Mine Closure 2011 — A.B. Fourie, M. Tibbett and A. Beersing (eds)

doi:10.36487/ACG_rep/1152_04_Keefer

# Comparative inventory of vegetation and soils surrounding Teck Coal Ltd.'s coal mountain operations – 2010

**M.E. Keefer** *Keefer Ecological Services Ltd., Canada*

**A.D. Kennedy** *Keefer Ecological Services Ltd., Canada*

**R. Moody** *Keefer Ecological Services Ltd., Canada*

**P. Gibeau** *Ripple Environmental, Canada*

## Abstract

*This is the second year of a comparative study examining soil and plant characteristics between mine sites that had not actively been reclaimed and early seral natural sites that had experienced some type of disturbance. Results from this study describe native plant species and communities potentially suitable for establishment on ecologically comparable mine sites, and long-term experiments will test their applications in mine reclamation. Thirty-four field plots were established in 2010, 14 of which were located on areas that had experienced some form of mining activity, and 20 on selected natural areas. A total of 239 plant species were recorded in 2010 field work, including 92 new species not seen in 2009. The total number of plant species recorded from 2009 and 2010 field work is 256, including 222 native species, 11 introduced species, 13 invasive species and eight agronomic species. This study has identified 88 species with high potential for use in reclamation, based on occurrence in reference plots, native versus non-native, and ease of seed collection and propagation. Native plant species were observed on a wide range of elevations, slopes and aspects, and mean biomass production ranged between 560–1,360 kg/ha. Soil sampling revealed a mean of 8.4 kg/ha N in non-reclaimed mine sites, and 13.8 kg/ha N on natural reference sites, which were closer than expected for the two site types. No relationships were found between either pH, EC or coarse fragment content and total cover, species distribution or species richness, confirming null hypotheses. Recommendations include the establishment of long-term trials that will investigate native plant installation techniques, native plant successional plantings, fungal inoculation, fertilisation, and specific seed collection efforts and or seed increase projects to facilitate these trials.*

## 1 Introduction

The Elk Valley has a diversity of native plant species that are found in an array of different habitats that range from wetlands to interior temperate rainforests to xeric grasslands. Native plant species are sometimes referred to as being indigenous (occur naturally) to a given area or region and have typically evolved in the area over a long period of time. Within this diversity of habitats are a wide number of native plant species, some which are primarily found in undisturbed sites, many that are found in a wide diversity of habitats, while others are found in greater abundance on open disturbed sites. A number of native species have been observed to naturally colonise reclaimed mine spoils.

Since mine reclamation began in the Elk Valley roughly forty years ago, there have been a number of attempts to integrate some native species into mine reclamation activities that have been summarised in the recent document entitled "Teck Coal Limited - Reclamation Research Summary "What We Have Learned" "What We Need To Know" 1969–2010" (Teck Coal Ltd. and Integral Ecology Group Ltd., 2010). Overwhelmingly this reclamation has been characterised by the use of agronomic grasses and legumes with a compliment of native woody species, and an emphasis on conifers important to the forest industry and shrubs of high value for wildlife browse.

This project has the ambition of exploring the flora, soil structure and chemistry of both naturally disturbed sites and those within old mine spoils that have not been deliberately reclaimed. The overarching goal of this exploratory research is to record the native species (and their related site conditions) found thriving on disturbed sites, and to develop long-term experiments to test these species applications in mine reclamation at a variety of the Teck Coal mines. Such descriptive information may be used to guide mine reclamation in a number of ways, including: plant species selection and plant site requirements, soil fertility and others. Those data may also be modelled in a manner similar to terrestrial ecosystem mapping (TEM) onto post mine environments with the goal of developing appropriate selections of species to meet revegetation objectives. The soil chemistry portion of the study is designed to provide those involved in mine reclamation with a baseline inventory of soils found. Such a baseline may provide valuable insight into fertilisation practices, especially in the context of a project focussing on the rebuilding of native plant communities that may follow natural pathways. The link between soil texture and plant species will also provide insight for planting prescriptions and plant selection.

