STATE OF COLORADO

Ebert - DNR, Jared <jared.ebert@state.co.us>

Comments on Loveland Ready Mix (LRM) Permit Application # M-2017-036.

ROBERT N HAVIS <rhavis@msn.com>
To: "jared.ebert@state.co.us" <jared.ebert@state.co.us>

Wed, Feb 21, 2018 at 12:11 PM

Dear Mr. Ebert:

No LaPorte Gravel Corp submits the following 2 documents for consideration by the Colorado Division of Reclamation Mining and Safety (DRMS) in review of the subject 112 Application. The first document contains comments on the LRM comments to the DRMS adequacy review. The second document is a study of the potential water quality issues and risks to public health and environment from mining in the Pierre Shale bedrock environment.

1. Comments on Loveland Ready Mix (LRM) Response (dated January 2, 2018) to the DRMS Adequacy Review of Application M-2017-036 (dated November 14, 2017), Prepared by HAVIS Engineering for The No LaPorte Gravel Corporation (file - CommentsOnResponsesHAVIS.pdf)

2. Potential Water Quality Issues from Cretaceous Pierre Shale in the Proposed Loveland Ready Mix Knox Pit, Larimer County, LaPorte, Colorado. Prepared by HAVIS Engineering for the No LaPorte Gravel Corporation (file – PitWaterFinal.pdf)

Thank You

Robert N. Havis, PhD, PE for

No LaPorte Gravel Corporation

3 attachments

CletDRMS022118.pdf
199K

PitWaterFinal.pdf
312K

CommentsOnResponsesHAVIS.pdf
1605K

NO LAPORTE GRAVEL.ORG

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February 21, 2018

By email: jared.ebert@state.co.us -

Jared Ebert

Colorado Division of Reclamation, Mining and Safety

1313 Sherman Street

Denver, Colorado 80303

Re: Loveland Ready Mix (LRM) Permit Application # M-2017-036.

Dear Mr. Ebert:

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Thank You

Robert N. Havis, PhD, PE for

No LaPorte Gravel Corporation

No Laporte Gravel P.O. Box 523 Laporte, CO 80535 970/490-1776

Comments on Loveland Ready Mix (LRM) Response (dated January 2, 2018) to the DRMS Adequacy Review of Application M-2017-036 (dated November 14, 2017)

Prepared by HAVIS Engineering for

The No Laporte Gravel Corporation

Comments 1-11 No Comment

Comment 12

In accordance with Rule 3.1.8, please explain the measures that will be taken to protect the safety of wildlife near the mining operation and processing sites and along all access roads to the mine site.

Response 12:

The maximum slope of 3:1 ensures grazing animals can easily traverse the reclaimed slopes.

**********Comment 12:**

Provide justification that a slope of 3:1 is easily traversed by grazing animals. There is a 60% reduction in cattle grazing capacity on slopes over 30%, a 30% reduction for slopes 11-30 % and no reduction for slopes 0-10% slope. (Oberlie and Bishop, 2009). Slopes should be around 10% maximum for grazing to be an effective reclamation plan.

Oberlie, D.L. and J.A. Bishop, 2009. Determining Rangeland Suitability for cattle grazing based on distance-to-water, terrain, and barriers-to-movement attributes.
Geographic Information Science Degree from the Dept. of Geography, Pennsylvania State University, Spring 2009.

Comments 13-16

**********No Comment**

Comment 17

Section 7.4.2 of the reclamation plan indicates LRM plans to utilize native grass species for revegetation. The proposed seed mixture included on Table 1 of the reclamation plan includes five species of grass and only two of these are native to Colorado. Please revise the seed mixture to include native grasses. The Division recommends contacting the local Natural Recourses Conservation Service office to identify appropriate species to establish at the site. LRM may want to consider proposing two seed mixtures, one for the area to be reclaimed to pastureland and the other for areas to be reclaimed for Wildlife Habitat.

Response 17

**********Comment on Response to 17:** LRM states they will need no supplemental water because native plants are to be used. This is unrealistic. In the natural landscape native plants will germinate only during wet seasons and even then survival rates may not be high. In addition, moving the top soil will destroy the structure and microorganisms that aid in providing growth in Front Range clayey soils. Any bare soil allows invasion of weedy species considered noxious that sometimes do grow well in dry, high pH soils. Plants will very likely need establishment irrigation and trees will need supplemental water for several years.

Comments 18-26

**********No Comment**

Comment 27

The Exhibit cites a groundwater study report (Telesto 2017b). Please submit this report.

Comments on Ground Water Report Second Submittal

With reference to Comment 33 below, the revised ground water report shows ground water mounding to the west of the project after reclamation.

Comment 28

LRM did not include an estimate of the consumptive use of water for the office and batch plant because municipal water will be used for this. However Rule 6.4.7(3) and (4) requires an estimate of the annual volumes of water to be used for these facilities and a projected amount from each of the sources of water to supply the project. Please provide this information.

Response 28

LRM utilized a dynamic systems model (DSM) to evaluate its water requirements over the 10-year anticipated life of the Knox Pit. The consumptive use results of this model are documented in the request for a substitute supply plan from the Colorado Division of Water Resources (DWR, Attachment 8).

************Comment on Response 28:** LRM promises to, among other things, mitigate groundwater level changes. They say they have enough water rights but give no details. They will need a well permit for using groundwater, water rights for using stormwater and appear to be saying that they have purchased water rights along with the land. Do they actually have nearly 30 million gallons per year of water rights as well as that needed for mitigation for local wells? And can that water be delivered? They promise to submit a Substitute Plan to Colorado Natural Resources. Will this plan not be provided until after the mining committee makes their decision?

Comment 29

How has the water management pond been sized to provide adequate infiltration for the constant incoming volume of water from dewatering discharge? Is there enough capacity to account for increased pumping volumes if the Little Cache La Poudre Ditch leaks during periods of flow? Please provide documentation to substantiate your response.

Response 29

The water management pond was sized in a two-step process involving the DSM and the numerical groundwater model. The pond was first sized for operational requirements utilizing the DSM. This pond (size and shape) was inserted into the numerical groundwater model, and operations were simulated to calculate the rise in head required to discharge the dewatering water back to the aquifer. Because of the high permeability of the aquifer material, only a few feet of head in the pond above the surrounding groundwater elevation is required to return the dewatering water. Simulation results for the various mining phases are documented in Section 5 of the groundwater modeling report.

