NITRATE REDUCTION PROGRAM AT THE LINE CREEK OPERATION

by

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Abstract

Blasting activities at the Line Creek operation are releasing oxides of nitrogen and are contributing to chemical changes in the surrounding watersheds. Through analysis of the mechanisms of nitrogen release, history of explosive usage, historical nitrate release, changing regulatory requirements, strategy analysis and social impacts associated with the release of nitrates a nitrate reduction plan will be established.

The paper develops the framework for engineering groups, operations groups and managers to make decisions around the development of a sustainable and achievable communication and monitoring plan for nitrate release while working to meeting the regulatory, social, and stakeholder requirements to continue efficient and effective mining operations.

The strategy recommended within this document is to develop practices around nitrate management through effective operational practices, introduction of high stability emulsion and emulsion contact with water. The effective operational controls will provide the mechanisms for reduction of oxides of nitrogen rather than through capital projects.

Executive Summary

Mining activities at the Line Creek operation (LCO) contribute to chemical changes in the surrounding watersheds and ecosystems through the release of nitrogen's (NH_4, $N0_2$ and $N0_3$) during the loading and blasting process. The subsequent paper describes the mechanisms of nitrogen release through exploring mining activities at the Line Creek operation (LCO). The paper will describe the mechanisms of nitrogen release through exploring: history of explosive usage at LCO, historical nitrate release to surrounding water sources, regulatory requirements to continue mining, strategy analysis and social impacts associated with the release of nitrates. Through the exploration of the complex problems associated with nitrate release, the paper will provide a strategy for LCO. The management of nitrates will provide the guidance to maintain water quality guidelines established by the British Columbia water quality guidelines.

The following paper will set the stage and begin to develop the framework for engineering groups, operations groups and managers to make informed decisions around the development of a sustainable and achievable communication and monitoring plan for nitrate release. The document will provide guidance to meet the regulatory, social, and stakeholder requirements to continue efficient and effective mining operations.

The strategy around nitrate management will not increase our customer's willingness to pay for our final product coal and in many cases increase the cost of production. However, nitrate management will allow Teck, and specifically LCO, to continue productive mining operations while working to meet regulatory requirements and maintain/enhance social license with the surrounding communities.

The current path taken the Teck in the coal business unit around the impacts to water management has been the development of treatment facilities to remediate the effects of mining by-products, i.e. active water treatment facilities. The current path for the reduction of selenium is the introduction of active water treatment facilities. At this time, LCO has an AWTF in re-commissioning phase, and additional facilities planned, for the treatment of selenium and nitrates.

2018: Fording River South

2020: Elkview (Phase 1)

2022: Fording River North (Phase 1)

2024. Elkview (Phase 2)

2026: Greenhills

2028: Line Creek Dry Creek

2030: Fording River South (Phase 2)

2032: Line Creek West Line Creek (Phase 2)

The strategy recommended within this document is the development of effective operational practices to control nitrogen release and realize potential efficiencies increases within the AWTFs. The effective nitrate management plan as well as the introduction of high stability emulsions, reintroduction of ammonia nitrate and fuel oil (ANFO) will reduce the nitrogen loading in the Elk Valley water shed.

Dedication

The dedication of thesis paper and EMBA is to my wife, who spent countless hours alone while I pursued my EMBA. The extended dedication is to my kids, co-workers, and friends who may not have received my full attention while I devoted the required time to complete the EMBA program.

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Glossary

LCO	Line Creek Operation
KPI	Key Performance indicator
ANFO	Ammonia Nitrate Fuel Oil
HSE	High Stability Emulsion
BRX	Burnt Ridge Extension
MTM	Mount Michael
NLX	North Line Creek Extension
LOM	Active Water Treatment Facility
AWTF	Active Water Treatment Facility
MEM	Ministry Environment and Mines
HEF	Heavy Emulsion and Fuel
NMP	Nitrate Management Plan
EVWQP	Elk Valley Water Quality Plan
CCME	
cP	centipoise
EAC	Environmental Action Committee
OHSC	Occupation Health and Safety Committee

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1: Introduction

Teck Coal Ltd. (Teck) operates five coalmines within the Elk River watershed in South-Eastern British Columbia (BC). Line Creek is one of the mines within the Teck Coal Business unit. The current mining activities at Line Creek occur in the southern half of the mine property. In 2017, operations at Line Creek will transition to Phase II mining operations. Phase II mining will transition to Burnt Ridge in 2015 and Mount Michael in 2016 with Burnt Ridge North beginning in 2019. Mining areas will transition to previously undisturbed mining areas.

The release of selenium, nitrates, cadmium, and calcium are through mining activities or mining practices. The release of selenium is through water contacting fragmented waste rock. The current control of Selenium is through active water treatment facilities (AWTF) at Line Creek. The release of selenium and nitrogen from the mine operations reports to the surrounding environment through: surface water discharges, groundwater or dust. Nitrogen is not present in high levels host rock and is primarily a consequence of blasting and mining activities.

On February 20th 2015, MEM granted permission to begin mining and dumping operations of the Burnt Ridge Extension pit (BRX). Mining BRX will begin dumping activities in the Dry Creek drainage. The letter of approval, Authorization number 106970, from the Ministry of Environment (MEM) consists of a series of obligations for continued mining within Dry Creek. Among these conditions outlined in the MEM authorization of BRX is the requirement of a Dry Creek Nitrate Management Plan because of rising levels of nitrates within the surrounding watercourses:

> 5. Teck will update the December 15, 2014 LCO Nitrate Management Plan to control Nitrate releases from the site. The updated Nitrate Management Plan must be implemented and submitted to the Director by June 1 2015. (Excerpt from MEM Authorization number 106970)

Meeting the above conditions allows for the continued authorized operation within the Dry Creek drainage. This report outlines various alternatives and their viability in achieving this condition.

2: Phase II Mining and Issues around Nitrate Release

Phase II mining and dumping will primarily take place in the Dry Creek drainage. Figures below, LOM Pit Phasing - 2015 Q1 and LOM Pit Phasing - 2036 End of Mine Life, show the before and after plans for mining activities in Phase II. Drainage from Dry Creek feeds directly to the Fording River system. BRX will be the first mining area as part of Phase II. Dumping for BRX will occur in the Dry Creek drainage, an area untouched by historic mining. Burnt Ridge Extension (BRX) pit mining must provide a nitrate reduction plan to the MEM in order to continue to operate because of current and predicted nitrate release.

BRX offers a unique opportunity to provide a controlled environment where the effects of nitrates can be controlled, documented and understood from the onset of mining. This unique mining environment allows for the monitoring of the effects of nitrate release and the results of the associated reduction plans. This paper will identify such plans and the associated risks surrounding each plan.

Line creek is beginning development of the Burnt Ridge South Extension (BRX) pit. The BRX pit will be the first instance of mining for LCO where dumping occurs in the north end of the property (Phase II Mining), as shown currently Figure: Life of Mine Phasing 2014, and figure: Life of Mine Phasing 2036, indicating mining activity at the end of mine life.

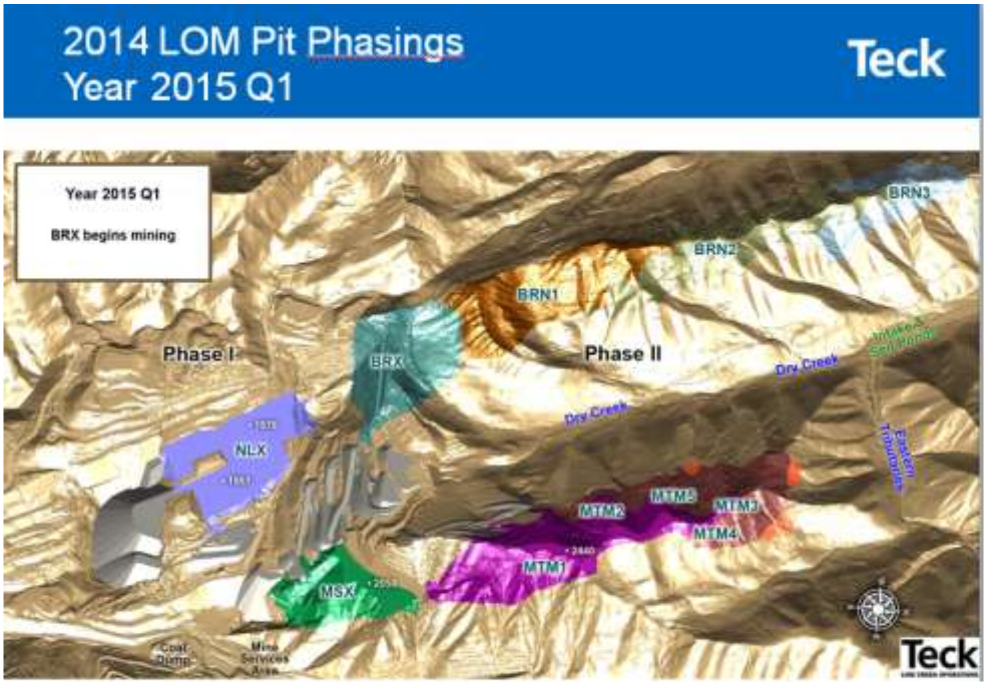


Figure 1 - LOM Pit Phasing - 2015 Q1- Source LCO LOM Report

Figure 2 - LOM Pit Phasing - 2036 End of Mine Life - Source LCO LOM Report

BRX began mining in 2015, MTM will begin in 2016 and BRN in 2019. The mining of BRX is an estimated 108 million BCM of waste, Burnt Ridge North will mine 356 million BCM of rock, and Mount Michael will mine 1.092 billion BCM of rock. In order to blast this material requires an estimated 658 million KG of explosives in Phase II, at a 0.79 powder factor). Assuming current utilization of products, 197 million Kg of Nitrogen will be loaded and detonated as part of blasting activities.

To appreciate the values of loading and blasting mentioned above refer to the Figure 3: Material moved and Explosives loaded. The aforementioned figure shows the actual blasting and waste movement mined since 2005-2014 as well as predicted levels based on the LCO 2014 life of mine plan (LOM). The graph clearly shows the relationship between mining rates and blasting volumes as well as the increased mining rates above historical. Following the current mining plan volumes, the levels of nitrate release will to continue to increase at historic levels without the introduction of alternative methods of nitrate management.

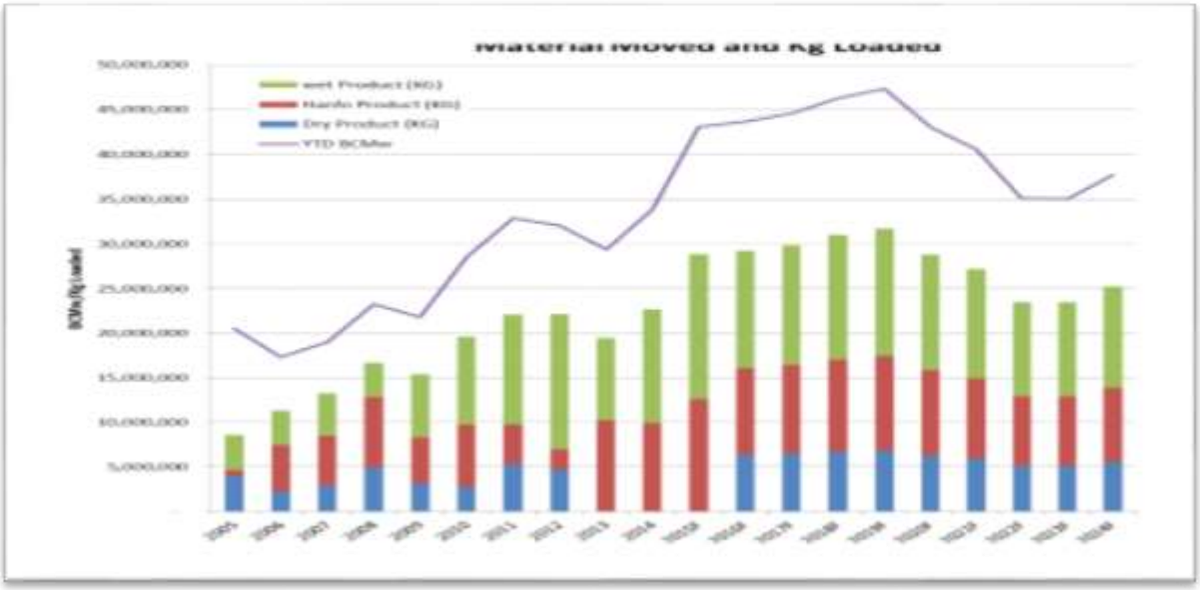


Figure 3 - Material moved and Explosives loaded

The following figures below illustrate the magnitude of the increasing levels of nitrates within a few of the surrounding watercourses. The order of the graphs is from closest mining activity to furthest away. In each instance, nitrates are rising and many approaching allowable limits for watersheds where drinking water, or fish bearing habitats exist. Figures below show the timing of AWTF's and the associated drops in nitrate levels related to these facilities. Under certain flow conditions nitrate levels do not meet acceptable levels without additional measures, mouth of Fording River in years 2015-2019, 2023 and 3031.

