- Subsea Pumbing

Arctic Challenges (4 of 4)

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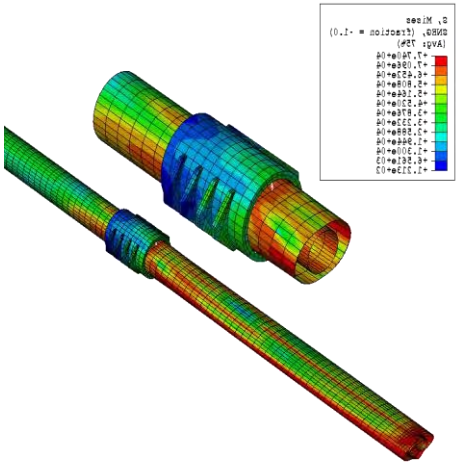
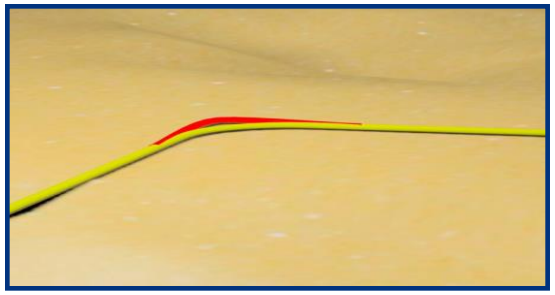
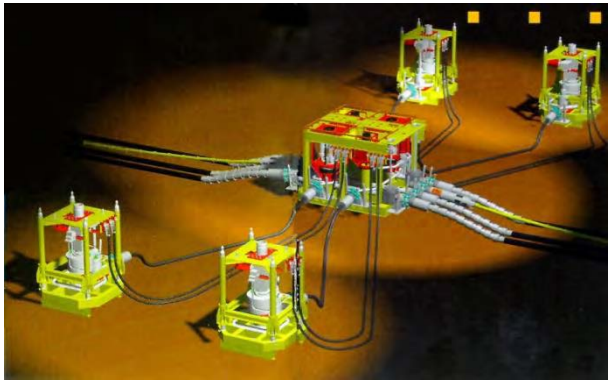
Environmental Conditions

- Extremely Sensitive Ecosystem
- Deepwater Ecosystem
- Stringent Environmental Standards
- Zero Discharge / Zero Emission

Design of Pipelines for Arctic Conditions





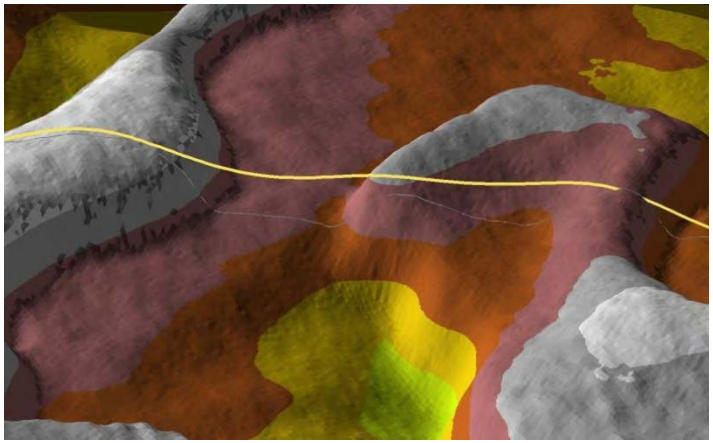


Arctic Challenges: The Opportunity

Wood Group kenny

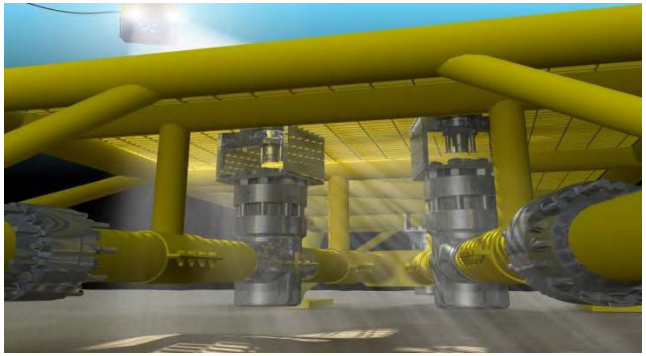
The industry needs:

- Safe and economical solutions
- Reduce unnecessary conservatism
- Innovation

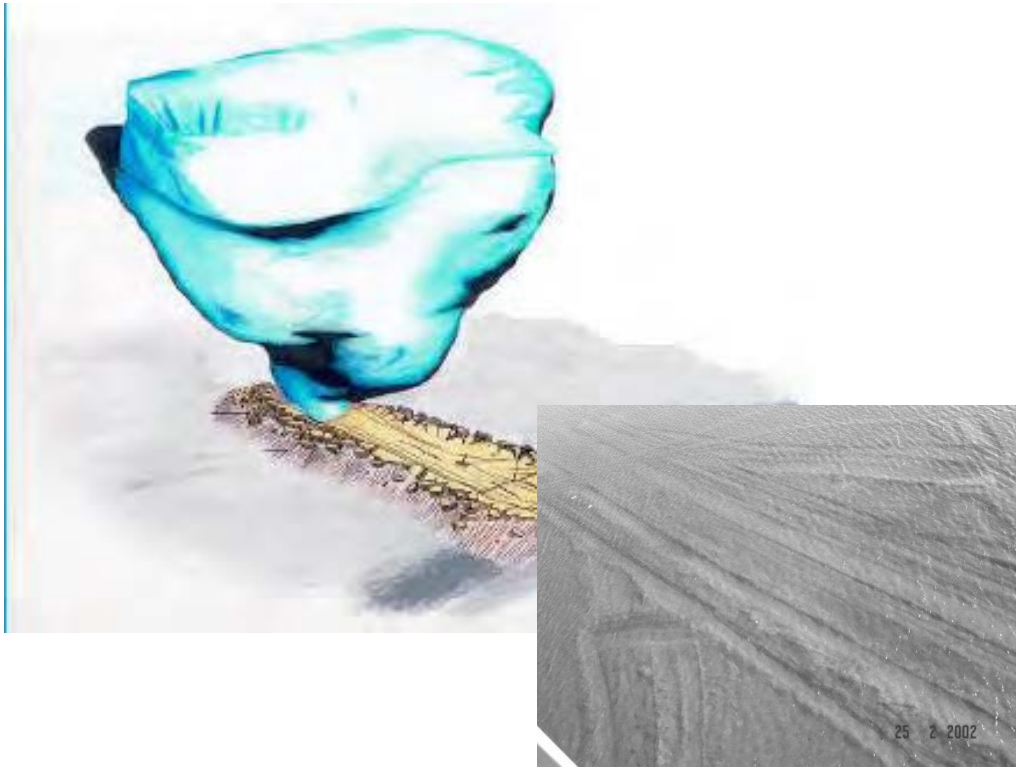


can be provided:

- Advanced analysis
- Realistic simulation tools
- Optimization



1. Ice Gouging



The Ice Gouge Phenomenon

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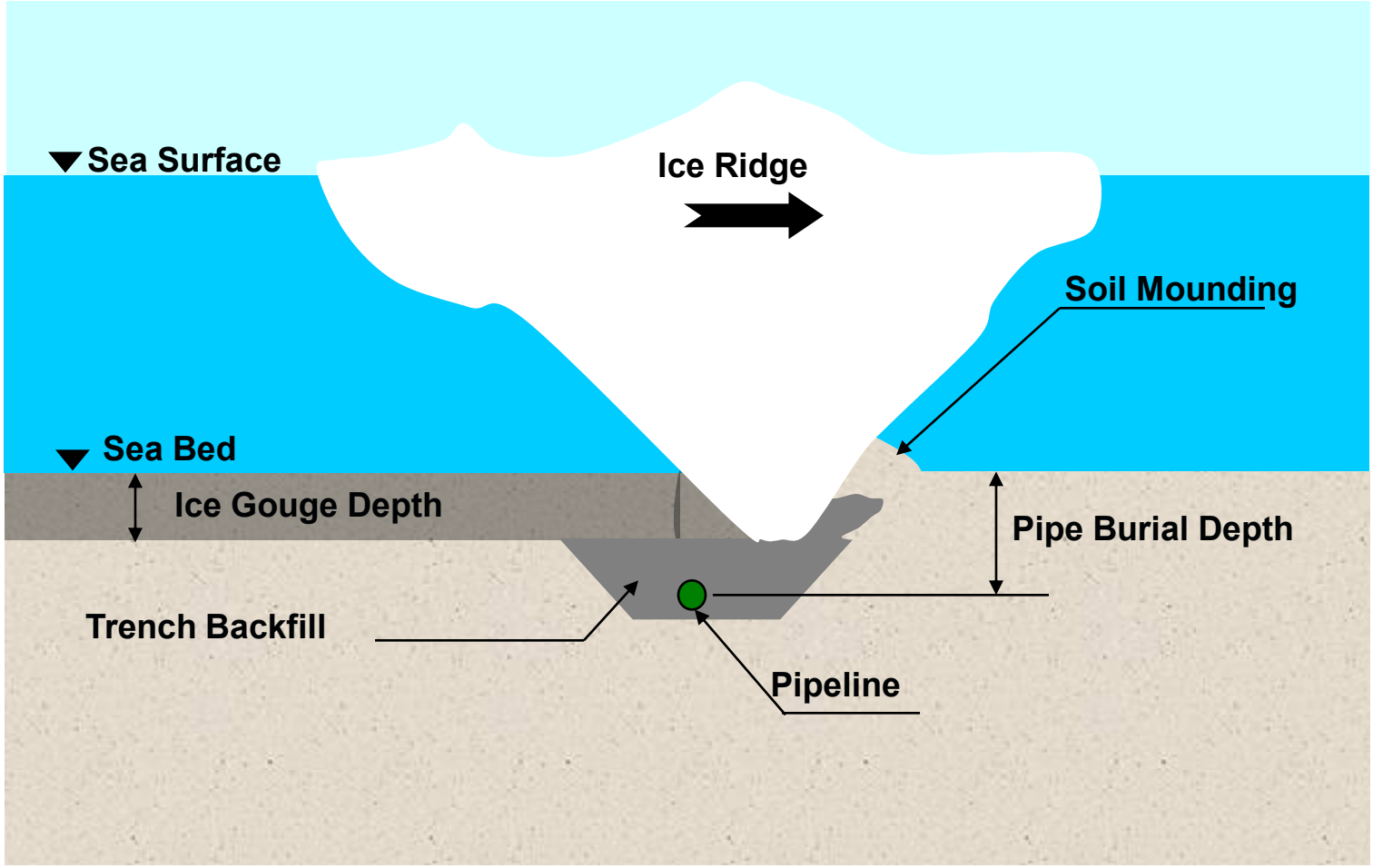

Ice Gouging Simulation

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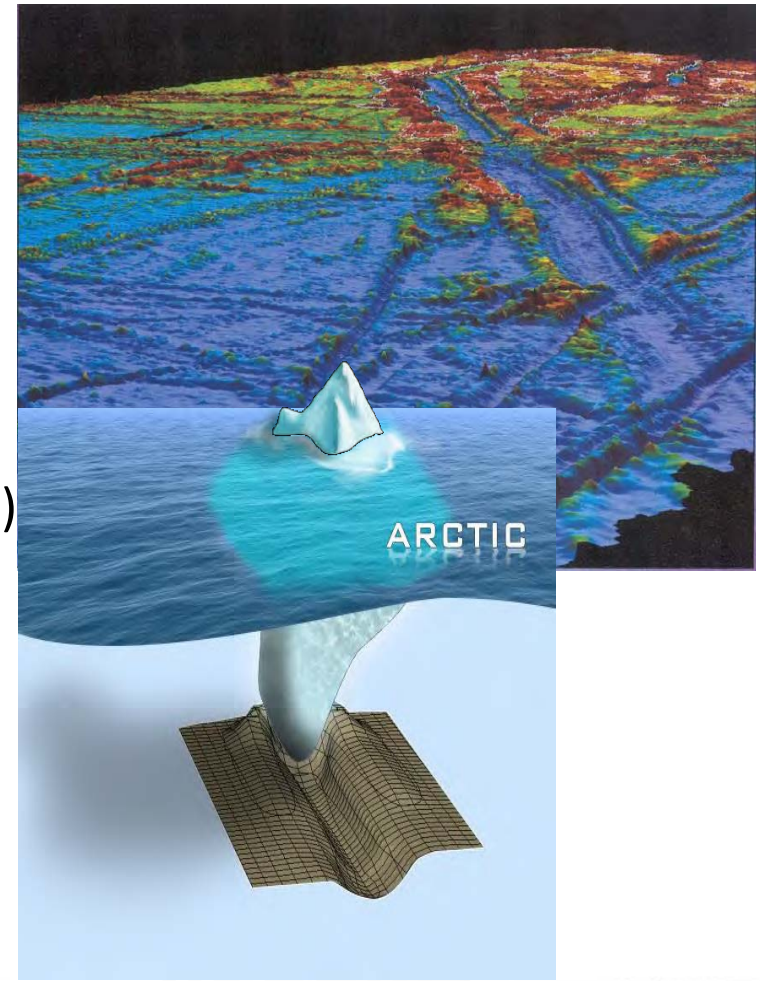
- Locations;
  - WN American Arctic
  - Arctic Island
  - Eastern Arctic: Icebergs
- Gouges 5 m deep
- Water depths of 20 - 40 m
- Design Factors: **burial depth, trench material**
- Burial Depth = 2 ~ 3 x Scour Depth (Literature)



<u>Objective of Ice Gouge Simulation:</u>

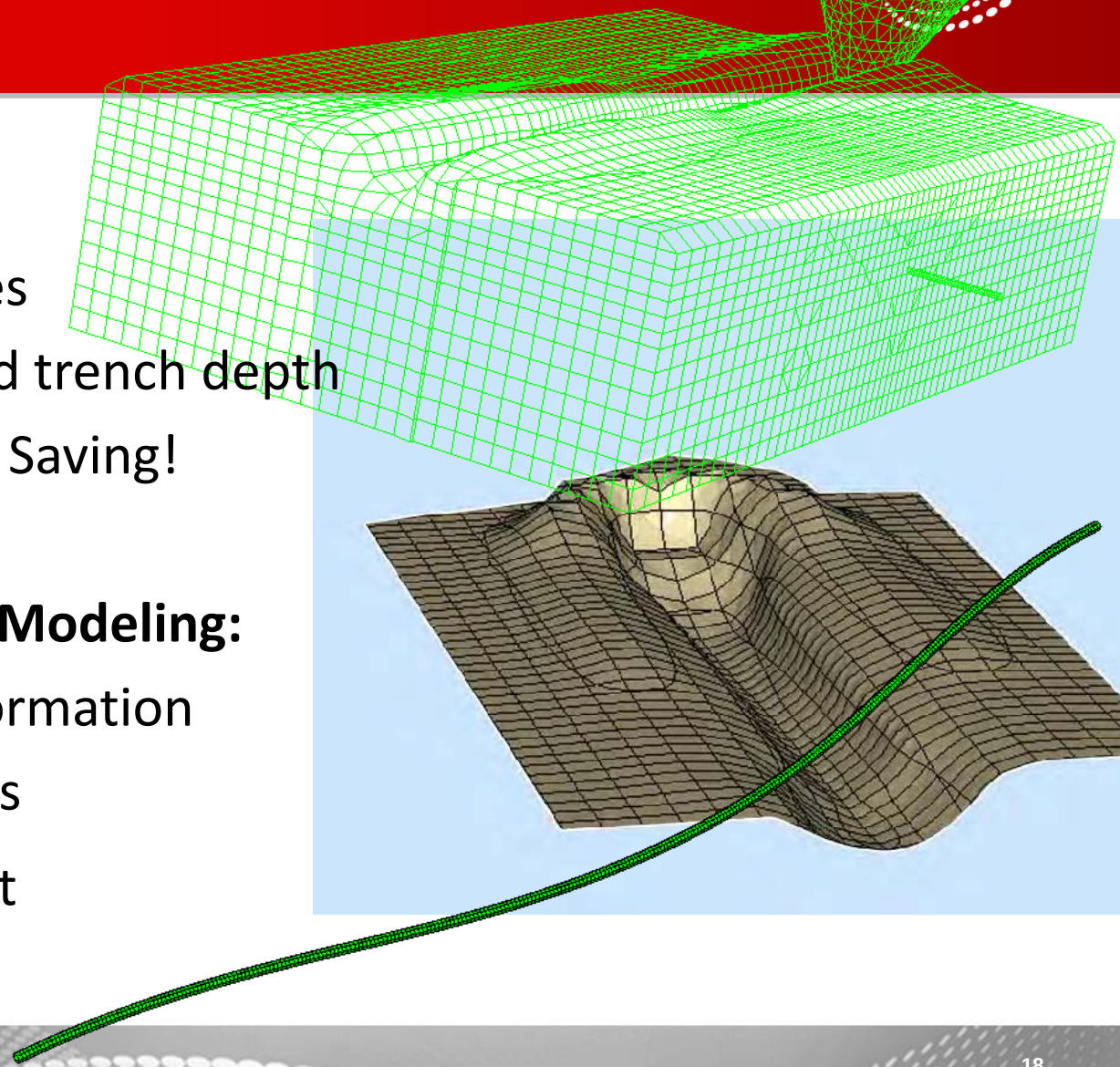
- Optimize required burial depth
- Maintain pipeline integrity
- Tolerable permanent deformation
- Reduce intervention cost

Finite Element Modeling (FEA)

Wood Group kenny

- **Why Modeling?**
  - Experimental Studies
  - Benefits is optimized trench depth
  - Significant Financial Saving!

- **Challenge of Ice Scour Modeling:**
  - Large Soil/Pipe Deformation
  - Complex Soil Models
  - Ice-Soil-Pipe Contact



Arctic Engineering
Ice-soil-pipeline Interaction (1 of 2)

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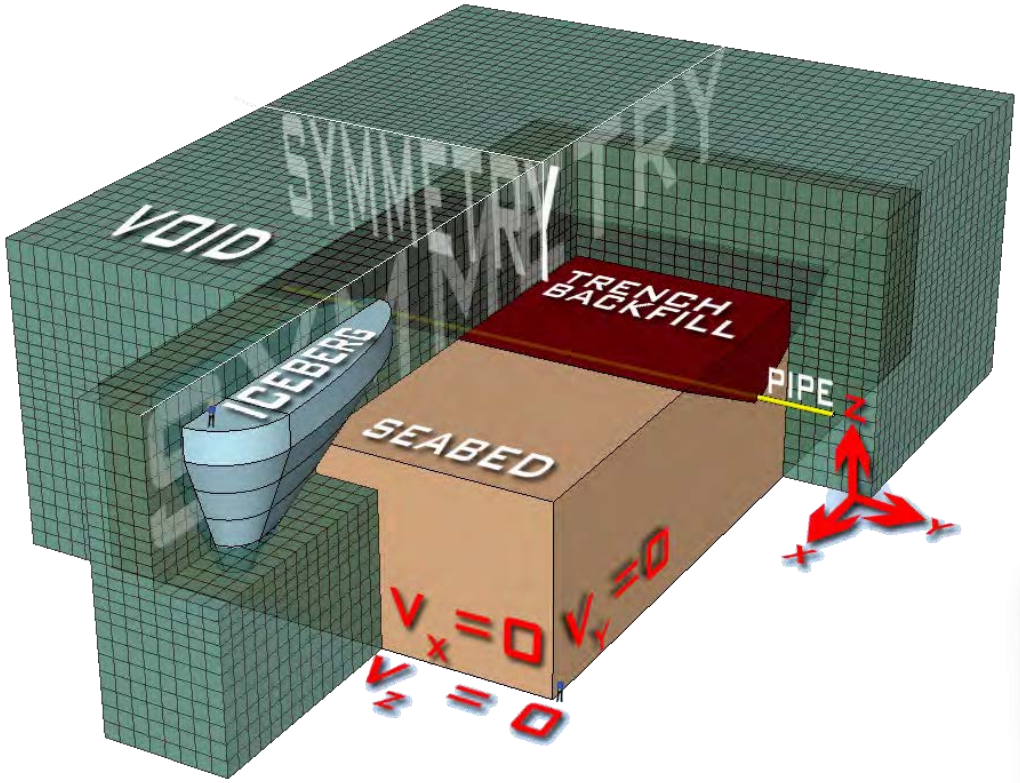
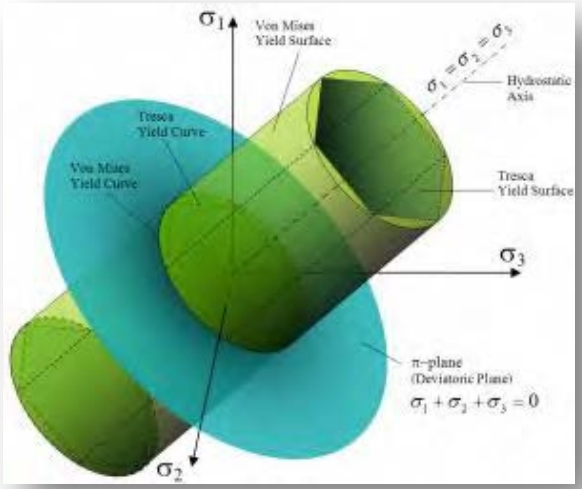
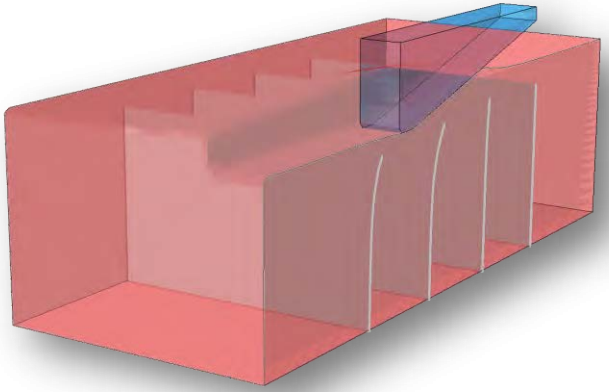
- Coupled Eulerian Lagrangian (CEL) ABAQUS FE Model