The Little Cache Ditch is not lined through the site. However, the ditch company performed a leakage analysis recently. They have indicated that the ditch leaks very little through this section, indicating that natural siltation has likely sealed up the ditch.

**********Comment on 29 30:** Figure 3, Site Water Balance, shows washing wastewater flows to the reclamation pond. Is the reclamation pond the same as water management pond? Would expect that sediment from washing wastewater would quickly seal bottom of pond preventing infiltration to ground water.

Comment 30

Has any modelling been done to show that there will not be significant impact to groundwater levels in the area surrounding the infiltration pond (mounding) due to the constant influx of dewatering discharge?

Response 30

The effects of returning dewatering flow to the groundwater system through the water management pond is documented in the revised groundwater modeling report. The anticipated head build up immediately adjacent to the pond is a few feet (Section 5.0).

Comment 31

What is the maximum elevation of water in water management pond anticipated to be, and is there enough additional freeboard capacity to account for storm and runoff events?

Response 31

The projected, maximum water surface elevation in the pond is projected to occur as dewatering is initiated in Phase 1 (when groundwater storage and the natural groundwater flow rate must be captured). As dewatering commences, the rates drop resulting in a reduced standard operating surface elevation. Both conditions leave adequate freeboard in the pond to accommodate stormwater flows. See Section 5.1 in the revised groundwater modeling report.

Comment 32

The "general backfill detail" provided on Exhibit F shows a perforated drain pipe set at the level of the base of the excavation on top of bedrock and fed/drained by perforated riser pipes. Please provide more detailed plans for this drain construction including, but not limited to: pipe diameter, elevations and gradients, riser spacing, filter material, geo-textile wrap used, etc.

Response 32

Telesto has added an additional figure to the mine plan, and three new drawing sheets in Exhibit G that details the plan for the perimeter drain system. The drain on the south side of the Little Cache is projected to be 8" diameter while the drain on the north is 6" diameter. The drains will be installed from 0 to 0.5% overall slope. Risers are planned every 400 feet. Filter material is limited to drain sand as specified with no geo-textile wrap.

**********Comment on Response 32:** See comment on Response 33.

Five phases of mining describe the mine plan and are modeled to predict potential impacts on the groundwater system. Sealed portions of the mine pits were simulated as no-flow boundaries. The perimeter drains were simulated using a higher hydraulic conductivity at a factor of 2 times higher than the CDSS value used for the rest of the model. This conductivity value is lower than the calculated equivalent (Appendix F) hydraulic conductivity that the drain system will provide, lending a level of conservatism to the predictions.

**********Comment on Response 32**: See comment to response 33. Figures 16 – 21 show proposed reclaimed pits modeled as having no-flow but high conductivity boundary condition. Modflow is not designed to model the complexity of the proposed perforated drain system.

Comment 33

Please provide documentation that the perforated drain as designed will function to pass groundwater around the lined pits to mimic pre-pit groundwater hydraulics and will prevent offsite impacts from mounding and shadowing.

Response 33

The purpose of the perforated drain system is to "replace" the natural hydraulic capacity of the aquifer that has been reduced by the lining system. The current groundwater flow parallels the Cache la Poudre River. The flow rates through the site area range from 160 (north side) to 280 (south side) gallons per minute (gpm). The corrugated and perforated pipe placed horizontally (totally flat) has the capacity to transmit 172 and 388 gpm,

respectively. Thus, the drain system as designed has more than adequate capacity to move groundwater around the perimeter of the lined gravel pits. Calculations documenting this result are attached as Attachment 9.

**********Comment on Response 33:** The pipes in the drain system can be engineered to carry the estimated flow that needs to be directed around the proposed pit liner structure, but from this simple calculation it cannot be concluded that the perforated pipe ground water diversion system will work in practice. The Modflow model was not designed to simulate the geometry of the complex hydraulic system. LRM attempted to simplify the geometry of the drain system, assuming that the pits are rectangular, and the full area of the pit walls conduct flow. Neither of these assumptions are credible in simplifying the proposed complex geometry of the drain system for simulation with the Modflow model. For example, the geometry of the western pit wall in the southern pit is far from rectangular. In Figure 13 the western wall geometry is complex, and it appears that peripheral drain geometry would require flow to travel up-gradient, to the southwest, to be conducted around the pit. This geometry is not represented in the rectangular pit geometry used in the Modflow simulations in Figure 21 reclamation ground water flow simulation. In addition to the over simplification of the complex geometry of the up-gradient pit walls, the static head difference between the north and south sides of the pit appears insufficient to drive flow around the west side of the pits so that mounding could be much more than is simulated.

The Modflow simulations of flow around the pit walls (e.g. Figure 21) shows a tendency towards ground water mounding in the neighborhoods to the west of the project, as would be expected. There are many unknowns in the design, construction and performance of the drain system. Among the unknows is the long-term hydrology of the area. The current ground water flow regime represents abnormally dry conditions in the LaPorte area. How will the drain system work if in the future there are successive years of abnormally high rainfall? Would LRM be around in 50 or 100 years or more to try to fix the ground water flow when variations in precipitation cause a failure of the drain system? Was sensitivity analysis performed on ground water flow rates? If the pit lining system was allowed to be constructed, the ground water flow around the pits would need to be reliable in perpetuity without maintenance. The proposed design does not appear reliable and has significant uncertainty about performance. Remediation to address failure of the ground water flow plan, as described in section 7.1.3, is not acceptable as a long-term plan. LRM proposed building a second drain system as remediation. If the original drain system fails to work how certain can the public be that a second drain system will work?

Comment 36

Given the number of permitted groundwater wells in the area, please provide a groundwater model showing likely impacts to the groundwater surface (drawdown/mounding) resulting from the proposed mining activity at the time of maximum dewatering.

Response 36

The revised groundwater report will be provided within a few days of this response. The modeling files can be provided should DRMS wish to recreate the simulations.

