Trans-Alaska Pipeline System

Low Flow Plan

Summary

A Report on Low Flow Issues Through 2030

Prepared by the TAPS Owners

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1.0 Executive Summary

This document summarizes the findings of a screening study of options for the Trans Alaska Pipeline System (TAPS) and the development of a recommended project scope for the time period 2008 to 2030. The objective of this study is to understand the likely type of investments required to continue operations and offset effects of declining TAPS throughput and potential crude composition changes.

The level of future transportation volumes through TAPS is critical to the long-range plan. Declining volumes correlate to declining velocity and temperature which drive the schedule required to mitigate problems associated with low flow. While January 2008 TAPS throughput at Pump Station 1 (PS1) was approximately 700,000 BOPD, the future TAPS throughput is unknown due to uncertainty in North Slope field production. This evaluation suggests that TAPS can continue to transport Alaska North Slope (ANS) crude for the plan period, but will require significant capital and operating investments to do so.

The plan recommendations address the critical issues facing TAPS to ensure long-term viability, including further evaluation and testing to validate the assumptions upon which this study is based. The four critical issues facing TAPS as throughput declines are: (1) the geotechnical temperature limit of the pipeline; (2) water in the TAPS stream; (3) deposition of crude oil solids on the interior pipeline wall; and (4) the possibility of high viscosity oils delivered to TAPS in the future.

Geotechnical Limit

This study assumes that the buried portion of TAPS must operate above freezing to prevent the formation of ice lenses in the ground, which could lead to frost heaves and place strain on the pipeline. As a result, the plan assumes that it is necessary to maintain a TAPS operating temperature limit of 38 degrees Fahrenheit by adding heat, where necessary, and recommends further evaluating the true geotechnical temperature limit of the pipeline.

Water

The volume of free water transported through TAPS becomes increasingly problematic as throughput volume and velocity decline. Free water in TAPS poses three concerns: (1) at lower velocities, water will separate from oil and may create an environment for internal pipeline corrosion; (2) during cold weather pipeline shutdowns, separated water may accumulate at valves and pipeline low points, potentially freezing and causing problems when resuming flow; and (3) during extreme winter operations, without the addition of heat, the operating temperature of TAPS may fall below 28°F, which could cause problems resulting from ice formation during flowing conditions.

The plan recommends addressing free water in TAPS immediately by investigating water management measures. Further study will investigate the potential volume and location of any water drop-out, the freezing characteristics of water in the crude stream, and how these factors may impact the pipeline.

Crude Oil Solids (Wax)

The volume of crude oil solids, or wax, that crystallizes in the TAPS oil flow increases at lower oil temperatures caused by declining throughput. Increased wax deposition on the pipe wall potentially poses internal pipeline corrosion concerns. However, there is no evidence that increased crude oil solids are causing internal corrosion issues at current throughput.

The two evaluations of future wax deposition conducted for this study produced significantly different results. One preliminary evaluation suggests that increasing the frequency of pigging for wax removal will significantly mitigate the risk of corrosion associated with wax build-up. Another evaluation suggests that current pigging frequency is adequate and increased pigging may not be necessary.

To address crude oil solids concerns, the plan recommends pursuing conceptual engineering for increased pigging using the more conservative wax deposition rate. The plan also recommends establishing a monitoring system for wax deposition and pigging effectiveness; performing a risk assessment on increased pigging; investigating wax management systems in Valdez and pigging methods at low throughputs; and further studying and testing both the wax deposition rate and correlation between crude oil solid deposition and corrosion in TAPS.

Viscosity

Current crude composition does not pose viscosity problems in TAPS. Should crude composition change in the future and become heavier, as some predict, resulting viscosities may exceed the physical limitations of TAPS.

The plan recommends further study of TAPS operating limits to determine if there is a need for pipeline viscosity specifications in order to transport future volumes.

