Opportunistic AMD Sampling from Multi-Discipline Drilling Programs for Large Mining Companies

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ABSTRACT

The application of drilling surveys to assess economic viability, ground stability and hydrogeological conditions are typically completed prior to commencement of mining. It is generally accepted that in many instances insufficient geological samples are collected from these drilling programs specifically for geochemical analysis to effectively characterise the acid and metalliferous drainage (AMD) potential of the deposit. To minimise risk associated with incomplete characterisation of AMD potential, a continuing AMD sampling and analysis program can be developed and implemented to ensure adequate sample collection occurs.

The focus of this paper is to outline a case study of the development of such a sampling program for a large mining company that incorporates all of their Western Australian iron ore operations. The program utilises multi-discipline drilling programs at all stages of mine development to minimise AMD risk.

The continuing sampling and analysis program is initiated at the long term drilling schedule planning stage by selecting relevant upcoming programs. Potential drilling programs include exploration, geotechnical, hydrogeological and grade-control drilling. Engagement with project teams responsible for the individual drilling programs to express interest in drill core is initiated early with upfront cross-discipline drilling planning meetings. Once approval has been given to select splits of drill core, a sampling plan is developed and provided to the responsible project teams along with a detailed and easy to follow sample collection and dispatch procedure.

The implementation of the program over the previous ten months has successfully seen the selection and collection of geological samples from more than 35 drilling programs across 25 deposits spanning six mining operations within Western Australia. In addition to increasing the size of their regional environmental geochemical database, this has resulted in significant cost-savings by incorporating AMD sampling into existing drilling programs. Designing the program to have minimal impact on existing procedures and the positive adoption of site personnel to reducing AMD risk has contributed strongly to the success of the program.

Keywords: AMD sampling and analysis, large scale sampling, multi-discipline drilling

INTRODUCTION

Geological samples, in some form or another, are collected from the first to last drill hole for any given mining project. Drilling programs to assess economic viability, ground stability and hydrogeological conditions are typically completed prior to commencement of mining and all present opportunities for the collection of geological material. However, sufficient environmental geochemical samples to adequately characterise a site for its potential to generate acid and metalliferous drainage (AMD) are not commonly collected. This deficiency in waste rock geochemical knowledge can be due to a number of reasons:

- Exploration programs do not generally actively target waste units which are typically the key materials of interest for AMD predictions, rather they focus on ore bodies.
- Minimum sampling requirements for AMD assessments set by regulatory bodies are often vague and/or poorly interpreted by those developing sampling programs.
- AMD sampling programs are often considered to be complete and are ceased once approval to mine has been granted.
- The true monetary value of AMD risk is often poorly understood and/or insufficiently weighted against exploration/production targets.

AMD sampling programs can also have the propensity to be set at a level that is too intensive in the early stages of mine development. Intensive analysis of geological materials for AMD assessments prior to developing a sound geological understanding of the deposit can lead to disproportionate analysis of waste units. This can in many cases result in unnecessary expenditure by mining companies on environmental geochemical data not providing the value of its capital outlay.

These potential causes for insufficient sample collection or conversely early phase over-intensive analysis for AMD assessments, can be addressed by implementing an iterative sampling program throughout the life of the mining operation (Kentwell et al. 2012). Leveraging off the multiple drilling programs routinely completed as part of resource assessment can mean costly standalone drilling programs specifically for AMD assessments may be avoided.

Successfully taking advantage of drilling programs designed for purposes other than AMD sampling requires close interaction with the multiple stakeholders specific to each drilling program. Carefully designed and easy to follow procedures are critical to ensure consistency and sample integrity is achieved in sample selection and collection stages.

As part of geochemical risk management activities, an ongoing AMD sampling and analysis program was developed for the Western Australian iron operations of a large iron-ore mining company by the authors in collaboration with the mining company. The program developed utilises multi-discipline drilling programs at all stages of mine development to minimise AMD risk. This paper presents the various stages that comprise the developed ongoing sampling program including the incorporation of a data management and tracking procedure to ensure sample and data integrity is maintained.

