CIM Estimation of Mineral Resources & Mineral Reserves Best Practice Guidelines

Prepared by the
CIM Mineral Resource & Mineral Reserve Committee
Adopted by CIM Council November 29, 2019

Canadian Institute of Mining, Metallurgy and Petroleum
Suite 1040, 3500 de Maisonneuve Blvd. West
Westmount, Quebec H3Z 3C1 CANADA
Tel.: (514) 939-2710
mrmr.cim.org | www.cim.org

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1. INTRODUCTION

The CIM Estimation of Mineral Resources and Mineral Reserves Best Practice Guidelines (MRMR Best Practice Guidelines) were prepared by the Canadian Institute of Mining, Metallurgy and Petroleum's (CIM) Mineral Resources and Mineral Reserves Committee (CIM MRMR Committee) to update an earlier version that was accepted by CIM Council on November 23, 2003 (CIM, 2003). These 2019 MRMR Best Practice Guidelines supersede and replace the November 23, 2003 version of the MRMR Guidelines.

These 2019 MRMR Guidelines are not intended to be prescriptive and are not intended to provide detailed and exhaustive instructions for preparation of Mineral Resource and/or Mineral Reserve (MRMR) estimates. Rather, they are intended as general guidance to assist professional geoscientists (or equivalent) and engineers (or equivalent) in preparing high quality estimates of MRMR that incorporate sound geoscientific, engineering, evaluation and design practices. They are based on well-established estimation and mine planning principles and are designed to provide general guidelines of best professional practices employed in the preparation of MRMR estimates. Although the 2019 MRMR Best Practice Guidelines are intended for use by Canadian-based mining/exploration practitioners, many of the concepts and practices presented herein are in general agreement with current industry practices in jurisdictions with membership in the Committee for Mineral Reserves International Reporting Standards (CRIRSCO).

For this document, persons preparing MRMR estimates are called Practitioners. Preparation of MRMR estimates should be carried out by Practitioners who either hold the status of Professional Geoscientist (or equivalent) or Professional Engineer (or equivalent), or who prepare the estimates under the supervision of a Professional Geoscientist (or equivalent) or Professional Engineer (or equivalent). For the purposes of this document, all references to reporting describe such necessary reports and related documentation that are created as part of the normal-course work flow of preparing MRMR estimates for internal purposes. For clarity, all public disclosure of MRMR estimates made by, or on behalf of, an issuer and intended to be, or reasonably likely to be, made available to the public in a jurisdiction of Canada must comply with the requirements of National Instrument 43-101 Standards of Disclosure for Mineral Projects (NI 43-101), as amended from time to time.

At least one Qualified Person (QP) must take responsibility for each part of the estimation process when publicly disclosing the results of MRMR estimates.

The intended audience for these 2019 MRMR Best Practice Guidelines includes Practitioners at all levels of skill and experience, government agencies, academic institutions, and the public.

2. HISTORY

On January 9, 2018, the CIM Council formed the CIM MRMR Committee, which is a combination of the previous Standing Committee on Reserve Definitions and the Best Practices Committee. Among others, the CIM MRMR Committee's mandate is to update the 2003 MRMR Best Practice Guidelines.

The new document was adopted by CIM Council on November 29, 2019 and supersedes the 2003 MRMR Best Practices Guidelines.

3. GENERAL GUIDELINES – MINERAL DEPOSITS

This document deals primarily with the description of best practice guidelines as they apply to the preparation of MRMR estimates for metalliferous and other deposits. The CIM MRMR Committee recognizes that preparation of MRMR estimates for certain commodities, deposit types, and recovery practices requires specialized estimation methodologies and considerations. Additional Best Practices Guidelines have been prepared for those commodities, deposit types, and recovery practices, and these are available on the CIM website at www.cim.org.

In planning, implementing, and directing any MRMR estimation work, Practitioners should ensure, to the extent practical, that the estimates are prepared using sound evaluation practices, sound estimation and scientific principles, and according to best mining practices. They should also ensure that the provisions of the CIM Definition Standards on Mineral Resources and Mineral Reserves adopted by CIM Council, as amended from time to time (CIM Definition Standards) and the CIM Mineral Exploration Best Practices Guidelines adopted by CIM Council as amended from time to time have been adhered to. These documents are updated on a periodic basis; thus Practitioners should consult the CIM website at www.cim.org to ensure that they are adhering to the current version.

In addition to assisting the Practitioners in the preparation of MRMR estimates, these 2019 MRMR Best Practice Guidelines are intended to promote quality of work with a broad consistency of form and content that will increase public confidence in the validity of publicly disclosed MRMR estimates. Practitioners should ensure that all main assumptions, methods, and procedures which were used in the preparation of MRMR estimates are disclosed using clear and concise language.

While Practitioners are encouraged to follow the concepts and principles presented within these 2019 MRMR Best Practices Guidelines, it is certain that some deposit-specific situations will be encountered that are not covered by the Guidelines. Where guidance has not been provided, the Practitioners should be guided by good scientific and engineering principles and conduct MRMR estimation such that they can support and defend their methodology to their peers.

4. THE MINERAL RESOURCE DATABASE

4.1. Introduction

This section considers important factors in the creation and maintenance of a Mineral Resource Database (Database) and other information (e.g. photographs, topographic surfaces, digital imagery, and excavation models) used to prepare Mineral Resource estimates.

A Database consists of two types of data, primary observed and measured data, and interpreted data. Primary data are features amenable to direct physical measurement. Common examples include geological attributes, assay results for various sample types, drill hole survey data, weathering state, core photography, etc. Primary data can also include excavation volumes, topography, mine production and processing plant information.

Interpreted data are derivations or interpretations based on the primary data. Examples are geological projections, correlation of mineralized intervals, depicted mineralization limits, and multiple estimation domains.

The Database is established by the collection, verification, recording, storing, and processing of the relevant primary geological and technical data that forms the critical foundation necessary for the estimation of Mineral Resources. The Database can include information collected from exploration stage properties, advanced properties, or from producing mines and hence can evolve over time.

The Database is a record of all the data collected throughout the work history of a mineral deposit and includes the dates when the work was conducted, observations relating to the work, and conclusions based on the results obtained. The Database should contain all of the information available to support current geological interpretations and modelling and should be easily accessible. It is essential that systematic recording of geological observations from field mapping, drill hole logging, and core photography be easily retrievable and stored in an organized and legible manner.

The Database may typically include information for such items as:

- geological data (e.g. lithology, mineralogy, mineralization style, alteration, structure, etc.),
- collar location/orientation,
- drill hole length,
- core or hole diameter,
- down-hole deviation survey data,
- topographic data,
- geophysical data,
- geotechnical data,
- geochemical data,
- geometallurgical data,
- sample types,

- assay data,
- assay method,
- quality assurance and quality control data,
- rock quality data,
- bulk density information, and
- activity dates.

Additional information can be added to the Database to suit the circumstances of specific situations.

Practitioners should evaluate the suitability of information in the Database for use in the preparation of the MRMR estimates; this evaluation includes examining data-input protocols and validating the database content. The utilization of a Database Management Protocol is recommended for the collection and addition of new information. The protocol should be designed to validate, store, and secure all data that is used in the preparation of Mineral Resource estimates. Verification of data within the Database should be undertaken to assure the accuracy, completeness, and suitability of the information for Mineral Resource estimation. In some cases, independent verification of the Database can be carried out.

4.2. Data collection, recording, storing and processing

It is recommended that the Database be maintained in an electronically-stored digital format using a documented, standard format and a reliable medium that allows for secure storage, access, documentation of any changes made to entered data, and easy and complete future retrieval of the data.

Guidance regarding standardization of digital data formats has been proposed by the Prospectors and Developers Association of Canada (2017). An additional example regarding standardization of digital data formats can be found in the guidelines prepared by the Australian Government Geoscience Information Committee (2017).

All primary data collected should be recorded even if it is not used for an MRMR estimate. All sampling, sample preparation, analytical procedures, and methodologies should be clearly described and a discussion provided for the choice of the particular methods used. Drill hole, channel sample, or other sample data acquired over multiple periods and by various workers should be verified and checked prior to entry into the Database.

Data records should possess unique identifiers (e.g. unique drill hole, zone and sample numbers, etc.). Distinctions should be made between samples collected by different methodologies (e.g. reverse circulation drill holes versus diamond drill holes, etc.) and an explanation should be provided on how these data sets are integrated.

The analytical methods and sample preparation procedures can have a major effect on the reported values and these should be documented. Original assay data should be recorded in the Database in the units of measure as received from the laboratory (e.g. large ppm values should not be reported as percentages). Analytical data should be converted into common units of measure, where possible. Original and converted values should be reported, including the conversion factor(s). Where multiple analytical data have been created from such activities as re-assaying of samples or by multiple analytical methods, a clear description must be provided of how the final analytical results used for preparation of Mineral Resource estimates were derived.

A series of Database management protocols that describe the standards, procedures, and security measures used to manage and update the Database should be prepared and maintained on a regular basis. The protocol should also include provisions for validating the accuracy of newly entered data, validation checks for ensuring that no unintended changes have occurred in previously entered data, and documentation of any changes or edits made to previously entered data. This protocol should be designed to validate, store, and secure not only analytical data, but all data as well as other technical and scientific information that is used in the preparation of Mineral Resource estimates. Duplicate, secure off-site storage of data is recommended, along with frequent backups of any digital data. An archived copy of the Database, documentation, and all support data that was used to prepare a Mineral Resource estimate should be assembled and stored for reference and audit purposes.

4.3. Bulk Density Measurements

The determination of the bulk density values for the deposit is as important a part of the MRMR estimation as determination of the volume or grade of the mineralization. Method(s) used to determine bulk density values should be described in detail and must account for any void spaces or cavities that may be present to avoid over-estimation of tonnage. Density values determined for materials such as drill cuttings or highly fractured materials must have their porosity satisfactorily taken into account. Useful guidance on sample collection and preparation for bulk density measurement is given in Lipton and Horton (2014).

Factors such as mineralogy, weathering, primary alteration and moisture content can be highly variable and have significant control on bulk density. These factors should be considered by the Practitioner. For example, where Mineral Resource estimates are to be prepared on an in-situ, dry bulk tonnage basis, it is important to document the nature and spatial distribution of the moisture content.

The number of measurements required depends on the variability of density within each material type for any given mineral deposit; direct measurement of the bulk density for each sample assayed is preferred. The bulk density of waste rock material that may be mined should also be determined.

In certain cases, the density of a sample can be estimated using a formula that relies on the chemistry or the mineralogy of the sample. The data and methods used to derive such a formula should be clearly documented. The accuracy of the formula used to estimate the bulk densities should be demonstrated by comparison of the calculated values with the corresponding measured values. In cases where the error can be quantified it could be included as a criterion of the resource confidence classification.

Pre-existing density measurements should be validated. Validation procedures include duplicating measurements, use of alternative procedures, or use of materials of known density. Monitoring the collection of density values and the application of quality control procedures is recommended as new data are collected. Additional discussion regarding collection of density information is provided in the CIM Mineral Exploration Best Practices Guidelines and the references quoted therein.

In all cases, it is important to document all sample collection and measurement procedures. Review and reporting of the results for all major material types is important in understanding the distribution of the density values for the materials included in a Mineral Resource estimate, including waste materials that will likely be mined. In cases where the initial data are modified (such as to address outlier sample values), the Practitioner should provide a discussion supporting all such modifications.

4.4. Quality Assurance/Quality Control

Quality Assurance and Quality Control (QA/QC) information must be considered and evaluated for all data used for MRMR estimation. Historical data require validation which may include, to the extent possible, re-locating the historical data in the field, and resampling and re-assaying of historical drill core or drilling samples and submission to a laboratory with certified reference materials. Historical drill hole data should be supported with newly completed drill holes and sampling. In this context, "historical" means data acquired by previous operators of the mineral property.

In general, a program of data collection should have quality control measures integrated into the normal sampling-subsampling analytical protocol. QA/QC protocols should include replicate analyses of appropriate standards and blanks and duplicate analyses of field samples, crushed sample material, and pulps. Regular monitoring of assays by an independent laboratory is considered as best practice. The results of the QA/QC program, a description of the pass/fail criteria, and the actions taken to address results that are outside of the pass/fail limits of the QA/QC program should be documented. Where an indirect analytical method is used the results should be validated with physical samples. The QA/QC programs should be structured to include all the grade attributes reported in the Mineral Resource statement and should also include evaluation of any deleterious elements. Where precision is quoted quantitatively the calculation method should be indicated clearly and the sample type (pulp, field duplicates, etc.) to which the precision applies should be stated.
The results from the QA/QC program should be reviewed and evaluated upon receipt so that any errors and discrepancies can be addressed in a timely manner. Discussions regarding QA/QC practices and procedures have been presented in Long (1998), Abzalov (2011), and Roden and Smith (2014).

4.5. Data Adequacy

Geological and sample information of suitable quality and completeness remain the foundation of Mineral Resource estimates. A key step prior to the commencement of a Mineral Resource estimate is the assessment of data adequacy and its representativeness of the mineralization to be modelled. While the contents of the Database are frequently collected by a number of individuals other than the Practitioners, the Practitioners have the primary responsibility of judging whether the Database is suitable for use in the preparation of Mineral Resource estimates. If the sample population size, quality, and spatial distribution of data are inadequate to determine the variability and distribution of the economically significant minerals, the Practitioners should estimate and state how much additional data may be needed before a Mineral Resource estimate can be completed.

The Practitioners should be diligent in ensuring that the Database fairly represents the primary information. Data verification is an essential part of determining whether the Database is suitable to support estimation of a Mineral Resource. Data integrity verification activities on such items as the accuracy of drill hole collars and sample locations, down-hole deviation, the accuracy and internal consistency of lithological and alteration data, and the accuracy and precision of analytical information should form an integral component in the construction/review of a Database. The Practitioners should carry out their own data verification activities on the Database to search for (1) factual errors, (2) completeness of the lithological and assay data (e.g. intervals with no information), and (3) suitability of the primary data. As part of the Database verification activities, the Practitioners are encouraged to examine assay information and certificates that are under the signature of an authorized individual. It is considered best practice to examine analytical information obtained directly from the analytical laboratory whenever possible.

A key step before relying on the Database for preparation of a Mineral Resource estimate includes reviews and personal inspection by the Practitioners of any geological and sample information that is used in the preparation of a Mineral Resource estimate.

The Practitioners should ensure that the available information and sample density allow preparation of a reasonable estimate of the geometries, tonnage, and grade continuity of the mineralization in accordance with the level of confidence established by the Mineral Resource categories in the CIM Definition Standards.

5. GEOLOGICAL AND MINERALIZATION INTERPRETATIONS

5.1. Introduction

This section outlines the requirements for the interpretation of geological and mineralization data, consideration of economic and mining criteria, and the application of that information to the grade distribution and volume component of the Mineral Resource estimate.

Interpretation of the deposit's geometry, geology, alteration, and structure, along with a clear understanding by the Practitioners of mineralization types, distribution, character, and controls forms the fundamental basis of a Mineral Resource estimate. **The preparation of a geologically sound interpretation that honours the sample data and the controls on mineralization is an important activity when preparing a Mineral Resource estimate.**

An understanding of the mineralogy and mineral assemblages, textural/structural character, and their spatial variations can be helpful in preparing geological interpretations. The data should be integrated into, and reconciled with, the geological interpretations as part of the estimation process. The interpretation should include the consideration and use of reasonable assumptions on the limits and geometry of the mineralization, mineralization controls, and internal un-mineralized or "waste" areas (e.g. barren dikes, sills, etc.).

In general terms, all primary data should be recorded in their entirety, in original form. For those cases where, in the Practitioners opinion, the primary data are deemed not of adequate quality for use in Mineral Resource estimation, the Practitioners must clearly explain their exclusion. The primary data should be analyzed in an unbiased, scientific fashion to develop a geological concept which forms the underlying premise upon which the geological and mineralization interpretations are developed. The geological concept should include consideration of the geological setting, analogous deposits, styles of mineralization, mineralogical characteristics, and genesis. The geological concept should also include consideration of such operational-related items as potential mining and processing methods. A conceptual operating scenario can then be developed.

Development of a conceptual operating scenario should be considered early in Mineral Resource estimation process. Clearly, this initial view is a forward-looking item that is formed by Practitioners based on their judgement, experience, and consultations with their colleagues. This initial conceptual operating scenario may evolve with time as new information becomes available.