Observations

There is significant uncertainty regarding the magnitude of the impact of each of the critical issues associated with TAPS future throughput, as well as the required investment to mitigate those issues. As a result, there is a wide range of possible future project scope for TAPS; current estimates vary plus 150% to minus 100%. Further modeling and field testing should narrow the range of uncertainty and enable improved forecasting of capital and operating expenses for TAPS.

2.0 Background Information

The Trans Alaska Pipeline System (TAPS) consists of the 800-mile Trans Alaska Pipeline, the Valdez Marine Terminal (VMT) and the Ship Escorts and Response Vessel System (SERVS). BP Pipelines (Alaska) Inc., ConocoPhillips Transportation Alaska, Inc., ExxonMobil Pipeline Company, Koch Alaska Pipeline Company, L.L.C., and Unocal Pipeline Company ("TAPS Owners") own TAPS. The TAPS Operator is the Alyeska Pipeline Service Company (APSC), which is the agent of the TAPS Owners.

Since the completion of its construction in 1977, TAPS has provided a safe, environmentally responsible, cost-effective, and reliable means to move liquid hydrocarbons from the North Slope of Alaska to the VMT. However, changing operational conditions associated with declining throughput are dominant among the challenges that TAPS faces through 2030 (refer to Figure 2.1 below). How best to address these challenges is the focus of this TAPS low flow evaluation.

2.1 Declining Throughput

Declining throughput has both near and long term impact on pipeline operations. Current TAPS throughput is approximately 700,000 BOPD, with historical throughput decline averaging approximately 6% per year (refer to Figure 2.1 below). Proactive planning to address declining throughput issues will ensure the long-term viability of TAPS to continue transporting ANS crude to market safely and cost-effectively.

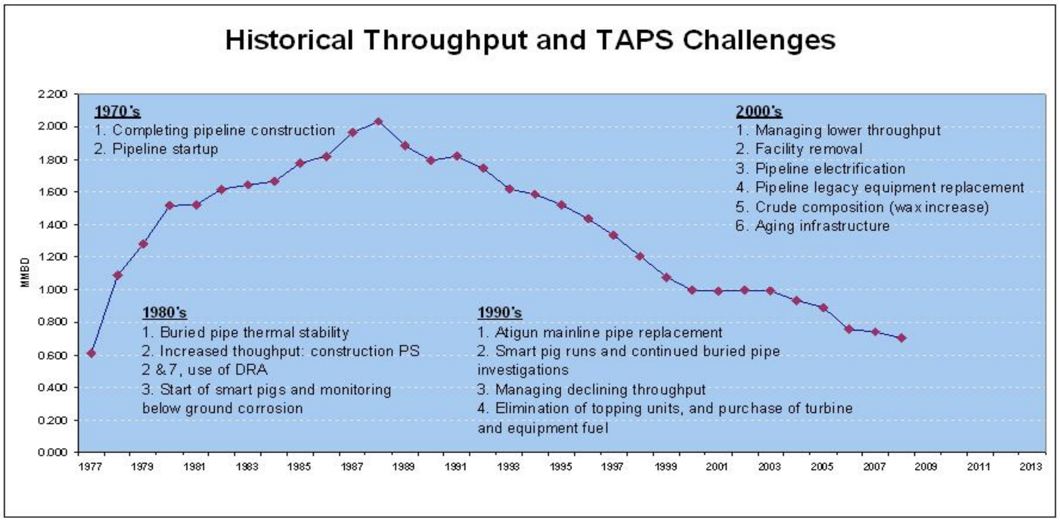

Figure 2.1 – Historical Throughput and TAPS Challenges

2.2 Declining Temperature

Due to the potential magnitude of some of the investments, sufficient time will be required to study, design, plan and implement effective solutions. The biggest challenges associated with declining throughput relate to temperature drop in the TAPS crude stream (as shown in Figure

2.2 below). Temperature drop presents issues such as ice formation, wax/gel formation, and potential geotechnical problems if the below-ground pipeline temperature were to drop consistently below the surrounding ground temperature. Mitigation remedies for these issues may require a series of capital investments over time and may have significant effect on annual operating expenses.