METHODOLOGY

The mining company's ongoing sampling and analysis program comprises multiple stages with input required from various groups within the company. To ensure that sample and data integrity could be maintained over such a large program, a data tracking and management procedure was incorporated into the ongoing sampling and analysis program. The stages of the developed program are presented in Figure 1 and are:

- Identification and initiating involvement with key drilling programs and program stake holders.
- Development of a consistent sample selection procedure.
- Development of consistent sample collection procedure.
- Data tracking and management.
- AMD Data interpretation.

Adoption by Key Stakeholders

The first step to designing an ongoing sampling and analysis program that is to be successfully adopted by multiple operations and disciplines is understanding the drivers of each of the key stakeholders. That is, when taking advantage of planned drilling programs for opportunistic AMD sampling, the program must be designed to work around the key stakeholder's objectives.

For individual AMD sampling plans created within the ongoing sampling and analysis program, requesting site personnel or those responsible for the planning of the drilling programs to significantly alter an established process was deliberately avoided. The objective being to minimise the burden (perceived or actual) of the AMD sampling, particularly for site staff.

Some key factors that the effective adoption and implementation of the program (by multiple stakeholders) depended on, included:

- Frequent and open communications with site personnel and drilling program coordinators.
- Understanding the various sampling/logging/dispatch procedures employed across the site(s), e.g. geotechnical versus hydrogeological versus exploration versus grade control.
- Understanding the limitations of each drilling technique employed and therefore the limitations for AMD sampling.
- Designing the sampling and analysis plans to be cohesive with planned drilling programs.
- Avoiding requests for unnecessary collection of samples.

