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Suite 1900, 736 6th Avenue SW
Calgary, AB T2P 3T7
Canada
www.okc-sk.com

Memorandum

From:	Andrew Baisley, Senior Geoscientist
Cc:	Dave Christensen – Okane Consultants
To:	David Harpley – VP, Permitting, NorZinc (Canadian Zinc)
Our ref:	0000
Date:	July 29, 2021
Re:	**Norzinc Prairie Creek Cover System Regulator Responses**

This memorandum serves as basis to provide NorZinc technical responses to regulator comments based on Okane's 2010 cover system technical report. In total, 7 comments/ recommendations were provided by reviewers that pertained to Okane's original scope of work. Okane has provided responses to the following comments:

- GNWT 97;
- MVLWB 41;
- PC 18; and
- Racher 27-29, 33.

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Table 1: Reviewer Comment 97 GNWT - Lands: Katie Rozestraten

Comment	Recommendation	Okane Response
Section 2.1.4 of the Waste Rock Ore Stockpile Management Plan (WROSMP) – Limiting /Managing ARD/Metal Leaching states that a soil cover is proposed to "limit leaching and seepage". Zinc in the seepage is estimated to be 8 - 12 mg/l. A "preliminary numerical modeling" is presented in Appendix A of the Closure and Reclamation Plan (OKane Consultants, 2010). Two cover types were simulated, non-compacted till and compacted clayey till (rejected in Appendix A as not feasible to construct). It is GNWT's opinion that construction of any type of cover on a 2:1 slope will be very difficult. Additional uncertainties include: where will the till material come from, and is there a sufficient quantity available? What are the soil properties? How will the cover resist erosion? These issues are identified in the 2010 O'Kane memo and remain unresolved in the application submitted by the proponent. Potentially up to 150,000 m3 of select till type soil (not colluvium) could be required to cover the WRP. Therefore, the demonstration that this quantity of material is available is critical for the viability of the cover design.	The GNWT recommends that the proponent's cover design be advanced sufficiently to show that it can be constructed and that it will be effective at reducing the flushing of zinc to the environment. Preliminary numerical modeling based on assumed parameters does not satisfy this recommendation. The design should be supported with field assessment to demonstrate a sufficient quantity of suitable material.	

Reference - OKane Consultants, 2010. Memorandum to David Harpley – Canadian Zinc Corporation: Results of Preliminary Numerical Modelling Program of WRP Cover System Alternatives at Prairie Creek. Appendix A of NorZinc Prairie Creek Mine Closure and Reclamation Plan – Version 2.0, May 2021.

Enter table source here.

Response:

The comment and recommendation are comprised of three facets, all of which will be addressed separately within the response.

Constructability

The first part of the recommendation speaks to demonstration of the constructability of the preliminary cover system design. The proponent is relying on the cover system practitioner's industry knowledge of similar sites and slope configurations to determine the practicability and success of constructing the proposed cover system designs.

Constructing either cover system configuration (granular till cover system or a compacted clayey till) on plateaus of the mine rock storage facilities is not expected to pose constructability issues for conventional earth moving equipment. Okane's 2010 report recommended employing the granular till cover system compared to the clayey till cover system on the plateau due to its simplicity for design, construction and cover maintenance when comparing the similar net percolation (NP) performance. It was further stated that the for the 2H:1V slopes, the non-compacted granular fill should be placed as the cover system with the thickness of 1m and being dependant on the available borrow quantities (which will be answered in more detail below). The key recommendation for this technique was that a stability assessment be completed on a slope stability and erosion control perspective. These assessments are typically completed as part of a detailed cover system design and will be completed for this project in the detailed design phase where the cover system and landform designs are integrated.

Flushing Water Quality

The proponent agrees that the cover system design will be advanced as the project progresses into detailed design stages. At this stage of the design, estimates of net percolation into the underlying waste rock have been provided. No flushing, toe seepage, or basal seepage estimates were provided in the 2010 Okane report as this was not part of Okane's scope. To state that the preliminary numerical modeling does not satisfy that the cover design will be effective at reducing the flushing of zinc to the environment, is incorrect. Flushing and seepage water quantities and qualities are dependant on many factors. Net percolation rates are but one parameter, but an important one, that affects water quality. Internal waste rock geochemical controls will likely be another strong determinant for seepage water quality. At this stage, we can conclude that either cover design will significantly reduce NP.

In the future for detailed cover system designs, net percolation performance will be determined based on site wide water quality requirements. Into operations, seepage will be monitored and used to calibrate model results to improve long term predictions for water quality.

