Elk Valley Water Quality Plan

Annex J.1

Approach and Methodology to Monitor and Assess Calcite Impact

Teck

Approach and Methodology to Monitor and Assess Calcite Impact

September 6, 2013

Teck

Table of Contents

List of Figures

List of Tables

List of Appendices

Appendix 1. 2013 Calcite monitoring streams by reach
Appendix 2. Calcite Monitoring Plan Field Manual

Definitions

- Characteristics – The degree of embeddedness or the form of the calcite deposition.
- Degree – The amount of calcite deposition estimated by the level of concretion.
- Extent – The amount of calcite deposition expressed as the area covered at a specific location or the linear coverage over a stream profile.
- Habitat unit – A distinct channel unit possessing homogeneous geomorphological characteristics (e.g., riffle, pool, glide, cascade).
- Reach – A relatively homogeneous section of stream in terms of channel morphology, riparian cover and flow [Resource Inventory Standards Committee (RISC) 2001]
- Sampling unit – A single unit used to facilitate the analysis of a larger entity. For example, a reach could be considered the sampling unit for estimating the average calcite coverage over an entire stream.

1 Introduction

Teck must manage calcite formation resulting from its mining activities within the Elk Valley watershed to the levels necessary to protect the aquatic ecosystem. This requires understanding the mechanism and potential impact of calcite formation.

In 2008, Teck initiated a survey of calcite occurrence in the Elk Valley [Berdusco 2009]. Since then, Teck has developed a conceptual model for calcite deposition and has initiated several projects to research the mechanism of deposition and to develop possible mitigation strategies.

The monitoring program to date has focussed on the geochemical aspects of calcite deposition and on the general presence or absence of deposition. To advance the program to the next level, a refined approach and methodology was needed to monitor and assess the calcite impact within the Elk Valley watershed. This document describes the resulting plan, which has been prepared through the collective efforts and guidance of Teck and its consultants Lotic Environmental, SRK Consulting and Swanson Environmental Strategies.

The approach and methodology have been designed to quantify the rate (i.e., status and changes over time) of calcite formation downstream of mining activities and to assess the potential impact of calcite through the regional and local Aquatic Effects Monitoring Programs (AEMPs).

1.1 *Problem Statement and Principal Study Questions*

Weathering of waste rock dumps has led to increased levels of dissolved carbonate minerals in some areas of the Elk Valley watershed. As a result of shifts in water chemistry equilibrium due to the nature of the water exiting the waste rock dumps the formation of calcite deposits in streams is occuring in some areas downstream of these dumps, which may adversely affect the receiving environment.

To better evaluate the potential impact, a rigorous study is needed to quantify the extent, characteristics, and degree of calcite formation over time. Principal questions to be addressed include:

1. What is the spatial distribution of calcite (i.e. extent and degree)?
2. How do we measure calcite deposition qualitatively and quantitatively?
3. How does calcite deposition vary over time (i.e., trends in extent and/or degree)?

1.2 *Monitoring Plan Objectives*

The objectives of the monitoring plan are:

1. Document the extent and degree of calcite deposition, analyzing over time to determine trends.

2. Satisfy calcite-specific monitoring regulatory requirements.

3. Standardize the approach and methodology for data collection and reporting for calcite monitoring efforts.
4. Assist in determining when and where calcite mitigation may be required.

Additionally, data collected as outlined in this plan will be used to inform regional and local AEMPs in the assessment of potential impacts due to calcite formation. To date, information on the rate of calcite formation has been lacking in the interpretation of AEMP data such as benthic community structure and composition.

1.3 *Development Process*

While Teck's understanding of calcite has advanced since the initial discovery of the issue, there is still work to be done to assess the rate of calcite formation and its potential impact.

Over time, Teck has pioneered data collection methods to describe calcite deposition. Reviewing past data, Teck has identified the need for additional monitoring and data collectionto develop:

- suitable, reproducible measures of calcite deposits (quantitative and qualitative)
- spatial variability (within site, reach and stream levels)
- temporal trends (annual)
- reference conditions

Section 4 describes how data collected through this plan will be used to refine the monitoring program, both immediately and in the longer term. This includes subsampling designs, to assess issues such as spatial resolution and measures of calcite degree, as well as ongoing re-evaluation of streams that: (1) need to be added to the program; and, (2) those that no longer require monitoring.

In summary, this plan is intended to standardize data collection and reporting for calcite, and to support regional/local impact assessments.

2 Stream Selection Process

A primary objective of the revised monitoring plan is to document the extent and degree of calcite deposition (assess the rate of formation/precipitation). Prior monitoring programs were inadequate in accurately assessing the extent of calcite deposition. This section describes the stream selection process for the 2013 monitoring program.

2.1 *Accepted Stream Selection Criteria for the 2013 Program*

Accepted stream selection criteria for the 2013 program include:

1. **Mine exposure:** This criterion describes whether or not a stream is downstream of past or present mining. Mine exposure was considered a key part of the stream selection process because mine influenced streams have the potential to exhibit elevated calcite deposition. Therefore, all reaches downstream of mining were included in the initial monitoring program.
2. **Regulatory requirements:** Streams that were previously committed to include calcite monitoring as a regulatory requirement (e.g., baseline assessments), will be included in this monitoring program.Additional monitoring criteria are discussed below.

2.2 *Selected Mine-Affected Streams*

A total of 65 streams were selected for monitoring in 2013 (including reference reaches). These streams were selected by inspecting mine site maps to generate a preliminary list, which was then reviewed by the respective operations. The review resulted in additional streams being identified, and certain streams being identified as non-exposed.

The selected streams were further differentiated into reaches. A complete list of reaches by geographic region, reach statistics (e.g., gradient, watershed area, elevation) and fish bearing status is provided in Appendix 1. The stream/reach listing may be enlarged as a result of field observations.

2.3 *Reference Streams*

Reference streams were sampled as part of the monitoring plan, to provide context for the extent, degree and trends of calcite formation/deposition occurring downstream of mining. Reference streams are particularly useful for long-term and large-scale spatial monitoring, because they provide a comparison to account for natural environmental variability.

Reference sites were selected from areas considered to be persistent over the long term and located a sufficient distance from further mine development. Furthermore, recommended reference areas must encompass the variability of important aspects of the set of exposure areas, such as: elevation, stream order, geology, and channel morphology. Reference sites were selected using the following process.

1. Characterize exposure reaches by stream order, bedrock geology, spatial distribution, and channel morphology.
2. Review reference sites from past calcite monitoring and other programs such as the regional AEMP or baseline assessments, and select appropriate locations using reach characteristics.
3. Review additional locations to obtain reference streams to adequately represent the spectrum of stream characteristics represented in the exposure areas.

Using the above-listed process, the following eight streams were evaluated in 2013:

1. Alexander Creek R3
2. Andy Good Creek R1
3. Chauncey Creek R1
4. Elk River R12
5. Fording River R12
6. Grave Creek R3
7. Henretta Creek R3
8. Line Creek R7.

2.4 *Sampling Stratification*

Calcite is assessed using a stratified approach based on the hierarchy of spatial scales within stream networks. The benefit of spatial stratification is that it allows for observations to be extrapolated over larger spatial areas [Bisson et al. 2006]. Three scales at which sampling could be conducted within a stream network have been considered in this plan: catchment, reach and habitat unit.

When selecting the appropriate spatial scale for sampling, we must consider the inverse relationship between resolution and sampling efficiency – going from the habitat unit (small) to catchment (large) scales. The key is to select the appropriate scale at which to sample, while maintaining the spatial resolution needed to inform management decisions (e.g., when to initiate mitigation).

Monitoring at the catchment scale was determined to be unsuitable for this plan, as this scale is too large to provide the spatial resolution necessary to adequately assess calcite deposition. Catchments typically include multiple streams that can exhibit high intra- and inter-catchment variation in calcite deposition. Because of this, it is likely that calcite management actions will be stream-specific and not based on a larger catchment. Thus, the monitoring program needs to provide data at a finer spatial resolution. Nevertheless, catchment characteristics will be considered in the monitoring plan, specifically when selecting reference locations, and to provide information such as percent disturbance.

Monitoring at the habitat-unit scale provides the finest resolution. However, calcite mitigation actions are unlikely to be implemented at this scale; therefore, the habitat unit represents a resolution (and sampling effort) that exceeds the level of detail required in the monitoring program.

Accordingly, the stream reach is recommended as the sampling unit for the monitoring program. A stream reach is a stream network subdivision that represents a spatial scale finer than a catchment, but larger than a habitat unit [Bisson et al, 2006].

Benefits of using the stream reach as a sampling unit are:

1. It closely matches the scale at which mitigation may be implemented.
2. It represents a relatively homogeneous section of stream in terms of channel morphology, riparian cover and flow [RISC, 2001], and should exhibit low intra-reach variability of calcite deposition.
3. Monitoring by reach should allow for the variability of calcite deposition within a stream to be accurately accounted for.
4. Defining a stream reach as the sampling unit provides an appropriate balance between spatial resolution and field sampling effort.

2.4.1 Reach Identification – Sampling Unit

Reaches were identified for all streams recommended for monitoring in 2013. Existing reach breaks were identified for specific streams from the following information:

- Amos, L. 2000 – Dry Creek Fish-stream identification.
- Amos, L. 2006 – Aqueduct, Spring and Qualtieri Creek Fish Stream Identification
- Arnett, T. and M.D. Robinson. 2012 – Line Creek Aquatic Monitoring Program (2011).
- Berdusco, J. 2008 – Fish and Fish Habitat Assessment for Cedar/Dry Creek Extension
- Edeburn A. and J. Wright. 2001 – Fish Habitat Assessment of Otto Creek & Bodie Creek.
- Interior Reforestation. 2008 – Coal Mountain Project Pre-Feasibility
- Pattenden, R. 1994 – Review of Fisheries and Habitat Investigations on Thompson Creek.
- Robinson, M.D. 2009 – Erickson Creek Fish Presence/Absence Survey.