Comment on Response to 36: Did not see a map showing impacts to ground water surface at time of maximum dewatering.

Comment 37

Please submit a groundwater monitoring and impact mitigation plan to DRMS for approval. This plan should include: all historic water level data available for the site wells and immediately surrounding area if available, monthly monitoring of water levels at all existing wells if possible, trigger levels for each well based on historic high and low water levels for that well, proposed reporting and mitigation plan when groundwater levels deviate beyond proposed trigger levels to minimize any impact to groundwater levels and especially off-site impacts. Section 9.1 states LRM may mitigate adverse effects to existing wells by supplementing water supplies or deepening wells. Due to the approximately 1,900 feet of Pierre Shale bedrock underlying the area at a depth of 12-30 feet below ground surface (bgs), deepening the existing wells is unlikely to be a successful mitigation solution.

Response 37

Please see Section 7 of the revised groundwater report. Note that deepening of neighbors' wells is a viable solution as most wells are shallow (less than 10 feet deep with approximately 5 feet of saturated thickness). The majority use of the wells is for

domestic lawn and gardening at pumping rates less than 20 gpm. Well drawdown required in this aquifer to achieve 20 gpm is less than 1 foot. Thus, deepening of wells is a viable mitigation strategy, assuming that the wells are legally permitted.

Comment on Response to 37: The response is inadequate. If wells are less than 10 feet and have 5 feet of saturated thickness, then when the well drawdown reaches the LRM trigger of 5 feet the well will be dry and unusable. How long must neighbors be inconvenienced by dry wells before LRM corrects the problem? Also, the comment points out the proximity of bedrock. Deepening to achieve an adequate saturated thickness will likely be impractical.

Comment 38

Please explain how LRM will prevent groundwater drawdown from impacting adjacent vegetation.

Response 38

LRM is unaware of any vegetation that requires protection as there are no jurisdictional wetlands in the area. The groundwater report shows the anticipated extent of drawdown during each phase of mining. The subsequent figures show the current depth to groundwater (average of 5 feet) and the maximum depth from anticipated drawdown (10 feet). The aerial photograph shows that there are currently no vegetation species in the area of maximum drawdown that could survive on groundwater alone given the current depth-to-water. Ergo, they must be currently irrigated. LRM does not plan on engaging in activities that will inhibit adjacent lands from continued irrigation. As always, LRM is open to discussing potential impacts with its neighbors and providing mitigation as necessary.

**********Comment on Response to 38: The max drawdown (10') occurs mostly on LRM land and on the Hawkeye land. The vegetation survey is irrelevant to LRM's neighbors where significant drawdown, 5 feet and more, occurs on neighboring properties. There are plenty of life forms on neighboring properties that survive year-round on ground water resources alone. As well as stressing or killing plants by lowering ground water resources LRM dewatering dries up irrigation wells that could be used to augment ground water resources. The LRM trigger to fix wells experiencing drawdown of 5 feet or more leaves many neighbors with dry wells and potentially dead vegetation on their properties. The proposed ground water draw down on residents property is unacceptable.

Comment 39

Section 7.3.2 of the application claims that "ground water quality is not anticipated to be an issue." Exhibit G cites a groundwater study (Telesto, 2017b) that was not submitted with the application. Has LRM analyzed the baseline groundwater quality? If so, please provide this data. Please provide a prediction of the probably hydrologic impacts to the groundwater quality from excavating the alluvial material and exposing the Pierre Shale.

Response 39

The statement that *"ground water quality is not anticipated to be an issue"* comes from three fundamental pieces information:

- Nearly every gravel pit on the Poudre River has exposed the Pierre Shale and there are not wide-spread water quality issues associated these activities
- Constituent mobility requires two principal components:
  - Source chemistry

- Water movement

- LRM commits to monitoring and managing its water to limit the potential for water quality issues

While the Pierre Shale is documented to have source constituents available, it is also well documented that it is highly impermeable. On site, the Pierre Shale drilled dry, meaning there is no water present. Thus, the only mechanism to move source constituents from the Pierre into contact water is through molecular diffusion, which is a slow process.

Recently, LRM collected samples of the Pierre Shale at the contact with the alluvium and subjected the samples to the synthetic precipitation leach procedure (SPLP) testing. One of 5 samples resulted in detectable selenium. Three groundwater quality samples were taken from monitoring wells MW-06, MW-13, and MW-02. MW-06 showed detectable levels of selenium below the drinking water standard. The sample from MW-06 contained sedimentation (i.e., the well has not completely developed), thus it is most likely that the detected selenium was part of the solid matrix. LRM will sample MW-06 again and filter the sample to corroborate this supposition. These data corroborate the potential for the Pierre Shale to contain selenium, and on the whole, show that ground water quality is not significantly impacted by the Pierre Shale. LRM's water management activities keep the groundwater system outside of the mining area in tact with respect to water contacting the Pierre Shale. Inside the mining area, no water that is in direct contact with the shale is proposed to leave the site. Thus, no water quality issues are anticipated. Regardless, LRM commits to monitoring its water quality in the water management pond and respond accordingly should discharges be an issue.

************Comment on Response to 39**: If there are not widespread water quality issues in gravel mines exposing Pierre Shale, what are the concentrations of arsenic, lead, selenium and uranium associated with the pit water in these mines? How does LRM propose to key the pit liner into the Pierre Shale without disturbing the shale and exposing ambient ground water and pit water to toxins in the shale? Pit water would also likely be contaminated during the excavation of the bedrock key. Contaminated pit water will be pumped into the water management pond which discharges to ground water and likely exceed National Drinking Water Quality Standards for arsenic, lead, selenium and uranium. The water management pond is used for dust suppression. Contaminated water from the pond will be spread throughout the site and entrained in the fugitive dust. LRM has taken samples and measured the Pierre Shale for selenium. However, the sampling plan, as designed provided no new information. One would not expect that the surface of the weathered shale, that has been in contact with ground water for thousands of years, would contain appreciable concentrations of mobile contaminants. The LRM samples of the Pierre Shale surface in contact with alluvium confirmed this presumption. LRM discovered that well sampling showed low levels of Selenium. This would also be expected since the well water was in contact with a relatively small area of shale (the inside of the well cylinder) for a short period of time and this would have been in an oxygen poor environment limiting leaching from shale. LRM measured Selenium in well MW-13 at a depth of 2.5 feet into the Shale. It is well know that the Pierre Shale is contaminated with selenium so this finding was not a surprise.

