Alberta Guidance for Protocol Development
Technical Protocol Plan

Part B
Description of Technical Protocol Plan Content

This section is an overview of the Protocol including: project type, project-specific technology, quantification methodology and how the projects using the protocol will reduce GHGs.

B.1. Description of the Project Type: (The **project type** is a set of project practices or technologies that represent the change from a normal business operation/practices or common industry practice.)

Pulp sludge is a traditionally discarded by-product created by the operations of mechanical pulp mills. Land application of mechanical pulp sludge is an improved, environmentally responsible alternative to incineration and landfilling sludge.

Mechanical pulp sludge provides benefits to the soil such as added nutrients and organic matter and improved physical properties such as soil structure and water holding capacity, resulting in enhanced above and below ground carbon reservoirs. The sludge contains approximately 45% carbon, which when added to soil results in an increase in the initial soil carbon (below ground carbon) reservoir, which in turn enhances the above ground carbon reservoirs (tree and shrub growth) which subsequently produces increased root biomass which is contributed to the soil resulting in additional carbon being stored in the below ground reservoir.

Description of how real reductions or removals will be achieved: (The Protocol Developer must ensure the GHG(s) that will be reduced by the activities for this project type are within the scope and criteria of the Alberta Offset System.)

The opportunities for generating carbon offsets with this protocol arise mainly from the quantification of direct and indirect reduction of atmospheric greenhouse gases (GHG) through the application of mechanical pulp mill sludge on juvenile forest stands as opposed to the previous practices of incineration or landfilling the waste material. This protocol can theoretically be applied to all mechanical pulp mills spreading sludge on all juvenile forest stands across the country. Business as usual practices for sludge handling includes drying, incineration, and beehive burner combustion. Emissions from these practices are avoided through utilization of sludge by land application. Sludge application affects carbon reservoirs including tree biomass, herbaceous understory biomass, litter and duff and soil. The carbon reservoirs store and accumulate carbon rather than releasing greenhouse gases to the atmosphere.

B.2. Description of Background Information/Best Practice Guidance Used:

Table 2.1. Good Practice Guidance

1. Document Title	2. Publishing Body/Date	3. Description
National Inventory Report, 1990-2004 Greenhouse Gas Sources and Sinks	*Environment Canada, 2004*	*Description of quantification methods greenhouse gases emitted from landfills and incineration*
American National Standard: Greenhouse Gases- Part 2	*American Society for Quality* (ANSI/ISO/ASQ E14064-2:2006(E))	*Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements*
Canada's National Inventory	*Government of Canada, 2006*	*Description of IPCC tier 2 and 3 applications for quantifying GHGs from sectors at a national level*
Calculation tools for	*Prepared by: National*	*This report presents the*

estimating greenhouse gas emissions from wood product facilities (Version 1)	*Council for Air and Stream Improvement Inc. (NCASI), 2005*	*results of a review of existing greenhouse gas (GHG) inventory protocols and calculation tools designed to assist companies in preparing GHG inventories.*
Ecolgocially based individual tree volume estimation for major Alberta tree species	*Huang, S. Alberta Environmental Protection 1994*	*Description of estimated tree volumes in Alberta with relevant expansion factors*

B.3. Regulatory, Legal Requirements and/or Government Incentive/Grant Programs:

List of potentially relevant regulations/legal requirements: N/A

List of potentially relevant climate change incentives: N/A

B.4. Barriers to Implementation:

Technology operation and maintenance: Most pulping processes produce sludge which is not suitable for land application due to high B, Na, metal concentrations or chlorinated compounds.
Infrastructure: Type and amount of land available for sludge land application limits the facilities capable of implementing this practice.
Institutional: Government required assurance that the sludge was beneficial to forestry practices and thus there is a need for third party verification.
Other: Regulation barriers: There are no regulations in place for operational application however sufficient research has been conducted and the existing guidelines for application on agricultural land provide some direction.