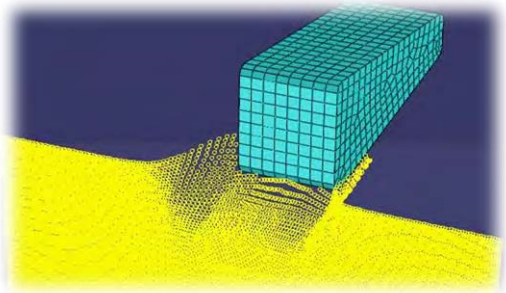


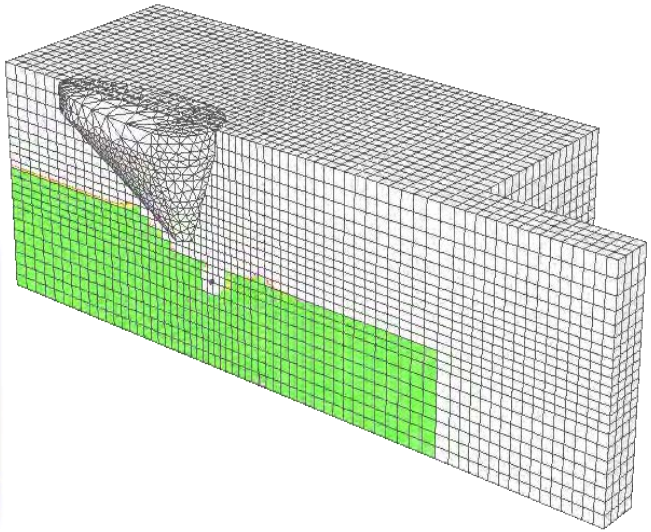


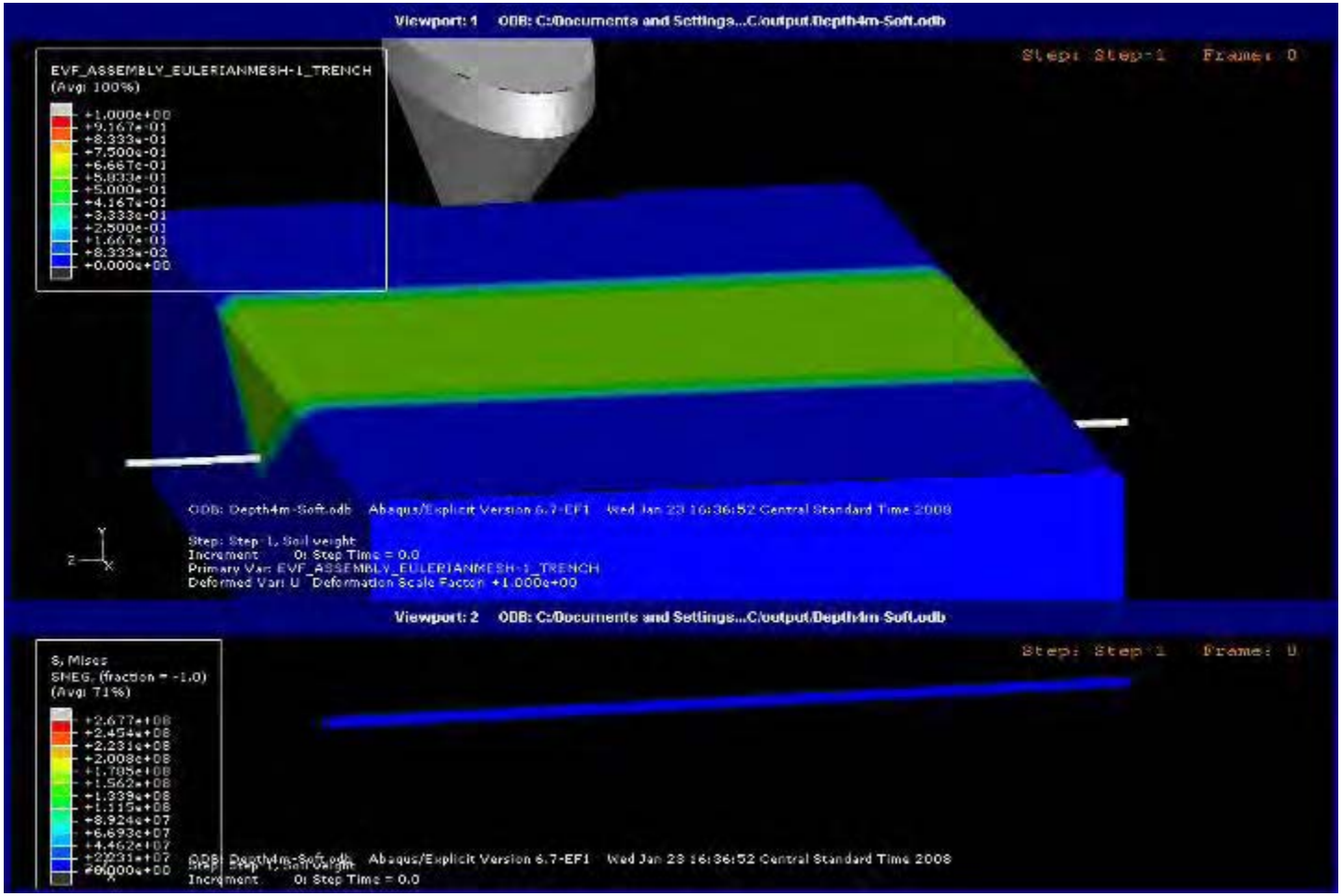


Coupled Eulerian Lagrangian (CEL) Method:

- Allows Very Large Deformations
- Overcomes Mesh Distortion & Convergence Issues
- Dynamic Response
- ABAQUS Explicit
- Unique approach






Viewport: 1 ODB: C:/Documents and Settings...C/output/Depth4m-Soft.odb
EVF_ASSEMBLY_EULERIANMESH-1_TRENCH
(Avg: 100%)
+1.000e+00
+9.167e-01
+8.333e-01
+7.500e-01
+6.667e-01
+5.833e-01
+5.000e-01
+4.167e-01
+3.333e-01
+2.500e-01
+1.667e-01
+8.333e-02
+0.000e+00
Step: Step-1 Frame: 0
ODB: Depth4m-Soft.odb Abaqus/Explicit Version 6.7-EF1 Wed Jan 23 16:36:52 Central Standard Time 2008
Step: Step-1, Soil weight
Increment 0: Step Time = 0.0
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Deformed Var: U Deformation Scale Factor: +1.000e+00
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SNEG, (fraction = -1.0)
(Avg: 71%)
+2.677e+08
+2.454e+08
+2.231e+08
+2.008e+08
+1.785e+08
+1.562e+08
+1.339e+08
+1.116e+08
+8.924e+07
+6.693e+07
+4.462e+07
+2.231e+07
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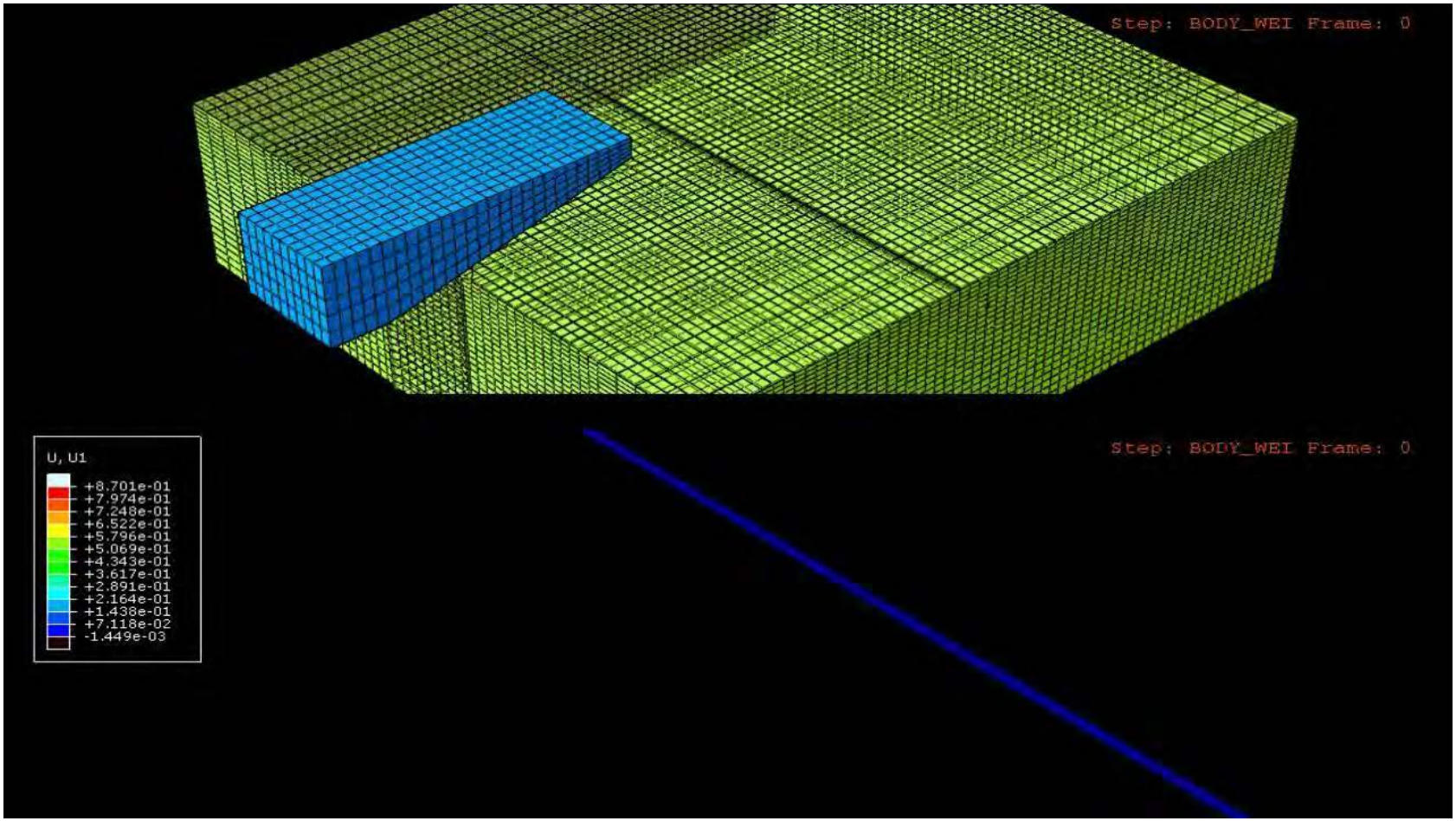
Step: Step-1 Frame: 0
ODB: Depth4m-Soft.odb Abaqus/Explicit Version 6.7-EF1 Wed Jan 23 16:36:52 Central Standard Time 2008
Step: Step-1, Soil weight
Increment 0: Step Time = 0.0

Ice Gouging – FE Modeling

Wood Group kenny



Validation

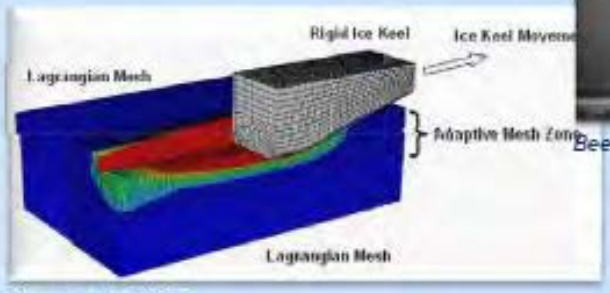
- Centrifuge testing
  - N times the gravity, $N{\cdot}g$
  - PRISE

PRISE, Alaskan Arctic Pipeline Workshop Presentation, 1999

- Laboratory scale testing
  - (1·g environment)

Been et al., 2008

- FE Numerical Models
  - Decoupled structural models
  - Lagrangian FE
  - ALE FE



Kenny et al., 2007

DNV ICE PIPE JIP

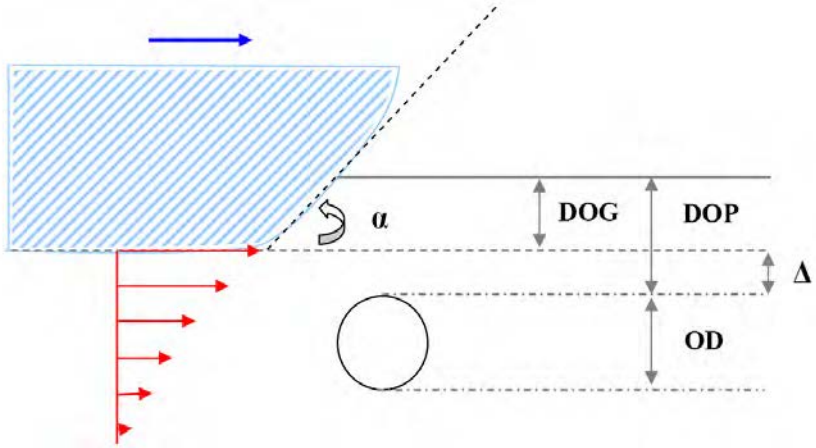
Wood Group kenny

Objective

- Defined acceptance criteria for the design and operation of offshore pipelines in Arctic regions
- Best practices
- Handling of uncertainties

Our work scope

- Numerical Benchmarking
  - Parameter influence
  - Compare FE models
  - Numerical uncertainty
  - Qualify structural models



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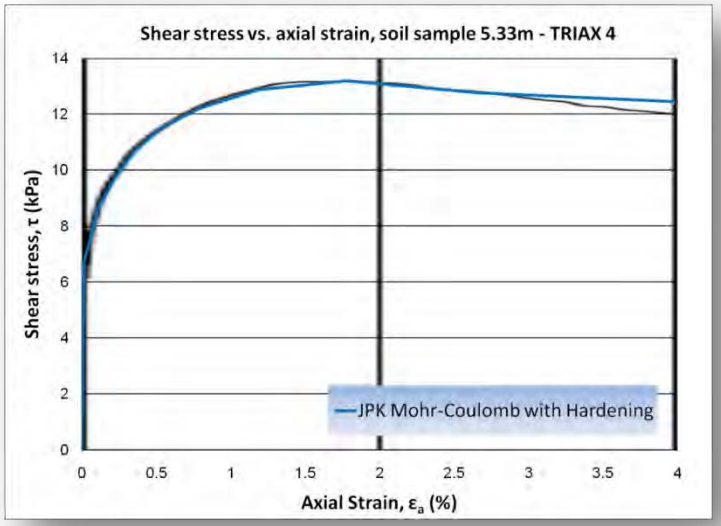
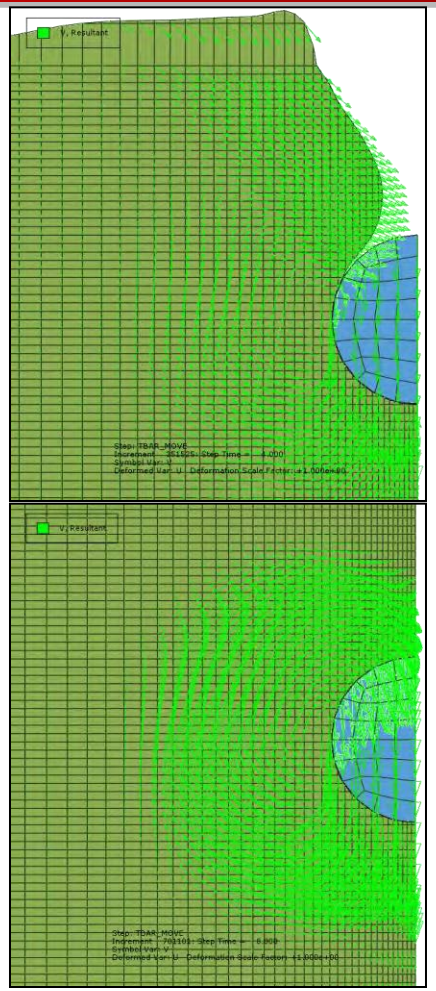
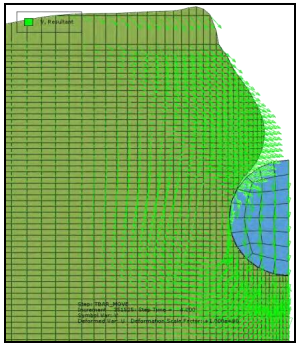
Three phases:

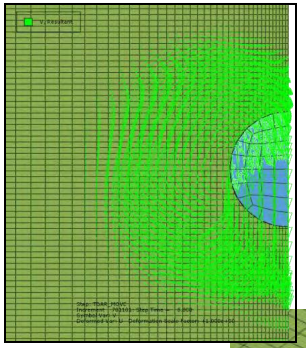
1. Soil model calibration
2. Free-field subgouge displacement
3. Ice-soil-pipeline interaction matrix

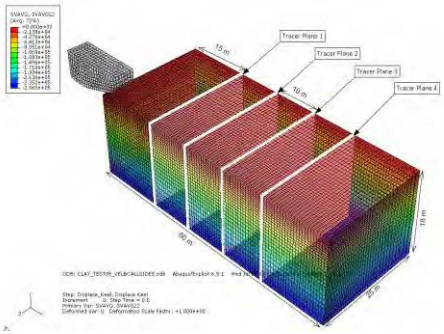


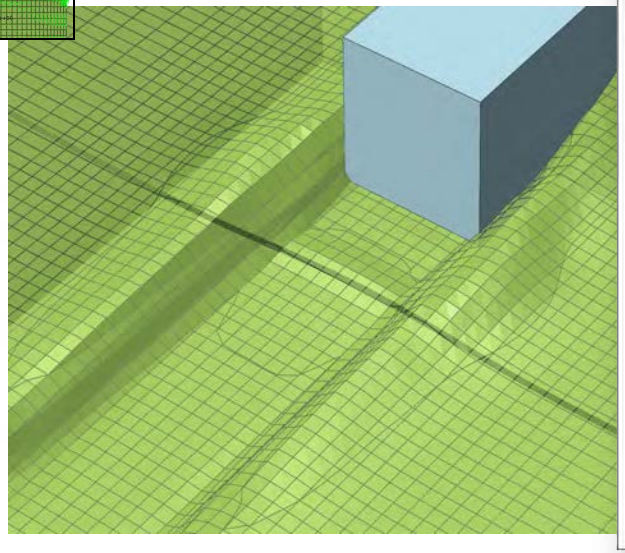


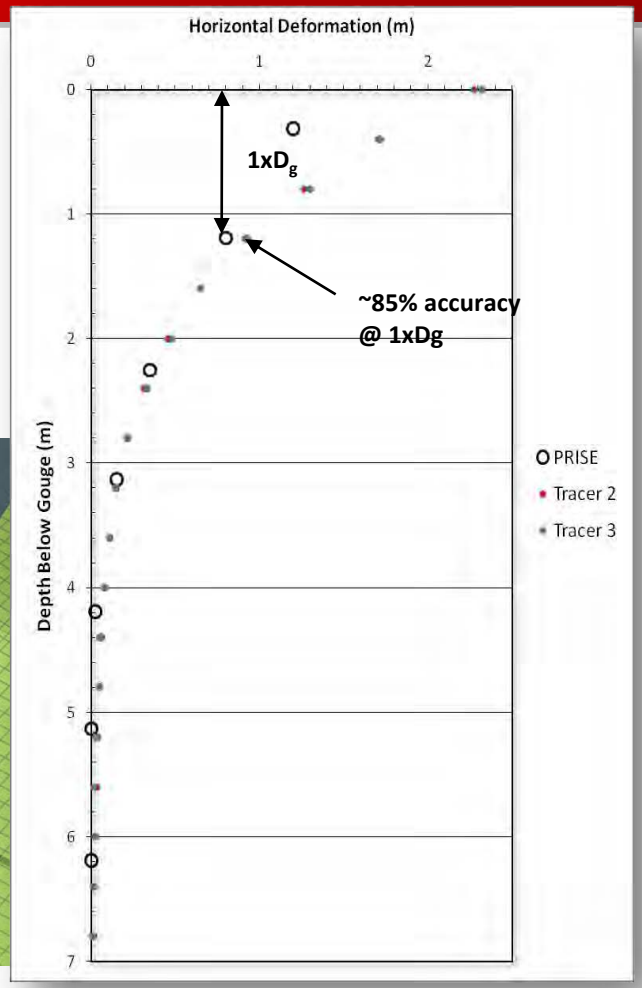
- Model Validation



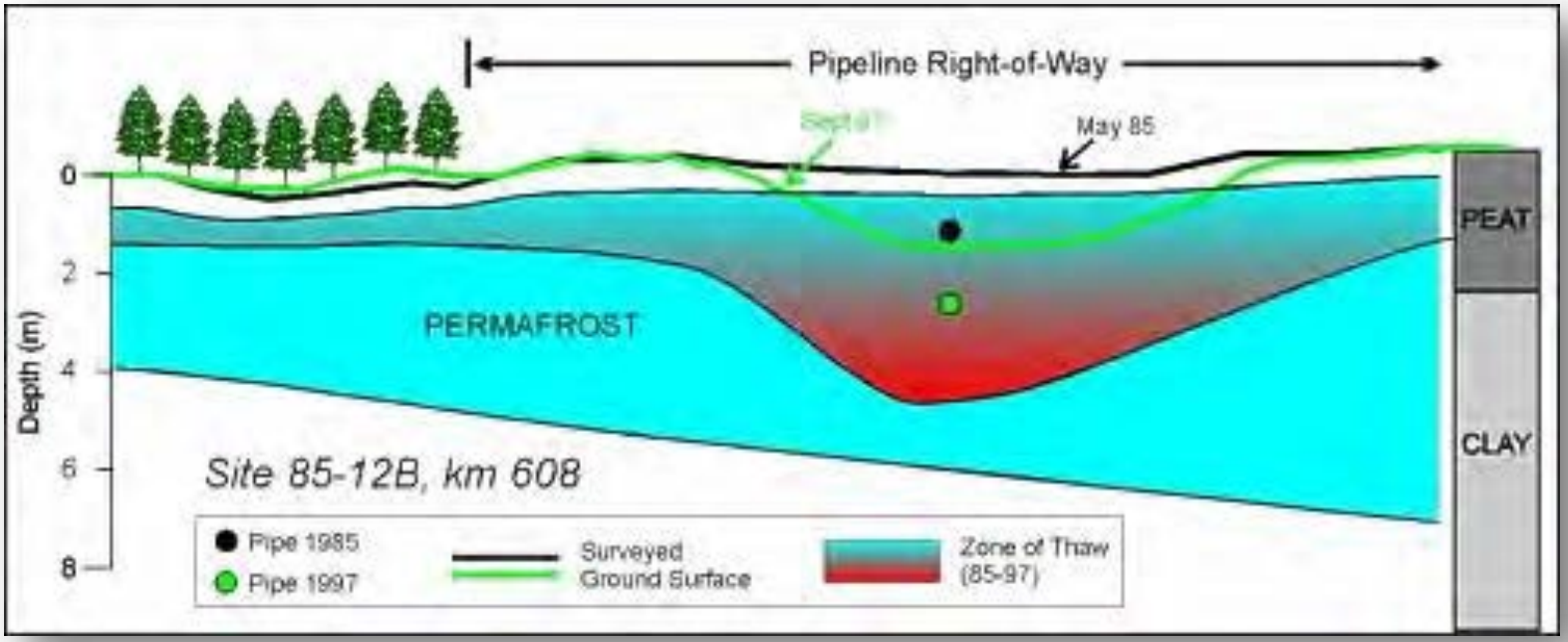








2. Permafrost Thawing



Permafrost - Distribution

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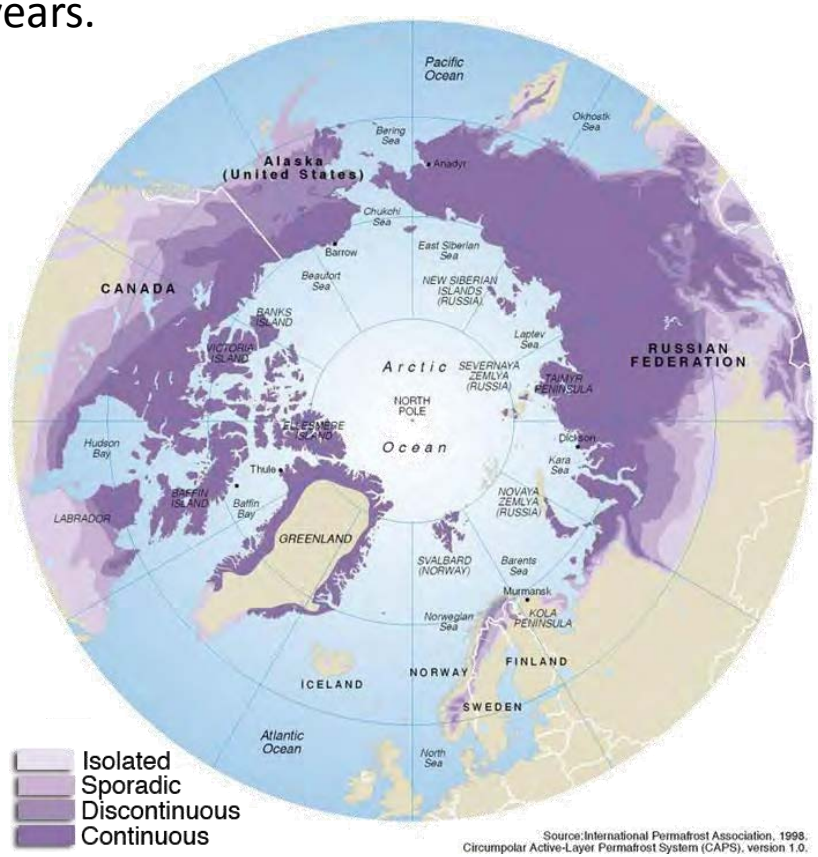
Soil at or below the freezing point of water (0 °C or 32 °F) for two or more successive years.

