Feasibility Study

Lik Deposit Transportation System

Prepared for the Alaska Industrial Development and Export Authority

Proposed Lik Mine, Northwest Alaska

December 31, 2014

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NOTICE

HDR Engineering, Inc. prepared this throughput and capacity report for AIDEA. The quality of information, conclusions, estimates, and recommendations contained herein is based on: (i) information made available to HDR at the time of preparation; (ii) data supplied by outside sources; (iii) field survey of the current mine and port facility; and (iii) the assumptions, conditions, and qualifications set forth in this report.

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Acronyms and Abbreviations

Abbreviation	Full Title/Term
AIDEA	Alaska Industrial Development and Export Authority
CAPEX	capital cost estimate
CSB	concentrate storage building
dmt	Dry metric tons
DMTS	Delong Mountain Transportation System
DWT	dead weight tons
gpd	gallons per day
gpm	gallons per minute
IRR	internal rate of return
IX	ion exchange
MW	Megawatts
NPV	net present value
NSR	net smelter revenue
OPEX	operating cost estimate
PEA	Preliminary Economic Assessment Technical Report
R/O	reverse osmosis
SAG	semi autogenous grinding
SWMT	stored wet metric tons
TAK	Teck Alaska, Inc.
tpa	tons per annum
TUB	truck unloading building
µm	Micrometer (1 µm =$1x10^{-6}$m)

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1 Executive Summary

The primary objective of this study is to evaluate the Delong Mountain Transportation System (DMTS) and determine what, if any, operational and infrastructure modifications may be necessary to support additional receiving, storage, reclaiming, load-out and shipping (a process referred to as "throughput") of lead and zinc ore from the potential Lik Mine in northwestern Alaska. Zazu Metals Corporation ("Zazu") shares ownership equally (50/50) with Teck Alaska, Inc., and is the named operator for the deposit, which is located approximately 17 miles from the Red Dog Mine.

The scope of this study also includes a review of the Preliminary Economic Assessment Technical Report (PEA) for the Lik Mine, prepared by JDS Energy and Mining Inc., (April 23, 2014), and a review of current and potential future commodity prices to determine how price variability affects the proposed mine and project.

This Feasibility Study report is organized according to the above objectives and priorities.

DMTS Capacity Evaluation

To give proper due diligence to the evaluation of the DMTS system and more specifically the DMTS Port facility, HDR developed an Microsoft Excel-based capacity and throughput model that, once calibrated, became the basis upon which all improvements and recommendations were evaluated and recommended. The model included all of the critical operational and capacity input parameters.

The model was populated and successfully calibrated with historical throughput volumes recorded at the port facility. Once calibrated, HDR verified the forecast in the PEA report and obtained agreement to its accuracy. HDR used the calibrated model to perform a series of "what if" scenarios by changing operational parameters to determine the best combination of parameters that would reasonably predict the movement of the projected volumes of both Lik and Red Dog mine products through the system.

Impact of Lik Mine Development

The evaluation of Lik Mine's impact on DMTS hinges significantly on the accuracy and timing of the mine production forecast. The forecast, obtained from the PEA report, projects a constant production volume of approximately 350,000 SWMT (short wet metric tons) annually over a projected nine year productive mine life. This is assumed to occur from 2020-2028 during which the production rate at Red Dog Mine is also assumed to be consistent, at <1,000,000 SWMT annually. This evaluation gages the ability of the current DMTS infrastructure and operations practices to throughput the required combined product volume of four unique materials delivered from two different mines.

The results of this evaluation indicate that only capital expenditures related to additional fuel storage (to support the Lik Mine) and a new road (connecting Lik Mine to the existing DMTS haul road) will be required to accommodate the combined product volume forecasted from Red Dog and Lik mines. The total installed cost estimated for these investments is $89 million in 2019 dollars. Otherwise, only operational adjustments associated with the delivery, storage, and shipment of both Red Dog and Lik Mine products will be required. This involved the reassignment of existing resources to properly support production at both mines simultaneously.

The throughput evaluation was also expanded to study what, and when, capacity upgrades would be required in the event the forecasted production schedule underestimated the actual realized production during Lik Mine development. While a detailed description of recommended upgrades is provided in Sections 6 and 7, the results of this exercise are summarized as follows:

- For up to 1.3 million SWMT (100,000 SWMT greater than average forecast) combined production volume/throughput, additional haul trucks during the shipping season would be required to increase the haul operation capacity and reduce the time required to replenish the storage piles at the port. As such, only an increase in operating costs associated with the additional haul trucks would result. Therefore, no additional capital expenditures are estimated to provide the additional throughput of 100,000 SWMT of product.
- For a total throughput volume of up to 1.35 million SWMT annually, additional haul trucks are required year-round to increase haul operation capacity during the non-shipping and shipping seasons. To compliment the non-shipping season haul capacity increase, additional storage is necessary. Extending CSB No. 2 (to equal the current capacity of CSB No. 1) will provide approximately 100,000 SWMT of additional storage space. The total estimated capital expenditure (+/- 35% in 2019 dollars) associated with the extension of CSB No. 2 is $9.1 million.
- For a production volume of up to 1.45 million SWMT annually, (250,000 SWMT greater than average forecast), in addition to a ramp up in haul truck operations and the extension of CSB No. 2, a third CSB would be required to provide an additional 225,000 SWMT of storage at DMTS. The estimated capital expenditure (+/- 35% in 2019 dollars) for the new CSB which would include an additional transfer tower, truck unloading building (TUB), and associated conveyor system is $58.8 million.

Review of Potential Lik Mine Preliminary Economic Assessment

HDR reviewed the PEA for the Lik Mine released by Zazu on April 23, 2014. The following observations are provided based on that review:

- Lik Mine contains excellent grade lead and zinc ore, averaging 2.71% and 8.23% respectively. This compares to other worldwide mines that average 2.2% for lead and 5.8% for zinc.
- The preliminary production schedule, a mill feed of 5,500 tons per day of ore throughput production, seems reasonable and appears to be achievable with proper management controls. An average grade of 7.7% zinc is anticipated in the ore, which will be processed to 53.4% zinc concentrate. The concentrate production rate is then expected to be maintained relatively constant for a nine-year period based on current delineations of the deposit. One year is allocated

to remove the mine site overburden before ore concentrate production can reach the expected daily rate.

- The estimated mining fleet availability and utilization levels are generally higher than typical industry benchmarks for a mine program of this size. However, this may be achievable with new and properly maintained equipment, but may not be sustainable in the long-term as the equipment ages.
- The PEA's preliminary mineral processing route is well proven and appears reasonable for this type of zinc and lead ore. However, a metallurgist with advanced ultra-fine grinding and flotation skills will be needed to stabilize the process plant quickly after commissioning; such individuals are in limited supply globally.
- Overall, the potential project capital cost (not including the costs outlined above for the DMTS upgrades) over the life of the mine of $351.7 million, $324.7 million in pre-production capital and $27.0 million in sustaining capital (all in 2014 dollars), appears to be reasonable for the size of the mine and mineral resources anticipated. An opportunity may exist to optimize and reduce these capital expenditures through a proper value engineering program and the advancement of the design which could reduce the uncertainty and allow for a reduction in the 20% contingency ($54 million) allotted in the total cost of the project.
- The costs for mine operation at $116 million per year seem to be reasonable but are generally lower than other projects of similar size and utilizing similar modes of operations; this is likely due to the higher anticipated ore grades (versus other mines). However operational costs may be under-estimated due to the mine's remote location and will need further evaluation at later mine planning and development stages.
- As is the case with most projects of this type, the overall project economics are sensitive to the ore/metal commodity prices and the operating costs.

Based on this assessment, the development of the potential Lik Mine is a viable project but with small operating margins based on current projected commodity prices and the assumptions as identified above. Project economics can improve substantially if additional ore reserves are delineated, as this reduces the capital cost intensity (i.e., spreading these costs over a longer period) and improves the net present value (NPV) and internal rate of return (IRR) of the project. The PEA estimates the post tax $NPV_{8\%}$ to be $25 million and the IRR to be 9.75%.

Zinc Commodity Analysis

HDR reviewed the commodity price estimates for zinc as this is a key driver in the potential project economics. The zinc price outlook used in the Lik Mine PEA is between $0.92 per pound and $1.00 per pound, and is well substantiated based on the historical average and the known forward price curve. HDR found this estimate to be consistent with the average broker's price forecast for zinc. In HDR's opinion, the zinc prices used in both of these price scenarios are reasonable for a project at this stage of development.

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2 Introduction

Zazu Metals Corporation (“Zazu”) is planning for the potential development of a lead and zinc deposit, known as the Lik Mine, near the existing Red Dog Mine in northwestern Alaska. The Red Dog Mine, located 50 miles east-northeast of Kivalina, Alaska, is served by the Delong Mountain Transportation System (DMTS). The DMTS is owned by the Alaska Industrial Development and Export Authority (AIDEA), a corporation of the State of Alaska. The DMTS provides the means for export of the ore from the mine and receipt of all bulk materials for mine/port operations.

The DMTS is comprised of a 50-mile, dual-lane haul road, two large concentrate storage buildings (CSB), support facilities, and a shallow draft bulk materials handling port. As mentioned, fuel and other commodities required for operations are transferred to the mine along the same haul road. Zinc and lead concentrate is loaded from the two CSBs for ocean shipment via conveyor system to transfer barges at the port, and then to larger vessels anchored offshore, bound for markets worldwide. Currently, Teck Alaska, Inc. (TAK) operates the Red Dog Mine and operates the DMTS for AIDEA under a user fee arrangement. Currently, TAK is the sole operator and user of the DMTS infrastructure.

The primary objective of this study is to investigate the feasibility of adding additional throughput to the DMTS with a particular emphasis on improvements needed at the port facility to accommodate both the Red Dog and Lik export volume. Specific goals set to achieve this objective were to:

- Confirm the storage and throughput capacity of the existing DMTS system;
- Identify existing capacity deficiencies and opportunities by evaluating DMTS’s current transportation, receiving, storage, reclaiming, and load-out operations;
- Evaluate the impact on the current system that may occur due to the additional throughput demand from the development of the potential Lik Mine deposit; and
- Provide capacity and operational recommendations to ensure DMTS can efficiently move the anticipated future throughput demands from simultaneous operation of the Red Dog Mine and a potential Lik Mine facility.

Sections 3 through 7 of this report evaluate the various infrastructure and operational change requirements to the DMTS that may be necessary to support the storage, load-out, and shipping of ore from the potential Lik Mine. The evaluation focuses primarily on the DMTS facilities located at the port including the transportation, receiving, storage, conveyance, and transfer barge delivery system at the port. The potential overland transportation route (an ~22 mile stretch of road, proposed to be similar to the DTMS road) from the proposed Lik Mine to the DMTS haul road and use of the existing DTMS roadway to the Port was evaluated and is not considered a limiting factor and therefore was not a major focus of the DMTS evaluation. However, the haul road(s) must be maintained on a consistent basis to allow safe travel between the mine and port; this maintenance requirement will factor into the overall operational costs for the Lik mine.

Sections 8 and 9 of this report provide the results of two activities also related to understanding the overall feasibility of the potential Lik Mine:

- A review of the PEA for the Lik Mine, dated April 23 2014; and,
- A review of current and potential future commodity prices with an emphasis on how the variability in prices affects the proposed mine development and the long term returns and economics of the proposed project.

3 DMTS Upgrade Design and Development Criteria

3.1 Ore Concentrate Throughput Analysis

In order to provide a basis for the recommendations provided at the conclusion of this report, a mathematical throughput analysis for the transportation, receiving, handling, storage, reclaiming, and load-out of zinc and lead concentrate was developed using Microsoft Excel (the model). The model was developed in part to verify and confirm the current port facility capacity, both stated and actual (if different). The model also allows for the adjustment of the critical input parameters representing the physical resources deployed which directly contributes to the overall throughput capacity of the DMTS Port facility. Some of the key input parameters include:

- Haul truck capacity and number of trucks in service/day
- CSB Storage configuration and arrangements
- Product density, storage angle of inclination, storage height
- Delivery rates at the Truck Unload Building (TUB)
- Separation time between Haul truck deliveries
- System belt speed and capacities
- Surge bin capacity
- Reclaim rates
- Barge loading rates
- Barge capacity
- Barge off Load rates ship side
- Shipping season duration (95 days as base line)

The throughput model provides the ability to simulate a typical shipping season and analyze the entire DMTS system capacity as a whole, instead of looking at the import, storage, and export processes individually – an approach that can provide misleading information. For example, the annual load-out capacity is not solely dependent upon load-out operations; it is also dependent upon product availability in the storage buildings at the time shipping activities are to commence each year. Likewise, the import capacity can be limited by insufficient storage space in the existing storage buildings. The model and subsequent analysis of each scenario is intended to identify system deficiencies and perform a realistic assessment of DMTS's throughput capacity.

The throughput model was calibrated by entering the known quantities of resources currently used at the DMTS facility, and efficiency parameters were adjusted to confirm the existing throughput capacity. This effort is documented in Section 4. Next, the model was used to determine if sufficient excess capacity exists in the current configuration to handle the additional anticipated throughput resulting from the potential development of the Lik Mine. See Section 5 for these results. In the instances that insufficient capacity existed, input parameters were increased (simulating the addition of resources or capacity) to help identify the most practical approaches for increasing the throughput capacity of the DMTS facility. The results of this exercise form the basis of capacity upgrade recommendations provided in Section 6.

During the development of the model, some assumptions were required to simulate a typical shipping season. Most notably, the unpredictable nature of each year's shipping schedule required the development of an assumed "typical" load-out process to determine the timing of shipments of each product stored at DMTS. The assumptions made to complete the analysis are identified and their implications are discussed in the relevant sections of this report.

3.2 Indirect Throughput Influences

Critical resources and infrastructure/utilities required for the development and operations of the potential Lik Mine, such as fuel, electricity, potable water and waste water, are not factored into the model. Instead, these requirements are discussed separately in the following sections of this report.

4 DMTS Current Operations

4.1 Overview

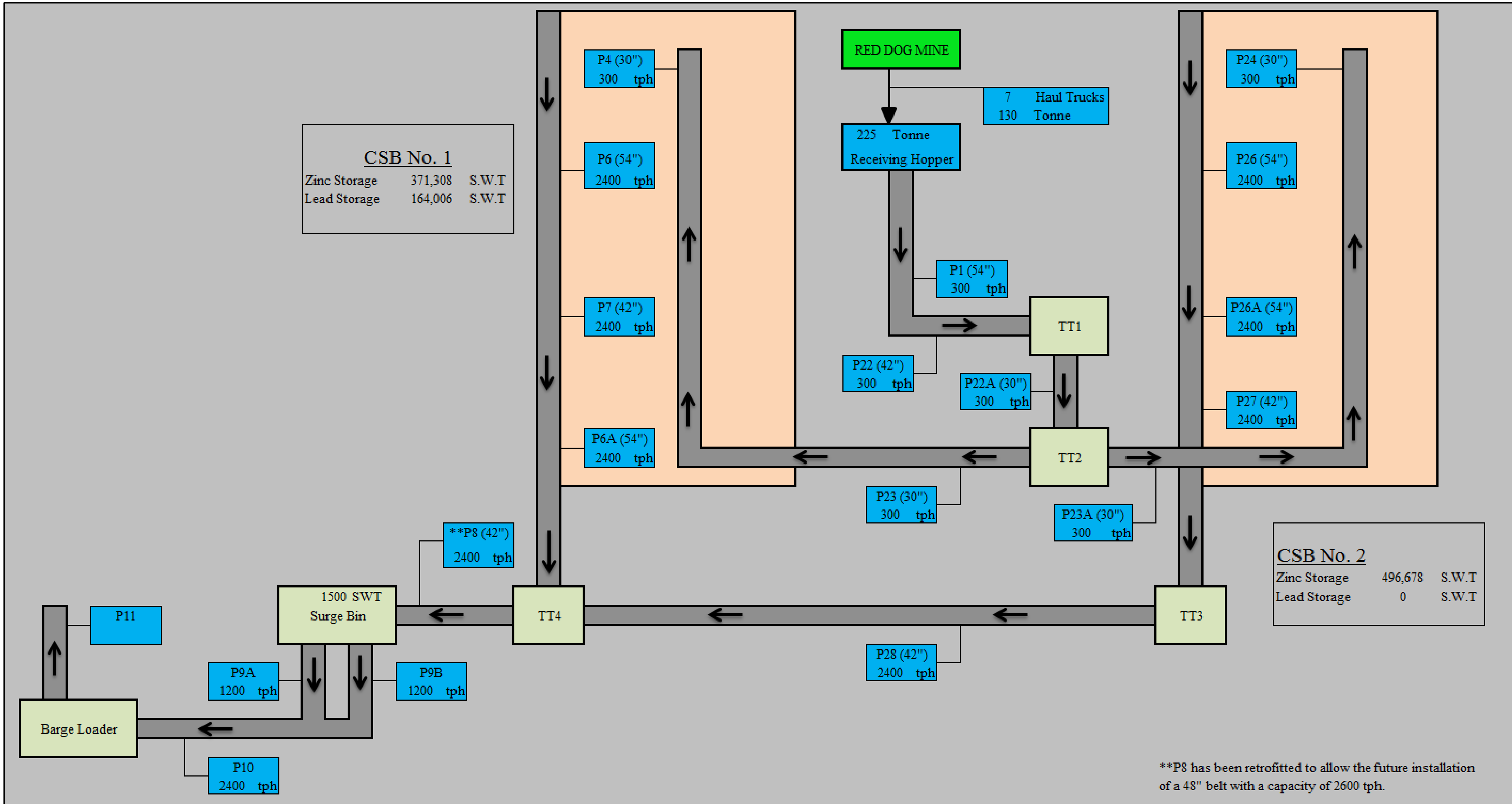
The DMTS provides the necessary infrastructure for transportation, stacking, storage, reclaiming, and load-out of lead and zinc concentrate delivered from TAK's Red Dog Mine. Lead and zinc concentrate is delivered year-round to the port in preparation of, and during, each annual shipping season which averages 90 to 110 days between the months of July and November. Materials are transported from the mine via a fleet of specially designed large capacity haul trucks. The truck receiving system at the port consists of one enclosed truck unloading building (TUB) which features a 225-ton capacity receiving hopper. From the TUB, or hopper, concentrate is directed onto a system of conveyor belts that deliver the product to the concentrate storage buildings (CSBs), CSB No. 1 and CSB No. 2. The majority of the product is transported, delivered and stored at the port facility in advance of the start of the shipping season. Products are re-claimed from the CSBs using front-end loaders which load the stored concentrate onto a reclaim system of load-out conveyor belts to a 2,000-ton capacity surge bin and eventual delivery to a barge loader docked at the shallow water dock. At the dock, transfer barges receive materials loaded from the barge dock and transport the product to a charter fleet of 30,000 to 75,000 Dead Weight Ton (DWT) bulk carriers that are anchored approximately 3 to 5 miles offshore. Ultimately, the bulk carrier's ship the lead and zinc concentrate to customers located in North America, Asia, and Europe. The production and transfer of product from the barges to the vessels off shore are subject to weather conditions. High winds and heavy seas can hinder the loading process and delay the vessels as they wait for the weather to improve. Weather delays can increase the cost of demurrage or waiting time of the vessels. Discussion of the ocean transport is outside the scope of this study, though it is important that the overall mine feasibility and operating costs accommodate appropriate ocean transport considerations.