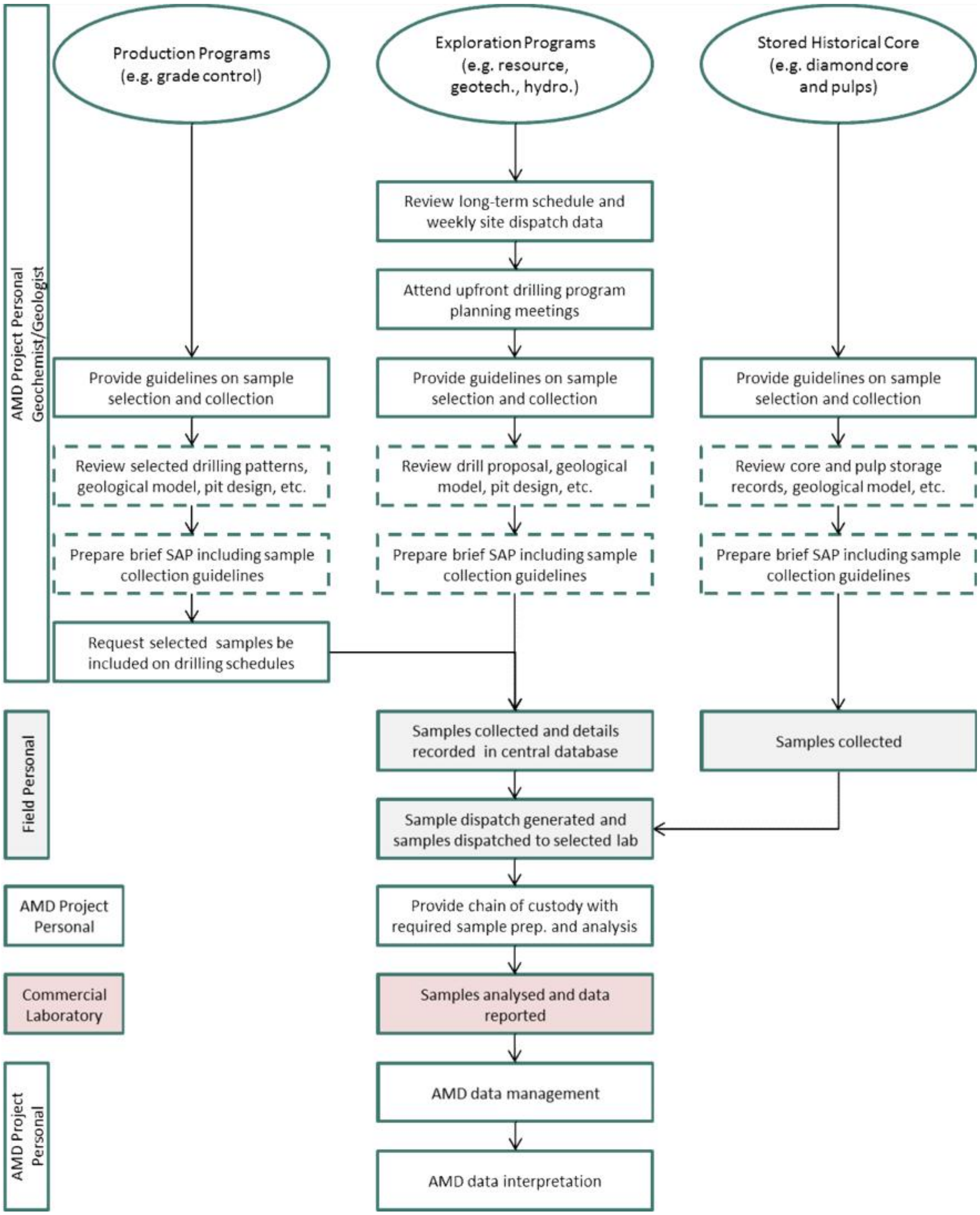

Figure 1 Ongoing sampling and analysis program flowchart

Identification and Initiating Involvement with Key Drilling Programs

The ongoing sampling and analysis program is initiated at the long term drilling schedule planning stage by selecting relevant upcoming programs. Potential drilling programs include exploration, geotechnical, hydrogeological and grade-control drilling. Engagement with project teams responsible for the individual drilling programs to express interest in drill core was initiated early with upfront cross-discipline drilling planning meetings.

For large mining companies with several standalone mining operations, careful consideration must be given to which drilling program is selected to avoid unnecessary expenditure. Unnecessary expenditure are not limited to direct laboratory costs but also the time taken by employees to select and collect samples.

Some key questions asked when deciding whether to pursue a planned drilling program included:

- Does the planned drilling program target a deposit of significant interest to the company?
- Will the drilling program intersect key lithological units with respect to AMD generation?
- Will the drilling program intersect lithological units for which little data is currently available?
- Is there sufficient knowledge of the orebody and potential pit shell to avoid unnecessary sampling, i.e. is it worthwhile waiting for an infill drilling program planned at a later date?
- Is the drilling method conducive to the collection of meaningful AMD samples?

Development of a Consistent Sample Selection Procedure

Once approval had been granted by project teams responsible for the individual drilling programs to select splits of drill core, a sampling plan was developed. A sample selection procedure was developed to promote consistency across the various operations. The procedure included the selection of samples from upcoming drilling programs and the selection of stored core/pulps.

The sample selection procedure was designed to be used for each phase of sampling with each preceding phase informing the current planned phase and is therefore iterative in nature. Several informed decisions are required throughout the procedure which are primarily based on the sampling program objectives, the size of the drilling program, the type of drilling method and existing geochemical information.

The sample selection procedure was comprised of the steps presented in Figure 2.