Russia	80% of Siberia
Canada	50% of Canada
Alaska	80%
Greenland	81% (Ice sheet)
China	22% (Tibet Plateau)
Northern Euro	North coast, Norway
	Alpine Mountain



Ref. International Permafrost Association, 1998

Permafrost – Challenges

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- Thaw Settlement
- Frost Heave

Ref. NASA and USGS

Permafrost

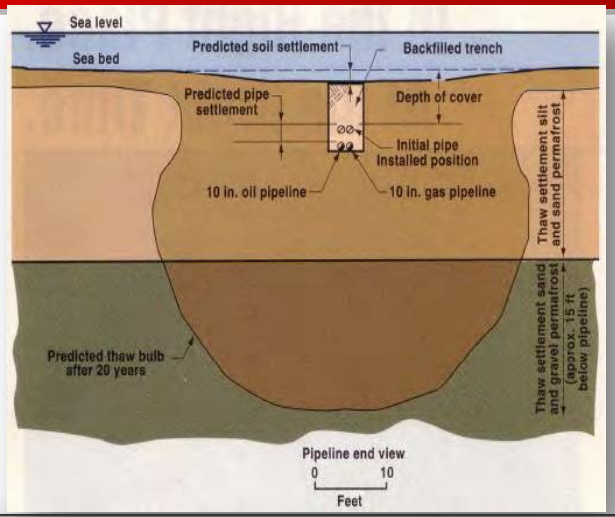
Wood Group kenny

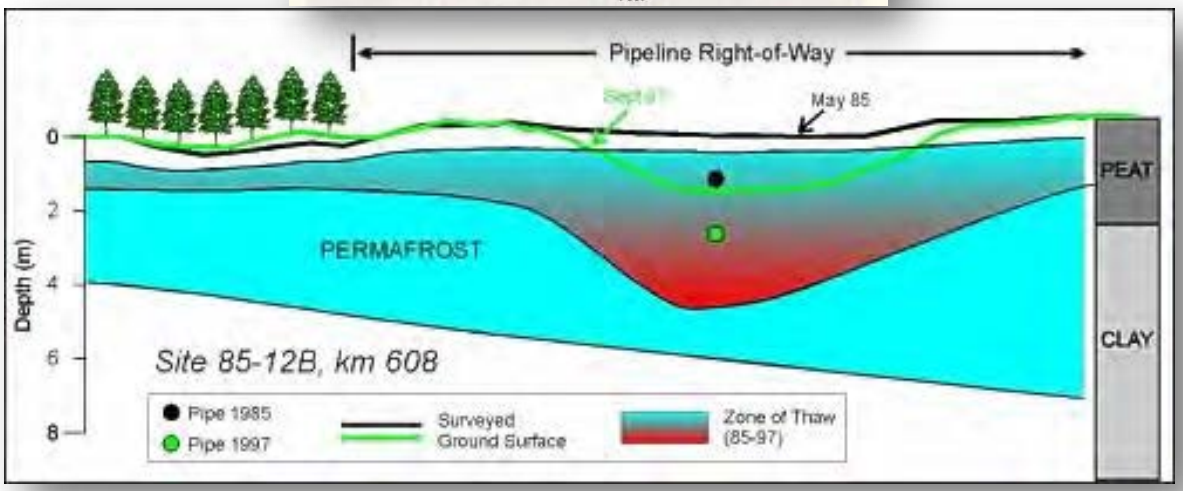
Permafrost is:

- Permanently frozen ground

The issue is:

- Thaw settlement-pipeline interaction





Permafrost thaw-pipeline Interaction

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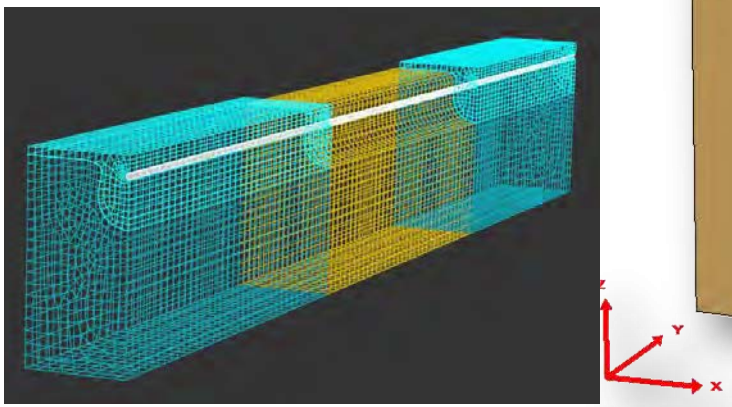
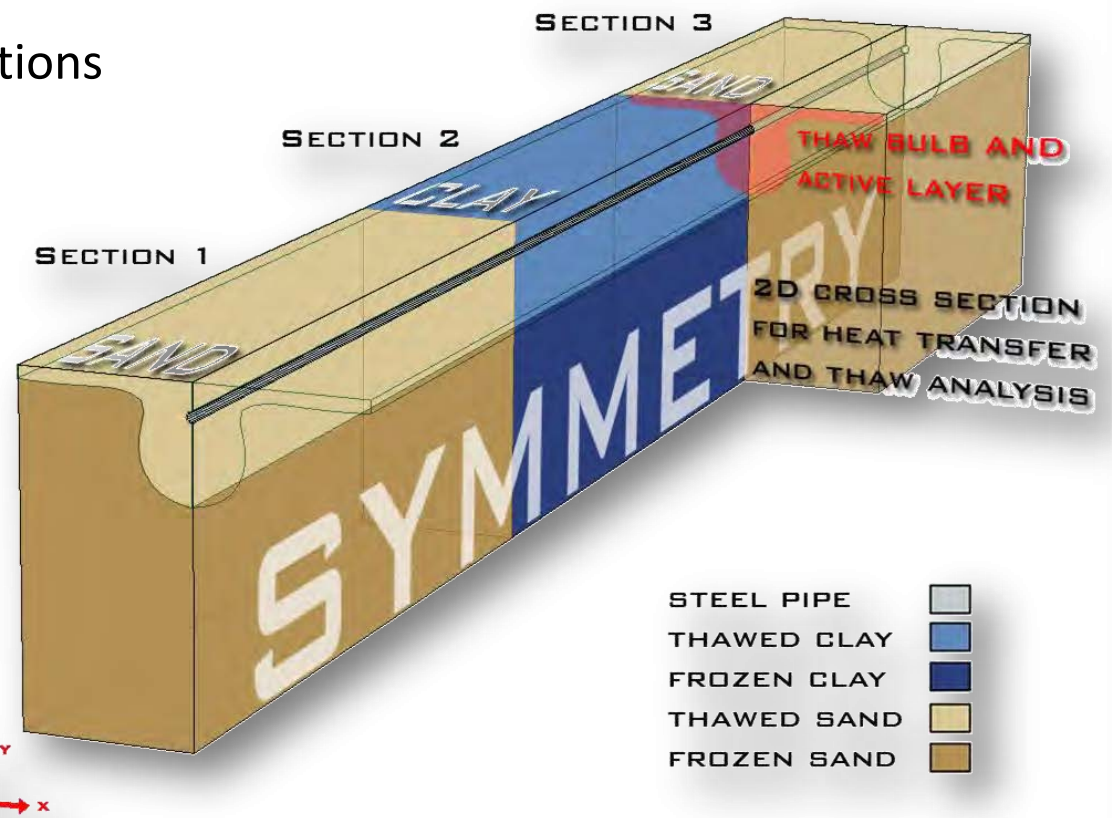
Objective:

- thermal and mechanical interactions
- differential settlement
- pipeline response





Model overview

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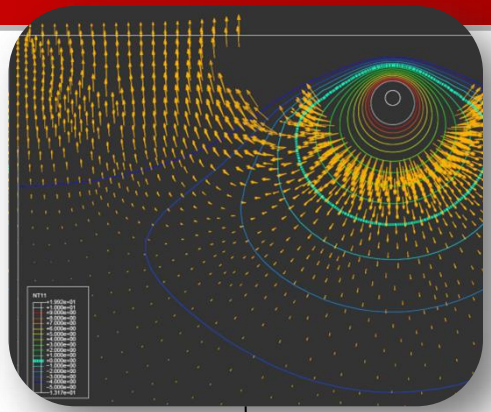
2D Heat Transfer

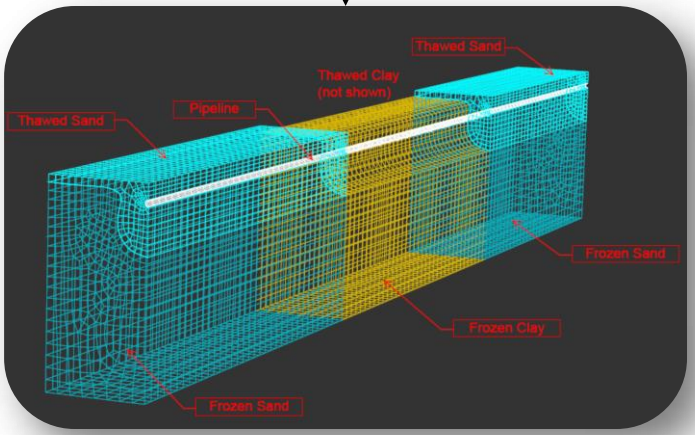
↓

Map Thaw Bulb Profile to 3D Model

↓

Thaw settlement and pipeline deformation





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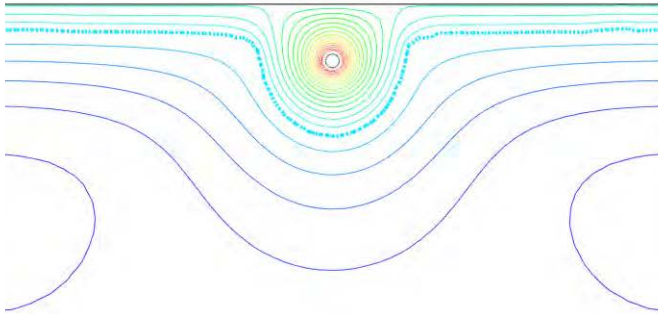
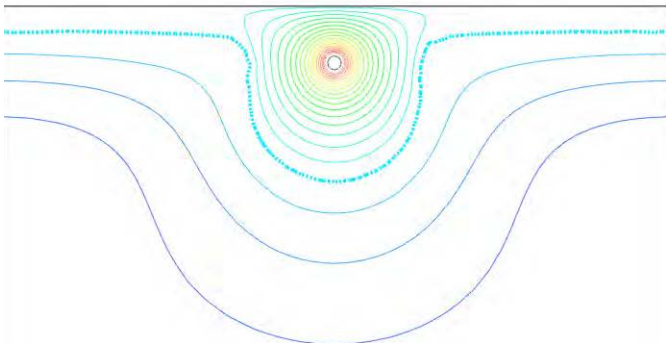
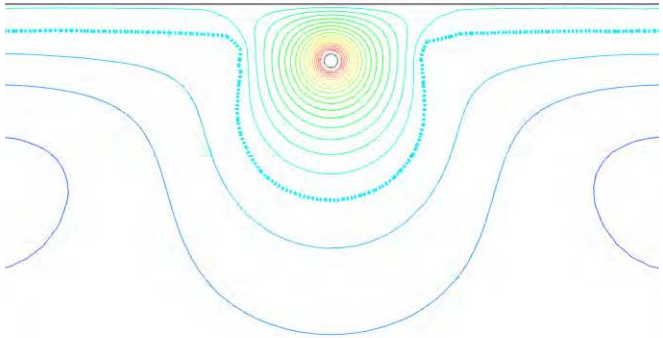
Thaw bulb development



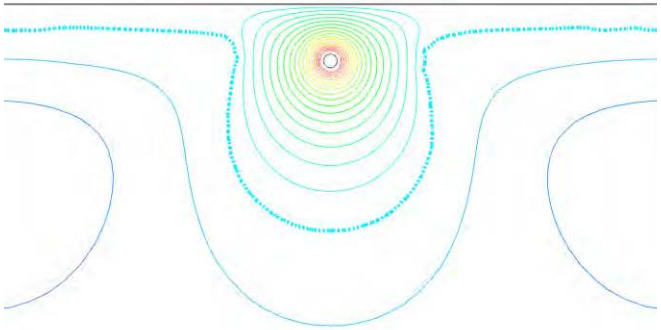
1 year



5 year



10 years



20 years

Typical Results – Permafrost Thaw

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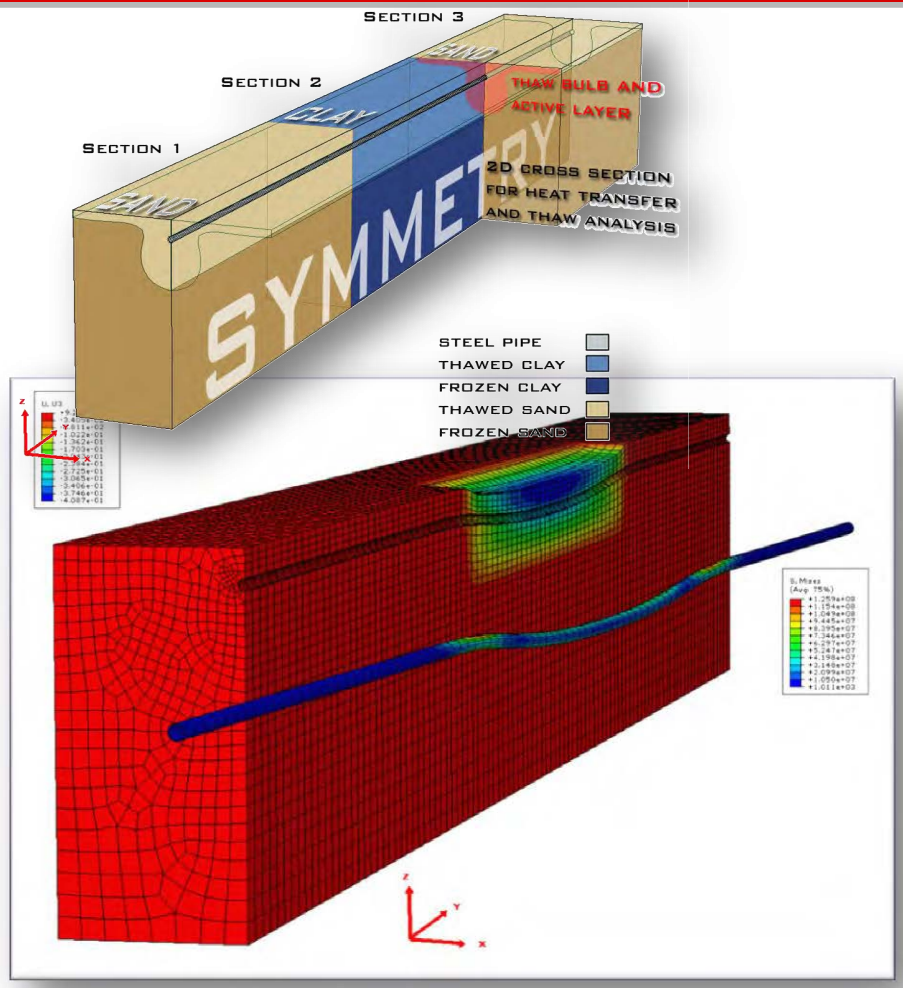

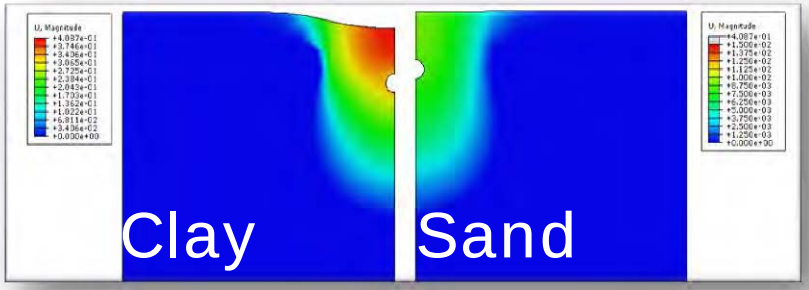

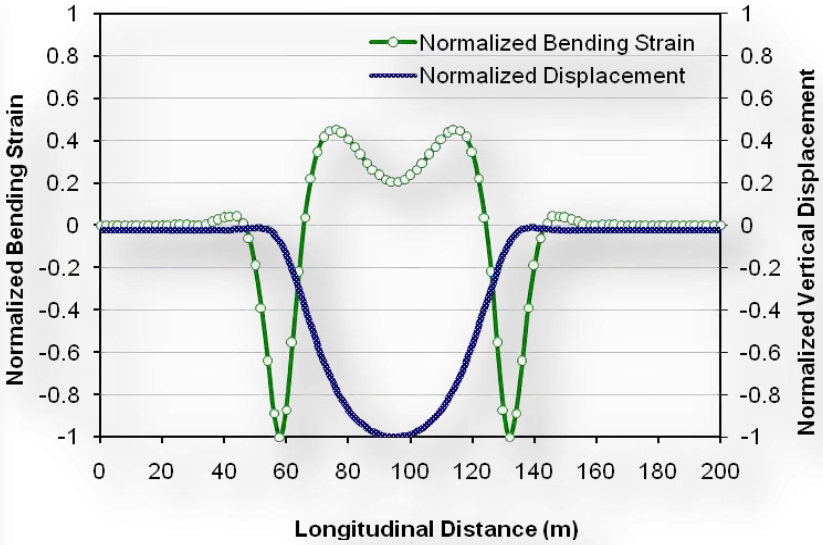

Permafrost – Thaw Settlement Mitigation

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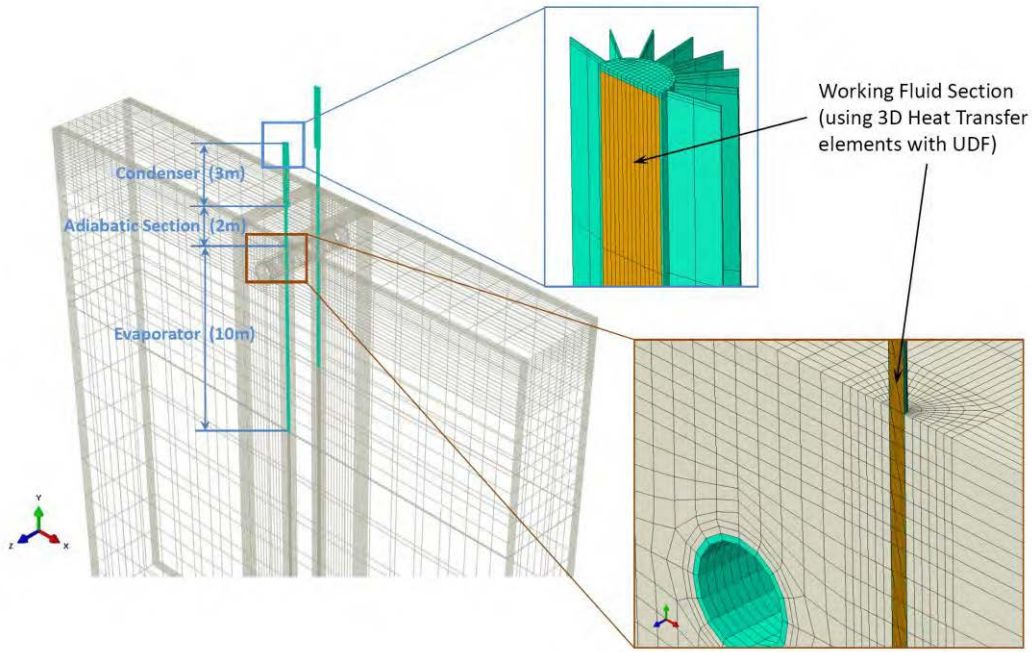
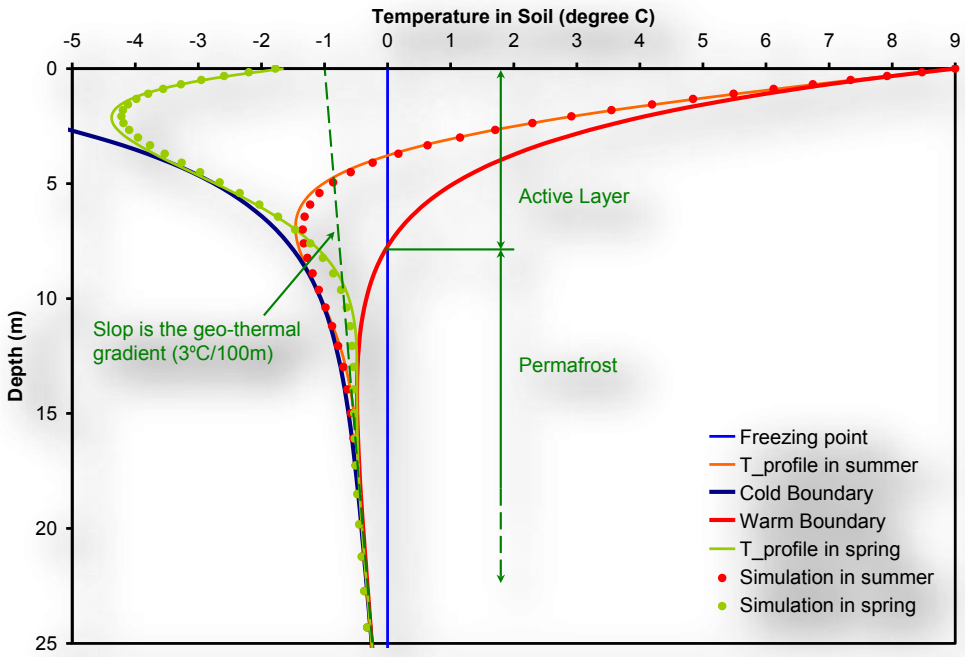
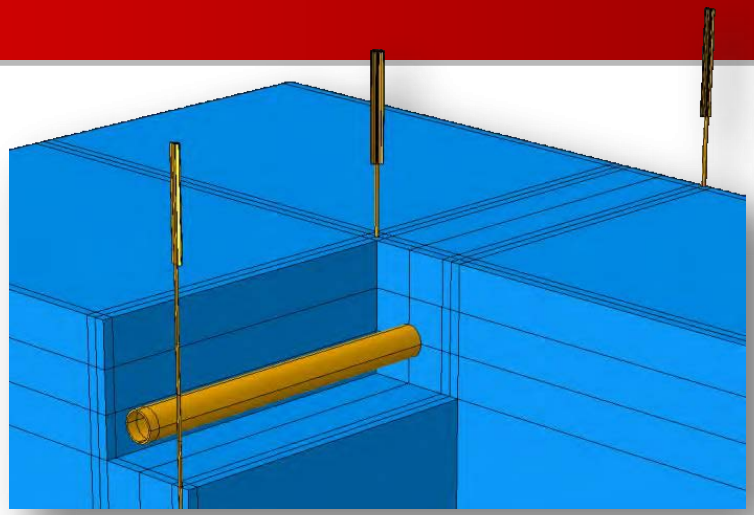
- Permafrost Geothermal Analysis with Buried Pipeline and Thermosyphon
  - Rule of thumb in Arctic Engineering
  - Thermosyphons application in permafrost stabilization;
  - The modeling of the inner processes can be overwhelming for engineering purposes;
  - A simplified method is introduced.