(Figure 4-1 Existing DMTS Schematic) provides a complete system schematic illustrating the major components at DMTS from the TUB to the barge unloader. Noted in this figure are conveyor belt sizes and capacities, CSB storage capacities, and hopper and surge bin capacities. Currently, CSB No. 1 stores only zinc concentrate, while one-third of CSB No. 2's available storage is for lead concentrate and the remaining two-thirds is used for zinc concentrate.

4.1.1 Shipping Season

The shipping season at DMTS is heavily dependent upon weather and ice formation within the shipping lanes. Historically, the shipping season has varied between 90 and 110 days, between the months of July and November. However, historical data collected during HDR's site visit indicates that the shipping season has the potential to last up to 140 days. A short shipping season imposes pressure on load-out and barge operations over the reduced time period. A long shipping season, which can provide an opportunity to export more products, cannot be realized due to mine ability to process the raw materials to make the product, and operational limitations of storage and haul operations. Since the predictability of future shipping seasons is uncertain, the model will provide capacity feedback as a function of the shipping duration of between 90 and 140 days and will assume an average shipping season lasts 95 days. For the purposes of this analysis, market demand is assumed to be present throughout the duration of the shipping season and does not directly factor into throughput capacity calculations.

Figure 4-1 Existing DMTS Schematic



Source: Screenshot taken from HDR Throughput Model

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4.2 Haul Operations

Currently, lead and zinc concentrate is transported from the Red Dog Mine to the DMTS Port on a year-round schedule utilizing a fleet of 11 specialized 130-ton haul trucks. Red Dog Mine is located approximately 52 miles from the DMTS Port which results in a round-trip time for each truck of approximately four hours. The current truck unloading building (TUB) permits one truck to unload at a time, so truck delivery times are staggered amongst the fleet to eliminate bottlenecks at the unloading building and mine.

AIDEA has confirmed that the port receives an average of 25-35 deliveries per day from an average of 7-9 trucks in operation on any given day. Traditionally, as the shipping season advances, the number of truck deliveries increase in an effort to make sure all concentrate is shipped before the shipping lanes close up for the year. The most truck deliveries the port has received in a single day is 39. The model includes input parameters for both the shipping season and non-shipping season so that a ramp up in haul operations can be modeled, if desired, during the shipping season. Table 4-1. Existing Import Truck Haul Operations summarizes input parameters selected for the baseline model calibration.

Table 4-1. Existing Import Truck Haul Operations

Resource	Input Value	Note
Haul Schedule[1]	24 hr / day 350 day / year	Assumes a 260-day non-shipping season and a 90-day shipping season with 10 days inactive
Fleet Size[2]	7-9 trucks	On average, 7 of the 11 available trucks are active during the non-shipping season. During the shipping season, a slight ramp up is observed to 9 active trucks maintaining a relatively balanced schedule for drivers throughout the year while still responding to production goals.
Truck Capacity[2]	125 SWMT	An average load of 125 SWMT (96% truck fill)
Truck Round-Trip Time[1]	4.10 hr	Incudes time for loading and unloading and transport
Truck Delivery Spacing[1]	40-45 min	Estimated spacing of trucks between port arrivals
Truck Dump Time[1]	9 min	Average time for truck to unload at TUB
Average Fill Truck %[2]	96%	Factor to account for less than completely filled trucks

Sources:
[1]Reported values communicated by TAK representatives during site visit.
[2]Reported values communicated by AIDEA from TAK.

Using the input parameters defined in Table 4-1 for normal (average) haul truck operations, the model confirms there is sufficient capacity in the existing haul truck fleet and the operations employed between the Red Dog Mine and the DMTS, to deliver approximately 3,875 short wet metric tons (SWMT) of material through approximately 31 truck deliveries per day. Likewise, the model also confirms there is sufficient capacity to achieve the historical maximum number of deliveries in one day; 39 truck deliveries resulting in approximately 4,875 SWMT received at DMTS.

The model also confirms the DMTS intake conveyor system has sufficient capacity to accept material at these rates. During the normal operating schedule of 35 deliveries per day, the intake conveyor belt system (Belts P1, P22, P22A, P23, P23A, P4, and P24 shown in Figure 4-1), which has a rated capacity of 300 tons per hour, operates approximately between 40% and 50% of its operational capacity. When ramped up to 39 deliveries per day, the intake conveyor system operates approximately between 45% and 55% of rated capacity.

The operating capacity of the conveyor belt is influenced by three factors: the volume of product delivered by the haul truck, the unload time of the haul truck, and the time in between haul truck deliveries (referred to as truck gap time in the model). By utilizing the intake hopper, trucks can unload product into the 225 ton receiving hopper first (dump time is approximately 7-9 minutes) and then the product is moved onto the conveyor belts before the next truck delivery. TEK staff has reported that average truck gap time is approximately 45 minutes; therefore, this was the value input into the model for normal operations. For maximum operations, the assumed gap time was decreased to 40 minutes to help fit in a few additional truck deliveries in a 24 hour period.

To simulate a typical year using the model, during the non-shipping season it is assumed that both zinc and lead are delivered daily at a ratio proportional to their allocated storage volume. The end result of this approach allows for the storage buildings to be filled to over 90% of each product's allocated volume (only minimal storage, 35,000 SWMT is available at Red Dog Mine) at the start of the shipping season. Once the shipping season begins, the model automatically adjusts the ratio of each material delivered to best suit the remaining needs to achieve each product's shipping goal. For example, if the annual export goal for zinc is met, the import of zinc ceases and the focus turns to delivering lead.

For the baseline model calibration, which intended to simulate realistic operations at the DMTS Port, it was assumed that the haul operations would be ramped up to meet product goals as necessary but, would not exceed the reported historical maximum 39 deliveries in one day.

4.3 Concentrate Storage Buildings

Concentrate Storage Building (CSB) No. 1 is approximately 1,425 feet long, by 218 feet wide by 140 feet high and was constructed as part of the original DMTS system. In 1998, CSB No. 2 was added to provide additional storage capacity at the facility. CSB No. 2 is approximately 1,200 feet long by 218 feet wide by 140 feet high. Each storage building receives concentrate from fully enclosed stacking conveyors that run parallel to the length of each building. Between the TUB and CSBs are two transfer towers, which are used to direct concentrate along the conveyor belt system to the desired building. The rated capacity of the conveyor belt system is 300 tons per hour.

Both storage buildings feature 5-foot-tall retaining walls that run parallel to the length of the building. The retaining walls provide an effective width for concentrate storage of approximately 174 feet and allow additional storage at the base of each bulk pile. An assumed 15 feet of spacing is provided to maintain separation of product piles in CSB No. 1.

One of the calibration requirements for the throughput model was to confirm the total available volume of product storage at the DMTS facility. This calculation was based on construction drawing No. D-A1511-SK-060 and the material properties and bulk pile dimensions provided in Table 4-2. CSB Input Dimensions and Material Properties.

Table 4-2. CSB Input Dimensions and Material Properties

Input Parameter	Value	Note
Lead Concentrate Density	154.0 lbm/ft^3	
Lead Concentrate Pile Angle of Repose	28.0 deg.	
Zinc Concentrate Density	148.5 lbm/ft^3	
Zinc Concentrate Pile Angle of Repose	38.0 deg.	
Zinc Concentrate Space Allocation in CSB No. 1	65.0%	35% Space allocation for Lead Concentrate
Zinc Concentrate Space Allocation in CSB No. 2	100.0%	No lead Concentrate stored in CSB No. 2

Source: CSB building dimensions taken from construction drawing D-A1511-SK-060; space allocation values taken from AMEC "Navigational Improvement Feasibility Study" - Chapter 3 (2003)

The resulting calculated values are included in Table 4-3. Concentrate Storage Building Capacities, which provides a comparison between original building design storage values and model calculated values that were developed referencing building construction drawings. As shown, the model calculated storage values are in adequate agreement with building design values. Also notable is that the values used in the throughput model are considered conservative based on TAK staff feedback. TAK has indicated that current storage values are actually higher than those presented in Table 4-3. Concentrate Storage Building Capacities. This difference can be attributed to the operators' ability to compact and increase the angle of repose of the material allowing for better utilization of the buildings. This is accomplished using a dozer to push up the material, compact it, and create benches at various heights as the pile is formed. The benches provide a base to build up material as the pile goes higher, efficiently using space that would otherwise be lost if the material was allowed to fall naturally from the tripper creating its own angle of repose. Making better use of the storage space allows the terminal operator to stockpile more products before the start of the shipping season which allows for more shipment contracts, assuming the shipping season lasts long enough to support load-out operations.

Table 4-3. Concentrate Storage Building Capacities

Concentrate Storage Capacity	Building Design	Model Calculated
CSB No. 1 Zinc	375,750 SWMT	359,257 SWMT
CSB No. 1 Lead	165,000 SWMT	166,340 SWMT
CSB No. 2 Zinc	496,600 SWMT	512,453 SWMT
CSB No. 2 Lead	0 SWMT	0 SWMT

4.4 Load-out Operations

The term “load-out operations” refers to the processes involved between reclaiming product stored in the CSBs, moving the product through DMTS’s downstream conveyor belt system, loading it onto barges at the barge dock, and ultimately delivering that product to the customers’ bulk carriers moored 3 to 5 miles offshore from the DMTS facility.

During the shipping season, concentrate is reclaimed from the CSBs utilizing front-end loaders to move concentrate into material hoppers which distribute that product onto the belt system. To begin this process, hoppers with a rated capacity of 1,500 tons per hour collect the front-end loader’s contents before passage onto the conveyor belt system. Each CSB contains two front-end loaders, two hoppers, and a conveyor belt that transports the concentrate out of the storage building. Concentrate is moved within the CSB by bull dozers that push up product close to the load-out hopper which allows the front end loaders to make minimal movements when loading product into the hoppers, thus aiding in maintaining acceptable rates of production.

After leaving the CSB, the conveyor belts, which have a rated capacity of 2,400 tons per hour, deliver the concentrate to a transfer tower. The transfer tower diverts the product to another conveyor which routes the product to a 1,500-ton surge bin located landside and adjacent to the barge dock. From the surge bin, there is a final set of conveyor belts, with a capacity rating equivalent to the previous section of conveyor belts (2,400 tons per hour), that deliver the material to the barge loader. TAK has reported that this portion of the conveyor belt system is operated at approximately 1,800 tons per hour. The surge bin is designed to allow the reclaim process to continue relatively independent of the barge loading operations effectively decoupling the two processes while it also acts to dampen minor variations in the speed of the conveyor belts located between the CSBs and the surge bin. Because it is located adjacent to the dock, the surge bin provides a constant source of product conveniently located for barge loading operations.

The model includes an input parameter to define the average operating speed of the conveyor belt system. This affects the time required to move product to the surge bind and to load barges and therefore can directly affect the export capacity. Red Dog Port barge side reported load-out rate of 1,800 tons per hour was used to calibrate the model.

4.5 Barge Operations

During the shipping season, two 5,600-ton (nominal rating) lightering barges are used to collect and deliver lead and zinc concentrate from the barge loader at the dock to bulk carriers moored three to five miles offshore. AIDEA/TAK feedback indicates that the maximum load on these barges is less than their nominal ratings at approximately 5,440 SWMT each. The bulk carriers have rated storage capacities ranging from 30,000 to 75,000 DWT (Panamax ships). Barge operations are choreographed such that while one is loading at the barge loader, the second is unloading at the bulk carrier. The current DMTS facility contains one barge loader and thus only one barge can be loaded at a time. A barge round trip requires approximately eight hours to complete loading, unloading, and transit to and from the barge loader. On average, three to four barge deliveries can be made in a 24-hour period, weather permitting, equating to an export capacity of approximately 21,760 tons per active shipping day. This includes a 97% average barge fill assumption. Product within the barge is pushed up and piled by front end loaders which are stored on the barge at all times occupying some of the active storage space. This is necessary to move product on the to the reclaim conveyor on board. Table 4-4. Existing Load-out Operations lists the throughput parameter inputs used to model current barge operations.

Table 4-4. Existing Load-out Operations

Resource	Input Value	Notes
Daily Operational Schedule	24 hr / day	
Barge Capacity	5,440 SWMT	Estimated max barge capacity
Fleet Size	2 barges	Third-party operator supplied barges
Barge Round-Trip Time	8.0 hr	Includes time for loading and loading and transport
Barge (loading) Spacing	1.5 hr	Estimated spacing between barges
Red Dog Zinc Bulk Carrier Capacity	70,000 SWMT	Typical capacity of Panamax Ship
Red Dog Lead Bulk Carrier Capacity	35,000 SWMT	Typical capacity of Handyman Ship
Average Barge Fill %	97%	Factor for calibrating model output to reported export
Source: Reported values communicated by TAK representatives during site visit.		

The model calculates throughput capacity as a function of shipping season duration, allowing throughput capacities to be considered for different shipping season durations.

It is also noted that the model does not simulate the timing of weather related delays or outages that commonly occur during the course of any given shipping season. Instead, it is assumed that there is a 20% deduction from the assumed non-shipping season duration, which reduces the number of days available for product load-out operations (delivery from the mine to the port). However, since the timing of weather related interruptions can have a significant effect on the ability to meet export goals in a given season, recommendations are included in Section 6 that should provide the DMTS with added flexibility to work around potential weather events.

To complete the throughput analysis, it was necessary to make a list of key assumptions that define a realistic shipping schedule for materials stored at the DMTS Port. These assumptions are:

- One product ships at a time from the port to the barge, and products are only eligible to ship when there is sufficient volume of that product available in the CSBs to completely fill one bulk carrier (no partial shipments).
- Based on annual production goals, it is assumed that Red Dog Mine zinc concentrate is shipped in 70,000-ton bulk carriers (Panamax ships). Red Dog Mine lead and Lik Mine zinc and lead concentrates are assumed to ship in the smaller 35,000-ton bulk carriers.
- When more than one material is available for shipment at any given time, priority is given to the material that has the largest remaining volume left to be shipped to meet its respective annual export goal. This approach alternates products being shipped as the shipping season progresses.
- Once an individual product meets its annual export goal, that product is removed from the list of materials considered for future shipments for the remainder of the shipping season.
- Sufficient market demand exists through the shipping season to drive continuous shipment of all products (assuming full loads as described above).

The results of the baseline model calibration described in this section of the report are discussed in detail in Section 6.

5 Impact of Lik Mine Development on DMTS

5.1 Annual Production

Table 5-1. Forecasted Annual Production lists the forecasted annual production estimates for the Lik Mine. The historical max values listed in the first row defines the production goals used for model calibration of current throughput operations for Red Dog product. The Red Dog Mine is expected to decline in production somewhat between the years 2014 and 2020. After 2020, the production is expected to settle out at <1,000,000 SWT for the remaining 10 years of the mine's expected productive life.

The forecast estimates that the proposed Lik Mine will begin 1 year of pre-stripping activities in 2019, followed by an estimated 9-year productive mining life, consistent with the projections in the recent PEA. The timeline of this assumption is optimistic, though not unreasonable, given the required lead time to open a mine (assume 4-5 years to acquire environmental permits and complete construction activities). For the Lik Mine, the forecast predicts a spike in production during the second productive year (2021 in this forecast) but otherwise expects a relatively constant production rate of approximately 350,000 SWMT over the nine year productive life span. Because it is not economically justifiable to recommend capital expenditures for a one year spike in production, recommendations for upgrades at the DMTS Port facility will instead consider the average production rate forecasted for the Lik Mine.

Table 5-1. Forecasted Annual Production

Year	Lik Zinc (SWMT)	Lik Lead (SWMT)	Lik Total (SWMT)
Red Dog Historical Max[1]	-	-	1,400,000
2020	295,000	76,000	342,000
2021	366,000	82,000	448,000
2022	295,000	68,000	363,000
2023	271,000	66,000	337,000
2024	274,000	60,000	334,000
2025	273,000	60,000	333,000
2026	279,000	68,000	347,000
2027	277,000	60,000	337,000
2028	242,000	66,000	308,000

1. Source: "Capacity Analysis for the Delong Mountain Port Facility in Support of Developing the LIK Deposit" PND Engineers, Inc., October 2010.
2. Lik Development forecast obtained from the Preliminary Economic Assessment Technical Report (PEA) Zazu Metals Corporation (Table 16-7), Lik Deposit Alaska, USA; April 23, 2014

Average forecast production of Lik Mine ore concentrates (at approximately 350,000 SWMT per year) is expected to largely supplant the potential forecast decline of product from the Red Dog Mine as given via Teck supplied information and other public information sources. This analysis suggests only a modest net increase of product will be delivered to the DMTS Port facility as compared to the 2014 annual production of approximately 1,200,000 SWMT. Furthermore, the combined Red Dog and Lik mine production average during the life of the potential Lik Mine (2020-2028) is expected to be up to an estimated 1.2 million SWMT, which is approximately 200,000 SWMT less than the historical maximum volume (see row one in Table 5-1) handled at the DMTS Port facility. While the raw numbers suggest that the existing DMTS Port facility should be able to handle the sheer volume from both mines, this report and the upgrade recommendations provided herein will also consider the logistical and operational challenges that will result from receiving, storing, and shipping four separate products coming from two different mines.

5.2 Haul Operations

Current haul operations will likely need to be modified to accommodate the delivery of product from the Lik Mine without affecting support of the Red Dog Mine haul and delivery operations. The model was used to evaluate the possibility of dividing the available time during an average non-shipping season between receiving Red Dog product and receiving Lik product at the port's one existing TUB. The analysis assumes the capacity of the existing intake conveyor system will remain unchanged.

The schedule devised held separate days devoted to receiving either Lik product or Red Dog product. In doing this, a maximum of only two different products were received at the port in a given day, reducing time lost on zeroing out and clearing/cleaning the TUB and conveyor belts between receipt of the different products. The assumed number of available days for shipping during the non-shipping season remained the same as for the baseline model at 260 days per year.

For this analysis, the forecast goals of the year 2022 were selected for simulation as it serves as a reasonable representation of the average forecasted demand over the life of the Lik Mine. The division of allocated storage space was determined based on the forecast goals for each product received at the port. Consequently, this allocation of storage space for each product sets the goal for the delivery of each product during the non-shipping season. (The goal being to completely fill each of the allocated product storage spaces in the CSBs by the beginning of the shipping season.) Based on the forecast goals for the year 2022, of the available 260 days during the non-shipping season, 200 days were devoted to the shipment of Red Dog product and the remaining 60 days were devoted to receiving Lik product. In addition to the storage of product at the port, the potential Lik mine will store approximately 10,000-15,000 tons. (Red Dog stores approximately 25,000 with a total capacity of 35,000. Storage at the mine sites are designed to be a buffer to ensure the processing plant can operate at full capacity at all times without having to slow down when haul operations or port operations experience delays due to weather or breakdowns.

Table 5-2. Haul Operations Analysis Inputs, summarizes the input parameters used for this analysis and Table 5-3. Haul Operations Analysis Results provides a summary of results obtained from the model and includes the resulting utilization of the TUB and conveyor belt system.