An understanding of the possible mining methods, mineral deposit location, mineral processing methods, and potential product quality is necessary to ensure that the resulting Mineral Resource estimate is appropriate for the assumed physical and operational limits. For mineral properties that are currently in production, the selection of operational scenarios can be guided by the existing operations or can contemplate potential changes to the current operations.

For non-producing properties, the selection of conceptual operational scenarios requires assumptions appropriate for the deposit type, location, and available operational procedures for comparable deposits. It is acknowledged that the conceptual view is often required to be established at an early stage, using incomplete knowledge or limited testing results, and therefore requires application of judgement and experience of the Practitioners or Mineral Resource estimation team based upon all information available at the time. Practitioners are encouraged to consult with colleagues in other disciplines for guidance and assistance in establishing an appropriate set of initial parameters for a conceptual operational scenario. As the preparation of a Mineral Resource estimate is often an iterative process, Practitioners and their colleagues should periodically re-visit the assumptions and update the proposed inputs as more current and detailed information becomes available. Multiple estimates can be prepared for internal decision-making purposes to examine the sensitivity of alternate conceptual operational scenarios, but the Mineral Resource estimate will be prepared using only one conceptual operational scenario for final reporting to the public domain. Geostatistical conditional simulation methods can also be applied to quantify uncertainties in the resource models.

Information used to prepare geological interpretations can include surface or sub-surface information on geology at suitable scales (lithologies, mineralogical zones, structural data, alteration, etc.), topographical data, density information, a complete set of all available and verified sample results and surveyed locations of all sample sites (channels, drill samples, etc.), excavation models, weathering surfaces, geometallurgy, etc. This information is typically captured and stored in a Database as described above, or as a series of maps and sections in either digital or physical format, or in various digital formats.

Preparation of geological, alteration, and structural models should be developed to scales that are consistent within the regional and local context of the mineral deposit. Accordingly, it is important to have an understanding of the regional geology and property geology in relation to the style of mineralization under consideration, and structural controls on the mineralization.

5.2. Primary Data Visualization

Data collection and display must support the geological interpretation of the various mineralization styles of a deposit as a prerequisite for the Mineral Resource estimation process.

The important primary data (e.g., lithologies, assays, etc.) should be identified and accurately presented in three dimensions.

Where local mine coordinates are used on geological maps and sections, a procedure for conversion to universal coordinates should be provided as appropriate. Maps and sections should include appropriate grid coordinates, elevation, scale, date, author(s), and appropriate directional information such as a north arrow or viewing direction.

Data positioning information should be relative to a common property co-ordinate system and should include the methodology and accuracy used to obtain that information. Accurate location of data points is essential, and proper survey procedures and control systems must be established to ensure a high degree of confidence. If data points are located in relation to a particular map or grid reference system, those reference data should be included as part of the Database, the map properly identified and the coordinate system clearly stated. The details of the projection system used should also be described.

If primary data have been modified or intentionally omitted from the preparation of a Mineral Resource estimate, those data should be identified with an explanatory note for the modification or exclusion.

5.3. Geological Interpretation and Modelling

Understanding the relationship between the mineralization and the geological processes that resulted in its spatial distribution, geometry, and paragenetic history is a key concept in the preparation of a Mineral Resource estimate. A sound understanding of the applicable mineral deposit model(s) and a current understanding of the character of the mineralization for the deposit under consideration is a fundamental requirement of the Practitioners. This understanding can be greatly improved by input from individuals with direct personal knowledge of the deposit gained through mapping and core logging programs for development-stage properties, or through grade control programs in operating mines or advanced-stage projects. Personal inspection of the host geological units is also of great benefit to the Practitioners.

Preparation of digital three-dimensional lithological, alteration, and structural interpretations are often important for the Practitioners to understand the type, spatial location, distribution, and continuity of the mineralization under consideration. The geological limits within which the Mineral Resources are to be estimated must consider the three-dimensional distribution and continuity of the mineralization, along with any alteration, structural, or other relevant information. This information is typically viewed, interpreted, and depicted in plan, cross section, longitudinal section, or three-dimensional views. Digital models of the deposit's geological, alteration, weathering, and structural features should honour the informing data as closely as practical.

Practitioners traditionally have used explicit geological modelling techniques to create digital three-dimensional wireframe models. In more recent times, implicit modelling techniques have gained in acceptance. Practitioners are responsible for understanding the strengths and weaknesses of each technique when preparing wireframe models. In all cases, the final wireframe models must be examined to ensure that they are a reasonable reflection of the current understanding of the deposit's geological, alteration, weathering and structural features, do not contain unrealistic artifacts, and honour the informing data as closely as practical. Additional guidance in relation to the use of implicit modelling techniques is provided in Cowan et. al. (2014), Gradim et. al. (2014), and Haddow and Cowan (2014).

Viewing the resulting digital interpretations in at least two or more viewing directions is helpful to ensure that the digital interpretations are reasonable and internally consistent.

The geometallurgical characteristics, degree of weathering, and other secondary alteration associated with the mineralization often has important implications across the entire scope of the project from the drill recoveries to the metallurgical characteristics of the mineralization. Consequently, Practitioners should develop an understanding of how the type and intensity of weathering, alteration or the other physical and chemical characteristics may potentially impact on the other mining disciplines.

Digital models of the various types and intensities of weathering are often prepared as integral components of a Mineral Resource estimate. The selection of the criteria for the preparation of these weathering models is best accomplished by the Practitioners consulting with the logging geologists and individuals in the other disciplines such as mining, metallurgy and environmental. In general, digital models of the weathering surfaces should honour the informing data as closely as practical.

5.4. Mineralization Modelling

To the extent applicable, once the lithological model of the deposit has been established, three-dimensional models of the mineralization of interest can be prepared. Attention to detail is vital for early recognition of important features that control the spatial distribution, variability, and continuity of potentially economically significant mineralization. Personal inspection of the mineralization character by the Practitioners is a critical element in developing an understanding of the spatial distribution, variability, character, and continuity of the mineralized zones.

All interpretations of mineralization information within the deposit should be examined in three-dimensions to assess the continuity of the mineralization and reasonableness of the interpretations relative to available observation points such as drill holes, channel samples, or geological mapping information. Mineralized solids are often extended beyond the limits of supporting data to achieve a particular geological shape for modelling purposes. Interpreted mineralization models should honour the primary data as closely as possible and the Practitioners should be convinced of the geological continuity of mineralized intervals in three dimensions and be prepared to explain and defend their interpretations to their peers.

Different styles and geometries of a deposit under investigation should be identified and understood to allow the Practitioners to prepare acceptable three-dimensional models of the mineralized zones, correctly establish domains, and complete reasonable interpolation. Grade continuity can be variable from zone to zone and should be documented.

Mineralization outlines may be defined or limited by some combination of features such as:

- structure,
- lithology,
- mineralogy,
- degree of weathering,
- oxidation,
- alteration,
- timing of mineralization,
- elevation of the deposit top or bottom,
- metallurgical characteristics, or
- other relevant factors.

These controls should be described and used to constrain the interpolation of grade or quality within the Mineral Resource model as appropriate. An assessment of alternate interpretations can be carried out to evaluate the effect of the different interpretations on the resulting tonnage and grade estimates. When determining limits of mineralization, the Practitioners should recognize that mineral deposits can consist of more than one type of mineralization, consist of multiple mineralizing events, be telescoped, be controlled/influenced by different lithologies or structures, be overprinted by different mineralizing events, be affected by supergene processes, or be affected by weathering, all within a single deposit. The characteristics of each mineralization type may require adaptations of the modelling techniques and/or parameters to suit the specific segments of the mineralization.

When establishing criteria for interpretation of mineralized zones or domains, the Practitioners should consider potential controlling factors such as:

- anticipated mining method and mining rate,
- anticipated economic limits of the extraction (such as a grade, grade equivalent or a value parameter) and processing scenario under consideration,
- spatial distribution and continuity of the mineralization,
- continuity and distribution of the grade of the mineralization,

- spatial density and distribution of the sample information,
- pertinent geological features such as lithology and structure, and
- nature of the boundaries (e.g., sharp or gradational).

Assumptions concerning the spatial continuity of the mineralizing structures in the mineralization wireframe models should be reasonable, be supported by the direct geological evidence, and be consistent with similar deposits where the spatial continuity has been demonstrated. The parameters used for the construction of all mineralized wireframe models should be fully documented.

In all cases, the final wireframe models must be examined to ensure that they are a reasonable reflection of the current understanding of the mineralization, do not contain unrealistic artifacts, and honour the informing data as closely as practical.

For clarity, the use of a grade equivalent or a value parameter should be for the sole purpose of preparing the outlines of potentially economic mineralization. Subsequent grade estimations should be carried out for each grade element separately.

5.5. Estimation Domains

The identification of estimation domains is an important component to Mineral Resource estimation. The estimation domains should be defined based on geological and statistical characteristics. They subdivide a deposit into discrete volumes of rock with mineralization controls and statistical characteristics that result in a consistent distribution of the attribute being estimated (e.g. grade). The estimation domains can be based on a combination of geologic variables that have a relationship with the attribute being estimated. For example, the estimation domain can be defined by a combination of structural and oxidation controls on mineralization. The determination of estimation domains should be supported by a clear understanding of the controls on the mineralization, extensive statistical analysis (exploratory data analysis), and spatial autocorrelation studies. The geometry of the estimation domains needs to reflect the style of mineralization being modelled, and the operational constraints associated with the conceptual operating scenario selected for preparation of a Mineral Resource estimate. In multi element deposits different elements might be controlled by different geological characteristics, and they may require identification of a different sets of estimation domains. A sound definition of estimation domains is a critical aspect of mineral resource estimation

6. MINERAL RESOURCE ESTIMATION

6.1. Introduction

This section provides guidelines with respect to data analysis, sample support, model setup, estimation, and model validation. Estimation of Mineral Resources is best achieved by a multi-disciplinary effort that includes consideration of such topics as:

- land title issues,
- surveying,
- exploration techniques,
- geophysics,
- sampling theory,
- sample preparation equipment and methods,
- assaying equipment and methods,
- quality assurance and quality control,
- treatment of outlier values (capping),
- mineralogy,
- comminution characteristics and how they relate to geology,
- processing methods and how they relate to geology,
- deleterious elements or minerals and how they relate to geology,
- acid rock drainage modeling of waste rock,
- hydrogeology,
- permafrost,
- effects of weathering,
- strip ratios,
- geotechnical considerations and mining methods,
- selective mining unit sizes as they relate to geology,
- estimations of mine dilution and mine recovery,
- environmental and social considerations,
- application of cut-off and recovery formulas,
- geostatistical and geological knowledge, and
- grade estimation procedures.

A multi-disciplinary approach might involve geologists, metallurgists and mining engineers. For example, one person or team may be responsible for collecting the geological data, another person or team may be responsible for the metallurgical testing program, another person or team will deal with environmental issues, another person or team will deal with mining constraints, and another person or team may be responsible for preparing the Mineral Resource estimate. As a general principle, all parts of the Mineral Resource Estimation process should be documented to facilitate peer reviews and reproduction of the results to within reasonable limits.

Critical elements to a Mineral Resource estimate are:

- consideration of the appropriate geological interpretation,
- assumed mining method and mining rate,
- assumed mineral processing method and recoveries, and
- the application of reasonably developed economic parameters based on generally accepted industry practice, experience, and understanding based on deposit location, shape, and available testwork of rock characteristics, product recoverability and value.

The iterative nature of Mineral Resource estimation permits the Practitioners and team to re-examine any initial assumptions in light of the results and update them as deemed necessary. While innovation is acceptable in preparing Mineral Resource estimates, comparisons and validations with other established and tested methods are essential prior to publicly disclosing Mineral Resource estimates prepared using novel methods or approaches.

Transparent, concise, and comprehensive documentation of the various procedures used, assumptions made, and parameters selected is essential in preparation of a Mineral Resource estimate.

6.2. Exploratory Data Analysis

The Practitioner should use a comprehensive approach to, and appropriate methods of, exploratory data analysis to understand the statistical and spatial character of variables on which the estimate depends, to detect possible errors, and recognize any information that is useful for deposit model validation.

Such data analysis includes interrelationships among variables of interest, recognition of systematic spatial variation of the variables (e.g. grade, thickness, density, etc.), definition of distinctive domains that must be evaluated independently for the estimate, and identification and understanding of outliers. In particular, it is necessary to understand the nature and magnitude of the geological "nugget effect" (as distinct from the geostatistical nugget (C0)) and its impact on estimation. This is often a major concern for precious metal deposits and may be important in other types of deposits. Important decisions resulting from data analysis should be documented.

The Practitioner should examine whether un-sampled intervals, treatment of below detection limit and method over-limit values, evidence of multiple types of analytical methods, negative values, the presence of special characters (e.g. a "<" symbol), or other data artifacts and anomalies exist in the Database to assess their implications to resource estimation. Guidance on recommended sampling procedures can be found in the CIM Mineral Exploration Best Practices Guidelines. Where modifications to raw assay values are required (e.g. ounces per ton to grams per tonne, etc.), a clear description of the rationale and procedures used must be documented. Preparation and maintenance of a list of the changes or modifications to the raw assay information is recommended as good practice.

Data analysis can include a range of univariate, bivariate, and/or multivariate statistical procedures applied to data for each mineralization (or waste) domain. Results should be summarized in part by tables and diagrams that supplement the text and can include features such as statistical summaries (mean, median, standard deviation, etc.), and graphical summaries such as histograms, boxplots, probability plots, swath plots, scatter plots, quantile-quantile plots, relative differences plots, contact plots, variogram plots, regression analysis and various multivariate procedures such as trend analysis, multiple regression analysis (e.g. bulk density–metal relationships) and multiple variable plots (e.g. ternary diagrams). All diagrams should be accompanied by a caption and/or legend with adequate information to interpret the diagrams unambiguously.

In addition to basic statistical tools, examination of the raw assay data by visual methods is an essential component of data analysis and is often helpful in characterizing and understanding the spatial distributions of the various mineralized intervals. Visual methods can include traditional two-dimensional presentations in plan, cross section, or longitudinal views, or can be accomplished by three-dimensional means.

6.3. Outlier Values

Outliers, those small proportion of values inconsistent with the majority of the data, must be recognized and managed in the estimate because high value outliers can contribute to serious overestimation of global and local grades or values.

Recognition of the spatial extent of outlier values (a component of grade continuity) should be investigated and a procedure devised for incorporating such data appropriately into an estimate. Procedures including domaining, grade capping (also known as top cutting), spatially restricting the influence of high-grade assays, single and multiple indicator kriging, and Monte Carlo simulation methods all compensate in varying ways for potential overestimation. Regardless of the methodology selected, the Practitioners must provide documentation of the approach selected, along with justification and support for the decision possibly including reconciliation of estimated block model grades with available production information. Comparisons of the outcome of the different approaches can be useful.

Selecting an approach for treating outlier values is best carried out by reconciling the resulting estimated block model grades with production information. In the absence of production data, statistical methods and graphical methods may be used.

6.4. Sample Support and Compositing

Sample or data supports (size, shape, and orientation of samples) should be considered. Data for the Mineral Resource estimate generally are obtained with a variety of supports and statistical parameters that can differ substantially. If composites are used as a basis for estimation, the data should be combined in a manner to produce composites of approximately uniform support prior to grade estimation.

Selection of a composite length should be appropriate for the data, deposit, and conceptual operational scenario (e.g. bench or half bench height, dominant assay interval length, vein thickness). Commonly, compositing of samples is specific to a geological or mineralization domain, and composite samples do not cross domain boundaries. The methods and procedures used to prepare composite samples should be clearly described.

Preparation of descriptive statistics of the composited sample values is useful for evaluating the nature of the mineralization being modelled, estimating the accuracy of the compositing method by comparison with the descriptive statistics of the un-composited assay values, and evaluating the global accuracy of the estimated grades of the Mineral Resources.

Data declustering techniques to minimize the bias due to data clustering can be used to get an unbiased prediction of the global mean. This can be done through a declustered histogram in order to estimate unbiased grade tonnage curves.

6.5. Bulk Density Estimation

Estimation of the bulk density is a critical component in the preparation of an accurate tonnage estimate for both the mineralized volumes, and the adjoining non-mineralized or weakly mineralized material. Lithologies, weathering characteristics, alteration types and character, variations in ore mineral assemblages, and primary and secondary porosity all contribute to possible spatial variations in bulk density and require examination.