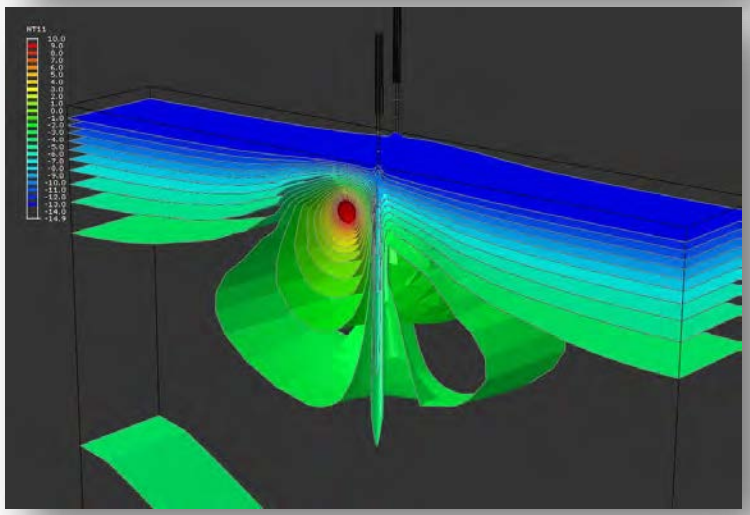


Permafrost – Thaw Settlement Mitigation

Wood Group kenny

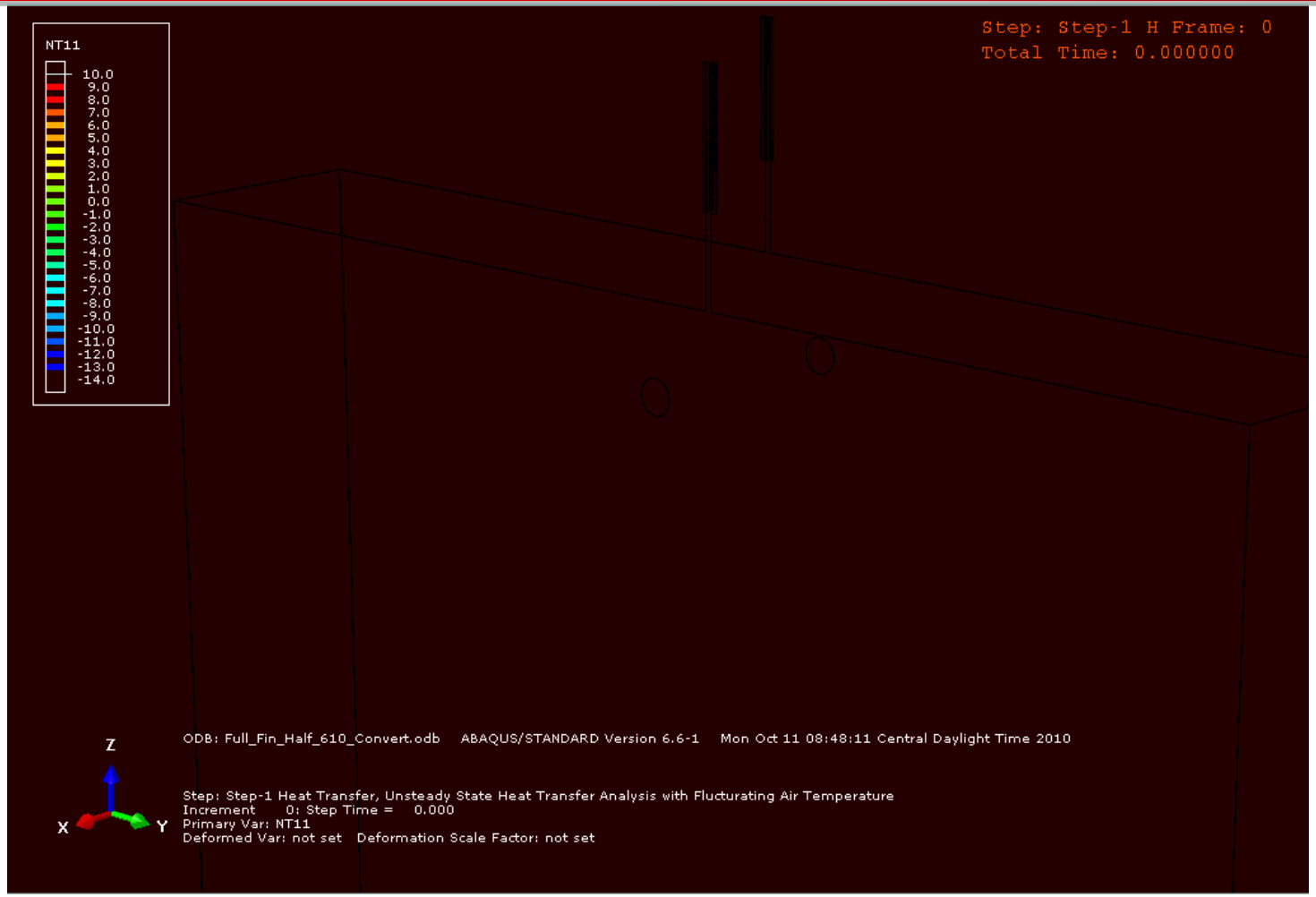




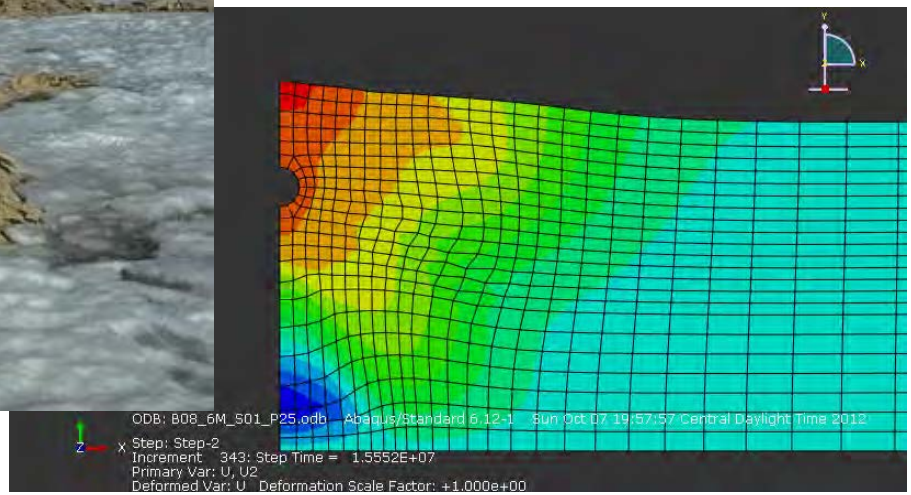


Permafrost – Thaw Settlement Mitigation

Wood Group kenny



3. Frost Heave



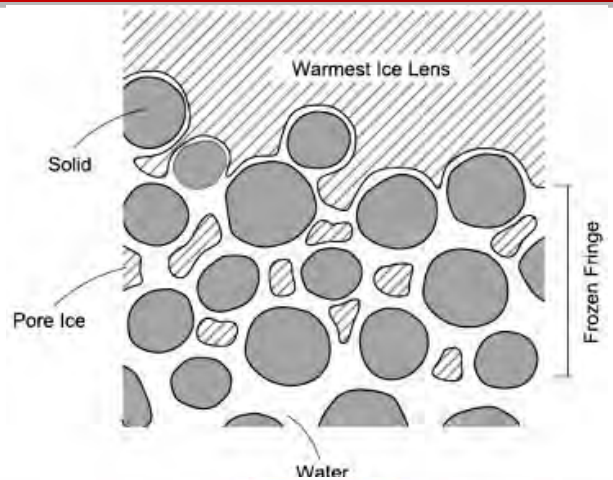
Frost heave model selection and validation (1/3)

Wood Group kenny

What is Frost Heave?

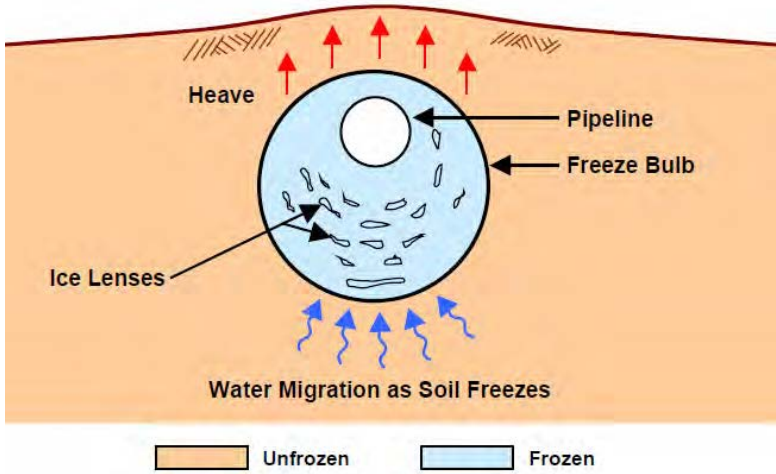
Heave is a complex phenomenon. Made of 2 parts:

- Insitu heave: expansion of pore water upon freezing
- Secondary heave: moisture migration and the formation of ice lense due to cappilary suction from the unfrozed surrounding



Three requirements must be met for frost heave to occur:

• frost susceptible soil, Silt, silty Clay, (Sand and Gravel are not Susceptible)
• supply of unfrozen water, (permafrost → precipitation water stays in active layer)
• freezing temperature



Frost heave model selection and validation (2/3)

Wood Group kenny

Available frost heave models

- **Rigid Ice Model**
- **Segregation Potential Model (SP)**
- **Porosity Rate Function Model**

$$\dot{n} = \dot{n}_m \left(\frac{T-T_0}{T_m}\right)^2 e^{1-\left(\frac{T-T_0}{T_m}\right)^2}, T < T_0, \frac{\partial T}{\partial t} < 0$$

$$\dot{n} = \dot{n}_m \left(\frac{T-T_0}{T_m}\right)^2 e^{1-\left(\frac{T-T_0}{T_m}\right)^2} \frac{\left|\frac{\partial T}{\partial l}\right|}{g_T} e^{-\frac{|\sigma_{kk}|}{\varsigma}}$$

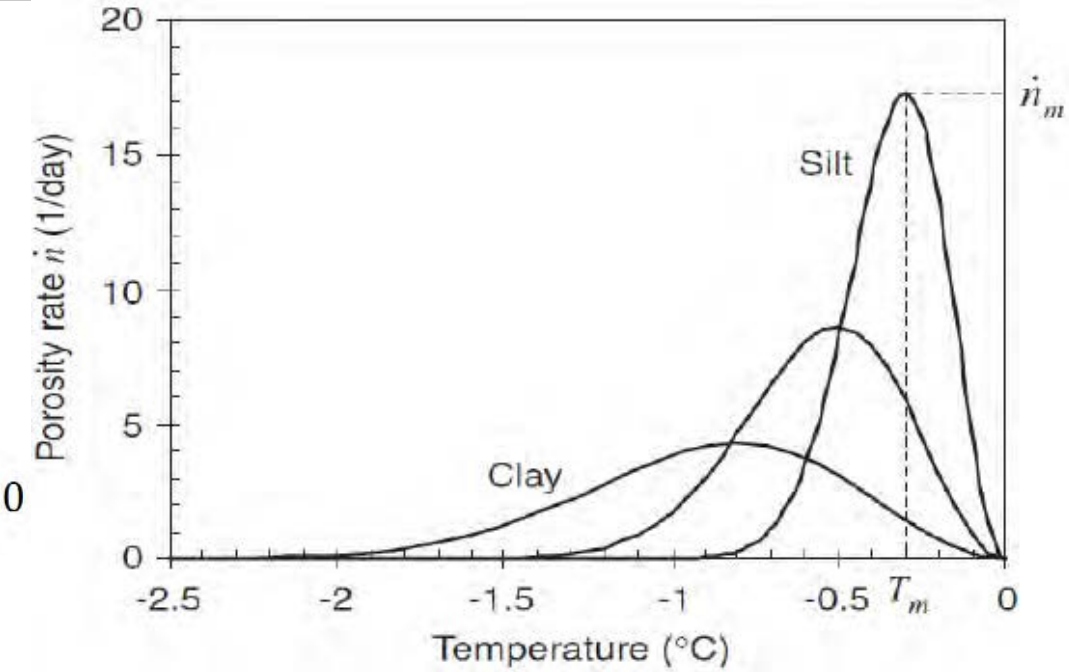
$\dot{n}$ is the porosity rate;

$\dot{n}_m$ is the maximum porosity rate of a given soil;

T is the local temperature;

T_0 is the freezing point of water;

T_m is the temperature at which the maximum porosity



The Challenge: soil parameters required for the porosity rate function are not entirely available (limited literature, no standardised tests …) → Decision was made to compensate by sensititivity analysis.

Frost heave model selection and validation (3/3)

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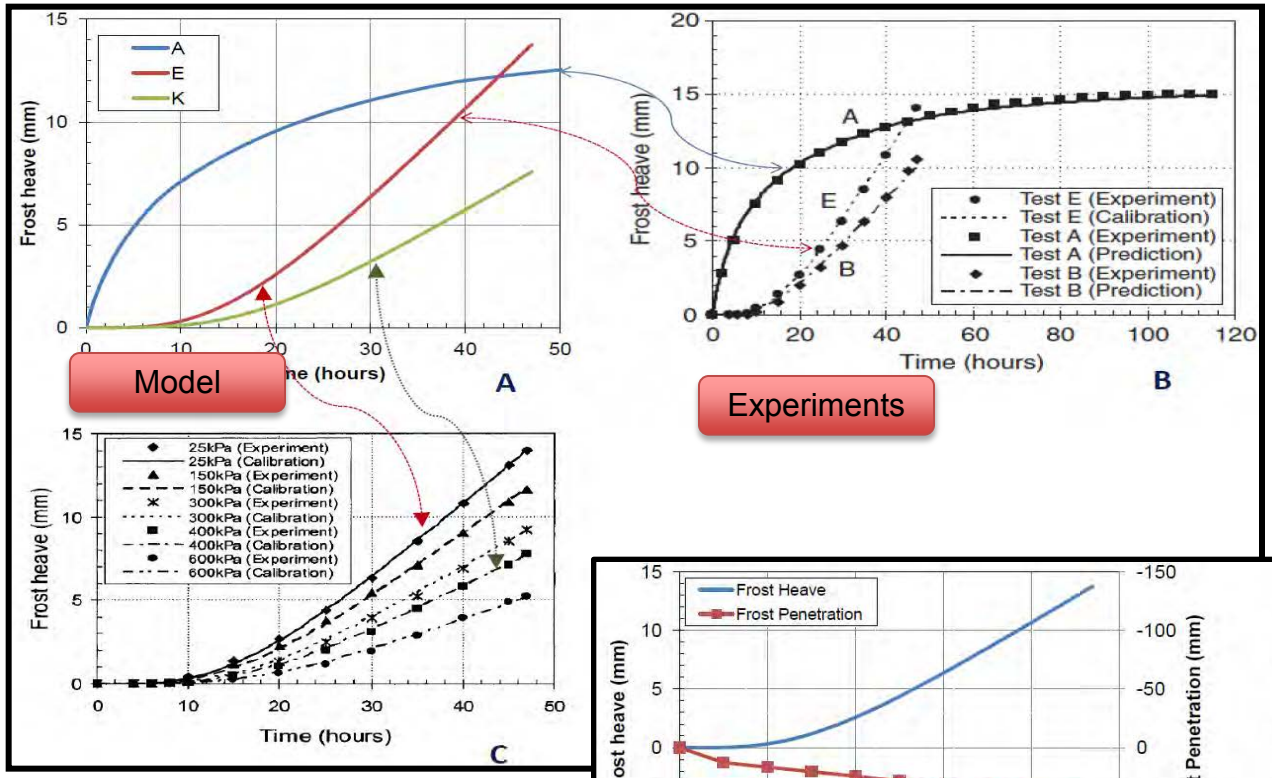

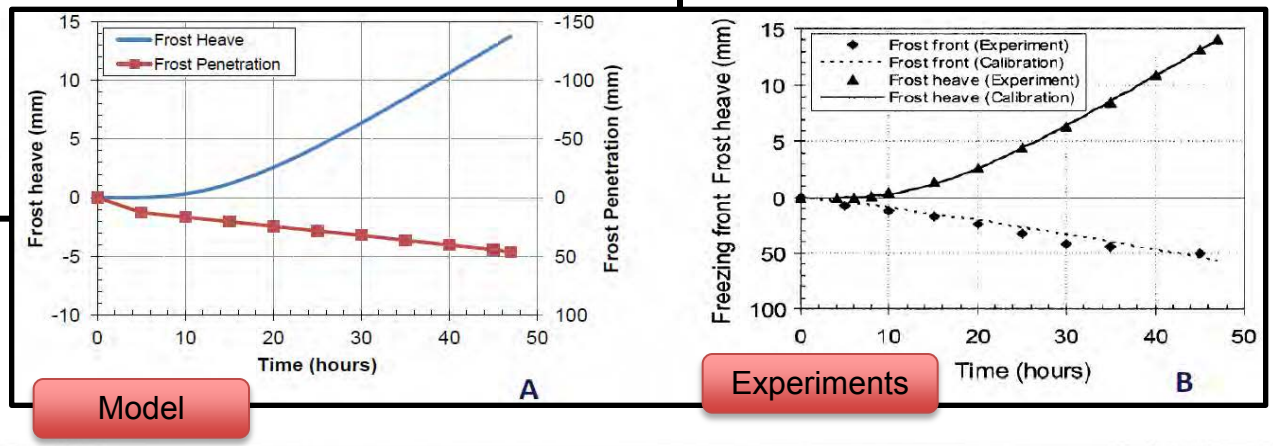

Numerical Analyses methodology

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Geothermal FE Analysis

Input data: Soil thermal and mechanical properties, pipe and environmental data.

Results: Isothermals, depth of the active layer.

Frost heave modelling

Input data: Porosity rate function (with relevant model parameters).

Results: Soil displacements due to frost heave for various conditions.

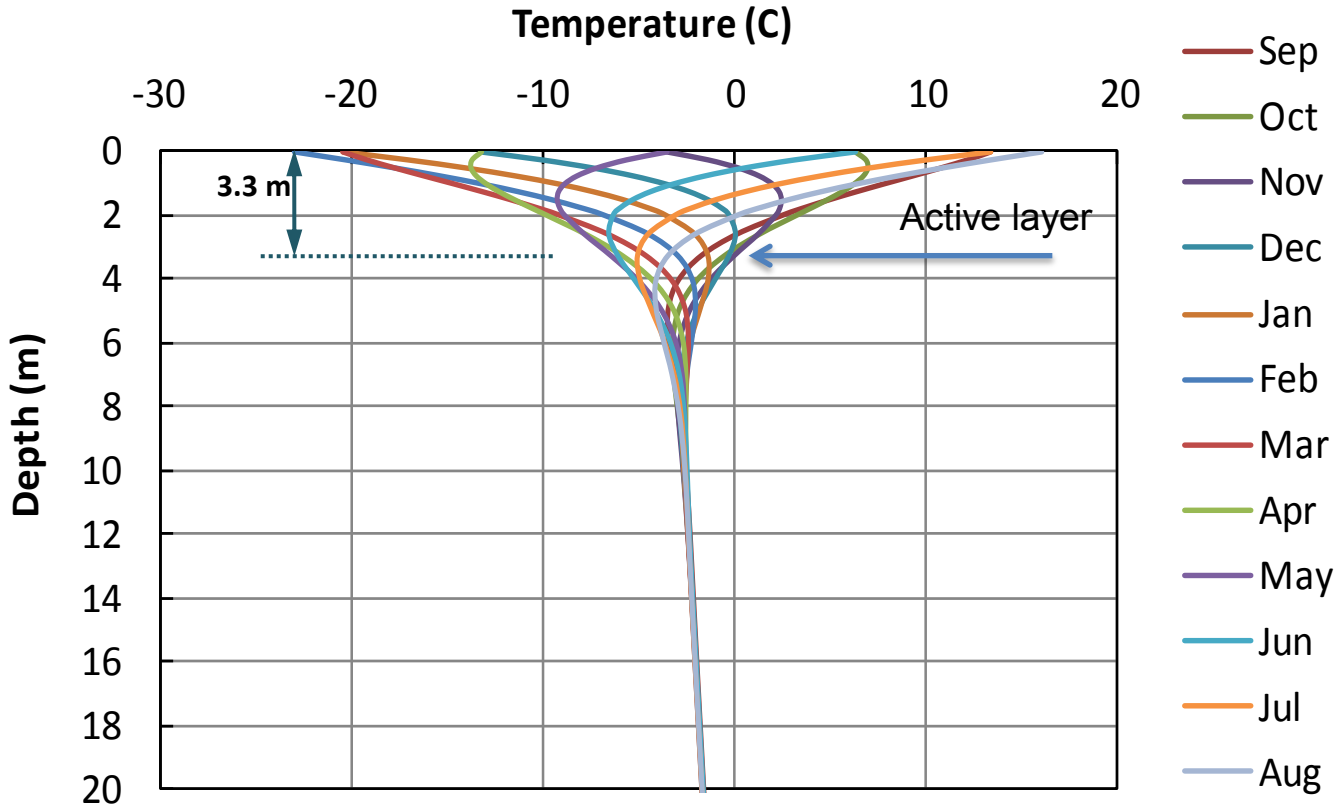
Pipeline straining calculations

Input data: Soil displacements, pipe soil interaction model (soil spring representation) pipe material properties

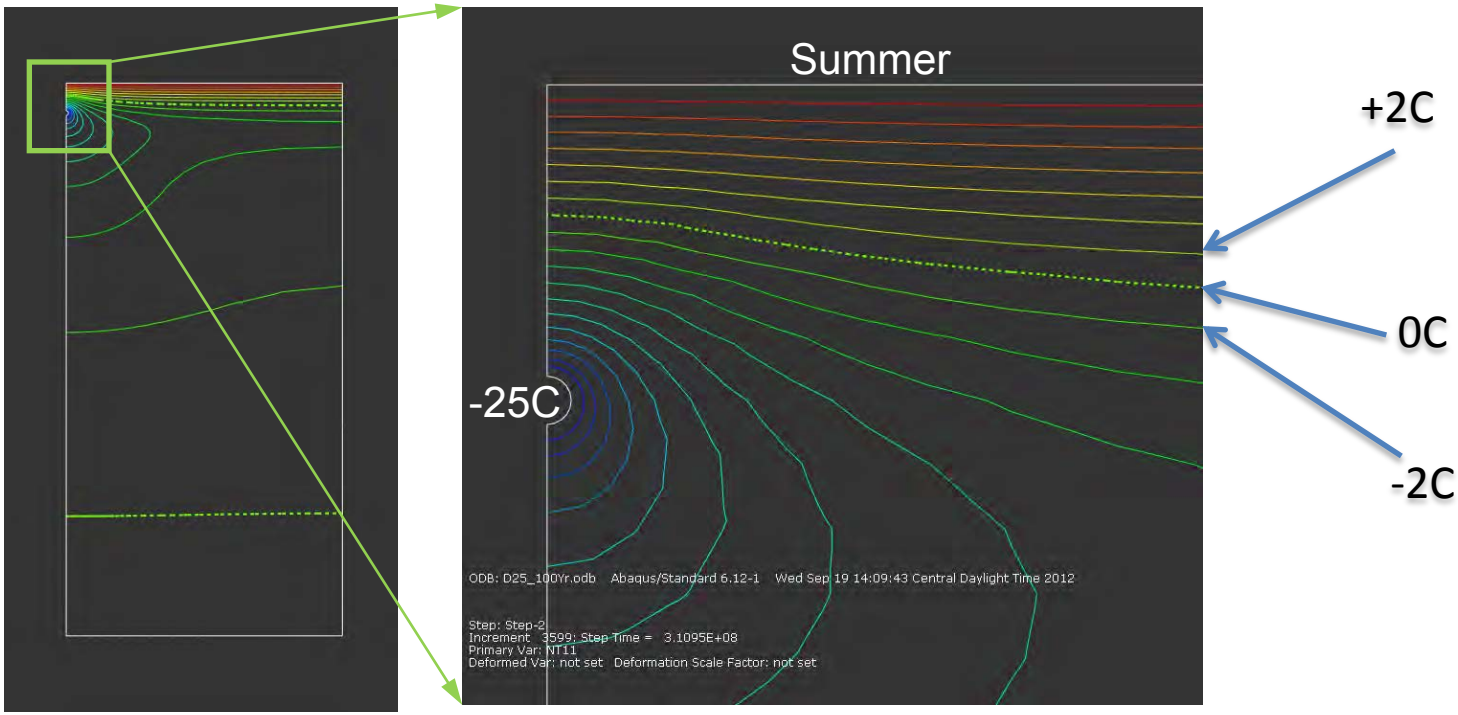
Results: Plastic strain levels in the pipeline.