Table 5-2. Haul Operations Analysis Inputs

Analysis Inputs	Red Dog Mine Haul Operations	Lik Mine Haul Operations
Non-Shipping Season Operational Days Per Year	200 days	60 Days
Non Shipping Season Fleet Size Shipping Season Fleet Size	7 trucks* 9 trucks*	7 trucks 9 trucks
Gap Time between Trucks	40-45 mins*	40-45 mins
Truck Round-Trip Time	4.17 hrs*	5.40 hrs
Truck Capacity	125 SWMT*	125 SWMT
*Input Parameters unchanged from baseline model calibration, done so to simulate realistic operating schedule and provide comparable results.		

Table 5-3. Haul Operations Analysis Results

Analysis Results	Red Dog Mine Haul Operations	Lik Mine Haul Operations
Non-Shipping Season Average Deliveries Per Day Shipping Season Average Deliveries Per Day	31.0 39.0	24.0 30.0
Non-Shipping Season Daily Haul Capacity Shipping Season Haul Capacity	3,870 tpd 4,870 tpd	3,000 tpd 3,740 tpd
Operating Speed of Intake Conveyor Belts during product receipt.	46.2%	46.2%
Total volume received at port during shipping season is reflective of each annual product shipping schedule and is therefore not a constant number to be listed in this table.		

The model is also used to estimate the capacity of import operations during the shipping season by automatically selecting the two most depleted products at the port and dispatching haul trucks to replenish the CSBs. To increase haul capacity after the shipping season begins, both the Red Dog Mine fleet and the Lik Mine fleet are assumed to use an average of 9 trucks to transport product to the port on their respective days. The fleet size of 9 trucks is maintained as a shared asset fleet with 9 trucks hauling Red Dog and then Lik Mine product on their respective transport days. The haul operator will need to clean and maintain the trucks to ensure no mixing of product. This haul process is also in line with reports of current operations at the DMTS Port. The automated selection process was re-evaluated every one to three days to help maintain the availability of all products evenly, as the shipping season progressed (i.e. import operations shadow export operations). Once the annual production goal for a particular product was met, that product was removed from consideration for future import to the DMTS Port.

PND Engineer's 2010 "Capacity Analysis for the Delong Mountain Port Facility" study recommended a new portion of haul road be constructed from a point approximately five miles from the Red Dog Mine to the Lik Mine. Due to the topography in that area, a 22-mile roadway will need to be constructed to service the potential Lik Mine Development. HDR has reviewed the recommendations in the referenced report and believes that they form an adequate basis for development of an additional roadway to service the Lik Mine. Careful design of this new roadway will be important to minimize permitting considerations, construction costs, and other operational aspects.

Based on the haul operations analysis described, final recommendations for capacity upgrades are provided in Section 6.

5.3 Concentrate Storage Buildings

Currently, the CSBs provide storage for a shipping season that lasts 90-110 days on average. Based on the haul truck operations defined in Section 4.2, the CSBs are filled to over 90% capacity by the beginning of each shipping season. It is estimated that this initial volume of storage provides approximately 40 days of consecutive shipping, based on the existing imbalance between import capacity rates (i.e., CSB loading rates) and export capacity rates. The actual product export (barge loading) rate is influenced by the shipping schedule of each material. The end result is that, as the shipping period progresses and the CSBs are depleted, DMTS becomes increasingly susceptible to loss of shipping opportunity either while stock piles are replenished via mine truck shipments or due to the inability to schedule additional shipments of product at seasons end.

To set up the haul operations analysis, which considers the forecasted year 2022 with the inclusion of the Lik Mine, (as described in Section 5.2) the existing storage space was divided as listed in Table 5-4. Allocation of Storage in CSBs. With the inputs selected for the haul operations analysis, the model calculated that each allocated storage space was on average 95% full by the beginning of the shipping season. It should also be noted that in order to ensure that each product is kept isolated, available storage volumes are calculated assuming a 15-foot separation between piles of different materials that exist in the same building.

Table 5-4. Allocation of Storage in CSBs

Product	CSB No. 1	CSB No. 2
Red Dog Zinc	55%	100%
Red Dog Lead	10%	0%
Lik Zinc	25%	0%
Lik Lead	10%	0%
Percentage (XX%) of space allocated input into HDR's Throughput Capacity Model.		

The results of this configuration, with regards to its ability to adequately support the forecasted shipping goals, and the resulting recommendations regarding additional storage space needs are provided in Section 6.

5.4 Load-Out Operations

As noted in Section 4.4, the load-out conveyor belt system operates at an average speed of 1,800 tons per hour, which is 75% of the system's rated capacity. Increasing the load-out conveyor belt speed is one way to reduce the number of active shipping days required. However, the more aggressively the load-out conveyor system is used, the more likely it will be to experience maintenance-related issues. Also, as discussed further in Section 5.5, limitations on the load-out conveyor speeds are based on the ability of the barge to take the product. Considering the barges currently utilized, it was determined that a small increase (5-10%) in conveyor belt speeds is acceptable and would help to maintain and/or increase the load-out capacity that exists at the DMTS Port. Final recommendations for load-out conveyor system operation are provided in Section 6.

5.5 Barge Operations

The estimated capacity of the existing barge operation is limited to approximately 21,760 tons per day using an average barge fill percentage factor of 97%. This requires that both barges make two offshore vessel deliveries each active shipping day. By increasing the load-out conveyor belts' operating capacity from 1,800 tons per hour to 1,920 tons per hour (an increase from 75% to 80% of the belts rated capacity), the model indicates sufficient time savings for one additional barge delivery in a 24-hour period. The additional capacity results in an increased export capacity of 5,440 tons per day for a daily average shipment total of 27,200 tons. Assuming an active shipping period of 45 days (45 active barge loading and shipment days in a 90-95 day season), up to 244,800 additional tons can be moved, or just over four additional 60,000 ton vessel calls per year.

Increasing the throughput capacity is one way to reduce the number of required active shipping days during the shipping season. However, significantly increasing loading rates (beyond the 5% increase discussed above) requires larger, more stable barges. An alternative to increasing barge loading rates would be to increase the barge fleet size by adding a third barge of equal loading capacity and operating at or only slightly above current load-out rates. In fact, with three barges loaded at 80% conveyor belt speed, up to six barge loads can be delivered each day resulting in an export capacity of approximately 32,640 SWMT per active shipping day. Final recommendations for barge operation modifications are provided in Section 6.

5.5.1 Construction Effort Impacts

In the event the actual export volume beyond 2022 exceeds the forecast used for this analysis, it may be necessary to move forward with the recommendations presented in Section 6 of the report. Irrespective of the recommendations deployed, such as finalizing the construction of CSB No. 2 and the installation of a second truck dump facility, the current operations would continue to be unaffected by the construction. Final tie in into the current materials handling system would be carried out at the end of the shipping season and before winter sets in. This would also be done without impact to the current operations. Delivery and handling of the Lik mine construction materials, equipment, and modules would be required before any modifications or improvements to the DMTS

Port would be required so there would be little to no impact to operations. It should be noted that the receiving of construction material, equipment and fuel can take place simultaneously while export operations is taking place. However, during fuel operations only the north berth can be used for concentrate export, which has limited impact to the overall operations.

5.5.2 In-Bound Supplies

Supplies required for the potential Lik Mine Development would come to the port facility over the expanded roll-on roll-off ramp and dock area. Mobilization of the construction contractor(s), materials, and equipment, would be carried out several years before the first shipment of any Lik product. Coordination of the receipt of these shipments and modules would require careful coordination with TAK to minimize impacts to the continued load out of Red Dog products. Transport of large modules/equipment to the potential Lik Mine site would similarly require coordination to avoid road slowdowns or other traffic related issues.

To reduce the need for additional capital investments for a separate independent stockyard area, it is recommended that TAK continue to provide the stevedoring and cargo handling/storage services for both Red Dog Mine and Lik Mine as a single operator. Having a single operator is the most cost effective and efficient process especially given the limited space and the critical nature of operational interface it has with the TAK operations and the arrivals and departure of concentrate barges. These critical items would need to be delivered along with the Red Dog Mine requirements.

5.6 Port Infrastructure

5.6.1 Warf / Quay

The wharf and quay are not a traditional platform supported deck system. The infrastructure is made up of three docking dolphins, which provide a location for the barges to dock as well as providing structural support for the ship loader. No improvements are required to the wharf area to support the potential Lik development.

5.6.2 Bulk Loader

The current ship/barge loader is a single vessel unit mounted on a turntable allowing it to work the south, west, and north sides of the wharf while loading barges. The unit maintains an average load-out production rate of 1,800 SWMT while loading the 5,440-ton lightering barges. One of the key factors in determining the loading rates for ship loaders is not the nominal rate they are designed to load but instead, the rate upon which the vessel, or in this case the barge, is able to accept the bulk commodity. Barge stability and its structural integrity is a critical part of the load-out process; loading too fast can cause structural damage due to hogging or sagging of the barge or can cause significant stability issues which could cause the vessel to roll over while loading. The barge/vessel captains or chief mates typically provide guidance as to the loading rate before operations commence and monitor the loading continuously to ensure a safe and efficient loading operation.

With an average load-out rate of 1,800 SWMT per hour and a two barge fleet with a maximum capacity of 5,440 SWMT each, the facility is maintaining a high average load rate for the type of ship loader and for the barges that are being loaded. It is assumed that load-out rates can not be safely increased more than 10% than their current operational status. To increase port capacity, the following possibilities were contemplated (these options are discussed further in Section 6 and final recommendations are provided):

- Increase in load-out rates no greater than 10% of current actuals;
- Add one barge for a total fleet size of three barges;
- Upgrade the barges to a larger carrying capacity;
- With larger barges, increase the load-out conveyor belt speed and increase the load-out rate of the current ship loader; and
- Combinations of the four previous options.

5.6.3 Fuel Delivery

The shallow water dock at DMTS currently receives approximately 17-18 million gallons of fuel each year. Approximately 15 million gallons are stored at the port with the remainder stored at the Red Dog Mine. Fuel is received almost immediately when shipping lanes become navigable, continues throughout the shipping season, and is often one of the last deliveries completed each year. Fuel is typically delivered four million gallons at a time using barges that are capable of utilizing the shallow water dock. Occasionally however, larger vessels requiring lightering barges to intercept and deliver fuel are used. Barges and larger vessels are subject to the same weather conditions as product vessels.

Adding additional Lik Mine fuel requirements may put a strain on current operations. Although fuel barges can operate during concentrate operations, concentrate operations is restricted to the north berth only. The impact is an additional 20-30 min vs normal operation. Adding more vessel calls, more fuel barge calls, and more stores/equipment vessels to support Lik Mine will require a high degree of coordination between the yard operator and terminal operator to ensure all requirements are met.

Teck is evaluating the addition of another fuel tank to the current tank farm area. If it is determined that another fuel tank is required, additional land area should be allocated to accommodate the additional tank and the tanks required for Lik fuel needs. Although not recommended at this time, the bulkhead could be extended to the south and an additional off loading/loading platform could be built to ensure more flexibility when handling fuel and stores/supplies.

5.6.4 Equipment

The DMTS Port has a significant amount of equipment on hand to carry out operations. There are front end loaders, dozers, and a ship loader to handle material in the CSBs and to load barges. There are conveyors, transfer towers, surge bins, and other conveyor systems to move the material from storage to the wharf, all of which need to be maintained. In addition, forklifts provide for unloading and loading of containers and other stores/equipment.

Given the port's remote location, maintenance and repair operations must be self sustaining. Maintenance crews are on duty for 12 hours per shift, two shifts a day and provide everything from general maintenance to full fabrication and repairs. The majority of the time for maintenance is allocated to perform major equipment maintenance on the conveyor and materials handling system. This includes such items as the replacement of the rollers, both for the feed or the return rollers, the diverters and other parts of the system. The maintenance team does an excellent job of keeping the equipment running during summer load-out operations, when it matters most.

Similar maintenance and repair efforts are anticipated for any potential management of Lik products. Minimal additional equipment is anticipated necessary.

Trucking and other mobile equipment are discussed in Section 5.2 above.

5.7 Road Infrastructure

The roadway system serving the Red Dog Mine is well developed and is wide enough to allow trucks to pass each other along the route. Turn outs are designed every two miles which are used to allow trucks to pass in areas considered hazardous for side-by-side passing.

The roadway is used on a daily basis to move concentrate and supplies such as food, water, fuel, and maintenance items from the port to the mine (and vice versa). Roadway conditions are monitored by the roadway crew who makes up to two trips per day to gauge the conditions. Annual road maintenance costs are estimated at $2 million.

The roadway is also used by light duty vehicles and vans on a daily basis. Once a week personnel are transported to and from the airport to the port for crew change outs. A total of 45-50 trips are made to and from the mine and the port on a daily basis. The roadway has enough capacity to accommodate the additional Lik Mine Development haul trucks, supply trucks, and light duty vehicles planned with the required trucks for continued Red Dog Mine operations (Table 5-5. Lik Mine Vehicle Traffic Volume Average per Day).

Table 5-5. Lik Mine Vehicle Traffic Volume Average per Day

Type of Equipment	Maximum Available	Average in use per day
Haul Trucks (130 SWMT/truck)	11	7-9
Fuel Truck	1	1
Stores/Supply Trucks	1	1
Light Duty Vehicles	1	1
	Total	12

5.8 Facilities

5.8.1 Temporary Camp / Permanent Crew

To implement the DMTS capacity upgrade recommendations, should they be required, housing to accommodate construction crews and permanent staff will be required. Temporary camp facilities, like those at Red Dog Mine and along the roadway route, will need to be developed. It is recommended that accommodations for construction crews for the upgrades to the port be located at the port. This is the most efficient process and will avoid moving crews on a daily basis via vans and buses to the port from the Lik Mine area. (Table 5-6. Temporary Camp/Crew Requirements)

Table 5-6. Temporary Camp/Crew Requirements

Position	Number Required
Laborers:	24
Machine Operators:	6
Crane Operators:	2
Dozer Operators:	2
Truck Drivers:	8
Management:	6
Medical Staff:	Assume service covered with existing port medical staff
Total:	**48**

5.8.2 Fuel

Based on the forecast of approximately 0.350 million tons of Lik Mine material processed annually, it is estimated that there is a need for an additional 9 million gallons of fuel storage to support the Lik Mine operations and haul truck operations (per the PEA report April, 2014). Additional fuel may also be required to support road and mine construction.

Red Dog Mine currently stores most of their fuel at the port. The fuel is trucked from the port to the mine as required. Although having the majority of the fuel stored at the mine would be the preferred alternative (stored where it is used), it is an easier process for operations to off load the fuel directly to the storage tanks in the port and then as necessary, transport fuel to the mine during the off-peak shipping months.

To accommodate the Lik Mine Development estimated fuel requirements, four additional 2.5 million gallon fuel tanks will need to be installed. Since the Lik Mine is a greenfield site, it would be prudent to install two, 2.5 million gallon tanks at the mine site and two tanks at the port. Trucking of fuel can take place as needed and in good weather. Storing too much fuel at the port presents a risk that fuel may not get through during adverse weather conditions. Having more capacity at the mine will reduce or eliminate that risk. The fuel capacity should be added early in the development of the new mine to serve construction needs and the initial stripping of the overburden required before reaching the ore deposit. Additional fuel transport trucks/trailers would be needed to support the transfer of Lik fuel supplies from the port to the Lik mine site.

5.8.3 Laydown / Storage

For this study, it has been assumed that the port facility will be operated by TAK who will provide third-party materials handling, stevedoring, and containerized, bulk cargo operations to support both Red Dog Mine and Lik Mine volume. Maintaining one terminal operator eliminates the landside laydown area redundancy required to support two operators. However, even with one operator there will be a requirement to expand the current area by approximately five acres. The five acres could be located just adjacent to, and east of, the current laydown area or, as a separate area further east (near the current eastern storage area is located). Should geotechnical reviews determine that placing all additional cargo in either of the two alterative is not possible, a combination of the two areas could be used. The additional space closest to the ramp could be for heavy and oversized cargo and the area further east could be for loaded and empty containers.

5.8.4 Utilities

TAK has four generators at the facility. Three units are generally online at all times leaving one generator as a backup to provide a bit of redundancy; a critical feature in a remote location where grid power is not an option. The maintenance team does an excellent job at keeping the units up and running by maintaining a tightly controlled maintenance and repair schedule for each of the units. However, despite having one generator on standby, using it to cover any additional load from the installation of a new shed, conveyor system and truck dump, would put significant pressure on the system and virtually eliminate the ability to take other units off line to perform routine maintenance and repair services. Should future volume requirements require the port to move forward with capacity improvement recommendations, it is recommended that an additional 1.2 megawatts (MW) generator be added. By adding an additional 1.2 MW generator, maintenance can be performed on a routine basis without any restrictions on system usage levels. Should no improvements be made, there would be no need to add an additional generator.

Water is provided to the facility by beach intake wells and it is treated with a reverse osmosis (R/O) desalination unit. According to the on-site operator, these R/O units are aging. Potable water production is approximately 4,000 gallons per day (gpd) in the winter and 11,000 gpd in the summer. Reported capacity of the water production units is 14,000 gpd. These levels of water production are believed sufficient to support the potential Lik development.

Wastewater is treated with an ultrafiltration treatment system. The equalization tanks need to be replaced. Wastewater is treated at a rate of approximately 160 gallons per person per day.

Process water is treated with an ion exchange (IX) treatment system. This system consists of three trains operating in series with a capacity of approximately 250 gallons per minute (gpm) each.

For all three water systems (potable water, wastewater, and process water), should volume dictate facility recommendations be implemented, approximately 1/3 additional capacity will be required to accommodate the construction and additional operational staff identified in Section 5.8.1 above.

6 DMTS Upgrade Conclusions and Recommendations

The main objective of the port throughput study was to identify the capacity limitations of the DMTS Port facility and to provide infrastructure recommendations to the port to meet future demand requirements. To aid in the analysis, HDR developed a Port Capacity Model. HDR used actual historical throughput data to successfully calibrate a model, representative of current operations at the port, which was then used to develop realistic recommendations intended to meet the forecasted throughput volumes through 2030. Recommendations for capacity upgrades are provided based upon the agreed upon production forecast for Red Dog and Lik Mine. Additionally, after considering what capacity upgrades would be needed in the event actual production volumes exceed the forecasted production volumes, a separate set of recommendations is provided. Additional detail regarding this exercise is provided following the baseline model calibration and the agreed upon production forecast discussions.

6.1 Baseline Model Calibration

The throughput model was successfully calibrated upon simulating the maximum historical shipped volumes of lead (400,000 SWMT) and zinc (1,000,000 SWMT) received from the Red Dog Mine, using currently employed resources. Figure 6-1 Product Export Goal presents the results of the calibrated model. The graph plots the progression of shipments (as simulated in the model) for both lead and zinc as the shipping season progresses. These results indicate a high level of inflexibility in terms of lost opportunity during the shipping season. In fact, the model indicates that it takes approximately 100 days, which is a few days above the historical average 95-day shipping season, to reach this shipment goal. It is also understood that in reality, the ability to utilize the available capacity estimated by this model depends heavily on weather related downtime and the shipping schedule of each product.