Other issues directly related to lower volume throughput that will need further evaluation, but could have less monetary impact, include: vibration, maintaining adequate leak detection, monitoring system performance, and resizing of VMT storage tankage. While these issues are important, potential solutions for these issues are being addressed separately from this study.

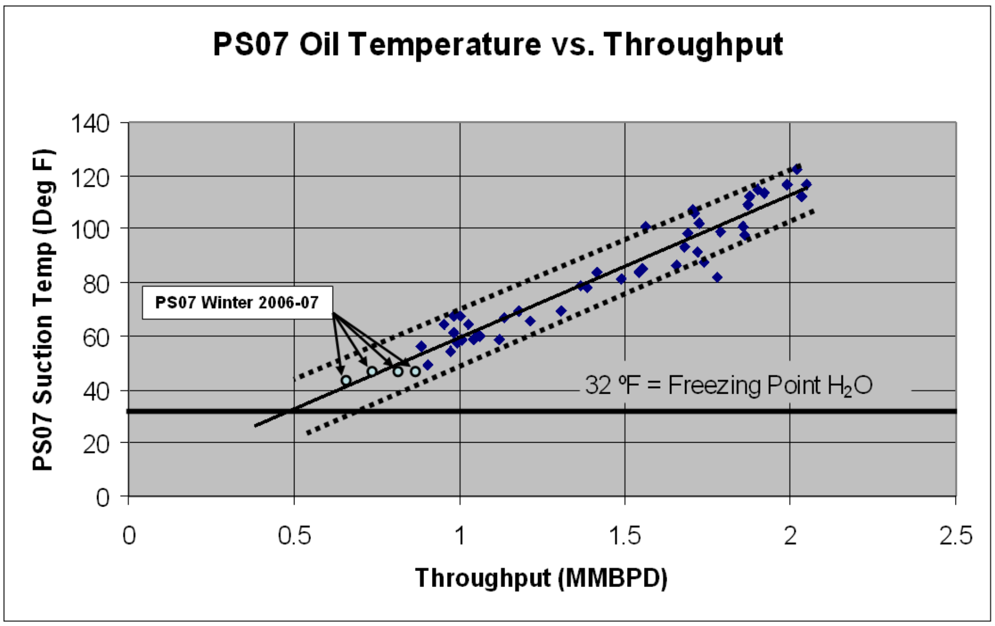

Figure 2.2 – Throughput Temperature at Pump Station 7

2.3 Critical Issues

There are four critical issues (detailed in Figure 2.3 on the following page) related to crude throughput and composition through 2030 that the plan addresses to ensure the long-term viability of TAPS; they are:

(1) The geotechnical temperature limit of the pipeline,

(2) Water in the TAPS stream,

(3) Deposition of crude oil solids (i.e., wax) on the pipeline wall, and

(4) The possibility of high viscosity crude delivered to TAPS in the future.