A major risk in mining on the Pierre shale is mechanical erosion of the Pierre shale, mixing with pit water, pumping into the water management pond and discharging from the bottom of the water management pond to ground water. Mixing of the fine particles in the shale (Pierre Shale is more than 50% clay) with the pit water provides an efficient environment for desorption of contaminants into solution. LRM has stated that Pierre Shale tested negative for metals. For what metals was the analysis performed? Where were the samples taken?

Comment 40

Regarding the item discussed above, please provide a rational and any applicable data to substantiate the claim that groundwater quality will not be an issue.

Response 40

See previous response and section 5.5.3 of the revised groundwater report.

Comment 41

The "Natural Areas" will essentially be lined pit excavations that will on average be about 15 feet deep. After the site is reclaimed, please demonstrate how precipitation and storm water will not be allowed to stand in the pit? If storm water is retained onsite for more than 72 hours, a permanent plan for augmentation must be obtained from the Colorado Division of Water Resources.

Response 41

LRM's primary plan is to obtain the water rights needed to capture and retain stormwater after reclamation. Swales are planned around the site perimeter after closure to manage stormwater and divert it to internal sumps. Should water rights not be obtained for long-term augmentation, LRM plans to return captured stormwater to the watershed (see Attachment 2 – Exhibit F, sheet 1).

Comment to response 41: Storm water retained in the pit will likely become contaminated with arsenic, lead, selenium and uranium from the Pierre Shale. If these contaminants are detected what pre-treatment methods are proposed before discharge to surface water.

RULE 6.4.8 EXHIBIT H – WILDLIFE INFORMATION

Comment 44

The Division received an objection from the No Laporte Gravel Corp. One of the issues raised in the objection was a concern vegetation grown in the bottom of the pit excavation would have greater exposure to possible toxin such as Selenium (Se) from the Pierre Shale pit bottoms which could provide a risk to both wild and domestic animals. Please provide a response to this concern.

Response 44

The pit bottoms will be covered with over three feet of cover material at closure. Because the Pierre Shale has a low hydraulic conductivity and is relatively dry, the only mechanism for moving constituents upward into the cover material will be by molecular diffusion, which is a slow process in and of itself. When occurring in relatively dry materials, molecular diffusion is even slower. Regardless, LRM commits to sampling vegetation after closure to evaluate if plant uptake is an issue.

************Comment 44:** Response 44 is incomplete, Significant contaminated moisture can be expected at the weathered Pierre Shale – cover material interface, through exposure during mining operations and infiltration during periods of low evapotranspiration. The contaminated pore moisture would be subject to both diffusion and the well known mechanism of capillary rise, whereby upward movement of toxins through up the cover material would be significant through this advective transport mechanism.

LRM commits to sampling vegetation and test for Selenium. What is the proposed corrective action if Selenium is detected?

Potential Water Quality Issues from Cretaceous Pierre Shale in the

Proposed Loveland Ready Mix Knox Pit

Larimer County

LaPorte Colorado

Prepared by

HAVIS Engineering

P.O. Box 1437, LaPorte Colorado

February 2018

HAVIS Engineering

PROJECT STATEMENT

The proposed Loveland Ready Mix Knox Pit is a relatively large (127 acre) project only 50 feet away from residential neighborhoods and the center of the town of LaPorte, Colorado. Gravel mining and crushing operations on the Pierre Shale bedrock, known to be contaminated with toxins, beneath the alluvial deposit is a critical concern because of potential water contamination. This report focusses on short- and long-term water and air quality degradation that threatens public health and the environment.

EXECUTIVE SUMMARY

The proposed gravel pit in LaPorte Colorado is only 50 feet away from residential neighborhoods. Mining will disturb the Pierre Shale bedrock underlying the alluvial deposit threatening residents with exposure to arsenic, lead, selenium and uranium toxins from the shale. Literature values for toxin concentrations in Pierre Shale outcrops in the area were compiled and toxin extraction and transport rates were estimated based on the proposed mine plan. As much as 5 million gallons of ambient ground water could be contaminated to the National Drinking Water Quality Standard (NDWQS) levels during construction of pit periphery drains. Ground water contamination through leakage from the water management pond could create a contaminant plume reaching 5 times the NDWQS. Contamination of storm water detention ponds through pumping from the pits after reclamation and the transport of toxins from the Pierre Shale to reclamation soils and vegetation through capillary transport mechanisms are long-term risks. Use of pit water in mining operations could result in air transport of toxins off-site. Gravel mining and concrete production at the LRM Knox Pit site poses a long-term threat to the environment and to public health.

INTRODUCTION

Loveland Ready Mix (LRM) has proposed a gravel pit (Knox Pit) and concrete batch plant project in LaPorte Colorado. Gravel mining is proposed to bottom on the Sharon Springs Member of the Cretaceous Pierre Shale bedrock in each of the mining phases. Elevated dissolved solids, selenium and uranium have been associated with water resources having outcrops of Cretaceous shales in their watersheds. The Pierre Shale underlying the proposed Knox pit is described as fissile and weathered making it susceptible to erosion and dispersion into pit water. The contamination of pit water through contact with the Pierre shale can be estimated by considering particle concentrations in the pit-bottom environment.

Water flowing over Pierre Shale can be expected to entrain sediment concentrations consistent with Newtonian fluids. Opportunities for pit water-shale contact include mechanical mixing of shale with ground water and pit water during construction of the periphery drains, mechanical mixing from machinery in the pit-bottom, and turbulence around dewatering well intakes and pit-bottom sumps. Construction of the proposed drains around the outside of the gravel pits has potential to release significant contamination to the ambient ground water. Turbulent flow of water over the weathered Pierre Shale would be expected to pick up sediment and dissolved toxins approaching National Drinking Water Standards (NDWQS) concentrations. Turbulence and mechanical mixing with concentrated sediment around dewatering well intakes will contaminate inflows.