The inflexibility found in these conditions is largely a result of the export rate being significantly larger than the import rate of product from the mine. In general, it takes approximately six days to receive enough product for one 30,000-ton vessel shipment. Figure 6-1 illustrates that as the shipping season progresses the port becomes increasingly susceptible to inactive shipping days because the CSBs are being replenished. (This is represented by the stretches of horizontal lines that indicate product goals are not being advanced.) Of course, the import rate can be compensated by constructing additional storage at the port. This would allow more product deliveries before the shipping season started, easing the demand of haul operations once the season begins. Figure 6-2 Product Availability During Shipping Season illustrates the required replenishment periods for lead and zinc during the simulated shipping season.

Given the level of inflexibility described above, the 1.4 million SWMT historical throughputs is considered to be the (two product) limit for the DMTS Port facility under current operating conditions. Should greater throughput be desired, changes to operations and/or allocated resources would be recommended. Because the combined Red Dog and Lik mine production forecasts do not exceed the expected annual historical maximum, these considerations were not necessary. Instead, recommendations provided in the remainder in this section focus on the DMTS Port having to handle four separate materials supplied from two different mines.

Figure 6-1 Product Export Goal

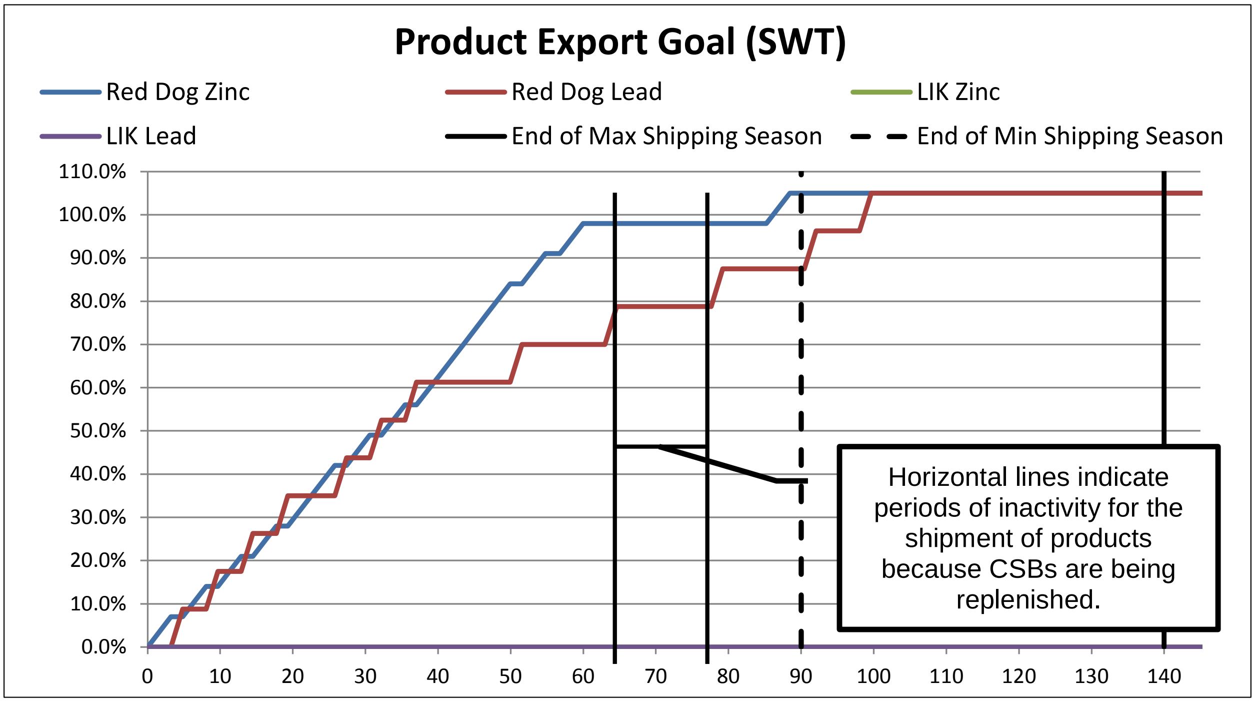
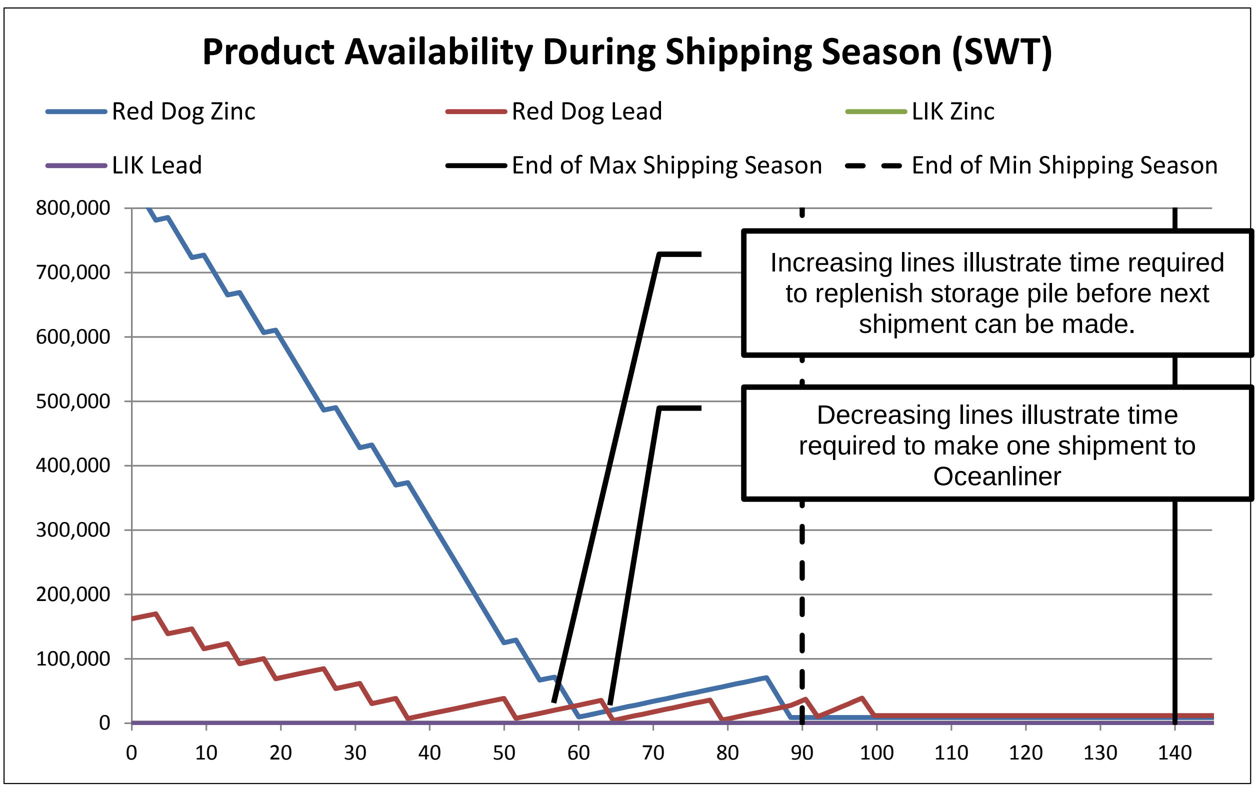


Figure 6-2 Product Availability During Shipping Season



6.2 “No Upgrades” Analysis

The first step in developing any future recommendations was to establish a base line as a way to measure the value of the each recommendation. From the base line a “no upgrades” analysis was performed to understand how current operations and resources could handle the product goals for Red Dog and Lik Mine simultaneously. Only changes deemed necessary to handle the Lik product were made to current port operations. Those changes were:

- Adjust haul operations by dividing available time during the non shipping season between receiving Red Dog product and Lik product at the one existing TUB. Recall that the specifics for this modification are described fully in Section 5.1.
- Reorganize storage in the existing CSBs to make room for Lik product. CSB No. 2 was unchanged (and continues to store only Red Dog zinc). CSB No. 1 was reorganized to store a reduced volume of Red Dog product to make room for Lik lead and zinc. Specifics for this modification are defined fully in Table 5-3. Haul Operations Analysis Results.
- Update the simulated shipping schedule to also include the import and export of Lik products during the shipping season without adding new resources at the port. The rules governing the simulated shipping schedule were unchanged from the baseline model, only expanded to consider Lik product; the same applies for the simulation of import (haul) operations. Recall that during the shipping season, haul operations shadow the shipping schedule, working to replenish depleted storage piles in the CSBs.

Table 6-1. “No Upgrade” Analysis Results provides the results of this no upgrades analysis for the years 2020-2028. Figure 6-3 Product Export Goal (for 2022) and Figure 6-4 Product Availability During Shipping Season (for 2022) illustrate the results of the model simulation for the year 2022, which is representative of all productive years of the Lik Mine (as shown in Table 6-1 the forecasted production from Lik and Red Dog is expected to be consistent between 2022 and 2028.)

Table 6-1. “No Upgrade” Analysis Results

Year	Percentage of Goal Achieved*					
	Lik Mine		Red Dog Mine		Lik Mine	
	Zinc	Lead	Zinc	Lead	Zinc	Lead
2020	266,000	76,000	100%	100%	100%	100%
2021	366,000	82,000	100%	100%	76.5%	100%
2022	295,000	68,000	100%	100%	100%	100%
2023	271,000	66,000	100%	100%	100%	100%
2024	274,000	60,000	100%	100%	100%	100%
2025	273,000	60,000	100%	100%	100%	100%
2026	279,000	68,000	100%	100%	100%	100%
2027	277,000	60,000	100%	100%	100%	100%
2028	242,000	66,000	100%	100%	100%	100%

As shown in Table 6-1. “No Upgrade” Analysis Results, the “no upgrades” analysis results indicate that with the exception of the production forecast for 2021, only the operation adjustments described and used to set up the analysis are required to be implemented to achieve the throughput capacity forecast requirement. These operational adjustments are summarized in Table 6-2. Recommendations Summary for (agreed upon) Forecast.

It is noted that in the year 2021, the total volume forecasted exceeds the port’s annual throughput capacity. In fact, the model indicates that a shipping season of approximately 120 days would be needed to meet the shipping goals. As this is longer than an average shipping season, the total throughput volume allocated to either the Lik mine or the Red Dog mine may need to be adjusted to meet the ports capacity limits. It would be assumed that the port operator would negotiate the respective throughput volumes with each customer should the actual yearly volume exceed the port’s capacity. This approach is recommended as it would not be economically justifiable to invest in capacity upgrades just to meet a one year spike in throughput requirements.

Figure 6-3 Product Export Goal (for 2022)

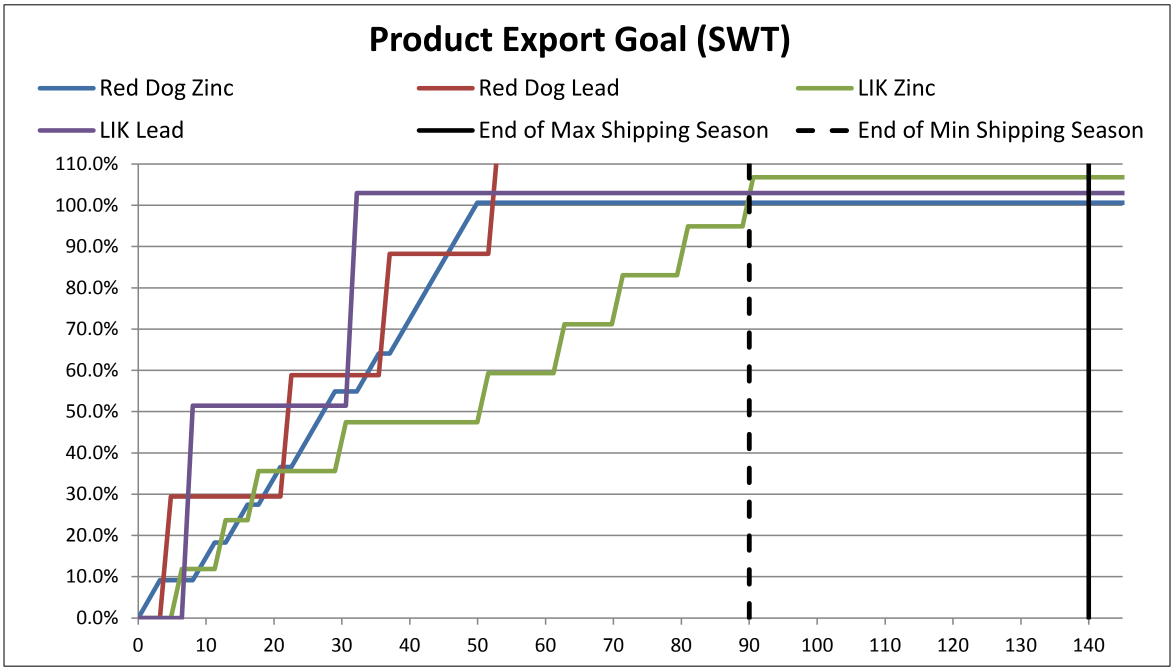


Figure 6-4 Product Availability During Shipping Season (for 2022)

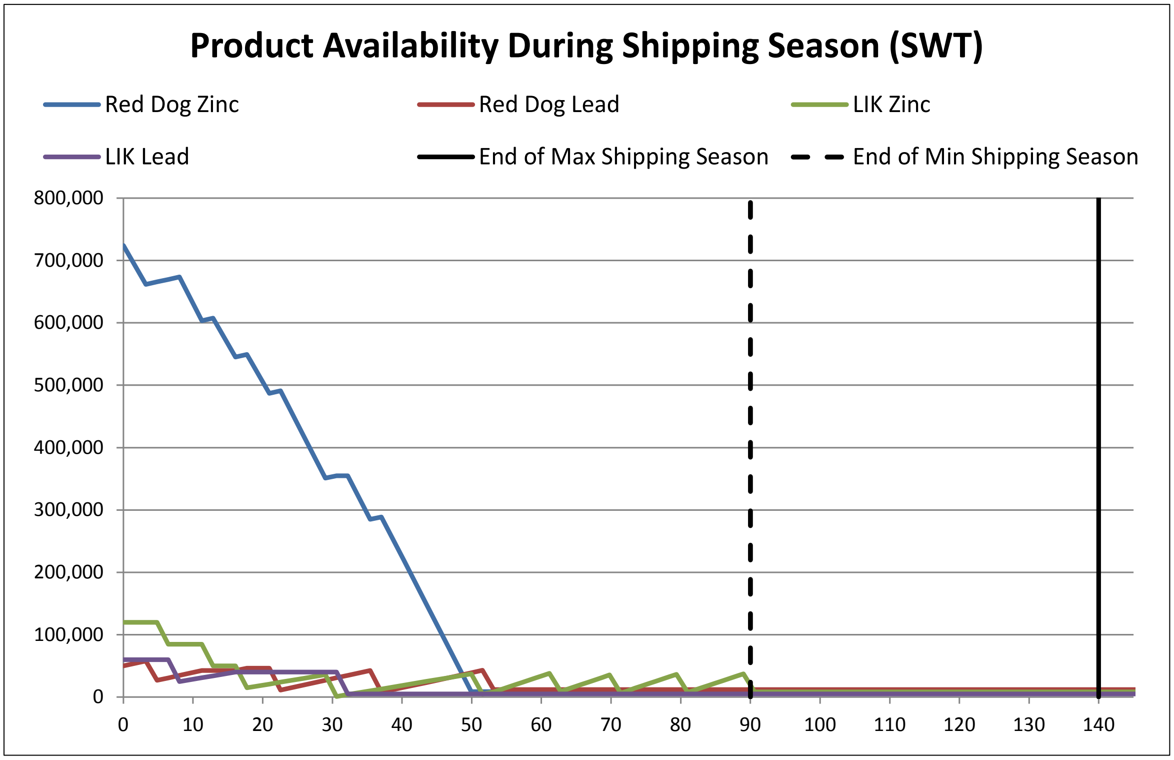


Table 6-2. Recommendations Summary for (agreed upon) Forecast

Operating Parameter	Red Dog Mine	Lik Mine
Haul Operations Recommendations		
Division of time during the non shipping between receiving Red Dog product and Lik product at the one existing TUB.	200 days	60 Days
Non-Shipping Season Average number of Active Trucks Shipping Season Average number of Active Trucks	7 trucks 9 trucks	7 trucks 9 trucks
Non-Shipping Season Average Deliveries Per Day Shipping Season Average Deliveries Per Day	31.0 39.0	24.0 30.0
Concentrate Storage Building Recommendations		
Allocation of Space in CSB No. 1 (% of total building volume)	55% Zinc 10% Lead	25% Zinc 10% Lead
Allocation of Space in CSB No. 2 (% of total building volume)	100% Zinc 0% Lead	0 SWMT (0%) Zinc 0 SWMT (0%) Lead
Load-Out Recommendations		
Beyond including the shipment of Lik product in the shipping schedule, no changes in operation required. See Table 4-4 for summary of current load-out operations.		

6.3 "Conservative" Production Forecast

In addition to the agreed upon production forecast, HDR also studied what capacity upgrades would be required in the event that actual production values exceed the production forecast defined in this report. This analysis was performed by adding additional throughput volume to the total forecasted throughput volume in 50,000 SWMT increments starting at 1.25 SWMT. For this, the total additional volume considered in each increment was assumed to be equally distributed amongst the four products. This analysis was performed for up to 250,000 additional SWMT of volume beyond the average combined 1.2 million SWMT forecasted during the life of the Lik Mine. Tables 6-4 and 6-5 summarize the results of this study by listing all of the operational parameters upgraded to meet the shipping goal in a 95 day shipping season. All parameters not listed, such as number of barges or belt speed of load-out conveyor belts, are purposely omitted from the table because upgrades or changes from current operations are not required.