Mine reclamation poses a great number of challenges given the often huge scale of the disturbances, that mine dumps typically have low organic content and water holding capacity, are frequently nutritionally deprived, and have a lack of nutrient cycling due to a lack of vegetation, mycorrhizal fungi and other microbial action (Voeller et al., 1998; Juwarkar et al., 2009; Teck Coal Ltd. and Integral Ecology Group Ltd., 2010). Also, soil temperatures (60°C) lethal to plants have been recorded in the mines in the Canadian Rockies (Baig, 1992). Practices in the Elk Valley have been moderately to highly successful in establishing plant cover on these substrates, however, frequently the result has been the creation of a novel ecosystem (Hobbs et al., 2009). Given the scale of the mines, it is obvious that the pre-disturbance ecosystem will not be re-created by ecological restoration activities, regardless if entirely native plant species are used. The most accepted and simple definition of ecological restoration is: ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SERBC, 2010). Given the vast hydrological and other changes to the landscape from mining, an appropriate goal in post-mining restoration is to re-initiate natural processes through the creation of suitable terrain and the use of an assemblage of mostly native species which will facilitate the development of a new ecosystem that roughly follows native analogues or reference ecosystems. Data from this research project provides a number of reference ecosystems from which to model from.

Vegetation sampling in revegetation works can be problematic (Goslee, 2006), especially if one wants to achieve high statistical power from the experimentation for the purpose of publication in journals. Vegetation ecology research in the past often assumed that vegetation is evenly dispersed, and that through appropriate plot size, shape and number that vegetation could be statistically evaluated. Now it is realised that spatial autocorrelation results in spurious results (Goslee, 2006). Goslee reports that traditional transects used on an area with high variability and too few sampling points resulted in estimates of 19–94% cover when the actual cover was 50%. A particular concern with sampling is that rarer species are often missed (Goslee, 2006). In the case of describing vegetation plots in a rapidly evolving post-mining environment it would be unfortunate to miss these rarer plants that may become prominent at a later point in plant succession. Multi-scale plots are believed to reduce spatial autocorrelation and are more effective at identifying the rarer species (Goslee, 2006).

A further complication in sampling is that over a period of years some species may not persist. In the case of a species such as yellow mountain avens (*Dryas drumondii*) such a loss may be seen as positive, providing that its reduction in cover has been replaced by other species that are further along the trajectory of ecological succession. Other plants may be difficult to detect in mixed species plots and appear as apparently unsuccessful at early stages, however, may flourish when the appropriate conditions are created by plants such as the yellow mountain avens withdrawing from the site or black cottonwood obtaining sufficient size to modify site conditions through shade and leaf litter.

Russell and Roi (1986) conducted a study on two neighbouring abandoned coal mines east of the continental divide near Hinton Alberta (Townsite and West Mine). This study sought to describe plant succession in unreclaimed portions of these mines. Though the mines are north of the Elk Valley there is a sizeable overlap in the reported floras, suggesting that this study is of relevance to research for Teck Coal in the Elk Valley. Within this study plant cover was found to be low (<10%) and dominated by grasses and forbs. few-flowered milkvetch (*Astragalus vexilliflexus*), Indian milkvetch (*A. aborigum*), nodding locoweed (*Oxytropis deflexa*), showy locoweed (*O. splendens*), and alpine hedysarum (*Hedysarum alpinum*) are all legume species regularly encountered in this study on coal mines.

A similar study that examined both soils and vegetation at 10 mines, including Tent Mountain, was conducted by Baig (1992). Baig reports the following species as being the most prominent on these mines in the 'subalpine belt' on younger spoils: fireweed (*Chamnerion angustifolium*), common yarrow (*Achillea millefolium*), tufted hairgrass (*Deschampsia caespitosa*), wild strawberry (*Fragaria virginiana*), foxtail barley (*Hordeum jubatum*), prairie junegrass (*Koelaria cristata*) and diverse leaved phacelia (*Phacelia heterophylla* – likely silverleaf phacelia, *Phacelia hastata*). At high elevations Baig frequently found Norwegian mugwort (*Artemisia norvegica*), white mountain avens (*Dryas octopetata*) and alpine bluegrass (*Poa alpina*). Soil physical properties were reported as being low in nutrients (N, P, K, S and Ca) and higher concentrations of Mg and Na (Baig, 1992). Baig also describes the exotic plant communities produced by agronomic seeding as having low species diversity. It is reported by Baig (1992) that agronomic species have poor viability at higher elevations, and in high elevations felt that native plants are particularly advantageous.

There is a distinct difference in biomass production levels of agronomic species and native plant species. Biomass production has previously been used as an important metric of success in mine reclamation. Research conducted for Teck Coal showed that pre-disturbance grassland productivity had an above-ground biomass production that ranged between 400–650 kg/ha on xeric sites and 400–800 kg/ha on mesic sites (Teck Coal Ltd. and Integral Ecology Group Ltd., 2010). Another study which measured native grass biomass on high elevation reference sites found a range of approximately 50–350 kg/ha. Agronomic biomass production levels at high elevations (above 1,900 m) have been reported to range between 500–1,500 kg/ha (Teck Coal Ltd. and Integral Ecology Group Ltd., 2010).