Ground water contamination through infiltration from the water management pond during mining and from the storm water detention ponds are short- and long-term risks. Minimum contaminant concentrations in the water management pond should be estimated with the Newtonian fluids having sediment concentrations that would occur in nature. Pit water flowing over high sediment concentrations and subject to mechanical mixing risks contamination of the water management pond from 5 to 130 times the NDWQSs for the case of arsenic.

The use of water-management pond water for dust suppression risks toxin transport off-site as vapor and attached to dust particulates. Toxin transport after reclamation includes seepage from retention ponds that receive inflows from sump pumps on the pit bottom. Capillary transport of toxins from the contaminated pit bottom to the reclamation soil surface threatens vegetation success and wildlife.

PIERRE SHALE OF THE UPPER CRETACEOUS

The Sharon Springs Member of the Upper Cretaceous Pierre Shale forms outcrops along the Front Range of Colorado in the vicinity of Boulder and Fort Collins (Gautier et al., 1984). Because of the potential for oil, gas, and uranium resources it has been extensively studied. The Sharon Springs Member of the Pierre Shale is composed of greater than 50% clay minerals, is more easily weathered than other Pierre Shales, and contains more organics and pyrite. It contains unusual amounts of selenium and arsenic (Tourtelot, 1955). Grain density is about 2.46 g/cc, and in weathered samples the bulk density is about 1.72 g/cc, and the porosity is about 0.3 (Schultz, 1980). Chemical analyses of outcrop material have identified toxic elements including arsenic, lead, selenium, and uranium shown in Table 1.

Table 1. Inorganic Toxic Contaminants in Regional Outcrops of the Sharon Springs Member, Pierre Shale (mg/kg).

Reference	Arsenic	lead	Selenium	Uranium
Kulp and Pratt (2004)			16.4	12.0
Landis (1959)	30	30	7.5	7.5
Tourtelot (1955)	35	6.7	24	6.7
Schultz et al. (1980)	18	21	4.7	4.8
Average	27.7	19.2	13.1	7.7

Elevated dissolved solids, selenium and uranium have been associated with water resources having outcrops of Cretaceous shales in their watersheds (Sares, 2000; Miller et al., 2010). Concentrations measured in watersheds influenced by the shale outcrops were 83% higher in dissolved solids, 646% higher in selenium and 55% higher in uranium than flows in watersheds not influenced by Cretaceous shale outcrops. Median concentrations in Cretaceous shale-influenced inflows were about 4 µg/L selenium, and 24 µg/L uranium (Berna and Stogner, 2017). The influence of Pierre Shale on water quality in the proposed Knox pit depends on the degree of bedrock erosion and mixing with pit water. The mobility and health effects of the important Pierre Shale contaminants arsenic, lead, selenium and uranium are discussed below.

<u>Arsenic</u>

Elevated arsenic concentrations in groundwater occurs by oxidation of sulfide minerals and desorption from mineral particles. This produces methylated and inorganic forms of arsenic, the most common species in groundwater (Peters and Burkert, 2008). This process is accelerated when subsurface material becomes oxidized thus elevating Eh and dissolved oxygen concentrations, pH and alkalinity. The EPA MCL for arsenic is 10 µg/L. Health effects from long-term consumption include skin disorders, irritation of the stomach, intestines and lungs, neurological disturbances, and cancer.

<u>Lead</u>

Lead is weakly soluble in water but has become ubiquitous in the modern environment. It is estimated that the average lead concentration in the blood of pre-industrial humans was 175 times lower than the average blood levels in the United States today (Flegal and Smith, 1995). There are many human health effects of lead exposure, particularly in children, including neurological disorders that may occur later in life.

Selenium

In subsurface reducing conditions, selenium exists in immobile and biologically unavailable forms, selenide (Se^{2-}) and elemental selenium (Se^0). The mobility of selenium in oxidizing conditions in shallow groundwater and soils and surface water depends on pH and Eh conditions. Most common forms of selenium in oxidized and neutral pH environments are selenate (+4)(SeO_4^{2-}) and selenite (+6)(SeO_3^{2-}). Selenate is the most mobile and biologically available form, and selenite is most likely to be absorbed by organics and clays. Groundwater that is high in dissolved solids may also contain high concentrations of Se (Sharif and Korom, 2010; McNeal and Balistrieri, 1989).

Plants can absorb selenite and selenate from soil moisture. Selenium accumulator plants may concentrate high levels and pose a risk to animals consuming these plants. Selenium is a necessary micronutrient in animals, but large amounts can be dangerous. Humans need about 40 micrograms of selenium per day but greater than 400 micrograms per day can be toxic (Wikipedia, Dec. 2007). There is narrow range between nutritionally optimal and toxic levels of selenium.

Uranium

Along with other organic and inorganic contaminants, uranium (U6+) becomes mobilized when organic-rich shale deposits are oxidized (Wilke et al., 2015). Uranium occurs in 4 oxidation states in ground water derived from the dissolution and desorption from minerals. Ground water concentrations range from 0.1 to 120 µg/L. Human exposure to uranium may cause chemical and/or radiological toxicities. The main consequence is kidney toxicity (Suma et al. 2016).

POTENTIAL PIT-WATER CONTAMINATION FROM PIERRE SHALE

The Pierre Shale underlying the proposed Knox pit is described as fissile and weathered making it susceptible to erosion and dispersion into pit water. Highly and moderately weathered core descriptions (borings MW-02 and MW-07) tend to be softer and have higher water contents. Most of the weathered Shale cores shown in Table 2 are described as dark or black, indicating high concentrations of organic matter therefore having a high potential as a source of toxins (Tourtelot, 1955; Tuttle et al., 2014; Gautier, et al. 1984)

Table 2. Boring Logs of Pierre Shale, LaPorte Colorado (Terracon Consultants Inc. 2017)