Table 6-3. "Conservative" Production Forecast

Analysis	Lik Mine	
	Zinc	Lead
Average Forecast (2020-2028)	282,556	67,333
1.25 SWMT Total	286,583	71,361
1.30 SWMT Total	299,083	83,861
1.35 SWMT Total	311,583	96,361
1.40 SWMT Total	324,083	108,861
1.45 SWMT Total	336,583	121,361

Table 6-4. "Conservative" Production Forecast – Red Dog Operating Parameters

Red Dog Operating Parameters		Current Operations	1.25 Million SWMT Total	1.30 Million SWMT Total	1.35 Million SWMT Total	1.40 Million SWMT Total	1.45 Million SWMT Total
Haul Operations Recommendations							
Non-Shipping Season	Average Number of Active Haul Trucks	7	7	7	8	9	10
	Spacing of Truck Deliveries to TUB (Gap Time)	40-45 mins	40-45 mins	40-45 mins	40-45 mins	40-45 mins	35-40 mins
	Average Truck Deliveries in 24-hour period	31	31	31	35	38	41
Shipping Season	Average Number of Active Haul Trucks	9	10	10	9	10	10
	Spacing of Truck Deliveries to TUB (Gap Time)	40-45 mins	30-35 mins	20-25 mins	40-45 mins	25-30 mins	35-40 mins
	Average Truck Deliveries in 24-hour period	39	45	47	39	46	41
Concentrate Storage Building Recommendations							
Allocation of Existing Storage - CSB No. 1	Lead	166,340	59,141	59,141	59,141	59,141	59,141
	Zinc	359,257	215,919	215,919	215,919	215,919	215,919
Allocation of Existing Storage - CSB No. 2	Lead	0	0	0	0	0	0
	Zinc	512,453	512,453	512,453	512,453	512,453	512,453
Added Storage via Upgrades	Lead	-	0	0	50,000	80,000	120,000
	Zinc	-	0	0	50,000	100,000	125,000
Total Storage	Lead	166,340	59,141	59,141	109,141	139,141	179,141
	Zinc	871,710	728,372	728,372	778,372	828,372	853,372

Table 6-5. "Conservative" Production Forecast – Lik Operating Parameters

Lik Operating Parameters		Current Operations	Average Forecast (2020-2028)	1.25 Million SWMT Total	1.30 Million SWMT Total	1.35 Million SWMT Total	1.40 Million SWMT Total	1.45 Million SWMT Total
Haul Operations Recommendations								
Non-Shipping Season	Average Number of Active Haul Trucks	-	7	7	7	8	9	10
	Spacing of Truck Deliveries to TUB (Gap Time)	-	40-45 mins	40-45 mins	40-45 mins	40-45 mins	40-45 mins	35-40 mins
	Average Truck Deliveries in 24-hour period	-	24	24	24	27	30	33
Shipping Season	Average Number of Active Haul Trucks	-	9	10	10	9	10	10
	Spacing of Truck Deliveries to TUB (Gap Time)	-	40-45 mins	30-35 mins	20-25 mins	40-45 mins	25-30 mins	35-40 mins
	Average Truck Deliveries in 24-hour period	-	30	34	35	30	35	33
Concentrate Storage Building Recommendations								
Allocation of Existing Storage - CSB No. 1	Lead	-	59,141	59,141	59,141	59,141	59,141	59,141
	Zinc	-	122,277	122,277	122,277	122,277	122,277	122,277
Allocation of Existing Storage - CSB No. 2	Lead	-	0	0	0	0	0	0
	Zinc	-	0	0	0	0	0	0
Added Storage via Upgrades	Lead	-	0	0	0	25,000	35,000	40,000
	Zinc	-	0	0	0	25,000	20,000	40,000
Total Storage	Lead	-	59,141	59,141	59,141	84,141	94,141	99,141
	Zinc	-	122,277	122,277	122,277	147,277	142,277	162,277

6.4 Concentrate Storage Buildings

While the model indicates that no additional storage space is required to meet the shipping goals stated in the agreed upon production forecast (Table 6-1. "No Upgrade" Analysis Results), the conservative forecast (Table 6-5) indicates that additional storage space is required if the actual combined production volume exceeds 1.30 million SWMT. To determine the most economical way to add storage space at the DMTS port facility, HDR reviewed three possible approaches:

- Extending CSB No. 2,
- Raising the pile retaining walls within the existing CSBs to increase the base footprint and
- Adding a third storage building (CSB No.3)

Based on the required additional volumes indicated by the model for production forecasts greater than 1.30 million SWMT, it was found that raising the pile retaining walls provides insufficient volume gains and would not be economically justifiable to pursue. It was found that by extending CSB No. 2 approximately 225 feet, such that CSB No. 2 equals the length of CSB No. 1 (1,425 feet) an estimated additional 100,000 SWMT can be gained from the build-out.

To gain additional storage beyond this upgrade, a third CSB, complete with a new TUB, intake conveyor belt system, and load-out conveyor belt system, would be required at the port facility. Section 7 provides cost estimates for the storage upgrade recommendations.

6.5 Throughput Operations

As discussed in Section 5.3, the current load-out conveyor belt system is operated at 75% capacity which allows for the two active barges to make a total of four deliveries each active shipping day. As noted in Section 5, a 5 to 10% increase in operating speed would allow for an additional barge delivery during active shipping days which may become useful in a condensed shipping schedule. However, normal operation at slower rates (75-80% capacity) helps to preserve the belt speeds at a reasonable operational rate and decreases wear and tear and likelihood of maintenance issues. For normal operations, HDR recommends no changes for throughput operations.

6.6 Barge Operations

The throughput model indicates a three-barge fleet can make five to six barge deliveries each day, thereby increasing export capacity. While this may become useful in a condensed shipping schedule, the addition of a third barge is not required to meet the demand of the additional Lik Mine export forecast because of the other recommendations provided in this Section. The addition of a second barge loader was also considered; however, based on the expected demand from both Lik Mine and Red Dog Mine, this additional increase (which would only make sense if barges were added too) would provide more capacity than is needed for the forecasted throughputs.

7 DMTS Upgrade Capital Cost Estimate

7.1 No Upgrades Cost Estimate

Based on the agreed upon forecast, it was determined that DMTS Port in its current configuration has the ability to meet the demand throughput and volume without having to make any infrastructure changes. However, some upgrades and modifications to the DMTS network must be carried out to accommodate the needs of the potential Lik Development. Table 7-1. Summary of Costs for Fuel Storage and Roadway Development provides a summary of the costs to add additional fuel storage at the port for Lik and for Red Dog and for the development of the 22-mile roadway from the Lik Mine to the existing Red Dog DMTS roadway. The estimate includes both direct cost and indirect costs (Project Overhead and Program Costs in 2018 dollars).

Table 7-1. Summary of Costs for Fuel Storage and Roadway Development

Item	Quantity	Unit	Description / Notes	Cost Estimate
DIRECT COSTS				
Electrical, Mechanical and Systems to support fuel tanks	1	LS	Misc. Infrastructure needs, electrical, mechanical, etc.	$560,000
22 Mile Gravel Road to Lik				
Project General Conditions	1	LS	Project General Conditions Cost (8%)	$3,983,627
Mobilization/Demobilization	1	LS	Contractor Mob/Demob Cost (8%)	$3,983,627
Clear and Grub-150-ft x Light Grading	400	AC		$4,000,000
Geotextile 50 ft Wide	645,333	SY		$3,549,332
Excavate to fill 50,000-CY per Mile	1,100,000	CY		$9,900,000
Select fill 5-ft and 3:1 Side Slope	1,098,000	CY	Select fill	$15,372,000
Surfacing 1-ft	142,000	CY	1ft surfacing required	$5,396,000
Bridges	32,000	SF	4 bridges each 200ft x 40’	$8,800,000
Major Culvert Locations	3	EA		$1,650,000
Minor Culvert	125	EA		$3,125,000
New Gravel Road Sub Total				**$59,759,586**
Fuel Storage Tanks	5	LS	5 - 2.5 million gallon capacity storage tanks; includes infrastructure for footings, foundation, and containment. 4 tanks for Lik, 1 for Red Dog	$13,375,000
			TOTAL DIRECT COSTS	**$73,694,586**

Item	Quantity	Unit	Description / Notes	Cost Estimate
PROJECT OVERHEAD				
Home Office	2.00%	-		$1,473,892
Overhead & Profit	5.00%	-		$3,684,729
Bonds	0.75%	-		$552,709
Insurance	1.00%	-		$736,946
Subtotal Construction Cost				$80,142,862
PROGRAM COSTS				
A/E Design Fees	6.00%	-		$4,808,572
Owner Administrative Cost	2.50%	-		$2,003,572
Geotech & Survey	-	LS		
Permits and Fees	3.00%	-		$2,404,286
			TOTAL COST	**$89,359,292**

7.2 CSB 2 Expansion

Plans should be put in place to add additional storage at the DMTS Port in the event the actual volume in the years prior to the opening of the Lik deposit indicate that the Red Dog volume is not reducing as previously thought, and that combined, the revised forecasted volume will exceed that of the forecast used for this study. The first and most logical modification would be to complete the build out of CSB No. 2 (i.e., expansion to match the size of CSB No. 1). This will provide an additional 100,000 SWMT of storage space. Table 7-2 provides a summary of costs for upgrades related to the conservative production forecast in which product totals exceed 1.2 million SWMT delivered to the port facility annually and additional storage space of up to 100,000 SWMT is required.

These costs are not carried forward in the overall recommendations given the currently anticipated production forecasts. Instead, these costs are provided for planning purposes, in the event that it is determined the production forecast underestimates the throughput demand at DMTS. These costs are also shown as a stand-alone project and include both direct cost and indirect costs (Project Overhead and Program Costs).

Table 7-2. Summary of Costs Related to Expansion of CSB No. 2

Item	Quantity	Unit	Description / Notes	Cost Estimate
Project General Conditions	1	8%	General Condition Cost	$634,500
Mobilization/Demobilization		8%	Mob/Demob Cost	$634,500
Misc. Infrastructure, electrical, fiber optics etc.	1	-	Misc. Infrastructure needs, electrical, mechanical, etc.	$750,000
Overhead Conveyor System	200	LF	Extend overhead conveyor system in CSB 2	$1,050,000
Concentrate Storage Building CSB 2	32,700	SF	Estimated Building Dimensions: 225 ft (L) x 218 ft (W) x 140 ft (H)	$6,131,250
			Total Direct Cost	**$9,200,250**
		PROJECT OVERHEAD		
HOME OFFICE	2.00%	-		$158,625
OVERHEAD & PROFIT	5.00%	-		$396,563
BONDS	0.75%	-		$59,484
INSURANCE	1.00%	-		$79,313
SUBTOTAL CONSTRUCTION COST				**$9,894,235**
		PROGRAM COSTS		
A/E DESIGN FEES	2.50%	-		$215,631
OWNER ADMINISTRATIVE COST	2.50%	-		$215,631
GEOTECH & SURVEY	-	LS		
PERMITS & FEES	1.00%	-		$86,252
			TOTAL COST	**$10,411,749**

7.3 Addition of a Third CSB

Table 7-3 provides a summary of estimated costs for the addition of a third CSB at the port. The additional storage capacity obtained from adding this building would only be required if the actual forecast exceeds the conservative production forecast of 1.2 million SWMT delivered to the port facility annually. Because the cost to mobilize and demobilize a contractor to perform the work is higher than in other more urban locations, it would be recommended that a minimum of 225,000 SWMT of storage capacity be developed. The additional storage space would be supported by adding a new TUB, intake conveyor belt system, transfer tower, and load-out conveyor belt system.

Although the cost of adding this additional storage space is included in the report, HDR is not recommending this be implemented. Instead, these costs are provided for informational purposes, in the event that it is determined the production forecast underestimates the throughput demand at DMTS. The cost is also shown as a stand-alone project and includes both direct cost and indirect costs (Project Overhead and Program Costs).

Table 7-3. Summary of Costs Related to New CSB No. 3

Item	Quantity	Unit	Description / Notes	Cost Estimate
Project General Conditions	1	8%	General Conditions	$3,850,520
Mobilization/Demobilization	1	8%	Mob/Demob	$3,850,520
Bulk Material Receiving Hopper	225	SWT	Equal in size to the existing Red Dog receiving hopper	$2,130,095
Bulk Material Receiving Hopper	225	SWT	Equal in size to the existing Red Dog receiving hopper	$2,130,095
Transfer Tower	1	-	New Transfer tower for Lik intake conveyor belts	$824,555
42” Wide Conveyor Belts	5,000	ft	Additional conveyor belts necessary to deliver bulk materials between new Lik truck unloading building and new CSB.	$592,500
Misc. Infrastructure, electrical, fiber optics etc.	1	-	Misc. Infrastructure needs, electrical, mechanical, etc.	$2,800,000
New Concentrate Storage Building	163,500	SF	Estimated Building Dimensions: 1500 ft (L) x 218 ft (W) x 140 ft (H)	$35,152,500
1.2 MW Diesel Generator	1	-	Added power generation capacity / redundancy	$850,000
Potable water System Capacity Upgrade	4,700	GPD	Permanent staff increase of 1/3 to cover new infrastructure	$2,191,056
Domestic Wastewater System Capacity Upgrade	900	GPD	Permanent staff increase of 1/3 to cover new infrastructure	$730,352
Service Water System Capacity Upgrade	260	GPM	Permanent staff increase of 1/3 to cover new infrastructure	$730,352
			Total Direct Cost	**$55,832,545**
		PROJECT OVERHEAD		
HOME OFFICE	2.00%	-		$976,278
OVERHEAD & PROFIT	5.00%	-		$2,440,696
BONDS	0.75%	-		$366,104
INSURANCE	1.00%	-		$488,139
SUBTOTAL CONSTRUCTION COST				**$60,103,762**
		PROGRAM COSTS		
A/E DESIGN FEES	3.50%	-		$1,857,979
OWNER ADMINISTRATIVE COST	2.50%	-		$1,327,128
GEOTECH & SURVEY	-	LS		$2,000,000
PERMITS & FEES	1.00%	-		$530,851
			TOTAL COST	**$65,819,720**

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8 Mine Feasibility Summary

8.1 Summary

HDR reviewed the PEA for the potential Lik Mine released by Zazu, dated 23 April 2014.

HDR's observations are summarized below:

- The potential Lik Mine contains excellent grade lead and zinc ores, averaging 2.71% and 8.23% respectively. This compares to other worldwide mines that average 2.2% and 5.8% for lead and zinc.
- The preliminary production schedule seems reasonable and appears to be achievable with proper planning and management controls.
- Compared to typical industry benchmarks, the mining fleet appears to be designed to operate at higher availability and utilization which may be a stretch for older equipment. However, this should be achievable with new equipment and a proper maintenance program.
- The mineral processing route adopted is well proven. The PEA's preliminary process flow sheet appears reasonable for this type of zinc and lead ore. However, the ore's ultra fine mineralization and the plan detailed in the PEA to regrind to a particle size of P_{80} of 10 μm for lead and P_{80} of 8 μm for zinc adds complexity to the regrinding and flotation process. A metallurgist with advanced ultra-fine grinding and flotation skills will be needed to stabilize the process plant quickly after commissioning; such individuals are in limited supply globally.
- Overall, the project capital cost (at $351.7 million in 2013 dollars, with ±20% confidence/contingency) appears to be reasonable for the size of the mine and mineral resource. Opportunity may exist to optimize and reduce capital expenditure. These costs do not include the costs identified in this report for the DMTS.
- The mining operation cost (at $67.66/ton of ore processed in 2013 dollars with ±25% confidence) seems to be reasonable, but is lower than others when compared to similar operations and may not completely account for the mine's remote location. This cost excludes road transport, road maintenance, DMTS/port operations, and ocean freight costs.
- The project is sensitive to fluctuation in metal prices and operating cost estimate. The project net present value (NPV) increases by 49% if the price of zinc increased to $1.05/lb from the assumed level of $1.00/lb. Similarly, for a 15% rise in operating cost, the project NPV falls by 84% to $16.3M.

The review indicates that the Lik Mine Development project is potentially viable, but with a small operating margin. It is sensitive to both the zinc concentrate price outlook and operating cost. Project economics can improve substantially if additional ore reserve is delineated as this can reduce capital cost intensity (e.g., enable amortization of these costs over a longer period), which would improve the NPV and internal rate of return (IRR) of the project.

8.2 Review of Mining Operation

8.2.1 Pit Shell Optimization

As of 31 December 2013, the total estimated open pit mineral resource of Lik Mine was 20.3Mt, comprising 17.4Mt Indicated and 2.9Mt Inferred Resources. HDR understands that mine planning and optimization studies were based solely on Indicated and Inferred Resources for zinc, lead and silver. There is no Measured Resource within the block model.

JDS Energy & Mining ("JDS"), an independent consultant, carried out pit shell optimization studies using Whittle software. Pit optimization modifying parameters included factors for revenue, operating cost, loss and dilution, pit slope consideration, and a discount rate (10%). Pit slope considerations and the chosen slope angles were based on the recommendations of a separate geotechnical study by the geotechnical specialist firm EBA. The key modifying factors used in the pit shell optimization appear to be reasonable.

Under the preferred case for the pit shell optimization, the potential ore tonnage to be mined was estimated at 19.2Mt, indicating a 95% conversion of resource to mineable inventory of ore. This indicates that Inferred Resource has been included in pit optimization and mine scheduling. The mining production schedule was prepared for a total 17.1Mt, which is almost 84% of total resource. It is not a common practice to include Inferred Resource in the assessment of reserves and potential life of mine inventory. Typically, only Measured and Indicated Resource is used for assessment of Reserves as the geological uncertainty associated with the Inferred Resource is high. The mineable inventory (at the 17.1Mt value) appears to be optimistic but achievable, provided the geological uncertainty associated with Inferred Resource is addressed in further drilling and feasibility studies (to convert it from inferred to the indicated or measured resource categories).

8.2.2 Mine Production Schedule

The mine is designed with the maximum throughput of 2Mtpa, resulting in an approximately 10-year mine life, which includes one year of pre-stripping (overburden removal) activities. The throughput rate in Year 1 is assumed to be 80% of full capacity. The mining production schedule is based on a maximum mineral processing capacity of approximately 5,500 tons per day.

The mining schedule is reproduced in (Table 8-1. Production Schedule).

Table 8-1. Production Schedule

Year	Ore (Mt)	Zn (%)	Pb (%)	Ag (g/t)	NSR ($/t)	Waste (Mt)	Total Material (Mt)	Strip Ratio (waste : ore)
-1	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	1.6	8.60	3.47	62.58	114.39	5.64	7.23	3.53
2	2.0	9.46	2.99	58.29	115.95	11.33	13.33	5.68
3	2.0	7.62	2.48	57.24	94.99	11.18	13.17	5.60
4	2.0	7.00	2.37	31.73	87.24	11.35	13.34	5.69
5	2.0	7.10	2.15	27.96	85.38	10.82	12.82	5.42
6	2.0	7.05	2.18	33.58	85.49	11.31	13.31	5.67
7	2.0	7.22	2.43	51.55	91.21	11.22	13.22	5.62
8	2.0	7.16	2.15	37.69	86.68	11.57	13.57	5.80
9	1.6	7.97	3.02	75.51	106.09	2.33	3.89	1.48
Total	17.1	7.66	2.55	47.45	95.72	86.96	104.09	5.07

Source: Table 16-7 of "Preliminary Economic Assessment Technical Report Zazu Metals Corporation, Lik Deposit", Alaska, USA page 16-7

A production ramp up time of two years (one year pre-stripping and one year ramp up to 80% of rated capacity) is applied for scheduling purposes, with an assumed start year of 2019. The pre-stripping is expected to remove only 0.21Mt before first ore will be mined. Tonnage during pre-stripping is based on JDS's opinion that the majority of the pre-stripping requirements are likely to be associated with the removal of organics (soil, etc.). Decline in waste movement in Year 9 is typical for a mine nearing closure as much of the ore is generally already exposed. Just before the end of the mine's life, it generally becomes uneconomical to expose further ore deposit. Therefore, incremental waste is not mined and reserves decline towards the end of the mine's life.

The requirement to remove only 0.2Mt of top soil during pre-stripping to expose 1.6Mt of ore appears optimistic, considering the stripping ratio for Year 1 is estimated at 3.53:1 (Waste: Ore). However, the local topography and conditions may permit this.

8.2.3 Waste/Tailings Dump/Pond

Detailed discussion of a waste dump and its location is not included in the PEA studies. Further work may be required at the detailed economic assessment stage. However, costs for construction of a tailings management facility were estimated to be $5.8M and have been included under the "surface facility" category in capital cost estimates of the PEA studies. The tailings facility costs are based on the assumption that the facility will be built using the waste rock from the pre-strip and stripping operations, pending suitable characterization of these materials.

8.2.4 Mine Equipment

Mine Equipment Design Parameters

The PEA discusses the design parameters for the selection of mine equipment. An availability of 85% and a utilization of 85% are considered for estimating the amount of equipment required. HDR was not able to find any information on inclusion of time loss due to inclement weather which, considering Alaska's adverse weather conditions, may impact production in an open pit mine. Operating mining equipment 6,329 hours per annum appears possible, but may be optimistic.