B.5. Review of Technology/Scientific Knowledge:

The carbon offsets from this protocol will be based on the quantification of increased carbon reservoirs and decreased GHGs resulting from the application of pulp sludge to juvenile forests as opposed to its incineration or placement in a landfill. The sludge is traditionally a discarded by-product of the pulp mill and at baseline is incinerated or put in landfills which are practices that produce GHGs. Sludge application significantly increases carbon accumulation in the forest (both above and below ground) (Appendix A lists relevant research conducted by the Alberta Research Council for verification). Carbon reservoirs store and accumulate carbon rather than releasing greenhouse gases to the atmosphere. The Alberta Research Council has been doing research on the land application of sludge in the forest for 16 years. Initial work began with characterization of the sludge material and evaluation for the suitability of land application through greenhouse trials and plot scale field investigations. Results from some of their research has been attached as an appendix. The activities that are included in the quantification of carbon offset credits are above and below ground carbon accumulation, avoided use of fossil fuels for sludge incineration and drying, CO_2 emissions from sludge incineration, landfill GHG emissions, sludge transportation, and sludge N_20 emissions.

B.6. Review of Existing Projects: (Review of trends and statistics on existing practices/projects in the Alberta and/or Canadian context.)

The Alberta Research Council has been conducting research on the benefits of land application of sludge since the 1990’s. There are currently 3 mechanical pulp mills in Alberta (Alberta Newsprint Company, Slave Lake Pulp, and Millar Western Forest Products) who have participated in the research of land application of sludge in the forest. Other mechanical mills in the Canadian industry have not implemented the practice of land application for various reasons, such as different pulping processes leading to sludge which is unsuitable for land application, inappropriate or insufficient land for spreading sludge on, etc.

B.7. Summary of Quantification Approaches: (Include a summary of GHG quantification approaches and methodologies. At a broad level, not exact formulae and emission factors, but where formulae will come from, activity data and emission factors, ie. Best Practice Guidance.)

The baseline condition is defined by the disposal of pulp mill sludge by incineration and/or landfilling, the below ground biomass in the soil, and the growth of planted forest stands without pulp sludge application. The emissions produced at baseline will differ for each project due to variations in sludge disposal practices, annual sludge production, forest management, climatic conditions, and soil chemical and physical properties. Data collected through Alberta regeneration surveys will be used to establish the baseline condition for an area.

This protocol will deal with emission reductions from utilization of sludge for forest application. Business as usual practices for sludge handling includes drying, incineration, and beehive burner combustion. The amount of greenhouse gases emitted from these activities will be quantified using the methods listed in Environment Canada's 2004 National Inventory Report on Greenhouse Gas Sources and Sinks. Emissions from these practices are avoided through utilization of sludge by juvenile forest application. A further reduction in GHG reductions are achieved by increased carbon biomass in the trees and soil carbon storage which will be quantified based on actual measurement data obtained from merchantable volume based forest inventory data and operational records of treated and untreated areas to determine the increase in carbon sequestration. Biomass conversion and expansion factors for expansion of merchantable volume to above ground biomass will be applied and are taken from the IPCC 2006; Canada's National Inventory document.

B.8. Other Impacts (Optional): (Include other air emissions, odours, risks, environmental impacts on vegetation, wildlife, water resources etc.)

There is the possibility of a slight odor when sludge is applied to the forest, however it is assumed that no residences or occupied land would be in the vicinity of land application operations.

B.9. Assessment of Baseline Scenarios

a) Evaluate all possible Baseline Approaches in the list below, and identify which ones are appropriate for the Projected Protocol. Justify why each selected Baseline Scenarios is appropriate. Also justify why the other Baseline Scenarios are not appropriate and are excluded from the Protocol.

TABLE 1.2: Assessment of Possible Baseline Scenarios

1. Baseline Options	2. Description	3. Static / Dynamic Baseline	4. Accept or Reject and Justify
Historic Benchmark:	*(Typically site-specific and can be constructed to reflect reductions in a base period (such as the average emissions of the previous three years).)*	Dynamic	Reject: The amount of sludge being land applied is variable each year and this method would not give an accurate estimate of the amount of carbon being sequestered above or below ground due to variability.
Performance Standard:	*(Assumes the typical emissions profile for the industry or sector is a reasonable representation of the baseline.)*	Dynamic	Reject: Each mechanical mill operator has different processes and operating procedures thus an industry baseline is not reasonable.
Comparison-based:	*(Actual measurements of parameters from a control group to compare with the project.)*	Dynamic	Accept: Actual measurements produce the most accurate and reliable results and can not be discounted by variability.
Projection-Based:	*(Projections of reductions in the future can use a variety of techniques, from simple straight-line growth assumptions to complex models.)*	Dynamic	Reject: There are too many variables that would need to be input into a model such as soil type, landscape variability, climate factors, tree species and forest

			management practices
Adjusted Baseline:	*(Takes into account current practice levels of a particular project and specified that the same baseline is used for all projects of a certain type, regardless of historical practices.)*	Dynamic	Reject: There are no well documented current practice levels and too much variability associated with the baseline for an adjusted baseline.
Other (Explain):			

B.10. Selection of Baseline Scenario: (For the selected baselines scenario(s) from the above analysis, the Protocol Developer must explain why the Baseline approach is static or dynamic, justify the selection of the most appropriate baseline scenario(s) including references and any assumptions.)