# 2 Methodology

A detailed description of our methodology may be found in Keefer et al. (2010). The following description is a brief overview of the method along with any changes that occurred for the 2010 field season.

As with the 2008/2009 fieldwork, plot locations were selected based on a number of criteria; most notably local knowledge from Teck staff. Staff members were queried on the location of sites occurring within the mines that may not have received the traditional revegetation and reclamation treatments. Sites were chosen both on and off active or closed mines to represent high elevation sites in the Elk Valley that were either disturbed by mining operations and not intentionally reclaimed, or early seral natural sites that had experienced some disturbance (e.g. avalanche slopes, heavy wind, high insolation, ungulate pressure, fire history, and resource road cuts and fills) and were left to follow natural successional pathways. Teck staff members were invaluable in the field as they were able to provide background knowledge of the sites visited, and any information regarding if and when treatments were applied.

Five sites were visited in the Elk Valley in 2010, and multiple plots were sampled within each site. Plots were sampled at Sparwood Ridge (SPR), Wheeler Ridge (WR), Tent Mountain (TM), Andy Good (AG), and Elk View (EV). Plots were taken within these five sites where land had either experienced some sort of mine activity and was not reclaimed as per standard practices at the time, or were naturally disturbed areas with native plant communities re-establishing (reference sites).

Data were collected using the BC Government Ground Inspection Form (GIF), a standardised form widely used in ecosystem mapping work. Exhaustive vascular plant species lists (releve's) were collected in plots approximately 20 × 20 m in area and included estimates of percent cover. Basic terrain information was also recorded on the GIF form. Geographical information was recorded using hand held GPS. At each plot a scaled digital photo with a sign board and range pole was taken of a representative view of the site. To build upon the baseline inventory of soils collected in 2009, soil samples were collected in 2010 and mixed to produce a composite soil sample.

Above-ground biomass samples were collected from each plot visited. A 50 × 50 cm quadrat was thrown randomly in the plot, and all aboveground vegetation within the quadrat was clipped and collected. If the first quadrat landed in an area that did not represent the overall plot, a second biomass sample was taken from the plot, and the subsequent data was averaged from the two quadrat collections. Biomass samples were air dried for three months, and then sent to the Ministry of Environment office in Cranbrook BC to be further dried in a dryer at 70°C for 24 hours. Final weights were taken for each biomass sample once they were completely dry. Biomass weight mean and standard deviations were calculated for each plot and overall site, as well as biomass production in kg/ha.

Vegetation data from 2010 were analysed and discussed in this report. Also, vegetation data gathered in 2009 and 2010 for this study, as well as vegetation data collected during research conducted by Clint Smyth for multiple studies were pooled into one database for analysis (Smyth, 1997, 1998). The vegetation database compiled for 2009 and 2010 from this study was also provided to Clint Smyth.

Relationships between distribution of vegetation species and elevation, slope and aspects were assessed with a series of box-plots. Soil characteristics from inside mined areas were compared to soil characteristics from naturally disturbed plots with an ordination. Principal component analysis (PCA) was used to illustrate the representation of complex multidimensional data in a Euclidian, reduced space. Relationships between cover of 27 main vegetation species (sampled in >9 plots in 2009 and 2010) and soils were analysed with a canonical analysis. Redundancy analysis (RDA) was used, as it preserves the Euclidian distance in the ordination spaces and allows the computation of adjusted-R2 (Legendre and Legendre, 1998). A complete and detailed description of the statistical analyses conducted can be found in the original report (Keefer et al., 2011).

# 3 Results

This project was not designed to test the tenacity of agronomically seeded areas to native plant establishment. Further, sites with heavy agronomic plant cover were not selected for recording as part of this study as they did not meet the objectives. While walking through such agronomic sites, it was anecdotally observed that many plots seeded with agronomic species had little invasion by native plants, especially those that were dominated by alfalfa. This was particularly true on more ecologically productive sites in lower to middle elevations (1,100 to 1,800 m). Within these agronomic seedings a number of native species were regularly observed, including black cottonwood, willow, common yarrow, silverleaf phacelia and wild strawberry. Some but not all agronomic seedings directly adjacent to less disturbed areas had higher levels of native plant invasion while others displayed little evidence of native plant establishment.

## 3.1 Vegetation

### *3.1.1 Vegetation 2010*

Site means of above-ground biomass clippings resulted in Elk View (EV) and Sparwood Ridge (SPR) as having the highest mean biomass production at 1,320 and 1,360 mean kg/ha respectively (Table 1). Tent Mountain (TM), Wheeler Ridge (WR) and Andy Good (AG) plots had similar biomass production, ranging from 560 kg/ha at Andy Good to 680 kg/ha at Wheeler Ridge. The mean biomass production from all plots taken at all sites was 880 kg/ha.