The PEA's estimate of mining equipment numbers required during operation is presented in (Table 8-2. Mining Equipment Requirements). It should be noted that haul trucks are not required. The haul truck operator will use the same truck fleet to move both mine products on a scheduled number of consecutive days.

Table 8-2. Mining Equipment Requirements

Equipment Type	Initial	Ultimate
Drill Rig - rotary tri-cone, 7-7/8"(200mm) dia.	0	1
Drill Rig - down-the-hole, 6.5"(165mm) dia.	1	1
Hydraulic Shovel - Diesel,16yd3 (12.5m3)	1	1
Wheel Loader - Diesel,16yd3 (12.5m3)	0	1
Haul Truck - 100-ton (90-tonne) class	1	8
Dozer - D10 class track	1	2
Grader - 16H-class	1	1
Source: Table 16-8, PEA		

HDR assumes that the amount of equipment required was estimated after factoring in operating efficiency. The current equipment configuration includes one shovel for waste removal and one loader for ore digging. Although there does not appear to be any contingency for breakdowns, the specified equipment should be sufficient assuming proper maintenance and typical fleet utilization rates.

8.2.5 Explosive Requirements

Explosives will be supplied by a single service provider using conventional heavy ANFO explosives. They will be delivered by an on-site mixing truck to the blast hole. Explosive powder factor was calculated between 0.21 – 0.28 kg/t, which appears to be reasonable for a preliminary economic assessment.

8.2.6 Mine Personnel

The mining work schedule is presented as two 12-hour shifts per day, 7 days per week. Crews will work a standard rotation of two weeks on, two weeks off. This will require four mining and maintenance crews. Options for workforce rosters of two weeks on, one week off may be explored. This is a common mining roster which can assist in eliminating the need for the fourth crew.

The PEA estimates a peak total mining personnel of 193, comprising 65 in mining operations, 47 in maintenance, and 12 in technical services.

HDR has reviewed mining personnel requirements and estimates that the manpower estimates appears reasonable. The costs associated with mining personnel were developed by JDS for the remote mine-camp scenarios. Adequate allowances for supervision, employee benefits, and overtime have been built into the final rates used.

8.3 Mineral Processing

The processing facilities are designed to process the lead/zinc/silver run of mine (ROM) ore from the Lik Mine at a nominal throughput of 5,480tpd (equating to 2.0Mtpa).

The process route adopted comprises multi-stage crushing, stockpiling and reclaiming, milling (combination of ball and sag mill), and a staged flotation circuit followed by dewatering of products and tailings rejects. This is a standard plant configuration often adopted for processing of lead and zinc ores. The process parameter used and equipment selection are based on the results of test works conducted in bench scale and pilot scale by Zazu during 2008-2013.

8.3.1 Processing Plant Availability

The PEA projects a 24 hour per day plant operation and 92% plant availability. The 92% availability factor is factored for the grinding and flotation circuit, while the crushing plant is designed with 75% availability. These availabilities are comparable with industry benchmarks.

8.3.2 Primary Crushing Circuit

The PEA proposes an appropriate crushing circuit comprising of ROM hopper, rock breaker, vibrating grizzly, primary jaw crusher, apron feeders, conveyor, belt magnets, and an appropriate dust suppression system. A top size of feed ore of 850mm is assumed, while the P_{80} product size of 150mm will be fed to the grinding circuit. The calculated reduction ratio for the primary crusher will be 5.6:1, which is acceptable for a jaw crusher.

Other components of primary crushing circuits are well documented in PEA, and in HDR's opinion, there is no reason to doubt the accuracy of the calculations.

8.3.3 Stockpile

The PEA proposes to have an intermediate stockpile with a live capacity of 5,500 tons. A stockpile of this size would provide a buffer between the mine and process plant for one day only. Many lead/zinc process plants are designed with a five to seven day buffer. Considering the remote location of the project and the adverse weather conditions, a larger stockpile with a capacity of five to seven days' stock may be considered.

8.3.4 Grinding Circuit

The grinding circuit will reduce the size of the crushed material to a product size P_{80} of 40 µm. The grinding process will be a two-stage operation with the semi autogenously grinding (SAG) mill followed by one ball mill in a closed circuit with the cyclones. A pebble crusher will be included in closed circuit with the SAG mill to handle coarse pebbles from the SAG mill discharge screen.

SAG mill discharge will combine with the ball mill discharge in the cyclone feed pump box. Slurry from the cyclone feed pump box will be pumped to cyclone clusters. Process makeup water and the required reagent will also be added to the cyclone feed pump box. The cyclone underflows will gravity-flow to the ball mill feed chute, while the overflow will gravity-flow to the bulk rougher flotation bank. The cyclone clusters will have a cut size of P_{80} of 40 µm, and the circulation load to the individual ball mill circuits will be 250%. The ball mills will operate at a critical speed of 73.1% with 34% ball loading.

The grinding circuit configuration appears to be reasonable for the style of mineralization.

8.3.5 Flotation Circuit

The flotation circuit will consist of carbon pre-float followed by lead flotation, and finally zinc flotation sections. The lead rougher flotation circuit will consist of eight flotation tank cells (six rougher and two rougher scavengers). The concentrate from the rougher and rougher scavengers will be combined and sent to the regrind circuit. The rougher scavenger tailings will be forwarded to zinc flotation conditioner tank.

The lead rougher concentrate will be reground to a particle size of P_{80} of 10 µm in a regrind mill complete with a cyclone cluster. The overflows from the cyclones will gravity-flow to the lead cleaner circuit; the underflow of the cyclones will feed to the regrinding mill for further regrind. The lead regrind cyclone overflow will be cleaned in three cleaner stages. The final lead concentrate will be sent to the lead concentrate thickener.

The zinc flotation circuit will consist of one bank of eight rougher tank cells and an additional bank of four rougher scavenger tank cells. The concentrate from the rougher and rougher scavengers will combine and report to the zinc regrinding circuit. The rougher scavenger tails will be transferred to the tailings thickener for thickening prior to being discharged to the tailings facility.

The zinc rougher concentrate will be reground to a particle size of P_{80} of 8 µm in a regrind circuit consisting of a mill in closed circuit with a cyclone cluster. The overflows from the cyclone cluster will gravity-flow to the zinc cleaner circuit, while the underflow of the cyclones will be recycled back to the regrind mill.

HDR has reviewed the flotation circuit and in our opinion, the process configuration appears to be reasonable for the style of mineralization. However, the ultra fine nature of mineralization and subsequent regrind to particle size of P80 of 10 µm for lead and P80 of 8 µm for zinc signifies the need for a specialist metallurgist with advanced ultra-fine grinding and flotation skills to stabilise process plant quickly after commissioning. Such individuals are of limited availability globally.

8.3.6 Dewatering and Filtering

The lead and zinc concentrate will be thickened to 65% solids in separate concentrate thickeners. Thickener underflow will be pumped to the respective concentrate stock tanks prior to being filtered. The lead thickener overflow will be recycled to the grinding circuit, while the zinc thickener overflow will be transferred to water treatment or directly to the process water tank for recycling back to the process plant. The thickened underflows from the lead and zinc thickeners will be pumped from the stock tanks to dedicated lead and zinc pressure filter presses for further dewatering to a target moisture content of 8%. This process configuration appears to be reasonable.

8.4 Review of Capital Cost Estimates

8.4.1 Key Assumption in Capital Cost Estimate

The following key assumptions were used for the capital cost estimate in the Lik Mine PEA study:

- The capital cost ("CAPEX") estimate includes the costs required to design; procurement of mining equipment; development of on/off-site infrastructure; and construction services, as well as sustaining capital and mine closure cost. The CAPEX estimate is summarized in Table 8-3. Capital Cost Estimates (2013 Dollars). As noted above, these costs do not include those identified in Section 6 for the road and port upgrades.

Table 8-3. Capital Cost Estimates (2013 Dollars)

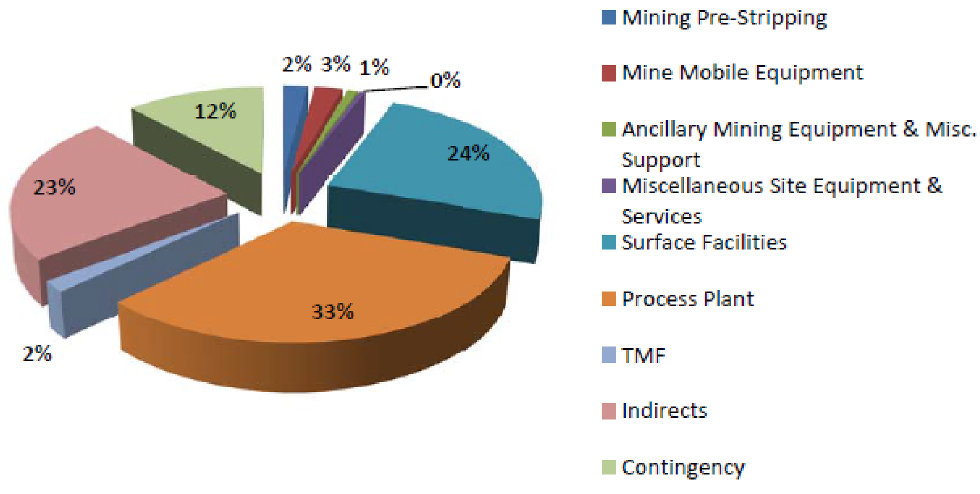
Description	Total ($M)
Pre-production CAPEX	324.7
Sustaining capital and closure cost	27.0
Total CAPEX	351.7
Source: PEA, Page 21-1	

- JDS prepared the CAPEX estimate on the basis of a combination of quotations received from vendors/suppliers and their in-house data and experience with similar projects.
- The CAPEX estimates are based on 2013 dollars with no provision for escalation (inflation).
- Structural steel, tank steel, electrical hardware, and instrumentation supply pricing were based on recent quotations for similar projects in North America. JDS applied piping allowances commensurate with the plant areas and type of equipment being installed.
- JDS estimated civil, concrete, structural steel, process tanks, electrical and instrumentation bulk quantities from the drawings, with pricing based on current in-house cost information.

- The sustaining capital cost was assessed over operating year one to nine and includes mine closure costs.
- The input accuracy of this estimate is on the order of ±20%.

Figure 8-1 Project Capital Cost Allocation presents the allocation for the project capital cost.

Figure 8-1 Project Capital Cost Allocation



Source: PEA, page 21-2

The capital estimate for key process stages is discussed in the following subsections.

8.4.2 Mining Capital Cost

Mining Pre-strip

Mining pre-strip cost includes the cost associated with the open pit mine development prior to commencement of mining operations. A provision of $6.7M was made for mining pre-strip. This appears to be reasonable if the majority of the pre-stripping requirements are likely to be limited to the removal of organics and top soil.

Mining Fleet

The CAPEX estimates for mining equipment are based on the actual budgetary quotes received from equipment suppliers. Based on the equipment requirement estimated during the PEA mine planning study, the expected cost of the mining fleet, including ancillary equipment, is $12.6M. An additional excavator may be required for smooth mine operations as the production ramps up.

Mine Closure Cost

JDS estimated the mine closure cost at $5M (Appendix B, PEA) to be incurred in Year 10, after the depletion of ore reserves.

HDR reviewed and compared the estimated closure cost with the nearby Red Dog Mine, which is a 3.6M tons per annum (tpa) operation. The mine closure cost appears to be low considering that the planned mine closure cost for the nearby Red Dog Mine is almost $46.9M (as estimated by SRK in May 2009). The PEA study assumed closure cost at the end of the mine life rather than any environmental bond or on-going rehabilitation. This will need further work in detailed feasibility studies.

8.4.3 Process Plant

The total capital cost for the processing plant was estimated at $106.6M. This includes costs associated with process buildings, civil works, stockpiles, process equipment and piping, and electrical substation.

The estimated cost for civil works includes items that will be required for the construction of the process plant excluding tailing dam and mine waste dump. In PEA, the costs for the civil works (Process plant) have been taken as $1.5 million.

In HDR's opinion, the capital cost appears to be reasonable when compared with similar projects.

8.5 Review of Operating Cost Estimates

The following are the PEA's key assumptions for the Operating Cost Estimate (OPEX):

- All costs are based on 2013 dollars, with no escalations for inflation, etc.
- JDS estimated the manpower requirement on the basis of their industry knowledge. Regional labor rates, in US dollars were provided to JDS by Zazu. Allowances for supervision, employee benefits and overtime are built into the final rates.
- Mine equipment maintenance costs are based on supplier's advice and JDS's industry knowledge. Fuels, lubricants, and explosive prices are based on recent budgetary quotations.
- Process Plant reagent use rates are estimated from the process test work and the reports done by others. Spare parts and consumable requirements are based on JDS's experience with similarly sized projects.
- Electrical Power cost is based on budgetary quotations from natural gas fired reciprocating engine generator sets. Although the use of natural gas as primary fuel for the generation of electricity is typically cost effective and environmentally friendly, the future availability of natural gas for power generation at Lik is not known. It would be more conservative – and consistent with current power generation options along the DMTS – to assume the use of diesel powered generation. This will increase operating costs and should be more fully evaluated in future feasibility studies.

The estimated OPEX in PEA is summarized in Table 8-4. Operating Cost Estimate, Lik Project, and its percentage breakup is depicted in Figure 8-2.

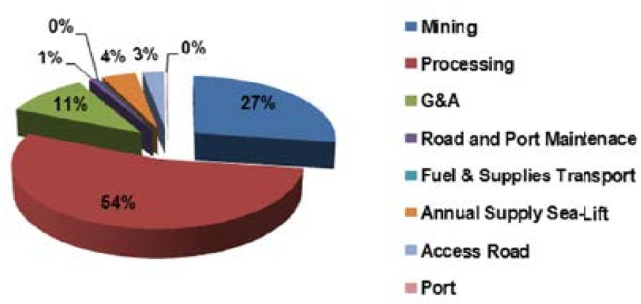
Table 8-4. Operating Cost Estimate, Lik Project

Items	LOM ($M)	$/t Milled
Mining	$315.60	$18.42
Processing	$629.20	$36.72
G & A	$121.80	$7.11
Road and Port Maintenance	$10.05	$0.61
Fuel and Supplies Transport	$1.50	$0.09
Annual Supply Sea- Lift	$48.90	$2.86
Access Road	$30.20	$1.76
Port	$1.70	$0.10
Total OPEX	$ 1,159.40	$67.66
Source: PEA, Page 22-9		

These costs exclude road transport, stockpiling at the port, ship loading, and ocean freight costs. Detailed transportation costs have been included in net smelter return calculations (Net revenue). The estimated costs deducted from gross revenue towards transportation and shipping is shown below.

- Zn/Pb Concentrate – Transport mine to port: $13.73/t concentrate
- Port and Road Fee - $21.04/t concentrate
- Ocean Freight - $60/t concentrate

Figure 8-2 Project Operating Cost Allocation



Source: 2014 PEA, Page 22-9

It is should be noted that Lik Mine's PEA has already factored in $13.73/ dry metric tons (dmt) for road haulage from mine to port, $21.04/dmt for port costs, and $60/dmt for ocean freight in Net Smelter Revenue (NSR) calculation rather than factoring them as operating cost. This has resulted in lower revenue and lower operating cost but with no material impact on NPV of the project.

8.5.1 Comparison of OPEX between the Lik Mine Project and the Red Dog Mine

HDR compared the operating cost estimate given in the PEA with the actual annual cost for the nearby Red Dog Mine in 2013. Table 8-5. Cost Comparison: Lik Mine & Red Dog Mine presents our comparison.

Table 8-5. Cost Comparison: Lik Mine & Red Dog Mine

Parameters	Red Dog Mine	Lik Mine
Tonnes Mined & Milled (Mt)	3.85 Mt	2.0 Mt
Strip Ratio (Waste: Ore)	<3:1	5:1
Operating Cost ($/t)	55.58	62.25*
Distribution Cost ($/t)	27.53	5.41**
Royalty ($/t)	31.16	
Depreciation and amortization ($/t)	13.76	

*G&A cost for Lik is included in operating cost
** PEA has factored in additional distribution cost of approximately $33.77/t in Net Smelter Revenue (NSR) calculation
Sources: PEA (2014), Teck Resources (2014)

It is difficult to directly compare the operating costs of the Lik Mine project with the Red Dog Mine due to the varied treatment of distribution costs and royalty rates. However, in HDR's opinion, the operation cost appears to be reasonable.

HDR notes that Lik Mine's PEA has already factored in $13.73/dmt for road haulage from mine to port, $21.04/dmt for port costs, and $60/dmt for ocean freight in Net Smelter Revenue (NSR) calculation.

Several royalties also factor into the operating costs. The PEA notes that the project is subject to a Net Profit Interest Royalty calculated at 1% to GCO Minerals Company. This royalty is included in the costs reported in the PEA.

A separate 2% net proceeds interest royalty is also owed to GCO Minerals Company by Zazu, based on the percentage of ownership held by Zazu. The PEA studies haven't incorporated this royalty in its economic calculation since the level of Zazu's ownership during development has not yet been defined at this stage.

Finally, the PEA does not appear to account for State of Alaska Production Royalties. Although the Lik property was initially staked as federal claims, the property has since passed from the U.S. Federal Government to the State of Alaska. Zazu opted to convert the claims to state claims in 2013. The production royalty is three percent of net income as determined under the Mining License Tax Law AS 43.65 and regulations 15 AAC 65.

Although the project remains marginally profitable, these additional royalties will affect profitability and should be accounted for during subsequent analyses.

8.5.2 Mining Operating Cost

The cost associated with pre-stripping has been capitalized for the purpose of depreciation. This is a reasonably standard practice in mining operations. The mining cost components are broken down by the activity. The PEA estimates a total operating cost on account of mining as $18.42/ tons of ROM ore. PEA's cost breakdown for the mining operating cost has been presented in Table 8-6. Mining Operating Cost by Activity.

Although HDR was not able to determine the exact methodology by which the unit cost by activity is derived, the estimated mining cost appears reasonable when compared to the typical mining cost benchmarks for similar sized operation located in similar geographies.

Table 8-6. Mining Operating Cost by Activity

Activity	$/t, mined (waste or ore)	$/t, ROM Ore
Load and Haul	$ 1.53	$ 9.30
Drill and Blast	$ 0.74	$ 4.50
Mine General	$ 0.53	$ 3.25
Mine Maintenance	$ 0.23	$ 1.37
Total	$ 3.03	$ 18.42
Source: PEA, page 21-7		

8.5.3 Process Operating Cost

Process operating costs totaling $36.74/t were developed for a 2.0 Mt/a facility based on the following:

- Employee total costs of $4.67/t for a total of 82 employees are based on industrial norms for similar sizes and types of process facilities, and wages are based on published data for Alaska with overheads and overtime allowances based on industry accepted levels for fly-in operations.
- Steel consumption and costs are based on industrial standards and in-house data totaling $3.68/t.
- Reagent costs at $11.97/t are based on locked cycle test projected consumptions and updated pricing.
- An allowance of $0.77/t is included for miscellaneous operating supplies and services.
- An allowance of $1.86/t is used based on in-house data for general operating and maintenance supplies and consumables covering filter cloth, vehicles, small tools and motors, water treatment, and other miscellaneous expenses. This allowance of approximately 5% of the total process operating cost appears to be reasonable at this level of studies.
- An assay and metallurgical laboratories allowance is estimated to be $0.20/t based on similar operations.
- Power costs of $13.59/t are based on a unit power cost of $0.248 per kWh and assume the use of natural gas as a fuel source. As noted elsewhere in this report, the use of diesel fired power appears more likely, but would add cost to the project.