The emissions profile for the baseline activity does change during the credit duration period. Although the input parameters and the quantification methodology remain constant throughout the credit allocation period, variations in annual sludge production, landfill and incineration practices, forest management, climatic conditions, and soil chemical and physical properties, etc., can affect the input parameters and thus the baseline approach is dynamic.

B.11. Definition of the Project Condition: (Define the project condition and justification for the scope of the activity considered.)

The project condition consists of land application of mechanical pulp sludge in the forest. Pulp sludge is a traditionally discarded by-product created by the operations of mechanical pulp mills. Land application of mechanical pulp sludge is an improved, environmentally responsible alternative to incineration and landfilling sludge.
Mechanical pulp sludge provides benefits to the soil such as added nutrients and organic matter and improved physical properties such as soil structure and water holding capacity, resulting in enhanced above and below ground carbon reservoirs. The sludge contains approximately 45% carbon, which when added to soil results in an increase in the initial soil carbon (below ground carbon) reservoir, which in turn enhances the above ground carbon reservoirs (tree growth) which subsequently produces increased root biomass which is contributed to the soil resulting in additional carbon being stored in the below ground reservoir.

B. 12. Functional Equivalence: (Explain how the project and the baseline are comparable in terms of products and/or activity level. Justify any lack of equivalency.)

The project and baseline condition are both serving as a management mechanism for the waste product (sludge) produced during the pulping process of mechanical pulp mills. Sludge is disposed of by landfilling or incineration in the baseline condition and in the project condition it is disposed of by land application thus the two are functionally equivalent. The amount of energy required for disposal in the baseline and project condition is not equivalent. The baseline condition requires energy inputs to dry the sludge and emits CO_2 in the case of incineration. Landfilling results in CH_4 emissions. The project condition requires more energy for transportation and application of the sludge than the baseline condition.

B.13. Flexibility Mechanisms: (Explain optional approaches for quantifying the reductions to be achieved from the project type.)

1. This protocol applies to the reduction of atmospheric GHGs through the use of mechanical pulp mill sludge. This protocol can be combined with other protocols where multiple projects are undertaken by the mechanical pulp mill to reduce overall GHG emissions.

2. Site specific emission factors may be substituted for the generic emission factors indicated in this protocol document. The methodology for generation of these emission factors must be sufficiently robust as to ensure reasonable accuracy.

3. An alternative quantification method for evaluating baseline emissions can be based on control plots representative of the treated areas and pre-application measurements. The established baseline will be considered as static for each project, where the coefficients remain constant, subject to periodic revision to reflect the evolving performance standard. The quantification approach would be the same as in the previous section.

Appendix A. Relevant Research Conducted by the Alberta Research Council

Pojasok, T. and H. Ertl. 2001. The effect of pulp mill sludge application on CO_2 flux and carbon sequestration in forest soils. March, 2001.

Objective:

- To determine the effect, if any, of pulp and paper sludge application and vegetation growth on CO_2 flux near the surface of previously harvested areas in the boreal forest.

- Used 2 CO_2 flux chambers to assess flux at the following locations (June 26 to 28, 2000)
  1. ANC Cut-Block – de-ink sludge applied and incorporated eight years prior to monitoring. Sludge rates of 0 and 100 t/ha.
  2. Millar Western Thinned Forest – mature thinned forest area where 0 and 53 t/ha of Millar Western sludge was applied 2 years before CO_2 monitoring. Measurement of dominantly grass and also of dominantly herbaceous plants.
  3. ANC Juvenile – juvenile lodgepole pine and 58 t/ha of ANC sludge applied 2 years prior to measurement which included 80 cm lodgepole pine
  4. ANC Spread Without Incorporation – 0, 50, and 80 t/ha treatments. Sludge was applied 3 years prior to assessment.