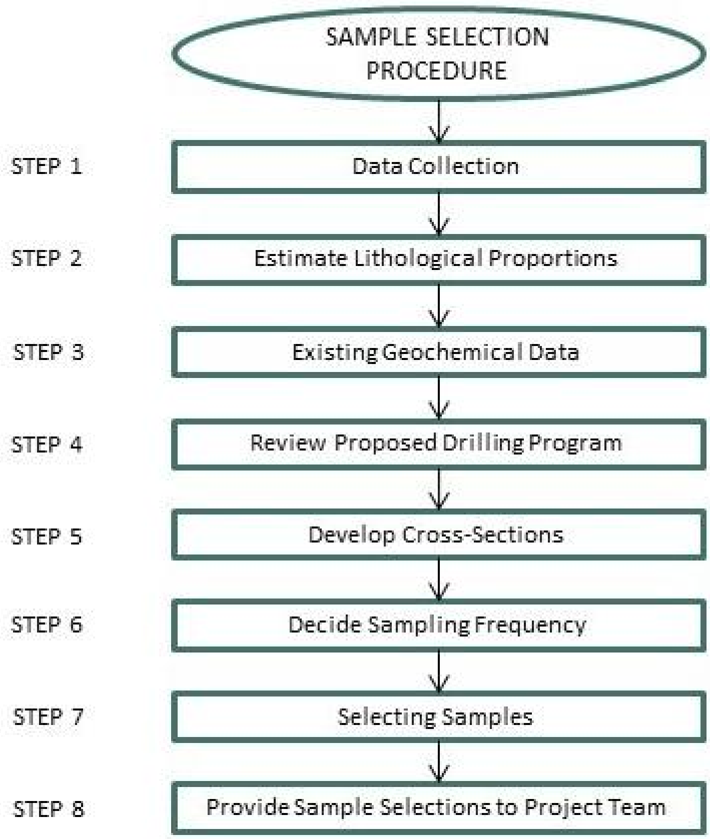

Figure 2 Sample selection procedure flowchart

Initially, the most up to date drilling proposal and geological resource model from the central database was collected (Step 1). Then, using geological modelling software, the percentages of each waste lithology to be mined within the proposed pit shell was estimated as well as lithologies remaining in the pit wall (Step 2).

To ensure informed sample selections incorporated all applicable data collected prior, relevant geochemical data for the deposit including the current assay database was reviewed (Step 3). If sulfur data was available within the assay database, the sulfur distribution within the geological model was assessed to identify any regions of high sulfur concentrations. The average sulfur concentrations per lithology was also estimated.

Following the review of all relevant data, the proposed drilling program was studied within the resource model to assess what lithologies may be intersected (Step 4). The potentially intersected lithologies were cross-checked with:

- Any lithologies previously identified as important with respect to AMD processes such as sulfide/carbonate bearing units or enrichment in elements of concern.
- Results of the existing geochemical data review (Step 3).

To assist site personal with sample selection and to also aid the later stages of data interpretation, geological modelling software was used to create cross sections (Step 5). Cross-sections included, at a minimum, proposed drill holes, historical drill holes (if appropriate), geological information (lithological domains, ore zone(s), weathered zones), proposed pit shell(s) and pre-mining water tables.

For drilling programs covering the entire deposit, cross-sections were spaced at relatively equal distances spanning the deposit in order to achieve a good spatial representation. For smaller targeted drilling programs (geotechnical, etc), all drill holes were presented on the cross-sections.

Several factors need to be considered when deciding the sampling frequency for Step 6. For large, deposit encompassing drilling programs, sufficient numbers of samples should be taken to accurately characterise the variability and central tendency (e.g. average, median, and 10th and 90th percentiles) of the different waste materials, project components and geological units (DoITR, 2007 and Price, 2009). For smaller targeted drilling programs (e.g. geotechnical) the sample frequency was largely reduced and was not necessarily focussed on spatial representativeness.

Figure 3 presents some of the factors to be considered when deciding on the sampling frequency for an individual drilling program.