For streams without predetermined reach breaks, a desktop reach delineation exercise was completed. Methods generally followed RISC standard 1:20,000 level reconnaissance fish and fish inventory methods [RISC, 2001]. Mapping data were used to determine channel pattern, channel confinement and gradient. From these, reach breaks were identified at points of significant change in morphological variables, as well as at significant tributary confluences.

One deviation from the standard reach break process presented by RISC was the treatment of highly modified channels. Constructed channels (e.g., Fish Pond Creek) or areas with high levels of disturbance (e.g., Smith Ponds) were classified as single reaches even though they may have distinguishable stream morphology characteristics within them. In highly modified channels, sampling should still be conducted to cover the range of morphological conditions observed.

Note: Where reach break observations in the field differ from those delineated during the desktop exercise, the field data may be used to add, remove or modify reach break locations. Therefore, the overall number of reaches sampled will likely evolve over time.

2.4.2 Within-Reach Replication – Sample Sites

Replication is required to assess variability within the sample unit – a key objective of this monitoring program. Replication also improves the accuracy of estimates made at the sample unit scale.

The amount of replication is determined by setting the number of replicates so that an estimate can be made with a predetermined level of accuracy (e.g., power analysis). However, this requires a prior understanding of the variability within a sampling unit. Because calcite variability within a sampling unit is unknown, it is recommended that triplicate sampling be performed within each reach, using systematic-stratified sampling set at 25, 50 and 75% of the total reach length.

Within-reach replication will be sampled based on total reach length as follows:

1. <200 m – Collect one sample over the entire length.
2. <300 m – Collect one sample beginning at the downstream end of the reach. Collect a second sample beginning at 100 m and work upstream. Do not overlap.
3. ≥300 m – Conduct systematic stratified sampling at 25, 50 and 75%.

The appropriateness of triplicate sampling will be assessed after the 2013 field program; if necessary, changes will then be made to the 2014 program.

2.4.3 Off-Channel Areas

Past monitoring and related field observations during fish habitat assessments indicate that it is possible that off-channel areas may exhibit different degrees of calcite deposition relative to mainstems. These areas include: side channels, oxbow lakes, beaver ponds and wetlands. While these areas have not been specifically identified, observations on such areas should be made opportunistically when surveying the systematically selected sites. If these observations find that calcite deposition in off-channel areas is frequently higher than that of the mainstem habitat, we recommend that off-channel habitat be included as a formal monitoring component.

2.4.4 Additional Considerations

While the conceptual model developed by SRK [MacGregor et al. 2011] provides a plausible explanation for the processes leading to the precipitation of calcite, little is known about the mechanisms behind deposition on a reach or sub-reach level. For example, not all streams with waste rock or rock drains exhibit calcite deposition. In addition, the distance downstream of mining where calcite deposition does occur is variable and difficult to predict. Mechanisms such as changes in channel morphology may all play a role in determining where (and where not) calcite may precipitate (e.g., Teepee Creek on Line Creek).

It is recommended that:

1. Where the degree of calcite deposition is observed in the field to be moderate-high at the 25% site, observers should survey the downstream confluence to investigate whether or not an abrupt change in deposition occurs (i.e., start/stop points)
2. Opportunistic sampling will take place if calcite deposition is encountered while going to planned sites. Should calcite be found, a site should be established and included in the monitoring program.

2.5 *Sampling Timing and Frequency*

The timing of sampling will be compatible with past monitoring programs and will be completed between September and October annually. Given that the rate of inter-annual change in calcite deposition is presently unknown, annual sampling is necessary to assess the appropriate sampling frequency. Annual sampling is recommended for the first three years of this program. At the end of this period, sampling frequency will be re-evaluated and adjusted accordingly. The reconnaissance level surveys will also follow this frequency.

3 Data Collection Components

The calcite monitoring program will be used to describe: (1) calcite extent; (2) degree; and, (3) characteristics of the deposition. The following sections describe the general concepts for each data collection component, along with benefits and limitations. Detailed data collection methods and procedures can be found in Appendix 2.

3.1 *Calcite Deposition Extent*

In this plan, the extent of calcite deposition describes the spatial coverage expressed on two scales: (1) areal coverage at a specific location (i.e., sample site); or, (2) linear coverage over a reach. The two scales are related in that detailed measurements made at a site-scale will be used to extrapolate calcite extent over a reach.

3.1.1 Site-Level Extent

A modified Wolman pebble count [Wolman, 1954] will be used to estimate calcite extent at each site. A Wolman pebble count is a well-known method for obtaining estimates of stream bed particle size distribution, which can be easily modified to derive estimates of calcite coverage as a percent of stream bed particles. The standard pebble count procedure requires an observer move systematically over the area of interest, stopping periodically and randomly selecting a particle using one finger. It is standard for 100 particles to be measured. For the monitoring plan, the diameter of all particles larger than 2 mm (i.e., gravels and larger) will be measured along the intermediate (“b”) axis. All fine particles (i.e. <2 mm) will noted as “fines”, but not measured. The adaptation to obtain an estimate of calcite coverage is such that the observer will note whether or not the individual particle has surficial or complete calcite coverage. From this, an estimate of percent calcite presence will be derived.

For representative estimates of linear extent over an entire reach, it is important that the pebble count include the different habitat types observed at each site. Four habitat types are used: riffles, cascades, pools and glides. This generally follows the “Type 2” habitat types outlined in the BC Fish Habitat Assessment Procedure, with a distinction between riffle and cascade [Johnston and Slaney 1996]. For the purpose of this plan, a habitat unit is considered a cascade when it has >4% slope, and a riffle if it has a slope of ≤4%.

Lentic reaches will be measured at three points along the shoreline. Pebble counts will be completed to cover the relative proportions of habitat types observed. The habitat type from which a rock is sampled will be recorded with each pebble.

3.1.2 Linear Extent

The linear extent of calcite deposition will be estimated using Geographic Information Systems (GIS) techniques. Estimates of the degree and site-level extent will be interpolated spatially over the length of a reach to report the following:

1. Mean degree of calcite per kilometre total reach length by
2. Reach-level calcite coverage as: mean stream width × mean site-level extent × reach length
3. Any linear gradients in degree or extent over multiple reaches

Analysis of the actual data collected may yield additional or different reporting methodologies.

3.2 *Degree of Calcite Deposition*

The term "degree" is used in this plan as describing the amount of calcite deposition at a given location. The degree of calcite will be described as the level of stream bed concretion. Qualitative estimates will be derived from the level of effort required to remove a particle from the stream bed during the pebble counts. Observers will report whether the particle was removed with (1) negligible resistance (not concreted); (2) noticeable resistance but removable (partially concreted); or, (3) immovable (fully concreted). This will be based on a typical amount of effort for removal and is specific to resistance created by calcite. Observers will also report specifically if calcite is present on larger particles, interstitial particles, or both.

3.3 *Characteristics of Calcite Depositions*

Characteristics of calcite deposits will be measured in addition to degree and extent. Four potential characteristics of calcite deposition were considered as part of this plan. Of these, only the type of calcite (form) was accepted and included. Characteristics of calcite coverage and thickness (included in past programs) were determined to be effectively addressed under calcite degree, therefore, not recommended for the 2013 sampling program.

Types of calcite formation have been included in past monitoring programs as general descriptions of calcite deposit morphology [Vast, 2013]. Types of deposit that will be visually determined are: calcified algae, calcareous laminate, calcified moss/tufa, barrage tufa, calcite scale, and insect tufa.

3.4 *Rate of Change (Formation/Deposition)*

Rate of change in calcite depositions will be assessed after multiple years of data have been collected. Change will be determined by comparing the various measures of extent and degree of calcite deposition between the years. Rate of change estimates will be feasible over time if the proposed methods are found to produce quantitative estimates of the degree of calcite deposition as anticipated.

3.5 *General Site-Level Field Procedure*

This protocol describes the steps a field crew will follow once at a site. A complete field manual is provided in Appendix 2.

1. Access the targeted stream reach and follow decision pathway:

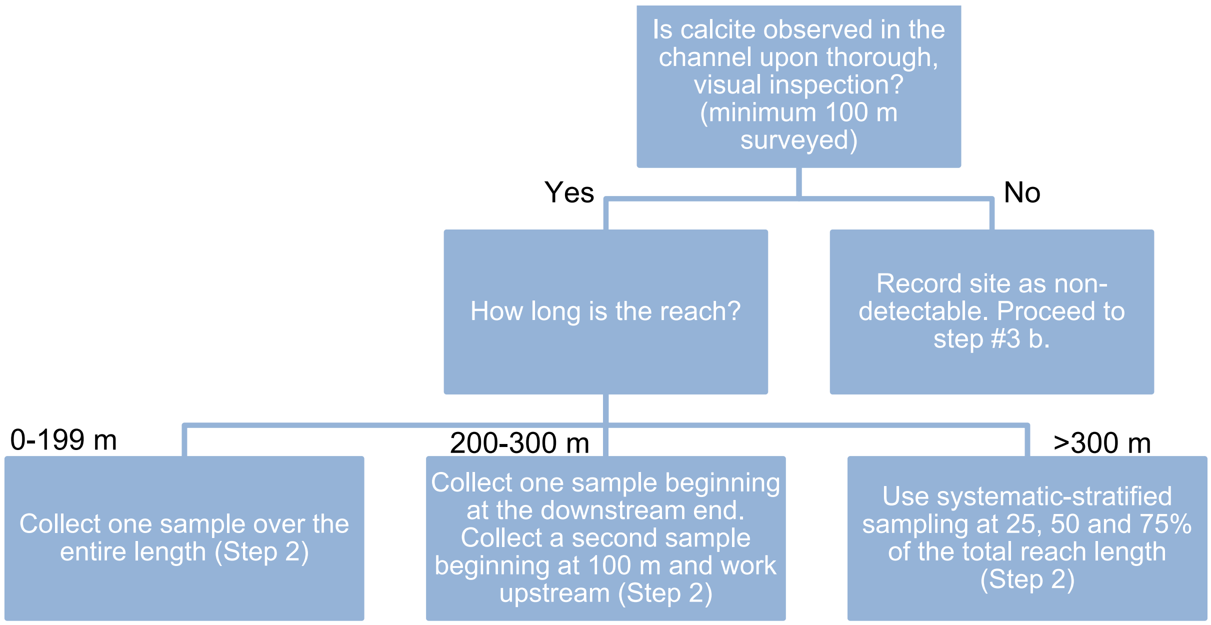


Figure 1: Stream Reach Decision Pathway

2. Complete a pebble count. Record:
    a. Calcite presence/absence
    b. Level of concretion
    c. b-axis length
    d. habitat type