Bulk density can be integrated into MRMR estimates by use of average density values for a given geological or mineralization domain, estimation of bulk density values directly from sample data, and estimation of the bulk density values by means of a mathematical relationship with other variables such as grade(s) or gangue mineralogy. In all cases, Practitioners should include a clear explanation of the procedures used and why they are considered appropriate.

6.6. Topography and Excavation Models

The effective date and origin of the digital models of topographic surfaces or excavation pits used for MRMR estimates should be clearly stated in the supporting documentation, along with a description of the methods used in their preparation. For advanced stage properties, digital models of the current bedrock and topographic surface should be prepared to enable the proper coding of the grade block model.

For open pit mines, current digital models of the as-mined topographic surfaces should be prepared to enable the proper coding of the grade block model for that portion of the Mineral Resource that has already been exploited. In circumstances where material has been placed back into the open pit excavation, the Practitioners may deem it appropriate to include this information into the grade block model. The accurate determination of the bulk density of any pit back-fill or sloughed material is an important component of this task.

For underground mines, current models of all excavation voids in digital format should be prepared for coding into the grade block models. Many tools and approaches are available to collect, prepare and process this information, and Practitioners should be aware of the strengths and limitations of each when selecting the preferred method. In certain circumstances, either the grade or the bulk density of any stope back-fill or caved material is an important component of an estimate.

6.7. Trend Analysis

An understanding of the two-dimensional or three-dimensional distribution of metal grades or other parameters, or values throughout a mineral deposit can provide important information regarding metal zoning or spatial trends as well as aid in conducting autocorrelation studies. This understanding is facilitated by preparation of two-dimensional contour maps in either level or bench plan, longitudinal, or cross-sectional views using available analytical data contained within a selected mineralization or estimation domain. Preparation of fully rendered three-dimensional contours of the element contents is also useful. A description of the methods and parameters used to prepare any trend analysis maps, including identification of software used, is essential. The results should be carefully reviewed to ensure that the results are a reasonable reflection of the informing data points.

Evaluations of the local-scale distribution of the thickness of the mineralized zones are also of benefit to the Practitioners and their colleagues in the other disciplines. For horizontal or shallowly dipping deposits, the thickness is typically measured in the vertical direction. For dipping deposits, the thickness of the mineralized zones is commonly measured either as the true thickness (e.g. approximately perpendicular to the dip of the mineralization), or as the horizontal or vertical thicknesses. The resulting trend analyses should clearly state the basis of the thickness being presented. Where thickness of a mineralized zone is the variable under consideration, the nature of the thickness variable should be clearly stated (e.g., vertical, horizontal, or apparent thickness relative to a specified dip orientation).

Where evaluations of the grade times thickness product (commonly referred to as the GxT product) are completed, it is important to verify that contoured GxT maps are a reasonable reflection of the thickness of the mineralization because high grades can introduce significant bias. When preparing grade-thickness maps using drill hole information, the Practitioner should use true-thickness to prevent the significant bias which can result from the use of apparent thicknesses.

6.8. Spatial Autocorrelation Studies (Measures of Spatial Continuity)

In practice, both semivariograms (variograms) and correlograms are common spatial autocorrelation functions used to quantify average grade continuity in 2D or 3D space; parameters of both are widely used in defining data selection criteria for block estimation and are essential to geostatistical estimation procedures. Spatial variability of grade can differ significantly among deposit types and within different zones of the same deposit. Autocorrelation modelling of this variability has become a standard step in Mineral Resource estimation that commonly is assisted by the preparation of contour maps for the element or value under consideration. Practitioners should ensure that data abundance, appropriateness, and spatial distribution are adequate to produce acceptable experimental variograms/correlograms to which models can be fitted with confidence. These variograms/correlograms should be developed using data selected within carefully designed exploratory data analysis envelopes. Parameters (e.g., nugget effect, ranges, anisotropy) of these models are the basis of critical decisions in the estimation procedures and must be consistent with established geological features. Behaviour of the spatial autocorrelation function near the origin, which impacts block model selectivity analysis, should be fitted by an appropriate mathematical equation.

Outlier grades are a complicating factor in establishing spatial autocorrelation models to be considered by the Practitioners, as are variations of the informing data from a simple tabular arrangement.

In cases where locally varying anisotropies are present (such as in folded stratigraphy or in areas of faulting), consideration should be given to a coordinate transformation to reconstitute the data and account for the spatial correlation on a pre-deformation or pre-faulting basis prior to the spatial autocorrelation studies.

The results of spatial autocorrelation studies should be documented along with a description of all parameters of the model(s), and should specify the conventions used for the anisotropy rotation angles (e.g. left- hand or right-hand rotation around respective axes). Well-labeled diagrams are particularly useful in this regard. The commercial software version used should be specified. Where non-commercial software has been used, adequate descriptions must be provided.

Additional guidance on the preparation of autocorrelation models can be found in Srivastava and Parker (1988), Isaaks and Srivastava (1989), Sinclair and Blackwell (2002), and Rossi and Deutsch (2014).

6.9. Mineral Resource Block Models

The estimation work flow (i.e. the series of procedures that are carried out for the development of a resource block model) adopted for the preparation of a resource block model should include consideration of the distribution of the informing data, along with the size, distribution, and geometry of the mineralized zones, all of which must be compatible with the anticipated mining method(s) and related equipment. The modelling work flow will be influenced by the anticipated end use of the Mineral Resource estimate. Estimates of global mean grade and overall tonnage may suffice for early-stage projects, whereas, for advanced stage projects, or producing properties, the objective could be to prepare a Mineral Resource estimate which will be suitable for short to medium range planning. The Practitioners must select appropriate estimation method(s) or techniques for the resource model. Estimation methods include polygonal, nearest neighbour, inverse distance to a power, various kriging approaches (e.g. ordinary kriging, simple kriging, and multiple indicator kriging), conditional simulation, and other non- linear estimation methods. The choice of method(s) should be based on the geology, the attribute/variable being modelled, quantity and spatial distribution of data, complexity of grade distribution within the deposit, presence of high-grade outliers, results of reconciliation studies for projects with production histories, and the anticipated end use of the Mineral Resource block model.

The choice of estimation techniques to be employed is dependent to a degree on the size and geometry of the deposit and the quantity and spatial distribution of available data. Simple geometric methods can be acceptable in some cases (e.g. early stage deposit definition) or for some deposit types (e.g. potash and coal). Three-dimensional modelling techniques may be more appropriate for more spatially complex deposits. In some cases, different estimation techniques might be necessary for different parts of the deposit.

The block size used in a block model is dependent on features including the geometry of mineralization controls, mining method, drill hole and sample spatial distribution, and anticipated grade control method. A change in either cut-off grade or value or mining method(s) can necessitate the development of new or updated block models and perhaps require additional sampling. Block sizes should be justified and a summary of the block model size, origin and limits, model orientation, sub-blocking parameters, and list of attributes or variables modelled should be documented. The possible loss of critical geological and assay details through smoothing inherent in the selection of estimation parameters should be considered. General validation of the block model against original data, degree of “smoothing”, and expected mining selectivity is required to ensure reasonableness of the interpolated results. This entails internal dilution modelling as a consequence of predicting block model grade at a different volume than the volume of the original data. This is generally done using the "volume – variance" or change of support correction

A clear description of the data conditioning procedures undertaken and the search strategies employed in preparing estimated attributes, including grades within the block model, is considered best practice. The Practitioner should ensure that the selected estimation method is documented adequately and should not rely solely on the computer software to produce a comprehensive document or report "trail" of the interpolation process. At the Practitioners discretion, detailed estimation runs covering representative areas of the block model can be prepared to confirm the proper implementation of the estimation parameters and procedures. Once confirmed, the estimation parameters and procedures can then be applied to the entire block model.

6.10. Resource Block Model Validation

6.10.1. Validation of Global and Local Estimates and Model Selectivity

Practitioners should ensure that the final resource block model is consistent with the primary data such as the geology and mineralization wireframe models, structural models, topography and excavation surfaces and volumes, and the analytical data that were used to prepare estimates of the modelled attributes. The validation steps could include:

- comparison of volume estimates between the block model and the three-dimensional wireframe models,
- visual inspection of interpolated results on suitable plans and sections and comparison with the informing data,
- check for global bias (comparison of interpolated and nearest neighbour or declustered composite statistics), by estimation pass, by domain, by resource category, etc.,
- check for local bias considering the supporting information (analysis of local trends in estimates using, for example swath plots),
- checks to ensure the boundary conditions between estimation domains are honoured, and
- a change of support check using such models as affine correction, indirect lognormal correction, and discrete Gaussian model to introduce the desired resource model selectivity (degree of smoothing in the estimated model).

Also, validation of all or part of a digital grade block model could be completed manually. Additional guidance in carrying out global and local estimation validation can be found in Isaaks and Srivastava (1989), Sinclair and Blackwell (2002), and Rossi and Deutsch (2014).

6.10.2. Reconciliation Studies

For Mineral Resource block models of deposits that have had mine production or are currently being mined, the validation should include a reconciliation of production against the Mineral Resource model, to the extent that reconciliation data are available and are in a format suitable for comparison purposes. These reconciliation studies are useful in evaluating both the long-term and short-term accuracy of the data collection, sample collection, preparation and analysis procedures, and modelling procedures and parameters used to prepare a Mineral Resource block model. A number of methods and techniques exist for reconciling mine and process production information with a Mineral Resource model. Descriptions of these methods have been presented by Morley (2014) and Hargreaves and Morley (2014). While selection of appropriate reconciliation methods resides with the Practitioner, the method or methods used should be described in detail, along with the results. Two principle types of reconciliation studies are used to validate a Mineral Resource block model.

6.10.2.1. Long Term Model vs. Short Term Model

The goal of the first type of block model reconciliation study is to compare the performance of block models prepared using only results from exploration drill hole data (LT models) with the performance of block models prepared using all information, including all results collected from grade control programs (ST models). The information used to prepare ST models typically includes information collected from chip/channel samples, blast hole samples, or detailed grade control drilling programs in addition to the results from exploration programs.

The purpose of this type of reconciliation study is to examine the LT model for its accuracy in predicting the tonnage, grade, and metal content of the mineralized material at various time intervals. A discussion of the procedures followed for this type of reconciliation study is provided in Parker (2014). This type of reconciliation provides information regarding the adequacy of the exploration drill hole spacing and the modelling parameters and procedures.

In all cases, it is important to ensure that the mineralized material being evaluated is comparable between the two models. The location of the mineralized material in the LT model commonly is different when compared to the ST model due to the increased density of sample information that was not available for the LT models. Consequently, the Practitioners must take into account this potential difference when conducting reconciliation studies.

A LT model vs. ST model reconciliation study can be carried out to include various time intervals ranging from monthly to the total production of the mine from inception. The results of the reconciliation study can be presented in either tabular or graphical formats for the time period under consideration. Inclusion of a variance analysis is commonly presented in graphical displays of reconciliation, and to establish thresholds for acceptable levels of variance.

Long Term Model vs. Plant Production Data

A typical approach in this type of reconciliation is to compare the performance of the LT models against information obtained from the process plant. The purpose of these studies is to examine the accuracy and effectiveness of the sample collection procedures, sample reduction and analytical protocols, and Mineral Resource estimation procedures and parameters. A discussion of the procedures followed for this type of reconciliation study is provided in Parker (2014). It is important to understand that several important items must be considered in these situations before any studies can be carried out:

- Material excavated from the block model is not necessarily the source of the process plant feed in the time period studied, since many mining operations employ stockpile strategies. In these situations, a clear understanding of the flow of materials is important in preparing a meaningful reconciliation study. Preparation of a material flow diagram is often of great assistance.

- The Mineral Resource model presents the estimated tonnage and grade of the mineralized material on an in-situ basis, with no allowances for dilution or mining losses. The material received by the processing plant on the other hand includes diluting materials and does not include mining losses. Care must be taken to ensure that any tonnage and grade reports prepared from the Mineral Resource block model for reconciliation purposes have adequately accounted for any diluting materials and mining losses to the extent possible.

- Information obtained from the block model should be compared to the plant feed data rather than the plant production data.

The preparation of a LT model vs. process plant reconciliation study can be carried out at different time periods ranging from monthly to the total production of the mine from inception. The results of the reconciliation study can be presented in either tabular or graphical formats for the time periods under consideration. Inclusion of a variance analysis is commonly presented in graphical displays of reconciliation, whereby thresholds for acceptable levels of variance are established.

6.11. Mineral Resource Classification

Mineral Resources are classified into three confidence categories, Measured, Indicated, and Inferred. These terms are defined under the CIM Definition Standards. Since each Mineral Resource estimate contains its own unique set of conditions, the selection of the criteria by which the Mineral Resource is assigned to each category relies on the judgement and experience of the Practitioners. In selecting these criteria, the Practitioners must have a clear understanding of the practical limitations of the conceptual operating scenario. Important considerations of the classification criteria are spatial aspects including continuity of grade, and the locations, types, and spatial density of the informing data. The confidence category selection should consider uncertainty and risk existing in the Mineral Resource estimate.

With many computer-based estimation methods, the criteria used for separating the Mineral Resource into the confidence categories can rely solely on numeric-based parameters that are included with individual blocks along with the estimated grades or values. Examples of such numeric-based parameters include:

- the number of data points used for estimating the grade or value of a given block,
- the number of drill holes or drill hole composites used,
- the estimation pass (and underlying assumptions) used to estimate a given block,
- the kriging variance or standard deviation of the block estimates,
- the slope of regression of the "true" block grade on the "estimated" block grade (Vann, Jackson, and Bertoli, 2003),

- the relative distance from a data point based on the range of the selected variogram model,
- the assessment of relative confidence in grade / tonnage estimation, i.e. geostatistical drill hole spacing studies (Froidevaux, 1982, Deutsch, Leuangthong, and Ortiz, 2007, and Verly, Postolski, and Parker, 2014),
- proximity to nearest drill hole,
- average distance to drill holes,
- median distance to drill holes, and
- combinations of the parameters described above.

While the advantages of a numeric-based, automated approach can be rapid implementation and reproducibility, the approach can result in a solution that, while being mathematically correct, may not resemble what can be achieved practically during a mining operation. Furthermore, the outcomes may generate difficulties when preparing Mineral Reserve estimates. Typical outcomes were presented in Stephenson and Stoker (1999) and Stephenson et. al. (2006) who coined the phrase “spotted dog” to describe examples of this phenomenon.

The use of numeric-based criteria should be viewed merely as the first step in the Mineral Resource confidence classification process. Practical solutions to remedy the “spotted dog” effect include preparation of resource categorization wireframes which are then used to modify and refine the initial numeric-based classification. While this approach allows the Practitioners to exercise judgement in situations where only a limited number of cases must be addressed, the method is not of practical use when a large number of cases must be evaluated. In these situations, the use of computer functions, known as “categorization smoothers”, designed to reduce the impact of the “spotted dog” phenomenon may be considered.

In addition to numeric-based parameters, it is important to consider the relative confidence of all of the data inputs during the assignment of the resource confidence category. Additional criteria can include:

- the reliability of the drilling data,
- reliability or certainty of the geological and grade continuity, geological model interpretation, structural interpretation, and the assay database,
- reliability of inputs to assess reasonable prospects of eventual economic extraction and cut- offs (e.g. metallurgical testwork, geotechnical data, ability to obtain permits, social acceptability, etc.), or
- legal and land tenure considerations.

Regardless of which criteria or methods are used, they should be documented in sufficient detail so that the results are reproducible by others.

Classification of material into the Measured, Indicated, or Inferred categories need not apply solely to material within mineralization wireframe outlines. Depending upon the end use of a Mineral Resource model, classification of materials outside of the mineralization wireframe boundaries (e.g. for the diluting materials) might also be required.

In addition, for those Mineral Resource models which will be used in preparation of Mineral Reserve estimates, Practitioners are encouraged to collaborate with mining engineers preparing the Mineral Reserve estimates to select estimation parameters that are compatible for each groups' requirements. To the extent possible, Practitioners are encouraged to conform the Mineral Resource classification parameters to the practical limits of the potential mining methods (e.g. matching up Mineral Resources category boundaries to mining levels, stope edges, or zone boundaries, where reasonable to do so).

6.12. Mineral Resource Statements

By definition, a Mineral Resource must have "reasonable prospects for eventual economic extraction". Regardless of the specific approach used or the procedures followed, the Practitioners must ensure that all Mineral Resource statements satisfy the "reasonable prospects for eventual economic extraction" requirement.