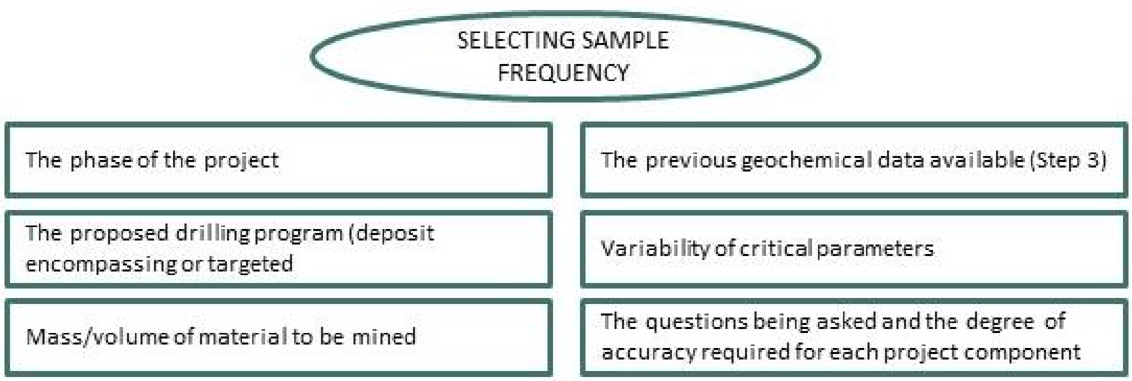

Figure 3: Selecting sample frequency

Providing good spatial, geological and geochemical representation in the sample population is important as AMD may be produced by only a portion of the geological materials (Price, 2009). For large deposit encompassing programs, the aim was to select sample proportions equivalent to the waste material to be mined as determined in Step 2.

Sampling locations (Step 7) were largely based on:

- The required accuracy and precision of the sampling program.
- Knowledge of the deposit.
- Areas of notable physical, mineralogical, geochemical and degrees of weathering differences.
- Findings from Step 3 and Step 4.

The proportions of specific lithologies may increase if lithologies to be intersected have been identified in previous geochemical assessments as units of interest. In addition, lithologies may have been targeted for extra sampling if specific drainage prediction questions were being investigated.

Once all samples were selected, selections were tabulated and their corresponding details were provided in a format easily followed by field personal (Step 8).

Development of a Consistent Sample Collection Procedure

To maintain sample and data integrity, particularly within a large company with multiple disciplines responsible for sample collection and dispatch, a consistent and easy to follow sample collection procedure is essential and as such was developed.

Sample recording, bagging, labelling and dispatch instructions were clearly provided in the sample collection procedure. The recording and entering of sample details into the central database represents the commencement of the phase that follows the ongoing sampling and analysis program (data tracking and management procedure).

Clear sample collection instructions for each drilling technique were needed to ensure sample integrity was maintained. Three separate sub-procedures were therefore developed for the three main drilling techniques employed at the various operations:

- Diamond Core – exploration, geotechnical, metallurgical and hydrogeological.
- Reverse Circulation – exploration, geotechnical, metallurgical and hydrogeological.
- Blast hole – grade control.

Diamond Core (Exploration, Geotechnical, Metallurgical and Hydrogeological)

Sampling of diamond core for AMD testing was undertaken in various ways because of the multiple programs employing this drilling method. Quarter core splits were generally collected and were largely obtained following a coarse crushing stage. Greater proportions than quarter were generally only permitted when core was not to be assayed.

Timing was critical for the requesting of diamond core intervals because generally all core was processed; if the request was delayed samples may have not been available. Therefore, when core arrived at the processing facilities, borehole logs had to be reviewed within the geological model as a priority prior to submitting a sample request form.

Reverse Circulation (Exploration, Geotechnical, Metallurgical and Hydrogeological)

Drilling programs employing reverse circulation drilling collected requested samples as a split sample directly from the cone or rotary cone splitter. For exploration drillholes, one composite sample was collected per rod (3 m interval).

Unlike diamond core selections which were selected after reviewing borehole logs, sample selections from reverse circulation drilling were made prior to drilling. Therefore, targeted lithologies were often missed as field staff collected requested intervals irrespective of the material intersected. This was counteracted by over-selection during the sample selection phase as the cost to collect and dispose of additional unwanted samples was considered to outweigh falling short on collection of key lithologies.

Blast hole (Grade Control)

Although the quality of samples collected from blastholes for environmental geochemistry purposes were considered lower than samples collected from diamond and reverse circulation drilling, there is still benefit in utilising this source for AMD characterisation. .

Taking the limitations into consideration, only one sample was collected for any given blasthole and specifically from the middle 3 m interval. This was to minimise contamination from the upper bench blasting pattern and bias introduced from collecting material from the lower portion of the drillhole.

Data Tracking and Management

The data tracking and management procedure begins when sample collection details are recorded and entered into the central database (Figure 4). Samples are then dispatched under a standardised dispatch system.