3. Record general site descriptions (see Appendix 2 for more details):
    a. Calcite deposition type
    b. Channel morphology, channel gradient, channel width, channel depth, wetted width and wetted depth)
    c. Canopy cover, riparian vegetation type
    d. Periphyton/algae cover

4. Complete site mapping and photograph site (see Appendix 2 for more details).

3.6 *Calcite Deposition Index*

A Calcite Deposition Index (CDI) was first presented in 2010 [Hlushak 2011]. This index was designed to incorporate a series of metrics providing a single scale from which comparisons over time and among areas can be made. Specifically, sites were assigned a CDI value using scores derived from calcite coverage, calcite hardness and concreted status. Indices can be valuable tools and provide insight from multiple parameters that may otherwise be difficult to detect.

A potential concern in developing an index is covariability among the components. Covariability is a measure of how much two or more variables change in a way predictable by one another (i.e., how much variables change together). In an index model, the stronger the covariability, the greater the "overlap" in contribution to the final index value. Thus, while the model produces a wider range of values (i.e. combinations of model component values), the results tell little more than if just one component were used. Monitoring completed to date provides an opportunity to examine the covariability of the CDI.

The current CDI model was assessed using a simple covariance matrix (see Figure 2). The three input variables appeared to be highly colinear

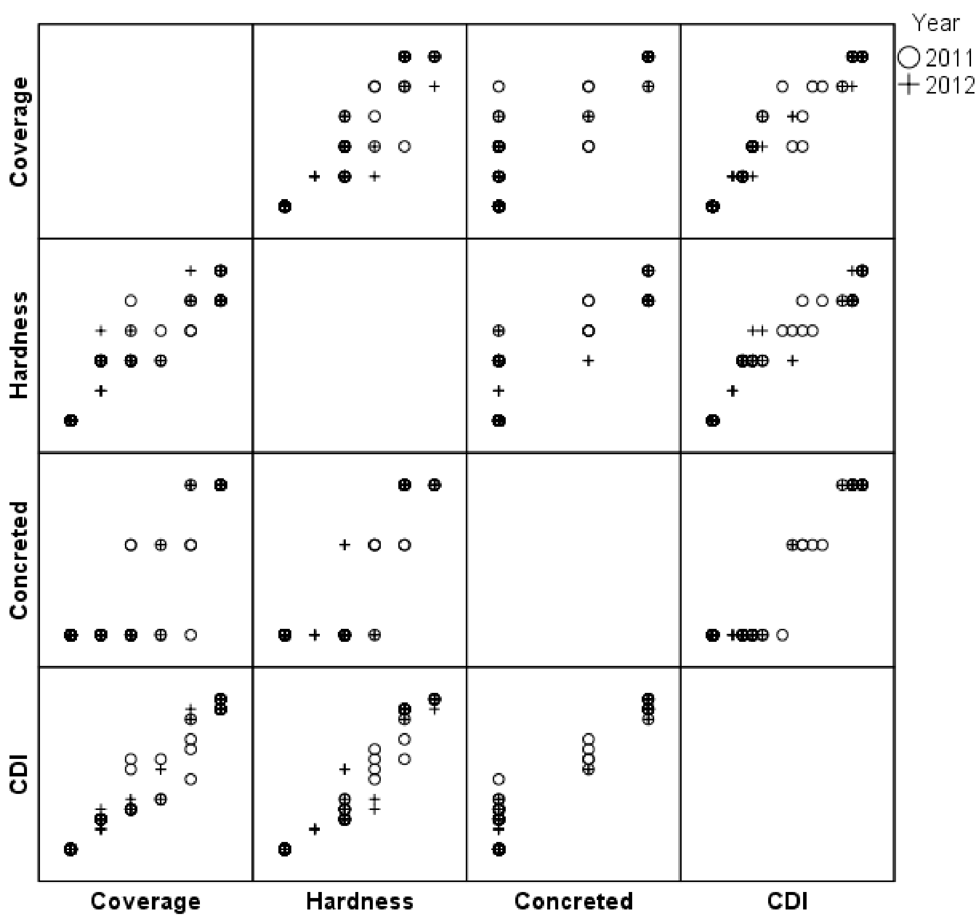


Figure 2. Matrix plot of CDI and CDI components from 2011-2012.

Pearson-correlation analysis was then used to identify significant correlations, which were found for all pairings (see Table 1).

Table 1. Pearson-correlation analysis results.

	Coverage	Hardness	Concreted
Coverage	1.00	0.950*	0.899*
Hardness		1.00	0.840*
Concreted			1.00*

*Correlation significant at least at the 0.01 level (2-tailed) (N=160).

Given that all of the three possible pairings are correlated, it is unlikely that the current CDI is responding as intended. The incorporation of three variables was expected to provide a more in-depth description of a site and thus finer resolution for comparing between sites and over time. However, the covariance matrix results demonstrate that similar CDI results could have been obtained using only one of the variables presented. For example, linear regression results showed that coverage explains 97% of the variation in CDI (R2 = 0.97, slope = 2.82, intercept = 0.123, $p < 0.0001$). With an intercept approaching zero, the slope of the regression equation demonstrates that multiplying a coverage estimate by approximately 3, would have a 97% likelihood of the same CDI as the three-variable model.

4 Program Assessment and Refinement

Evaluation of the program is expected to be more extensive in the initial years of this monitoring program, as information on site selection and field methods becomes available. Program refinement will be ongoing as site-specific trends are identified and mine operations extend or move towards closure in various areas. The following sections discuss three levels of program assessment and refinement.

4.1 *Pre-Field Assessment*

Before the 2013 field season, pebble count and point-intercept methods of estimating calcite deposition were assessed: at eight sites of varying calcite deposition severity. The assessment found no significant difference in the data returned, but that the pebble count was nearly twice as efficient to complete. Accordingly, pebble counts was selected as the primary assessment method.

4.2 *Assessments from 2013 Field Season Data*

Several assessments will be completed in 2014 and 2015, after the 2013 field data have been collected. Generally, these will be assessments of the various methods that have been proposed.

Method reproducibility, sample design (e.g., number of replicates), and variability of data within a site must all be assessed in the initial years of the program. From these assessments, methods will be accepted, modified, and/or rejected depending on the value of the data provided.

4.2.1 Observer Variability

A key aspect of this plan development is to provide practical and accurate methods of assessing calcite deposits in streams, but most importantly this plan should facilitate reproducible data collection among sampling crews. To assess observer variability, a subsample of sites will be selected where measurements will be conducted by all field crews, with no person serving on more than one crew. Observer bias among crews will be determined by comparing data collected by each group.

4.2.2 Linear Extent

The proposed design is based on the assumption that three sites will be adequate for detecting and describing calcite deposition over a stream reach. To confirm this, estimates of deposition from sample sites will be compared to observations from streams that are surveyed in their entirety. The assessment will ask, “How reliably can calcite be detected within a reach by sampling at only three locations?” From this, it will be possible to determine the number of replicates within a reach required to estimate the linear extent of calcite deposition to an acceptable level of accuracy.

4.2.3 Calcite Index

Although all parameters that measure calcite deposition are inherently related, quantitative sampling methods and a wider range of variables will be used in 2013 to help mitigate covariance in the CDI.

4.3 *Ongoing Stream Selection Process*

For maximum effectiveness in monitoring calcite deposition accurately, this plan is designed to evolve as information is gained and mine operations develop. Sampling frequency is a key aspect that will need to be re-evaluated in subsequent years. The plan recommends annual sampling over 2013-2015 to address the data gap in understanding inter-annual variation of calcite deposition. After 2015, the monitoring program results will be assessed to investigate the change in calcite degree and extent over time on a stream reach basis.

Stream reaches showing negligible change should be considered for a reduced sampling frequency (e.g., once in every three years). Importantly this monitoring plan would be synchronized with the regional AEMP. Stream reaches showing higher rates of change may require continued annual sampling until trends level at non-concerning levels or mitigation is triggered.

Stream selection for 2013 resulted in two criteria, mine exposure and regulatory requirements, being used exclusively. These criteria should continue to be used to identify streams included in the calcite monitoring program. However, with an improved understanding of calcite deposition, additional selection criteria such as saturation index may also be added. Reassessment of stream inclusion criteria should be completed prior to each year of the monitoring program; annually for the next three years and potentially at a reduced frequency thereafter.