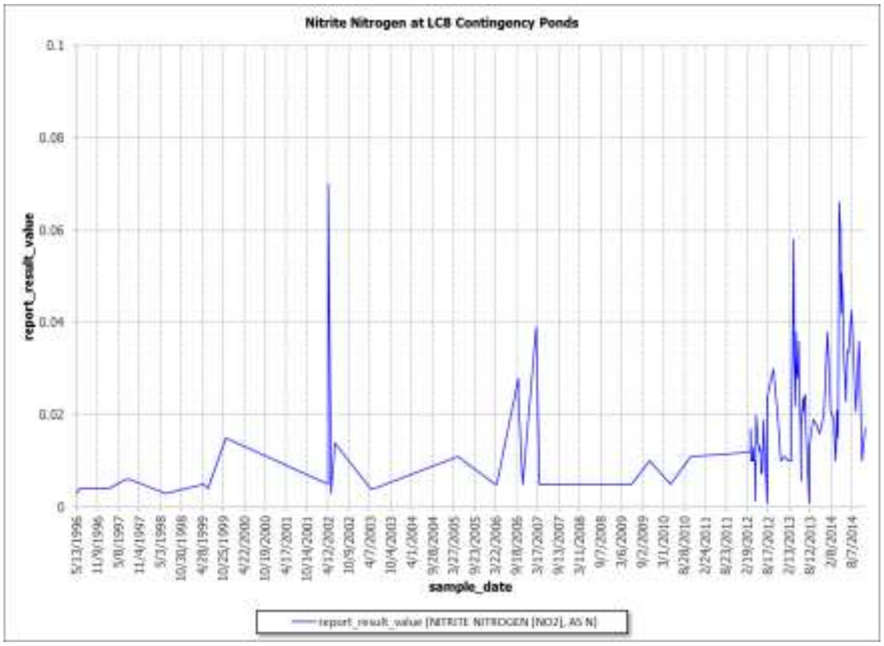


Figure 4 - LC Contingency Ponds Nitrates – Source data LCO Environmental group

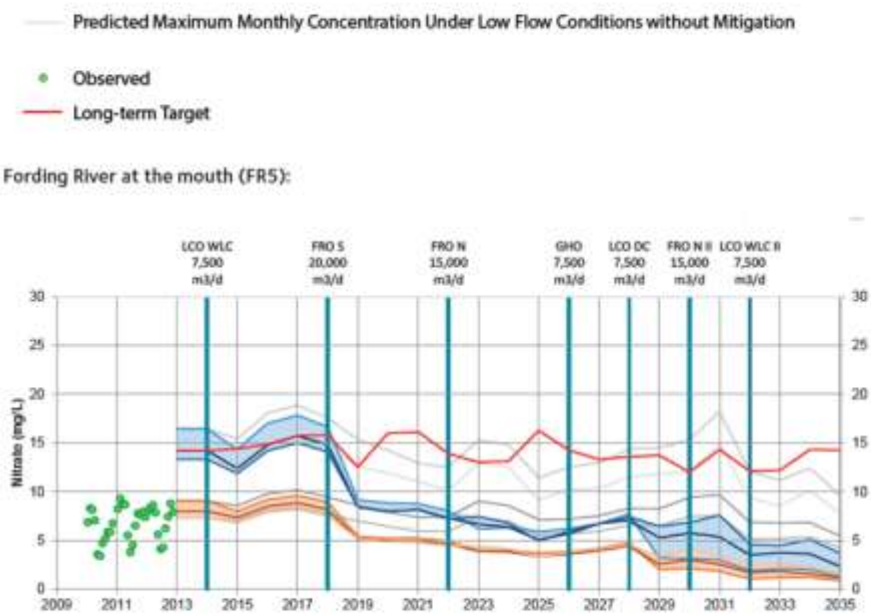


Figure 5 - Predicted Levels of Nitrates in Fording- EVWQM Graph page8-56

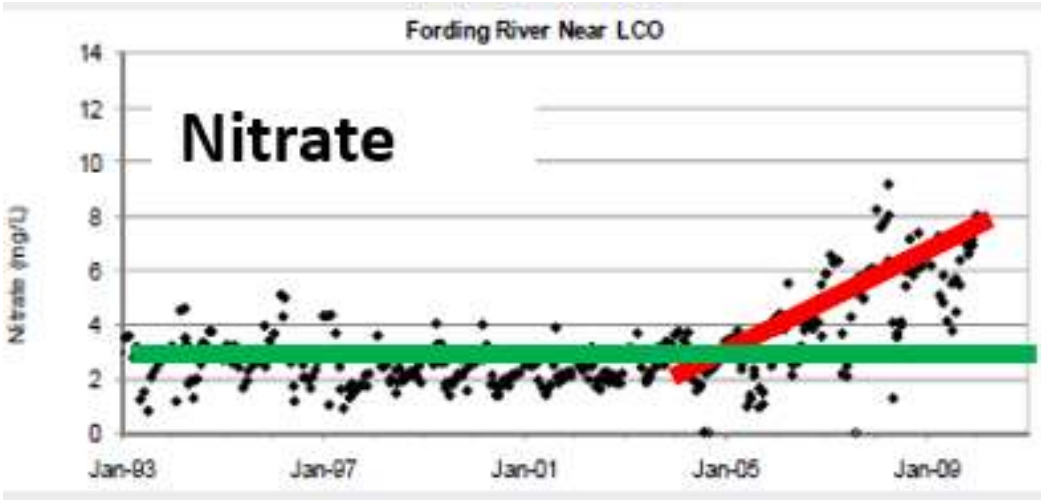


Figure 6 - Actual Nitrate Levels in the Fording River

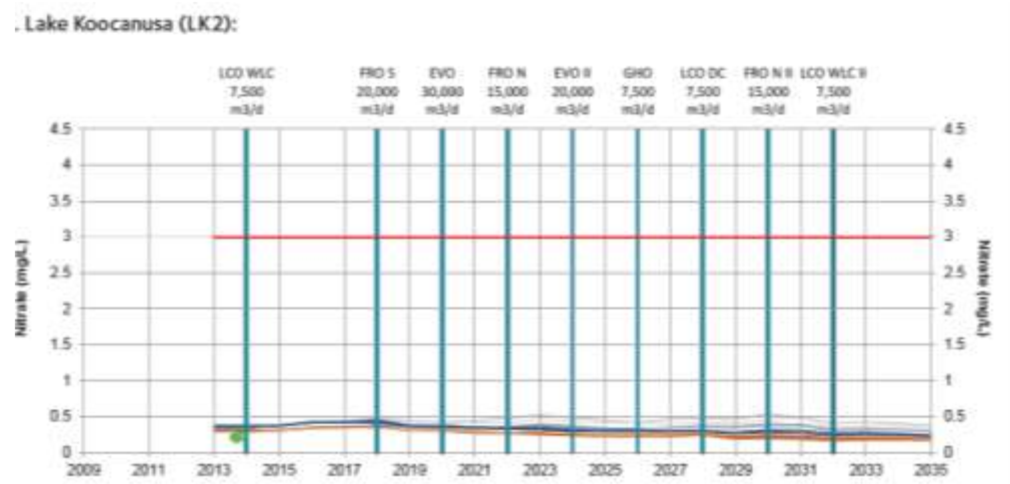


Figure 7 - Predicted Nitrate Levels in Lake Koocanusa - EVWM Graph page8-56

3: Alternatives Scenario Analysis for Reduction of Nitrates

3.1 Alternative 1: Status Quo - Development of Additional AWTF.

Alternative 1 would be the status quo for explosive usage and management of nitrates. With this option LCO will not change practices around loading of explosives and treat nitrates with active water treatment facilities (AWTF). Removing nitrates from water with AWTF's is an expensive option (approximately 100 million per AWTF). AWTF's are required for the removal of selenium. As treating nitrates is a part of the AWTF process, the treating nitrate in in current AWTF incurs minimal additional operating when considering the requirement to treat selenium. The current AWTF treats the water on the southern exposure of the valley and does not provide nitrate reduction on the north of the property, i.e. BRX.

AWTF is not a preferred alternative for the BRX mining due the high construction costs and the planned completion date of 2028 for LCO's second AWTF. This second active water treatment facility would not meet MEM required date and will not be completed in time if expedited. The current AWTF was not without risk, as evident in the 10/19/2014 Teck global announcement: Occurrence at Line Creek Water Treatment Works "Between Thursday, October 16 and Friday, October 17, 11 fish were found deceased in the area of the water treatment works at Line Creek Operations."

The above statement does not imply that the AWTF intended to cause a loss of fish, simply that the best-intended projects are not without risk.

Benefit to Alternative 1 is that no additional incurred costs to blasting. Cost deferred for the additional of another AWTF. Alternative 1 requires no change to current practices, SP&P, or additional hiring requirements. Downside to Alternative 1 is an inability to reduce nitrates in Fording River as per MEM request, until completion in 2028.

Viability of Alternative 1: Because of the timelines associated with BRX mining, in meeting MEM requirements for the control of nitrates, the lack of immediate change or action is not an option for continued approved mining in Dry Creek. This alternative may ultimately lead to LCO's inability to meet government requirements and potentially lead to LCO's inability to produce coal.

3.2 Alternative 2: Introduction of HSE

Alternative 2 is the introduction of a High Stability Emulsion (HSE) and mineral based ANFO. HSE is a blend of diesel and mineral oil in emulsion blends (45% mineral oil and 55% diesel blend). Traditional emulsion is 100% diesel fuel. Preliminary testing of HSE compared to traditional emulsion has shown positive results in testing as HSE showed greater resistance to leaching. HSE leaching rates resistance was four times greater than traditional emulsions as performed by Teck Resources Ltd. Elkview Operation. The introduction of HSE products and mineral based ANFO have a potential nitrate reduction of 10% for HSE and 20% reduction for bagged ANFO, when compared to un-bagged.

Costs associated with Alternative 2 include mineral oil tank, bags for ANFO, electrical power lines to a mineral tank, the potential of additional blast crew personal and training on pump truck. Power line work and mineral tank are one time expenditures expected to be less than $200,000. The bags are required for life of mine and include one in three blast holes at a cost of $30 per bag. An estimated 16,000 liners per year will be required for a total cost of $480,000 per year. An additional blaster may be required to operate a previously unnecessary pump truck. Saving in reduction of powder will occur with utilization of ANFO due to its lesser density as compared to 50% and 70% emulsion blends. An estimated $45 per blast hole savings from ANFO usage loaded in a similar hole vs emulsion blends. Savings using ANFO loading will represent $740,000 per year. These savings outweigh the cost of bagging.

Alternative 2 offers a low initial start-up cost and minimal reduction in total cost of operation, with a savings potential of $250,000 per year. The expected projected effects on nitrates reduction are to be immediate, however do not meet long-term nitrate reduction requirements. Mining rates are increasing 25% over the next 5 years and Alternative 2 proposes only a 10% reduction in nitrates. Implementing this alternative without further action may ultimately lead to LCO's inability to meet government requirements and potential lead thus its inability to produce coal

3.3 Alternative 3: Alternative Fuels and Additives

Prior to choosing mineral oil, alternatives fuels were benchmarked using conductivity. Figure 8- Alternative Blasting Fuels, shows the explosives manufacturer testing results.

Conductivity is not a definitive measure of nitrate release as it does not simulate real world conditions, but is an indicator of an explosives ability to resist leaching.

Testing shows that increasing diesel stability to 44000 centipoise density, up from its traditional 33,000 centipoise, resulted in insignificant changes to conductivity. While the increased stability resulted in marginal results in conductivity, the increased viscosity proved problematic to pump.

Testing of Parflax HT22 and HT32, show excellent results in conductivity. Sourcing and delivery of these products could not be guaranteed therefore were not considered as long term viable options.

Faxam 32 shows results similar to HT22 and 32 however, Faxam 32 could more reliably be supplied therefore was chosen as best mixing option with diesel.

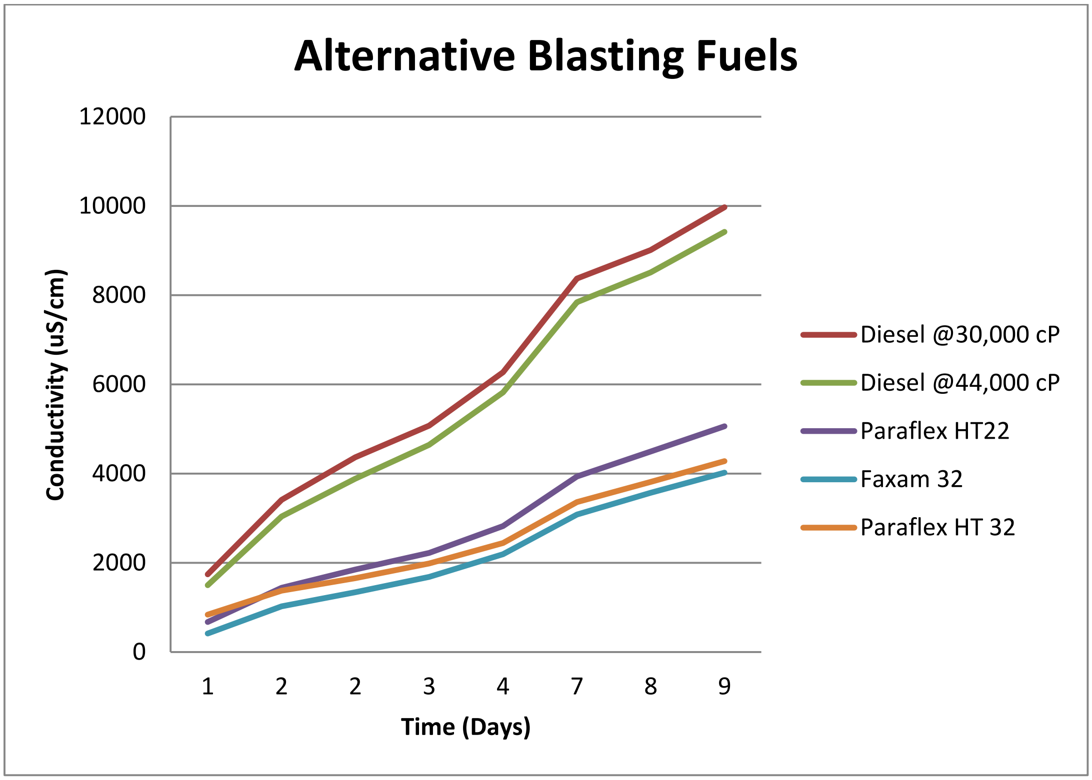


Figure 8 - Alternative Blasting Fuels- Source Powder Supplier for LCO

Alternative 3 offers capacity in nitrate reduction. The costs associated with alternative three are minimal. The cost of mineral oil is at current market prices similar to diesel, requires no additional cost to LCO or additional training.