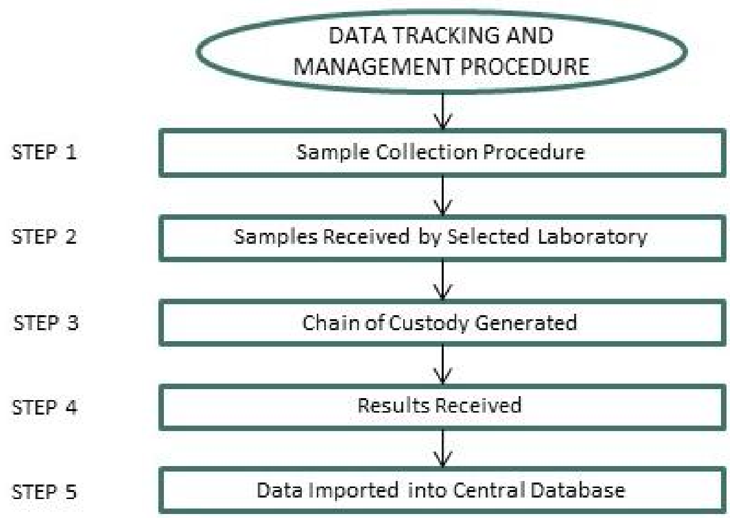

Figure 4: Data tracking and management procedure flowchart

Once samples arrived at the laboratory, received samples were assessed and analysis requests (chain of custodies) were prepared. This also provided an opportunity to review assay data if available for specific intervals to reduce unnecessary analysis. It also provided an additional control step to identify primary samples sent to the environmental laboratory that should have been directed to the metallurgical laboratory.

To streamline the importation of laboratory data into the central database, a database compatible format was developed. This file was provided to internal database specialists.

Data Interpretation

Once all data is located within the central database, it needs to be readily available for inclusion in AMD assessments for specific operations. To streamline the collation of required data for AMD assessments, an “AMD Export” file (readable as a csv) was developed that included all critical available information for AMD assessments. The export includes a range of parameters for each data point, such as:

- Project and orebody.
- Borehole name, drilling method, borehole coordinates and coordinates grid name.
- Unique internal sample number and unique laboratory sample number.
- Sample depth.
- Lithology, waste/ore, degree of weathering, above or below water table.
- Laboratory results (environmental and assay where available).

RESULTS AND CONCLUSIONS

The implementation of the program over its first ten months successfully saw the selection and collection of geological samples from more than 35 drilling programs across 25 deposits spanning six mining operations within Western Australia. In addition to increasing the size of the regional environmental geochemical database, this has resulted in significant cost-savings by incorporating AMD sampling into existing drilling programs.

Designing the program to have minimal impact on existing procedures and the positive inclusion and "buy in" of site personnel to reducing AMD risk has contributed strongly to the success of the program. As a result of the careful consideration for implementation, it was noted that as the program developed teams in other disciplines were willing to allow redesigning of planned drilling programs for AMD specific drillholes. This was considered a positive sign of internal acceptance and approval of the program.

Some key learnings from the implementation of the program included:

- Understanding the limitations of the drilling methods and the already established sample collection procedures was required to ensure sensible sample requests were made.
- Understanding the limitations of the selection/collection procedures was paramount to (a) understanding the limitations of the data collected, and (b) appreciate that not all targeted units may be collected and to prepare inbuilt contingencies within the sampling plans.
- When selecting samples from geological block models, it is important to recognise the limitations in resolution/accuracy and select samples accordingly. That is, the successful collection of a targeted lithology is more likely if a wider interval range is provided to field personal (15-21m opposed to 15-18m).
- Different field staff may interpret requested sample intervals differently; one composite sample (3 m) collected within the requested 10 m interval opposed to the entire interval being collected (three samples). For this reason, the analysis request step was not included at the dispatch stage which allowed the prevention of unnecessary analysis.

Potential areas for further program development include:

- Incorporate other parameters where available into the sample selection procedure that may also be recorded within resource block models, (calcium, magnesium, selenium, etc).

- Where possible, request field staff to differentiate between sub-units when selecting and collecting samples. For example, sub-units can have significantly different acid forming potentials and reaction rates leading to different management options.

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