Cover System Materials Balance

Finally, the third component of the recommendation from the reviewer was that the cover system design be supported with field assessment to demonstrate a sufficient quantity of suitable material. NorZinc has provided Okane an initial assessment for the required cover system design soil volumes (Table 6-1). The information provided indicates the cover system material requirements total 194,000 m^3 while the total available borrow sources initially identified, exceed 320,000 m^3. The identified borrow material appears suitable for cover material, but Okane will confirm this from a hydraulic properties perspective. Potential upcoming work programs will further correlate existing borehole data to material properties of the till to further refine the soils suitability in the proposed cover system design.

TABLE 6-1: WRP COVER AND SOURCE VOLUMES

Item	Till Requirements	Base Sediments	Borrow or Excess	Clay	Total Material (m^3)	Comment
WRP Cover	194,000				**194,000**	97,000 m^2, 2,500,000 m^3 WRP. Assumed cover of 2 m of till.
Excess Material Pile Sources						
WSP		50,000	0 to 21,000		Up to 71,000	During detailed design, the Excess material may decrease to zero.
WRP			0 to 21,000		Up to 21,000	
WSP Source						
WSP South Dyke			221,000	10,000	231,000	1980 Golder design used to generate Clay. 2014 Golder design used to generate Excess.
Total Borrow Sources					**Up to 323,000**	

Table 2: Reviewer Comment 41 MVLWB: Kim Murray

Comment	Recommendation
While it appears that most of the design factors or variables, in O'kane' Preliminary Numerical Modelling Program of the Waste Rock Pile (WRP) Cover System, may still be applicable to the expanded waste rockpile cover system currently being proposed, some of the deign factors/specifications may need to be updated to ensure complete applicability to the expanded cover system.	Confirmation should be provided on whether the current model will completely apply to the expanded waste rock pile cover system, and if not, provide details on whether/when the model will be updated.

Enter table source here.

Response:

Okane's 2010 model results represented a preliminary cover system design and will be applicable to the expanded waste rock pile cover system. The cover system modelling represents a water balance calculation at the soil-plant- atmosphere interface. Being that nothing in the surface boundary conditions is expected to change, the model is not anticipated to be updated until detailed cover system modelling commences in the future. The only parameters expected to change in the design is the waste rock pile's geometry and size, and the proportion of plateau area to slope area. This change will have no bearing on the individual NP rates calculated for each area, but instead would influence the total volume of infiltrated water into the facility which will be considered in future water quality assessments.

Table 3: Reviewer Comment 18 Parks Canada: Alexandra Taylor

Comment	Recommendation
The waste rock and ore storage stockpile will be a permanent feature remaining at the mine post-closure. The closure and reclamation plan describes that this stockpile will receive a cover. The performance of the cover is important to limit precipitation from contacting the waste rock and ore since this waste material can leach metals under neutral pH conditions. It is not clear in the Proponent's document how climate change was considered in the selection of the proposed cover type and thickness, or the importance of climate change on the post-closure seepage quality and quantity.	Parks Canada recommends that CZN describe: 1. How climate change was considered, or will be accounted for, in the design of the waste rock and ore storage stockpile cover. 2. The implications of climate change for each of the following: a) selection of cover material type and thickness, b) post-closure seepage water quality, and c) post-closure seepage water quantity.

Enter table source here.

Response:

Climate change simulations were not included in the initial cover system design modelling work. Site- specific data available for the site from 2005 to 2008, and from Environment Canada weather stations at Ft. Liard and Ft. Simpson were used to develop the 4-year climate input record.

Potential upcoming work programs will compare the climate record developed for the 2010 modelling to an expanded climate dataset to the current period (16 years) to determine its representativeness. A model update can incorporate confirmation of material properties determined through borehole log correlations as well as the expanded climate database. Climate change scenarios will be incorporated appropriately within the detailed cover system design.

Differences between general circulation model (GCM) downscaled data will require collaboration with organizations such as Environment and Climate Change Canada to determine which models and scenarios will be most applicable to the site for future evaluation of the detailed design.

Table 4: Reviewer Comment 27 Racher Consulting: Kathy Racher

Comment	Recommendation
The successful closure of the WRP is a critical part of ensuring good post-closure water quality. This in turn relies on good design, construction, and maintenance of the WRP cover. The WRP cover recommended by O'Kane Consultants is a 1-2 meter "store and release" cover, meaning it's job is to capture precipitation and snowmelt and allow evapotranspiration to return some of the water back to the atmosphere. This would reduce how much precipitation and snowmelt percolates into the pile and therefore improve the water quality of seepage entering the creek. The predicted infiltration is highly dependent on predicted weather. We did not see in the O'Kane Consultants memo how the modeling of cover performance accounted for climate change.	What are the predicted impacts of climate change on the WRP cover performance?