- Factors significant to technical feasibility and potential economic viability must be considered and clearly stated when preparing Mineral Resource statements. These will include such items as:
- the size and legal conditions of the land tenure sufficient to fully enclose the Mineral Resource,
- the extraction selectivity for the mining methods under consideration relative to the size and geometries of the mineralization interpretations,
- the processing method under consideration, the expected recovery from the mined material to a commercially marketable product and the proposed production volume,
- the price/value of the product and the market for the product at that price, and
- the factors significant to cut-off grades or values (e.g. process recovery, smelter payability, treatment charges, operating costs, royalties, etc.) used for reporting of Mineral Resource estimates.

For a Mineral Resource, factors significant to technical feasibility and economic viability should be current, reasonably developed, and based on generally accepted industry practice and experience. The assumptions should have a reasonable basis, be clearly defined, and should reflect the level of information, knowledge and stage of development of the mineral property at the time. Tonnage and grade figures should be quoted only to the level of accuracy and precision of the estimate.

6.12.1. Economic Parameters

Cut-off grades or values used for preparing Mineral Resource estimates are largely determined by consideration of:

- reasonable long-term commodity price(s) or contracted prices,
- exchange rate(s),
- mineral process recovery, and
- operating costs relating to mining, processing, general and administration, and smelter terms, and royalties, among others.

Additional considerations include:

- deposit location,
- deposit scale,
- geologic and grade continuity,

- assumed mining method,
- concentrate quality (where applicable),
- environmental and social considerations,
- metallurgical processes, and
- waste disposal costs.

All assumptions and sensitivities should be clearly identified. Additional guidance on selection of appropriate commodity prices for use in cut-off grade or value estimates is provided in CIM (2015), as amended from time to time.

Variations of rock characteristics, metallurgy, mining methods, processing methods, etc. within the Mineral Resource model may necessitate more than one cut-off grade or economic limit for different parts of the deposit. All the inputs for each cut-off grade or economic limit should be clearly reported.

6.12.2. Constraining Surfaces and Volumes

Open Pit Mining Methods:

For Mineral Resources that are amenable to open pit mining methods, the "reasonable prospects for eventual economic extraction" should consider not only an economic limit (such as the cut-off grade or value), but technical requirements as well (such as the wall slope angles). At a minimum, the constraints can be addressed by creation of constraining surfaces (pit shells) using either commercial software packages or manual methods. The constraining surfaces can then be used in conjunction with other criteria for the preparation of Mineral Resource statements.

For properties with currently producing operations, the derivation of the input parameters for the constraining surfaces can be determined using factual operational data. For properties that are in the discovery or study stage, the input parameters are best determined using first principles. All input parameters for constraining surfaces used in the preparation of Mineral Resource statements should be fully documented.

Underground Mining Methods:

For Mineral Resource estimates which are prepared on the assumption of underground mining methods, Practitioners should carefully review the results of all Mineral Resource estimates that utilize the application of an economic limit (such as a cut-off grade or value) only, because reliance on an economic limit alone may produce undesired results due to a selective reporting bias. Mineral Resource statements for underground mining scenarios must satisfy the "reasonable prospects for eventual economic extraction" by demonstration of the spatial continuity of the mineralization within a potentially mineable shape. In cases where this potentially mineable volume contains smaller zones of mineralization with grades or values below the stated cut-off (sometimes referred to as "must take" material), this material must be included in the Mineral Resource estimate.

At a minimum, these constraints can be addressed by creation of constraining volumes. Constraining volumes should be used in conjunction with other criteria for the preparation of Mineral Resource estimates. For properties with currently producing operations, the derivation of the input parameters for creation of the constraining volumes can be determined using factual data from the current operations. For properties that are in the discovery or study stage, the input parameters are best determined from first principles that are consistent with the conceptual operating scenario. All input parameters, methods, and techniques should be fully documented when preparing Mineral Resource statements.

In many cases where the Mineral Resource estimate is prepared by digital methods, isolated and discontinuous blocks may be present that have grades or values above the stated cut-off grade or value. For underground mining methods, these blocks should be excluded from the Mineral Resource statement if their spatial continuity or their size is insufficient to achieve a potentially mineable shape above the nominated cut-off grade or value.

Preparation of images of the classified Mineral Resources is an effective tool used by Practitioners to ensure that the spatial continuity requirements of a Mineral Resource are met. For steeply dipping tabular deposits, these images are most effective when presented as longitudinal views. Plan views, cross-sectional views, or inclined views are also effective in other geological settings. When preparing statements of the Mineral Resources, Practitioners are encouraged to include images that display the spatial continuity of the Mineral Resources. As a minimum, the images should include a display of all blocks comprising the Mineral Resource estimates, including confidence categories, along with the location of all informing sample data, and any other relevant information used to prepare the Mineral Resource statements. All figures should contain suitable legends, scale bars, and annotations disclosing the viewing directions.

6.13. Mineral Resource Peer Reviews

Best practice includes the use of internal or, if required, external peer reviews of the Mineral Resource estimate prior to release of the Mineral Resource statement to the public domain. Considerations of the review should include:

- suitability of the drill hole and sample database,
- appropriateness of analytical methods and sample representativity,
- appropriateness of the geological domains, mineralization wireframes, and estimation domains,
- appropriateness of the volume/tonnage of the mineralized zones
- treatment of outlier assay values,
- sufficiency and reliability of inputs, and underlying assumptions, including the selective mining unit,
- estimation methodology,
- resource model validation and selectivity,
- Mineral Resource confidence category criteria,
- Mineral Resource reporting criteria, and
- Mineral Resource statement and accompanying footnotes.

6.14. Mineral Resource Risk Assessment

While the classification of the Mineral Resources into the Measured, Indicated, or Inferred categories allows Practitioners to identify technical risk in broad terms, best practice includes identification and ranking of risks associated with each input of the Mineral Resource estimate. The methodology applied, ranking, and analysis should be well documented. One approach is to use a quantitative measure of uncertainty related to a production volume over a given time period, accompanied by a probabilistic confidence statement. The goal is to assist Practitioners in establishing the Mineral Resource confidence category criteria, thus providing an understanding of the various technical risks associated with the Mineral Resource estimate. Information regarding some approaches used to estimate risk is provided in Verly, Postolski, and Parker (2014) as well as Murphy et. al. (2004).

7. MINERAL RESERVE ESTIMATION

7.1. Introduction

Estimation of Mineral Reserves should be a team effort involving a number of technical disciplines, with geologists, mining engineers, metallurgists, and specialists dealing with commodity pricing and marketing, environment, social, permitting, and economic modelling all having roles. This section considers important factors in preparing a Mineral Reserve estimate and documenting the estimation process.

Mineral Reserves are estimates of the tonnage and grade or quality of material contained in a Mineral Resource that can be economically mined and processed. To be considered a Mineral Reserve, modifying factors must be applied to the Mineral Resource estimate as part of the preparation of a prefeasibility study (PFS) or a feasibility study (FS) as outlined in the CIM Definition Standards. The estimated amount of saleable material contained in the final product must demonstrate a positive Net Present Value (NPV) using an appropriate discount rate, and must demonstrate that eventual extraction could be reasonably justified. The major categories of modifying factors include:

1. mining,
2. processing,
3. metallurgical,
4. environmental,
5. location and infrastructure,
6. market factors,
7. legal (including land tenure and third-party ownership),
8. economic,
9. social, and
10. governmental.

A Mineral Resource estimate and a mine plan based on open pit and/or underground mine designs, and production schedules within at least a prefeasibility study are required to support a Mineral Reserve statement. A processing option for the production of a saleable product is also required, along with product recovery estimate(s) and capital and operating costs to mine and process the mineral/material of interest and deliver the product to a market that can absorb the proposed volume without disruption. Because a Mineral Reserve estimate often requires a collaborative effort by numerous professional disciplines, the Practitioners responsible for producing the Mineral Reserve estimate must understand the significance of each discipline's contribution towards assessing the technical feasibility and economic viability of the project.

The test of economic viability should be well documented as part of the Mineral Reserve estimation process. The demonstration of economic viability requires estimation of after-tax annual cash flows and the project's NPV and inclusion of all the parameters that have an economic effect on the project. As a minimum, the NPV must be positive using a reasonable discount rate appropriate for all project risks, in order for the grade and tonnage to qualify as a Mineral Reserve.

The Mineral Reserves are estimated from the Measured and Indicated portions of the Mineral Resource estimate. Inferred Mineral Resources must not be converted to Mineral Reserves.

Practitioners should document all aspects of the estimated Mineral Reserves to ensure that no significant factor is omitted. Pre-planning is important to identify the factors affecting the Mineral Reserve estimate. For a Mineral Reserve estimate, checklists can be used to ensure that all relevant aspects have been considered.

7.2. Cut-off Grades or Values

The concept of a cut-off grade or value is a fundamental component in the preparation of Mineral Reserve estimates, mine designs, and mine production schedules. The cut-off grades or values applied should be clearly stated, unambiguous, easily understood with documentation on what is included in the calculation. Sample calculations should accompany these cut-off grades or values. Complex deposits may require more comprehensive procedures to determine economic cut-off grades or values and to define the Mineral Reserves. The procedures used to establish the cut-off grade or value strategies should be well documented, easily available for review, and clearly stated in reporting statements.

A cut-off grade or value is defined as the grade or value that is used to differentiate between ore and waste for a given set of conditions, parameters and time frame. As such, the criteria and processes by which a cut-off grade or value are determined will often be different between mineral properties, for different situations within a given mining operation, and at different times.

A large variety of cut-off grade definitions and cut-off grade strategies are employed in the mining industry. The concepts and strategies used to calculate cut-off grades have been discussed in Lane (1988), Rendu (2008), and Hall (2014). Given the large number of situations in which a cut-off grade or value is applied, clarity and documentation are of the greatest importance when defining, describing, and stating a cut-off grade or value.

7.2.1. Cut-off Grade or Value Definitions

While a detailed review of all of the definitions of cut-off grades or values and cut-off grade strategies is beyond the scope of these MRMR Best Practice Guidelines, some of the more commonly used terms and definitions include:

Break-Even Cut-off Grade: The lowest grade or value of material that can be mined and processed at an operating profit, considering all applicable costs. It can be used as a first estimate in the early mine planning phases of a project. The break-even cut-off grade or value assumes that the material does not have to be mined to access other above cut-off material and classifies this material as ore or waste.

Mine Design Cut-off Grade: Also referred to as the planning cut-off grade or value, the mine design cut-off grade or value is used to prepare initial mine designs. The input parameters are selected to reflect the average Life-of-Mine values or parameters. For underground mines, these are typically calculated on a breakeven cut-off grade or value basis. For open pit mines, these are typically calculated on an open pit discard cut-off grade basis, but a breakeven cut-off grade basis can also be applied. For development stage properties (properties for which Mineral Reserves are being estimated as part of a PFS or a FS), estimation of the input parameters will be based on an envisioned operating scenario. For producing properties (active mines), the input parameters can be based on the current operating parameters, or they can consider the technical and economic parameters for any expansion projects.

Mineral Reserve Reporting Cut-off Grade: Used to prepare the Life-of-Mine schedule and reports of the Mineral Reserves. The technical and economic parameters can be identical to those used to derive the mine design cut-off grade, or can be more conservative.

Optimal Mineral Reserve Cut-off Grade: Used to identify the maximum value from an initial Mineral Reserve statement and Life-of-Mine plan. The optimal Mineral Reserve cut-off grade reflects the corporate strategy which can include such goals as:

- maximization of a project’s NPV or achieving a target economic goal,
- maximization of a project’s mine life;
- controlling the metal or value production through a project’s mine life,
- controlling the distribution of a project’s cash flow through time, or
- maximization of contained metal or value in the Mineral Reserve category.

Open Pit Discard Cut-off Grade: The lowest grade or value of material in an open pit mine at which all costs, excluding mining costs, are equal to the revenue received. The open pit discard cut-off grade assumes that the material must be excavated, as it is contained within either the pit shell or designed pit outline.

Operational/Marginal Cut-off Grade: Used on a short-term basis in both open pit and underground mines to consider the technical and economic conditions at the time of excavation. The operational cut-off grades can vary from those used to prepare the Life-of-Mine plans or the Mineral Reserve statements.

The basis for these cut-off grades or values can consider current metal prices, sunk costs, appropriate variable costs, material destinations, and equipment capacities. These cut-off grades or values apply only to material which must be excavated due to the normal course workflow of the mining operation.

Open Pit Stockpile Cut-off Grade: The lowest grade or value in an open pit mine below which the material is destined to be placed in a temporary location for potential treatment at a later date or using an alternative process. The open pit stockpile cut-off grade or value assumes that the material must be mined either within a Life-of-Mine open pit design or at the operational stage. The basis for establishing this cut-off grade or value can include either economic criteria or strategic objectives and should include estimated re-handling costs.

Underground Incremental Cut-Off Grade: The lowest grade or value of material in an underground mine at which all costs, excluding mining costs, are equal to the revenue received. The underground incremental cut-off grade or value assumes that the material forms part of the Life-of-Mine design, must be excavated, and must be transported to the surface. The final destination of this material can be either the processing plant, or a stockpile. The underground incremental cut-off grade or value can be applied either at the planning stage, or at the operational stage.

7.2.2. Cut-off Grade Inputs

The types of input costs will depend on the mining methods and processing methods selected. A summary of operating costs generally used in cut-off grade calculations is presented in Table 7-1. These operating costs are commonly expressed on a per-tonne of processed material basis, however other cost basis can be used. It is important to note that these operating cost inputs represent items that are commonly encountered in open pit and underground mines and are presented as guides only. Additional inputs are possible depending on the specific circumstances of the operations under consideration. It is important to note that these cost types are general descriptions of the common work types encountered in mining operations. They are not intended as a comprehensive list, as a detailed listing of all specific work types for all mining situations is beyond the scope of these Guidelines.

Metal price assumptions, foreign exchange rates (where applicable), metallurgical recoveries, and the relationship between recovery and head grades are critical input parameters for determination of cut-off grades or values. Guidance regarding the selection of metal prices for use in the preparation of Mineral Reserve estimates has been presented in CIM (2015), as amended from time to time. Additional inputs are possible depending on the specific circumstances of the operations under consideration.

Table 7-1 Summary of Typical Operating Cost Inputs in Cut-off Grade Calculation

Cost Centre	Work Type
Underground Mines:	Payroll costs including burdens Stope costs (drilling, blasting, mucking, and ground support) Haulage transportation and hoisting Pumping, electrical & ventilation Backfill Waste and ore development Planning, grade control, supervision, and technical
Open Pit Mines:	Payroll costs including burdens Drill and blast costs Loading costs, haulage costs, and dewatering costs Planning, grade control, supervision, and technical Equipment and infrastructure maintenance Sampling and assaying
Processing:	Payroll costs including burdens Plant maintenance, including contracted services Crushing and grinding consumables and power Mineral recovery process consumables, fuel, and power costs Product dewatering, handling and shipping costs Tailings storage, effluent treatment, and monitoring costs Sample and analytical laboratory costs Effect of grade on product recovery and processing cost
General and Administration:	Site G&A Business unit G&A, as applicable Other cash costs
Royalties:	Government mandated Surface and mineral title holders Contractual

7.2.3. Net Smelter Return and Metal Equivalents

In many types of deposits, the value of mineralized material results from the extraction and sale of more than one metal (e.g. copper and gold). Two methods are widely applied in the mining industry to address the polymetallic nature of such deposits. These include the use of a metal-equivalent or the calculation of the Net Smelter Return (NSR). For the NSR method, the dollar value that each metal contributes towards the total value is calculated and is expressed as one value referred to as the NSR value. The calculation of an NSR value considers revenues, metallurgical recoveries, smelter deductions, treatment charges, penalties and transportation costs for all metals of potential economic interest. This NSR value can then be used to derive a cut-off value, where the NSR cut-off value is then the dollar value of a given sample or block that equals the total operating costs, as appropriate. Additional guidance on the calculation of an NSR value can be found at Queen's University (2016) and the references therein.

It is important to note that the calculations of NSR values will vary substantially depending on such inputs as the commodity type, treatment and refining methods and rates, penalty terms, contract terms, transportation details, etc. A sample NSR calculation is provided in Goldie and Tredger (1991).