**Table 1 Biomass production (kg/ha) averaged across sites in 2010**

| Site | Mean kg/ha | SD |
|---|---|---|
| AG | 560 | 440 |
| EV | 1,320 | 920 |
| SPR | 1,360 | 760 |
| TM | 640 | 640 |
| WR | 680 | 360 |
| Mean | 880 | 720 |

A total of 239 species or taxa were recorded across all plots sampled in 2010. Many of the native plant species recorded in 2010 were only observed in plots once (81 species) or twice (37 species).

Species and taxa were distributed differently according to elevation (Figure 1). For example, whitebark pine (*Pinus albicaulis*), black huckleberry (*Vaccinium membranaceum*), grouseberry (*Vaccinium scoparium*), Sitka valerian (*Valeriana sitchensis*), and Liddon sedge (*Carex petasata*) were observed mainly at high elevations (>2,050 m), while the mean occurrence for hair bentgrass (*Agrostis scabra*) was below 1,650 m.

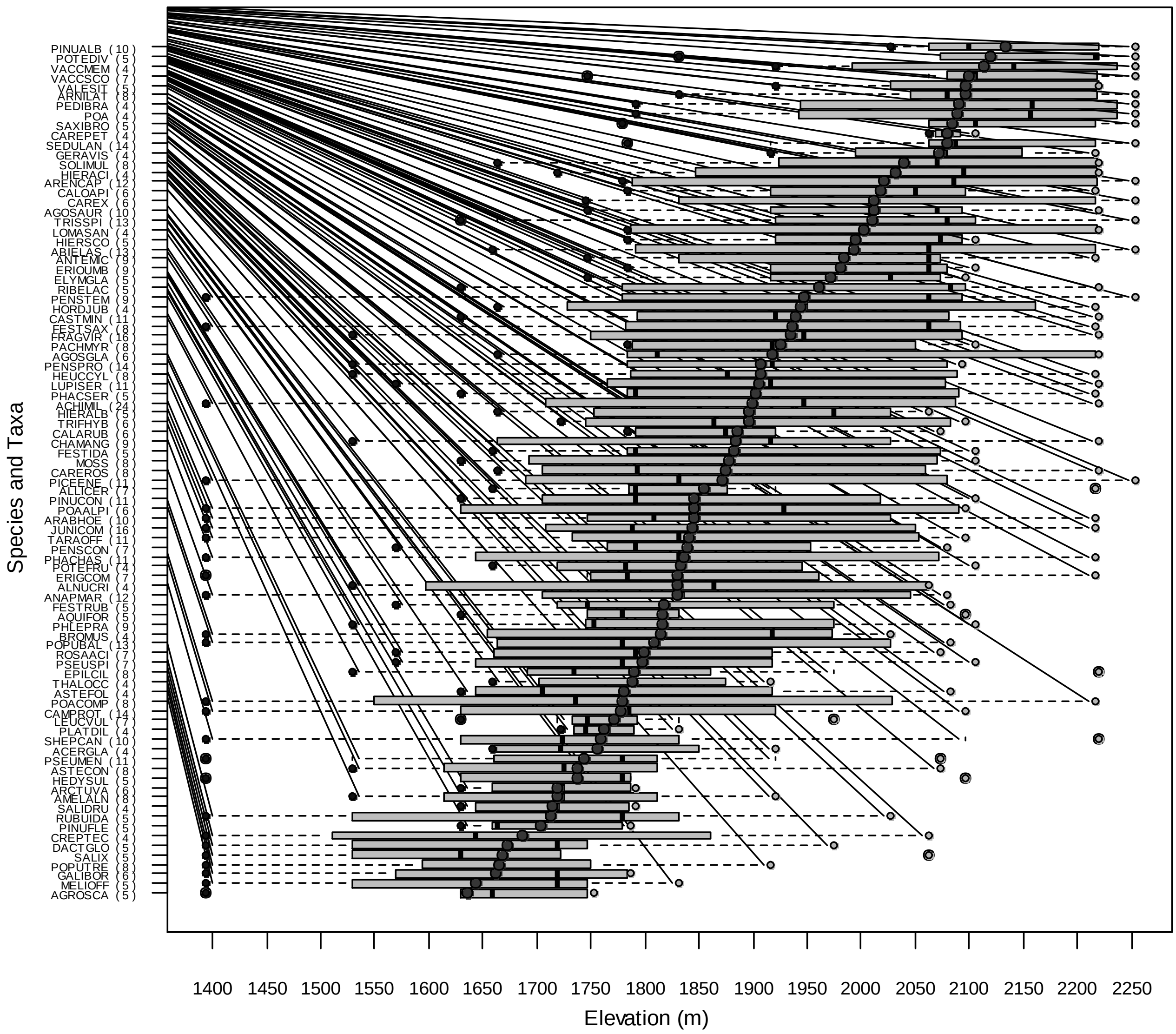


**Figure 1** **Distribution of 89 plant taxa and species by elevation. Dots in the middle of the grey boxes show species mean elevation, black bars are median values based on species occurrence, dots to the right and left of the boxes show minimum and maximum elevations, and grey boxes show the limits of 25 and 75 per cent quartiles. Only species occurring in >3 plots are shown. Numbers in bracket besides species names are the number of plots where species appeared (total of plots sampled = 34 plots)**

Many species had a minimum and maximum occurrence that covered a wide range of elevation, such as penstemon (*Penstemon* sp.), Rocky Mountain fescue (*Festuca saximontana*), yarrow, Engelmann spruce, Canada bluegrass (*Poa compressa*), silverleaf phacelia and Holboell's rockcress (*Arabis holboellii*). It was found that most species occurred between 1,650 and 2,000 m.

Many species, such as white bog-orchid (*Platanthera dilitata*) and willow were only found on gentle slopes (<15%) (figure not shown). The mean slope for leafy aster (*Aster foliaceus*) and purple-leaved willowherb (*Epilobium ciliatum*) were also low (<15%), but were also observed to occur on steep (up to 50%) slopes. Many species were seen on steeper slopes (Scouler's hawkweed (*Hieracium scouleri*), prickly rose (*Rosa acicularis*), Idaho fescue (*Festuca idahoensis*), Sanberg's lomatium (*Lomatium sanbergii*), nodding onion (*Allium cernuum*), round-leaved alumroot (*Heuchera cylindrica*), bluebunch wheatgrass (*Pseudoroegneria spicata*), whitebark pine, pinegrass (*Calamagrostis rubescens*), sulphur buckwheat (*Eriogonum umbellatum*), spotted saxifrage (*Saxifraga bronchialis*) and falsebox (*Pachistima myrsinites*); >35%). Most species were observed to occur on a wide range of slopes (1 to 50%).