… before Pipe Operation

- the soil temperature profiles of the 100th year
- (whiplash curves)
- active layer subject t freezing/ thawing



… after Pipe Operation (Summer time)



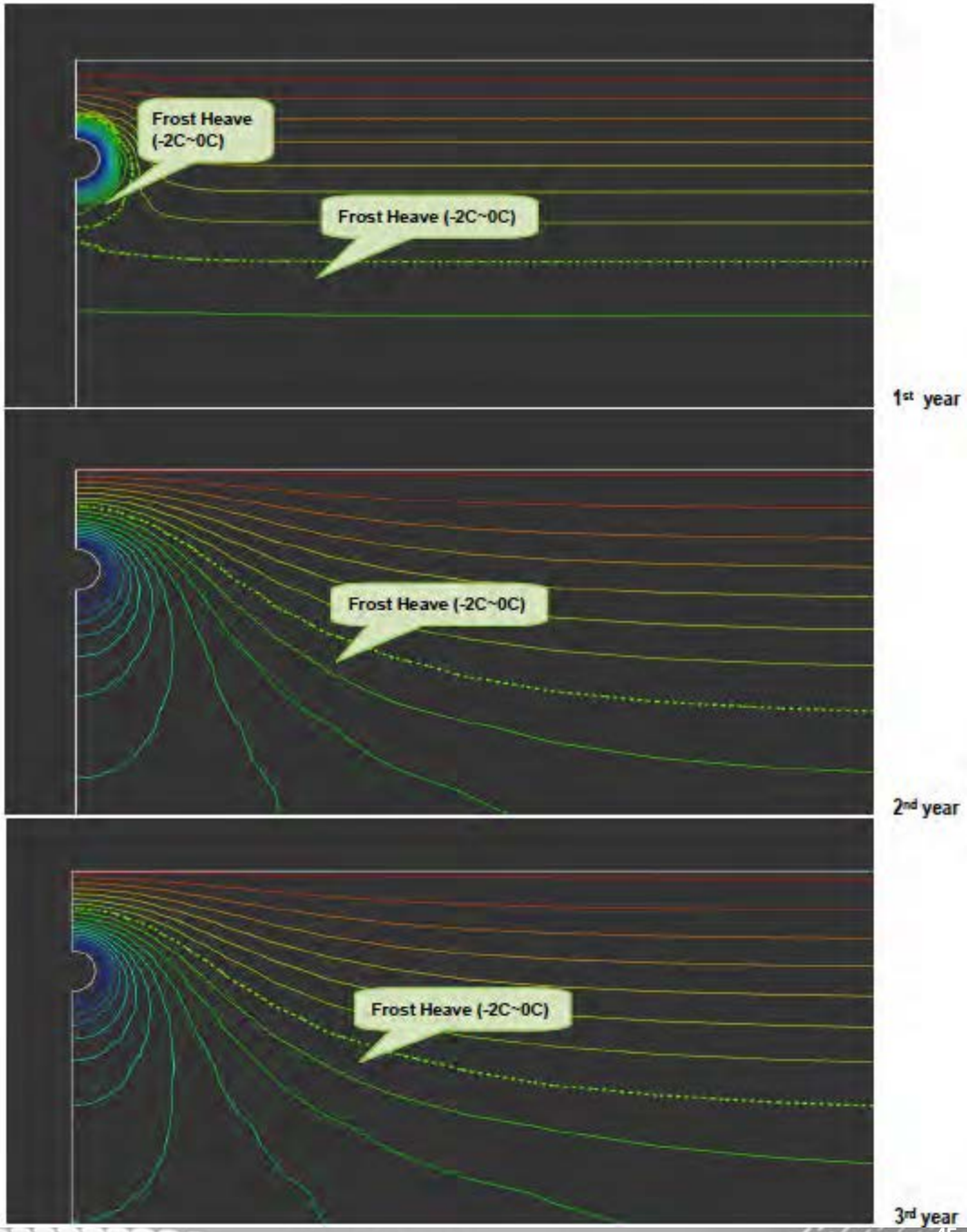
Isothermals of Typical Summer Condition - Pipe inner side temperature of -25°C (2.5 m Burial Depth)

- Freezing Thawing for several years Pipe temp = -25C

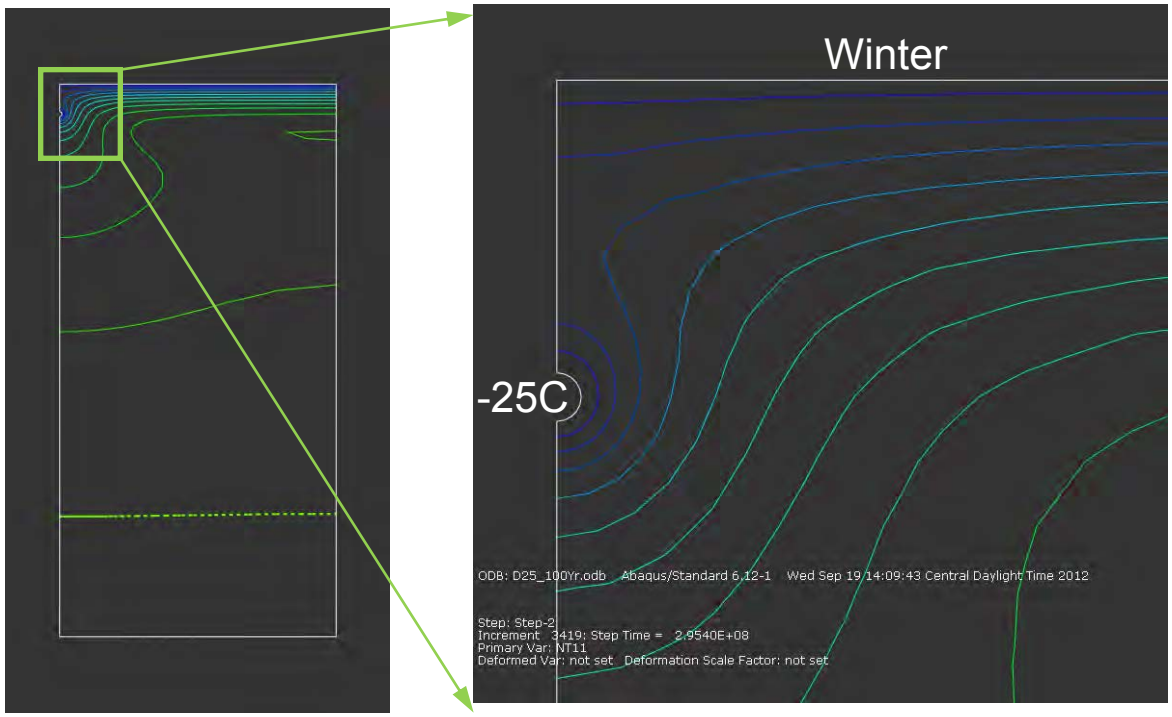
- most of the frost heave occurs between the temperatures of 0°C and -2°C

- pipe frost upheaval will decrease with years of operation

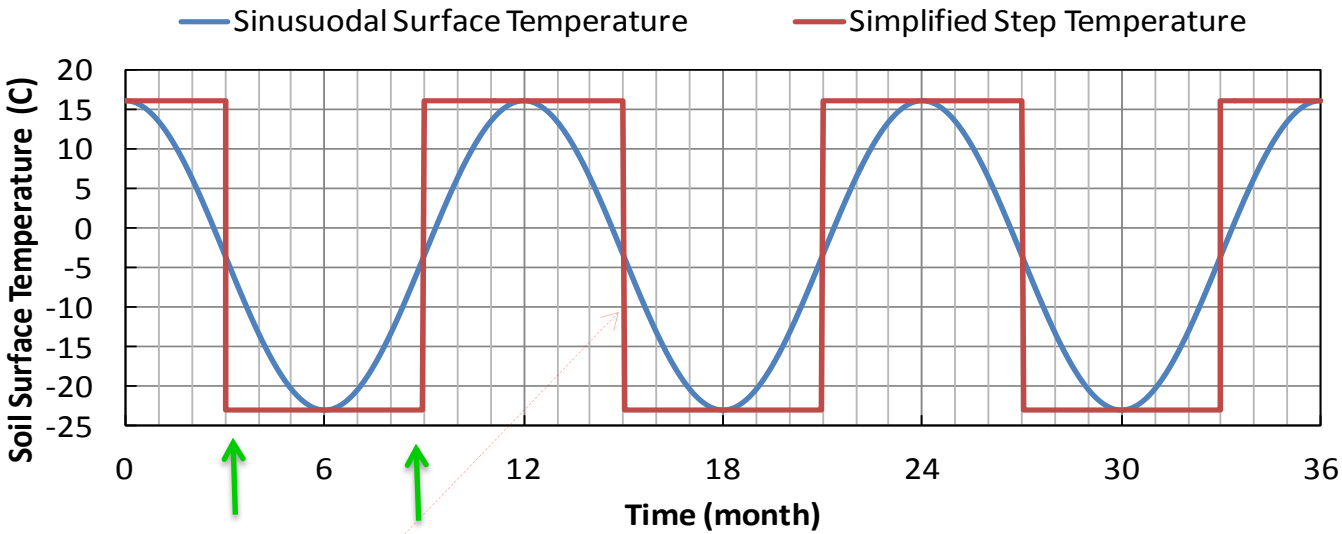
- reduction will be quicker and larger for -25°C to -10°C, while slower and lower reduction will occur in the pipe lengths with warmer temperatures (-5°C to -2°C).



… after Pipe Operation (Winter time)



Isothermals of Typical Winter Conditions - Pipe inner side temperature of -25°C (2.5 m Burial Depth)



Surface Temperature for Frost Heave Analysis

Step approximation required due to numerical instabilities

Surface = +1C, Pipe = -25C

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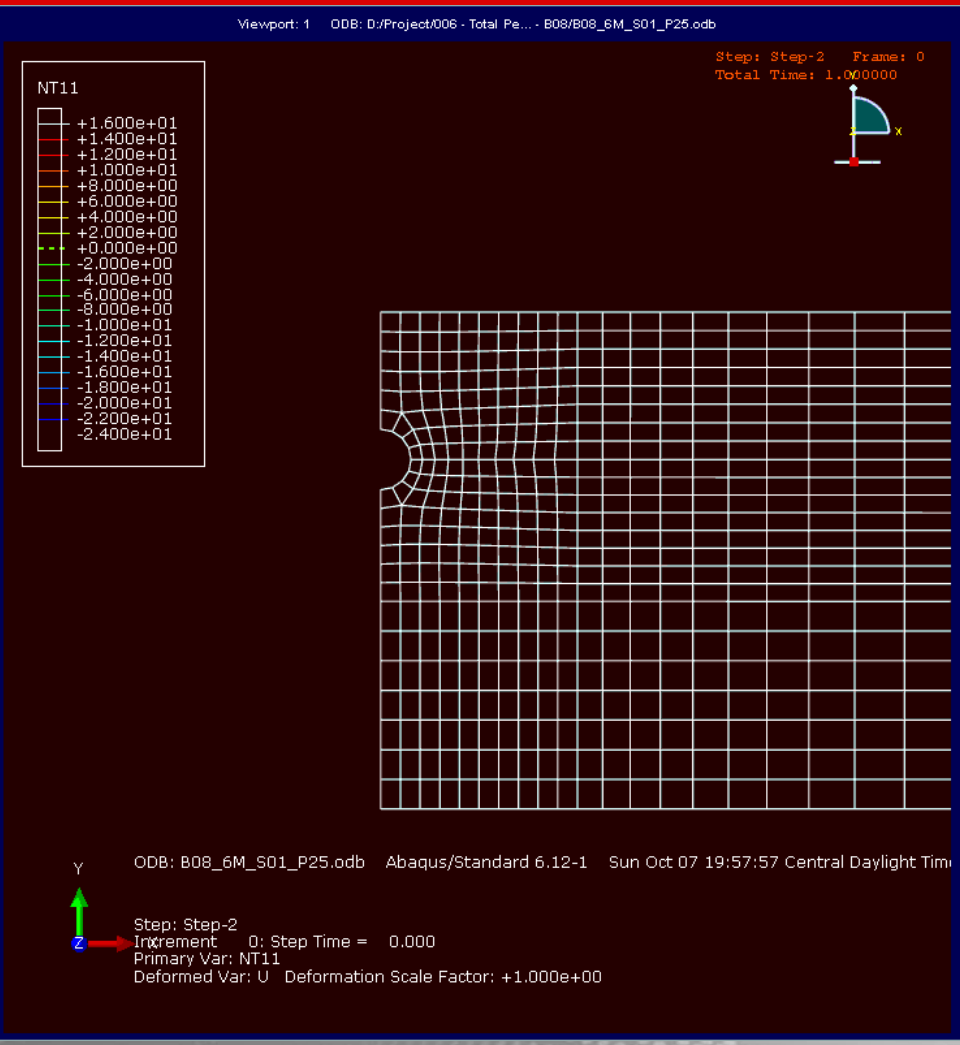

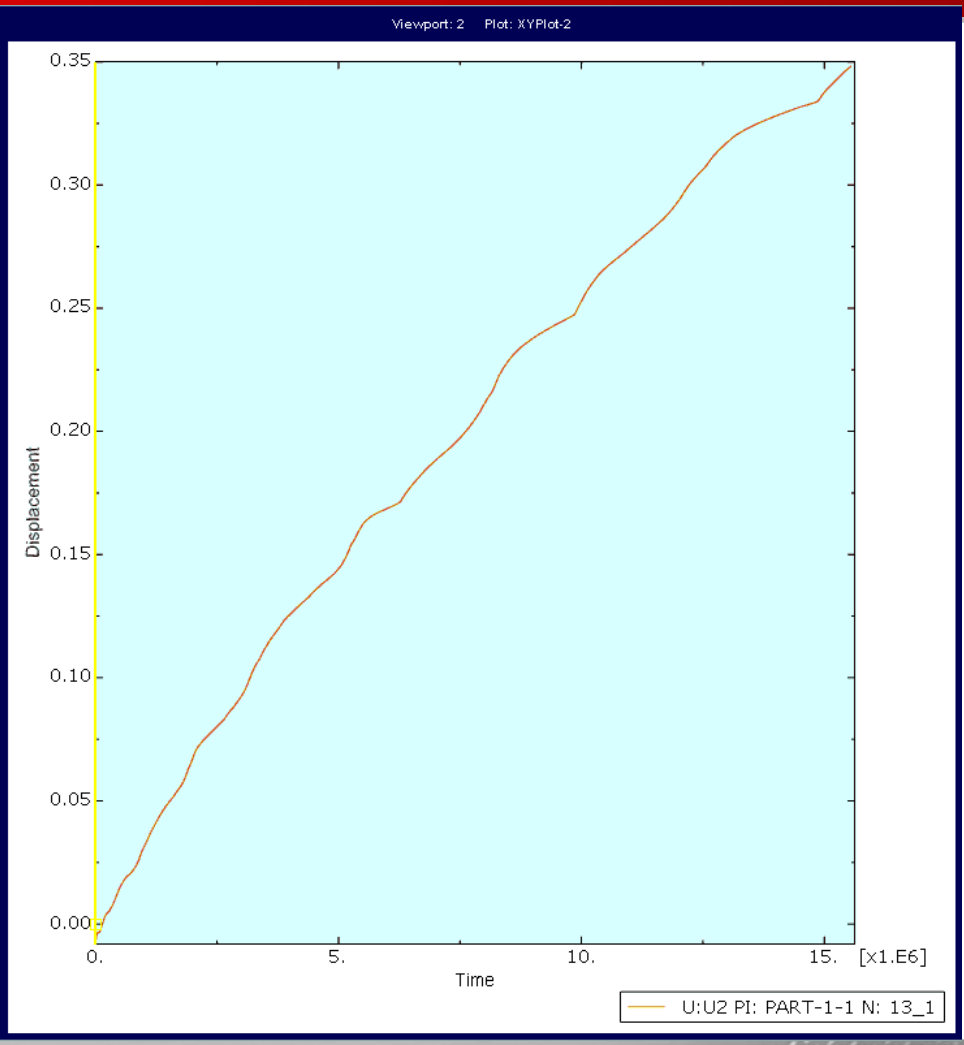

Surface = -23C, Pipe = -10C

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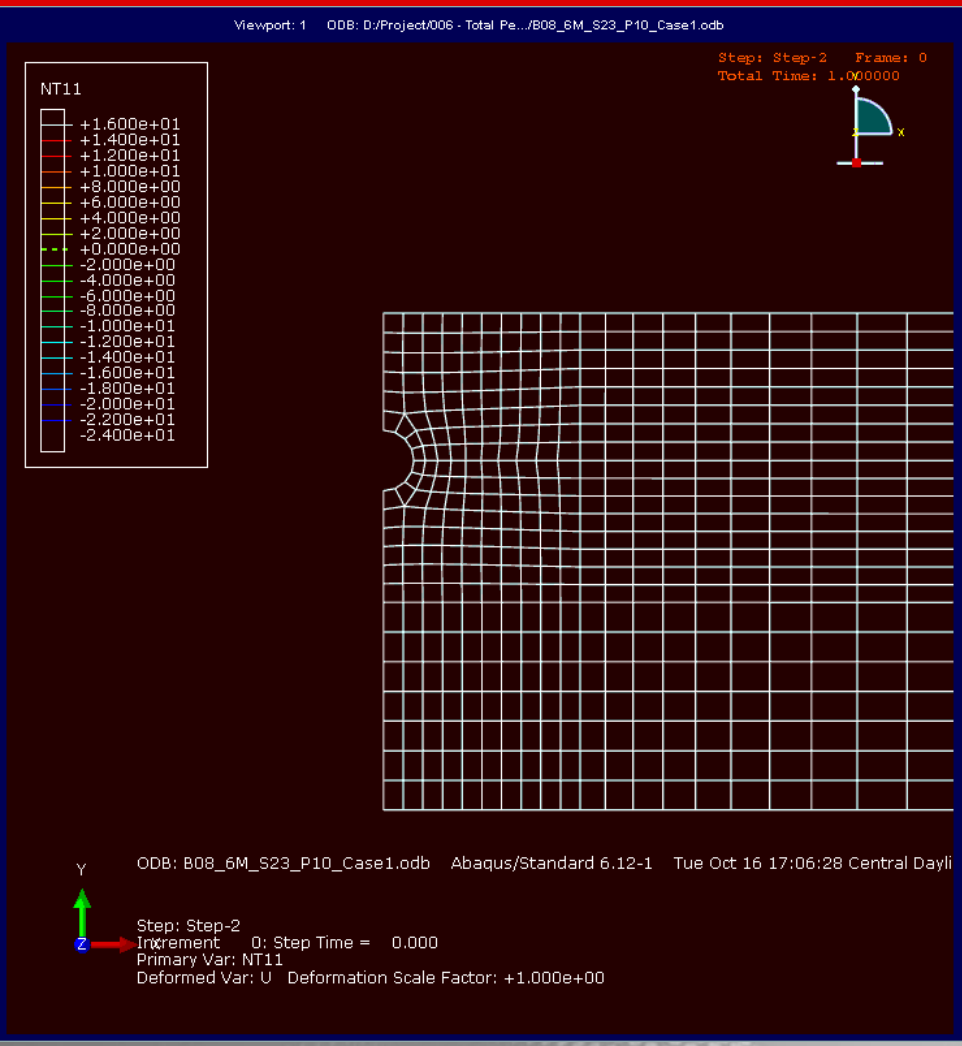

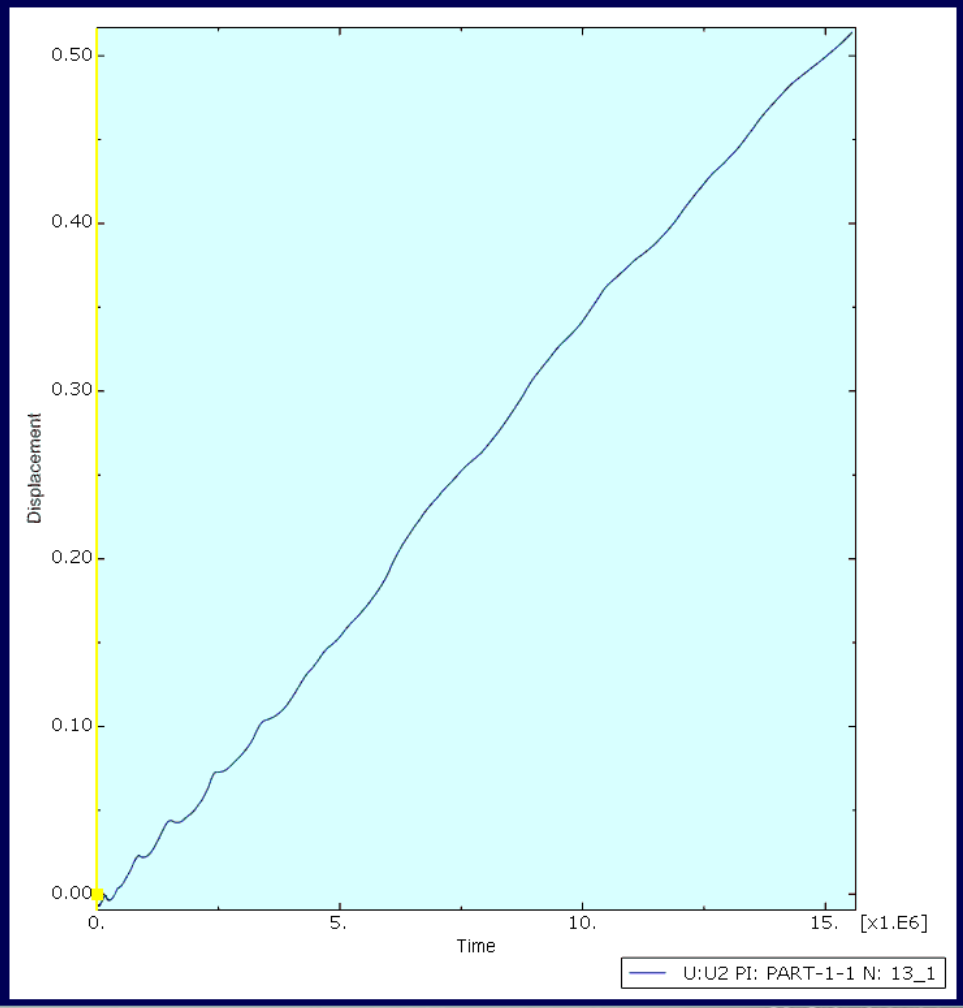

Frost heave modeling - Results

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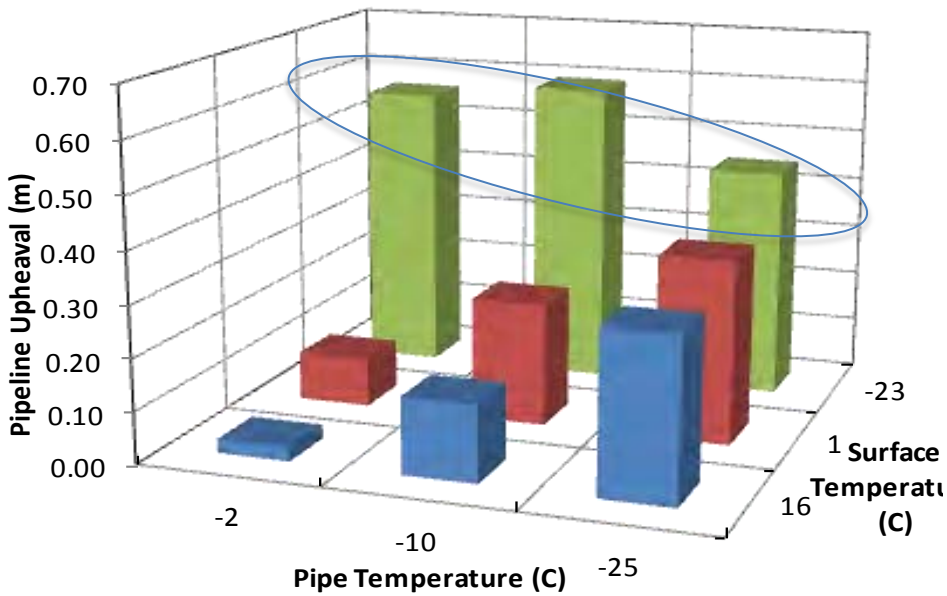
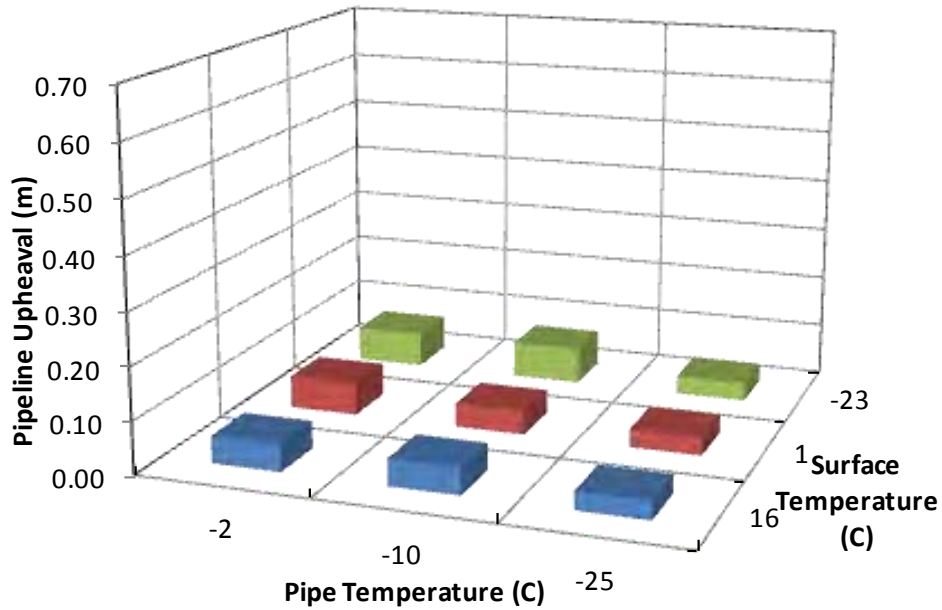