It should be noted that in situations such as inclusion to obtain baseline conditions (i.e., environmental assessment regulatory requirement), sampling of specific reaches may be required in “off-sampling” years to meet specific regulatory requirements. After regulatory requirements have been met, however, sampling frequency will be brought into synchrony with the larger monitoring program.

An important consideration of the overall monitoring program is when to discontinue sampling on any particular stream. Three criteria have been identified to determine when a stream will no longer require calcite monitoring:

1. The stream channel, seep, or pond outflow is dry/ephemeral for most of the year (other than spring), and does not exhibit calcite deposition.
2. The stream channel, seep, or pond outflow does not meet the definition of fish habitat as per the federal Fisheries Act.

3. Future research and development and/or monitoring demonstrate, with a high level of confidence, that a particular stream channel, seep, or pond outflow is not susceptible to calcite deposition.

5 Quality Assurance and Quality Control (QA/QC)

QA/QC steps have been added to three stages of monitoring as described below.

5.1 *Pre-Field QA/QC*

The following steps will be taken during the pre-field preparation stage to ensure data quality:

1. A project manager will complete a review of the recommendation section from previous monitoring reports, recommending which data collection methods are have been accepted as valid methods, and providing justification for eliminating those methods which are not accepted as valid.
2. Immediately prior to each field season, sampling crews will be trained on all field data collection methods by a crew member experienced with these methods. This training will be done at one site, where each crew will have the opportunity to gain experience with each of the sampling methods.

5.2 *Fieldwork QA/QC*

During the field program, data quality will be controlled as follows:

1. Each sampling crew member will conduct the same task at each site. For example, crew members conducting pebble counts will do so for the entire field season. This will eliminate observer bias and improve data consistency.
2. If multiple crews are used, observer bias will be assessed by having each crew complete data collection tasks at three reference sites with low, moderate and high levels of calcite deposition.
3. Within-site variability will be assessed by collecting triplicate samples used for calcite degree.
4. Within-reach variability will be assessed by sampling at triplicate sites whenever the reach is greater than 100 m in length.
5. At the end of each field day, data collection forms will be reviewed for completeness by the crew lead and signed off by that person.
6. Signed data collection forms will be scanned and submitted to the Project Manager.

5.3 *Data entry QA/QC*

The quality of data will be assured and controlled during the data entry/management stage as follows:

1. Submitted data forms will be reviewed and signed off as complete by the Project Manager on a weekly basis. The review will look for completeness as well as any

anomalous results. By entering data on a weekly basis, biases between crews as well as any errors in data collection can be captured and mitigated.

2. Data will be managed by maintaining digital copies on a secure computer server. As well, hard copies of scanned field forms will be printed and maintained in a secure location.

6 Literature Cited

Amos, L. 2000. Dry Creek Fish Stream Identification within CP 609. Letter report prepared by Interior Reforestation. Prepared for Crestbrook Forest Industries Ltd.

Amos, L. 2006. Aqueduct, Spring and Qualtieri Creek Fish Stream Identification. Prepared by Elk Valley Coal Corporation, Elkview Operations, for Ministry of Environment. 37 pp. May 2006.

Arnett, T. and M.D. Robinson. 2012. Line Creek Aquatic Monitoring Program (2011). Prepared for Teck Coal Ltd. – Line Creek Operations. Prepared by Lotic Environmental Ltd. 48 pg. 7 appds.

Berdusco, J. 2009. Teck Coal Ltd. Mine Site Calcite Deposition Mapping Project. Consultant report prepared for Teck Coal Ltd. Prepared by Interior Reforestation Co. Ltd., Cranbrook, BC.

Berdusco, J. 2008. 2008 Fish and Fish Habitat Assessment for the Proposed Cedar/Dry Creek Extension. Consultant report, prepared by Interior Reforestation Co. Ltd. Prepared for: Teck Coal Ltd. 18 pp. October 2008.

Bisson, PA, Montgomery, DR and JM Buffington. 2006. Valley Segments, Stream Reaches, and Channel Units. Chapter 2 *in* Methods in Stream Ecology. Elsevier, US. 28 pp.

Edeburn, A. and J. Wright. 2001. Fish Habitat Assessment of Otto Creek and Bodie Creek. Consultant report prepared by Interior Reforestation Co. Ltd. Prepared for Elkview Coal Corporation. 8pp. August 2001.

Hlushak. 2011. Calcite Monitoring Program – 2010 Field Assessment Reporting. Consultants report prepared for Teck Coal Ltd. Prepared by Interior Reforestation Co. Ltd. 13 pg + appendices.

IR. 2008. *Marten Wheeler Project Pre-Feasibility Environmental Overview Report*. Consultant report prepared for Elk Valley Coal Corporation, Calgary Operations, Calgary, AB. Prepared by Interior Reforestation Co. Ltd., Cranbrook, BC. 44 pp. + 12 appendices.

Johnston N.T. and P.A. Slaney. 1996. Fish habitat assessment procedures. Watershed Restoration Technical Circular No 8. Watershed Restoration Program, Ministry of Environment, Lands and Parks and Ministry of Forests.

MacGregor, D., Day, S. and G. Lopez. 2011. Investigations of Calcite Deposits in Streams Downstream of Coal Waste Rock Dumps, British Columbia and Alberta, Canada Prepared by SRK Consulting (Canada) Inc. and Teck Coal Ltd. 24 pp.

Pattenden, R. 1994. Review of Fisheries and Habitat Investigations on Thompson Creek. Prepared for Fording Coal Ltd by R.L.&L. Environmental Services Ltd.

RISC (Resource Inventory Standards Committee). 2001. Reconnaissance (1:20 000) Fish and Fish Habitat Inventory Standards and Procedures, Version 2.0. Prepared by BC Fisheries Information Services Branch for the Resources Inventory Committee.

Robinson, M.D. 2009. Erickson Creek Fish Presence/Absence Survey. Consultant report prepared by Interior Reforestation Co. Ltd. Prepared for Elk Valley Coal Corporation. 20 pp. December 2009.

Vast. 2013. Calcite Monitoring Program – 2012 Field Assessment (Elk Valley). Prepared for Teck Coal Ltd. Prepared by VAST Resource Solutions. 131 pp.

Wolman, MG. 1954. A Method of Sampling Coarse River-Bed Material. Transactions of the American Geophysical Union. 35(6):951-956.