Alternative 3 cannot be considered as a standalone nitrate reduction option as it offers only a 10% reduction in nitrates. The potential reduction in nitrates is less than the 25% increase in mining rates over the next 5 years. Implementing this alternative without further action may ultimately lead to LCO's inability to meet government requirements and potentially lead to an inability to produce coal

3.4 Alternative 4: Introduction of HSE and Operational Controls

Introduction of high stability emulsion (HSE) and mineral based ANFO and operational controls. Operation controls include:

- Double priming – Potential decrease in misfires and bootlegs
    - 5% reduction in nitrate leaching
    - Average 165,000 dollars additional per year in booster
- Crushed stemming rather than traditional drill cuttings – improved detonation process
    - 5% reduction in nitrate leaching
    - No additional cost to operation
- Control surface water to mining contact with ground water and explosives – improved detonation
    - Minimal cost of operation as pumps and water line are sunk costs. No additional purchases required
    - Unable to quantify reduction, however removal of water offers great potential for reduction of nitrates.
- Bagged ANFO and dewatered holes – where applicable would eliminate contact with water
    - Offers 20% reduction in nitrates when compared to non-bagged holes
    - $480,000 additional cost per year expected for bags to line damp holes
    - $750,000 reduction in operating costs when loading ANFO vs emulsion product –per hole value provided by EVO blasting engineer - $45/hole
    - Offers a potential saving to operation of $280,000 per year
- Reduce sleep time to strictly adhere to manufactures guidelines.
    - Offers 15% reduction in nitrate leaching
    - No additional cost to operation
    - Minimal impact to operation
- HSE introduction
    - Offers 10% reduction in nitrate leaching

- No additional cost to operation
- Mineral oil pricing similar to diesel at current market prices

The following figure, Figure 9 Nitrate Reduction Opportunities, is from a Diavik report, (Diavik Diamond Mine, Ammonia Management Plan, Terry Matts, and February 2007). The report below shows the results of testing ANFO, and the reduction potential for different types of remediation efforts.

Table 2-3: Summary of AN Loss Reduction Options from Blasting Practices

Option	Description	Practicality	AN Loss Reduction	
			Average	Peak
EM-1	Double Priming	Practical	5%	10%
EM-2	Improved Loading	Practical	5%	5%
EM-3	80% Emulsion/20% ANFO Ratio 100% Emulsion/0% ANFO Ratio	Practical Impractical	80/20: 15% 100/0: 20%	80/20: 20% 100/0: 20%
EM-4	Thicker Emulsion	Practical	10%	10%
EM-5	New Low-Leaching Blasting Product	Impractical	10+%	10+%
EM-6	Reduce Explosives Residence Time	Practical	15%	30%
EM-7	Dewater Wet Blastholes	Impractical	No effect	No effect
EM-8	Dewater and Line Blastholes	Impractical	See EM-9	See EM-9
EM-9	PE Liner in Wet Holes	Questionable	20%	50%
EM-10	Packaged Blasting Product	Impractical	See EM-9	See EM-9
EM-11	Low Density Emulsion	Practical	0%?	0%?
EM-12	Microballoon Sensitization	Impractical	See EM-11	See EM-11
EM-13	Improve Stemming	Practical	5%	5%
Combo#1: EM-1,-2,-3,-4,-6,-13		Practical	45%	60%
Combo#2:EM-1,-2,-3,-4,-6,-9,-13		Practical	55%	70%

* Install PE liners in wet holes in high permeability areas of mine floor
** Recommended if brown fumes are emitted from blastholes after implementing EM-9 and other options

Figure 9 - Nitrate Reduction Opportunities

Alternative 4 offers the greatest potential reduction in nitrates as it is a merger of all alternatives. The expected potential reduction in nitrates is cumulatively, 55% beyond baseline nitrate leaching rates. The cost of operation is the most expensive alternative, at $645,000 per year (bags and boosters), plus the additional employee on the blast crew. The offset cost of operation associated with ANFO usage is through a reduction in explosives ($750,000). This option meets the requirement to reduce nitrates below government guidelines. Immediate reduction of nitrates has the short-term potential to delay a proposed multimillion dollar bypass structure between LCO boundary and the Fording River. This report outlines various components of Alternative 4 and the viability of each constituent.

4: Sources of Nitrates

4.1 Loading of Blast holes

Fording River and Elkview supply explosives to LCO. LCO relies on these two explosive manufacturing plants for all it blasting explosives. Bulk tankers transport the emulsion to LCO at a rate of two tankers per day to meet production requirements. Emulsion products are stored in heated emulsion silos. From the heated silos, the emulsion products are transported to the blast patterns and unloaded into blast holes.

During the process of transportation of emulsions and the loading of blast holes, spillage occurs. Loses between holes are shown in, Figure 10 Explosive Spillage at surface. Explosives lost between holes, or caught at the surface of the borehole will not detonate during the blasting process. Unexploded product is ultimately deposited in an active dump where leaching occurs when in contact with water.

In order to minimize spillage between holes, Elkview is developing a new design of hose. LCO will adopt the new hose design once completed.

Auguring and pumping are delivery methods for explosive loading and delivery. Auguring is the process where the delivery truck places a delivery hose over the top of the hole and drops explosive product into the hole. Pumping comprises a hose placed at the bottom of the borehole and pumping explosive product into the hole while raising the hose. Through visual analysis and conversations with blasters, the author has found auguring produces less spillage between holes. Usage of auguring wherever possible will reduce spillage between holes.

There is an expected 5% reduction in nitrate release from HSE product change and discharge hose modifications. Minimal costs will be associated with developing hose modifications at EVO. Proposed hose modifications include the use of site-fabricated flanges parts connected to small springs and plate metal.

Establishing an auditing process ensures process compliance around spillage procedures. The recommendation is the auditing of blast patterns where spillage reports be filled out during monthly EAC audits and added to EAC meeting agenda.

Figure 10 - Explosive Spillage at surface

4.1.1 Sleep time of explosives

Holes are loaded prior to detonation process. The interval between loading and detonation is sleep time of the explosive. Sleep time is limited to manufactures recommendation to maintain proper initiation. However, manufactures recommendation due not consider nitrogen release rather proper detonation of explosives.

Extending sleep times reduces the chances of explosives detonating properly, thus increasing potential of unexploded product post blasting or post fumes. Extending sleep time increases the time in which explosives are in contact with water, standing or flowing. Sleep time reductions initiatives offer a theoretical 15% reduction in nitrates.

Recommendation from this document is the addition of sleep time as a metric to the weekly engineering planning package to maintain focus of sleep times.

4.1.2 Water control

Water management is a key strategy to reduce nitrogen leaching. By reducing water contact with explosives and/or water contact with explosives residue on waste rock, there is less capacity for the transported of nitrates to receiving environments.

4.1.2.1 Run off

Surface water on bench floors can enter through faults/strata in the pit floors and cause leaching of loaded blast holes. Runoff during freshet increases the amount of water the mine manages. Keeping runoff away from blast patterns, with sumps, and utilizing pumps to move water away from blasted material is an effective way to control nitrate leaching. Figure below, Figure 11- Water Control during Mining Activities, shows how effective pumping activities can keep bench floors free of standing water.

Figure 11 - Water Control during Mining Activities

4.1.2.2 Pit dewatering

Traditional mining practise is that upon completion of pits or pit areas, the pits are backfilled. Backfilled pits allow a unique opportunity to collect water for the use in dust suppression on mine roads. However, performing routine water monitoring ensures an understanding of leached minerals prior to usage on pit roads or water release to environment. Below is a recently completed pit, Burnt Ridge South (BRS). BRS will be backfilled early in Q2, 2015. Once dump progression allows, a deep well and storage tank are to be installed for the collection, of road watering. The monitoring of water collected for contained minerals, pumping rates, to monitor infiltration rates, chemical changes and dewatering rates ensures compliance to water quality guidelines. Pit dewatering, water meeting water quality guidelines, will have no effect on the total release of nitrates, however timing of discharge flow rate scan be used to control the nitrate release for periods of high downstream flow. Thus utilizing flow rates in reducing the impact to fish bearing watercourses through reduced total nitrate loading.

Figure 12 - BRS Pit - Planned Pit Dewatering Location

4.1.2.3 Reclamation

As a general rule, reclamation practices are intended for mined areas to be remediated to conditions equal to or better than mining. Re-sloping dumps allows vegetation and grasses to develop on slopes. Vegetation and cover materials provide a cap layer to help reduce water infiltration. The combination of re-sloping and vegetation will aid in reduction of water entering dump. Vegetation on the surface of the dump will help to limit the infiltration of water into the dump and promote the evaporation of water. The use of cap layers reduces water from entering dumps, thus reducing waste rock explosives reside with water.

4.1.2.4 Blast Hole Dewatering

Blast holes that utilize ANFO should be dewatered in the event the bagged product fails to resist water. Dewatering blast holes creates dry conditions for loading, however can only be utilized in holes with static water. Dynamic water conditions require the utilization of water resistant products such as 70% emulsion blends. Identifying and using proper explosive products adds no additional cost however can have a 5% total reduction in nitrates.

4.1.3 Detonation process

Sleep time, poor rock impedance matching, blast initiation timing, misfires, or ground shifting increases poor/incomplete detonation of blasting agents. In each of these, the result is typically improperly detonated blasting product. Improperly detonated blasting agents are susceptible to nitrate leaching, as they remain exposed to weathering once placed in an active dump.

4.1.4 Blasting Parameters

Typical blasting at line creek utilizes blast holes designed utilizing the criteria in table below, LCO drill and blast criteria. The blast holes are loaded according to drilled hole conditions: wet or dry. The determination of wet or dry is performed the by blasting personnel at the time of loading based on amount of water in the blast hole. These design criteria used in the design of a blast pattern ultimately determines the powder factor of a typical blast pattern.

Pattern design is based on:

- the properties and quantities of explosives;
- blast geometry – spacing, hole size
- blast size – number of holes
- the priming method – single of double priming and size of booster
- the initiation sequence- timing of blast holes
- water conditions – wet or dry

Design Criteria	Soft Rock(BI <50)	Hard Rock (BI >50)
Drill Design		
Hole Diameter	13 3/4	13 3/4
Pre Shear		
Burden (m)	8.67	9.54
Spacing (m)	10	11
Sub Drill (m)	1.5	1.5
Powder Factor (kg/bcm)	0.56	0.56
Loading Density	132kgs/m	132
HEF 700 (kg/hole)	1088	1024
HEF 500 (kg/hole)	1122	1056
Powder Colum (m)	8.5	8
Stemming Depth (m)	8	8.5
Buffer Protection		
Burden (m)	8.67	8.67
Spacing (m)	8.67	8.67
Sub Drill (m)	0	0
Powder Factor (kg/bcm)	0.64	0.64
Loading Density	132kgs/m	132kgs/m
HEF 700 (kg/hole)	768	768
HEF 500 (kg/hole)	792	792
Powder Colum (m)	6	6
Stemming Depth (m)	9	9
Production Hole		
Burden (m)	8.67	8.67
Spacing (m)	10	10
Sub Drill (m)	1.5	1.5
Powder Factor (kg/bcm)	0.8	0.8
Loading Density	132	132
HEF 700 (kg/hole)	1088	1088

HEF 500 (kg/hole)	1122	1122
Powder Colum (m)	8.5	8.5
Stemming Depth (m)	8	8
Explosives Property		
Wet Loading		
Maximum Sleep Time (days)	10	10
Dry Loading		
Maximum Sleep Time (days)	12	12

Table 1 - LCO Drill and Blast Criteria

4.1.5 Powder Factor

Powder Factor is a mathematical relationship between the quantities of explosives loaded (kg) and the volume of waste rock to be fragmented (BCM). PF is a measure of the required explosive powder required to blast intact rock. Powder factors that are higher than required provide limited increases in shovel productivity, reduced dump stability resulting from increased fine proportion in waste rock, and increase the amount of blasting agents used. The increase in blasting agents above baseline increases the amount of potential nitrate leaching due to increased explosives used. Low powder factors reduce shovel productivity. Powder factor when optimized maximizes powder usage, and provides a compromise between potential nitrate release, and shovel productivity.

Line Creek powder factors historically shown in the figure below, figure 13Mines Comparison on Powder Factor. The powder factors shown for LCO are traditionally lower than all mines, with the exception of GHO. Powder factors are a method of ensuring the minimizing of nitrate release through the optimization of powder. When powder factors begin to rise above, other mines in the valley, engineering should consider reductions through investigation into variances or initiatives around reduction.

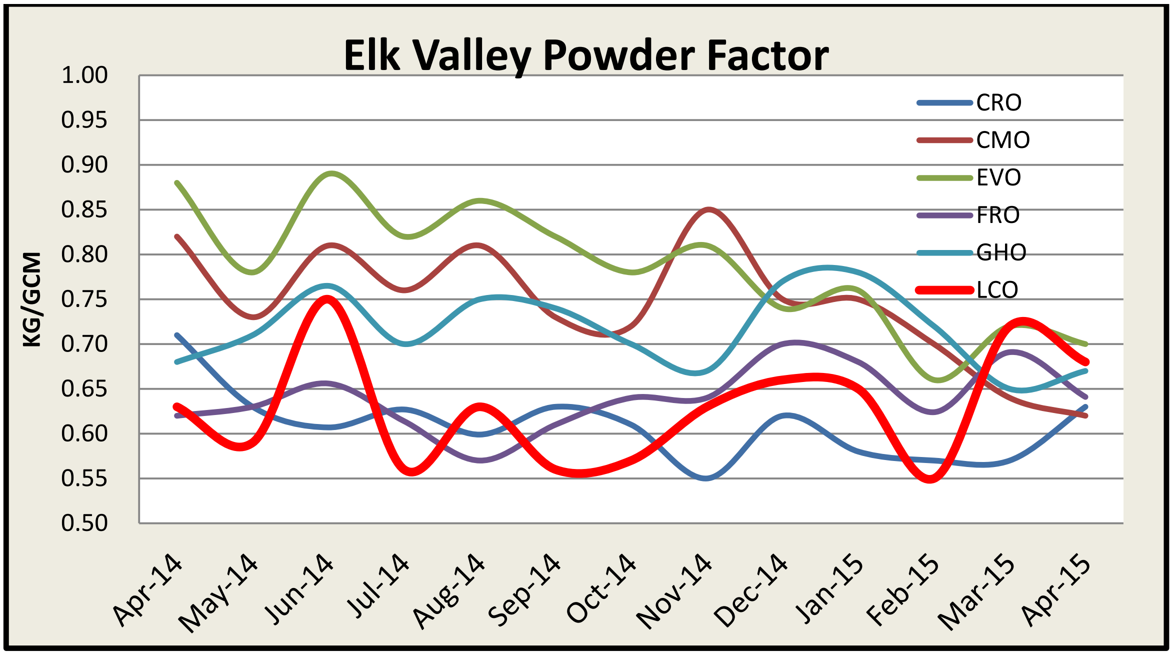


Figure 13 - Mines Comparison on Powder Factor- source Teck Mines Comparison

The author recommends constant measuring of the counter physicals to powder factor when utilizing P.F as a metric to minimize loading of explosives. A number of factors affect shovel production: trucks, single or double side loading, road condition etc. Comparing load times per individual truck on a similar shovel bucket size is an industry recognized metric. In this regard, LCO production rates remain at the higher end of productivity.