Most species were sampled between aspects of 60 to 270 degrees (figure not shown). Liddon sedge and sulphur buckwheat were seen mainly at southeastern aspects (<150 degrees), while red raspberry was mainly sampled at northwest aspects (>240 degrees).

## 3.2 Pooled vegetation

In the pooled data, we see that bunch berry (*Cornus canadensis*) and sweet-scented bedstraw (*Galium triflorum*) were only found at low elevations (<1,300 m) (figure not shown) except for one outlier each. Species such as creamy peavine (*Lathyrus ochroleucus*), twinflower (*Linnaea borealis*), veiny meadowrue (*Thalictrum venulosum*), common snowberry (*Symphoricarpos albus*), redosier dogwood (*Cornus stolonifera*) rough fescue (*Festuca scabrella*) and prince's pine (*Chimophylla umbellata*) were mainly found at lower elevations (<1,500 m). Approximately half of the species tested in this pooled dataset were observed to occur below 1,850 m. Some species (mountain arnica (*Arnica latifolia*), umber pussytoes, bracted lousewort (*Pedicularis bracteosa*), and Liddon sedge, appeared mainly at high elevations; >1,950 m (figure not shown). Also, some species occurred over a very narrow range of elevations (white bog-orchid, fern-leaved lomatium (*Lomatium dissectum*), Liddon sedge and shrubby penstemon).

Using this pooled dataset, we see that several species occurred mostly on gentle slopes (<25%), such as white bog-orchid, common horsetail (*Equisetum arvense*), black elderberry (*Sambucus racemosa*), red columbine (*Aquilega fromosa*), and alpine bluegrass (figure not shown). Most species were found to occur between 10 and 60% slopes. Some species, such as Oregon woodsia (*Woodsia oregana*), highbush cranberry (*Viburnum edule*), Sanberg's lomatium and shrubby cinquefoil (*Potentilla fruticosa*) occur over very small slope ranges; 50–60% for Oregon woodsia, approximately 45–55% for highbush cranberry, and from roughly 35–50% for Sanberg's lomatium and shrubby cinquefoil (figure not shown).