In some cases where there are multiple elements in the deposit that contribute to the deposit value, a one-commodity equivalent calculation is sometimes used as the cut-off grade or value. In this approach, all the grades for the various commodities are converted to an equivalent metal grade by consideration of the metal prices and recoveries. The calculation of equivalent cut-off grade or value is based on a formula developed by the Practitioners. This formula, and the parameters used for its development, must be clearly stated. The metal-equivalent grades are then used as the cut-off grades to estimate the Mineral Reserves.

7.3. Mining Methods

The location, size, shape, orientation (dip), and physical properties of a mineral deposit generally determine the selection of the appropriate mining method. In general terms, deposits located on or close to the surface are usually considered as candidates for use of open pit mining methods. Deposits located deeper below the earth's surface are generally considered for application of underground mining methods. At an early stage of the Mineral Reserve estimation process, various mining methods should be considered for mining the deposit. The advice of rock mechanics specialists should be included when selecting an appropriate mining method. In many deposits more than one mining method may be required. A typical situation includes an initial use of open pit methods followed by underground methods for the deeper portions of a deposit. Several mining methods can be utilized in an underground mine to accommodate variations in the character of the mineralization.

In the case of an extension to an existing mining and processing operation, operating cost and production data are readily available to assist in selection of parameters for the preparation of a Mineral Reserve estimate. Some changes to operating cost estimates may be required if the mining or processing operation is to be modified or throughput changed. Capital costs for any changes will have to be built into the profitability analysis. For new deposits, the capital and operating costs are usually estimated from first principles or can be derived from benchmarked information from similar operations.

For those cases where a combination of open pit and underground methods may be required, a different cut-off grade or value will be calculated for each mining method. Where a blending strategy of various mineralization types is contemplated, a metallurgist should review the proposed strategy to determine if the blending strategy is technically and economically viable.

Practitioners may then assess proposed mining and processing scenarios at various production rates when estimating a Mineral Reserve. When appropriate, alternative mine and plant configurations should also be considered. This work may involve several iterations and will require input from other members of the team such as metallurgists or environmental specialists. Other studies may be required as a prelude to the completion of a PFS. Unlike a PFS, these preliminary studies are not sufficient to support the designation of the estimated tonnage and grade as a Mineral Reserve.

Practitioners should also ensure that the mining equipment selected is appropriate for the planned mining method and production rate. Inappropriate equipment selection may adversely influence both dilution and extraction factors. Practitioners must have a high level of confidence in the viability of the mining and processing methods considered in determining the Mineral Reserves.

Maximum mineral extraction with minimal dilution is usually the principal criterion for the mining method selected, tempered by economic considerations in the context of the Life-of-Mine schedule. Metallurgical recoveries applied should be based on process test work which should establish the relationship between process plant feed grade and the recovery of the commodity of interest and operating costs. Any mixing of waste in feed to the mill circuit may affect the recovery or operating costs and this possibility should be considered during metallurgical testing.

7.3.1. Open Pit Mining Methods

The pit shell that defines the ultimate pit limit, as well as internal phases, is usually derived using open pit optimization algorithms; however other methods that do not require pit shells can also be used. These methods include direct block scheduling and stochastic simulation. The information stored in the Mineral Resource model, including grades, block percentages, material density, slope sectors, rock types, and NSR values, are imported into the optimization software. The optimization process for declaration of a Mineral Reserve is carried out using Measured and Indicated Mineral Resources only to define the optimal mining limits. The optimization process includes various pit shells which are defined according to different revenue factors. To select the ultimate pit limit, an analysis of incremental pit shells can carried out to evaluate the contribution of each consecutive pit shell to NPV at a constant processing plant capacity.

Optimization results from each of the shells are analyzed independently to select a final pit shell to use for preparation of the final pit design, along with any starter or phase pit selections. The objective of the final pit shell is often to maximize grade and project NPV; other objectives can also contribute to the selection of a final pit shell. To determine the optimum pit shell, cash flow analyses are performed considering the sequence of mining for all the nested pit shells.

The final pit design is based on the final pit shell selection, which is used as a guide for detailed pit design on a bench-by-bench basis. The final pit designs include all benches and berms and all haulage ramps. The ramp design criteria can include maximum gradients and design widths for traffic flow, safety berms, water table, and drainage.

7.3.2. Underground Mining Methods

Important parameters in the selection of the underground mining methods may include:

- minimum mining width, height and length,
- pillar sizes and location,
- ground support type,
- sequencing considerations,
- geological/structural considerations,
- equipment selection,
- ventilation and air quality,
- geotechnical considerations, and
- health and safety considerations (e.g. heat exposure).

A detailed discussion of all possible mining methods in all possible situations is far beyond the scope of these MRMR Best Practice Guidelines. Many reference sources are available on the topic, including the SME Mining Engineering Handbook (2014).

Representative drawings of the planned stopes should be included to clearly demonstrate the methodology being used and how well the planned stopes conform to the shape of the deposit. Dilution assumptions and calculations should be outlined.

Technical analysis of the rock properties (rock mechanics) should be reviewed and recognized during the mine design process.

For those cases where both open pit and underground mining methods are proposed, an analysis of the various possible scenarios is required to identify the most preferred option for the transition of mining methods. The open pit and underground Life-of-Mine designs are then prepared from the optimized mining shapes of the most favourable scenario.

7.4. Geotechnical, Hydrogeological, and Hydrological Data

Geotechnical and hydrogeological data are an important input to the engineering design for both surface and underground mines. Soil and rock quality can have a significant effect on surface and underground mine design and on the location and siting decisions for process plants, hoists and shafts, and, perhaps most importantly, tailings impoundment facilities and waste rock storage areas (RPM Global, 2015).

Geotechnical and groundwater conditions have a major influence on mine design and related infrastructure, and specific investigations are necessary to establish appropriate design parameters for each application (Whitham, 2014). Seismic activity and other natural hazards or environmental conditions in the area should also be considered.

7.4.1. Geotechnical Investigation

The type of proposed mine development and infrastructure should determine the nature and extent of the geotechnical investigation. Key aspects are the scale and required stability of the structure, and the following items need to be considered:

- site conditions,
- mine development,
- tailings management facilities,
- waste rock storage and earthworks,
- surface infrastructure, and
- mining induced seismicity.

Geotechnical data may be gained from drilling programs, excavations and/or trial mining where the goals are to confirm the accuracy of the key assumptions, including the underlying geology, presence and character of major discontinuities, rock mass strength, and hydrogeology. Additional discussion and information are presented in Sullivan (2014).

7.4.2. Hydrogeological and Hydrological Investigation

Hydrogeological and hydrological investigations are required to identify any major aquifers, assess the likely water balance, and evaluate potential impacts on open pit wall slopes, underground design, and production rates.

Where groundwater is considered a risk to extraction, a specific investigation is required to establish the characteristics of the site hydrogeological domains and their response to mining.

In the design and operation of open pit mines, two principle factors should be considered: groundwater quantity and location within the operations areas, and the influence of groundwater pressures on the stability of pit walls, pit floor, and in-pit waste dump or waste rock storage area.

For underground mines, groundwater inflows during operations are usually handled by the mine pumping system; however, there are situations where additional infrastructure and expenses are required, especially wherever significant aquifers or high permeability units are close to operations.

For both open pit mines and underground mines, it is important to evaluate the groundwater chemistry and the acid generation potential of the rock since this will determine if mine water can be used in the process plant or, if it is to be discharged to the environment, what treatment it will require.

Surface water studies include collection of rainfall and catchment data to provide flood predictions and define drainage requirements for the mine site and infrastructure, and are used in water balance analysis for process and mine waste engineering.

7.5. Mine Designs

Mine planning and preparation of mine designs and schedules form the basis of Mineral Reserve estimation. Mine planning requires a thorough understanding of the mineral deposit, rigorous standards and processes, robust and useful information technology, and skilled people. Life-of-Mine planning is key to identifying the strategic direction for any mine, and short-range mine planning is key to forecasting and budget expectations. Geotechnical design criteria are typically the primary drivers for the design of the size and shape of all safe excavations. It is imperative that a rigorous mine planning review process be implemented to ensure that the design criteria are met. The feasibility and success of any mine plan is contingent upon the accuracy of the input assumptions. The level of detail and accuracy should increase as the mine plan progresses from the initial study level through the advanced study level to the operational stage.

The preparation of Life-of-Mine designs typically begins with the preparation of optimized surfaces or volumes for open pit or underground mines using either software algorithms or manual methods.

7.5.1. Optimization

7.5.1.1. Open Pit Mines

While manual methods are still used to prepare initial open pit outlines in rare cases, the majority of initial open pit shells are created using digital methods. Initial pit shells are developed by applying open pit optimization routines to the Mineral Resource block model. While several optimization routines are in use by the mining industry, the Lerchs-Grossmann algorithm is a common choice for creating optimized open pit surfaces (Lerchs and Grossmann 1965, Alford and Whittle 1986, Roditis 1993). These optimization routines can generate a series of preliminary surfaces that make use of specific technical and economic input parameters including:

- overall wall slope angles,
- metal/commodity prices,
- metal/commodity recoveries,
- operating costs, and
- royalties and streams (as applicable).

The selection of input parameters for open pit optimization runs should be supported by all available relevant, factual data. Where factual data are not available, estimated/assumed values can be derived based on comparable situations. The limitations of the available data must be acknowledged when classifying material into either the Proven Mineral Reserve or the Probable Mineral Reserve categories.

It is important to understand that the resulting surfaces represent a series of mathematical solutions based on the given input parameters. These surfaces are not based on the detailed technical and economic criteria that are required to prepare the final Life-of-Mine designs. Consequently, surfaces generated using open pit optimization software programs must never be used to prepare statements of Mineral Reserves, as they only act as a guide for preparation of the final Life-of-Mine design.

Validation of the results from any open pit optimization runs should be carried out. Practitioners are strongly encouraged to conduct all necessary and appropriate validation exercises in order to ensure that results from the optimization runs are mathematically correct and in general agreement with the expected outcomes.

7.5.1.2. Underground Mines

For preparation of Life-of-Mine design for an underground mine, the process typically begins by generating a series of potential stoping panels that satisfy a series of input parameters and features such as:

- continuity,
- cut-off grade or value,
- geometry,
- geotechnical parameters,
- ground conditions,
- minimum mining width,
- maximum stope height,
- maximum stope length,
- minimum dip,
- maximum panel-to-panel change in strike and dip,
- variation in the strike and dip of the mineralization, and
- ground conditions.

Selection of a preferred mining method (or combination of mining methods) is required to complete this work. Initial stoping panels can be created by using either manual or digital methods.

As the shapes, locations, geotechnical characteristics, and metallurgical characteristics of the mineralization can vary within a given deposit, it is important for Practitioners to understand how these changes may affect the initial stoping panels including mining losses and dilution. The input parameters should then be varied and adjusted to accommodate for changes in the spatial, geometric, and metallurgical characteristics of the mineralization as appropriate.

When using digital methods, Practitioners should realize that the resulting potential stoping panels are a simple mathematical solution based on a given set of input parameters. They do not necessarily satisfy the complete technical and economic viability requirements of Mineral Reserve statements. As a result, mining shapes generated using any underground optimization software programs should never be used alone to prepare estimates of the Mineral Reserves without inspection, validation, and review, as they only act as a guide for preparation of the final Life-of-Mine design.

The selection of input parameters for preparation of underground stoping panels should be supported by all available relevant, factual data. Where factual data are not available, estimated values can be derived based on comparable situations. The limitations of the available data must be accounted for when classifying the material into either the Proven Mineral Reserve or the Probable Mineral Reserve categories.

Validation of the results from underground optimization runs or manually created stope shapes is an important step in ensuring the high quality of Mineral Reserve estimates. Practitioners should carry out all validation exercises as deemed appropriate and necessary to ensure that the results are mathematically correct, reasonable, and in line with expectations. Modifications and edits to the proposed stope panels should be applied manually where necessary to correct for any undesired outcomes prior to proceeding to the next phase of work.

7.5.2. Life-of-Mine Designs

7.5.2.1. Open Pit Mines

For existing open pit mines, the design stage should begin with the most current version of the excavated surface and current Life-of-Mine design. The design could then be updated to reflect any changes in the underlying input parameters and assumptions or any additions to the Mineral Resource base.

For development-stage open pit mines, the Life-of-Mine design stage begins with examination of the series of pit surfaces that have been generated from the optimization stage. The advantages and disadvantages of the various pit surfaces generated from the optimization runs are considered, and a final surface is selected to act as a guide for preparing the Life-of-Mine design. The ultimate pit shell may not always be the preferred candidate for the Life-of-Mine design.

Design considerations for preparation of a Life-of-Mine open pit design include:

- ramp starting collar location, maximum gradient, minimum road bend radii, and width,
- safety berm height and width,
- drainage ditch width,
- bench height, bench face angle and berm width for all materials,
- geotechnical slope sectors,
- minimum excavation and fleet mobility dimensions,
- maximum dimensions of the haulage fleet, and
- inter-ramp slope angle.

Following completion of the design phase of work, a report of the tonnage and grade of the mineralized material, along with the tonnage of all waste materials contained within the Life-of-Mine design, is typically prepared and examined for suitability. It is recommended that a shell-to-design reconciliation be prepared to examine the effectiveness of the design in maintaining the optimized shell configuration. Depending upon the results of the initial tonnage and grade reports, changes to the initial Life-of-Mine design may be required to achieve various goals or to address specific issues. Several iterations of the Life-of-Mine design may be required before a final design is identified and accepted. In many cases, the Life-of-Mine design will not follow the outline of the selected optimized pit, as Practitioners will often have to include additional waste materials or exclude mineralized material if this yields a better outcome for a final pit design.

7.5.2.2. Underground Mines

For existing underground mines, the design stage should begin with the most current version of the excavation model and Life-of-Mine design. The existing Life-of-Mine design can then be updated to reflect any changes in the underlying input parameters and assumptions and any new mineralized areas that may have been discovered.

For development-stage underground mines, the overall layout is determined by the size and shape of the mineral deposit as defined in the Mineral Resource block model. The design process begins with a confirmation of the assumptions and parameters used to create a series of potential stoping panels. The relative size of the deposit, dimensions of the mineralized zones, and the spatial orientation of the mineralization will influence the choice of the production rates that may be achievable. The objectives that should be considered in preparation of underground mine designs include:

- minimize construction or development cost/time required to access ore faces,
- allow for the supply of ventilation and mine services (air/water/power),
- provide for required infrastructure to support the mining strategies,
- adhere to recommended geotechnical parameters including the recommended mining sequence,
- maximize drilling, blasting, and excavation productivities,
- ensure proper drainage and dewatering,
- backfill infrastructure if required,
- minimize dilution and maximize ore recovery,
- minimize operating costs,
- maximize ore extraction, and
- maximize people and equipment safety.

Once the production rates and the final mining method(s) are selected, selection of the appropriate equipment fleet can be carried out. The selection of the equipment fleet will dictate the dimensions of all accesses to the stoping areas and between production levels. Allowances for ventilation ducting, air and water lines, communication lines, and electrical chases must be included in the design of all primary underground access ways.

The means of access to the potential stoping panels on each production level are designed to ensure maximum equipment productivity and worker safety while minimizing the amount of excavations in non-mineralized areas. Level access designs include all cross cuts necessary to access the mineralized zones, and all sill drifts and drill drifts. Once all level accesses have been designed, the design of the final ramp or shaft access can be carried out.

Mine designs for underground mines must include provisions for fresh air intake, exhaust air, and secondary escape ways. Additional considerations include provisions for pumping stations, electrical transformer stations, safety bays, backfill infrastructure, and refuge stations. Ore and waste passes and fill raises may also be required.

7.5.3. Phase and Sequence Designs

7.5.3.1. Open Pit Mines

Following completion of the Life-of-Mine open pit design, an analysis of the various options available within the design is carried out to assist in the selection of the optimal sequencing of the mining schedule. These options can be identified using open pit optimization software, which yields a set of nested pit shells. Care should be taken that the shells for the various pit phases form reasonably contiguous surfaces that are operationally feasible. The resulting designs from this pit sequencing activity will then be used as inputs to the mine schedule.

The various interim designs should always maintain a business focus that seeks to maximize the value of the mineralization being mined while guaranteeing safety and operational feasibility. Some considerations for selecting and designing the various interim open pit phases include:

- ensure sufficient feed to the process plant throughout the mine life,
- consider any blending requirements to achieve the desired plant feed grade or quality,
- maximize the drilling, blasting, and equipment productivities,
- minimize dilution and ore losses,
- minimize transportation costs,
- minimize operating costs,
- minimize waste removal,
- maximize ore extraction, and
- maximize people and equipment safety.