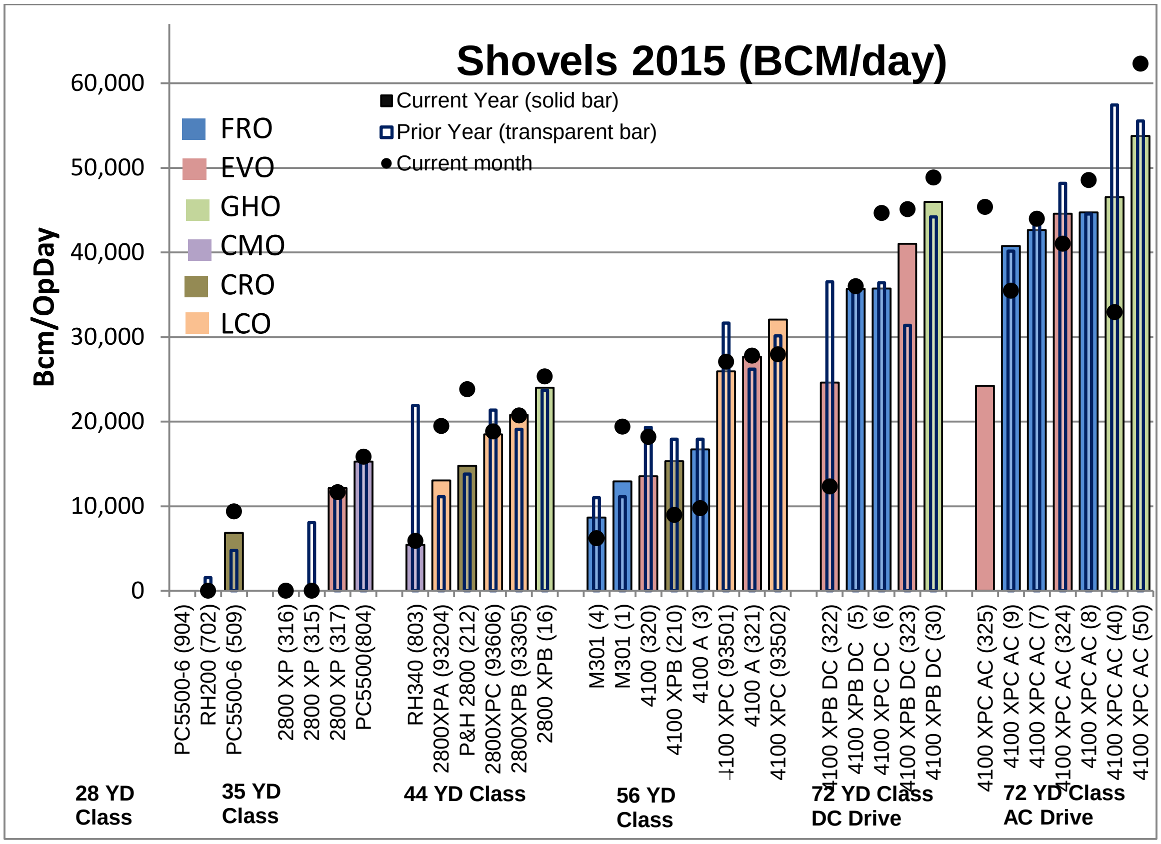


Figure 14 - Shovel Material Movement per Day- Graph from Teck Mines Comparison

The driver that compares shovels, Figure 14 - Shovel Material Movement per Day, on a normalized basis among the mines is in truck loading time. Comparing shovels by bucket size and consistent truck size normalized the load times. Loading times can compare the performance of powder factor. The shovel load times below indicate that while Line Creek has among the lowest powder factor in the valley and have among the lowest loading time.

The above KPI indicates that LCO powder factor is adequate to fragment the rock to a productive size, and maintain an above valley standard shovel productivity. LCO by maximizing powder is offering one of the greatest potential reductions on nitrates by limiting the amount of nitrogen placed in the ground.

A reduction in loading quantity of explosives reduces quantity of nitrates available for leaching. The reduction or maintenance of a low powder factor also has a reduction in cost. Year to date blasting represents 11% of the total costs associated with mining on a BCM/total material unit cost. The largest driver to blasting is the cost of explosive, which represents 91% of the total blasting cost. April 2015 saw an 18% increase in amount of powder used from the budgeted PF for April 2015. Budget PF was 0.67 Kg/BCM as compared to an actual 0.72 Kg/BCM. This increased PF represents an additional 418,000 kg of powder used in April, and an additional 125,000 kg of nitrates for actual waste loaded and blasted.

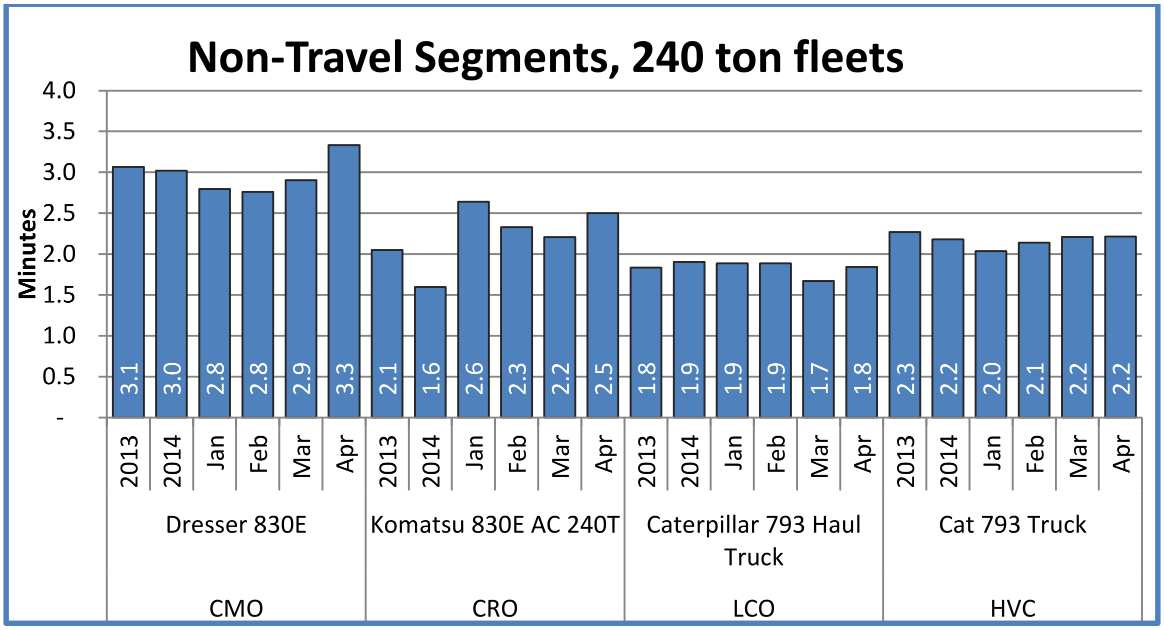


Figure 15 - Shovel Load Times – source Teck Mines Comparison Document

4.2 Post blast Fumes

Blasting explosives/agents fragment the rock to smaller size distribution to allow for productive mining with rope shovels, or large loaders. LCO blasting utilizes HEF500 (50% emulsion) and HEF 700(70% emulsion) as its primary blasting agents. Longer-term outlook is to reintroduce ANFO as a blasting agent.

The blasting agents used are primarily hygroscopic and with increases of moisture, the explosives lose strength and improperly detonate. Improper detonation results in post blasting fumes or partially exploded blasting agents found post blast. Through the incomplete detonation process, post blast fumes release NO_3 and NO_2 to the environment. Post blast fumes are red fumes, primarily nitrogen, released directly to the environment.

Detonation process is dependent of stemming material, impedance matching of rock properties, blast delay timing and influences of water on the blasting agents. Post blast fumes are an indicator of improper detonation of explosives. It is the role of the mining engineers to work diligently to ensure that rock properties, timing, detonation speed and appropriate use of stemming materials.

The tracking of the post blast fumes has been a continued focus for Teck. The figure below, Figure 16 Post Blast Fume at LCO, shows the results of post blast fume tracking for LCO beginning in 2014. Analysis of the figure below shows that LCO has no noticeable reduction in post blast fumes over the period. No reductions in post blast fumes are evident, as no initiatives introduced over this period have proven effective. Initiatives have included density variations of the product, emulsifier, and winter fuel additives to aid in gassing of explosive products.

Introduction of HSE is expected to show a decrease in post blast fumes.

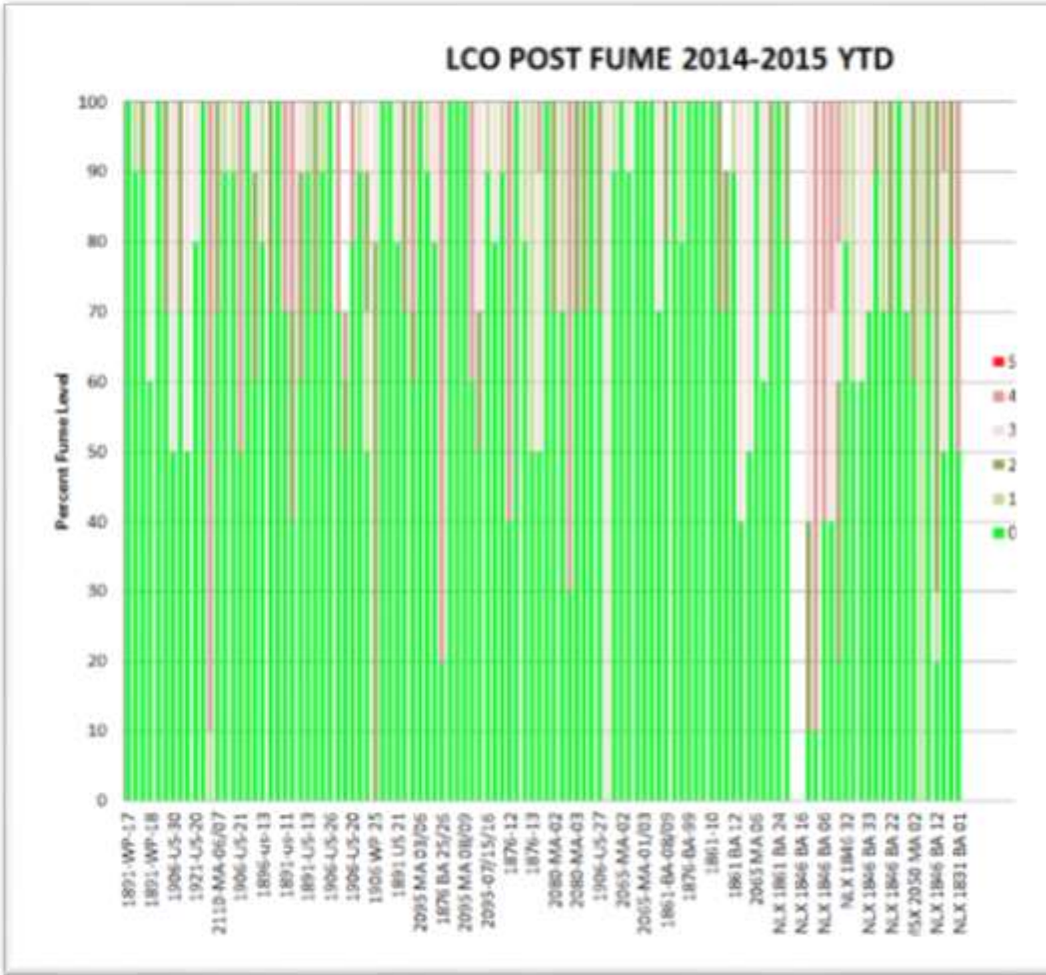


Figure 16 - Percent Fume Level LCO – Source data Teck Post Fume Analysis

Similar to LCO, post blast fume analysis occurs at Teck Resources Ltd. Elkview operation. Similar to LCO, EVO has been recording post blast fumes on a qualitative basis shown in Figure 17- Post Fume Levels at EVO. The data shows a decrease in post blast fumes. The attributed downward trend in EVO post fumes resulted from the introduction of double priming, HSE and introduction of ANFO.

Current business unit focus on post fume analysis is around worker safety – pulmonary oedema when nitrates are found in concentrations greater than, HSRC 2008, - TWA 3ppm, STEL

5ppm. Elkview is currently taking samples from employees wearing gas monitors while clearing blast patterns post blast. To date only two occurrences where NO_2 was detected post blast have been recorded, one in 2014 and another in 2015.

The OHSC reviews post fume data from a safety perspective. The recommendation from this paper is to introduce the same data to the EAC to ensure the similar focus to nitrate release at LCO. The intention of publication and review of this data is to ensure a spotlight remains on the post fume issue.