There were some species sampled in the pooled dataset observed on mostly eastern aspects (<75 degrees), such as cowparsnip (*Heracleum lanatum*), Sitka mountain-ash (*Sorbus sitchensis*), and alpine Timothy (*Phleum alpinum*) (figure not shown). The majority of species sampled were found to occur throughout all aspects. However, there were some species that had a small aspect range, such as white bog-orchid, field pussytoes (*Antennaria neglecta*), and Canada goldenrod (*Solidago canadensis*). These species were observed to only occur in a southwesterly aspect (between 200 and 240 degrees) (figure not shown). Few species were sampled that occurred in northerly aspects.

## 3.3 Soils

In the majority of natural plots, nitrogen (N) levels (measured as $NO_3$ in soil samples) ranged from 4.5 to 17 kg/ha, with a mean N level of 13.8 kg/ha. The mean N level for mining operation plots was 8.4 kg/ha. Both of these mean N levels fall within the deficient range for agricultural soils (standard for comparisons), which has an N threshold of 25 kg/ha, yet natural plots were observed to support a diverse plant community. No nutrients were ever applied to natural sites, and it is believed that various types and amounts of fertiliser may have been applied initially if planting did occur at our particular mining sites; however, no applications had occurred recently at those sites.

Phosphorous (P) and potassium (K) levels were quite variable over both natural sites as well as sites that had experienced mining disturbances; between 8–>148 kg/ha for P, and 134–>1,483 kg/ha for K. These numbers are categorised as ranging from deficient to sufficient agricultural levels for both P and K (as per soil laboratory standards). We also see high P and K levels on three mines plots at EV as well as at three natural plots on WR. The pH of natural and mining activity soils ranged from 5.4 to 7.7, and was slightly acidic in most cases.

A PCA ordination was conducted on soil samples taken from natural and mining activity plots. A group of six mined sites were clustered close together, and associated with higher pH (EV1, 2, 8 and 9, and SPR 1 and 4). They were found in loamy-sand and clay-loam soils. Two sites that had experienced mining disturbances had higher concentrations of P and K (EV5 and 6). Mine site EV3 was an outlier and appears markedly different than the other mined or natural sites. EV3 had high S, Zn, Fe and Cl levels compared with all other samples taken in 2010. There were also higher levels of Cu, Mn, and B, and high conductivity (both EC and EC.Calc). Plots EV1 and 2 occurred in a wet habitat that had a spring and surface water running through them, while EV3 was in another wet habitat that had its own separate spring and above-ground water.

Though EV3 is an outlier, and had high levels of S, Zn, Fe and Cl, no nutrient or metal concentration in any sample taken in 2010 had greater than sufficient levels for agricultural standards. No nutrient or metal measured reached into the excess level.

### 3.4 Soil and vegetation

Soil characteristics such as electrical conductivity, coarse fragment content, and pH were tested against three vegetation characteristics: total cover, species richness and species diversity. No relationships were found between any of these soil characteristics and the vegetation characteristics.

Relationships between cover of 27 main vegetation species (sampled in >9 plots in 2009 and 2010) and soil characteristics were analysed using a canonical analysis. Axis X shows 8.5% and axis Y, 6.4% of the variation associated with the per cent cover of vegetation species. The canonical analysis shows that the soils variables included (Cu, Mn, K, Coarse Fragment 1, B and pH) explained together 14% of the variations in covers of the 27 most frequent vegetation species observed (adj-R2 = 0.14, p = 0.0001). Results suggest that several mine plots (EV1, EV2, EV3, EV7, EV8 and Quary 3) clustered at high values of Cu and in sites with coarse fragment 1 (<20% coarse fragment content). They were also associated with higher covers of willow sp., black cottonwood, yarrow and pearly everlasting (*Anaphalis margaritacea*). Silky lupine (*Lupinus sericea*) was sampled with higher covers in soils of higher pH. Whitebark pine, subalpine fir, and grouseberry were seen in higher covers in natural sites PG3, WR1, WR2 and WR3, where soils had higher concentrations of Mn.

## 4 Discussion

Thirty-four field plots were established during the 2010 field season; 14 of which were located on areas that had experienced some form of mining activity, and 20 on selected natural or otherwise disturbed areas. Field work conducted in 2010 documented a wide range of excellent sites from which to build native plant species and community prescriptions for reclamation work.

A total of 239 plant species were recorded in 2010 field work, including 92 new species that were not observed in 2009 (field work was conducted during comparable time frames). The total number of plant species recorded from 2009 and 2010 field work is 256, including 222 native species, 11 introduced species, 13 invasive species and eight agronomic species. This study has now identified 88 species with high potential for use in reclamation (up from 67 in 2009), as well as 86 medium and 47 low priority species. Priority level was assigned based on occurrence in reference site plots, whether the species is native or non-native, as well as ease of seed collection and plant propagation. Propagation information is not yet available for each of the native plant species observed, but this information will be gathered over time.