PEA's cost breakup for the processing operating cost is presented in Table 8-7. Processing Operating Cost by Activity.

Table 8-7. Processing Operating Cost by Activity

Activity	$/t, Milled
Employees	$ 4.67
Reagents	$11.97
Other Supplies	$ 6.51
Power	$13.59
Total	**$36.74**

In HDR's opinion, the mineral processing cost appears to be reasonable based on industry benchmarks.

8.6 Review of Economic Analysis

JDS developed a techno-economics model to estimate annual cash flows and sensitivities of the project during the PEA studies. Pre-tax estimates of project values were prepared for comparative purposes, while a post-tax estimate was prepared for assessment of investment value. In HDR's opinion, use of post-tax measures may be more appropriate since they provide a better estimate of actual project cash flows.

HDR notes that the economic assessment completed by JDS is preliminary in nature as they are based on Indicated and Inferred Resources.

8.6.1 Key Assumptions in the Financial Model

Two scenarios were evaluated on the basis of different metal price outlooks. Scenario 1 is based on the three-year trailing average prices for zinc and lead as of December 30, 2013. Scenario 2 is based on forward price of zinc as published by Bloomberg on January 31, 2014. Other key inputs and costs were kept constant in both scenarios.

Metal price assumptions are given in Table 8-8. Two Scenarios for Metal Price Assumptions below:

Table 8-8. Two Scenarios for Metal Price Assumptions

Parameter	Units	Scenario 1 NSR Assumptions	Scenario 2 Forward Price zinc
Zn Price	US $/lb.	0.92	1.00
Pb Price	US $/lb.	1.01	1.01
Ag Price	US $/lb.	19.43	19.43

Source: PEA, page 22-3

Assumptions:

- Discount rate of 8%.
- Closure Cost $5M.
- Nominal 2014 dollars.
- Working capital of three months operating cost.
- Results are based on 100% ownership and do not include any management fees or financing costs.
- Exclusion of all sunk costs.

8.6.2 Key Outcomes of Economic Analysis

Analysis presents key outcomes from the financial model.

Table 8-9. Key Findings of Economic Analysis

Key Results	Scenario 1 Zinc $0.92/lb	Scenario 2 Zinc $1.00/lb
Pre-Tax NPV $_{8\%}$	$69.3M	$170.8M
After-Tax NPV $_{8\%}$	$25.0M	$99.1M
Pre-Tax IRR	12.5%	18.6%
After-Tax IRR	9.7%	14.4%
After-Tax Pay Back Period	5.8 years	4.5 years

Source: PEA, Page 22-11, Page 22-12

8.6.3 Economic Analysis Findings

HDR developed the following findings based on review of the key model outcomes and the sensitivities analysis performed on the key input parameters:

- The overall project is highly sensitive to zinc prices. An increase in 8.6% of zinc price (Scenario 2 over Scenario 1) results in an increase of almost 300% in NPV (after-tax) at 8% discount rate. As with most other base metals, the price for zinc is cyclic in nature; therefore, the project would benefit if the start-up was scheduled to coincide with a price upswing immediately after startup.
- The project is highly sensitive to any changes in operating cost. A 15% increase in operating costs results in a drop of $84M to $87M in project NPV in various scenarios. Although the operating cost estimate may be low or missing some cost categories as noted above, further review and analysis should be conducted during the detailed feasibility study stage to more accurately confirm these costs.
- The economic model uses an after-tax discount rate of 8%, which in HDR's opinion, is on the lower side of typical projects at this stage of development. The discount rate taken is generally dependent on the location and nature of the project, the commodity, and the risk appetite of project proponent.

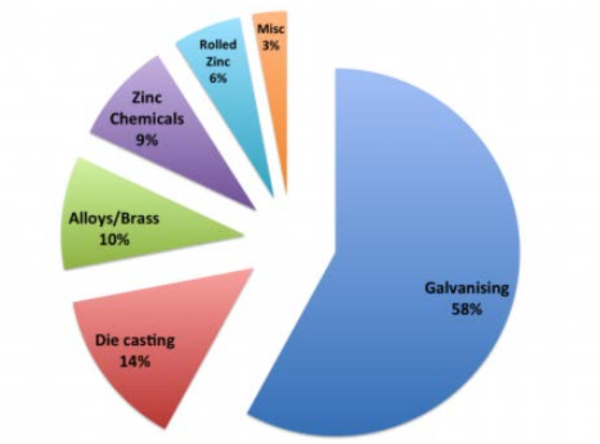
Based on our assessment, in HDR's opinion, the Lik Mine Development project is potentially a viable project but with a small operating margin. It is sensitive to both the zinc concentrate price outlook and operating cost. Project economics can improve substantially if additional ore reserve is delineated as this will reduce capital cost intensity and improve NPV and IRR of the project. An increase in discount rate from 8% to 10% will result in reduction of NPV by $32M to $36M in various scenarios.

9 Commodities Analysis

9.1 Zinc Usage

More than half of the zinc produced globally is used for galvanizing to protect steel from corrosion. Approximately 14% goes into the production of zinc base alloys, mainly to supply the die casting industry, and 10% to produce brass and bronze (Figure 9-1 Zinc Usage, 2013). A portion of the zinc produced is also utilized in rolled zinc applications including roofing, gutters, and down-pipes. The remainder is consumed in compounds such as zinc oxide and zinc sulfate.

Figure 9-1 Zinc Usage, 2013

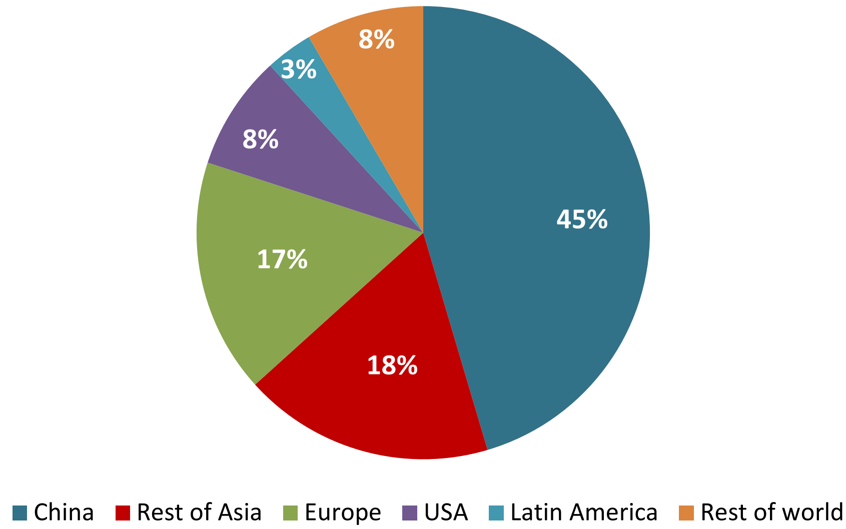


Source: International Zinc Association

9.2 Demand

China is by far the largest consumer of zinc, consuming almost 45% of total world zinc production (Figure 9-2 Global Zinc Consumptions, 2013). Global demand for refined zinc is estimated to have risen by 4% in 2013 to reach 13.5Mt. This is despite relatively soft demand from the key consumer (China) combined with concerns about the United States' plan to rein in its economic program which could reduce the growth rate of industrial metal usage. However, in Q4 of 2013, the global economy, particularly the Eurozone, showed signs of recovery, which seems to continue in 2014. This will likely have a positive impact on global demand for zinc, which is expected to show robust growth of more than 5% in 2014.

Figure 9-2 Global Zinc Consumptions, 2013



Source: HDR, International Zinc Association

In HDR's opinion, urbanization and industrialization in developing economies like China and India will continue to drive global zinc demand. Global zinc consumption is expected to increase from the current level of 13.5Mt to reach 20.5Mt by 2025 (CAGR of 4.3%). Per capita zinc consumption is also expected to rise from the current level of 1.9kg to 2.4kg over this period.

Under a short- to medium-term outlook, global demand for zinc is expected to grow by around 5%, which is underpinned by continued growth of the Chinese steel sector and trend towards value added steels. Demand for zinc will be driven by its end use as a cost-effective anti-corrosive coating, improving the longevity of steel. Continued growth in the construction, transportation, and infrastructure sectors, especially in the developing economies, will correlate to solid demand for zinc in the medium- to long-term.

In 2013, Chinese zinc smelters increased their output by around 10%, mainly on account of decent demand and slightly higher smelter treatment charges. This may extend well in 2014 as global refined metal markets are in deficit while the zinc concentrate market is in surplus. This will also be driven by growing use of galvanized sheet in the automobile sector against the painted sheets.

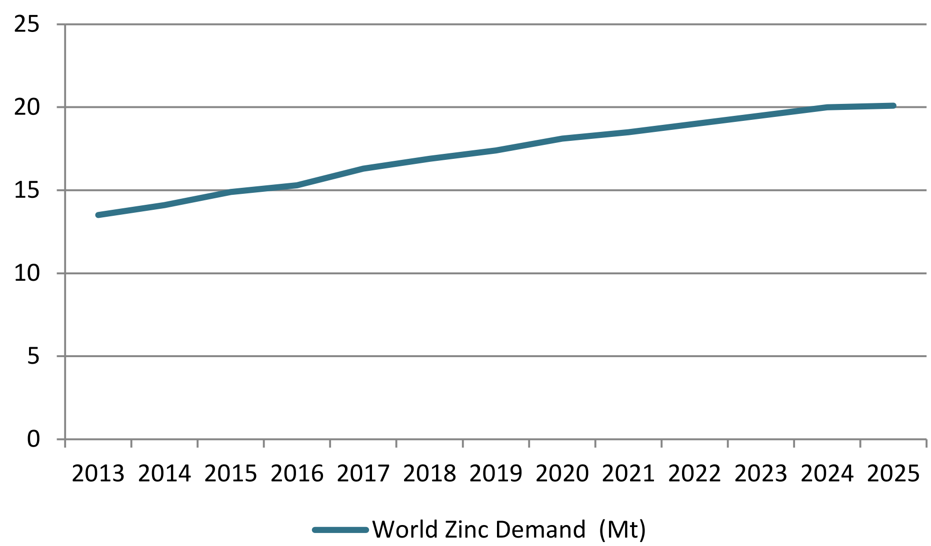
Although vehicle production growth is forecasted to slow down, this will not necessarily be reflected in the demand for galvanized sheet from China's automotive sector. Currently, vehicles produced by Chinese car makers typically contain one-third the galvanized steel of comparable models produced in Europe and North America.

Under a long-term outlook, growth in Chinese zinc consumption is expected to moderate, and by 2025 it is expected to reach to 11.5Mt from the 2013 level of 6.1Mt of zinc (a CAGR of 6.55%).

The United States is on the course of its economic recovery and is poised to post good economic numbers in 2014. The United States demand for zinc is expected to be driven by the construction sector — both residential and non-residential. In the medium- to longer-term, the outlook for U.S. non-residential construction is encouraging and forecasted to grow at an average rate of 4% per annum over the period 2013-2016.

After almost 2 years of contraction, some signs of recovery in the Eurozone were evident during 2013. Economists forecast that the recovery in the Eurozone is on track and expected to extend through 2014. A substantial drop in steel production was registered in the Eurozone in the last 2 to 3 years. However, it is showing a sign of improvement as the economy expands further. The construction sector in the Eurozone is still contracting, albeit at a lower rate. In 2013, the rate of contraction for zinc consumption was estimated to reduce to a level of 0.2% and to reduce further in 2014. Overall growth in European zinc consumption is expected to remain lackluster. Figure 9-3 Global Zinc Demand Forecast (Mt) illustrates the global demand forecast for zinc.

Figure 9-3 Global Zinc Demand Forecast (Mt)

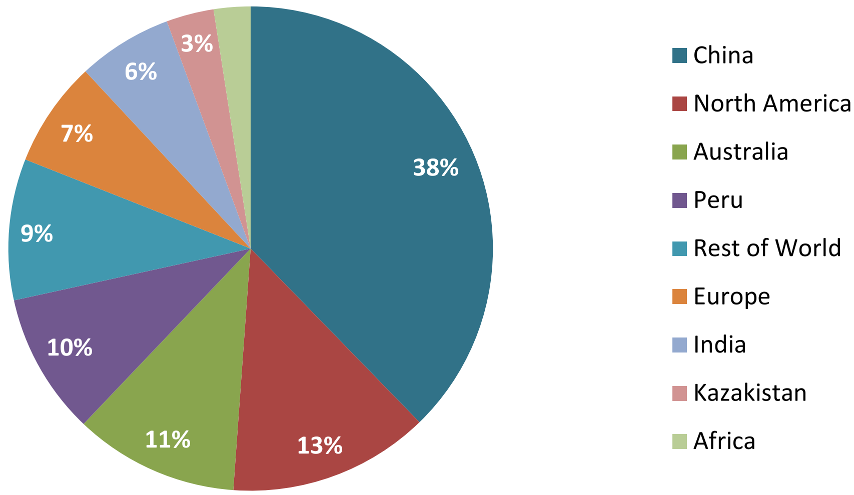


Source: HDR, International Zinc Association

9.3 Zinc Supply

China is the largest producer of zinc, producing 5Mt of zinc in 2013, followed by North America (Canada, United States, and Mexico), Australia, Peru, and India (Figure 9-4 Global Zinc Supply, 2013). Global zinc production for 2013 stood at 13.6Mt, almost balancing the global demand. In 2013, zinc production showed a moderate growth of 2% over 2012.

Figure 9-4 Global Zinc Supply, 2013



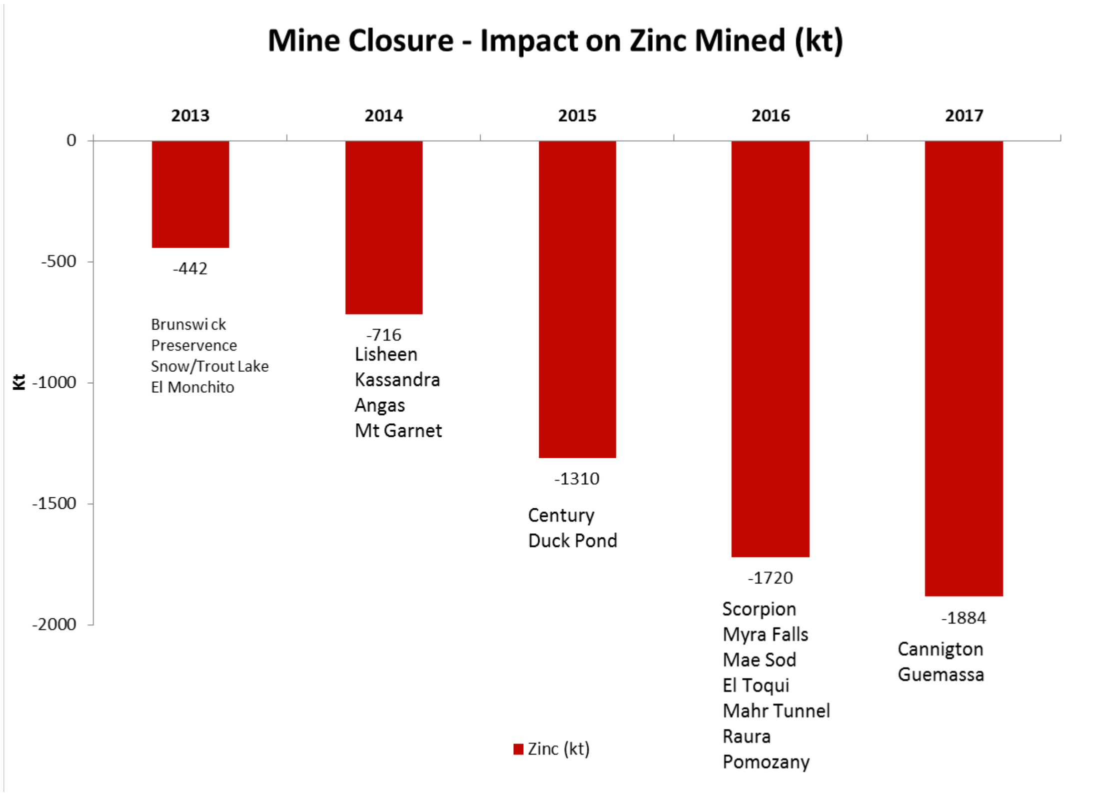
Source: HDR, International Zinc Association, ASX announcements

The slow growth of zinc supply has dropped the global stock level considerably as supply is unable to maintain pace with demand growth. This is reflected by the lower level of inventory present at the London Metal Exchange.

Moving forward, HDR believes that zinc supply is expected to tighten in the future with the market forecast to reach a significant supply deficit, given planned mine closures and a lack of major new development projects. In the short- to medium-term, a number of significant mine closures will limit zinc resources for the next several years. In early 2013, Glencore-Xstrata shut down its Canadian Brunswick and Perseverance Mine. Vedanta's Lisheen Mine in Ireland is also expected to close in late 2014 as reserves are depleted. MMG Century, the world's third largest lead zinc mine, is going to cease production because of depletion of its resources in early 2015.

Figure 9-5 Zinc Mine Closures exhibits the expected zinc mine closures in the next 5 years. The expected mine closures will reduce zinc supply by 1.9Mt, which is nearly 14% of the current global supply.

Figure 9-5 Zinc Mine Closures

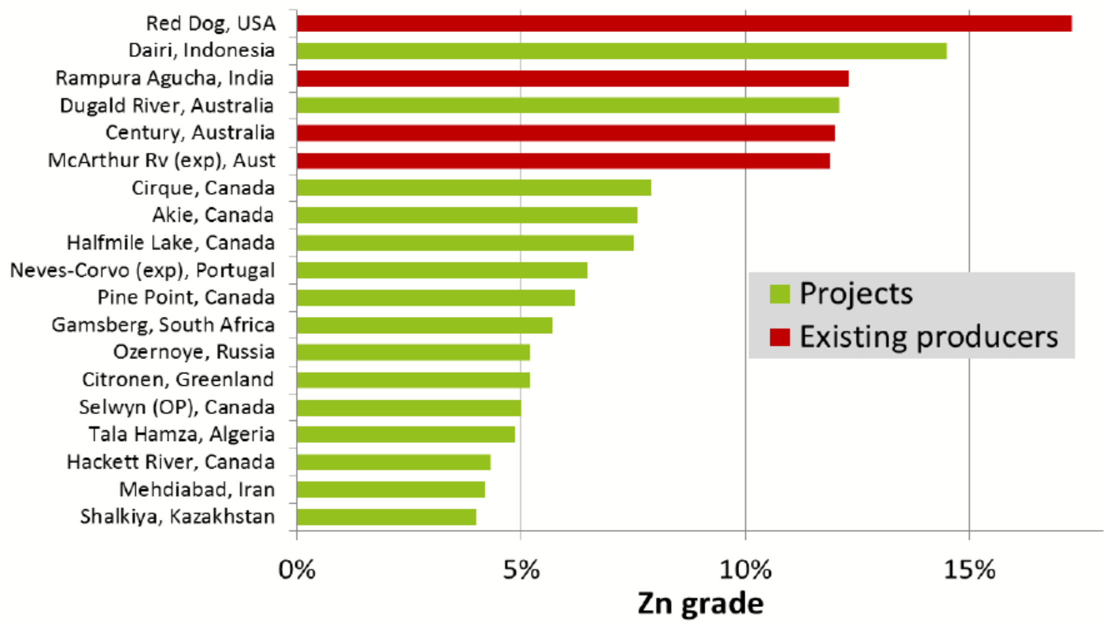


Source: HDR

In addition to significant expected mine closures, a dearth of new zinc projects are coming on-stream to replace lost production. In the early 2000s, because of low zinc and lead prices, investors were understandably less willing to invest in low return lead and zinc mine projects than in gold or copper projects where returns were potentially higher. Consequently, the pace of development of lead and zinc mine projects was slow. Project advancement came to a virtual standstill in the early 2000s, but with strong lead and zinc prices from 2005 to 2008 enthusiasm to develop new lead and zinc mines returned. The enthusiasm continues today, but the ability to actually advance the projects in a timely fashion is currently constrained by the availability of finance following the 2008/2009 financial crisis. Current explorers are still finding it extremely difficult to fund project advancement during this period of fragile global economic recovery.