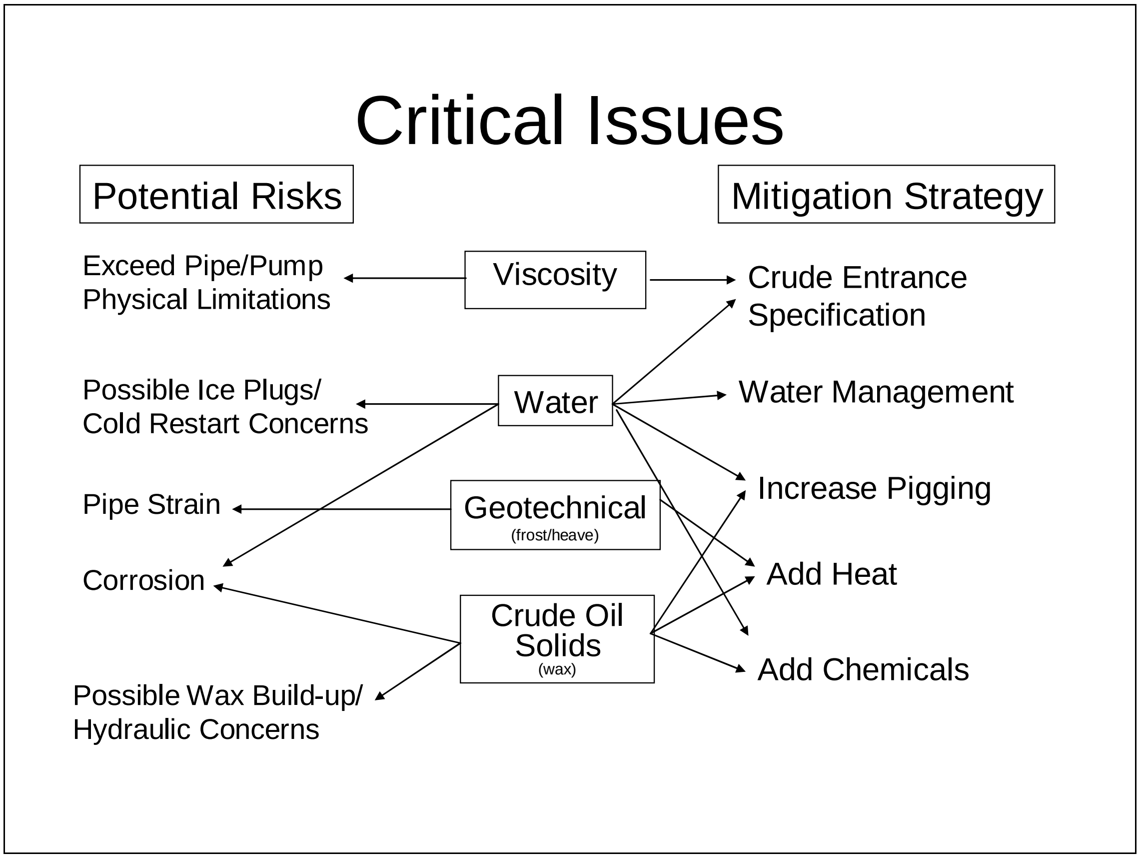

Figure 2.3 – TAPS Critical Issues

Geotechnical Issues

The TAPS 48-inch pipeline utilizes arctic grade steel and a strain based design, meaning it is designed to withstand a certain amount of distortion without failing. It was designed as a hot oil pipeline and buried in thawed and frozen soil, where testing demonstrated that if the permafrost melted, pipeline settlement would be acceptable. In areas where melting would result in excessive settlement, the pipe was insulated, elevated above ground, and supported to keep the permafrost frozen. As a result, approximately half of the pipeline is buried.

With declining TAPS throughput, and associated declining temperature, the thaw bulb that currently surrounds the buried hot pipe may shrink. Should this occur, there is concern that over time, if the crude oil temperature cools below freezing in an underground segment of the pipe, the thaw bulb may refreeze and form ice lenses. Eventually, this could result in frost heaves and impose strain on the pipeline beyond its design limits.

Ultimately, this could be a problem wherever the pipe is buried in permafrost. Due to limited information currently available on the TAPS minimum operating temperature, this evaluation assumes a geotechnical minimum temperature of 38 degrees Fahrenheit (of the TAPS crude oil stream) for the buried portion of the pipe.

Water

At lower throughputs, free water that enters TAPS at Pump Station 1 (PS 1) may coalesce, drop out of solution and travel to the bottom of the pipe as oil is transported to Valdez. Once water accumulates at a low point, the force of gravity may exceed the motive force that moves the oil and prevent it from being flushed through the pipe during normal flow.