Boring Log No.	Depth Weathered Shale (ft)	Water Content at Terminal depth (%)	SPT (number blows /penetration) bottom of bore hole	Description
MW-02	26.0 – 29.4	13	50/5”	SEDIMENTARY BEDROCK - CLAYSTONE, trace sand, dark gray, very hard, laminated bedding, moderately weathered
MW - 06	18.0 – 22.1	8	50/1”	SEDIMENTARY BEDROCK - CLAYSTONE, dark gray to black
MW - 07	9.0 – 9.5	11	50/6”	SEDIMENTARY BEDROCK - CLAYSTONE, olive gray, very hard, highly weathered, iron oxides
MW - 11	14.5 – 19.3	5	50/4”	SEDIMENTARY BEDROCK - CLAYSTONE, gray to dark gray/black, laminated bedding, highly weathered at 14.5' to slightly weathered at 19'

MW - 12	20.0 – 23.3	9	50/4"	SEDIMENTARY BEDROCK - CLAYSTONE, dark gray, highly weathered to slightly weathered
#	22-24			Weathered Shale: Shale bedrock, very soft, clayey black to orange
#	22-24			Weathered Shale: Weathered bedrock, wet, red to black, soft
#	15-20			Weathered Shale: Pasty claystone, orange to black, slight silt
#	19-20			Weathered Shale: Weathered bedrock, red/orange to light grey claystone. Pasty and sticky
#	17-19			Weathered Shale: Weathered bedrock, red to orange soft clay
#	15-18			Weathered Shale: Weathered bedrock, orange to black shale, soft, clayey
#	15-17			Weathered Shale: Weathered interface, orange to black claystone, competent at 16 feet
#	16-18			Weathered Shale: Weathered bedrock, orange to light grey claystone, pasty
#	17-18			Weathered Shale: Weathered bedrock orange to light grey claystone, pasty

Notes
unlabeled boring, approximate depths. Appendix B, Telesto Solutions, Inc. January 12, 2018, Second Submittal, Proposed LaPorte Operations, Knox Pit Groundwater Study

The toxin concentrations measured in Pierre Shale (Table 1) were used to calculate solid- and aqueous-phase concentrations at points along the relative viscosity curve (Zhu et al. 2017) shown in Figure 1 for the case of arsenic.

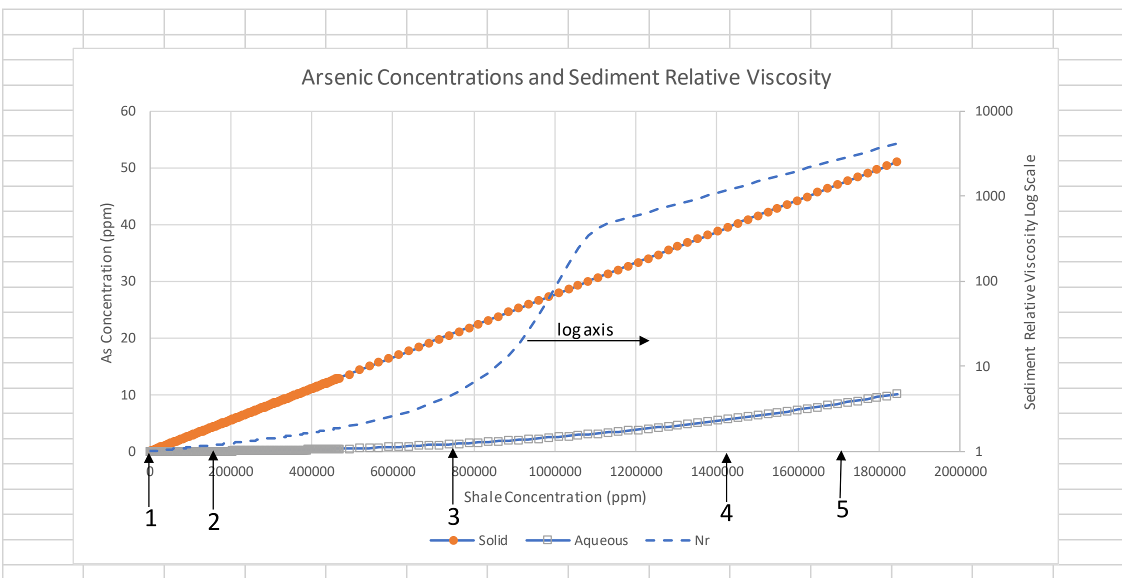

Figure 1. Relative Viscosity (right axis, Nr), and Solid and Aqueous Phase Arsenic Concentrations in Suspensions of Pierre Shale Particles.

The solid phase toxin concentrations increase linearly with sediment concentration. Desorption of toxins from the solid- to the aqueous-phase occurs relatively fast in oxidizing environments. The aqueous-phase concentrations in Figure 1 are based on sorption isotherm relationships specific to each toxin. The Freundlich sorption isotherm was used for arsenic (Hafeznezami et al., 2016) and for uranium (Mishra et al. 2011) and the Langmuir sorption isotherm was used for selenium (Dhillon and Dhillon, 2000). Lead is only weakly soluble in water so the aqueous phase for lead is assumed to be negligible, but solid and colloidal concentrations are significant, exceeding the NDWQSs for all sediment types in Table 3. The aqueous- and solid-phase concentrations for selenium and uranium are shown in Figures 2 and 3 (Appendix A), along with the same relative viscosity curve presented in Figure 1.

Table 3. Calculated Potential Toxin Concentrations in the Proposed Knox Pit Water. The Solid- and Aqueous-Phase Concentrations and National Drinking Water Quality Standards (NDWQS) are shown (mg/L).

Type of Sediment Suspension	Suspended Solids Concentration	Arsenic		Lead	Selenium		Uranium	
		NDWQS = 0.01		NDWQS = .015	NDWQS = 0.05		NDWQS = 0.03	
		Solids	**Aqueous**	**Solids**	**Solids**	**Aqueous**	**Solids**	**Aqueous**
1-Newtonian	3695	0.1024	0.0000	0.0709	0.0484	0.0014	0.0285	0.0024
2-Non-Newtonian Fluid	164820	4.5655	0.0413	3.1645	2.1591	0.0618	1.2691	0.1223
3- High Viscosity Sediment	751530	20.8174	1.3084	14.4294	9.8450	0.2761	5.7868	0.5893
4-Consolidated Sediment	1451400	40.2038	5.8596	27.8669	19.013	0.5203	11.1758	1.1655
5-Weathered Pierre Shale	1722000	47.6994	8.6496	33.0624	22.558	0.6116	13.2594	1.3915

Water flowing over the Pierre Shale can be expected to entrain sediment concentrations consistent with natural river flow (i.e. 3,700 ppm, USGS, December, 2017, position 1 in Figure 1, sediment Type 1 in Table 3) on the linear part of the relative viscosity curve. Mechanical and turbulent mixing with higher sediment concentrations such as non-Newtonian fluids (Position 2 in Figure 1, sediment Type 2 in Table 3) and highly viscous fluids (Position 3 in Figure 1, sediment Type 3 in Table 3) may entrain very high solid and dissolved levels of toxins as shown in Table 3.