Burial Depth = 0.8 m



Burial Depth = 2.5 m

- Surface temperature has an influence for 0.8 m burial depth.
- 2.5 meters burial depth strongly decrease the frost heave susceptibility whatever the value of surface temperature.
- Circled values are conservative – pipe is pushed upward due to shear interlocking between pipe and surrounding frozen soils

Pipe straining - Assumptions

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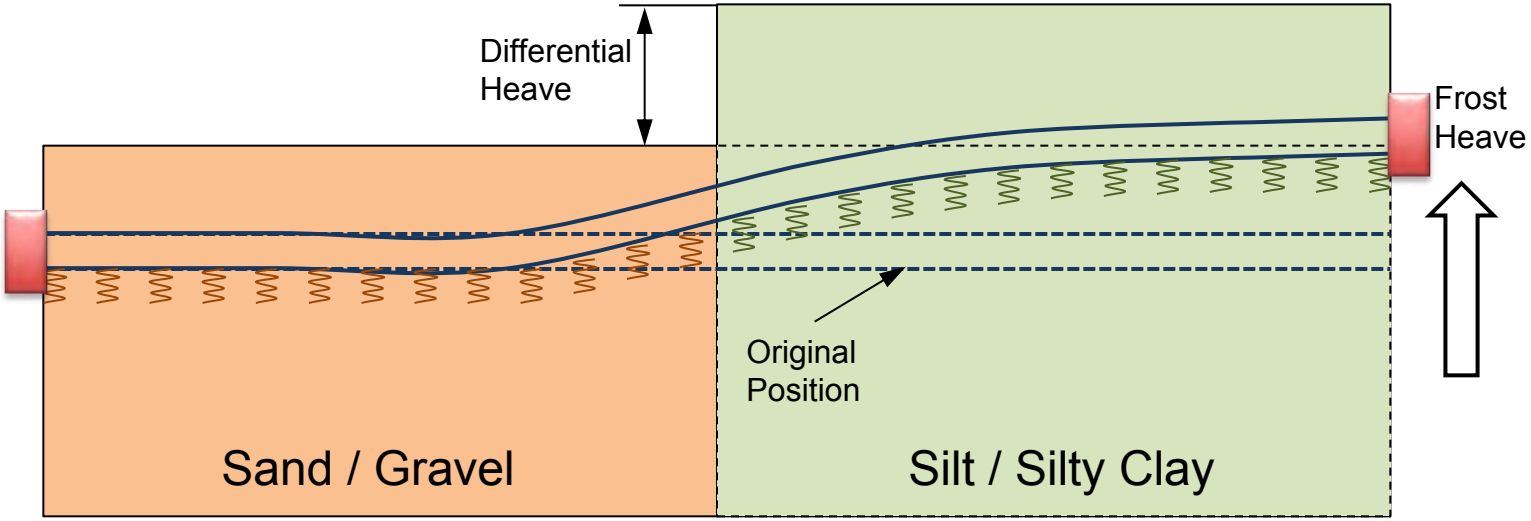

- Frost heave occurs vertically in the frost susceptible silt/silty clay section.
- Frost heave is ignored in the frost non-susceptible sand/gravel section.
- Pipeline is axially constrained on both ends of the model.
- Transition zone of sand/gravel to silt/silty clay is short, and the frost heave in one section of soil is independent of the other.

Pipe straining - Results

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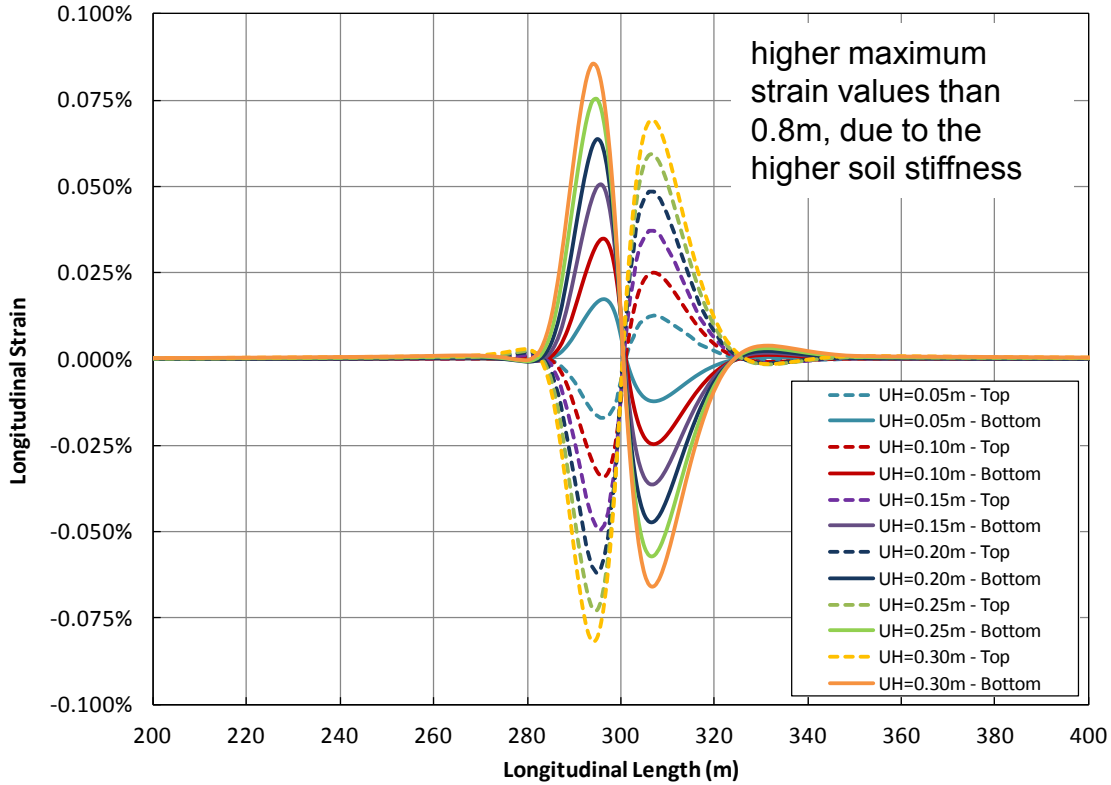


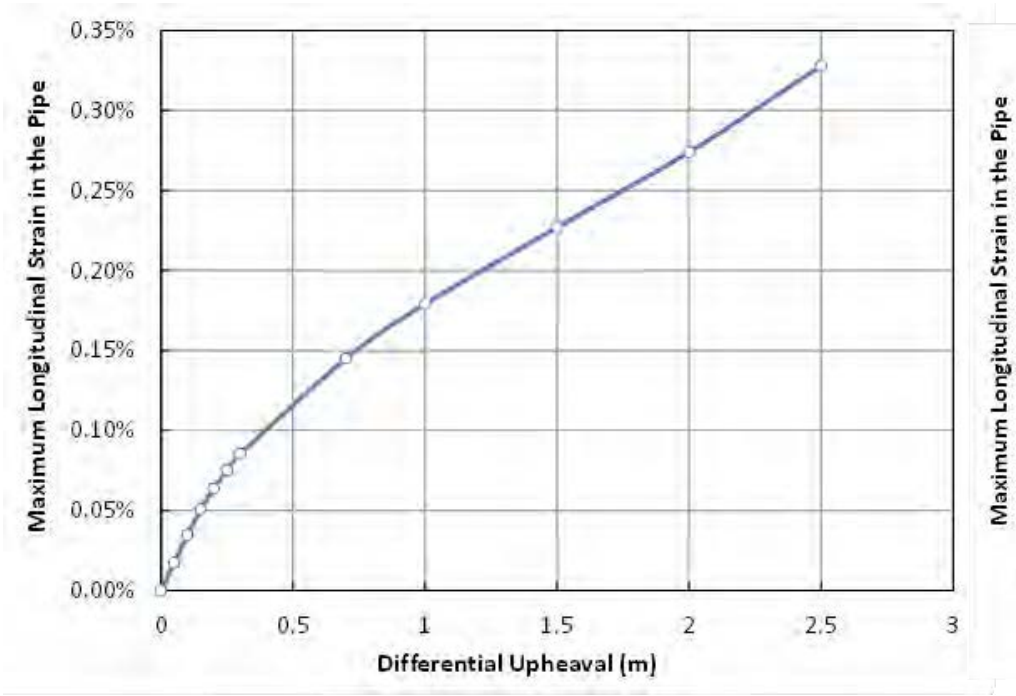
Burial Depth = 2.5 m

- Relatively soft springs
- Flowline deformation about 60 m
- Low strain values

Pipe straining - sensitivity

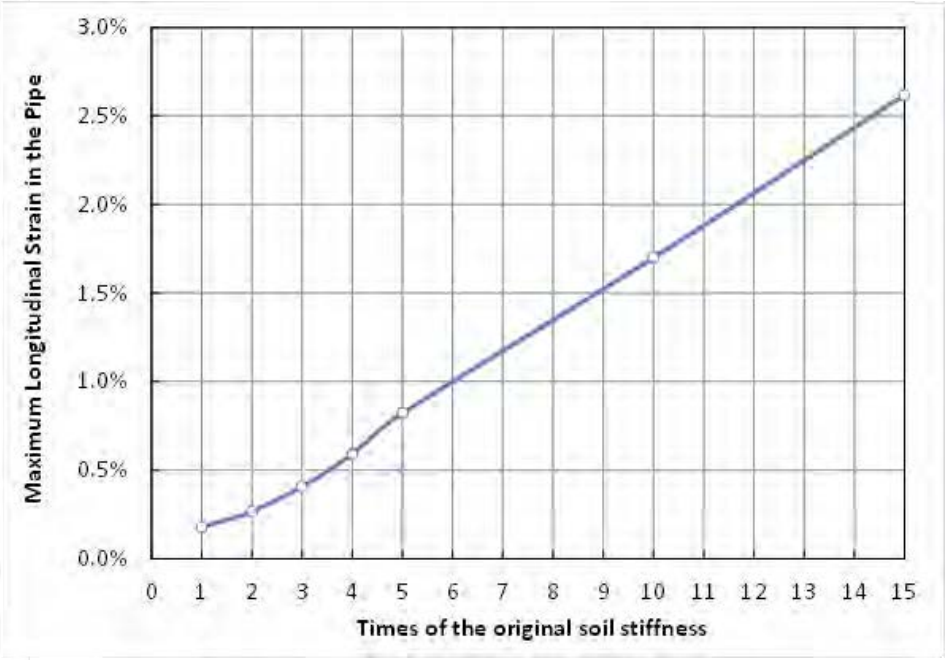
Wood Group kenny

Increasing differential uphave



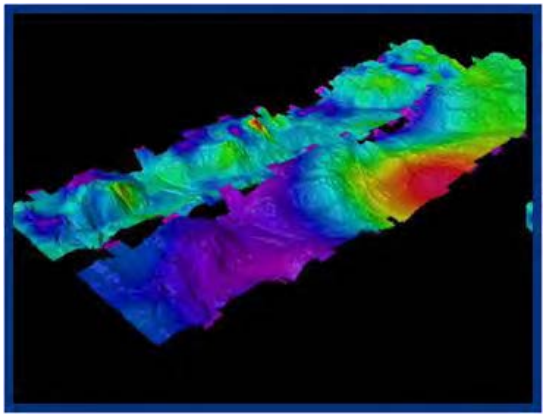
Burial Depth = 0.8 m

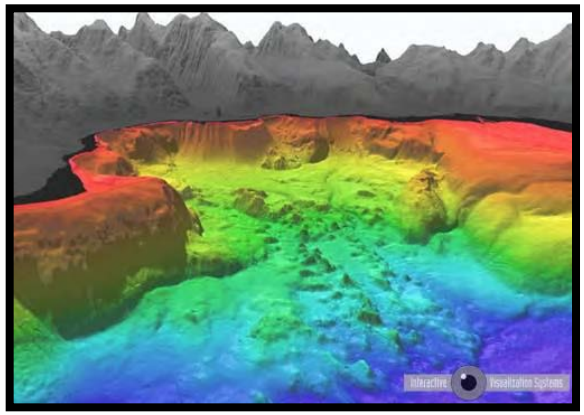
Use stiffer springs

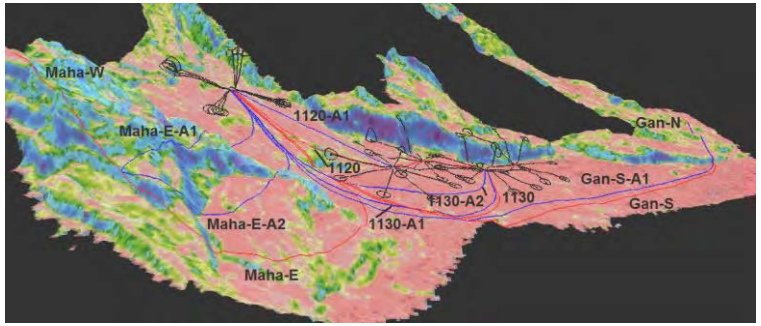


Burial Depth = 0.8 m

Conclusions







Closing Remarks

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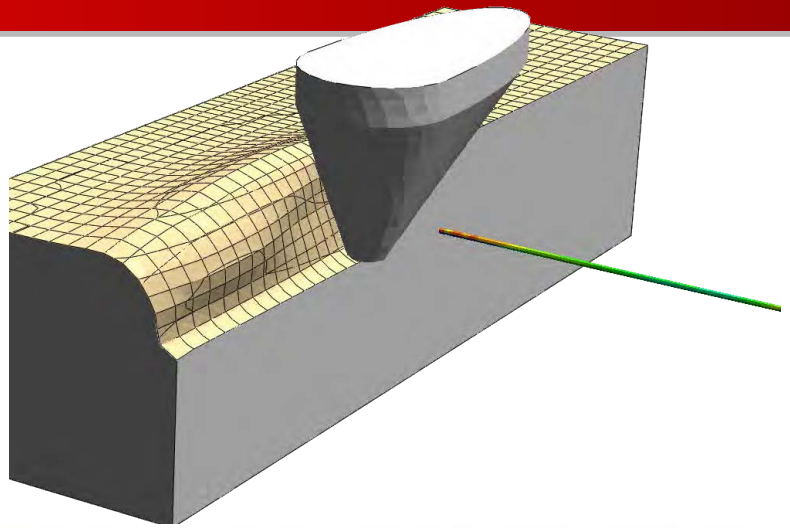
- Arctic Challenges &
  Challenges for Pipelines
- Finite Element Analysis Tools
- Optimized Trench Depth
- Reduce un-necessary conservatism
- Viable 'Cost-Effective' Solution



- "world energy demand will grow by 55% by 2030. …..we are still heading for a fossil future – 84% of the increase to come from oil, gas, and coal"

Nobuo Tanaka, executive director of the IEA. 26 Aug 2008

- Arctic developments are inevitable, let's be ready!

Images Credit

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- S. Kenny et al
- A. Nobahar et al
- I. Konuk et al
- A. Nogueira et al
- M. Paulin et al
- P. Liferov
- Tecnomare S.p.A.
- Been et al
- CNR

Related Publications

Wood Group kenny

- Jukes, P., Eltaher, A., Abdalla, B., and Duron, B. "The Design and Simulation of Arctic Subsea Pipelines", Russia Offshore, 3rd Annual Meeting, Moscow, Feb 2008.
- Jukes, P., Eltaher, A., Abdalla, B., and Duron, B. "The Design and Simulation of Arctic Subsea Pipelines – Ice Gouging Formulations", 4th annual Arctic Oil & Gas conference, Oslo, Norway, April 2008.
- Abdalla, B., Jukes, P., Eltaher, A., and Duron, B. "The technical Challenges of Designing Oil and Gas Pipelines in the Arctic", Oceans' 08 MTS/IEEE, Quebec City, Quebec, Canada, September 2008.
- Abdalla, B., Pike, K., Eltaher, A., Jukes, P., and Duron, B. "Validation of a FEA model for the Ice Scour Pipe Interaction using the CEL Method", Russia Offshore 4th Annual Meeting, Moscow, Russia, February 2009.
- Abdalla, B., Pike, K., Eltaher, A., Jukes, P., and Duron, B. "Development and Validation of a Coupled Eulerian Lagrangian Finite Element Ice Scour Model", OMAE, Honolulu, Hawaii, May 31 – June 5, 2009
- Xu, J., Abdalla, B., Eltaher, A., and Jukes, P. "Permafrost Thawing-Pipeline Interaction Advanced Finite Element Model", OMAE, Honolulu, Hawaii, May 31 – June 5, 2009
- Abdalla, B., Pike, K., Eltaher, A., and Jukes, P. "A Coupled Eulerian Lagrangian Finite Element Model for Ice-Soil-Pipe Interaction", ISOPE, Osaka, Japan, June 21-26, 2009.
- Abdalla, B., Xu, J., Eltaher A., and Jukes, P. "Three Dimensional Finite Element Model for Permafrost-Pipe Interaction", POAC, Lulea, Sweden, June 9-12, 2009.
- B. Abdalla, J. Xu, Advanced FE modeling of pipeline-permafrost interaction, Proceedings of the 20th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC), June 2009, Luleå, Sweden
- J. Xu, A. Eltaher and P. Jukes, Warm pipeline in permafrost – a sensitivity study of the major thermal properties, ASME – OMAE, Shanghai, China, June 2010.
- P. Jukes, A. Eltaher, J. Xu and B. Singh, The Challenges of Arctic oil and gas pipelines, and the use of advanced finite element analysis, ISOPE, Hawaii, 2011.
- J. Xu, A. Eltaher and P. Jukes, Three-dimensional FE model for pipeline in permafrost with thermosyphon protection, Arctic Technology Conference, OTC 22098, Houston, USA, February, 2011.
- J. Xu, A. Eltaher and P. Jukes, Ice sculptures, Offshore Engineer, July 2010, Pages 44-45
- J.Xu, B. Abdalla, etc. Arctic pipelines strain demand prediction, OMAE, Paris, 2013
- B. Abdalla, J.Xu, and V. Gaffard, Numerical simulation of frost heave in arctic pipeines, ISOPE, Anchorage, 2013.

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Thank You for Your Attention

Questions?

APPENDIX DD

PIPELINE RISK ASSESSMENT ESSENTIAL ELEMENTS WORK SHOP

Pipeline Risk Assessment Essential Elements

Sept 2013

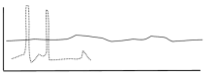
WKM

Meeting

The Basics – PL Risk Assessment

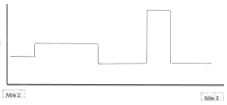
Objective:

Understand the essential elements of an effective risk assessment



Agenda
- Background
- Regulations/standards
- Inspecting a Risk Assessment
  - What to look for
  - Essential Elements

	IndexScore
depth cover	shallow = 8 pts
wrinkle bend	yes = 6 pts
coating condition	fair = 3 pts
soil	moderate = 4 pts



2

Bellingham, WA 1999

Appomattox, VA 2008

San Bruno, CA 2010

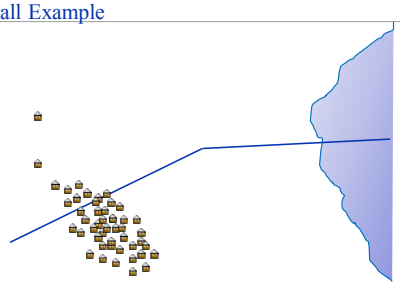
Kalamazoo River, MI 2010

Carlsbad, NM 2000

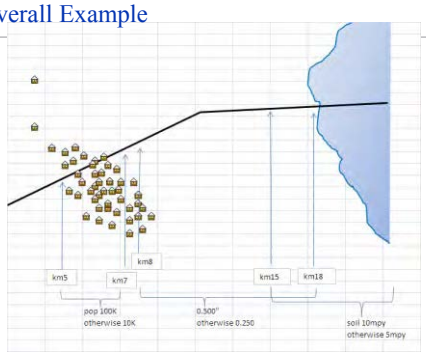
Mayflower, AR 2013

Sample Assessment

Overall Example



Overall Example



Overview Data Collection

beg	end	event	code	Units
0	8	pipe wall		inches
8	18	pipe wall		inches
18	20	pipe wall		inches
0	15	soil		mpy
15	20	soil		mpy
0	5	pop		$/event
5	7	pop		$/event
7	20	pop		$/event
0	20	coat/CP		% effective

How to segment?

Overview Risk Calcs

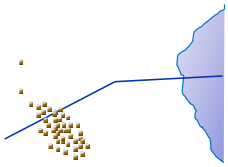
beg	end	pipe_wall	soil	pop	mpy mit	TTF, yrs	PoF, yr1	EL, $/yr
0	5	0.25	5	10000	0.5	500	0.002	$ 20
5	7	0.25	5	100000	0.5	500	0.002	$ 200
7	8	0.25	5	10000	0.5	500	0.002	$ 20
8	15	0.5	5	10000	0.5	1000	0.001	$ 10
15	18	0.5	10	10000	1	500	0.002	$ 20
18	20	0.25	10	10000	1	250	0.004	$ 40
							0.013	$ 310
				coat/CP	90%			

CoF = pop
TTF = pipe_wall / mpy mit
PoF = 1 / TTF
EL = PoF x CoF

Overall Example

1.3% PoF Corr Ext for 20 km
EL = $310 / km-year

Demonstrations of
Efficient data collection
Data management
Dynamic segmentation
Risk estimates
Risk aggregation



Background

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Key Concepts

- Risk = (event likelihood) X (event consequence)
- Probability = degree of belief
- Risk assessment -- risk management
- Management = choices in resource allocation

Reality Check

- RM is not new; requires RA
- Risk-based decision-making is complex
  - Because the real world is complex, measuring risk is complex
    - 200+ variables & 200+ calculations for every inch of pipe
    - real factors, real considerations
  - RM is even more complex than RA
- Dealing with the complexity is worthwhile
  - increases understanding
  - shows full range of options; many opportunities to impact risk
  - cheaper than prescriptive 'solutions'
  - Improves decision-making

Reality Check, Part Two

If you put tomfoolery into a computer, nothing comes out of it but tomfoolery. But this tomfoolery, having passed through a very expensive machine, is somehow ennobled and no-one dares criticize it.