Some anecdotal observations made during this field season which were interesting from a native plant succession perspective. It was observed that sites characterised by benign neglect resulted in the best reclamation observed with regards to plant diversity and closeness to native ecosystems, and were allowing for succession (such as EV4, 5, 7 etc., plot photos in Appendix of original report). Also, rough and varying terrain, including small wood pieces facilitated litter development which aided plant establishment.

### 4.1 Vegetation

It should be noted that in this study, there may be discrepancies for some plant species between their known versus observed elevation, aspect and slope values. This is a factor of where the plant was recorded in this study, and it should be acknowledged that plant species may occur at different sites on other slopes, aspects and elevations.

Although mean biomass production of native plant communities at five sites in the Elk Valley was highly variable, standard deviations were also high for each site, indicating that they may not be as different as the mean biomass measurements suggest. These high standard deviation values could be attributed to a few reasons: plots measured within each site (e.g. ten plots on EV) exhibited great variability due to the measurement of both natural and previously mined sites, and some sites had small sample sizes (e.g. four plots at SPR). Tent Mountain, Wheeler Ridge and Andy Good had similar biomass production means, ranging from 560 kg/ha to 680 kg/ha. This biomass range is consistent with other research conducted for

Teck, which exhibited a xeric native grassland biomass production of 400–650 kg/ha (Teck Coal Ltd. and Integral Ecology Group Ltd., 2010).

Biomass targets previously set for agronomic species should not be used for native species, and lower biomass ranges should be established. Rather than biomass being the measure of success it is suggested that it be one of a number of measures that include the current plant diversity, evidence of plant succession, provision of a variety of habitat types for wildlife including ungulates, bears and birds as well as a variety of other criteria such as time to establishment and erosion control.

Results from the 2010 field season show that some species recorded, such as whitebark pine, black huckleberry and grouseberry, were found mainly at high elevations (>2,050 m), while some species, such as hair bentgrass, were found mainly at low elevations (<1,650 m). Many species were found to occur over a range of elevations, and the majority occurred between 1,650 and 2,000 m elevation. More plots were sampled at elevations over 2,000 m than field work completed in 2009, which enhances the understanding of native plant communities at high elevations.

Most species were found to occur on a wide range of slopes (1–50%). Many species were observed to occur on gentle slopes (<15%), but there also were also numerous species such as prickly rose, Idaho fescue, Sandberg's lomatium, nodding onion, sulphur buckwheat and whitebark pine that were observed on steeper slopes (>35%). Most species sampled in 2010 occurred from 60 to 270 aspects. Some species, such as Liddon sedge and sulphur buckwheat were found on southeastern aspects, while red raspberry was on northwest aspects. The majority of species recorded were seen on a range of different aspects.

With the combination of results from 2009 and 2010 field work, we now have a more exhaustive list of native plant species that occur in a wide range of elevations, slopes and aspects. The results from this study are very encouraging, as we see that mine reclamation using native species should not be limited by whether a species exists for certain site characteristics. This information culminates in a list of native species for potential use in mine reclamation, and species prescriptions can be tailored to the elevation, aspect or slope of the site to be reclaimed.

When looking at the pooled data figures (not shown here), it is important to keep in mind that plot work conducted by KES, and subsequent vegetation recorded, was biased towards reference type habitats for future mine reclamation. Research conducted by Clint Smyth was investigating a range of other objectives, most notably wildlife habitat. The data set from Smyth's work is still relevant when looking at native plant observations, as it greatly adds to the sample size of this study and may fill gaps in elevation, aspect and slope observed for various species or gaps in aspects, slopes or elevations that were not sampled much, however might not be suitable for suggesting high priority species (native, easy to propagate, etc.) for use in mine reclamation.

The majority of species observed in 2010 occurred over a range of elevations, aspects and slopes, leading us to believe that there are many more generalist native plant species that would be appropriate for use in mine reclamation than previously thought.

## 4.2 Soils

It was found that N levels were similar in plots that had experienced some form of mining activity and natural plots, with a mean of 8.4 and 13.8 kg/ha respectively. Both of these N means fall within the deficient category for agricultural N levels, which extends up to 25 kg/ha of N. Yet, varied native plant communities were well established on natural plots, and had invaded and were thriving in some instances on plots that had experienced mining activities.

Further, we have seen that biomass production levels on natural plots were consistent with other research which investigated native plant biomass levels (Teck Coal Ltd. and Integral Ecology Group Ltd., 2010). The low N levels in these natural plots did not detrimentally effect biomass production on natural plots in this study.