Appendix 1. 2013 Calcite Monitoring Streams by Reach

Zone	Operation	Reach_Name	Type	2012 AEMP site	Start easting	Start northing	End easting	End northing	Start elevation (m)	Gradient	Length (m)	Sinuosity	Stream order	Fish bearing status	Watershed area (km_2)
Elk Valley	EVO	Alexander Creek R3	Reference	Y	664,028	5,502,824	664,967	5,509,032	1317	1.6%	8,122	1.3	4	FB	144.3
Elk Valley	CMO	Andy Good Creek R1	Reference	Y	667,175	5,488,205	669,464	5,488,776	1507	1.0%	2,172	1.1	4	FB	34.3
Elk Valley	EVO	Aqueduct Creek R1	Exposed	N	653,917	5,511,549	654,018	5,511,463	1139	0.0%	158	1.2	3	FB	2.8
Elk Valley	EVO	Aqueduct Creek R2	Exposed	Y	654,018	5,511,463	654,210	5,511,288	1139	1.0%	287	1.1	3	Unknown	1.9
Elk Valley	EVO	Aqueduct Creek R3	Exposed	N	654,210	5,511,288	654,452	5,511,160	1142	2.7%	376	1.4	2	Unknown	1.6
Elk Valley	EVO	Balmer Creek	Exposed	N					To be confirmed during field program						
Elk Valley	EVO	Beltline	Exposed	N					To be confirmed during field program						
Elk Valley	EVO	Bodie Creek R1	Exposed	Y	655,341	5,509,626	655,656	5,509,576	1157	0.7%	417	1.3	2	Unknown	8.8
Elk Valley	EVO	Bodie Creek R2	Exposed	N	655,656	5,509,576	655,855	5,509,462	1160	2.0%	560	2.4	2	FB	8.7
Elk Valley	EVO	Bodie Creek R3	Exposed	N	655,855	5,509,462	656,154	5,509,813	1171	26.4%	474	1.0	2	IFB	8.5
Elk Valley	CMO	Carbon Creek R1	Proposed	N	659,441	5,494,295	657,905	5,492,968	1342	6.1%	2,247	1.1	3	FB	10.5
Elk Valley	CMO	Carbon Creek R2	Proposed	N	657,905	5,492,968	656,401	5,492,639	1478	8.5%	1,648	1.1	3	FB	8.2
Elk Valley	FRO	Cataract Creek R1	Exposed	N	652,606	5,557,629	652,474	5,557,557	1582	18.6%	161	1.1	6	NFB	5.9
Elk Valley	FRO	Cataract Creek R2	Exposed	Y	652,474	5,557,557	652,391	5,557,455	1612	3.3%	338	2.6	3	NFB	5.9
Elk Valley	FRO	Cataract Creek R3	Exposed	N	652,391	5,557,455	652,114	5,557,375	1623	7.8%	296	1.0	3	NFB	5.9
Elk Valley	FRO	Chauncey Creek R1	Reference	Y	655,319	5,552,765	656,212	5,552,924	1557	2.6%	1,092	1.2	5	FB	34.8
Elk Valley	EVO	Chostner	Exposed	N					To be confirmed during field program						
Elk Valley	FRO	Clode Pond R1	Exposed	N	650,789	5,564,241	650,881	5,564,285	1675	0.0%	113	1.1	1	FB	7.8
Elk Valley	FRO	Clode West R1	Exposed	N	650,806	5,563,951	650,880	5,564,195	1671	1.0%	306	1.2	1	IFB	0.0
Elk Valley	CMO	Corbin Creek R1	Exposed	Y	668,189	5,487,096	668,560	5,487,422	1504	2.4%	588	1.2	4	FB	29.2
Elk Valley	CMO	Corbin Creek R2	Exposed	N	668,560	5,487,422	670,006	5,486,384	1518	3.4%	2,329	1.3	4	FB	28.7
Elk Valley	EVO	Dry Creek #2 R1	Exposed	N	659,420	5,517,528	659,360	5,517,456	1459	5.1%	137	1.5	2	FB	12.4
Elk Valley	EVO	Dry Creek #2 R2	Exposed	N	659,360	5,517,456	659,128	5,517,049	1466	5.0%	484	1.0	2	FB	12.4
Elk Valley	EVO	Dry Creek #2 R3	Exposed	N	659,128	5,517,049	658,579	5,516,336	1490	5.6%	927	1.0	2	FB	12.2
Elk Valley	LCO	Dry Creek (LCO) R1	Proposed	Y	655,860	5,544,765	656,776	5,544,026	1513	2.5%	1,917	1.6	6	FB	27.0
Elk Valley	LCO	Dry Creek (LCO) R2	Proposed	N	656,776	5,544,026	657,168	5,543,330	1561	3.3%	916	1.2	4	FB	25.7
Elk Valley	LCO	Dry Creek (LCO) R3	Proposed	N	657,168	5,543,330	657,639	5,542,389	1591	2.6%	1,359	1.3	4	FB	23.5
Elk Valley	LCO	Dry Creek (LCO) R4	Proposed	N	657,639	5,542,389	658,104	5,541,256	1627	4.5%	1,348	1.1	4	FB	18.8
Elk Valley	LCO	Dry Creek (LCO) R5	Proposed	N	658,104	5,541,256	658,635	5,539,666	1688	7.2%	1,744	1.0	3	IFB	9.0
Elk Valley	LCO	Dry Creek (LCO) R6	Proposed	N	658,635	5,539,666	658,478	5,537,261	1814	10.4%	2,714	1.1	3	IFB	5.8
Elk Valley	FRO	Eagle Pond Outlet R1	Exposed	N	651,235	5,562,779	651,247	5,562,776	1656	8.2%	12	1.0	5	Unknown	116.3
Elk Valley	Regional	Elk River R8	Exposed	Y	640,416	5,487,048	651,621	5,511,895	1003	0.4%	31,854	1.2	7	FB	3166.7
Elk Valley	Regional	Elk River R9	Exposed	Y	651,621	5,511,895	652,546	5,513,823	1119	0.5%	2,517	1.2	7	FB	2168.5
Elk Valley	Regional	Elk River R10	Exposed	Y	652,546	5,513,823	652,515	5,527,764	1132	0.5%	16,810	1.2	7	FB	2164.1
Elk Valley	Regional	Elk River R11	Exposed	Y	652,515	5,527,764	649,337	5,543,331	1212	0.2%	21,789	1.4	7	FB	1219.4
Elk Valley	Regional	Elk River R12	Exposed	Y	649,337	5,543,331	647,010	5,557,094	1259	0.4%	19,937	1.4	6	FB	1009.6
Elk Valley	Regional	Elk River R12	Reference	Y	648,302	5,577,678	645,901	5,589,166	1494	0.9%	14,176	1.2	6	FB	430.7
Elk Valley	EVO	Erickson Creek R1	Exposed	Y	659,848	5,505,073	660,119	5,505,189	1215	7.7%	352	1.2	4	FB	32.7
Elk Valley	EVO	Erickson Creek R2	Exposed	N	660,119	5,505,189	660,284	5,505,338	1242	8.8%	239	1.1	4	NFB	32.7
Elk Valley	EVO	Erickson Creek R3	Exposed	N	660,284	5,505,338	660,457	5,505,401	1263	8.5%	188	1.0	4	NFB	32.4
Elk Valley	EVO	Erickson Creek R4	Exposed	N	660,457	5,505,401	660,774	5,506,802	1279	4.2%	1,582	1.1	4	NFB	32.2
Elk Valley	EVO	Feltham Creek R1	Exposed	N	654,100	5,515,824	654,655	5,516,037	1406	32.8%	603	1.0	1	NFB	0.6
Elk Valley	EVO	Fennelon Creek R1	Exposed	N	653,061	5,516,207	654,524	5,516,671	1144	27.3%	1,587	1.0	1	Unknown	2017.4
Elk Valley	FRO	Fish Pond Creek R1	Exposed	N	650,809	5,564,427	651,174	5,565,010	1676	0.7%	842	1.2	3	FB	0.8
Elk Valley	Regional	Fording River R1	Exposed	Y	652,515	5,527,764	653,878	5,529,452	1212	0.9%	2,566	1.2	6	FB	621.0
Elk Valley	Regional	Fording River R2	Exposed	Y	653,878	5,529,452	654,224	5,533,449	1235	0.9%	5,471	1.4	6	FB	478.5
Elk Valley	Regional	Fording River R3	Exposed	Y	654,224	5,533,449	651,858	5,540,497	1285	0.9%	8,820	1.2	6	FB	466.1
Elk Valley	Regional	Fording River R4	Exposed	Y	651,858	5,540,497	652,907	5,545,666	1362	1.7%	7,204	1.4	6	FB	426.7
Elk Valley	Regional	Fording River R5	Exposed	Y	652,907	5,545,666	657,178	5,549,048	1488	0.4%	10,678	2.0	6	FB	415.6
Elk Valley	Regional	Fording River R6	Exposed	Y	657,178	5,549,048	656,439	5,551,856	1532	0.4%	4,727	1.6	6	FB	264.2
Elk Valley	Regional	Fording River R7	Exposed	Y	656,439	5,551,856	655,310	5,552,731	1551	0.3%	1,881	1.3	6	FB	255.0
Elk Valley	Regional	Fording River R8	Exposed	Y	655,310	5,552,731	653,752	5,556,036	1556	0.2%	7,017	1.9	6	FB	217.7
Elk Valley	FRO	Fording River R9	Exposed	Y	653,752	5,556,036	651,830	5,559,898	1569	0.7%	5,249	1.2	6	FB	192.9
Elk Valley	FRO	Fording River R10	Exposed	Y	651,830	5,559,898	651,279	5,562,590	1606	1.7%	3,336	1.2	5	FB	130.6
Elk Valley	FRO	Fording River R11	Exposed	Y	651,279	5,562,590	651,817	5,566,130	1662	0.8%	5,074	1.4	5	FB	116.9
Elk Valley	FRO	Fording River R12	Reference	Y	651,817	5,566,130	652,982	5,571,610	1702	2.2%	7,221	1.3	5	FB	87.2
Elk Valley	GHO	Gardine Creek R1	Exposed	N	654,271	5,547,699	652,908	5,549,372	1625	7.5%	2,416	1.1	2	IFB	2.7
Elk Valley	EVO	Gate Creek R1	Exposed	N	655,639	5,509,248	655,812	5,509,175	1161	1.5%	393	2.1	2	IFB	4.6
Elk Valley	EVO	Gate Creek R2	Exposed	N	655,812	5,509,175	657,392	5,509,745	1155	22.8%	1,823	1.1	2	FB	1.2
Elk Valley	EVO	Goddard Creek R1	Exposed	Y	652,848	5,514,113	653,145	5,514,132	1127	1.7%	401	1.4	3	FB	8.3