Enter table source here.

Response:

See our response to Parks Canada 18 above.

Table 5: Reviewer Comment 28 Racher Consulting: Kathy Racher

Comment	Recommendation
CZN updated the 2010 post-closure water quality predictions used in the original licensing proceeding to incorporate new data and assumptions. The 2010 O'Kane Consultants memo, which is a preliminary design for the WRP cover, was not updated. As noted by O'Kane Consultants, the modeling and design are preliminary and "a large amount of information required for detailed numerical modelling was unavailable"	When does CZN plan to update the O'Kane Consultants memo? Has CZN gathered additional information since 2010 which will inform this update?

Enter table source here.

Response:

Potential upcoming work programs can compare the climate record developed for the 2010 modelling to an expanded climate dataset to the current period (16 years) to determine its representativeness. A model update is expected to incorporate confirmation of material properties determined through borehole log correlations as well as the expanded climate database. Climate change scenarios will be incorporated later in the detailed cover system design.

Table 6: Reviewer Comment 29 Racher Consulting: Kathy Racher

Comment	Recommendation
O'Kane Consultants noted that "a large amount of information required for detailed numerical modelling was unavailable." This leaves a fair amount of uncertainty in the cover performance.	What design improvements could be made if the waste rock pile cover system performance falls into question based on the results of research recommended by O'Kane Consultants?

Enter table source here.

Response:

If the waste rock pile cover system performance falls into question, the data would first need to be reviewed and analyzed to better understand the mechanism leading to the questionable performance. Improvements may be identified after first understanding the root cause. At this stage in cover system design, the objective has been to propose a robust and resilient cover system. Within the detailed cover system design process, a risk assessment, such as a failure modes and effects analysis, is generally completed which will identify the likelihood of specific failure modes, their consequence, and potential mitigations. As the cover system design moves through the design process towards a detailed design, optimizations will arise due to addressing identified potential failure modes.

Table 7: Reviewer Comment 33 Racher Consulting: Kathy Racher

Comment	Recommendation
The proposed cover system for the WRP is meant to reduce the amount of water that contacts waste rock and DMS rock, and thereby minimize metals in seepage entering Prairie Creek post-closure. The cover is a store and release cover that relies in part on evapotranspiration, meaning evaporation and water loss through plant transpiration. It appears the initial assessment assumes that 50% of the WRP will be covered in vegetation with a root depth of 0.5 metres. This vegetation would assist with removing water from the cover and is therefore directly linked to the success of the cover and to long-term water quality. However, there is no information in the CRP about vegetating the WRP, how it will be achieved, whether organic material is needed to facilitate re-vegetation, and what research might be needed to determine successful vegetation methods. Likewise, the cost of vegetating the CRP is not in the security estimate.	Please confirm our understanding is correct and clarify why the CRP and the security estimate don't address vegetating the WRP to ensure the successful performance of the cover. Please clarify whether organic material (e.g., topsoil) is needed and whether any is available.

Enter table source here.

Response:

The cover system is a store and release cover that relies in part on evapotranspiration (evaporation and water loss through plant transpiration). A vegetation surface coverage of 50% with a root depth of 0.5 metres was used in the modelling. The uptake and transpiration of water from the cover system soil to the atmosphere contributes nearly equally (~30% of PPT) to water removal from the cover system as does bare surface evaporation (~30% of PPT). Vegetation assists in the removal of water from the cover system.

However, it is incorrect to assume that the vegetation is directly linked to the success of the cover system from a net percolation perspective. As vegetation coverage is decreased in the model, there is an increase (though not an off-setting amount) of bare surface evaporation. This is largely in part due to the shading effect vegetation plays on reducing bare evaporation. When vegetation is removed, more radiation is reaches the soil surface where it is partitioned into latent and sensible heat fluxes (i.e. latent heat flux: evaporation of water and sensible heat flux: represents the loss of energy by the surface by heat transfer to the atmosphere). Although vegetation helps increase overall evapotranspiration losses, it is not paramount for a store and release cover system to function.

We trust information provided in this memorandum is satisfactory for your requirements. Please do not hesitate to contact me at 587 583 4288 or abaisley@okc-sk.com should you have any questions or comments.