7.5.3.2. Underground Mine

Typically, the ultimate Life-of-Mine design is completed as an initial step. This is then followed by breaking the Life-of-Mine design into a series of smaller phases that are designed to maximize the value of the asset while ensuring safety and operational feasibility. These smaller phases then form the basis for production scheduling. Allowances are required for sufficient time between unit processes (e.g. definition drilling, development, stope drilling and blasting, stope mucking, backfill, etc.) in the selection of both production rates and equipment sizing.

The mining sequence should reflect the selected mining method, and be aligned with the geotechnical and excavation design constraints. Mining direction and timely backfilling should provide enough mining fronts to achieve the target production and development rates while guaranteeing the overall stability of the existing and future working areas.

7.6. Dilution and Mining Losses

Dilution is material that is below the cut-off grade or value but is intentionally or inadvertently mined and must be considered in Mineral Reserve estimates because it "dilutes" the average grade estimate and increases the volume mined. Practitioners must describe how estimates for dilution were applied in the preparation of the Mineral Reserve estimate. Preparation of a diagram to explain the dilution calculation used is often very useful. The following briefly describes some common types of dilution encountered in open pit and underground mines.

7.6.1. Open Pit Dilution

In open pit mines, a mining outline is established where mining is to take place. The mining outline in some cases includes material that is below the cut-off grade or value because this material cannot be removed selectively during the digging operation. This material is referred to as internal dilution.

External or planned dilution must also be considered when preparing Mineral Reserve estimates. This type of dilution results from the mining of waste material that is mixed with the mineralized material along the perimeter of the mined areas at the time of excavation. An estimate of this type of material must also be included in the Mineral Reserve tonnage and grade estimates.

Unplanned dilution typically takes place as a result of movement of the material within the mining outline due to blasting.

7.6.2. Underground Dilution

In underground mines, as in the open pit situation, situations occur in which some material that is below the cut-off grade or value must be mined because it cannot be selectively excluded from within the planned mining shapes at the time of excavation. This low-grade material is also typically referred to as internal dilution. In the stope design stage, in many cases the shapes of the planned excavation cannot be matched to the mineralized outlines. Areas outside of the mineralized outline, but inside the planned stope are typically referred to as planned dilution and must be excavated for technical, and operational reasons. In addition to the above planned dilution, dilution can result from additional material that is mined as a result of uncontrolled, unplanned, or unforeseen reasons. This material is often referred to as overbreak, unplanned dilution, or external dilution.

An estimate of both the planned and unplanned dilution must be included in the preparation of Mineral Reserve tonnage and grade estimates.

In operating underground mines, an additional type of dilution can occur. This dilution occurs when blasting of new stope panels takes place adjacent to a previously excavated stope containing backfill material. In these situations, a portion of the backfilled volume can become entrained with the newly blasted material. The grades of the backfill material are typically far below the breakeven cut-off grade or value, and this material contributes to the total dilution of the newly blasted material. Furthermore, the backfill can have very different chemical characteristics to the mineralized material and its inclusion in the process plant feed can have serious adverse consequences for the process plant. This dilution is referred to as secondary dilution.

Accurate reconciliation studies are required to estimate the tonnage and grade of the planned and unplanned dilution in an underground mine. The tonnage of the unplanned dilution can be measured by comparing the excavated volume of a given stope to the planned or designed volume. The grade of the planned and unplanned diluting materials can be estimated from the available sample information. The volume of the secondary dilution can be estimated by comparing the surveyed excavation shape of the backfilled stope with the surveyed excavation shape of the newly blasted stope.

7.6.3. Mining Losses

Mining losses refer to the percentage of ore grade material within the mine designs that will not be extracted for various reasons. These materials are sometimes expressed in terms of mining recovery; however, the term mining loss(es) is preferred to reduce confusion with process recovery.

Examples of mining losses include broken material left in a stope that cannot be recovered due to operational or safety constraints in an underground mine, material left in place for geotechnical purposes (e.g. sills and pillars), or blasted material in an open pit mine that is destined to be sent to the processing plant but which cannot be recovered.

The mining losses must be quantified and considered in the preparation of a Mineral Reserve statement.

7.7. Mineral Reserve Classification

Conversion of the Mineral Resources into either the Proven Mineral Reserve or the Probable Mineral Reserve categories can be completed once estimates of the diluted and mine recovered material have been prepared. In all cases, the requirements of the CIM Definition Standards must be satisfied when assigning confidence categories of Mineral Reserves. Classification of Mineral Reserves can be an iterative process for underground mines, where several iterations may be required before a final classification is achieved. Only those portions of the Mineral Resources that are classified into either the Measured or Indicated Mineral Resource categories can be converted to Mineral Reserves.

Inferred Mineral Resources must never be classified as Mineral Reserves. If Inferred Mineral Resources are used in the development of mine plans and production schedules, they should be treated as waste materials. The classification of any such Inferred Mineral Resources can be reviewed and updated as new information becomes available. Unclassified material must never be converted to Mineral Reserves.

The Practitioners should be mindful of all the inputs used in establishing the Mineral Reserve that affect the confidence in the categories. The methodology of establishing the confidence categories should be well documented and easily understood. Best practice includes providing a narrative description of the qualitative reasons behind the confidence category selection. Where practical, empirical evidence (e.g. production data) should be used to calibrate and justify the classification.

7.8. Mineral Processing

For more information on this subject please refer to the Canadian Mineral Processors (CMP) of CIM for their Best Practice Guidelines for Mineral Processing (CIM 2011), as amended from time to time. CMP is a Technical Society of the CIM and incorporates members of CIM concerned with the processing of material from mineral deposits. The guidelines contained in the document include:

- CIM Best Practice Guidelines for Mineral Processing,
- Appendix A – Use of Supporting Studies in Process for NI 43-101 Documentation, and
- Appendix B – Glossary of Terms Used in the Best Practice Guidelines in Mineral Processing.

These guidelines provide guidance specifically for Practitioners that use mineral process information when preparing MRMR estimates and supporting documentation.

7.8.1. Development Stage Properties

Mineral processing recovery, design and cost requirements in support of the preparation of Mineral Reserve statements for development-stage projects should include test work on samples of mineralized material and waste material that might be incorporated in the feed to the process plant. Test work can be performed on one or more master composites selected and prepared so as to represent the material that is expected to be delivered to the process plant. The testing objectives are to determine the optimal processing selection, the nature of the variability within the deposit, metal or mineral recovery level to a saleable product(s), mineral hardness and abrasion values, and required consumables such as reagents to achieve the predicted recovery. In the course of such testing, the handling or treatment for deleterious elements should be determined and samples for tailings disposal design will be generated.

Once a suitable process flowsheet has been developed on such samples, it is important to determine the response of variability samples covering a range of feed grades (or mineral content), deposit domains, lithological types, extents of weathering, etc., as is appropriate.

The test work must define process design parameters for all flowsheet segments including comminution, beneficiation, hydrometallurgical processing, liquid-solid separation, etc. Equally important is the definition of the relationship between process plant feed grade and recovery and operating cost determinants such as grinding energy and reagent consumptions.

In cases where the processing selection includes new or novel designs or equipment, or the deposit contains highly variable grades or mineralogy, in addition to testing of representative samples, testing might also include pilot plant testing of a bulk sample to improve confidence in the design and cost estimates. Otherwise, testing at bench scale of smaller samples obtained by drilling or trenching is typically adequate to support reliable and accurate designs, recovery values, and cost estimates

Processing facilities are designed to produce marketable products for shipment directly to the consumers or to subsequent processing facilities. In some cases, test work will be required to yield samples of the intended product that can be evaluated by potential customers for the product.

Process engineering studies can be initiated upon completion of metallurgical test work. These studies should generate designs for the processing plant in sufficient detail to generate capital and operating costs to the required level of accuracy. The process plant capital and operating costs generated in this way will be integrated with the capital and operating costs of other project areas such as mining and environment, to arrive at an assessment of the overall project economics.

Components of the process engineering study used to demonstrate mineral economics will include:

- a description of samples used and their sources,
- mineralogical studies,
- metallurgical test work results and methods,
- determination of processing design criteria and description,
- selection of processing flow sheet and design basis,

- equipment sizes and specification,
- processing facilities layout,
- processing plant services and infrastructure,
- consideration of project site conditions,
- identification of tailings containment location and form,
- identification of effluent treatment requirements,
- estimates of initial and sustaining capital cost, and
- estimate of processing operating cost for periods through to Life-of-Mine.

7.8.2. Current Operations

When a Mineral Reserve statement is being prepared for current operations with an operating process plant, it is necessary to obtain and document the current operating conditions including process plant feed source and characteristics, process flowsheet, operating cost parameters, and recovery correlated with feed characteristics. For expanded or modified processing facilities, a detailed engineering study including flowsheet, layouts, and capital and operating costs will be required to support the Mineral Reserve statement.

For cases where the Mineral Reserves of current operations are expanded as a result of newly discovered mineralization, the metallurgical characteristics of the new mineralization must be evaluated and compared to the material being processed in the current operation. The metallurgical testing should demonstrate that the existing process selection and facility are suitable for the newly discovered mineralization, or to identify what changes or additions might be necessary in the process design to economically process the new mineralization. If the new mineralization is expected to be very similar to that historically processed at the operation, it is reasonable to confine testing to demonstrate recovery and consumables required for the existing processing route. For differing mineralization, testing scope should be expanded to examine other process routes before the optimum design is selected.

7.9. Production Schedules

The production schedule of a mining operation is a timetable containing the estimate, timing, and duration of all material movement (ore, waste, and marginal material) for the period of the plan. The production schedule establishes production targets and serves as a basis for calculating the capital and operating costs of the operation. The main output of the production schedule is a forecasted metal (or product) yield in its final, saleable form.

When defining production schedules, a key objective is often to maximize the deposit's economic value. However other strategies can be applied when considering a production schedule. Considerations can include:

- compliance with Health, Safety, and Environmental standards, and social acceptability considerations,

- feeding ore as uniform in quality and as close to target feed grades as possible to the processing plant in every period,
- maintaining the material movement level in the mine,
- maintaining a smooth stripping ratio over time for open pit mines, and
- optimizing operating costs.

Production schedules are prepared initially from the Life-of-Mine designs. Subsequent schedules are prepared using any staged phase designs for either open pit or underground mines. Although production schedules can be prepared with the assistance of various software programs, care must be taken in the selection of the input parameters.

In all cases, close scrutiny of the results of any production schedule must be carried out to ensure that they are both feasible and achievable. Schedules should be consistent with the established overall mining sequence and reflect dilution and ore losses. Mine schedules should be achievable with the budgeted resources and under reasonable productivity calculations/assumptions.

Preparation of diagrams of the proposed mining sequence is of great assistance for visual confirmation in both open pit and underground mines. All diagrams should be accompanied by a caption and/or legend with adequate information to interpret the diagrams unambiguously.

7.10. Workforce and Equipment Requirements

Estimations of the mine workforce and equipment requirements are necessary to support estimates of human resource management, operating costs, initial capital requirements, and sustaining capital requirements.

7.10.1. Workforce

Estimation of the workforce requirements includes a detailed estimate of the number of persons required for each position for a given location. The estimated workforce operating costs are then calculated for each position. Workforce estimates are prepared on monthly, quarterly, and annual basis, as appropriate.

The Life-of-Mine plans should include an estimate of the overall workforce requirements, broken down by functional areas, along with each of the detailed mine design stages. Wage rates for the particular area are required to estimate operating costs.

In the case where the operation uses a contractor for all or a portion of its mining or support operations, a specific cost component should be included in the operating costs to account for the contractors' workforce requirements to carry out the planned work and the appropriate allowances for wages, benefits and other obligatory payments.

For properties with currently producing operations, the estimation of the workforce requirements can be determined using factual data from current operations. Workforce requirements for contemplated expansions at operating mines can be determined using productivity information from current operations or other productivity information. For properties that are in the study stage, the workforce requirements are best determined from first principles. The use of productivity information from comparable operations can be of great assistance.

7.10.2. Equipment

Estimation of the equipment requirements includes a detailed estimate of the number of units required for each work type for a given mine. The number of units required are calculated for each piece of equipment in the mobile fleet, long-life equipment, and such supporting equipment as fans and pumps for the entire life of mine. Equipment requirements are prepared on monthly, quarterly, and annual bases, as appropriate.

The Life-of-Mine plans should include an estimate of the overall equipment estimates for the life of mine, along with each of the detailed mine design stages.

Where the operation uses a contractor for all or a portion of its mining or support operations, a specific cost component should be included in the operating costs to account for the contractor's equipment necessary to carry out the planned work and the appropriate allowances for fuel, parts and consumables, maintenance, rebuilds, replacements and ownership costs.

For producing operations, the estimation of the equipment requirements can be determined using factual data from the current operations. Equipment requirements for contemplated expansions at operating mines can be determined using productivity information from the current operations. For properties that are in the study stage, the equipment requirements are best determined using first principles. Productivity information from comparable operations can be of great assistance.

7.10.2.1. Open Pit Mines

Selection of the appropriate type, specific model, size, and number of pieces of equipment for a given open pit mine design stage will require consideration of a number of parameters and factors as follow:

Drilling and Blasting:

- bench height,
- penetration rate,
- ore/waste physical properties
- hole diameter, depth, angle, burden and spacing,
- sub-drill,
- explosive type, and
- purpose (ore, waste, pre-split).

Loading:

- material type and physical characteristics (ore, waste),
- production rate,
- bench height, and
- selectivity requirements (dilution).

Haulage:

- production rate,
- transportation distance,
- material density,
- moisture content,
- haulage profile, and
- in-pit crushing.

Ancillary Equipment:

- supervisor equipment,
- lighting,
- communication,
- surveying,
- waste rock storage handling,
- marginal rock pile requirements,
- primary loader support,
- crusher/rock breaker,
- road maintenance,
- field equipment maintenance,
- fuel and lubrication, and
- dewatering requirements.

7.10.2.2. Underground Mines

Selection of the appropriate type, specific model, size, and number of pieces of equipment for a given underground mine design is governed chiefly by the mining method, means of access, and required mining rates. While a large number of possible combinations are possible for any given deposit, in general, the primary areas of consideration include:

Drill and Blast:

- production or development (level development, ramps, shafts, ore/waste passes),
- hole diameter and penetration rates
- ore/waste physical properties, and
- size of opening required (stopes vs access).

<u>Haulage:</u>

- level haulage,
- material density,
- moisture content,
- ramp haulage, and
- shaft skipping.

<u>Ancillary Equipment:</u>

- supervisor equipment,
- communication,
- surveying,
- pumping system,
- supply conveyances,
- haulage way maintenance,
- equipment maintenance,
- fuel and lubrication,
- dewatering support,
- ground support,
- crusher/rock breaker,
- ventilation system,
- backfilling,
- construction, and
- logistics and supply.

7.11. Capital Cost Estimates

In relation to the preparation of a Mineral Reserve statement, capital costs are the costs required to build a new project (i.e. a greenfields property), or to increase the throughput capacity of an existing operation (i.e. a brownfields property). Capital costs include the following:

<u>Direct Costs:</u>

Direct costs typically comprise quantity-based cost estimates encompassing all the permanent equipment, bulk materials, labour, and subcontractors associated with the physical construction of the project. In general, they include the following major functional areas:

1) Mining

a. Mine development

- underground development (e.g. haulage ways, production shafts, ventilation, pumping, and electrical requirements)

- open pit development (e.g. waste stripping, waste rock storage, ore stockpiles)

b. Mine fleet equipment

2) Processing facilities (from ore receipt through to product shipment and tailings disposal)

3) Waste management facility (typically defined as beginning at the processing plant and extending to tailings and waste storage area, including effluent water treatment facilities)

4) Infrastructure

a. On-site facilities such as camps, maintenance shops, administration buildings, analytical and metallurgical laboratories, water supply and management structures, etc.,

b. Off-site facilities such as access roads, airstrips, port or rail facilities, power lines or power generation facilities, concentrate pipelines, desalination plants and water pipelines, etc.