Most of the new projects contain low grade zinc apart from Dairi (Indonesia) and Dugald River (Australia). Figure 9-6 Zinc Grade – Key Mines and Projects exhibits the expected zinc grade for potential zinc projects. Most of these potential projects are small in size with significantly lower grades and face relative uncertainty in attracting development funding. While they have higher grades, the Dairi and Dugald River projects face significant technical and environmental approval challenges.

Figure 9-6 Zinc Grade – Key Mines and Projects



Source: Presentation by MMG at International Zinc Association, 2014

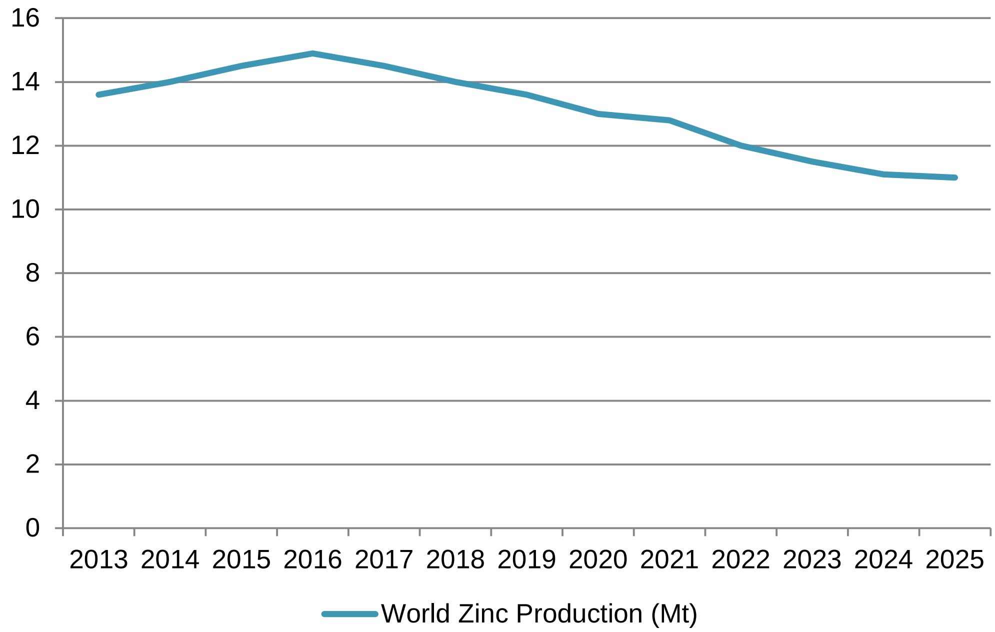
In 2013, China produced around 5 Mt of zinc, almost the same level as 2012. In HDR's opinion, zinc production in China is expected to remain at the same level moving forward, with production from existing mines expected to decline because of depletion of ore reserves and new projects coming online to replace the lost tons. However, it is unlikely that Chinese producers will register the same growth as in the recent past. This is because of the fact that the majority of new projects in China are smaller in size and contain lower grade ore. There also is limited scope for China to ramp up over the long term because of increasing cost and depletion of reserves. By 2025, the total zinc production in China is expected to reach 5.5Mt, a small growth of 0.5Mt in 10 years. In HDR's opinion, production of zinc from these small size mines in China is unlikely to be expanded further because of its low grade ores, relatively small size operations, increasing power, labor and higher environmental compliance cost.

Output from Europe is also expected to contract starting in Ireland with the closure of Lisheen Mine in 2014 and then again with the closure of Tara Mine in 2019. Similarly in Finland, a drop in production can be expected following the closure of Pyhasalmi Mine in 2017. In Sweden, Boliden Zinc is expected to shut down in 2021 which will be followed by closure of the Zinkgruvan Mine in 2022. The production loss is likely to offset by expansion of the Garpenberg Mine.

Output from Greece is expected to increase once the new Olympias Mine scheduled for start-up in 2016 comes online. Overall, in the long term (by 2025), Europe is expected to see a production drop of 3.75%, and total production is expected to be around 0.7 Mt of zinc.

Indian-based Vedanta Resources Plc, the world's largest zinc producer, is also likely to experience a significant drop in production as its Rampura Agucha open pit operations ceases production in 2018. This is one of the largest zinc mines in the world. Figure 9-7 World's Zinc Supply Forecast shows the estimated zinc production forecast.

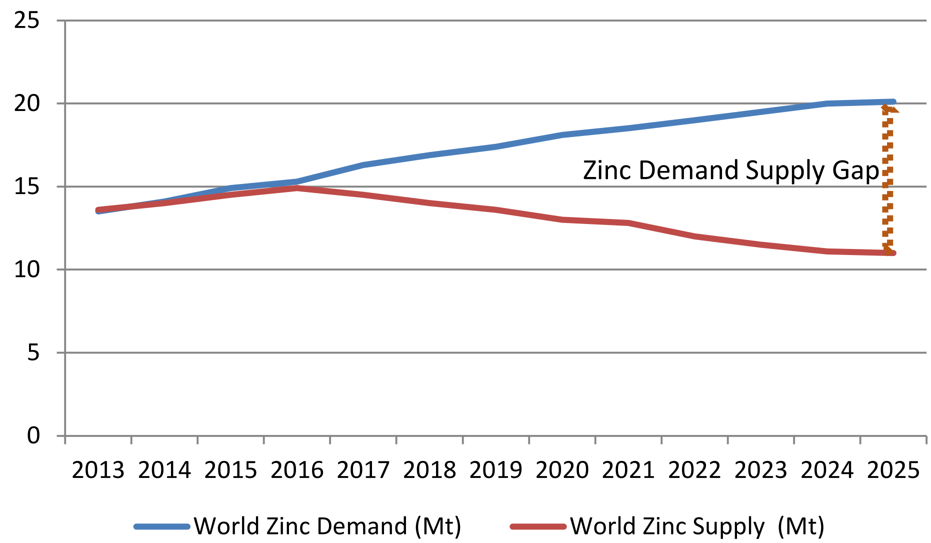
Figure 9-7 World's Zinc Supply Forecast



Source: HDR

Small incremental production is expected to come from reopening of closed pits, brownfield expansion of existing mines, and the development of some new projects. The lack of consolidation in the zinc industry is also one of the key reasons for the dearth of new projects. Overall, HDR expects a significant tightening in the supply side resulting in a deficit market. Figure 9-8 depicts the forecasted demand supply gap.

Figure 9-8 Zinc Demand Supply Forecast



Source: HDR

9.4 Zinc Price Outlook

The long-term outlook for the zinc market is dominated by the structural issue of whether mine supply growth will be able to keep pace with consumption growth.

Global zinc consumption is forecast to grow at a compound average annual rate of 3.5% p.a. with per capita zinc consumption increasing from the current level of 1.9kg to 2.8kg over the long term. The robust demand for zinc, along with the closure of existing mines, are likely to put upward pressure on zinc prices, resulting in increased prices in the short-to medium-term. In HDR's opinion, any price increase is expected to remain modest in 2014, but the widening demand supply deficit associated with the depletion of some of the major zinc mines from 2015 onwards will provide a clear signal to the market and a sharp rise in price may be expected.

The supply deficit is likely to intensify in 2016 and 2017 because the reduction in mine productions from mine closures may not be able to be offset by anticipated new mine output from development projects which pending finance. This will also stimulate the depletion of inventory and may put further pressure on prices, with prices expected to reach a cyclical high in 2018 before new mine projects starts kicking in. Long-term prices are anticipated to be higher than the current prices to compensate for lower ore grade in potential mining projects and higher capital costs to develop these mines.

The majority opinion of industry experts is that zinc prices are likely to improve from current levels as the demand for the metal is expected to remain strong while supply is expected to decrease in the absence of significant new projects. Table 9-1. Zinc Price Outlook in Nominal Dollar ($/tonne) summarizes the price outlook for the zinc provided by various industry experts and brokers. This data was collected by Consensus Economics Inc. in February 2014.

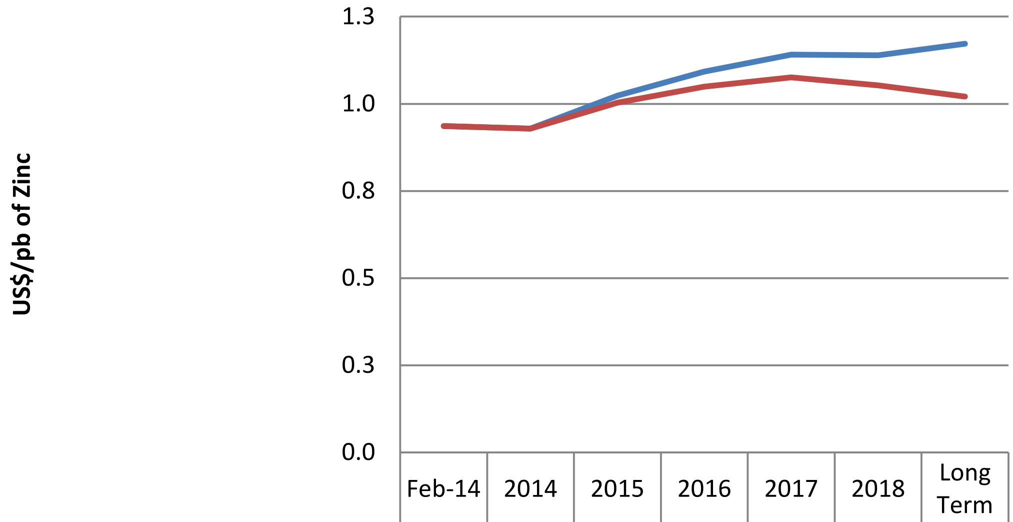
Table 9-1. Zinc Price Outlook in Nominal Dollar ($/tonne)

Parameters	2014E	2015F	2016F	2017F	2018F	Long Term (2019-2023)
BoA Merrill Lynch	2159	2500	2357	NA	NA	NA
UBS	2205	2315	2205	2315	2425	2425
BNP Paribas	2150	2650	NA	NA	NA	NA
Scotiabank	2158	2976	3307	3417	3307	3307
Barclays Capital	2138	2400	NA	NA	NA	NA
Credit Suisse	2100	2375	2500	2750	2658	2658
Commonwealth Bank	2056	2426	2703	2784	2838	2838
Liberium Capital	2039	2094	NA	NA	NA	NA
Euromonitor International	2094	2290	2486	2710	2968	2968
Wilson HTM	2094	2271	2381	2469	2403	2403
ANZ	2056	2284	2276	2235	2207	2207
Morgan Stanley	2127	2331	2425	2469	2579	2579
Macquarie Bank	2000	2251	2401	2350	2350	2350
Econ Intelligence Unit	2009	2179	2303	2425	2535	2535
CIMB Group	2056	2237	2287	2175	2200	2200
Investec	2039	2205	2370	2480	2425	2425
Societe Generale	2040	NA	2200	2300	2400	2400
CPM Group	2052	2166	NA	NA	NA	NA
BIPE	1984	2143	NA	NA	NA	NA
IHS Economics	2007	2145	2256	2354	2456	2456
China Int'l Capital Corp	1958	2199	NA	NA	NA	NA
Oxford Economics	2003	2066	2136	2205	2276	2276
RBC Capital Markets	1984	2205	2756	3307	0	0
Numis	2036	2011	2069	2121	2177	2177
HWWI	1940	2100	NA	NA	NA	NA
Capital Economics	1953	1980	2200	NA	NA	NA
BREE	1928	2177	2333	2421	2489	2489
Prometeia	1964	1902	NA	NA	NA	NA
Average (US$/t)	2159	2185	2407	2516	2511	2511

Source: Consensus Economics Inc., Feb 2014

To estimate the long term price for the Lik Mine zinc, HDR adopted an average of these forecast prices as an indicator of long-term benchmark prices. The future price forecast, as provided by Consensus Economics, is given in Figure 9-9 Zinc Price Forecast (US$/lb Zn). HDR assumed an inflation rate of 2% to determine real prices from nominal prices.

Figure 9-9 Zinc Price Forecast (US$/lb Zn)

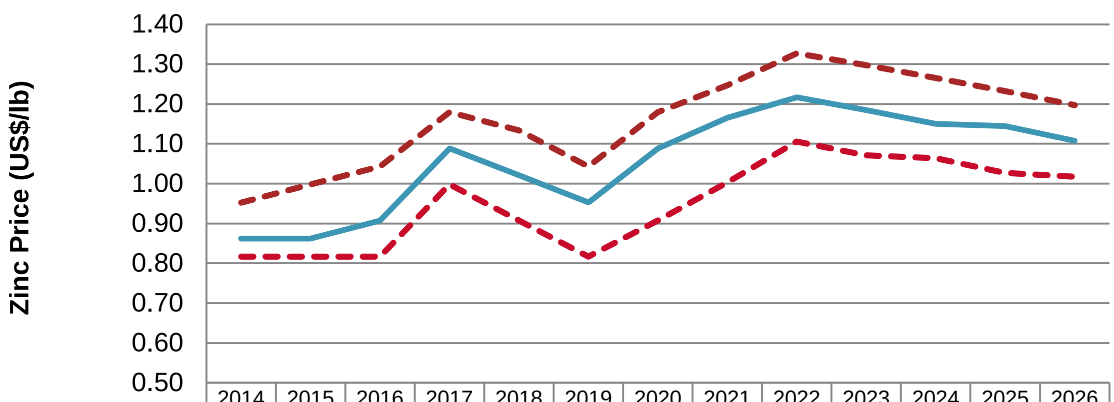


	Feb-14	2014	2015	2016	2017	2018	Long Term
Nominal Price ($/lb of Zinc)	0.94	0.93	1.02	1.09	1.14	1.14	1.17
Real Price ($/lb of Zinc)	0.94	0.93	1.00	1.05	1.08	1.05	1.02

Source: Consensus Economics

The Consensus Analysts and Brokers price forecast was compared with the zinc price forecast provided by CHR Metals Limited (CHR), which was prepared for the Alaska Industrial Development and Export Authority in December 2013. Figure 9-10 Zinc Price Forecast CHR, Nominal Dollars and Figure 9-11 Zinc Price Forecast CHR, 2013 US Dollars provides the CHR zinc price forecast.

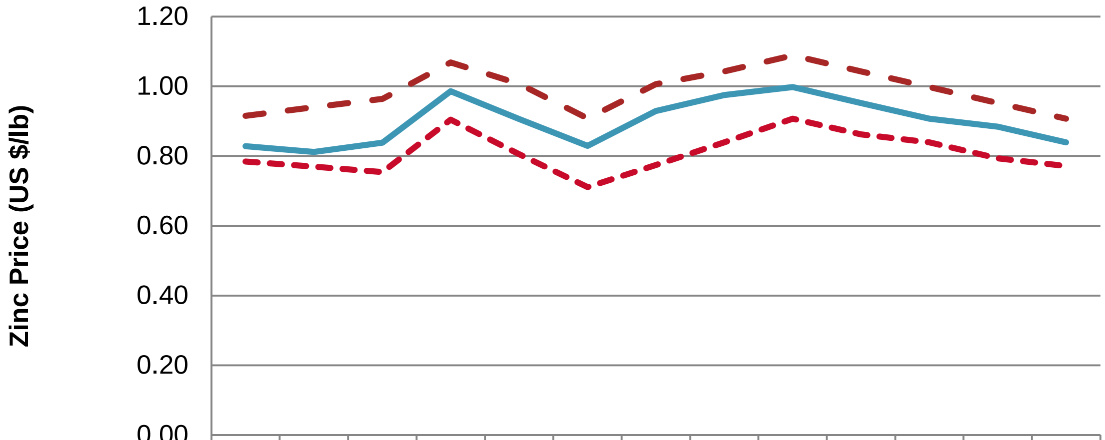
Figure 9-10 Zinc Price Forecast CHR, Nominal Dollars



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Base Case	0.86	0.86	0.91	1.09	1.02	0.95	1.09	1.17	1.22	1.18	1.15	1.14	1.11
Low Case	0.82	0.82	0.82	1.00	0.91	0.82	0.91	1.00	1.11	1.07	1.06	1.03	1.02
High Case	0.95	1.00	1.04	1.18	1.13	1.04	1.18	1.25	1.33	1.30	1.27	1.23	1.20

Source: CHR Metals Ltd, “Prospects for the Global zinc market to 2040” Note: zinc price forecast provided by CHR was converted into US $/lb basis.

Figure 9-11 Zinc Price Forecast CHR, 2013 US Dollars



	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Base Case	0.83	0.81	0.84	0.99	0.91	0.83	0.93	0.98	1.00	0.95	0.91	0.88	0.84
Low Case	0.78	0.77	0.75	0.90	0.81	0.71	0.77	0.84	0.91	0.86	0.84	0.79	0.77
High Case	0.92	0.94	0.96	1.07	1.01	0.91	1.01	1.04	1.09	1.04	1.00	0.95	0.91

Source: CHR Metals Ltd, “Prospects for the Global zinc market to 2040” Note: zinc price forecast provided by CHR was converted into US $/lb basis.

The price forecast provided by CHR shows an increasing trend until 2022, followed by a decreasing trend through the end of the project life. The price trend shown by CHR Metals and the Consensus Economics pricing of Zinc trends are consistent until 2018; however, they begin to differ with nominal pricing higher than real pricing after 2018 and long term.

Our review indicates that the long term zinc price forecast provided by Consensus Economics appears to be more appropriate to use since it includes a panel of industry experts comprised of banks, financial market participants and experts with experience in the relevant minerals markets.

HDR reviewed the price estimates for zinc in the economic analysis of the Lik Mine. The price outlook used in the Lik Mine PEA studies for zinc of $0.92/lb to $1.00/lb is well substantiated based on historical averages, spot zinc prices and known forward price curve. HDR found it consistent with the average broker’s price forecast for zinc. In HDR’s opinion, the zinc prices used in both scenarios are reasonable for a project at this stage of development.

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