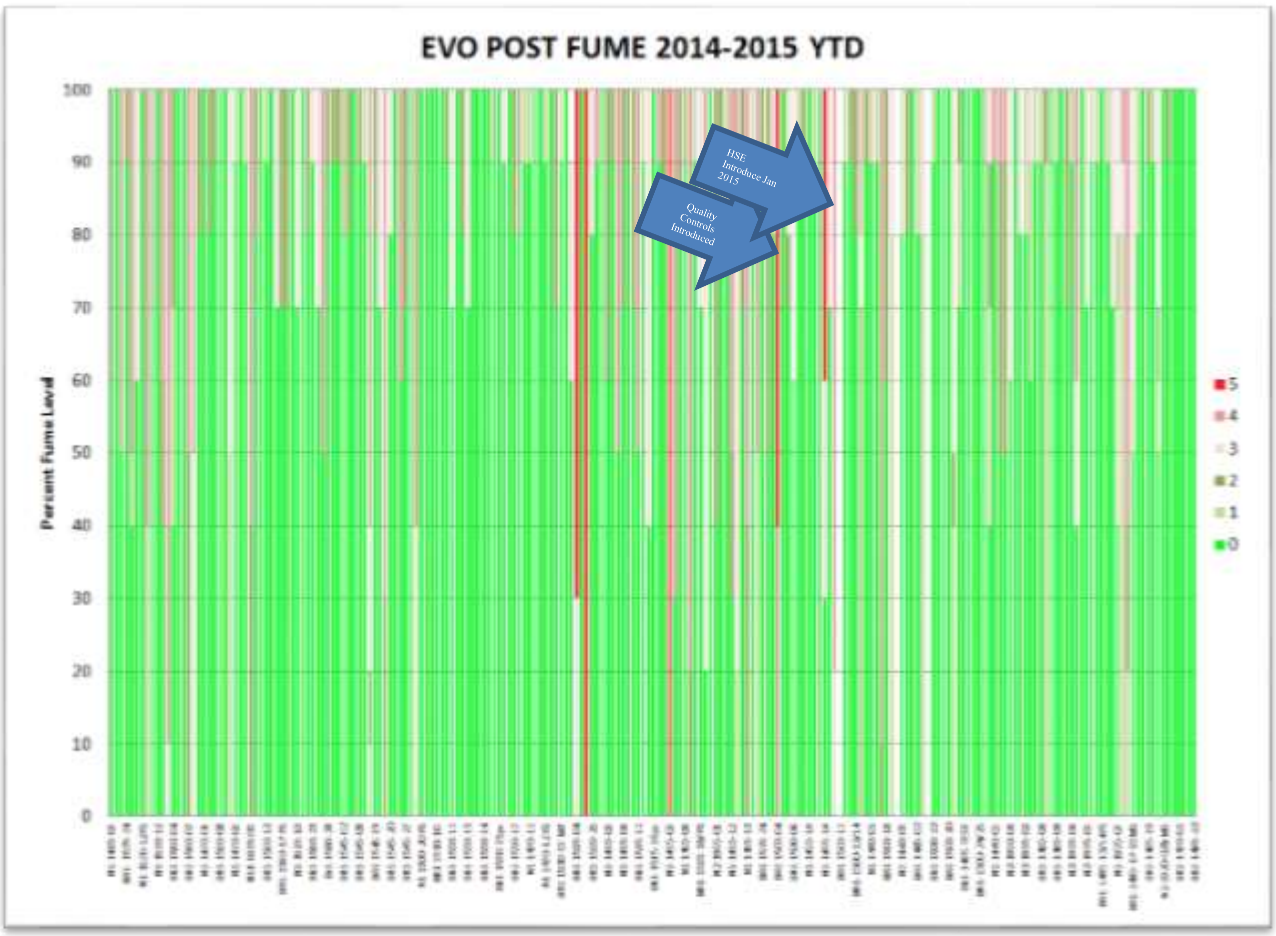


Figure 17 - Post Fume Levels at EVO

5: Explosive Usage to Control Nitrates

April 20th LCO reported to the MOE a nitrate exceedance a compliance station P107517. A Nitrate (as N) exceedance (14.4 mg/l) was identified above the monthly average limit (14 mg/l) at the sample location ‘line creek downstream of the influence of south line creek (EMS 297110)

While the primary source of nitrates is from leaching of nitrates from within the blast holes a large percentage of released nitrates are from field operations. Diavik Diamond Mine Ammonia Management Panel document, printed February 9 2007, indicates that the sources of leaching and the potential reduction rates. The author of this document proposes the control of surface activities around blasting field operations comes in the form of a nitrate management plan. NMP is included in the appendix.

The completion of the nitrate management plan will satisfy LCO’s requirement to continue dumping into Dry Creek, as per MEM requirement. The updated nitrogen management plan will detail the control of surface water, bench dewater practices, training, explosives storage, recycling of wash water, spill management, and loading practices.

The objective of the Nitrogen management is to manage nitrogen release to the receiving environment, while maintaining fragmentation and dig ability of blasted rock. The intention of the NMP is the effective reduction of nitrogen to the environment, therefore minimizing water quality impacts. The NMP will aid in reduction of potential aquatic effects within the watersheds LCO operates and prevent similar incidents as those recently reported at compliance station P107517

5.1 Explosives Usage

The type of application environment characterizes the explosive product used, dry vs wet. Dry products are typically ANFO while wet products utilize higher percentage emulsion. ANFO products require dry conditions to avoid breaking down through contact with water, as ANFO is hydroscopic. ANFO contact with water can be eliminated through bagging of explosives, thus eliminate release of nitrates. The use of heavy ANFO, blends of ANFO and Emulsion, falls between a fully wet and completely dry environments. Emulsion products are more expensive and thus increasing the amount of emulsion in a product substantially increases costs.

In 2012 Prill, the main ingredient in explosive products changed from explosive grade prill to a mini-prill. The change was required due to the prill supplier's inability to maintain constant/consistent supply of explosives grade prill. Teck Coal chose in order to guarantee product deliveries switched to mini-prill. The change to mini prill eliminated ANFO as a viable product due chemical properties causing an inability to make ANFO. Mini prill also eliminated emulsion-based products up to and including HEF450, 45% emulsion products.

Mini-prill has a smaller contact surface than explosive grade ANFO prill, resulting in less absorption of fuel and inadequate contact between fuel and oxidizer. The small weaker prill results in elevated post blast nitrate oxide (NOx) fumes and improper detonation.

Explosive Type	Nitrogen content by Weight
100%	26.4
80%	27.94
75%	28.28
70%	28.59
65%	28.92
60%	29.22
55%	29.53
50%	29.83
45%	30.14
40%	30.45
35%	30.75
30%	31.06
25%	31.37
20%	31.67
ANFO	32.9

Table 2 - Explosives Nitrogen Content

Established in the table above each explosive type has a varying content of nitrogen content. However, one must perform further powder factor analysis based on product type and relative bulk strength to ensure proper blasting. One finds when doing PF analysis is that the lower the emulsions content the lower the nitrogen content for an equivalent powder factor. The following sections will detail application specific products to ensure proper loading standards are developed.

5.2 ANFO

Ammonia Nitrate and fuel oil (ANFO) (94% Ammonium Nitrate, 6% fuel oil) contains over 30% by weight nitrogen. The primary use of ANFO products is in dry conditions. ANFO provides no resistance to breaking down in the presence of water. Benefits to ANFO are lower costs, and increased gas energy due nature of energy expelled during detonation. ANFO as it is hydroscopic, attracts water, and with contact with water begins to break down. Ammonium nitrate (AN) takes the form of porous prill, which combine with fuel oil (absorption and adhesion) to form an explosive where nitrogen is soluble in water. ANFO is approximately 30% by weight nitrogen.

Historically ANFO represented 25% of total explosives used, however, was discontinued in 2012 due to the switch to mini-prill. Using the current mini prill, ANFO is not available for use due to current supplier's characteristics of the prill: density, 1.05 vs 0.85 and limited porosity of the prill. Mineral oil proposed in alternative 4 will allow for reintroduction of ANFO. To eliminate contact with all sources of water the proposed NMP proposes only bagged ANFO. Wet or flowing water conditions exclude the use of ANFO, bagged or not, due to probability of bag puncturing and resulting in improper detonation.

5.3 Heavy ANFO

Heavy ANFO products, (HEF), provide a greater amount of resistance to water over ANFO. The amount of emulsion in the blend increases water resistance as emulsion percentage continues. HEF 200 contains 20% emulsion, and HEF 400 contains 40% emulsion with the remainder being ANFO. A HANFO blend's water resistivity is directly related to the amount of emulsion in the mix (more emulsion = more water resistant. Currently only HEF500 and above may be produced using miniprill. Mineral oil will allow for introduction of all emulsion blends. Figure 5: Leaching rates of Nitrates, Adrian Brown, and Dissolution Rate of ANFO based blasting emulsion August 29, 2007, shows the nitrate release of HANFO products over time. As percentage of emulsion used in blasting agents raises so does the cost.

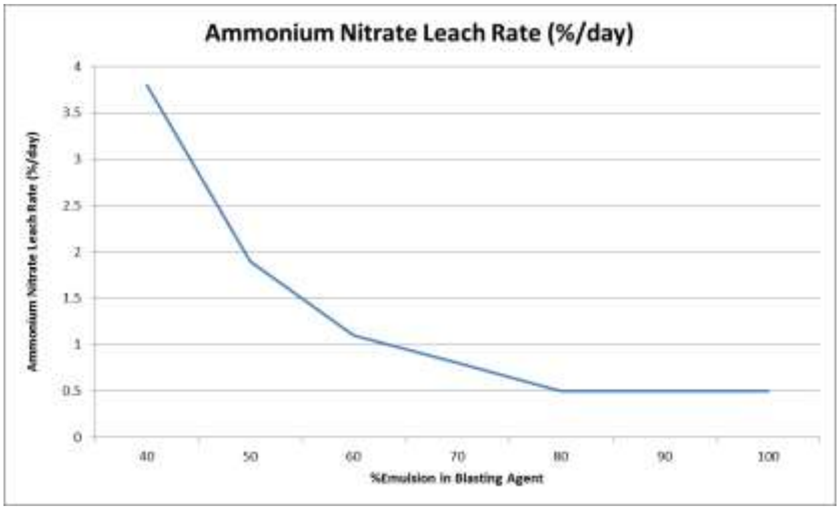


Figure 18 - Leaching rates of Nitrates- source data Adrian Brown, and Dissolution Rate of ANFO based blasting emulsion, August 29, 2007

5.4 Emulsion

One hundred percent emulsion offers the greatest resistance to standing, and flowing water conditions. ANFO has no ability to resist water effects; emulsions offer a very high resistance to water effects. Emulsions resistance to solubility with water contact makes them ideal where blast holes contain ground water. Wet products have the highest concentration of emulsion namely HEF 700 70% emulsion and HEF 1000 being 100% emulsion. The expected nitrate release from these products contributes the least to the release of nitrates due to their water resistant qualities. The cost of production increases for HANFO over ANFO blends resulting from higher densities and similar powder factors.

Traditional HEF 700

- 70% Emulsion
  - 6.6% fuel phase (100% diesel)
  - 1.4% Emulsifier
  - 92% Ammonium nitrate (AN) solution (80% AN concentrate, 19.95% water, 0.05% sulphmaic acid)
- 30% AN Prill (99.9% by weight AN, 0.2% coating agent)
- 0.3% Sodium nitrate (based on the entire mix at 30% w/w concentration in water)

SHE HEF 700:

- 70% Emulsion o 6.6% Fuel phase (55% mineral oil, 45% diesel)
  - 1.4% Emulsifier
  - 92% AN solution (80% AN concentrate, 19.95% water, 0.05% sulphmaic acid)
- 30% AN Prill (99.9% by weight Ammonium Nitrate, 0.2% coating agent)
- 0.3% Sodium nitrate (based on the entire mix at 30% w/w concentration in water)

5.5 Summary of Explosives

ANFO: Mineral oil as a fuel source with the current mini-prill will allow for the reintroduction of bagged product will eliminate nitrate release and reintroduce a lower cost explosive. The author proposes the strategy where mineral oil is in production of ANFO. ANFO use, in conditions where applicable, achieves lowest operational cost and reduction with water through use of using liners. Below is the current site performance in relation to HSE products used in blasting. LCO is currently in the initial stages of introducing HSE products.

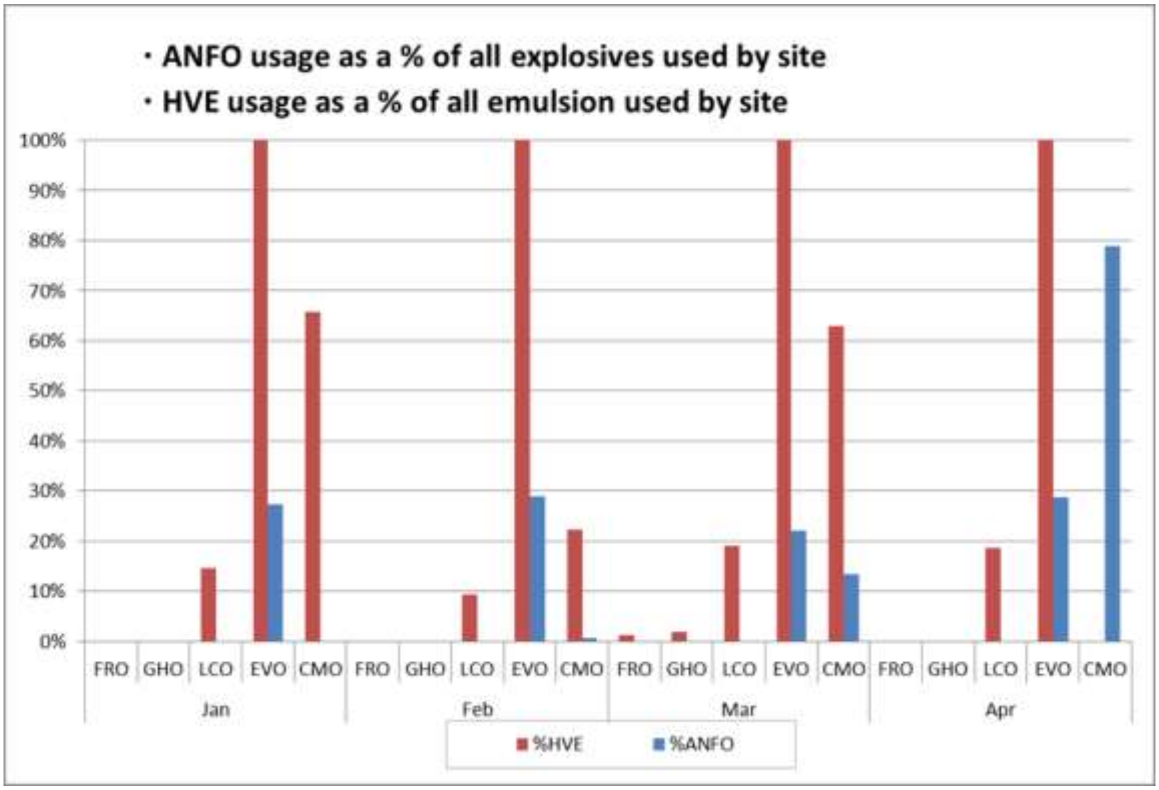


Figure 19 - HSE products by type in Elk Valley 2015 Year to Date.