Native plant communities on naturally disturbed sites will have had a longer time to initiate nutrient cycling than those planted on coal spoils, however after a number of years these natural sites do not have much more N available/present. Further experimentation on the N requirements of native plants installed on coal spoils should be conducted. The similar N levels for both mining operation and natural plot types and deficient N levels not adversely affecting biomass production of native plant species suggests that N levels should be of less concern when establishing native plant populations on mine sites. This may indicate that past practices of fertilising reclamation plantings may not necessarily benefit native species plantings and should be monitored closely.

Soil test results show that plots tested exhibited a slightly acidic pH. As native plant communities were established on sites that were surveyed, this slight acidity is not seen as a deterrent to native plant installations in similar pH soils in mine reclamation.

### 4.3 Soil and vegetation

No relationships were found between any of the soil characteristics tested (pH, EC or coarse fragment content) and species distribution, richness or cover. These three soil characteristics were chosen for analysis as they were thought of as the most likely candidates for existing relationships with vegetation variables. As no relationships were found, further analyses could be conducted using calculated C.E.C, base saturation rates, organic matter or soil nutrient levels.

The canonical analysis shows that the soils variables included (Cu, Mn, K, Coarse Fragment 1, B and pH) explained together 14% of the variations in covers of the 27 most frequent vegetation species observed. Results suggest that several mine plots (EV1, EV2, EV3, EV7, EV8 and Quary 3) clustered at high values of Cu and in sites with coarse fragment 1 (<20% coarse fragment content). Mine plots EV1, 2 and 3 all had wet habitats. EV1 and 2 had a spring which produced a very small and shallow creek with very low slopes running through the area, while EV3 had a separate spring, producing a small pond-like area. Wet habitats are typically characterised by finer substrates as supported by the low coarse fragments on these sites. There could possibly be a relationship between moisture content and Cu levels, but we are unable to make that distinction at this time.

## 5 Future research

As seen in literature review on the subject of native plant revegetation, there is a lack of directed long-term research conducted using a broad range of native plant species for revegetation in coal mines. Keefer Ecological Services Ltd. and Teck Coal Ltd. have identified a desire for more biologically diverse reclamation sites within their mines, and have expressed interest in using greater numbers of native plant species for operational use. We will be conducting research that is designed to build a statistically sound and time sensitive means for building the collective knowledge base of native plants for revegetating mine spoils in the Elk Valley. Both the statistically sound and time sensitive attributes are immensely important, as the statistical significance fosters a trust in your results and provides a solid foundation for moving forward. It is also expected that through proper research design we will have the ability to move to operational techniques and species recommendations after a relatively short period of research (1 to 2 years) for key species, allowing for the rapid evolution of mine reclamation using native plant species.

KES will be initiating a research programme that is designed to meet the needs of Teck internally, and also designed with potential peer reviewed publication in mind. Through an attempt to mimic natural site succession observed in surrounding environs by targeted native plant seeding and planting, it should be possible to initiate early successional pathways observed on sites described in the field investigations described above.

KES has designed two trials that will begin at Coal Mountain in the fall of 2011; one investigating installation techniques for native plants (seed versus plugs), and another investigating early seral community establishment and monitoring changes over time.

These trials will facilitate the achievement of several goals over various time frames, such as the determination of planting methods and proven winner species in the short-term as well as the guidance of appropriate species mixes in order to have a successional native plant community establish over the long-term. In addition, the naturally reclaimed disturbed reference site research will be conducted in the vicinity of Teck’s three other Elk Valley mines. There is a recognised ecosystem shift between the Coal Mountain area and the ecosystems surrounding the Line Creek, Fording River and Greenhills Operations. This research will provide guidance for native plant selection for future reclamation research and operational plantings for these mines.

KES will also be conducting reclamation research using native plants at Teck's Greenhills Operations, at a site that had been reclaimed approximately 30 years ago, but the vegetation is currently failing due to heavy grazing and other factors. We have developed an innovative experimental design which captures the range of microsites created during a new method of site preparation. Large, fairly uniform mounds approximately 1.8 m high, are produced during site preparation, which creates a multitude of microsites. Based on the information discussed in this paper, KES has produced a list of native species that are appropriate to plant at this high elevation site (2,200 m) that would be suitable for the range of microsite conditions that will be created. This site will be prepared and planted in the fall of 2011.

In order to facilitate the large demand of native plants foreseen in the near future for reclamation purposes, KES and Tipi Mountain Native Plants are now undertaking a native species seed increase project. This project is intended to reduce much of the risk and expense involved in annual native seed collections. The species chosen for this project are based on the reference site research, meaning they are very well suited for use in mine reclamation, and this project will allow for cost-effective, large-scale collection.

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