Opportunities for pit water-shale contact include mechanical mixing of shale with ground water and pit water during construction of the periphery drains, mechanical mixing from machinery in the pit-bottom, and turbulence around dewatering well intakes and pit-bottom sumps.

<u>Mechanical Mixing of Pierre Shale and Ground Water</u>

Construction of the proposed drains around the outside of the gravel pits has potential to release a significant mass of toxins into pit water and the ambient ground water. Contamination of dewatering intake flows would also be a risk during excavation of the bedrock key into the Pierre Shale for the pit liner system. The periphery drains were estimated to be a total of 2580 feet (Telesto, January 2, 2018). Assuming a trench approximately 1 square foot in cross section would be required, 2570 cubic feet of Pierre Shale material could possibly mix into the ambient ground water during construction. Assuming only the dissolved chemical masses in the weathered Pierre Shale shown in Table 3 would be mixed into ambient ground water, the following volumes could be raised to the NDWQS for arsenic, selenium and uranium shown in Table 3: arsenic 15.5 acre-feet, selenium 0.2 acre-feet, and uranium 0.8 acre-feet of potentially contaminated ambient ground water. These volumes represent the potential for ground water contamination, but even a fraction would cause a significant ground water plume exceeding ground water quality standards.

Mechanical Mixing from Machinery in the Pit Bottom

Turbulent flow of water over the weathered Pierre Shale would be expected to pick up sediment and dissolved toxins approaching NDWQS concentrations. Mechanical mixing on the pit bottom can be expected to mix pit water with concentrated (Type 2, Type 3 and Type 4) sediment suspensions, thereby increasing the toxicity level of the pit water. For example, in the case of arsenic, dissolved pit-water concentrations in the range of 0.04 to 1.3 mg/L can be expected, approximately 4 to more than 10 times the National Drinking Water Standard of 0.01 mg/L.

Turbulence Around Dewatering Well Intakes and Pit-Bottom Sumps

Turbulence and mechanical mixing with concentrated sediment around dewatering well intakes will contaminate inflows. Entrainment of Pierre Shale into dewatering well intakes during construction of the bedrock key for the pit liner system is likely. With slow sedimentation of solids, pit water mechanically mixed with pit-bottom sediments could resemble the aqueous-phase concentrations calculated for the non-Newtonian and high viscosity suspensions. For the case of selenium, these concentrations can be expected to range from 0.06 to 0.28 mg/L exceeding the National Drinking Water Standards by more than 5 times in the case of the higher concentration.

Risk of Ground Water Contamination

Ground water contamination through infiltration from the water management pond during mining and from the storm water detention ponds are short- and long-term risks. There are many unknowns in estimating contaminant concentrations in the pit impoundments. It is useful to bracket the range of concentrations with a low estimate and a high estimate. It is probable that the actual number will be somewhere in between.

Minimum contaminant concentrations in the water management pond should be estimated with the Newtonian fluids having sediment concentrations that would occur in nature (i.e. sediment suspension Type 1 in Table 3). These are less than the NDWQSs in the aqueous phase alone and would exceed or approximate the NDWQSs when considering the solid plus dissolved toxin concentrations in the Type 1 sediment suspensions.

Pit water flowing over high sediment concentrations and subject to mechanical mixing risks contamination of the water management pond from 5 to 130 times the NDWQSs for the case of arsenic. Outflows from the water management pond could pose a significant risk for contamination of ambient ground water with the toxins shown in Table 3.

Risks of Air Contamination

The use of water-management pond water for dust suppression risks toxin transport off-site as vapor and attached to dust particulates. Therefore, the health risk of particulate emissions from the site would include the inhalation of fine particles as well as exposure to arsenic, lead, selenium and uranium. The rate of toxin-contaminated air emissions from the site can be estimated using the calculated toxin concentrations and the dust suppression pumping rates.

Post Reclamation Water Quality and Toxicity Risks

Toxin transport after reclamation includes seepage from retention ponds that receive inflows from sump pumps on the pit bottom. Pit-bottom water is likely to be in contact with Types 3, 4 and 5 sediments. These sediments have a minimum contaminant concentrations 5 to 130 times the NDWQSs for arsenic. These flows would pick up toxins for many years before the toxins are eventually depleted from the Pierre Shale.

Capillary transport of toxins from the contaminated pit bottom to the reclamation soil surface threatens vegetation success and wildlife. The proposed reclamation of the pits includes placing topsoil overlying growth media (3 feet) in contact with the Pierre Shale. Mechanisms for contaminants becoming available to surface vegetation include diffusion and capillary rise, an advective transport mechanism capable of significant toxin transport and deposition through evaporation at the soil surface. If revegetation is successful on the reclamation growth media, evapotranspiration will accelerate the capillary transport of toxins from the pit bottom to the surface. Plants capable of accumulating selenium pose toxicity risks for wildlife consuming them.

CONCLUSIONS

Loveland Ready Mix proposes to mine and crush gravel on Pierre Shale bedrock underlying the Knox Pit in LaPorte Colorado. The easily eroded Pierre Shale contains high concentrations of the toxins, arsenic, lead, selenium, and uranium, and exposure of the Pierre Shale to oxygen mobilizes toxins into solution. The evidence of elevated surface water concentrations of selenium and uranium through contact with Cretaceous Shale outcrops is widely recognized. Excavation of the shale to build the pit liner risks dispersion of toxins into pit water and ambient ground water. Mechanical erosion in the pit bottom during mining accelerates the mobilization and transport of solid- and aqueous-phase toxins into the water management pond. Outflows from the water management pond threatens pollution of ground water above the NDWQSs. The use of the water management pond for dust suppression threatens down-wind receptors with toxins as well as particulates. Pumping from pit sumps after reclamation poses a long-term threat to ground water pollution from seepage. Capillary rise of toxins from the Pierre Shale into reclamation soils threatens vegetation and wild life. Gravel mining and concrete production at the LRM Knox Pit site poses short- and long-term threats to the environment and to public health.