This presents two problems. First, the accumulated water may provide an environment for corrosion. Second, during an extended TAPS winter shutdown, or at low flow rates, the locations with liquid hold-up may freeze and thereby impact the pipeline's ability to restart or maintain flow. Water accumulation within TAPS could also create conditions conducive to ice formation within the flowing oil stream.

Crude Oil Solids (Wax)

Crude oil includes paraffins, asphaltenes and other naturally occurring substances that tend to precipitate out of the crude as temperature drops. High molecular weight paraffin, or hard wax, is of particular concern because it can build up on the pipe walls (deposition) potentially creating an environment for corrosion to occur. Low molecular weight paraffin, or soft wax, can also precipitate and be deposited on the pipe wall, posing a problem if it ages sufficiently and transforms into a hard wax. Removal of both types of wax on a regular basis is required to ensure wax build-up is not excessive and to eliminate the creation of a host environment for corrosion causing bacteria.

The rate at which wax adheres to the pipe walls is directly related to the temperature difference between the crude oil and the pipe wall. Warm oil will deposit wax onto a cold pipe wall at a faster rate than colder oil will deposit wax onto a cold pipe wall. At lower crude oil temperatures, more wax will appear within the crude oil stream, but may not adhere to the pipeline walls as quickly.

The volume of wax that can be removed by a typical cleaning pig run will continue to be an operational and waste disposal issue. Wax build-up may cause failures in the sensors on an instrument pig, requiring a costly re-run of the pig. Excessive accumulation of wax may also cause pressure differentials along the pipeline, resulting in less efficient oil movement.

As part of this study, TAPS provided ANS samples to two laboratories for wax deposition analysis: The two labs analyzed the samples using different methods and yielded different wax deposition rate prediction results.

According to the more conservative analysis, wax should not be problematic in the northern segment of TAPS if a pig is run at least once every two weeks until the crude temperature declines to 48 degrees Fahrenheit, and then once a week thereafter. South of the North Pole Metering Station (NPMS), the analysis suggests that wax could be problematic at 48 degrees Fahrenheit, even with weekly pigging, and that heat would need to be added to stave off problems.

In contrast, the less conservative analysis suggests that the TAPS current pigging practice of once every two weeks from Pump Station 1 (PS1) to Pump Station 4 (PS4), and weekly from PS4 to the VMT is and will continue to be sufficient to manage wax along the entire pipeline throughout the planning period. If these results are correct, heat will not need to be added to

TAPS until the temperature of the crude declines to 38 degrees Fahrenheit, and then only to address geotechnical issues, not wax mitigation issues.

At very low throughputs the low crude oil velocities scraper pigs may no longer be effective.

Viscosity

The viscosity of the current ANS stream does not change significantly with decreases in temperature; therefore, declining temperature does not currently present a viscosity issue for TAPS. Although some currently producing fields ship quite viscous crude, their crude is blended with less viscous crude prior to entering the TAPS stream and is not problematic.

In the future, if production from the less viscous fields declines, the overall viscosity of the common TAPS stream may increase. By evaluating viscosity tolerances in the near-term, the TAPS Owners will be better prepared to proactively address viscosity-related issues in the future.

Due to the uncertainty associated with the future crude composition in TAPS, this study did not include plans to mitigate potential viscosity issues.

3.0 Evaluation Frame

3.1 Decisional Issues

The TAPS low flow evaluation focuses on determining options and timing of the implementation of those options to mitigate the adverse effects of declining TAPS throughput for the time period of 2008 through 2030. The goal of the plan is to minimize total costs while project scope to maintain safe, environmentally responsible, and cost-effective operations throughout the plan period.