Zone	Operation	Reach_Name	Type	2012 AEMP site	Start easting	Start northing	End easting	End northing	Start elevation (m)	Gradient	Length (m)	Sinuosity	Stream order	Fish bearing status	Watershed area (km2)
Elk Valley	EVO	Goddard Creek R2	Exposed	N	653,145	5,514,132	653,956	5,514,158	1134	13.9%	954	1.2	3	NFB	4.2
Elk Valley	EVO	Goddard Creek R3	Exposed	N	653,956	5,514,158	654,887	5,514,431	1267	22.1%	1,102	1.1	3	NFB	3.5
Elk Valley	LCO	Grace Creek R1	Proposed	N	653,594	5,538,258	653,873	5,540,417	1342	3.2%	2,727	1.3	6	FB	18.0
Elk Valley	LCO	Grace Creek R2	Proposed	N	653,873	5,540,417	655,923	5,540,424	1428	9.0%	2,594	1.3	4	IFB	8.9
Elk Valley	LCO	Grace Creek R3	Proposed	N	655,923	5,540,424	657,317	5,537,768	1661	13.0%	3,252	1.1	4	IFB	5.5
Elk Valley	FRO	Grassy Creek R1	Exposed	N	650,924	5,563,580	650,986	5,563,945	1666	0.7%	430	1.2	1	Unknown	0.2
Elk Valley	EVO	Grave Creek R1	Exposed	N	653,363	5,523,502	654,565	5,523,560	1181	3.2%	1,451	1.2	5	FB	84.2
Elk Valley	EVO	Grave Creek R2	Exposed	N	654,565	5,523,560	656,529	5,522,157	1227	2.4%	2,951	1.2	4	FB	83.0
Elk Valley	EVO	Grave Creek R3	Reference	N	656,529	5,522,157	660,447	5,524,183	1297	4.9%	4,745	1.1	3	FB	24.9
Elk Valley	GHO	Greenhills Creek R1	Exposed	Y	653,298	5,545,439	653,540	5,545,776	1492	2.4%	455	1.1	3	FB	16.0
Elk Valley	GHO	Greenhills Creek R2	Exposed	Y	653,540	5,545,776	653,732	5,546,134	1503	1.3%	1,317	3.2	3	FB	15.9
Elk Valley	GHO	Greenhills Creek R3	Exposed	N	653,732	5,546,134	654,261	5,547,642	1520	5.8%	1,697	1.1	3	FB	14.1
Elk Valley	GHO	Greenhills Creek R4	Exposed	N	654,261	5,547,642	654,063	5,550,708	1619	5.9%	3,236	1.1	3	IFB	12.1
Elk Valley	EVO	Harmer Creek R1	Exposed	Y	656,529	5,522,157	657,048	5,522,158	1297	4.5%	578	1.1	3	FB	42.2
Elk Valley	EVO	Harmer Creek R2	Exposed	Y	657,048	5,522,158	657,248	5,521,942	1323	0.6%	313	1.1	3	FB	41.9
Elk Valley	EVO	Harmer Creek R3	Exposed	Y	657,248	5,521,942	658,578	5,520,134	1325	2.3%	2,508	1.1	3	FB	41.5
Elk Valley	EVO	Harmer Creek R4	Exposed	N	658,578	5,520,134	659,185	5,518,368	1382	2.7%	2,097	1.1	3	FB	32.2
Elk Valley	EVO	Harmer Creek R5	Exposed	N	659,185	5,518,368	659,402	5,517,815	1438	1.7%	629	1.1	3	FB	22.3
Elk Valley	FRO	Henretta Creek R1	Exposed	N	651,830	5,566,169	652,064	5,566,383	1702	3.3%	394	1.2	4	FB	48.6
Elk Valley	FRO	Henretta Creek R2	Exposed	Y	652,064	5,566,383	653,163	5,566,730	1715	1.2%	1,682	1.5	4	FB	48.5
Elk Valley	FRO	Henretta Creek R3	Reference	Y	653,163	5,566,730	658,215	5,570,062	1735	2.6%	7,613	1.3	4	FB	45.8
Elk Valley	EVO	Harmer Dump Seeps	Exposed	N					To be confirmed during field program						
Elk Valley	FRO	Kilmamock Creek R1	Exposed	Y	652,063	5,558,910	653,043	5,559,924	1597	2.0%	1,673	1.2	5	NFB	44.1
Elk Valley	EVO	Lagoon C Seep	Exposed	N					To be confirmed during field program						
Elk Valley	EVO	Lagoon D Seep	Exposed	N					To be confirmed during field program						
Elk Valley	FRO	Lake Mountain Creek R1	Exposed	N	650,886	5,563,276	650,437	5,563,137	1663	5.8%	548	1.2	3	IFB	13.3
Elk Valley	FRO	Lake Mountain Creek R2	Exposed	Y	650,437	5,563,137	650,306	5,563,044	1695	0.0%	161	1.0	3	IFB	13.1
Elk Valley	FRO	Lake Mountain Creek R3	Exposed	N	650,306	5,563,044	649,949	5,563,891	1695	3.2%	1,160	1.3	3	IFB	13.0
Elk Valley	FRO	Lake Mountain Creek R4	Exposed	N	649,949	5,563,891	649,940	5,564,426	1732	0.3%	640	1.2	2	IFB	6.5
Elk Valley	GHO	Leask R1	Exposed	N	648,075	5,552,835	648,316	5,553,020	1311	2.3%	515	1.7	6	FB	5.6
Elk Valley	GHO	Leask R2	Exposed	N	648,316	5,553,020	650,056	5,553,788	1323	11.7%	2,393	1.3	3	NFB	2.0
Elk Valley	FRO	Lees Lake Outlet R1	Exposed	N	651,112	5,562,305	651,103	5,562,327	1651	0.0%	27	1.1	5	Unknown	0.3
Elk Valley	EVO	Lindsay Creek R1	Exposed	N	654,301	5,514,910	654,987	5,515,608	1363	21.6%	1,074	1.1	1	IFB	0.9
Elk Valley	LCO	Line Creek R1	Exposed	N	653,878	5,529,452	655,720	5,528,840	1235	2.2%	2,406	1.0	5	FB	139.8
Elk Valley	LCO	Line Creek R2	Exposed	Y	655,720	5,528,840	658,500	5,529,961	1288	2.6%	3,441	1.2	5	FB	137.5
Elk Valley	LCO	Line Creek R3	Exposed	Y	658,500	5,529,961	659,858	5,531,724	1376	2.2%	2,658	1.2	5	FB	131.0
Elk Valley	LCO	Line Creek R4	Exposed	Y	659,858	5,531,724	660,570	5,533,119	1435	2.6%	1,777	1.1	4	FB	68.8
Elk Valley	LCO	Line Creek R7	Reference	Y	661,922	5,538,219	662,044	5,538,551	1639	3.4%	824	1.3	3	FB	7.4
Elk Valley	Regional	Michel Creek R1	Exposed	Y	651,621	5,511,895	654,372	5,510,848	1119	0.6%	3,314	1.1	7	FB	714.0
Elk Valley	Regional	Michel Creek R2	Exposed	Y	654,372	5,510,848	660,086	5,504,794	1139	0.9%	9,042	1.1	6	FB	707.1
Elk Valley	Regional	Michel Creek R3	Exposed	Y	660,086	5,504,794	659,614	5,494,182	1219	1.0%	12,638	1.2	6	FB	629.7
Elk Valley	Regional	Michel Creek R4	Exposed	Y	659,614	5,494,182	667,175	5,488,205	1345	1.0%	13,318	1.4	5	FB	151.5
Elk Valley	Regional	Michel Creek R5	Reference	Y	667,175	5,488,205	668,846	5,480,759	1481	1.7%	10,617	1.4	5	FB	67.0
Elk Valley	EVO	Milligan Creek R1	Exposed	N	658,722	5,506,024	658,827	5,506,096	1200	5.8%	138	1.1	2	NFB	2.4
Elk Valley	EVO	Milligan Creek R2	Exposed	N	658,827	5,506,096	659,038	5,506,796	1208	21.4%	771	1.1	2	NFB	2.4
Elk Valley	GHO	North Thompson Creek R1	Exposed	N	649,736	5,550,946	650,790	5,551,648	1434	9.5%	1,997	1.6	3	NFB	9.4
Elk Valley	EVO	Otto Creek R1	Exposed	Y	652,233	5,512,621	652,368	5,512,636	1126	2.6%	139	1.0	2	FB	0.1
Elk Valley	EVO	Otto Creek R2	Exposed	N	652,368	5,512,636	652,999	5,513,252	1126	1.2%	921	1.0	2	FB	3.6
Elk Valley	EVO	Otto Creek R3	Exposed	N	652,999	5,513,252	653,288	5,513,476	1137	0.5%	408	1.1	2	Unknown	2.2
Elk Valley	CMO	Pengelly Creek R1	Exposed	N	670,063	5,486,606	670,221	5,486,438	1573	6.3%	239	1.0	3	IFB	6.8
Elk Valley	EVO	Pit Road 12 Seep	Exposed	N					To be confirmed during field program						
Elk Valley	FRO	Porter Creek R1	Exposed	Y	653,683	5,555,223	653,567	5,555,328	1564	6.1%	164	1.1	2	IFB	3.0
Elk Valley	FRO	Porter Creek R2	Exposed	N	653,567	5,555,328	653,515	5,555,317	1574	4.5%	179	3.4	2	IFB	3.0
Elk Valley	FRO	Porter Creek R3	Exposed	N	653,515	5,555,317	652,720	5,554,408	1582	23.2%	1,433	1.2	2	IFB	3.0
Elk Valley	EVO	Qualteri Creek R1	Exposed	N	654,105	5,511,353	654,234	5,511,427	1141	5.1%	233	1.6	2	Unknown	0.2
Elk Valley	EVO	Saw Mill Creek R1	Exposed	N	658,703	5,519,718	658,434	5,519,817	1394	8.4%	297	1.0	2	FB	2.0
Elk Valley	EVO	Saw Mill Creek R2	Exposed	N	658,434	5,519,817	656,816	5,518,743	1419	19.8%	2,118	1.1	2	IFB	1.8
Elk Valley	EVO	Seven Seam Seep	Exposed	N					To be confirmed during field program						
Elk Valley	EVO	Sixmile Creek R1	Exposed	N	653,142	5,519,746	653,859	5,519,931	1159	6.3%	1,440	1.9	2	IFB	4.1
Elk Valley	EVO	Sixmile Creek R2	Exposed	N	653,859	5,519,931	655,722	5,518,884	1250	21.5%	2,422	1.1	2	NFB	2.4