LCO is continuing to develop the strategy of reintroduction of ANFO. The planned introduction of ANFO in Q2 2015 has an expected to cost less than $200,000. The installation cost includes additional fuel tank and power lines. The increase to the daily operation of the mine will come in the form of additional bags to line holes, thus keeping ANFO dry. It is predicted on average 15,000 liners will be used per year at a cost of $30 per liner and resulting in $45 dollars in powder savings.

HANFO: HSE in blasting will have a similar cost of production when compared to traditional HANFO products through use of mineral oil versus diesel. However, HSE will have a 4x reduction in nitrate release over traditional products. The author proposes use of HSE and HANFO products to reduce nitrate release. The rate of change to HSE is a function of the manufacturing plants at EVO and FRO. Currently LCO is requesting 100% HSE emulsion products from EVO. FRO planned production of HSE is 2016.

The recommendation for a path forward is EAC monthly meetings review explosive usage by product, and requirement added to NMP. EAC meetings review all blast not utilizing HSE on a monthly basis and develop actions to reduce exposure.

6: Stakeholders

The effects of excess nitrogen in bodies of water can cause excessive growth of aquatic plants and algae. Excessive growth of aquatic plants and algae dissolve oxygen as they compose, and block light when occurring in deeper waters. In lakes and reservoirs with limited water movement there are increased risk of blooms of algae on the water surface, which ultimately deprive the water body of oxygen. Increased algae and decreased oxygen decrease animal and plant diversity. The impacts are not only water quality and the aquatic life, but also the activities associated with water bodies such as fishing, swimming and boating.

The urban dictionary defines a stakeholder as:

"A person, group or organization that has interest or concern in an organization. Stakeholders can affect or be affected by the organization's actions, objectives and policies. Some examples of key stakeholders are creditors, directors, employees, government (and its agencies), owners (shareholders), suppliers, unions, and the community from which the business draws its resources". http://www.businessdictionary.com/definition/stakeholder.html#ixzz3TZopTbLK.

LCO stakeholders with respect to nitrate release and water management can be local residents, tourists to the area, federal and provincial regulators, and fisherman to name a few. Stakeholders can be as near as residents located downstream of LCO and far-reaching as lake Koocanusa, and the state of Montana Department of Environment Quality.

The headwaters of the Elk River are the Elk Lakes. Glaciers and natural runoff feed the Elk Lakes. The Elk River runs through communities containing current and past mining activities, Elk ford, Sparwood, Fernie and it heads south to the Kooteney River. The Kooteney River ultimately feeds to Lake Koocanusa before reaching the Koocanusa dam in Montana. Michel creek, Fording River and Line Creek are tributaries, which feed the Elk River. Current mining activities affect the tributaries that feed the Elk River, as well as the Elk River.

The stakeholder of the coal business unit can be far reaching, as mentioned above. Therefore the impacts and actions of LCO and Teck Resources Ltd. can have effects beyond one would consider our local communities. As with any public voice, negative feedback can gain the attention of the media. One such negative stakeholder's negative view is evident in Mr. Hume's

Globe and Mail letter to the editor. Mr. Hume brings negative attention to selenium levels in Lake Koocanusa. The Flathead Beacon, Nov 17 2014, published an article highlighting the increasing selenium and other contaminants rising upstream of one of Montana's excellent trans-boundary watershed because of mining in the Elk Valley.

The mining industry is an industry developed around a complex multidimensional network of forces. These forces consist of an industry driven by commodity prices, weather, location, world demand, etc. According to Schneider Electric, the two major forces or barriers to entry to mining are qualified people and water.

Public and government agencies are beginning to have greater focus on the impacts to mining. Business Vancouver, June 9 2011. Headline reads "5.3 billion BC gold mine Faces Major Obstacles. The article references the Seabridge gold Inc. The Seabridge mine is hoping to propose a 5.3 billion dollar gold mine in Stewart BC. The proposed mine is 30 KMs from the Alaskan boarder. The obstacle facing the proposed mining developed is an environmental assessment. The stakeholders in this project are the first nations in both Alaska and BC with respect to the impact to fish bearing rivers. The impact to fish bearing waters are a result of the mines expected 50 year life. The article and potential environmental assessment focus on the mining operations impacts to the water sources. The environmental assessment and stakeholders are focusing on the potential requirement to have the site monitored for 200 years post mining.

The article referenced above, highlights the public's awareness around environmental impacts of mining and an increasing focus on mining activities. Mining companies are facing increasing pressures to building and expand new mines increases. While LCO is an active mining operation, they must maintain an environmental stewardship and social license. The EVWQM and current AWTF at LCO are such examples where a large company is spending large amount of money to do the right thing to maintain operations environmental stewardship in highly diversified environmental areas.

Through the evolution of stakeholder involvement in community and environment, Teck Coal as a business unit has worked to evolve along with its stakeholders. Teck Resources Ltd. has chosen to develop at substantial cost active water treatment facilities to process mine impacted water. Treating LCO phase I mine water before returning to receiving environment attempts to maintain water quality within acceptable guidelines. These plants however remain costly. The intention of HSE, ANFO and Nitrate management will reduce the load on the current and future active water treatment facilities with respect to nitrate reduction. AWTF treat nitrates along with Se, and reduction in nitrate concentrations will have a marginal increase in operating efficiency, but have a dramatic reduction in waste generated. The nitrate concentration is a factor of magnitude higher than selenium. The process for treatment of selenium rich waters remains constant, as it is not dependent of nitrate levels. However, a reduction of the by-products associated with water treatment reduces the cost of handling waste as nitrate levels reduce.

Nitrates permeate through waste rock at a rate equal to the water moving through a rock mass. (Conversation with Clara, Manager of R&D for Teck Resources Ltd.). While water volume affects leached selenium release, velocity, retention time, oxygen content etc. are also factors affecting release. Nitrates flow with the water, and retention time is a function of the dumps retention time of water. This implies that effectiveness of nitrate management strategies impacts should be rapid. As a result, it is the recommendation that a yearly review of the effectiveness of the approved nitrate management plan occur. It is the recommendation of the author that yearly review of the NMP by senior staff and EAC.

6.1 Government as a Stakeholder for Phase II and BRX mining

Nitrate levels in the watersheds surrounding Line Creek will continue to rise without the introduction of a NMP and high stability emulsions (HSE). The concentration of nitrates in the local watersheds have risen due in part to increases in waste volumes and associated explosive usage. Mining rates will continue to increase overtime as well as the explosive usage. Because of increasing explosive usage, nitrate levels will increase without changes in current load and blasting practices.

Teck is commitment to the environment and stability through statements such as the following. The following statement is an excerpt from the Teck Resources Ltd. vision statement.

> Sustainability is a core value that guides the way we conduct our business and Water is one of the key focus areas Teck is committed to. (Teck's Vision Statement for Water)
>
> Vision: We contribute to the ability of present and future generations to enjoy a balance between the social, economic recreational and cultural benefits of water resources, within ecologically sustainable limits. (Teck's 2013 Sustainability Report)

April 2013 the B.C. Minister of Environment, demanded Teck Resources Ltd. to develop a Water Quality Management Plan to address the increasing selenium and nitrate levels. July 22, 2014, Teck Resources Ltd. put forward the Elk Valley Water Quality Model to the Minister of Environment for approval. The EVWQM is a document developed by Teck with input from the public, First Nations, governments, technical experts and other stakeholders (Executive summary, EVWQM, Page i). The Elk Valley water quality model is an indicator of the efforts Teck is committing to its long-term goals of minimizing water quality impacts.

LCO, as part of Teck Coal, embarked on the development of Nitrogen Management is an initiative to achieve its goal of maintaining healthy water quality within the watersheds we operate. January 31 2014, the Chief inspector of Mines (file number 14675-35) accepted the LCO Nitrate management plan (NMP).

6.2 Nitrates Guidelines to Protect Environment and Community

Recreational activities around water with high concentrations of nitrate, or nitrite are not likely to cause direct problems in terms of contact and as a result, there are no CCME nitrogen guidelines. However, in recreational waters where ingesting water occurs, consider drinking water guidelines. (Water Quality Guidelines for Nitrogen, Nitrate, Nitrite, and Ammonia, September 2009, Nordin, Pommen pages 10-11). The most likely effect of high nitrate levels in bodies of water is the eutrophication related problems. Elevated levels of nitrogen can cause increased growth rates of aquatic plants and algae. Increased growth rates of the aforementioned plants and algae's may decompose, and the ultimately as they decompose, and block light to deeper waters. (http://water.usgs.gov/edu/nitrogen.html). Nitrate affects aquatic organisms by direct contact. At elevated concentrations, it can interfere with osmoregulation (the ability to maintain appropriate cellular ion levels) (CCME 2012).

Drinking water guidelines for Canada suggest that a maximum acceptable concentration for drinking water is 10 mgL-1 nitrates + nitrite (as N), while the water guideline for nitrite (as N) is maximum 1 mgL-1. (Water Quality Guidelines for Nitrogen, Nitrate, Nitrite, and Ammonia, September 2009, Nordin, Pommen, page 6). In order to protect freshwater aquatic life the 30 day average concentration is 3.0 mg and maximum concentration is 32.8 mgL-1while nitrate is 3.7 mgL-1 for average concentration. (Water Quality Guidelines for Nitrogen, Nitrate, Nitrite, and Ammonia, September 2009, Nordin, Pommen page 8).

Because of the impacts through nitrogen release and above guidelines, LCO continues efforts in the reduction of nitrates and research in the field of nitrates.

There is evidence that in some environments, nitrogen release can affect the attenuation and oxidation of Selenium. MEND report indicates a link between higher levels of Nitrogen and to the increases in selenium leaching, mobility and attenuation. (Executive summary, Page i, Role of Nitrogen and Attenuation of Selenium in coal Mine Waste, January 2015, MEND Report 10.3). The MEND report indicates that in certain environments that NO_3 can act as an inhibitor to selenium reduction, as well as an oxidant of pyrite and selenium. This report makes no claims about this fact, however does believe that future studies and research to understand if reduction in nitrates reduce selenium loading, and potential increases in AWTF performance.

7: Strategic Analysis of Components of NMP

7.1 Porters 5 forces for Introduction of HSE:

Potential Entrants/Barriers	Substitutes	Buyers	Regulators	Suppliers	Industry Competitors
• Low cost to switch to HSE for other mines around world • Marginal increase in cost of HSE may be too much for mines at breakeven point • Very heavy marketing needed to differentiate product • accessible mineral oil will be cost ineffective in areas where product is unavailable	• High cost alternatives for nitrate reduced blasting agents are available – extremely expensive • Mines can use mechanical methods to break rock, however time consumer, and more expensive	• Coal produced using HSE products will have no effect on willingness to pay.	• Increased regulations around water managemen t will not reduce over time • Requirement for continued operation in BRX • Competitors face same regulations	• HSE mineral oil is not clearly understood. No clear supplier set up for distribution long term at this time. • No change to supply of Blasting agents	• Coal prices received will not be affected by HSE or nitrate management plan. • Canadian Competitors in coal will have same environmental requirements around mine water discharge and as such will provide no competitive advantage to LCO
Difficult to compete without heavy marketing cost. Likely to show no positive effects on coal price	No competitive advantage to differentiation as known substitutes are more expensive	Buyers look for quality coal, not for the quality of waste rock and mine water discharge quality	Public perception and being ahead of regulators is a strong plus for continued coal production from LCO	Supply for LCO HSE mineral oil is in Calgary and close proximity will benefit LCO in long term	HSE will provide no competitive advantage to LCO or other mines within coal as coal is sold on quality not waste rock properties.

Table 3 - Porters 5 Forces

As shown above in Porter's 5 forces model, the greatest impact to the market around the switch to HSE blasting agents will come from in the form of meeting governmental regulation. Government regulations and laws are an aid to maintain, and guide corporations through enforcement, criteria to change corporation's actions. The mining industry is for all intents a self-regulation group. This self-regulation industry generally sets guidelines and standards prior to government regulations or at levels greater than the requirements. An example of such self-regulation is the mines act, and primarily written through input of leaders in the mining industry. Selenium research and the EVWQM are such examples where the industry has chosen to provide the government with the facts to set regulation. Introduction of the NMP, HSE and operational controls will again be a positive for the government's relationship for the mining industry. LCO's social license will be enhanced and continue to support Teck's sustainability goals around water management

LCO supplier advantage over other mines is in that the supply of HSE mineral oil, Faxam 32, is readily and easily available in Calgary. Supplier availability was a consideration in choosing Faxam 32. The determination of Faxam 32 over alternative fuel sources was availability and long term sourcing from supplier.

Classification of coal is by rank, with categories of lignite, sub-bituminous, bituminous and anthracite. Coals containing less carbon, more moisture and have lowered calorific content have the lower rank. Buyers of coal buy coal based on coal properties. Coal properties considered are CSR, FSI, and Sulphur content, phosphorus and size fraction to name a few. The switch to HSE will not affect coal prices as customers willingness is not currently affected nitrogen release in the receiving environment. Currently approximately 50% of LCO coal sales come through spot sales rather than long-term contracts. Considering that half of the sales by volume are on a spot sale, one can assume that customer loyalty through long term contracts do not exist. As a result, changes to product buyers are not interested in the product brand loyalty, rather price.

There are very few substitutes and limited barriers to entry by a switch to HSE or operational controls. Each manufacturer of explosives has an HSE substitute. Each mining company has the ability to introduce operation controls around loading.

While research around metallurgical coal substitutes continue, there is at this time no published advances in steel making on the horizon that indicate a substitute is nearing market readiness. Metallurgical coal as a product has no substitute in the making of steal at this time.

7.2 SWOT analysis of High Stability emulsion and Mineral Oil.

High stability emulsions (HSE) requires the introduction of mineral oil as a fuel source. The change from diesel to mineral oil has already gone through a management of change at the Teck Resources Ltd. business level and not be revisited in this document. Through the management of change process, no changes to processes or procedures were determined to require further evaluation.

In order to return to ANFO adding a heated mineral oil to the current production of blasting products is required. The weakness around the introduction of an HSE product is in that LCO has not seen the effects of loading HSE products in winter months. Below is a SWOT analysis for the introduction of HSE and a reintroduction of mineral oil based ANFO. The SWOT analysis was to determine viability, and potential weaknesses in the introduction of mineral oil.