3.2 Policies and Key Assumptions

The following policies and key assumptions guided the low flow plan evaluation:

- TAPS will provide a safe, environmentally responsible, cost-effective, and reliable means to move liquid hydrocarbons to market.
- TAPS will maintain a crude oil operating temperature above 38 degrees Fahrenheit during the life of the pipeline, consistent with the prior assumptions for the geotechnical design limits.
- Solutions will not negatively impact the TAPS Cold Restart Plan.
- Solutions will not assume the existence of a natural gas line from the North Slope to Canada, nor will they assume production of condensate from Point Thomson.
- The analysis assumes no production from the Arctic National Wildlife Refuge (ANWR), which is consistent with the near-term Alaska Department of Revenue forecasts.
- The refineries along TAPS (Fairbanks and Valdez) will continue to off take crude at the current combined level of approximately 71,000 BOPD (60,000 BOPD in Fairbanks and 11,000 BOPD in Valdez).
- Any treatment of pipeline fluids will be for the common ANS crude stream; i.e., TAPS will not selectively treat the streams of individual connectors.
- Alternative transport systems for the Fairbanks to Valdez segment of TAPS were not considered to be necessary solutions within the plan period.
- TAPS will only spend prudently incurred and reasonable capital and operating costs expected to be recovered over 30 years.

3.3 Strategic Focus

Several key strategic considerations guided the different solutions considered for TAPS over the next twenty years to address the following questions:

- What is the most appropriate solution or combination of solutions to apply to TAPS as throughput volume declines?
- At what volume will a particular solution no longer be technically viable?
- What is the appropriate timing for the implementation of each solution?

Some proposed solutions were, upon preliminary evaluation, deemed worthy of quantitative analysis; others were, for various reasons, not analyzed further. Details regarding the evaluated strategies, as well as a discussion regarding the "tabled" strategies, including the rationale as to why they were not evaluated further, can be found in Section 5, of this document.

3.4 Strategies

Four strategies were developed for final consideration. All strategies include water management as an action and adding heat as an investment when the crude temperature forecast drops to the assumed geotechnical minimum temperature of 38 degrees Fahrenheit.

Three of the strategies assume that the more conservative behavior model is correct, and address wax build-up issues at 48 degrees Fahrenheit in the southern segment of TAPS with different possible solutions: heat addition, chemical addition or increased pigging. One strategy, the Geotechnical Limit, assumes that the less conservative wax behavior model is correct and does nothing until geotechnical issues need to be addressed at 38 degrees Fahrenheit and then adds heat to the entire line.

Strategy	Water Management	Increased Pigging (Current 1x per 14 days North 1X per 7 days South)	Add Chemicals	Add Heat
Add Heat – Base Case	Water management or specification change	None	None	Add heat at 38°F north of NPMS and 48°F south of NPMS
Intermediate Chemicals	Water management or specification change	None	Add chemicals from 48°F to 38°F south of NPMS	Add heat at 38°F for entire line
Intermediate Pigging	Water management or specification change	Increase pigging to every 7 days north of NPMS and every 4 days south of NPMS at 48°F	None	Add heat at 38°F for entire line
Geotechnical Limit	Water management or specification change	None	None	Add heat at 38°F for entire line

Figure 3.1 – TAPS Low Flow Integrated Strategies Defined

Add Heat – Base Case Strategy

The "Add Heat – Base Case" strategy involves pigging at current levels - once every two weeks in the northern section, and weekly in the southern section. Once pigging at current intervals is no longer sufficient to manage wax build-up south of NPMS, heat is introduced at selected locations along the pipeline. The heat maintains the crude above the temperature at which paraffin builds to maximum limits on the pipe walls between pigging events. Heat is added in the southern segment when the crude drops to 48 degrees Fahrenheit south of NPMS, and heat is added pipeline-wide once crude drops to 38 degrees Fahrenheit for geotechnical reasons.

Intermediate Chemicals Strategy

The "Intermediate Chemicals" strategy, similar to the "Add Heat Base Case" strategy, involves pigging at current levels, but introduces chemicals (versus heat) to prevent problematic wax precipitation. This strategy introduces chemicals when the crude temperature decreases to 48 degrees Fahrenheit south of NPMS. The injection of chemicals ceases and heat is added to the entire pipeline when crude temperatures reach the geotechnical limit of 38 degrees Fahrenheit.