Indirect Costs:

Indirect costs are typically defined as costs that cannot be directly attributed to the construction of the physical facilities but are required to support the construction effort. These costs may include the following:

1. Construction costs (construction camp, temporary facilities, support services)
2. Engineering, Procurement, and Construction (EPC)/Engineering, Procurement, and Construction Management (EPCM) costs/fees
3. Commissioning and start-up costs (including vendor commissioning engineers and staff)
4. First fills and critical spares

Owner's Costs:

Owner's costs are generally defined as costs that are specifically attributable to the Owner that are not included elsewhere in the estimate. The Owner's role will vary if the Owner elects to select an Owner-directed project rather that selecting an EPC/EPCM contractor for project delivery. Regardless of delivery model, certain responsibilities are included in the Owner's costs as follows:

1. Owner's project management team,
2. Owner's project support staff (finance, travel, administrative, technical),
3. Owner's project expenses (insurance, permitting, land purchase, legal, marketing, IT),
4. Owners technical contributions (on-going drilling, metallurgical testing, studies),
5. Owners socio-economic work including liaison with local communities, and
6. Owner's operations team (from pre-commissioning through start-up phases).

Contingency

Contingency is an estimate of the unknown costs that are likely to occur but are not readily identifiable. Inclusion of contingency is essential to ensure that the capital cost estimate will be adequate to complete the project.

Adequate contingency allowance must be included in the capital cost estimate to cover items or functions needed for the completion of the project but not specifically included in the capital cost estimate. It must be clearly understood that the contingency allowance will be spent and that it is not intended to cover scope changes.

Capital costs are typically broken down into three categories as discussed below.

7.11.1. Initial/Development Capital

For development-stage properties, the initial capital represents the total investment required to establish the mining production based on the mine designs. These costs should typically include the following areas:

- Open Pit Pre-stripping,
- Underground development (shafts, declines, ventilation raises, etc.),
- Purchase of mining equipment fleet,
- Process plant construction or refurbishment/upgrade,
- Construction of tailing storage facility, waste dump preparation and water management facilities,
- Development of required infrastructure and facilities (power distribution, maintenance and administration buildings, water supply and distribution, access road, and the like),
- Camp accommodation facilities (in the case of remote sites),
- Land purchases and/or leases and rights-of-way,
- Maintenance and operating equipment (e.g. tools, computers, support systems, office equipment, etc.),
- Surface preparation (e.g. roads, storage areas, buildings),
- Pre-production/commissioning
- Payments under government or First Nations agreements,
- Working capital (e.g. initial fills of consumables, initial capital and critical spares inventory, initial warehouse inventory, operating cost required to build work in process inventories and operating cost required to be spent during the time to receive revenue from sales of product, recoverable value added tax, etc.),
- Taxes on capital purchases (e.g. sales taxes or value added taxes that are not recovered),

- Financial assurance and mine closure/reclamation bonds (different companies can finance these costs differently but need to be identified for the jurisdiction),
- EPCM costs, and
- Contingency.

Working capital is a term used to describe the inventory and cash required during the initial capital phase to support operation until revenue is received and includes:

- Initial fills of reagents and consumables that are required to start the plant (e.g. balls in ball mills, reagents in flotation cells, fuel in tank, etc.). Initial fills are often included as a separate line item rather than included in working capital.
- Warehouse inventory of parts and consumables that will be used during initial operations (e.g. explosives, mobile and process equipment parts, wear parts, mechanical or electrical spares, personal protective equipment).
- Capital spares inventory consists of large components of the equipment or even a duplicate for the purposes of managing the risk of loss of production (e.g. ball mill bull gear, spare skips and cage, electric motors).
- During the development phase, an inventory of product is stockpiled at the mine and the process plant and output does not become available for sale until the working inventory of the project has been reached. The operating cost required for these activities is also covered in working capital as the operation will carry the inventory until the end of mine life (e.g. stope drilled inventory, in pit drilled inventory, broken ore and waste inventory, ore stockpiles, product in process and otherwise at site).
- Cash is required from the time the product is sold and leaves the mine site to the time the cash is received in the account. Various commercial terms will dictate the need for more or less working capital in these instances.
- Net proceeds from saleable mineral material produced in the development phase while bringing the mine to the point of commercial production are deducted from the pre- production operating cost.

The initial capital that the project will incur during the pre-production period should be estimated to represent the actual costs to an accuracy commensurate with the level of the study. The Practitioners should ensure that the quantity and quality of engineering and costing support such level of accuracy. The Practitioners should also state clearly the level of accuracy used in the report. Additional guidance can be found in the AACE International Recommended Practice No. 47R-11 (2012).

7.11.2. Sustaining Capital

Generally, sustaining capital is required by a mining operation to maintain production at the planned level. This sustaining capital is distinct from the routine operating costs associated with labour, consumables, maintenance, and third-party supply, and is generally of a shorter-term nature. Examples of sustaining capital items include the following:

- Mine development (OP pre-stripping, UG haulage drifts and ventilation raises),
- Push-back waste stripping,
- Equipment rebuild (mining fleet, plant equipment) costs required to extend the useful life of asset,
- Equipment replacement or expansion as required by the reserve Life-of-Mine plan,
- Process facility replacements,

- Expansion of tailing storage facility,
- Progressive rehabilitation and on-going closure costs,
- Infrastructure facility replacements,
- Additional land purchases,
- Dewatering and pumping, and
- Contingency.

The Practitioners should list all assumptions that determine the sustaining capital policy. The sustaining capital should be estimated with an accuracy commensurate with the level of the study and in current dollars. The Practitioners should detail all assumptions regarding sustaining capital and also ensure that the quantity and quality of engineering and costing support such level ofaccuracy.

7.11.3. Expansion Capital

An investment in expansion capital would be required when an operating mine plans an expansion in production capacity given an adequate reserve and market capacity and demand.

The expansion capital that the project will incur should be estimated to an accuracy commensurate with the level of the study and in current dollars. The Practitioners should detail expected expenditures and ensure that the quantity and quality of engineering and costing support such level of accuracy.

7.12. Operating Cost Estimates

In general terms, operating costs are commonly considered as those costs that are incurred in the current year of production. However, preproduction operating costs such as those incurred during the ramp-up period or some pre-stripping activities in open pit mines are often capitalized. In general terms, the basis for calculation of operating costs includes the following common cost centres:

1. **Mining**: all costs to extract and haul waste rock to a storage facility or extract and haul ore to the process facility, which is generally either the feed hopper of a ROM crusher or one or more stockpiles.
2. **Processing**: all costs to process ore delivered from the mine to either the hopper ahead of the ROM crusher or ore stockpile(s) through to, and including, the tailings disposal and effluent treatment processes. In some reporting systems, tailings disposal, effluent treatment, and related environmental costs are reported as a separate cost centre, as is the cost to process tailings through a backfill preparation facility.
3. **General and Administration (G & A):** general and administrative expenses represent the necessary costs to maintain a mine's daily operations and administer its business, but not directly attributable to the production of goods and services. It is important to note that G & A costs can vary widely depending on such items as the country, project location, type of operation, production rates, etc.

Table 7.2 provides details for operating cost estimates in the major cost categories of a mine. The list of costs is by no means exhaustive. The items to consider depend on the specifics of a given mining operation under examination and can be estimated in several ways. However, in each case the cost components will include the costs for labour, consumables or materials, maintenance parts and third-party services. Additional information relating to estimation of operating costs can be found in the

AusIMM Cost Estimation Handbook (2012).

In the case of an expansion of an existing mining and processing operation, there is usually readily-available operating cost data. Some of the cost data will require modifications if changes are made to mining and processing methods or throughput rates. In cases where no operating history is available then estimates must be made from first principles. To check these estimates, a comparison or benchmarking with operating costs of similar operations is carried out..

Table 7.2 Typical Operating Costs Inputs for Mining Operations

Cost Centre	Work Type
Mining	Definition Drilling: Diamond drilling, reverse circulation drilling or other drilling to upgrade the resource confidence during operations or collect better information for design and/or grade control purposes.
	Development: Open pit stripping costs that have not been capitalized, and underground development.
	Production: Open pits: drilling, blasting, loading, haulage, dump management, road maintenance, dewatering, power Underground: drilling blasting, loading, haulage, backfill, dewatering, power, level maintenance, rehabilitation, ventilation.
	Technical Services: Geological and engineering services.
Processing	Crushing, grinding, flotation, leaching, refining, product dewatering, product marketing and sales, tailings management, environmental, power, assaying services, technical services, heap leaching, solvent extraction electrowinning, etc. as appropriate.
General & Administration	Management, accounting, procurement and logistics, human relations (HR), safety and health, community relations, insurance, information technology (IT), software licenses, other Infrastructure, Support, and maintenance costs, security costs, camp costs, travel for remote sites, royalty payments, external consultants, office and equipment leases, satellite office expenses. Legal and regulatory, property taxes, mineral tenure maintenance, and permitting costs. Additional information on estimation of G & A costs can be found in AusIMM (2012).

7.13. Additional Factors

In addition to the technical requirements related to the extraction of mineralized materials, Practitioners must also consider a number of other factors such as location, infrastructure, environmental, marketing, legal, and social issues when preparing Mineral Reserve estimates.

7.13.1 Location and Infrastructure

The location of the deposit, as well as its climate, topography, and vegetation, has a significant effect on all aspects of a mining project and the cost and schedule of construction and operations. Transport of supplies to support a mining operation is also affected by location.

Infrastructure requirements for mining projects are site specific. The capital cost for infrastructure can vary substantially from site to site, and is often a function of the location rather than the choice of the mining or processing methods. Infrastructure covers a wide range of facilities and services, examples of which are summarized below:

- access and service roads,
- utilities – especially power availability and costs,
- water supply,
- communications,
- port and Marine,
- fuels,
- waste disposal systems,
- administration facilities,
- industrial facilities,
- transportation, and
- townsite and/or camp site.

7.13.2. Environmental Management

An understanding of sustainability and corporate social responsibility requirements and commitments plays a fundamental role in the preparation of Mineral Reserve statements for both development stage properties and on-going mining operations.

For development stage properties, Mineral Reserve statements should include consideration of any environmental studies, whether they are planned, in progress, or completed. Environmental studies should identify all factors that may be impacted by the proposed operational scenario and, depending on the regulatory jurisdiction, often include the characterization of the air quality and background noise in and about the project area, characterization of the surface and groundwater quality, characterization of the terrestrial and aquatic flora and fauna and identification of any protected or sensitive species, and identification of any cultural or archeological features. Any factors that act to restrict the mine design, such as sensitive wildlife areas, fish habitat, forest reserves, etc., must be identified and considered.

All known environmental constraints, or those discovered as a result of these studies that may affect mine development or permitting requirements should be identified.

The water management scenarios/systems, as well as the identification of sufficient area/capacity for the storage of tailings and any waste rock material for the stated Mineral Reserves, should also be considered. The safety and stability of any existing tailings storage or waste rock facilities should be investigated.

All costs related to the mitigation and treatment of any non-compliant liquid effluent, and progressive reclamation and final closure requirements must be identified and addressed.

7.13.3. Closure and Reclamation Planning

The level and detail of closure and reclamation plans are dependent on the status of the property (development vs. operating), the stage of development of the project (greenfield vs. brownfield), and the presence or absence of a previous closure plan. General closure and reclamation concepts based on the known project facilities, environmental interactions, and monitoring and reporting requirements should be provided at a minimum. For development stage properties, estimated closure costs should be provided in sustaining capital. In general:

- for operating mines, all closure and reclamation costs must be identified and included in the economic models. These costs include:
- all costs related to on-going monitoring and compliance with requirements set out in the various permits issued.
- all costs related to final closure activities and post-closure monitoring, and
- all financial assurance posted for closure of exploration, construction, or operation.

7.13.4. Environmental Assessments and Regulatory Permitting

The Practitioners must identify the environmental laws and regulations applicable to the specific jurisdiction where the proposed development is to occur.

For development stage properties, all required environmental assessment processes, authorizations and/or permits, and land tenure requirements must have been identified and there must be a reasonable expectation of eventual approval. Jurisdictions often have unique processes to be completed to obtain approval of an environmental impact assessment and issuance of operating permits and approvals. Practitioners should ensure that a complete list of the certificates, permits, licenses and approvals for a given project is compiled along with a practical assessment of the expectation of eventual approval.

For operating mines, the current status of each permit should be documented and include either the main conditions of approval for those currently held, or alternatively, a practical assessment of the expectation of eventual approval.

As a minimum, all permits required for the continued operation of the mine must be current, their conditions and requirements must be met, and all financial obligations must be satisfied for the preparation of Mineral Reserve statements.

For both development stage properties and operating mines, all costs related to permitting and, where applicable, monitoring and compliance activities (operating projects) must be identified and included in the economic models.

7.13.5. Social Considerations

Mine development may impact on the surrounding communities, people, and their respective economies, including housing requirements, health and safety, employment opportunities, and community displacement. Impacted stakeholders should be provided with the social/community studies conducted in support of the Mineral Reserve estimate. Indigenous peoples and their rights as Indigenous people in certain jurisdictions may require specific actions such as consultation and binding agreements.

Any restrictions placed on the mine design caused by social factors, cultural, or archeological issues must be identified. All public or government stakeholder meetings or consultations, hearings, as well as proposed or actual stakeholder agreements should be discussed as part of the studies supporting the Mineral Reserve estimate.

7.13.6. Product Marketing

To determine if a mineral product is saleable, it could be a necessity that the physical and chemical characteristics of the product be demonstrated by preparing a representative sample of the final product. Some products of a mining operation can be sold directly from the mine site but others require additional off-site treatment (e.g. by a smelter). Some products are sold on an open market basis but many are sold on a contractual basis. The method and costs of transporting the product to the ultimate buyer must be considered.

Depending on the product, deleterious elements may restrict the saleability of the mine product. Some customers are able to treat such elements while others may not. The Practitioners should provide an assessment of the risk of the marketability of the product being evaluated and penalties that might be paid for off-specification products. Where possible, the Practitioners should also identify limitations for marketing the product by identifying particular customer restrictions.

Sources of market information may include any relevant market studies for the commodity, including supply and demand, commodity price projections, product valuations, or product specifications.

The Practitioners are advised to consult with marketing experts for the intended commodity to determine expected quality, costing, market capacity, and other parameters.

7.13.7. Legal

Clear title regarding the extraction, processing, and sale of the mineralized material and final product must be demonstrated.

7.14. Economic Analysis

7.14.1. Introduction

A fundamental requirement for declaring Mineral Reserve, whether it is relating to a current mining operation or a mineral property being evaluated at the study stage, is the demonstration of the economic viability (profitability) of the operation with the technical parameters under consideration as described in the CIM Definition Standards. This is most commonly achieved by preparation of an economic model on a discounted cash flow (DCF) basis.

In the mining industry, economic/DCF models are used to determine and validate such business or investment decisions as:

- declaration of Mineral Reserves,
- decisions to proceed with additional investments in a property,
- decisions on capital allocations between properties, and
- valuations of mining properties, mining projects, and business entities.

Economic models are commonly constructed using successive one-year periods and provide several DCF metrics such as NPV, internal rate of return (IRR), and payback period. Economic models should be prepared on both a pre-taxation and a post-taxation basis.

A detailed discussion regarding the construction of economic models is beyond the scope of this document; examples of best practices and procedures used to prepare economic models can be found in Smith (1999), Lattanzi (2000), Smith (2002), and Stermole and Stermole (2014).

7.14.2. Base Case

An economic analysis of the given set of technical parameters will include at least one cash flow model that will be referred to as the base case. This base case should include the following conventions:

- No debt. The reason for this is that debt and financing are not a measure of the economic viability of the technical parameters that are under consideration in relation to the preparation of a Mineral Reserve statement. They are more a measure of the borrowing ability of the owner company or companies. Additionally, debt-leveraged cases can be manipulated to give a wide range of positive outcomes that do not reflect the technical parameters under consideration.
- No inflation. Mining project forecasts are forward-looking exercises that can cover long periods of time. The addition of inflation over time to a DCF model requires numerous projections. Predictions of future costs and product values with any degree of accuracy are difficult at best and future predictions of inflation are likely to be inaccurate. These can cause unreasonable distortions to the base case DCF metrics.
- Constant metal price(s) and foreign exchange rates (as applicable). This is a generally accepted practice in mining evaluations. Constant (“flat”) price(s) refers to excluding cycles or trends in the long-term forecast. It is a separate consideration from inflation (see above). The price forecasts should be determined by suitably qualified members of the Mineral Reserve estimation team and should be carried out in consideration of the guidance provided in CIM (2015), as amended from time to time.
- All taxes, royalties, and streams (revenue-based, tonnage-based, or other) payable by the project should be included in the economic model. Practitioners preparing economic models should consult with suitably qualified individuals for guidance in relation to treatment of the tax or royalty obligations of a project.