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Appendix A

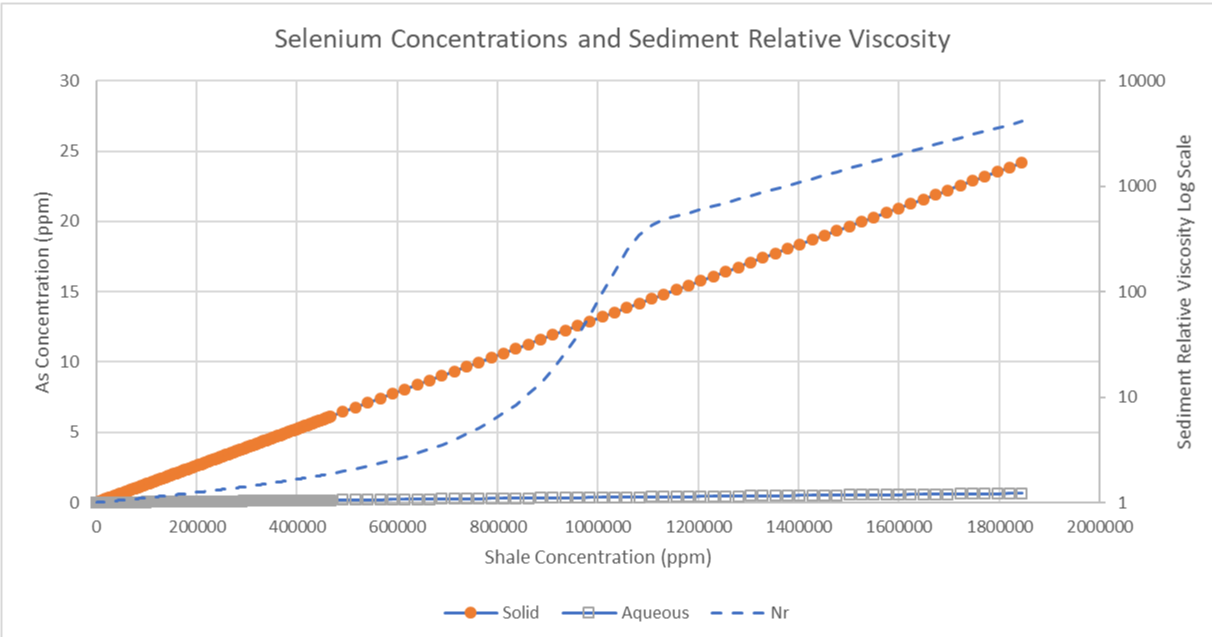

Figure 2. Relative Viscosity (right axis, Nr), and Solid and Aqueous Phase Selenium Concentrations in Suspensions of Pierre Shale Particles.

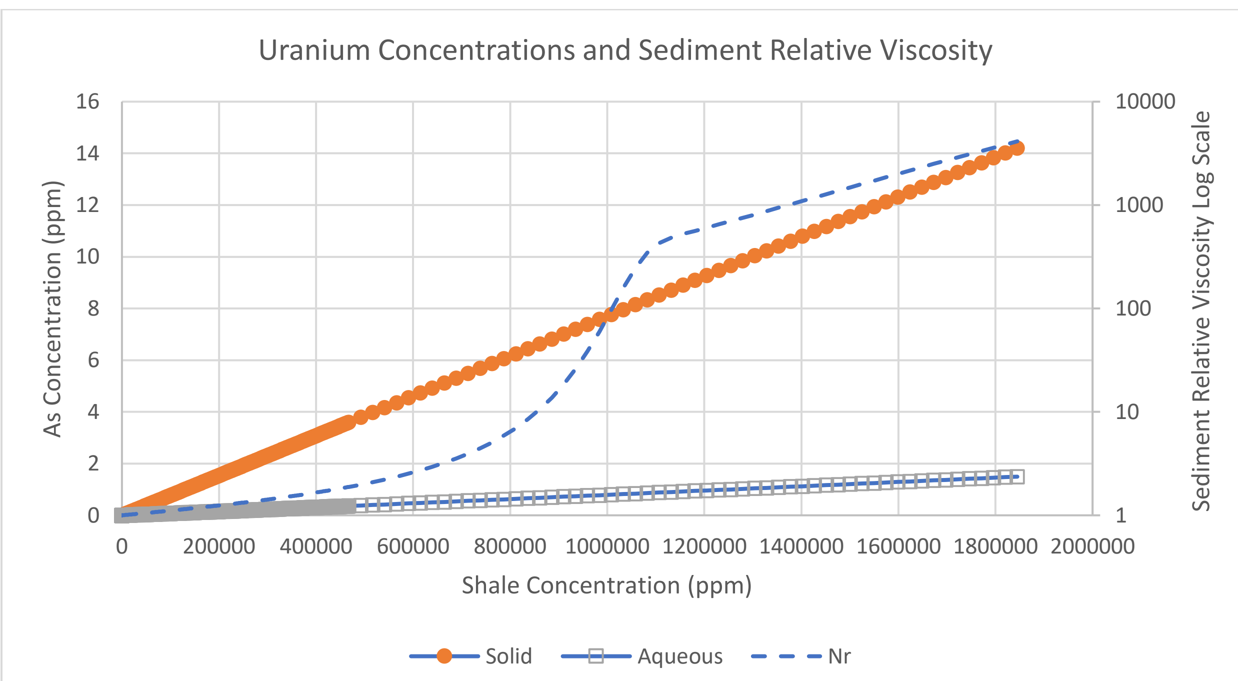

Figure 3. Relative Viscosity (Nr, right axis), and Solid and Aqueous Phase Uranium Concentrations in Suspensions of Pierre Shale Particles.