Zone	Operation	Reach_Name	Type	2012 AEMP site	Start easting	Start northing	End easting	End northing	Start elevation (m)	Gradient	Length (m)	Sinuosity	Stream order	Fish bearing status	Watershed area (km2)
Elk Valley	FRO	Smith Ponds Outlet R1	Exposed	N	651,002	5,560,588	650,982	5,560,573	1627	19.8%	25	1.0	5	Unknown	0.1
Elk Valley	CMO	Snowslide Creek R1	Proposed	N	659,514	5,494,525	656,153	5,494,383	1340	9.9%	3,650	1.1	3	FB	5.4
Elk Valley	LCO	South Line Creek R2	Reference	Y	660,857	5,531,591	661,833	5,530,806	1471	4.2%	1,502	1.1	3	FB	24.3
Elk Valley	EVO	South Pit R1	Exposed	N	659,443	5,505,512	659,592	5,505,522	1210	3.4%	324	2.2	1	IFB	0.7
Elk Valley	EVO	South Pit R2	Exposed	N	659,592	5,505,522	659,693	5,505,900	1221	26.3%	422	1.1	1	IFB	0.5
Elk Valley	FRO	South Pond Seep R1	Exposed	N	651,857	5,559,817	651,865	5,560,014	1605	1.5%	269	1.4	1	Unknown	3.6
Elk Valley	EVO	Spring Creek R1	Exposed	N	653,367	5,511,591	653,576	5,511,674	1133	0.9%	348	1.6	3	Unknown	3.3
Elk Valley	EVO	Spring Creek R2	Exposed	N	653,576	5,511,674	654,004	5,511,295	1136	0.5%	828	1.5	3	Unknown	3.2
Elk Valley	FRO	Swift Creek R1	Exposed	Y	652,245	5,558,326	652,012	5,558,524	1590	4.1%	387	1.3	3	FB	3.8
Elk Valley	FRO	Swift Creek R2	Exposed	N	652,012	5,558,524	651,548	5,558,578	1606	3.0%	959	2.1	3	NFB	3.8
Elk Valley	GHO	Thompson Creek R1	Exposed	N	648,355	5,550,164	648,417	5,550,193	1292	1.4%	72	1.1	3	FB	12.1
Elk Valley	GHO	Thompson Creek R2	Exposed	Y	648,417	5,550,193	649,284	5,550,900	1293	6.8%	1,258	1.1	3	FB	12.0
Elk Valley	GHO	Thompson Creek R3	Exposed	N	649,284	5,550,900	649,736	5,550,946	1379	10.3%	533	1.2	3	IFB	9.5
Elk Valley	EVO	Thresher Creek R1	Exposed	N	657,539	5,506,492	658,342	5,508,879	1187	17.2%	3,250	1.3	1	IFB	1.9
Elk Valley	EVO	Unnamed Creek (#3) south	Exposed	N	659,038	5,519,168	656,702	5,517,768	1417	21.2%	2,867	1.1	2	IFB	2.4
Elk Valley	LCO	West Line Creek R1	Exposed	N	660,112	5,532,179	659,972	5,532,232	1453	11.3%	169	1.1	3	FB	9.0
Elk Valley	CMO	Wheeler Creek R1	Proposed	N	659,513	5,496,900	655,684	5,497,921	1312	4.4%	4,727	1.2	4	FB	29.0
Elk Valley	CMO	Wheeler Creek R2	Proposed	N	655,684	5,497,921	654,956	5,495,968	1518	6.4%	2,282	1.1	3	FB	10.8
Elk Valley	CMO	Wheeler Creek R3	Proposed	N	654,956	5,495,968	654,402	5,494,948	1665	4.7%	1,408	1.2	3	FB	7.5
Elk Valley	GHO	Wolfram Creek North R1	Exposed	N	648,535	5,552,402	650,497	5,553,219	1348	13.7%	2,339	1.1	2	NFB	3.8
Elk Valley	GHO	Wolfram Creek R1	Exposed	N	648,329	5,551,713	648,184	5,552,069	1304	0.7%	568	1.5	3	NFB	5.2
Elk Valley	GHO	Wolfram Creek R2	Exposed	N	648,184	5,552,069	648,305	5,552,266	1308	1.0%	605	2.6	3	NFB	4.3
Elk Valley	GHO	Wolfram Creek R3	Exposed	N	648,305	5,552,266	648,535	5,552,402	1314	10.1%	337	1.3	3	NFB	3.8
Elk Valley	GHO	Wolfram Creek South R1	Exposed	N	648,535	5,552,402	650,207	5,552,288	1348	12.3%	1,852	1.1	2	NFB	2.0

Appendix 2. Calcite Monitoring Plan Field Manual

Calcite Monitoring Plan

Field Manual

Prepared by

Lotic Environmental Ltd.
2193 Mazur Road
Cranbrook BC
V1C 6V9

Table of Contents

1 Introduction

This appendix provides details on the field sampling protocol developed as part of the calcite monitoring plan. The monitoring program is being completed as part of the overall calcite management strategy. Results will be used to describe the degree and extent of calcite deposition downstream of mine operations.

2 Field protocol overview

Conduct an office exercise to plan how stream reaches will potentially be sampled, based on length (see Figure 1). After selecting a stream reach and replicate location to sample (i.e., 25%, 50% or 75%), a field crew will follow these steps to complete sampling.

1. Access the targeted stream reach.
2. If observations support reach breaks then sample at predetermined sites. Adjust site locations accordingly if obvious errors exist from desktop derived reach breaks.
3. Follow the decision pathway once at the sampling location (Figure 1). First confirm whether calcite is present in the channel through a visual inspection. Inspection should cover a minimum of 100 m. Observers should be very thorough in this inspection by covering the entire cross-section (e.g., from one bank across to the other) and handling/scraping rocks to investigate whether or not a calcareous crust is present. If calcite is present, proceed to step 4 below. If calcite is not present, proceed to step 5b.

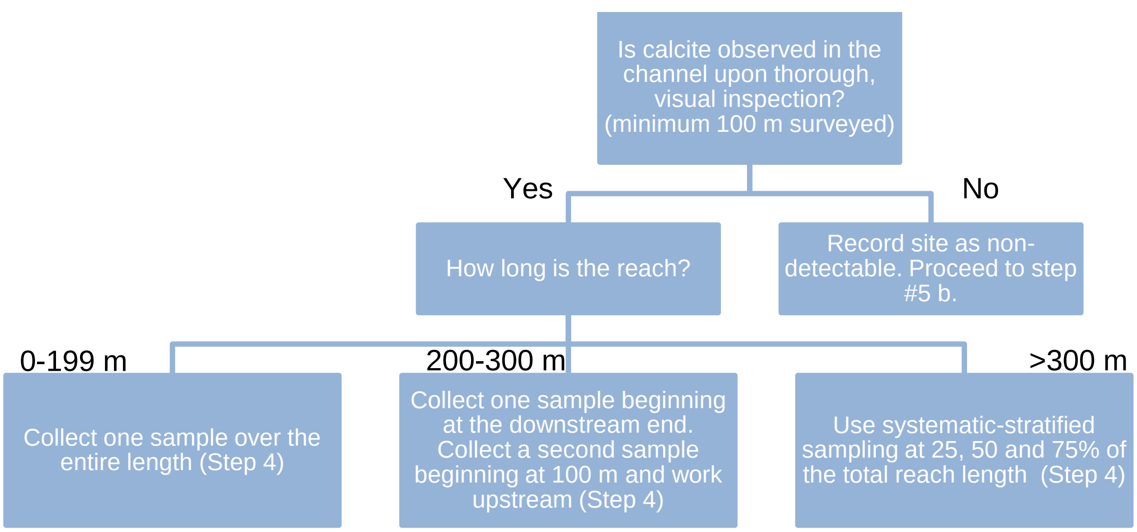


Figure 1. Calcite sampling decision pathway

4. Complete a pebble count. Record:
   a. Calcite presence/absence;
   b. Level of concretion; and,
   c. b-axis length.

5. Record general site descriptions;
   a. Calcite deposition type;

   b. Channel morphology, channel gradient, channel width, channel depth, wetted width and wetted depth);
   c. Canopy cover, riparian vegetation type; and,
   d. Periphyton/algae cover.

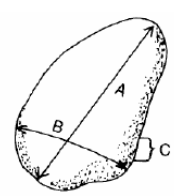
6. Complete site mapping and photograph site.

3 Detailed field protocol

3.1 *Pebble count*

When completing a pebble count, one crew member will be in the stream selecting rocks (100 in total) and one will be onshore as a recorder. The following steps will be completed:

1. Identify different habitat types (riffles, cascades, pools, and glides) present at the site and predetermine an approximate start and stop point of the count, such that counts cover the relative proportions of habitat types observed.
2. Beginning at the downstream end, the sampler is to enter the stream and randomly select an individual rock by touching the stream bed at the end of their toe with their index finger. The sampler is to then attempt to remove the exact rock first touched.
3. The following observations are recorded for each particle onto the pebble count form (Section 5) and in this order:
   a. **Habitat type** – Was the particle sampled in a riffle (R), cascade (C), pool (P), or glide (G)?
   b. **Level of concretion** – Was the particle removed without calcite-induced resistance (0); Was the particle removed with any noticeable amount of force to overcome calcite-induced resistance (1)? Was the particle non-movable or fully concreted by calcite (2)?
   c. **Calcite presence/absence** – Does the individual particle have calcite deposition? 0= No, 1= Yes.
   d. **b-axis length** – Record this in millimeters (mm) for all particles larger than 2 mm (i.e., gravel and larger). All fine particles (i.e. <2 mm) will be noted as “fines”, but not measured.



A = LONGEST AXIS (LENGTH)
B = INTERMEDIATE AXIS (WIDTH)
C = SHORTEST AXIS (THICKNESS)

Source: http://limnology.wisc.edu/courses/zoo548/Wolman%20Pebble%20Count.pdf , where a=longest axis, b=intermediate axis and c=shortest axis.

Where calcite deposition is so extensive that pure calcite is encountered and not a distinguishable rock, then that row of the pebble count form will be completed as follows: Concreted status = “2”, presence = “1”, and b-axis is assigned a letter “C”.

3.2 *General site descriptions*

Complete the following observations and record on the general site description field form:

1. **If present, identify the form of calcite deposition -** Form of deposit will be visually determined and listed as one of the following (forms and definitions from Vast 2013[1]):

Calcified algae - lumpy, soft, chalky coating on the substrate of a stream.

Calcareous laminate - an advanced stage of calcified algae.

[1] Vast. 2013. Calcite Monitoring Program – 2012 Field Assessment (Elk Valley). Prepared for Teck Coal Ltd. Prepared by VAST Resource Solutions. 131 pp.

Calcified moss/tufa - can range from soft easily broken apart to a solidified mass of moss tufa.