7.14.3. Economic Model

Essential elements in an economic model prepared in support of a Mineral Reserve statement should include, as a minimum, the following items.

7.14.3.1. Production:

Economic models should include annual schedules of mine production including ore tonnes, ore grades, product recovery (which can vary with grade and throughput rate), waste tonnes and grade (if any), and stockpile feed tonnes and grades (if any).

Annual schedules of process plant production must also be included in economic models where the mine production schedules differ from the plant production schedules (e.g. where a stockpiling strategy is employed). Process plant production schedules include ore tonnes, ore grades, metallurgical recoveries, and stockpile reclaim tonnes and grades (if any). The project production schedule should recognize any ramp-up requirements (McNulty 2014) for both the processing plant and the mine.

7.14.3.2. Revenue:

The major inputs required to calculate revenues for an economic model include the following:

- annual schedules of metal recovered, or tonnes and grades of intermediate products produced (concentrate, doré, etc).
- annual schedules of smelter and refinery costs including: payable (accountable) metal deductions, treatment and refining charges, marketing costs, freight, material handling, losses in transit, insurance, etc., and
- annual schedules of gross and net revenues.

7.14.3.3. Operating Costs:

The operating cost section of an economic model commonly includes consideration of the following components as separate line items:

- annualized schedule of mining operating costs,
- annualized schedule of processing operating costs,
- annualized schedule of G&A operating costs,
- annualized schedule of royalties, and social contract commitments, and
- annualized schedule of any other costs of operations, as applicable.

7.14.3.4. Capital Costs

The capital cost section of an economic model considers the annual schedules of all initial capital costs as separate line items including:

- open pit and underground development and equipment,
- pre-stripping (if any),
- processing facilities,
- services,
- infrastructure,
- construction of initial tailings and waste storage facilities,

- construction indirects,
- EPCM,
- owner's costs,
- contingency, and
- any other capital costs associated with the initial construction of the facility.

In addition to initial capital costs, the capital cost section of an economic model will also consider the annual schedules of sustaining capital costs including but not limited to:

- mine equipment replacement,
- tailings dam lifts,
- heap leach extensions,
- furnace rebuilds, etc., and
- annual schedule of costs associated with closure, both during and after operations.

7.14.3.5. Working Capital

An annual schedule of working capital requirements on a cash basis is typically included in an economic model as a separate line item.

7.14.3.6. Taxes, Royalties, and Streams

An annual schedule of all significant taxes and royalties (whether based on income, revenue, tonnage, time, or other characteristics) must be included in an economic model, as separate line items. They can include, but are not limited to, non-government royalties, Impact and Benefit Agreement payments, federal and state income taxes, state/provincial mining taxes, capital taxes, withholding taxes, and special levies by government bodies.

7.14.3.7. Economic Model:

An annual schedule of the cash flows is derived from the items listed under Economic Criteria. For clarity, in the context of these MRMR Guidelines, the economic model is constructed for the sole purpose of evaluating and demonstrating the economic viability of the selected technical parameters, in support of the Mineral Reserve statement.

To ensure that the DCF model is a fair evaluation of the economic viability of the selected technical parameters, it is considered good practice to use the same metal price(s) or value for preparation of the base case Mineral Reserve economic model as used to prepare the tonnage and grade estimates in the production schedules.

If the metal price(s) or value assumptions used for the economic base case differ from the price assumptions used to prepare the production schedules and the Mineral Reserve statements, the Practitioner should:

- explain the reasons for the different price assumptions, and
- provide the DCF metrics at the price assumptions used to determine the production schedules and the Mineral Reserve statements.

Guidance regarding the selection of metal prices (or values) for use in the preparation of Mineral Reserve estimates has been presented in CIM (2015), as amended from time to time.

The recommended format to show in the cash flow analysis is annual schedules of each of the items that follow:

Physicals:

- mined quantities and grade,
- processed quantities and grade,
- recoveries and recovered metal quantities, and
- quantities of payable metals.

Cash Flow:

- metal prices for each metal

A general example of a cash flow components is presented in Table 7-3.

Table 7.3 Cash Flow Model Components

+ Gross revenue for each metal (payable metal times metal price)

- Less transportation and treatment/refining charges

= Net Revenue

- Operating costs
- Non-government royalties and agreements*
- Working capital adjustments (cash basis)

= Operating Cash Flow:

- Initial capital costs
- Sustaining capital costs
- Closure and reclamation Costs

= Cash Flow Before Taxes:

- Government taxes and royalties (income, mining, severance, etc)
- Withholding taxes

= Free Cash Flow After Tax

*Note: Non-government royalties and agreements include Impact and Benefit Agreements (IBA), Net Smelter Return and other ad valorum-based royalties and production taxes, etc.

7.14.3.8. Net Present Value and Discount Rate

Once the annual cash flows are calculated, at a minimum, the following metrics should be reported:

- Total undiscounted after-tax cash flow,
- Net present value (NPV) at an appropriate risk adjusted discount rate (RADR),
- IRR, and
- payback period.

NPV is typically reported for a specific Risk Adjusted Discount Rate (RADR). The evaluation report must include an explanation of the development of this discount rate. This discount rate may have different names including: hurdle rate, minimum rate, required rate, etc.

If the NPV is positive at this discount rate, the project is considered to be economically viable and therefore a Mineral Reserve statement can be justified.

The risk adjusted discount rate is expected to reflect:

- the cost of capital to the owner of the project,
- the level of risk at the current stage of the project (PEA, PFS, FS, operating mine),
- any jurisdictional or country risk, and
- any other risk that can appropriately be incorporated into a discount rate.

Additional information on selection of appropriate discount rates is provided in Runge (1998) and Smith (2002).

7.15. Sensitivity Analysis

As appropriate, the economic evaluation will include sensitivity or other analyses using variants in commodity price, grade, capital and operating costs, or other significant parameters, as desired, and will include a discussion of the impact of the results. When carrying out a sensitivity analysis, it is important to examine the impact of both positive and negative variations of a given parameter, as examination of a positive variation alone or a negative variation alone may result in misleading conclusions.

The NPV of the annual cash flow should be calculated for a range of discount rates. If sensitivity to the discount rate is shown in the economic analysis, then the presentation must be balanced, with sensitivity to both higher and lower discount rates around the base case. Also, the lowest discount rate shown must still meet the reasonableness test for forward-looking information. The results could be presented as a table or as a graph.

Due to the complexities in carrying out such sensitivity analysis, a common approach is to maintain Mineral Reserves (tonnage, grades, production schedule) and all other values as constants while adjusting the desired variable across a range of values. This approach is commonly referred to as a deterministic approach. Additional information on evaluation of uncertainty and risk analysis is presented in Lattanzi (2000) and Stermole and Stermole (2014).

The results of any sensitivity analysis should be clearly presented in tables and/or graphs and be balanced and commensurate with the level of the study. One of the sensitivities must show the impact of different metal prices on the main DCF metrics. The range of metal prices is at the discretion of the Practitioner but the lower end of the price range should include a value at which the total undiscounted cash flow becomes zero and a value at which NPV becomes zero.

7.16. Mineral Reserve Statements

Mineral Reserve statements should be unambiguous and sufficiently detailed for a knowledgeable person to understand the significance of, for example, the economic cut-off(s) and its/their relationship to the Mineral Resource. In the case of open pit Mineral Reserve estimates, the waste to ore ratio (the strip ratio) should be unambiguously stated. There should be an obvious linkage of the Mineral Reserve estimate to the Mineral Resource estimate provided in earlier reporting documents. Best practice includes documentation of those linkages (e.g. dilution, mining losses, plant recovery) that were used in preparing the Mineral Reserve estimation.

Mineral Reserves are developed from the Measured and Indicated portions of the Mineral Resources that meet all of the necessary technical and economic criteria to demonstrate that the material can be extracted, processed and sold at a profit. Mineral Reserves include modifying factors and demonstration of the technical and economic viability through completion of a positive PFS, FS, or, for operating mines, preparation of a cash flow model based on a Life-of-Mine plan. The Life-of-Mine cash flow model must use only material in the Proven or Probable Mineral Reserve categories

As a minimum, Mineral Reserve statements must include a summation of the tonnage and grade for each of the Proven and Probable categories for all mineralized zones within the Life-of-Mine design. Additional reports of the Mineral Reserves that are broken out into each of the mineralized zones, by mining method, by period, or by any other criteria, can be prepared, with the provision that they conform to the requirements of the CIM Definition Standards.

Reporting of tonnage and grade figures should reflect the order of accuracy or precision of the estimate by rounding off to an appropriate number of significant figures.

At the Practitioner's discretion, the metal content of the Mineral Reserves may be disclosed, but only when accompanied by the corresponding tonnage and grade estimates. Metal contents alone must not be disclosed. Mineral Reserve statements should be accompanied by footnotes that provide such information as is relevant to assist in the understanding of the technical and economic inputs to the Mineral Reserve statement.

It is important to understand that a Mineral Reserve statement is based upon a given set of technical and economic parameters which have demonstrated their technical and economic viability at a stated point in time. In many cases, the technical or economic parameters can change with time, such that the viability test may no longer result in a positive outcome at a later date. In this way, the Mineral Reserve statement for a stated date may no longer be valid at a later time. For development stage properties, it is recommended that the Mineral Reserve statements be reviewed on a periodic basis and adjusted as necessary to reflect the technical and economic parameters of the day. For producing properties, a review of the Mineral Reserves should be conducted at least annually to verify that, at a minimum, the future undiscounted cash flow is positive. The cash flow ignores all sunk costs and only considers future operating costs (including revenue-based royalties and revenue-based severance taxes) and closure costs as well as future capital costs.

7.17. Stockpiles

Stockpiles may exist on a mining property that may have been sampled during production, or drilled and sampled, or assigned a grade based on a resource block model.

Active stockpiles should be periodically surveyed to determine the current tonnage and sampled to determine the density and estimate the grade. Original ground surface contours are necessary for determining accurate volume estimates.

Stockpiles may require ripping with a bulldozer, loading into surface haul trucks with an excavator or loader, and placement into the mill crusher or reclaim stockpile and blending with other mill feed material from other ore sources at the mine. Operating costs generally are lower and stockpiles have a lower cut-off grade or value because drilling and blasting generally are not required.

The stockpile cut-off grade or value is calculated using cost data, commodity prices, and milling recovery. Smelter returns, treatment costs, and freight costs were included in calculating the NSR for in-situ material and should similarly be applied. Mining dilution and ore loss factors should also be considered.

7.18. Mineral Reserve Risk Assessment

Although classification of Mineral Reserves into either the Proven or Probable categories allows the Practitioner(s) to identify technical risk in broad terms, establishment of a methodology to identify and rank risks associated with each input of the Mineral Reserve estimate is recommended. This will assist the Practitioners in establishing the Mineral Reserve categorization criteria, thus providing an understanding of the various technical risks associated with the Mineral Reserve estimate. This methodology, ranking and analysis should be well documented.

7.19. Peer Reviews

Best practice includes a peer review of the Mineral Reserve estimate including sufficiency and reliability of inputs, methodology, underlying assumptions, the results of the estimate itself, and test for technical feasibility and economic viability. The following items are typically considered when carrying out peer reviews of Mineral Reserve estimates:

7.19.1 Mining

- data to determine appropriate mine parameters, (e.g. test mining, RQD, etc.),
- open pit and/or underground production,
- production rate scenarios,
- cut-off grade or economic limit (single element, multiple element, dollar item),
- dilution: material which is not part of the original Mineral Resource estimate; often referred to as a "planned dilution",
- mining losses with respect to the Mineral Resource model,
- waste rock handling,
- fill management (underground mining),
- grade control method,
- operating cost,
- capital cost, and
- sustaining capital cost.

7.19.2. Processing

- sample and sizing selection: representative of planned mill feed, measurement of variability, is a bulk sample appropriate,
- adequacy of testing performed,
- pilot plant required for process confirmation and production of evaluation samples,
- product recoveries and dependence of recovery and costs on feed grade,
- mineral and rock properties such as hardness,
- bulk density,
- presence and distribution of deleterious elements,
- process selection,
- operating cost,
- capital cost, and
- sustaining capital cost.

7.19.3. Geotechnical/Hydrogeological/Hydrological

- slope stability (open pit),
- ground support strategy (underground), test mining,
- seismic risk,
- site and area hydrogeology, and
- water balance-water suitable for process plant or discharge with/without treatment.

7.19.4. Environmental

- baseline environmental studies,
- tailings management,
- waste rock management,
- effluent water recycle or treatment then discharge,
- acid rock drainage issues,
- closure and reclamation plan, and
- permitting schedule.

7.19.5. Location and Infrastructure

- Climate and seasonality; impact on cost and schedule for mine construction, and operations,
- supply logistics,
- power source(s),
- existing infrastructure; requirements to connect to existing infrastructure (surface rights, permits, time required) and who is expected to pay for infrastructure improvements, and
- labour supply, housing, and skill level.

7.19.6. Marketing Elements or Factors

- product specification, demand and prices,
- off-site treatment terms and costs, and
- transportation costs.

7.19.7. Legal Elements or Factors

- security of tenure,
- ownership rights and interests,
- Indigenous people and their rights,
- environmental liability,
- political risk (e.g. land claims, sovereign risk),
- negotiated fiscal regime,
- permits to operate, and
- permits to sell or export saleable products.

7.19.8. General Costs and Revenue Elements or Factors

- general and administrative costs
- commodity price and market forecasts
- foreign exchange forecasts
- inflation (considered or not considered)
- royalty and stream commitments
- taxes, and
- corporate investment criteria

7.19.9. Social Issues

- sustainable development strategy
- impact assessment and mitigation
- negotiated impact/benefit agreements
- cultural and social influences, and
- restrictions placed on mine design caused by existing infrastructure, socio-economic, cultural, or archaeological issues

Prior to first-time disclosure of a Mineral Reserve on a mineral property or significant changes to a Mineral Reserve estimate, a peer review should be carried out by qualified Practitioners. The peer review should consider the methodology used, test the reasonableness of underlying assumptions, and review conformity to Mineral Reserve definitions and confidence categories. The methodology for Mineral

Reserve risk identification, assessment and management should also be included in the Mineral Reserve peer review. The peer review should be documented.

8. CONCLUSIONS

Significant decisions that affect many stakeholders are often made on the basis of MRMR estimates. These MRMR Guidelines will provide some necessary and long-awaited directions to ensure that informed and rational decisions are made during the MRMR estimation process. These MRMR Best Practice Guidelines will assist in preparing high quality Mineral Resource and Mineral Reserve estimates that benefit the mining industry, government agencies, academic institutions, and the public.

Technological advances permit consideration of a greater number of inputs and a larger and more diverse set of information when preparing MRMR estimates than were possible in the past. Consequently, it is necessary to develop current procedures and practices that embrace these technological innovations while maintaining a sound basis in the good mining practices that have evolved over time.

The concepts, procedures, and practices described in this document represent the current cumulative knowledge, judgement and experience of a broad cross section of the Canadian mining community who have experience in preparing MRMR estimates in Canada and internationally. The CIM MRMR Committee believes that these MRMR Best Practice Guidelines will assist Practitioners for preparing MRMR estimates.

9. ACKNOWLEGEMENTS

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The list of documents below that are publicly available and are either cited as sources of specific content or they provide additional details and information on selected subjects. The list is not intended to be an extensive or complete, rather it is a selection of useful and easily accessible references that cover a range of topics. For clarity, the reference sources identified below are provided as a convenience and are intended to serve as sources of further information on various topics to interested parties. Readers of this document are not obliged to consider these references as the sole source of information on any of the topics covered.

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APPENDIX 1: GLOSSARY OF MINING TERMS

The information presented in the body text of the above document makes use of certain words and phrases of a technical nature that relate to specific concepts, methods, and techniques that are found in common usage throughout the mining industry. As an aid to ensure that the meaning of each of these words and phrases are clearly understood by all parties who consult this document, a compilation of Glossaries of Mining Terms has been assembled. In order to reduce duplication, these Glossaries are not reproduced in their entireties below. Rather the relevant reference information is provided to permit interested parties to source these documents individually.

The compilation is not intended to be extensive or complete. For clarity, the referenced Glossaries identified below are provided as a convenience and are intended to serve as sources of further information on various words and phrases that may be found in this document. Readers of this document are not obliged to consider these Glossaries as the sole sources of information.

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