7.2.1 Strengths

While the introduction of HSE may be new to LCO, the use of HSE is throughout the world. Because of use elsewhere, LCO is not introducing a new product rather utilizing an existing product. The website www.exploconsult.com/emulsion-explosives.html, recommends the use of mineral oils due to increased shelf life, re-pumping characteristics and increased viscosity. The introduction of HSE to LCO is not without cost. However, the expected cost of introduction is primarily power lines, transfer of storage tank from the Quintette mine, and minimal changes to bulk explosives pumping trucks. The introduction of HSE does not require changes to existing prill contracts, or diesel suppliers. Expected nitrates reduction from the reintroduction of bagged ANFO. The introduction of ANFO, due to low density of product eliminating contact with water and better impedance matched products with soft ground conditions, will show reduction in post fume nitrates.

The largest strength attributed to the introduction of mineral oil, is the reintroduction of ANFO. ANFO will reduce cost of blasting waste and reduce nitrate leaching when used appropriately. EVO and CMO have been testing ANFO with no adverse effects to digging. To date the greatest risk has been an increase in misfires. The misfire rate is currently being investigated, with preliminary data pointing to a requirement of larger boosters to properly initiate lower density explosive. It is the recommendation of the author, that prior to the introduction of ANFO, larger booster be introduced. As mentioned earlier, engineering groups require the introduction of misfire tracking processes to ensure the rates of misfires does not increase.

7.2.2 Opportunities

LCO expects a reduction in nitrates from HSE and mineral-based ANFO. The reduction of nitrates provides for a monitoring program, as part of NMP, to monitor downstream watercourses. The primarily undisturbed mining area, Dry Creek, provides a unique opportunity to understand and document the changes and impact of HSE.

The transition to HSE and bagged ANFO offers potential saving when utilizing bagged ANFO over traditional emulsion blends. Current pricing of mineral oil offers a saving over current pricing of diesel.

7.2.3 Weaknesses

HSE requires mineral oil as a blasting fuel in addition to traditional diesel. The introduction of mineral oil as a fuel source requires new suppliers and as such, introduces an unknown long-term relationship and supply consistency. The premise behind the introduction of HSE is around the reduction of nitrates. However, the evidence of reduction of nitrates is unknown and unproven at this time.

HSE has a starting viscosity higher than traditional emulsion blends. A side effect to usage of HSE is that viscosity increases with mixing and pumping. EVO blends LCO emulsions and require pumping a number of times before ultimately pumping in blast holes. The winter handling characteristics not been fully evaluated. The use of mineral oil to maintain stability and detonation process requires heated storage facilities. HSE usage has not been testing in all four seasons at LCO, and remains an unknown weakness at this time.

An established mineral oil long-term pricing structure is not developed. Because of unknown long-term pricing, variations in long-term market pricing between diesel and mineral oil remains an unknown in the costing of HSE.

7.2.4 Threats

One major threat to HSE is the new supplier required for mineral oil. Consequences with new suppliers include issues around delivery speed and effectiveness.

Introduction of HSE at LCO requires multiple pumping points. The increased pumping provides potential for higher truck pump failures due to increased pressures during pumping process.

8: Path Forward for to LCO

Long term management of water quality and reduction of nitrates will ultimately provide risk mitigation to LCO through continued high levels of stakeholder's confidence. Explosives best practices and management guidelines are required to manage the release of nitrates. Development of guidelines, alternative blasting agents, and planning tools will drive changes around explosives nitrate management.

Printed in Teck Sustainability report is the below caption:

"We contribute to the ability of present and future generation to enjoy a balance between the social, economic, recreational and cultural benefits of water resources, within ecological sustainable limits."

The first step and most effective process in the control of nitrates will be the introduction of HSE and bagged ANFO products. These will provide the greatest value in reducing the release of nitrates, and thus have the greatest impact on LCO's ability to meet regulatory guidelines.

The second step in the control of nitrates is the completion of the functional nitrate management plan. Administrative controls, control to surface water, bench dewatering practices, training, explosives storage and handling, recycling of bulk truck wash water, spill management etc. A copy of the draft NMP is attached in the appendix. A yearly review by the EAC is recommended.

8.1 Audit Program, Review and Improvements

Auditing and review of the data around in stream monitoring is a method of ensuring that the focus and results predicted are producing the correct results and affecting the anticipated behaviors. The auditing methods being currently being introduced and recommended within this paper are to be monitored by the EAC, LCO environment group and engineering groups.

Misfires, unexploded product, post fumes are examples of improper detonation of explosives. The improperly detonated explosives results in excessive nitrates being introduced into the receiving environment. A standardized and auditable process where blasting performance is monitored will identify opportunities and track effectiveness in blasting. The author recommends engineering groups at LCO have misfire tracking be reintroduced. The misfire tracking currently in place tracks misfires from a safety standpoint. The initiative proposed is to correct the behaviors that have caused the misfire.

- Introduce blaster names to holes loaded to recorded data to track blaster individual performance.
- Collect data on potential cause of misfire
- Track misfires by product type.
- Track misfire by rock type

Currently EAC audits are performed monthly by the operations group. The current audits focus on mining operations: fuelling, garbage disposal, drainage locations, etc. It is the recommendation of this paper that NMP initiatives be added to EAC audits. Audits should focus on the activities surrounding blast hole loading. Blast holes need to be dewatered when loading ANFO, and water control measures in place to divert water around blast patterns. All holes wet or dry must have water conditions sent to engineering for record keeping. It is proposed that the current EAC auditing process be modified to include blast pattern checks.

- Spills properly clean up as per NMP
- Proper loading product as per NMP
- Audit pattern clean-up, water control, water pooling standing water etc.
- Bulk supplier truck cleaning process evaluation for proper water collection and removal

NMP is currently under review for submittal to MEM for review. The most recent review of the NMP has been updated to include yearly updates, and yearly review with blasting crews and bulk explosives distributers. SP&P's can be utilized to ensure that initiatives around nitrate management continue to be enforced. Education and training programs for employees and contractors working with nitrogen sources need to be included in review of SP&Ps surrounding nitrate reduction programs

In conjunction with this paper, expected nitrate release patterns for dry creek are being developed. The latest version of the nitrate management should be updated once the release patterns and guidelines established to be included as part of the auditing process to ensure validity and compliance of plan. The environmental group is currently working towards the development of baseline data for nitrate release patterns. Once detailed plans to monitor these effects to water are completed, it is recommended these be added to NMP.

In order to ensure the blasting process is effective all step of the process need to be monitored. Quality loading controls are the first step in ensuring effective blasting. Auditing of explosives manufacture bulk truck calibrations regularly must be performed. Daily checks on product quality, and quarterly on truck calibration to ensure proper initiation safeguard quality loading.

Appendix

Appendix A

BRITISH COLUMBIA

January 31, 2014

Permit: C-129
Mine No: 1200003
File: 14675-35

Mr. Ian Anderson
General Manager
Line Creek Mine
Teck Coal Ltd.
PO Box 2003
Sparwood, BC,
V0B 2G0

Dear Mr. Anderson,

Re: Teck Coal Limited, Line Creek Operations
Approval of Nitrate Management Plan

I have received the Line Creek Operations Nitrate Management Plan (dated December 15, 2013) as required by conditions D.1(a) and D.4(a)(ii) of the November 1, 2013 amendment of the C-129 permit. Thank you for providing this information.

I have reviewed this plan and hereby approve it. Please ensure that I am notified of any proposed changes to this plan.

Please attach this to your permit.

Yours very truly,

Al Hoffman, P.Eng.
Chief Inspector of Mines

cc: Diane Howe, Deputy Chief Inspector of Mines - Permitting, MEM
Robyn Roome, Regional Director, MOE

Figure 20 - Letter of Approval: Nitrate Management Plan

Appendix B

BRITISH
COLUMBIA

Authorization Number:106970

February 20, 2015

Teck Coal Limited
Line Creek Operations
PO Box 2003
Sparwood, BC V0B 2G0

Dear Permittee:

RE: Approval of the Dry Creek Water Management Plan

Teck Coal Ltd – Line Creek Operations (Teck) submitted the Dry Creek Water Management Plan (DCWMP) to Ministry of Environment on December 22, 2014 to fulfill requirements under Section 3.2 of Order in Council (OIC) Permit 106970 and condition #9 of the Environmental Assessment Certificate (EAC) #M13-02. Additional information and comments in support of the plan were provided to MOE on January 23, 2015, February 3, 2015 and February 13, 2015. Comments on the plan were also provided to MOE from the Ktunaxa First Nation, Forests, Lands and Natural Resources, and Fisheries and Oceans Canada.

Section 3.2 of OIC Permit 106970 states that the Permittee must develop for approval by the Director, and then implement the DCWMP to achieve site performance objectives set out in the permit, while maintaining minimum in-stream flow requirements (IFRs).

Condition #9 of EAC Certificate #M13-02 states that prior to placement of waste rock in Dry Creek Valley Teck Coal must prepare and submit the DCWMP to the ministry. The plan must be to the satisfaction of the Regional Operations Director, and must include water quality based triggers regarding the initiation of the conveyance of mine-affected water to the Fording River, and the commissioning of active water treatment for Dry Creek.

The Dry Creek Water Management Plan dated December 23, 2015 is hereby approved subject to the following conditions:

1. Teck will participate in a process with KNC and MOE to establish long-term Site Performance Objectives (SPO) and In-stream Flow Requirements for Dry Creek and provide the required information for review in a timely manner. In this regard, reference is made to the recommended actions found in table 1 of the MOE memo dated February 10, 2015 (S. Reddekopp to J. Carmody-Fallows). Teck is requested to provide submissions for a decision making framework for this process by September 30, 2015.

Ministry of Environment | Mining Operations, Environmental Protection Division | Mailing Address: 205 Industrial Road G, Cranbrook BC V1C 7G5 | Telephone: 250 751-3100, Facsimile: 250 751-3103, Website: www.gov.bc.ca/env

2. All inflows into the Dry Creek Sediment Ponds must discharge through the return channel back into Dry Creek until December 31, 2019, with the exception of the commissioning period and during scheduled maintenance of the ponds.

3. For the purposes of commissioning the sediment ponds (diverting water to fill the ponds) and routine maintenance of the ponds, Teck must maintain a minimum instream flow requirement of 20% MAD in Dry Creek.

4. Teck will provide the predicted monthly mean SPO constituent concentrations at the SPO location (E295210) and at the mouth of Dry Creek(E288270), for all months from present up to January 1, 2020. This summary shall be submitted to the Director by May 30, 2015.

5. Teck will update the December 15, 2014 LCO Nitrate Management Plan to control nitrate releases from the site. The updated Nitrate Management Plan must be implemented and submitted to the Director by June 1, 2015.

6. Teck shall take reasonable efforts to collect at least two years of continuous monitoring is collected at the East Tributary of Dry Creek (E288274) and at Dry Creek near its Mouth (E288270) for the purposes of updating the streamflow model. Teck shall develop and implement contingencies to maintain continuous data collection at the Dry Creek Station.

7. Teck must report on and provide detail demonstrating how mine affected surface and sub-surface water is being captured by the lined head pond and embankment in its next annual report (2015), and provide an estimate of the proportion of mine-affected water (surface and sub-surface) that is not captured by the system, in its subsequent annual reports required by OIC Permit 106970.

To support the process for developing long term SPOs and IFRs for Dry Creek, Teck is required to undertake the following:

1. Completion of the Interim Report for the Tributary Evaluation Program as required by EMA Permit 107517 by August 31, 2016. This report shall be submitted to the Director and KNC for review.
2. Compilation of all available chronic toxicity and water quality monitoring data as required under Permit 107517 through August 31, 2016. The data must be provided to the Director and KNC for review by Sept. 30, 2016.
3. Submission of the report to the Director validating the Westslope cutthroat trout Habitat Suitability Index Model as required by Condition 13 of EAC #13-02 by August 31, 2016.

4. Submission of the in-stream flow needs study required by Condition 14 of EAC#13-02 by August 31, 2017. In addition, Teck must include a review of the IDF analysis to ensure appropriateness and applicability.
5. Submission of an updated streamflow model (based on the UBC Watershed Model) using all available data to Sept 30, 2016.
6. Submission of an options analysis on the SPOs and IFRs and the DCWMP by Oct. 30, 2016, which shall include the following:
   a. An evaluation of the resultant flow impacts to Dry Creek under differing SPO values ranging from the original SPO in OIC permit 106970 (10ug/L) to that proposed in the DCWMP date December 23, 2024 (70 ug/L), and timelines for when conveyance might be required to meet the specific SPO.
   b. An evaluation of other potential mitigations explored by Teck to meet both instream flow requirements and site performance objectives.
   c. Proposed triggers for construction of active water treatment, conveyance or other necessary mitigations.

7. Teck shall provide progress reports to MOE and KNC on July 30, 2015, and January 31, 2016, regarding the above requirements.
8. Teck must prepare an updated Dry Creek Water Management Plan in a timely manner as part of the process specified in Condition 1 of this letter. The plan must be submitted not later than July 31, 2019.

For the ORDER IN COUNCIL PERMIT –

The OIC Permit 106970 will be amended as follows in consideration of the process for developing IFRS and SPOs:

SECTION 2 – INTERIM INSTREAM FLOW REQUIREMENTS

All inflows into the Dry Creek Sediment Ponds must discharge through the return channel back into Dry Creek until December 31, 2019 except during the commissioning period, and during scheduled maintenance of the ponds. At any time during maintenance and commissioning when all inflows into the Dry Creek Sediment Ponds are not discharged through the return channel back into Dry Creek, the Permittee must ensure that at a minimum, greater than 20% Mean Annual Flow in maintained in Dry Creek unless otherwise approved by the Director.

Section 2.INTERIM INSTREAM FLOW REQUIREMENTS

Commencing on January 1, 2020, Interim Instream Flow Requirements for Dry Creek must be met if the Permittee discharges to Fording River through the conveyance and diffuser system authorized in Section 1.2. These Intermim Flow Requirements for Dry Creek will be the values outlined below or as otherwise speficied by the Director as the result of a process with KNC and MOE to establish long-term Site Performance Objectives (SPO) and In-stream Flow Requirements for Dry Creek, as required by Condition 1 of this letter.