- Pierre Gallois

The Illusion of Knowledge

PL RA Methodologies

ASME B31.8s
- Subject Matter Experts
- Relative Assessments
- Scenario Assessments
- Probabilistic Assessments

Probabilistic
Mechanistic
Deterministic

Qualitative
Quantitative
Semi-quantitative

QRA
PRA
Indexing
Scoring

	Index/Score
depth cover	shallow = 8 pts
wrinkle bend	yes = 6 pts
coating condition	fair = 3 pts
soil	moderate = 4 pts

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IMP RA Regulations & Standards

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Pertinent Regulatory/Standards

- 49 CFR Parts 192, 195
- Advisory Bulletin (Jan 2011)
- Public Presentations (June 2011)
- ASME B31.8s
- API STANDARD 1160
  - Managing Pipeline System Integrity
- API Risk Based Inspection (RBI) RP's
- NACE DA RP's
- CSA Z662
  - Annex O
- ISO

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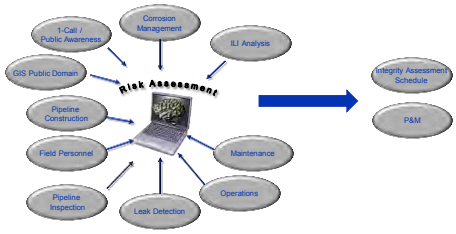
Gas IM Rule Objectives

- Prioritize pipeline segments
- Evaluate benefits of mitigation
- Determine most effective mitigation
- Evaluate effect of inspection intervals
- Assess the use of alternative assessment
- Allocate resources more effectively

ASME B31.8S, Section 5

RA is the Centerpiece of IMP



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B31.8S Threat Categories

- ASME B31.8 supplement considers 3 categories of threat:
  - *Time dependent* – may worsen over time; require periodic reassessment
  - *Time stable* – does not worsen over time; one-time assessment is sufficient (unless conditions of operation change)
  - *Time independent* – occurs randomly; best addressed by prevention

B31.8S Threat Categories: Time Dependent Threats

- External corrosion
- Internal corrosion
- Stress-corrosion cracking (SCC)

Threat Categories:
~~Time Stable Threats~~ Resistance

- Manufacturing-related flaws in
  - Pipe body
  - Pipe seam
- Welding / Fabrication-caused flaws in
  - Girth welds
  - Fabrication welds
  - Wrinkled / buckled bend
  - Threads / couplings
- Defects present in equipment
  - Gaskets, O-rings
  - Control / relief devices
  - Seals, packing
  - Other equipment

B31.8S Threat Categories: Time Independent (Random) Threats

- Third-party/Mechanical damage
  - Immediate failure
  - Delayed failure (previously damaged)
  - Vandalism
- Incorrect operations
- Weather related
  - Cold weather
  - Lightning
  - Heavy rain, flood
  - Earth movement

Myths: Data Availability vs Modeling Rigor

Myth:

- Some RA models are better able to accommodate low data availability

Reality:

- Strong data + strong model = accurate results
- Weak data + strong model = uncertain results
- Weak data + weak model = meaningless results

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Myth: QRA / PRA Requirements

Myth:

- QRA requires vast amounts of incident histories

Reality:

- QRA 'requires' no more data than other techniques
- All assessments work better with better information

- Footnotes:
  - Some classical QRA does over-emphasize history
  - Excessive reliance on history is an error in any methodology

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ASME B31.8s

- Subject Matter Experts
- Relative Assessments
- Scenario Assessments
- Probabilistic Assessments

Confusion: tools vs models

PL Risk Modeling Confusion

Types of Models
- Absolute Results
- Relative Results

~~ASME B31.8s~~
~~•Subject Matter Experts~~
~~•Relative Assessments~~
~~•Scenario Assessments~~
~~•Probabilistic Assessments~~

Ingredients in All Models
- Probabilistic methods
  - Scenarios, trees
  - Statistics
- SME (input and validation)

~~Qualitative~~
~~Quantitative~~
~~Semi-quantitative~~
~~Probabilistic~~

IMP Objectives vs RA Techniques

Objectives

(a) prioritization of pipelines/segments for scheduling integrity assessments and mitigating action
(b) assessment of the benefits derived from mitigating action
(c) determination of the most effective mitigation measures for the identified threats
(d) assessment of the integrity impact from modified inspection intervals
(e) assessment of the use of or need for alternative inspection methodologies
(f) more effective resource allocation

Techniques
- ~~Subject Matter Experts~~
- ~~Relative Assessments~~
- ~~Scenario Assessments~~
- Probabilistic Assessments

Numbers Needed
- •Failure rate estimates for each threat on each PL segment
- •Mitigation effectiveness for each contemplated measure
- •Time to Failure (TTF) estimates *(time-dep threats)*

Inspecting a Risk Assessment

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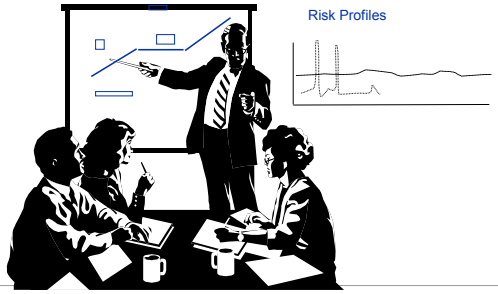
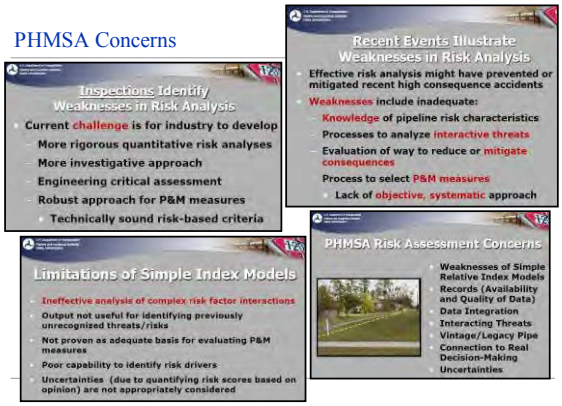
Judging a Risk Assessment

- "Technically justifiable . . ."
- "Logical, structured, and documented…."
- "Assurance of completeness…"
- "…incorporates sufficient resolution…"
- "Appropriate application of risk factors…."
- "Explicitly accounts for…" and combines PoF and CoF factors
- "Process to validate results…"
- P&M based on risk analyses

Passing the 'Map Point' Test



PHMSA Concerns



Hearsay

- Common Complaints:

  "We've been waiting for two years to start generating results we can trust"

  "We have a risk assessment, but we can't use the results for anything"

  "We purchased a sophisticated off-the-shelf solution, but we're not really sure how it calculates risk"

  "Our risk assessment methodology was developed internally ages ago, how do we know if it's still acceptable?"

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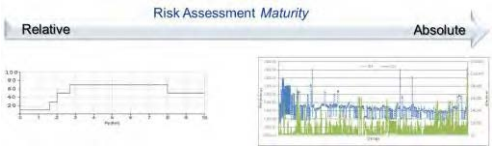
Risk Assessment Maturity



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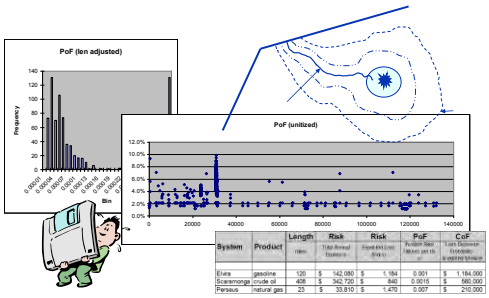
Modern Pipeline Risk Assessment



System	Product	Length (miles)	Risk: Total Annual Losses	Risk: Expected Loss (\$/mile)	PoF: Pipeline Failure (failures per mi. yr)	CoF: Total Expected Consequence (consequence/failure)
Elara	gasoline	120	\$ 142,080	\$ 1,184	0.001	\$ 1,184,000
Scaramonga	crude oil	408	\$ 342,720	\$ 840	0.0015	\$ 560,000
Perseus	natural gas	23	\$ 33,810	\$ 1,470	0.007	\$ 210,000

Essential Elements

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Essential Elements

- The Essential Elements are meant to
  - Be common sense ingredients that make risk assessment meaningful, objective, and acceptable to all stakeholders
  - Be concise yet flexible, allowing tailored solutions to situation-specific concerns
  - Lead to *smarter risk assessment*
- The elements are meant to supplement, not replace, guidance, recommended practice, and regulations already in place

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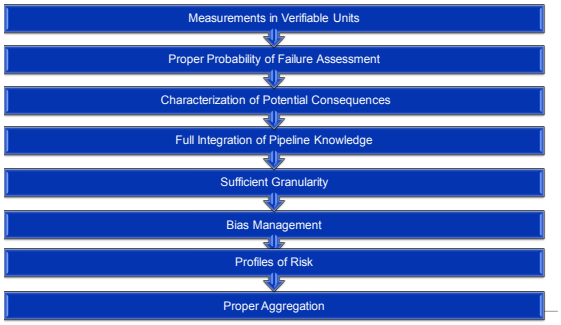
The Essential Elements



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Measure in Verifiable Units

- Must include a definition of "Failure"
- Must produce *verifiable* estimates of PoF and CoF in commonly used measurement units
- PoF must capture effects of length and time
- Must be free from intermediate schemes (scoring, point assignments, etc)

"Measure in verifiable units" keeps the process transparent by expressing risk elements in understandable terms that can be calibrated to reality

Absolute Risk Values

Frequency of consequence
- Temporally
- Spatially

•Incidents per mile-year

•fatalities per mile-year

•dollars per km-decade

conseq prob

Probability of Failure Grounded in Engineering Principles

- All plausible failure mechanisms must be included in the assessment of PoF
- Each failure mechanism must have the following elements independently measured:
  - Exposure
  - Mitigation
  - Resistance
- For each time dependent failure mechanism, a theoretical remaining life estimate must be produced

Proper PoF Characterization

- Exposure: likelihood and aggressiveness of a failure mechanism reaching the pipe when no mitigation applied (ATTACK)
- Mitigation: prevents or reduces likelihood or intensity of the exposure reaching the pipe (DEFENSE)
- Resistance: ability to resist failure given presence of exposure (SURVIVABILITY)

Information Use--Exposure, Mitigation, or Resistance?

pipe wall thickness	*maintenance pigging*
air patrol frequency	*surge relief valve*
soil resistivity	*casing pipe*
coating type	*flowrate*
CP P-S voltage reading	*depth cover*
date of pipe manufacture	*training*
stress level	*SMYS*
operating procedures	*one-call system type*
nearby traffic type and volume	*SCADA*
nearby AC power lines (2)	*pipe wall lamination*
ILI date and type	*wrinkle bend*
pressure test psig	

Updating Older Risk Assessments

	~~Index/Score~~	New	Measurement/Estimate
depth cover	~~shallow = 8 pts~~	mitigation	15%
wrinkle bend	~~yes = 6 pts~~	resistance	-0.07" pipe wall
coating condition	~~fair = 3 pts~~	mitigation	0.01 gaps/ft2
soil	~~moderate = 4 pts~~	exposure	4 mpy

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Probability of Damage or Failure—Simple Math

- Probability of Damage (PoD) = exposure x (1 - mitigation)
- Probability of Failure (PoF) = PoD x (1- resistance)

  {PoF = exposure x (1 - mitigation) x (1 - resistance)}
- PoF (time-dependent) = 1 / TTF

  = exposure * (1 – mitigation) / resistance *(example only)*

Exposure, Mitigation, Resistance } PoD } PoF

PoF: Critical Aspects

Estimating Threat Exposure

- Events per mile-year (mile-yr) for time independent mechanism
  - third party
  - incorrect operations
  - weather & land movements
- MPY for degradation mechanisms
  - Ext corr
  - Int corr
  - Cracking (EAC / fatigue)

List the Exposures

Sample Exposure Estimates

- Vehicle impact; 1 mile along busy highway
  0.1 to 10 events/mile-year
- excavation; 530 ft heavy construction
  ~400 events/mile-year
- vehicle impact; 1 mile along RR
  ~0.01 events/mile-year
- power pole falling
  0.05 to 2 events/mile-year

Rates: Failures, Exposures, Events, etc

Failures/yr	Years to Fail	Approximate Rule Thumb
1,000,000	0.000001	Continuous failures
100,000	0.00001	fails ~10 times per hour
10,000	0.0001	fails ~1 times per hour
1,000	0.001	fails ~3 times per day
100	0.01	fails ~2 times per week
10	0.1	fails ~1 times per month
1	1	fails ~1 times per year
0.1	10	fails ~1 per 10 years
0.01	100	fails ~1 per 100 years
0.001	1,000	fails ~1 per 1000 years
0.0001	10,000	fails ~1 per 10,000 years
0.00001	100,000	fails ~1 per 100,000 years
0.000001	1,000,000	One in a million chance of failure
0.0000000001	1,000,000,000	Effectively, it never fails

Measuring Exposure

If one in five 100-year rainfall events causes a landslide along 528 ft of pipeline, what is the landslide exposure (in units of events per mile-year)?

Cracking

The Paris-law equation described above has the following form:

$$\frac{da}{dN} = C(\Delta K)^n \quad \left(or \log \frac{da}{dN} = \log C + n \log \Delta K \right)$$

where

$\frac{da}{dN}$ is the increase in crack depth per cycle,

C and n are constants derived either on the basis of particular fatigue-failure occurrences or from laboratory tests, and

ΔK is the stress-intensity factor calculated using the technique of Raju and Newman (Raju, unknown):

$$\Delta K = \Delta\sigma \cdot f \cdot \sqrt{\pi \frac{a}{Q}} = \Delta P \cdot \frac{D}{2t} \cdot f \cdot \sqrt{\pi \frac{a}{Q}}$$

where:

ΔP is the size (pressure range) of the pressure cycle

a is the instantaneous crack depth

f and Q are constants that depend on pipe geometry and defect length, respectively.

The constants C and n are critical to the ability to accurately forecast an appropriate retest interval. However, as will be explained, cycle aggressiveness, one key to determining susceptibility, can be evaluated using any reasonable set of constants. This is because the set of constants chosen "washes out".

Cracking (cont)

Table 4.1 Benchmark Cycle Counts—Annual

Percent SMYS	Very Aggressive	Aggressive	Moderate	Light
72%	20	4	1	0
65%	40	8	2	0
50%	100	25	10	0
45%	500	125	50	25
35%	1000	250	100	50
25%	2000	500	200	100
Total	3660	912	363	175

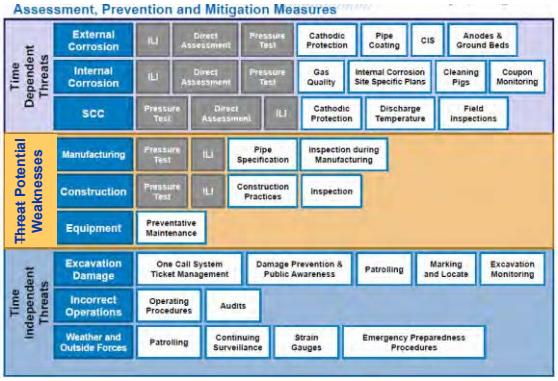
Table 4.2 Remaining Life Based on Categorized Aggressiveness

Pressure Cycle Category	Years to Failure for Various Defect Depth-to-Thickness Ratios			
	90%	70%	50%	30%
Very Aggressive	1.68	1.88	2.38	5.38
Aggressive	7.12	7.37	9.62	21.67
Moderate	18.12	19.12	25.12	56.12
Light	55.63	56.89	71.38	144.89

Table 4.3 Time to Failure Based on Test Scenarios of 1.25 x MOP and 1.39 x MOP

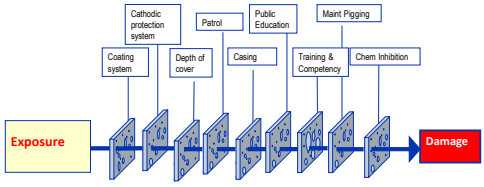
Test Stress Level	Years to Failure for Various Defect Depth to Thickness Ratios			
	90%	70%	50%	30%
1.25 x MOP	5.00	5.47	7.52	24.10
1.39 x MOP	10.32	10.62	13.79	31.08
Minimum value of 10.06 occurred for 80-percent-through defect.				

Assessment, Prevention and Mitigation Measures



Estimating Mitigation Measure Effectiveness

Strong, single measure
Or
Accumulation of lesser measures



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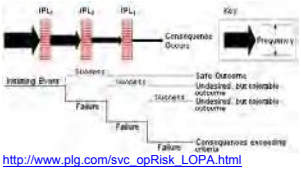
Reported Mitigation Benefits

Mitigation	Impact on risk
Increase soil cover	56% reduction in mechanical damage when soil cover increased from 1.0 to 1.5 m
Deeper burial	25% reduction in impact failure frequency for burial at 1.5 m; 50% reduction for 2m; 99% for 3m
Increased wall thickness	90% reduction in impact frequency for >11.9-mm wall or >9.1-mm wall with 0.3 safety factor
Concrete slab	Same effect as pipe wall thickness increase
Concrete slab	Reduces risk of mechanical damage to "negligible"
Underground tape marker	60% reduction in mechanical damage
Additional signage	40% reduction in mechanical damage
Increased one-call awareness and response	50% reduction in mechanical damage
Increased ROW patrol	30% reduction in mechanical damage
Increased ROW patrol	30% heavy equipment-related damages; 20% ranch/farm activities; 10% homeowner activities
Improved ROW, signage, public education	5–15% reduction in third-party damages

Level of Protection Analysis

LOPA
ANSI/ISA-84.00.01-2004, IEC 61511 Mod



http://www.plg.com/svc_opRisk_LOPA.html

SIL selection requirements of the American National Standards Institute (ANSI)/Instrumentation, Systems, and Automation Society (ISA) standard 84.00.01 – 2004

Measuring Mitigation

Strong, single measure

Or

Accumulation of lesser measures

Mitigation % = 1 - (remaining threat)

Remaining threat = (remnant from mit1) AND (remnant from mit2) AND (remnant from mit3) …

Measuring Mitigation

Exposure	Mitigation	Reduction	freq damage	prob damage
events/mi-yr			events/mi-yr	Prob/mi-yr
10	90.0%	10	1	63.2%
10	99.0%	100	0.1	9.52%
10	99.9%	1000	0.01	1.00%

Mitigation % = 1-[(1-mit1) x (1-mit2) x (1-mit3)…]

In words:

Mitigation % = 1 - (remaining threat)

Remaining threat = (remnant from mit1) AND (remnant from mit2) AND (remnant from mit3) …

Measuring Mitigation

Mitigation % = 1-[(1-mit1) x (1-mit2) x (1-mit3)…]

What is cumulative mitigation benefit from 3 measures that independently produce effectiveness of 60%, 60%, and 50%?

Measuring Mitigation

What is the independent mitigation effectiveness ranges of:

Patrol

One-Call

Depth of cover

Public Education

Signs/markers

OR/AND Gate Mitigation Examples

- Coating = 60% effective; CP is 80% effective; how effective is corrosion control?
- P/S distance is 40%; P/S age is 80%; P/S reading/criteria is 99%; what is CP effectiveness?

"OR" Gate

- Better reflects reality
  - Probability theory of accumulating impacts
  - Avoid masking threats
  - Captures single, large impacts as well as
  - Accumulation of lesser effects
  - Shows diminishing returns
  - No pre-set, pre-balanced list of variables
    - Easy to add new variables
    - No re-balancing needed when new info arrives

Damage Vs Failure

- Probability of damage (PoD) = *f* (exposure, mitigation)
- Probability of failure (PoF) = *f* (PoD, resistance)

Exposure
Mitigation } PoD
Resistance } PoF

Resistance

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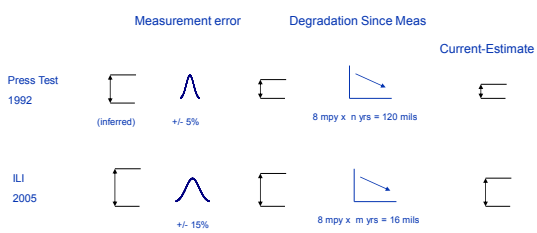
Figure 1. Photographs of the two fracture pipe segments and crater. Photograph on the upper page is looking north. Composite photograph at the lower portion of the page is looking west. The origin of the fracture was determined to be located in the area indicated by arrow "O". General direction of fracture propagation is indicated by white unmarked arrows.

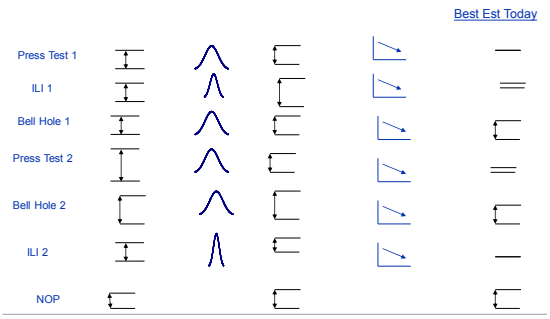
Estimating Resistance

- Pipe spec (original)
- Historical issues
  - Low toughness
  - Hard spots
  - Seam type
  - Manufacturing
- Pipe spec (current)
  - ILI measurements
  - Calcs from pressure test
  - Visual inspections
  - Effect of estimated degradations
- Required pipe strength
  - Normal internal pressure
  - Normal external loadings

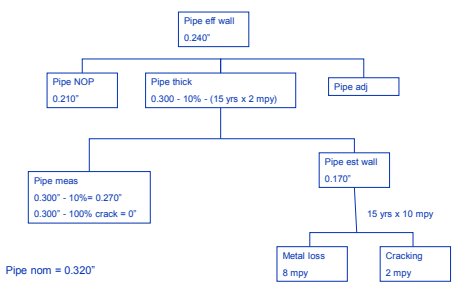
Best Estimate of Pipe Wall Today



Best Estimate of Pipe Wall Today



Pipe Wall Available



Anomaly Characterization

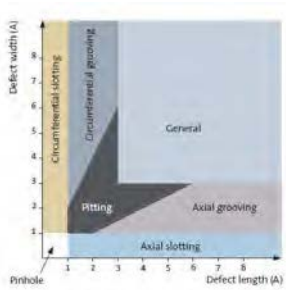
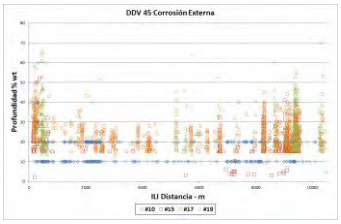


Figure 8. POF Specification graph

External Corrosion in DDV 45, ILI Distance vs. Depth



Pipe Resistance Issues

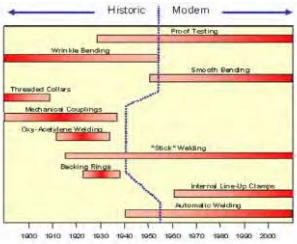


Figure G-1. Pipeline construction practices

Critical Strain

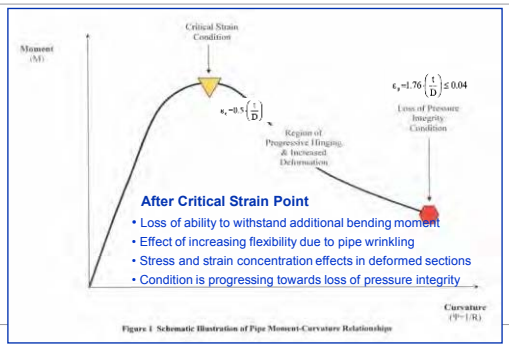


Figure 1 Schematic Illustration of Pipe Moment-Curvature Relationships

TTF as step to PoF

PoF = exposure * (1 – mitigation) / resistance

Examples

- PoF (time-dependent) = 1 / TTF
- PoF = ∫(TTF); lognormal, weibull, poisson

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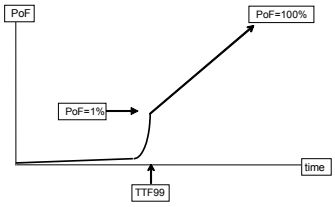
PoF: TTF & TTF99



Examples

- TTF = 0.160” / [(16 mpy) x (1 - 0.9)] = 100 years
- TTF99 = 0.160” / (16 mpy) = 10 years
- PoF => lognormal or other =>0.001% for year 1

- TTF = 0.016” / [(16 mpy) x (1 - 0.9)] = 10 years
- TTF99 = 0.016” / (16 mpy) = 1 year
- PoF = 1/TTF = 10% for year 1

Comprehensive

- Pipe specification;
- Last measured wall thickness;
- Age of last measured wall thickness;
- Wall thickness "measured" (implied) by last pressure test;
- Age of last pressure test;
- Detection capabilities of last inspection (ILI, etc), including data analyses and confirmatory digs;
- Maximum depth of a defect remaining after last inspection; age of last inspection
- Estimated metal loss mpy since last measurement;
- Estimated cracking mpy since last measurement;
- Maximum depth of a defect surviving at last pressure test and/or normal operating pressure (NOP) or last known pressure peak;

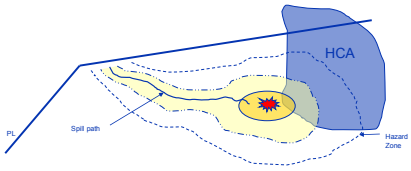
- Penalties for possible manufacturing/construction weaknesses

Why Exp-Mit-Res?