Intermediate Pigging Strategy

The "Intermediate Pigging" strategy involves increasing pigging south of NPMS to once every four days and north of NPMS to once every week at 48 degrees Fahrenheit, and adding heat to maintain a minimum 38 degrees Fahrenheit crude temperature along the entire length of the pipeline. This strategy is based on the more conservative analysis, which suggests that heat is not required pipeline-wide to address wax issues with this increased pigging frequency until crude reaches 38 degrees Fahrenheit, when it is then added to mitigate geotechnical concerns.

Geotechnical Limit Strategy

The "Geotechnical Limit" strategy involves adding heat to maintain a minimum 38 degrees Fahrenheit crude temperature along the entire length of the pipeline. This strategy is viable if it is determined that pigging can be done at an interval that is sufficient to keep wax build-up within acceptable limits (through an established monitoring program), and no intermediate addition of either heat or chemicals is necessary. Essentially, in this strategy, current pigging practices would be utilized to mitigate all wax concerns and heat would be added only to mitigate geotechnical concerns.

4.0 Conclusions & Recommendations

Based on the assumptions used in this study, the initial project scope recommendation is to pursue the Intermediate Pigging strategy. Table 4.1 provides the likely project scope.

Intermediate Pigging Strategy - Project Scope	
Linewide	Validate key water management assumptions Water management conceptual design, project planning, and implementation Install wax monitoring capability
PS-3	Add recycle manifold heat
PS-4	Add recycle manifold heat Add one 40 MMBTU/Hr crude heater
MP-203	Add one 40 MMBTU/Hr crude heater
PS-5	Add one 40 MMBTU/Hr crude heater
PS-6	Add one 40 MMBTU/Hr crude heater
PS 7	Add one 40 MMBTU/Hr crude heater
PS-8 through VMT	Install cleaning pig launcher and receiver to increase pigging frequency south of NPMS
PS-9	Add recycle manifold heat
PS- 10	Add one 40 MMBTU/Hr crude heater
MP-650	Add one 40 MMBTU/Hr crude heater
PS-11	Add two 40 MMBTU/Hr crude heaters

Figure 4.1 - Intermediate Pigging Strategy Project Scope

Further Study and Action

Phase II of this study includes the refinement and/or implementation of the recommendations contained in this report. This Phase will be implemented by Alyeska Pipeline Service Company and is expected to be completed in 4Q10. At the end of Phase II the TAPS Owners will have an improved understanding of the critical issues, which should narrow the band of uncertainty associated with the future project scope. The work listed below may change as the study progresses and issues are ruled out or new issues are identified.

Water Management

- Verify ice strength, or the ability to form true “plugs” with sufficient strength, to prevent cold restart of the pipeline.

- Begin work to reduce uncertainty regarding the potential impacts of sub-freezing temperatures on water slugs to TAPS cold restart capability.

- Study effectiveness of chemicals to prevent water drop-out and ice formation.

- Establish an acceptable maximum water percentage for pipeline transport.

- Consider (seasonal) changes to water specification for incorporation into the tariff rules and regulations, along with penalties given the specifications are exceeded.

- If necessary, begin conceptual studies/engineering for water management.

- Study the transport and accumulation of water in TAPS to better enable future predictions.

- Evaluate cold oil ice formation in tanks, valves, strainers, instrumentation and recommend mitigative measures.

Heat Addition

- Begin conceptual engineering for recycle heating at Pump Stations 1, 3, 4 and 9 and direct fired heaters at Pump Station 6.

- Evaluate the maximum viscosity that TAPS can transport in post SR configuration.

- Evaluate viscosity specification (may be seasonal).

Geotechnical Limit

- Determine which below-ground segments of TAPS, if any, may be susceptible to frost heaves.