Dates	**IRF (% Mean annual Discharge)**	**Purpose**
Aug 1- Apr 1	20	Summer Rearing and overwintering
Apr 15 – Apr 30	50	Natural freshet ramp-up
May 1-May 14	100	Braid, side channel connectivity
May 15-June 14	209	Migration and spawning
June 15 – July 14	105	Out-migration
July 15 – July 30	40	Out-migration, incubation

2.1 The Mean Annual Discharges for Dry Creek and the East Tributary are as follows:

Dry Creek – 0.382 m^3/s
East Tributary – 0.113 m^3/s

2.2In the event that the streamflow in the East Tributary drops below East Tributary IFRs, a Dry Creek IFR adjustment shall be calculated using the following equation:

$$(\text{Modified } DryCreekIFR) = (\text{Dry Creek } IFR) * \frac{(EastTributaryStreamflow)}{EastTributaryIFR}$$

The requirement to meet Site Performance Objectives for Dry Creek in Section 3.1 is suspended until January 1, 2020. Prior to this date the Director may re-establish or set alternative Site Performance Objectives as deemed necessary by the Director for the protection of the environment. The permittee may convey water to the Fording River to maintain any established SPOs provided IFRs are maintained. A plan and schedule for implementation of active water treatment to the Director's satisfaction, must be submitted to the Director by December 31, 2019, or earlier if required by the Director.

All other terms and conditions of OIC Permit 106970 remain in effect. If you have any questions please contact Jeanien Carmody-Fallows at 250-847-7273.

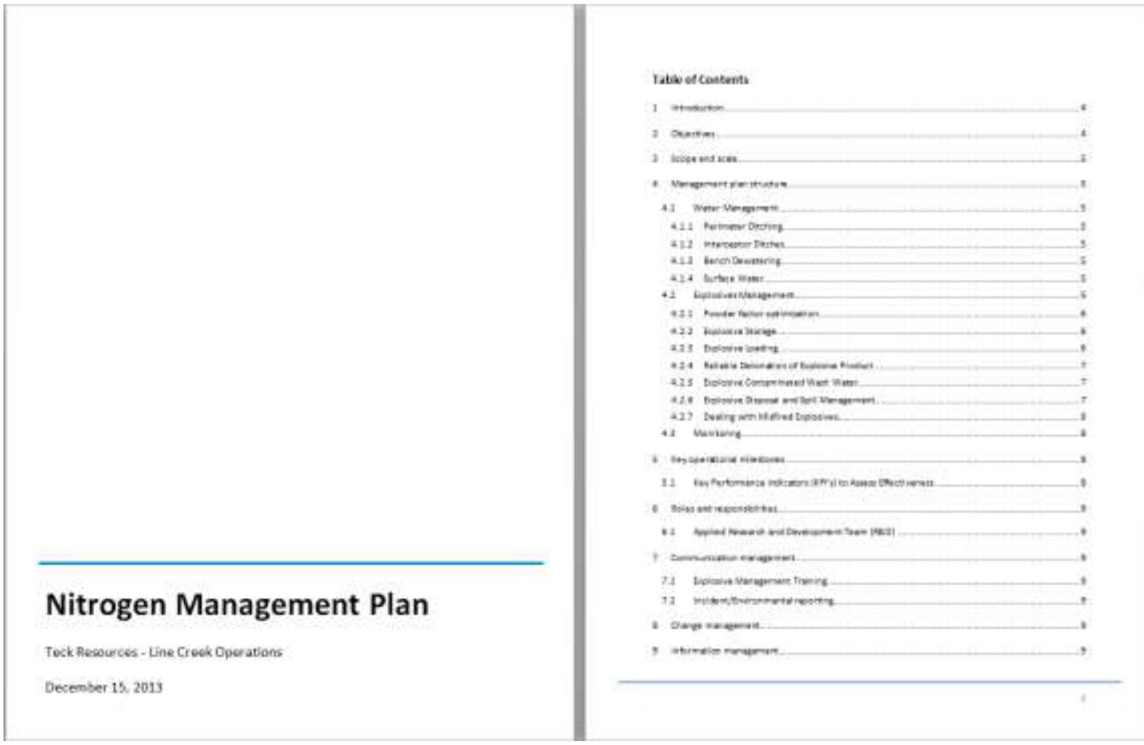
Yours truly,

Douglas Hill, P.Eng.
for the Director, *Environmental Management Act*
Mining Operations

ec: Liz Archibald, Ministry of Environment
Kathy Eichenberger, Energy and Mines
Karen Christie, Environmental Assessment Office
Andrew Rollo, Energy and Mines
Bill Green, Ktunaxa Nation Council
Herb Tepper, Forests, Lands and Natural Resources
Jeff Guerin, Fisheries and Oceans Canada

Figure 21 - MEM Authorization letter Number 10690 Dry Creek Approval

Current Nitrate Management Plan For LCO



Nitrogen Management Plan

Teck Resources - Line Creek Operations

December 15, 2013

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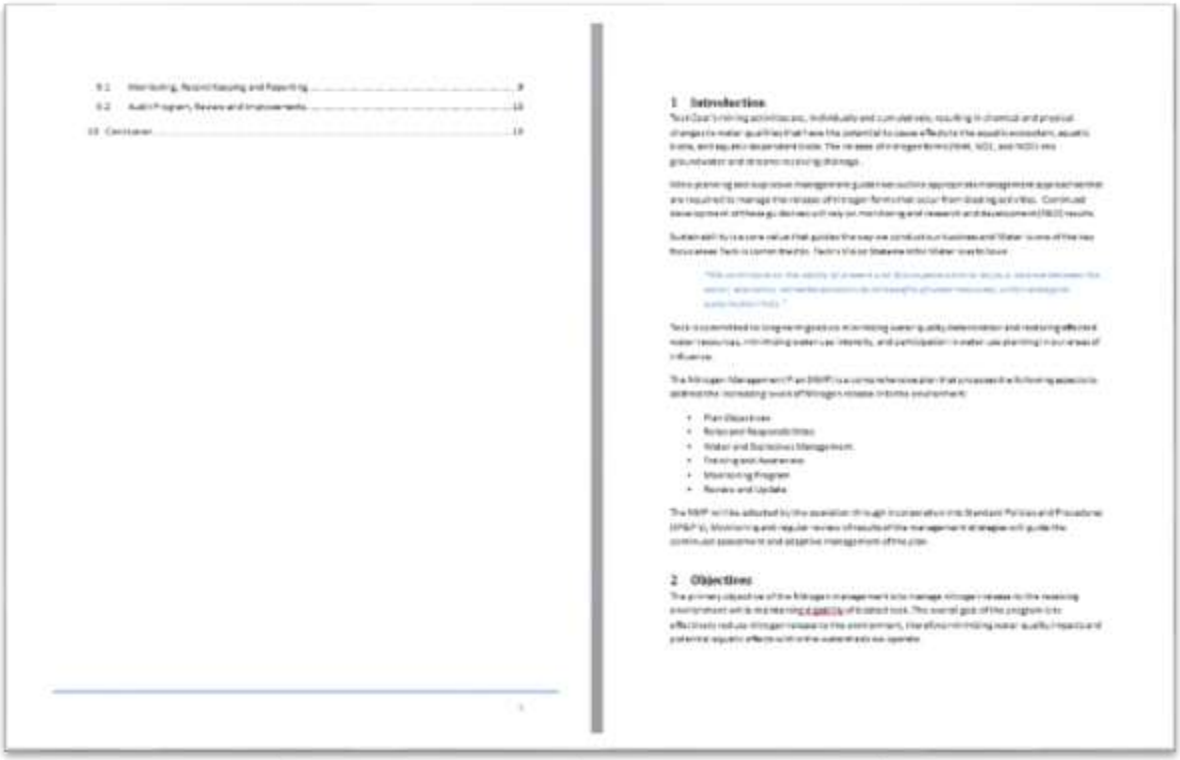

1 Introduction

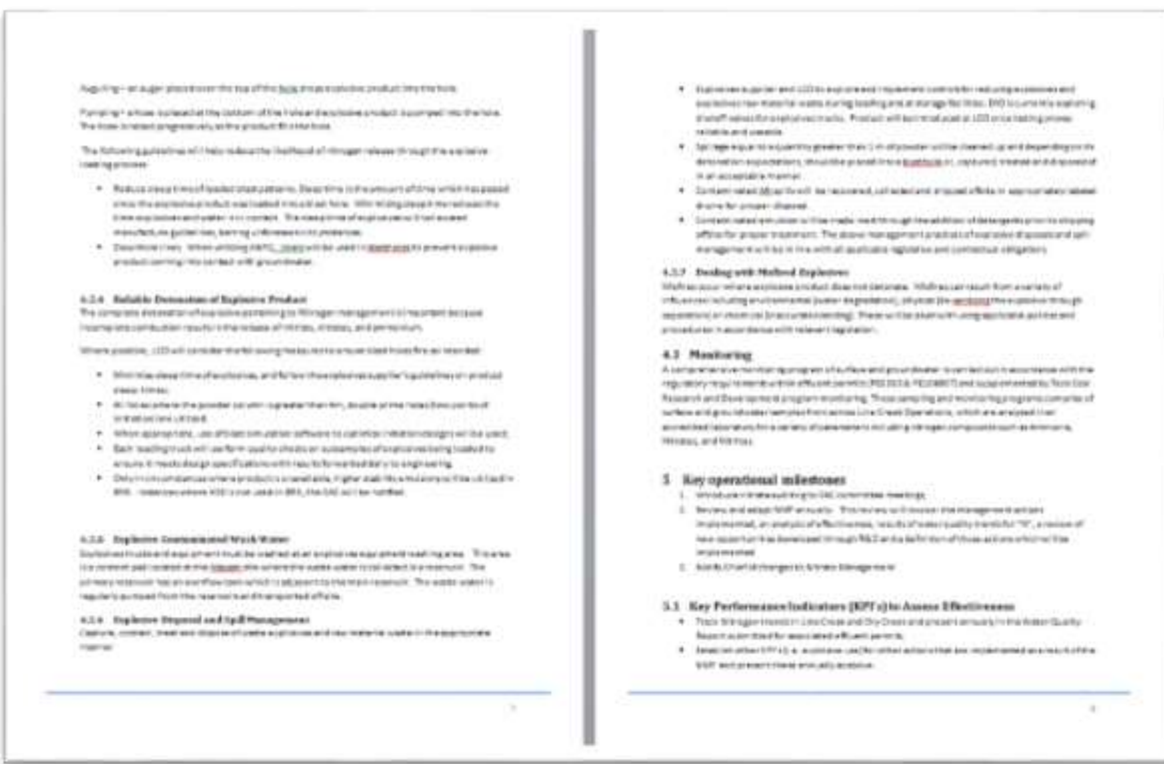
2 Objectives

3 Scope and scale

4 Management plan structure

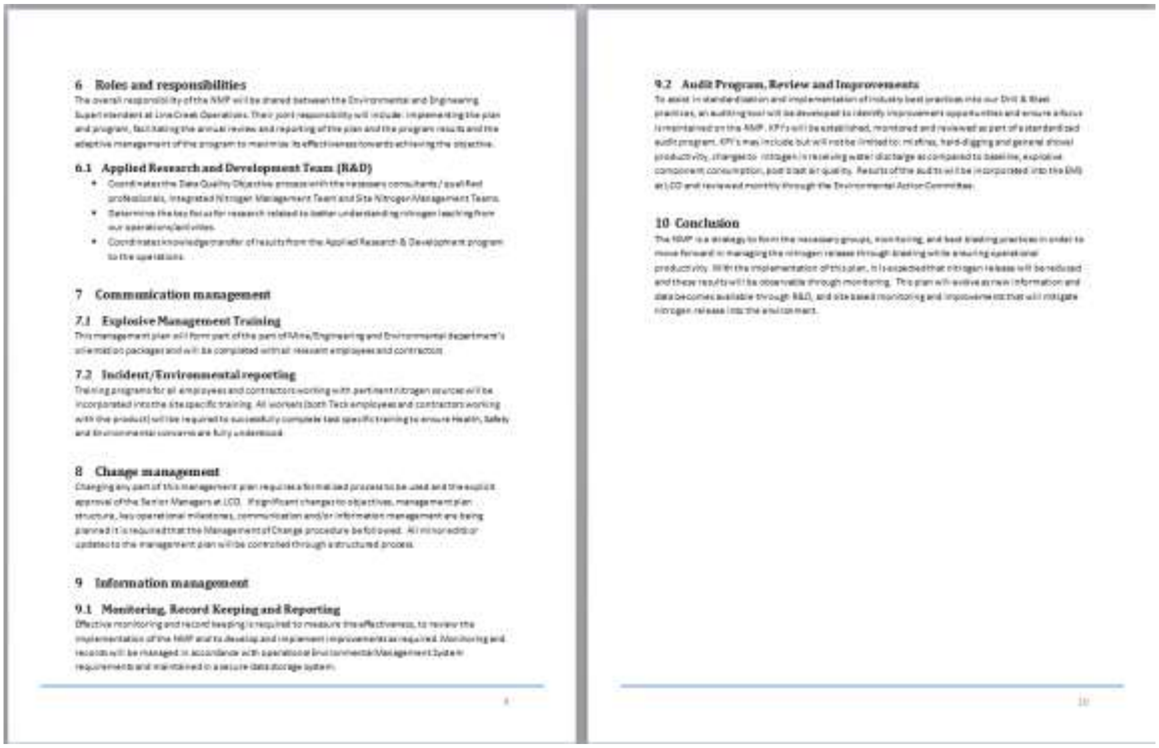
4.1 Water Management

4.2 Explosives Management



4.3 Monitoring

5 Key operational milestones



6 Roles and responsibilities

6.1 Applied Research and Development Team (R&D)

7 Communication management

7.1 Explosive Management Training

7.2 Incident/Environmental reporting

8 Change management

9 Information management

9.1 Monitoring, Record Keeping and Reporting

9.2 Audit Program, Review and Improvements

10 Conclusion

Figure 22 - Draft LCO Nitrate Management Plan

References

Teck Resources, Elk Valley Water Quality Plan ,Graph page8-56

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Water Quality Guidelines for Nitrogen, Nitrate, Nitrite, and Ammonia, September 2009, Nordin, Pommen pages 6,8,10-11