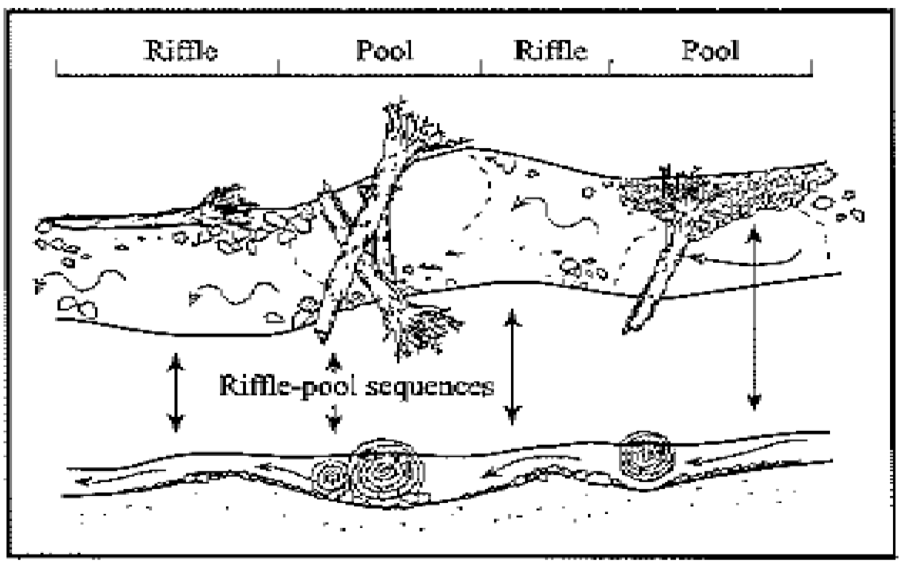
Barrage tufa - barrier-like growths extending cross-channel to block normal water flow.

Calcite scale - a relatively thin, crystalline coating, which is homogenous in texture.

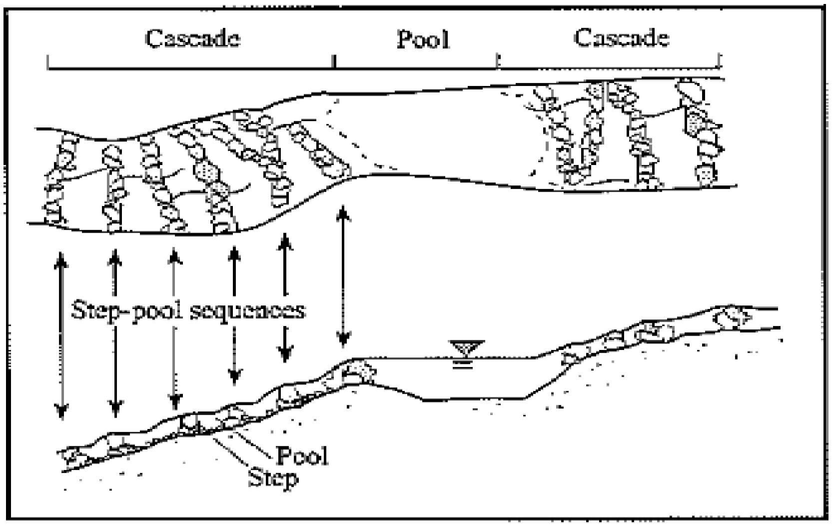

Insect tufa - formed by encrustation of the larval caddis fly cases by calcite precipitation

2. **Channel morphology**

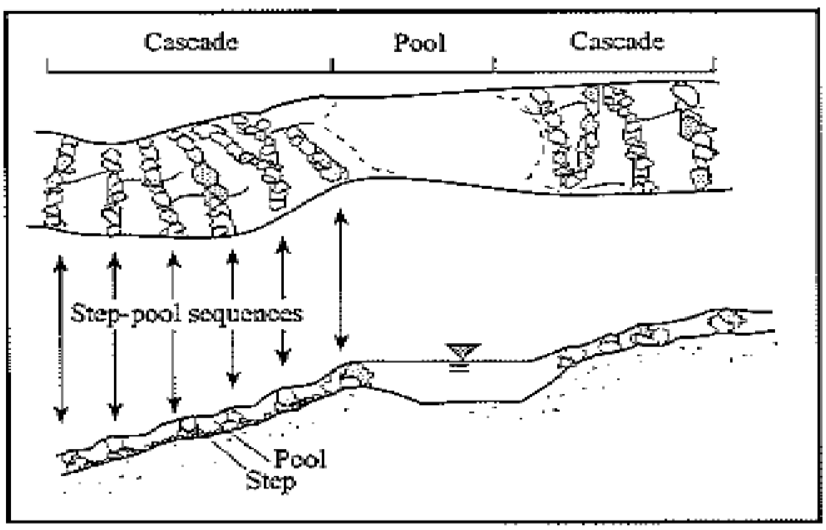
   a. Type (Photos from BC Channel Assessment Procedures



Riffle-pool (typical gradient <3%)



Cascade-pool (typical gradient <3-5%)



Step-pool (typical gradient <5%)

b. Channel gradient (%),

c. Three bank-full channel widths and channel depths (m) per site; and,

d. Three wetted widths and wetted depths (m) per site.

3. Riparian vegetation and algae/moss cover

a. % canopy cover,

b. riparian vegetation type as one of conifer, deciduous, mixed, shrub or grass; and,

c. Amount of algae using the five categories on the form

d. Moss cover as a percentage of the stream bed covered.

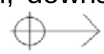
4. Mapping

Mapping can be quite effective at portraying field observations. For each site, a map will be created of the area sampled. It will show:

a. Individual habitat units – separated by solid lines across the channel and with habitat units labelled as a single letter for: riffle (R), cascade (C), pool (P), or glide (G),

b. Pebble count path - denoted as a dashed line,

c. Areas of calcite – denoted as hashed polygons. Calcite can be quite variable within a site. As such, indicating areas of deposition, if patchy, is one of the more valuable components of the map. For example, it is not uncommon to observe deposits only along the stream margin.

d. Photo points (upstream, downstream and a minimum of two substrate shots) - denoted by the symbol , with the photo number written along the arrow. Substrate photos can be taken looking through the water, looking at substrate removed from the water and placed on shore, or underwater. It is imperative that all photos accurately depict the observations. They will be particularly important where reporting that calcite was not detected, and;

e. Any other notable features.

4 Quality assurance and quality control (QA/QC)

During the field program, data quality will be controlled by:

1. Ensuring each sampling crew member conducts the same task at each site over the course of the entire field season. For example, crew members conducting pebble counts will do so for the entire field season. By ensuring consistency throughout the field season, bias will be reduced, thereby resulting in improved data quality.
2. If multiple crews are used, observer bias will be assessed by having each crew complete data collection tasks at three sites of reference, low, moderate and high calcite deposition status.
3. Within reach variability will be assessed by sampling at triplicate sites whenever the reach is greater than 300 m in length.
4. Data collection forms will be reviewed for completeness and signed at the end of each field day by the crew lead.
5. Signed data collection forms will be scanned and submitted to the Project Manager daily.

5 Data Collection Forms

- Pebble Count Form
- General Site Form

Stream:	Date:
Site:	Crew:
GPS:	Easting:
Camera:	Northing:

Calcite observations

Calcite present? (circle):	Yes	No

Calcite type (circle):	Calcified algae	Calcareous laminate	Calcified moss/tufa
	Barrage tufa	Calcite scale	Insect tufa

Channel morphology

Channel type (circle):	riffle-pool	cascade-pool	step-pool	
Wetted width #1 (m):		Channel width #1 (m):		Gradient %:
Wetted width #2 (m):		Channel width #2 (m):		
Wetted width #3 (m):		Channel width #3 (m):		
Wetted depth #1 (m):		Channel depth #1 (m):		
Wetted depth #2 (m):		Channel depth #2 (m):		
Wetted depth #3 (m):		Channel depth #3 (m):		

Riparian and algae

% canopy cover:	
Riparian type (circle):	Conifer Deciduous Mixed Shrub Grass
Periphyton cover (circle)	1 - Rocks are not slippery, no obvious colour (thin layer < 0.5 mm thick) 2 - Rocks are slightly slippery, yellow-brown to light green colour (0.5-1 mm thick) 3 - Rocks have a noticeable slippery feel (footing is slippery), with patches of thicker green to brown algae (1-5 mm thick) 4 - Rocks are very slippery (algae can be removed with thumbnail), numerous large clumps of green to dark brown algae (5 mm -20 mm thick) 5 - Rocks are mostly obscured by algal mat, extensive green, brown to black algal mass may have long strands (> 20 mm thick)
Moss coverage (circle):	0% 1-25% 26-50% 51-75% 76-100%

Photos

Upstream view of site:		Substrate #1:		
Downstream view of site:		Substrate #2:		

Map of area sampled showing individual habitat units, pebble count path, photo points and notable features.

Comments:

Stream:				Date:				
Site:								

Count	Concreted Status (0, 1 or 2)	Calcite Present (0 or 1)	Dia. (cm)	Hab	Count	Concreted Status (0, 1 or 2)	Calcite Present (0 or 1)	Dia. (cm)	Hab
1					51				
2					52				
3					53				
4					54				
5					55				
6					56				
7					57				
8					58				
9					59				
10					60				
11					61				
12					62				
13					63				
14					64				
15					65				
16					66				
17					67				
18					68				
19					69				
20					70				
21					71				
22					72				
23					73				
24					74				
25					75				
26					76				
27					77				
28					78				
29					79				
30					80				
31					81				
32					82				
33					83				
34					84				
35					85				
36					86				
37					87				
38					88				
39					89				
40					90				
41					91				
42					92				
43					93				
44					94				
45					95				
46					96				
47					97				
48					98				
49					99				
50					100				

Concretion status scoring: 0 = substrate moved freely, 1 = some resistance to movement from initial calcite formation, 2 = immovable substrate

Calcite presence scoring: 0= absent, 1=present.