- Determine minimum operating temperature for those segments.

- Re-run the heat model to determine sections where heat is required.

Wax Deposition

- Continue modeling wax deposition.

- Develop implementation plan for increased pigging frequency including a risk assessment.

- Build medium-size flow loops (2" - 8") to gain real-time information on wax deposition to validate the models.

- Develop quantitative wax monitoring program to evaluate the effectiveness of pigging.

- Evaluate the implications of increased wax precipitation for the Valdez crude oil tanks and possible wax management systems.

- Evaluate the potential impacts from the Fairbanks refineries as throughput declines and the overall percentage of residual in the crude stream increases.

- Evaluate pigging effectiveness for throughputs below 300,000 BOPD.

5.0 Tabled Strategies

The following strategies were evaluated and tabled prior to quantitative analysis for the reasons detailed below.

5.1 Wax Extraction Strategy

The Wax Extraction strategy is outside the scope of TAPS operations, but involves the removal, or extraction, of wax from the ANS crude stream before it enters TAPS at Pump Station 1. Wax is extracted either by using a solvent, such as propane, which is in relatively good supply on the North Slope, or alternatively, by using a heat fractionalization process. Either method involves construction of an appropriate wax extraction plant and storage facility for the extracted wax.

The Wax Extraction strategy was tabled for the following reasons:

- The strategy presents significant transportation and storage issues.
- There are commercial considerations within this strategy that would need to be resolved.
- The TAPS Owners decided to limit the consideration of options for dealing with declining throughput to those directly related to transporting crude from Pump Station 1 to the Valdez Marine Terminal.

5.2 Diluent/Crude Upgrader Strategy

Upgraders or diluents can be used to "dissolve" crude oil solids, or wax paraffins, when natural diluents are not available, e.g., in heavy oil fields.

The Crude Upgrader strategy involves adding diluent to dissolve or mitigate wax in crude as well as reduce the viscosity of heavy crude so that it can be pumped using existing equipment. After dilution, the crude travels to an upgrader that removes the diluent, then cracks and refines the remaining viscous oil into lighter crude. If sufficient diluent is not available on the North Slope, then the diluent can be extracted and re-circulated to the viscous oil entry point via a separate pipeline.

The Diluent/Crude Upgrader strategy was tabled for the following reasons:

- At present, upgrading has an upper operating limit of approximately 300,000 BOPD of crude, utilizing a diluent volume of approximately 100,000 BOPD.
- This strategy is an extremely capital intensive strategy, with costs estimated greater than $15 billion for a 300,000 BOPD upgrader.

5.3 Add NGLs Strategy

The Add NGLs strategy requires an NGL injection point to be added downstream of Pump Station 1 to allow more NGLs into the TAPS system.

The plan evaluation team tabled this strategy due to the limited volume of NGLs currently known to be available to the TAPS system in the plan period.

5.4 Cooled Crude Oil Strategy

The Cooled Crude Oil strategy involves chilling the crude oil either upstream or at Pump Station 1 to temperatures at which nearly 100% of the wax crystallizes. This would prevent the wax from depositing on the pipeline wall. An additional objective would be to maintain a crude stream temperature below that at which wax will melt in the crude along the length of the pipeline. This strategy requires a new cooling system at Pump Station 1 and possibly at the NPMS, plus equipment that could re-inject the precipitated wax into the crude stream at acceptable levels in order to retain the value of the crude.

Along with the need for a capital investment to chill the crude oil in possibly two locations, this strategy could possibly accelerate the need to heat other locations along the pipeline to prevent the temperature from dropping below the geotechnical limit of 38 degrees Fahrenheit. Hence, the team tabled this strategy as it did not appear cost effective in light of the requirement of a minimum temperature of 38 degrees Fahrenheit.

This strategy may be revisited if minimum temperatures for geotechnical concerns are determined to be less than 37 degrees Fahrenheit, and the cold restart plan can accommodate the colder crude.