- Implicit, if not explicit, categorization because:
  - knowledge of all 3 is required for PoF
- Benefits of explicit categorization
  - without all 3, inability to diagnose
  - without diagnosis, inability to optimize P&M

Fully Characterize Consequence of Failure

- Must identify and acknowledge the full range of possible consequence scenarios
- Must consider 'most probable' and 'worst case' scenarios



CoF at Facilities

- Hazard Zone Assessment

$$Potential\ Loss = Hazard\ Area^{*}\ x\ \Sigma(receptor\ unit\ value\ x\ receptor\ density\ x\ receptor\ damage\ rate)$$

* Probability-adjusted area

Common Consequences of Interest

- Human health
- Environment
- Costs

Ref HCA determination procedures

Other Consequences

- Service Interruption
- Production/transportation loss
- Repair costs
- Resumption of service
- Contract penalties
- Legal costs
- Increased regulatory oversight
- Corp reputation

Particle Trace Analysis

PIR Calculations

TTO13 & TTO14

Table 7.1 Summary of Potential Impact Radius Formulae

Product	PIR Formula
Ethylene	$r = 1.04 \cdot \sqrt{p \cdot d^2}$
Hydrogen	$r = 0.47 \cdot \sqrt{p \cdot d^2}$
Natural Gas (Lean)	$r = 0.69 \cdot \sqrt{p \cdot d^2}$
Natural Gas (Rich)	$r = 0.73 \cdot \sqrt{p \cdot d^2}$
Syngas	$r = 0.49 \cdot \sqrt{p \cdot d^2}$ [Note 1]
NOTE 1 See discussion in Section 4.0.5	

Table 8.1 Summary of PIR Formulae

Product		PIR Formula
Acetylene	1 psi Overpressure	$r = 0.023 \cdot (d^2 \cdot p)^{0.5}$
Anhydrous Ammonia (Liquefied under pressure)	1 psi Overpressure	$r = 0.014 \cdot (d^2 \cdot p)^{0.5}$
	Rural Conditions	$r = 0.08 \cdot (d^2 \cdot p)^{0.48}$
	Urban Conditions	$r = 0.07 \cdot (d^2 \cdot p)^{0.42}$
Carbon Monoxide	1 psi Overpressure	$r = 0.012 \cdot (d^2 \cdot p)^{0.5}$
	Rural Conditions	$r = 0.04 \cdot (d^2 \cdot p)^{0.1}$
	Urban Conditions	$r = 0.03 \cdot (d^2 \cdot p)^{0.42}$
Chlorine	Rural Conditions	$r = 0.38 \cdot (d^2 \cdot p)^{0.48}$
	Urban Conditions	$r = 0.16 \cdot (d^2 \cdot p)^{0.1}$
Ethylene	1 psi Overpressure	$r = 0.021 \cdot (d^2 \cdot p)^{0.5}$
Hydrogen Sulfide	1 psi Overpressure	$r = 0.015 \cdot (d^2 \cdot p)^{0.5}$
	Rural Conditions	$r = 0.37 \cdot (d^2 \cdot p)^{0.42}$
	Urban Conditions	$r = 0.27 \cdot (d^2 \cdot p)^{0.48}$
Methane	1 psi Overpressure	$r = 0.019 \cdot (d^2 \cdot p)^{0.5}$
Rich Gas	1 psi Overpressure	$r = 0.020 \cdot (d^2 \cdot p)^{0.5}$

Hazard Zone Exercise

prod	hole size	hole size prob	ignition scenario	prob	dist source	therm haz zone	overpress haz	contam haz zone	haz zone	prob of haz zone
					ft	ft	ft	ft	ft	
fuel oil	rupt	2%	immediate ignition							
			delayed ig							
			no ignition							
	med	8%	immediate ignition							
			delayed ig							
			no ignition							
	small	90%	immediate ignition							
			delayed ig							
			no ignition							

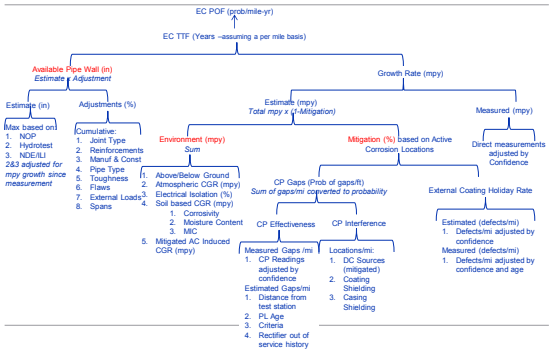
Integrate Pipeline Knowledge

- The assessment must include complete, appropriate, and transparent use of all available information
- 'Appropriate' when model uses info as would an SME

How much is enough?

- The risk assessment should use all the information in substantially the same way that an SME uses information to improve the understanding of risk

External Corrosion Model



Incorporate Sufficient Granularity

- Risk assessment must divide the pipeline into segments where risks are unchanging
- Compromises involving the use of averages or extremes can significantly weaken the analysis and are to be avoided

Dynamic Segmentation

Due to the numerous and constantly-varying factors effecting the risk to the pipeline, proper analysis will require at least 10-20 segments per mile*

*thousands of segments per mile is not unusual today

Control the Bias

- Risk assessment must state the level of conservatism employed in all of its components
- Assessment must be free of inappropriate bias that tends to force incorrect conclusions

Certainty

"ABSOLUTE CERTAINTY IS THE PRIVILEGE OF FOOLS AND FANATICS."

Dealing With Uncertainty

Error 1: call it 'good' when its really 'bad'

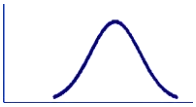
Error 2: call it 'bad' when its really 'good'

Understanding Conservatism and Uncertainty

A way to measure and communicate conservatism in risk estimates

- PXX
  - P50
  - P90
  - P99.9

Useful in conveying intended level of conservatism



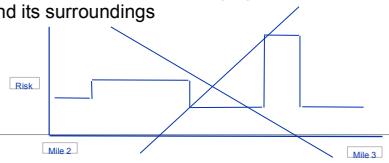
The Role of Historical Incidents

Problems:

- Historical data usefulness in current situation
- Small amount of data in rare-event situations
- Representative population
- Behavior of the individual vs population

Profile the Risk Reality

- The risk assessment must be performed at all points along the pipeline
- Must produce a continuous profile of changing risks along the entire pipeline
- Profile must reflect the changing characteristics of the pipe and its surroundings



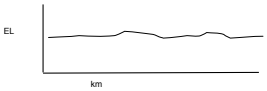
Profile to Characterize Risk

Scenario 1
100 km oil pipeline
widespread coating failure
river parallel
remote

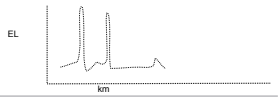
Scenario 2
50 km gas pipeline
2 shallow cover locations
high population density
high pressure, large diameter

Risk Characterization

Scenario 1
100 km oil pipeline
widespread coating failure
river parallel
remote location



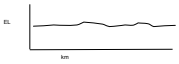
Scenario 2
50 km gas pipeline
2 shallow cover locations
high population density
high pressure, large diameter



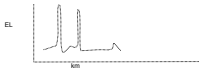
Very different risk profiles

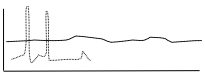
Risk Characterization

Scenario 1
100 km oil pipeline
widespread coating failure
river parallel
remote location



Scenario 2
50 km gas pipeline
2 shallow cover locations
high population density
high pressure, large diameter





What is best action to take?

Proper Aggregation

- Proper process for aggregation of the risks from multiple pipeline segments must be included
- Summarization of the risks from multiple segments must avoid simple statistics or weighted statistics that mask the actual risks

Aggregating Risks for Collection of Pipe Segments

~~PoF total = PoF1 + PoF2 + PoF3 + PoF4 + …. PoFn~~

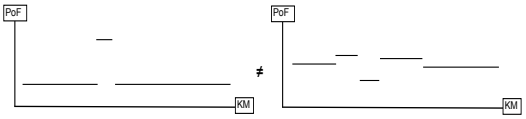
PoF total = 137% . . . ?

Simple sum only works when values are very low.

Aggregating Risks

~~PoF total = Avg(PoF1, PoF2, …PoFn)~~

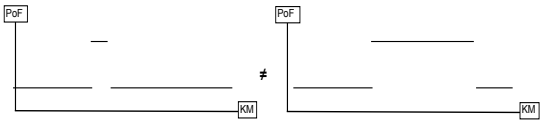
Avg PoF = Avg PoF
But



Aggregating Risks

~~PoF total = Max(PoF1, PoF2, …PoFn)~~

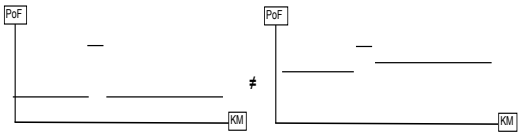
Max PoF = Max PoF
But



Aggregating Risks

~~PoF total = Max(PoF1, PoF2, …PoFn)~~

Max PoF = Max PoF
But



Aggregating Failure Probabilities

Overall pf is prob failure by [(thd pty) OR (corr) OR (geohaz)…]

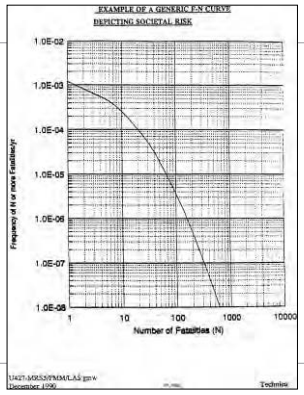
Ps = 1 - pf

Overall ps is prob surviving [(thd pty) AND (corr) AND (geohaz)….]

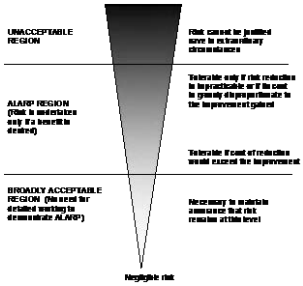
So…

$Pf_{overall} = 1-[(1-pf_{thdpty}) \times (1-pf_{corr}) \times (1-pf_{geohaz}) \times (1-pf_{incops})]$

FN Curve



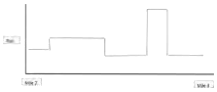
Acceptable Risk

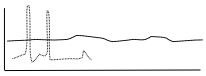


Uniform-Risk Reliability Targets

The Most Essential Elements

Easy to Spot (and Correct!) Methodology Weaknesses





	Index\Score
depth cover	shallow = 8 pts
wrinkle bend	yes = 6 pts
coating condition	fair = 3 pts
soil	moderate = 4 pts

PoF: Critical Aspects

Examples

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Practice PoD, PoF

What is PoD and PoF when . . .

- Exposure = 10 events/mile-year
- Mitigation = 99%
- Resistance = 90%

PoD = Exposure x (1 - mitigation)
= 10 x (1 - 0.99)
= 0.1 damages/mile-year = damage incident every 10 yrs

PoF = PoD x (1 - resistance)
= 0.1 x (1 - 0.9)
= 0.01 failures/mile-year = failure every 100 years

Practice PoD, PoF

What is PoD and PoF when . . .

- Exposure = 1 events/mile-year
- Mitigation = 50%
- Resistance = 50%

- Exposure = 2 events/mile-year
- Mitigation = 90%
- Resistance = 80%

- Exposure = 10 events/mile-year
- Mitigation = 99.9%
- Resistance = 90%

- Exposure = 0.01 events/mile-year
- Mitigation = 99.99%
- Resistance = 95%

Practice TTF, PoF

What is TTF and PoF when . . .

- Exposure = 10 mpy
- Mitigation = 50%
- Resistance = 0.100"

Damage rate = Exposure x (1 - mitigation)
= 10 x (1 - 0.5)
= 5 mpy

TTF = Resistance / Damage rate
= 100 mils / 5 mpy = 20 years

PoF = 1 / TTF
= 1 / 20 years = 0.05 / year = 5% prob failure in year one

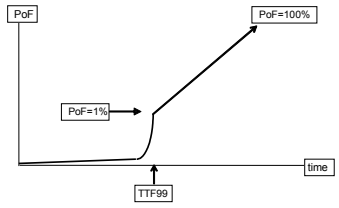
Practice TTF, PoF

What is TTF and PoF when . . .

- Exposure = 5 mpy
- Mitigation = 80%
- Resistance = 0.100"

- Exposure = 10 mpy
- Mitigation = 90%
- Resistance = 0.100"

PoF: TTF & TTF99



Examples

- TTF = 0.160" / [(16 mpy) x (1 - 0.9)] = 100 years
- TTF99 = 0.160" / (16 mpy) = 10 years
- PoF => lognormal or other =>0.001% for year 1

- TTF = 0.016" / [(16 mpy) x (1 - 0.9)] = 10 years
- TTF99 = 0.016" / (16 mpy) = 1 year
- PoF = 1/TTF = 10% for year 1

Example

Ext Corr	
1995 4" steel, 0.250", coated, CP	
Exposure (mpy)	10
Mitigation (%)	
coat	50%
CP	60%
Resistance (in)	
TTF (yrs)	
PoF (%/yr)	

Example

Thd Pty	
Excavations 2/yr in this area	
Exposure (events/yr)	2
Mitigation (%)	
cover	90%
one-call	50%
Resistance (%)	50%
PoD (%/yr)	
PoF (%/yr)	

Example

CoF

Hazard Zone (ft2)	1000
Receptors ($/ft2)	$ 500
Damage Rate (%)	1%
EL ($/incid)	

Example

Risk

Ext Corr	
Thd Pty	
CoF	
PoF (%/yr)	
EL ($/yr)	
Risk (relative)	

Ext Corr
1995 4" steel, 0.250", coated, CP

Exposure (mpy)	10
Mitigation (%)	
coat	50%
CP	60%
Resistance (in)	
TTF (yrs)	
PoF (%/yr)	

Thd Pty
Excavations 2/yr in this area

Exposure (events/yr)	2
Mitigation (%)	
cover	90%
one-call	50%
Resistance (%)	50%
PoD (%/yr)	
PoF (%/yr)	

CoF

Hazard Zone (ft2)	1000
Receptors ($/ft2)	$ 500
Damage Rate (%)	1%
EL ($/incid)	

Example

Risk

Ext Corr	0.9%
Thd Pty	5%
CoF	$ 5,000
PoF (%/yr)	5.9%
EL ($/yr)	$ 293
Risk (relative)	scaled from EL

Ext Corr
1995 4" steel, 0.250", coated, CP

Exposure (mpy)	10
Mitigation (%)	80%
coat	50%
CP	60%
Resistance (in)	0.22
TTF (yrs)	110
PoF (%/yr)	0.9%

Thd Pty
Excavations 2/yr in this area

Exposure (events/yr)	2
Mitigation (%)	95%
cover	90%
one-call	50%
Resistance (%)	50%
PoD (%/yr)	10.0%
PoF (%/yr)	5%

CoF

Hazard Zone (ft2)	1000
Receptors ($/ft2)	$ 500
Damage Rate (%)	1%
EL ($/incid)	

Example: Compare Alternatives

Scenario 1: Improve Air Patrol

PoF thd pty	Before	After	
length	10		miles
exposure	2		events/mi-year
mitigation patrol	40%	60%	
mitigation others	90%		
combined mit = 1-(1-patrol)x(1-others)	94%		
PoD = exp x (1-mit)	12%		per mile-yr
resistance	90%		
PoF = PoD x (1-res)	1.2%		per mile-yr
PoF all 10 miles (thd pty only)	12%		per year
TTF = 1 / PoF	83.3		years to fail
CoF	$ 200,000		per incident
Risk = EL = PoF x CoF	$ 24,000	$ -	per year

Example: Compare Alternatives

Scenario 2: ILI

PoF Corr	Before		After		
	corr ext	corr int	corr ext	corr int	
pipe wall nom	0.312	0.312			inches
mpy mitigated	10	4			mpy
age last inspection	20	20	1	1	years
pipe wall avail	0.112	0.232			inches
TTF = [pipe wall avail] / ([mpy] / 1000)	11.2	58			years to fail
PoF = 1 / TTF	8.9%	1.7%			per mile-yr
PoF =1-(1-PoFcorr_ext)x(1-PoFcorr_int)	10.5%				per mile-yr
CoF	$ 40,000.00				per incident
Risk = EL = PoF x CoF	$ 4,200				per year

Example: Compare Alternatives

	Patrol	ILI
PoF improvement	4.0%	5.9%
EL improvement	$ 8,000	$ 2,373

'Best' alternative depends on corporate priorities

Concluding Remarks

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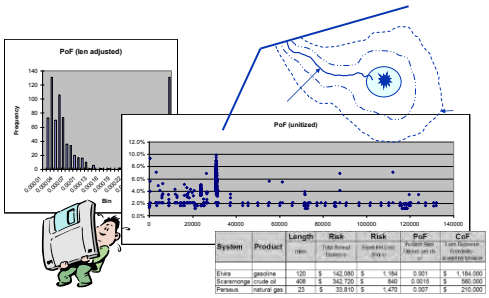
Modern PL RA: A Critical Process



System	Product	Length (miles)	Risk Total Annual Expected Loss	Risk Expected Loss (Events)	PoF Accident Rate (Accidents per mile)	CoF Total Expected Consequence (expected loss/event)
Elvira	gasoline	120	$ 142,080	$ 1,184	0.001	$ 1,184,000
Scaramonga	crude oil	408	$ 342,720	$ 840	0.0015	$ 560,000
Perseus	natural gas	23	$ 33,810	$ 1,470	0.027	$ 210,000

The Essential Elements

- Measurements in Verifiable Units
- Proper Probability of Failure Assessment
- Characterization of Potential Consequences
- Full Integration of Pipeline Knowledge
- Sufficient Granularity
- Bias Management
- Profiles of Risk
- Proper Aggregation

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Application of EE's—benefits realized

- Efficient and transparent risk modeling
- Accurate, verifiable, and complete results
- Improved understanding of actual risk
- Risk-based input to guide integrity decision-making: *true risk management*
- **Optimized resource allocation leading to higher levels of public safety**
- Appropriate level of standardization facilitating smoother regulatory audits
  - Does not stifle creativity
  - Does not dictate all aspects of the process
  - Avoids need for (high-overhead) prescriptive documentation
- Expectations of regulators, the public, and operators fulfilled

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Hawthorne Effect

"Anything that is studied, improves."

Anticipate enormously more useful information

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Safeguarding life, property and the environment

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MANAGING RISK

Appendix

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"…when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science, whatever the matter may be."

Lord Kelvin

Regulation [a]	Year Issued	Health or Safety?	Agency	Baseline Mortality Risk per Million Exposed	Cost per Premature Death Averted ($US Millions 1990)
Aircraft Cabin Fire Protection Standard	1985	S	FAA	5	0.1
Steering Column Protection Standard [b]	1967	S	NHTSA	385	0.1
Trihalomethane Drinking Water Standards	1979	H	EPA	420	0.2
Aircraft Seat Cushion Flammability Standard	1984	S	FAA	11	0.4
Auto Fuel-System Integrity Standard	1975	S	NHTSA	343	0.4
Aircraft Floor Emergency Lighting Standard	1984	S	FAA	2	0.6
Side-Impact Standards for Autos (Dynamic)	1990	S	NHTSA	NA	0.8
Auto Side Door Support Standards	1970	S	NHTSA	2,520	0.8
Low-Altitude Windshear Equipment & Training Standards	1988	S	FAA	NA	1.3
Side-Impact Standards for Trucks, Buses, and MPV's	1989 (Proposed)	S	NHTSA	NA	2.2
Rear Lap/Shoulder Belts for Autos	1989	S	NHTSA	NA	3.2
Benzene NESHAP (Original: Fugitive Emissions)	1984	H	EPA	1,470	3.4
Ethylene Dibromide Drinking Water Standard	1991	H	EPA	NA	5.7
Benzene NESHAP (Revised: Coke By-Products) [b]	1988	H	EPA	NA	6.1
Arsenic Emission Standards for Glass Plants	1986	H	EPA	2,660	13.5
Haz Waste Listing for Petroleum Refining Sludge	1990	H	EPA	210	27.6

Regulation [16]	Year Issued	Health or Safety?	Agency	Baseline Mortality Risk per Million Exposed	Cost per Premature Death Averted ($US Millions 1990)
Cover/Move Uranium Mill Tailings (Inactive Sites)	1983	H	EPA	30,100	31.7
Benzene NESHAP (Revised: Transfer Operations)	1990	H	EPA	NA	32.9
Cover/Move Uranium Mill Tailings (Active Sites)	1983	H	EPA	30,100	45.0
Asbestos Ban	1989	H	EPA	NA	110.7
Diethylstilbestrol (DES) Cattlefeed Ban	1979	H	EPA	22	124.8
1,2-Dichloropropane Drinking Water Standard	1991	H	EPA	NA	653.0
Haz Waste Land Disposal Ban (1st 3rd)	1988	H	EPA	2	4,190.4
Municipal Solid Waste Landfill Standards (Proposed)	1988	H	EPA	<1	19,107.0
Atrazine/Alachlor Drinking Water Standard	1991	H	EPA	NA	92,069.7
Haz Waste Listing for Wood Preserving Chem.	1990	H	EPA	<1	5,700,000.0

Sample Audit Questions

- What is maximum and average segment length?
  - If less than 20 segs per mile, then only appropriate if very low variations along route, including hydraulic profile
- How do you discriminate between low-exp and low-mit vs high-exp and high-mit?
- Show how non-HCA data is being used.
- Obtain counts and ranges (min, max, average):
  - Inputs
  - Defaults & assignments
  - Threats
  - Equations
- What is target level of conservatism? P50? P90? P99.9? For various uses of results.
- Explain how risk assessment is used in risk management (P&M).
- Show where remaining life (TTF) is used to set integrity re-assessment intervals.

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Final Pof

$$Pof_{overall} = pof_{thdpty} + pof_{ttf} + pof_{theftsab} + pof_{incops} + pof_{geohazard}$$

$$Pof_{overall} = 1-[(1-pof_{thdpty}) \times (1-pof_{ttf}) \times (1-pof_{theftsab}) \times (1-pof_{incops}) \times (1-pof_{geohazard})]$$

Guess pof if 1%, 4%, 2%, 2%, 0%

Calc:

Hazard Zones

Product	Hole size	Hole size probability	Ignition scenario	Ignition probability	Distance from source (ft)	thermal hazard zone (ft)	Contamination hazard zone (ft)	Total (ft)	probability of hazard zone
oil	rupture	4%	immediate ignition	5%	0	400	0	400	0.2%
			delayed ignition	10%	600	500	400	1100	0.4%
			no ignition	85%	600	0	900	1500	3.4%
	medium	16%	immediate ignition	2%	0	200	0	200	0.3%
			delayed ignition	5%	200	300	200	500	0.8%
			no ignition	93%	200	0	500	700	14.9%
	small	80%	immediate ignition	1%	0	50	0	50	0.8%
			delayed ignition	2%	80	100	0	180	1.6%
			no ignition	97%	80	0	80	160	77.6%
									100.0%
LPG	rupture	16%	immediate ignition	20%	0	400	0	400	3.2%
			delayed ignition	20%	500	2000	0	2500	3.2%
			no ignition	60%	500	0	0	500	9.6%
	medium	24%	immediate ignition	15%	0	200	0	200	3.6%
			delayed ignition	15%	200	1200	0	1400	3.6%
			no ignition	70%	200	0	0	200	16.8%
	small	60%	immediate ignition	10%	0	50	0	50	6.0%
			delayed ignition	10%	30	100	0	130	6.0%
			no ignition	80%	30	0	0	30	48.0%
									100.0%