- Measurements October 10 and 11, 2000
  1. ANC Operational Spreading – pine tree in each of 0 and 50 t/ha treatments
  2. Same location – bare soil vs. area with 50 t/ha sludge with no visible vegetation
  3. Same location – no vegetation however surface of sludge treatment and control soil was disturbed

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Conclusions:

Based on the results achieved some preliminary and general conclusions are presented. However, it must be noted that the work was a limited assessment that did not include replication of measurements or an assessment of variability at any of the monitoring locations. The measurements were conducted at only two times during the growing season and continuous day-time and night-time CO_2 flux data were not collected. From this limited assessment the following general statements can be made about CO_2 flux in the areas evaluated.

1. The CO_2 flux varied with the weather conditions during measurements. With sunny conditions, the microecosystem monitored was generally a CO_2 sink while under cloudy conditions, the same sites became sources of CO_2.
2. Soil, when disturbed by scraping the surface to remove vegetation, is a tremendous source of CO_2 emissions into the atmosphere. About 3.5 times CO_2 was emitted into the atmosphere from a disturbed surface soil than a relatively undisturbed soil.
3. Photosynthetic efficiency (CO_2 uptake per gram biomass) was generally higher in sludge-amended sites over control sites. Higher photosynthetic efficiency means that plants in the sludge treatment were more actively fixing CO_2.
4. In sludge amended areas where no vegetation had yet established, a certain amount of photosynthesis was detected. This CO_2 uptake was probably caused by photosynthetic microorganisms such as green algae, which were observed on the surface of the sludge.
5. With the exception of the juvenile stand area, it was found that the understory in the sludge amended treatments resulted in a higher net ecosystem productivity (NEP) than the control and could therefore, under certain conditions, improve the CO_2 balance in boreal forest ecosystems.

Macyk, T.M. and R.L. Faught. 2001. Carbon dynamics related to land application of mechanical pulp mill sludges. February, 2001.

<u>Objective:</u>

- To determine the impact of sludge application/utilization on ecosystem carbon levels
    - Evaluation of ecosystem carbon levels in agricultural use by using data from five years of measurements (1993 to 1998) at the agricultural research site in the Mayerthorpe area
    - Determining ecosystem carbon levels for the eight experiments involving sludge application in the forest

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<u>Summary:</u>

The largest total values of kg C/m^2 were reported for the older stand or near mature trees in the thinned forest area. For this experimental area there is a higher proportion of carbon stored in the above ground tree component followed ny the levels contained in the soil. The roots account for a relatively large component. The understory plant cover accounts for the smallest component of total carbon. The total ecosystem carbon values were slightly larger for the sludge amended treatments than the controls.

The differences were relatively minor due to the fact that threes which area near maturity have had limited time to show a major growth response to the sludge application which occurred in June 1998.

The differences are much more obvious for the sludge amended treatments at the juvenile stand and cut-block trial areas. For these treatment areas the soil carbon levels were substantially larger than the combined contribution of the above ground and below ground biomass.

<u>Conclusions:</u>

The initial results of the work completed demonstrated that pulp mill sludge application has had a positive impact on ecosystem carbon levels both in agricultural use and current use in the forest. The component of work associated with measurement of CO_2 fluxes is described in a separate report prepared by Pojasok and Ertl (2001).

Agricultural Applications

The sludge amended treatments had higher soil carbon levels than the controls five seasons after sludge application. In some instances, the levels were more than two-fold higher than baseline indicating that the carbon additions were sustained for five years and will continue to be sustained above control levels for several years to come.

The brome grass yield data demonstrated significant yield increases for the sludge amended treatments and a significant increase in plant residue carbon for the sludge amended compared to the control treatments.

These data indicate that the application of sludge has increased the carbon levels in the soils and has resulted in increased forage growth that would increase the removal of CO_2 from the atmosphere.

Forest Applications

The sludge amended treatments all had carbon levels that remained several fold higher than the baseline or pre-application levels. These sustained carbon levels can be attributed to the carbon applied initially as well as the carbon contained in the roots of the trees and understory cover established in the area. The combined carbon storage in the above ground (stem wood, bark, branches and foliage), understory plants and below ground (roots) vegetation component was substantially higher for the sludge amended treatments at the juvenile stand and cut-block trial areas.

The largest total ecosystem carbon levels occurred at the older stand or near mature trees in the thinned forest area.

Macyk, T.M. and R.L. Faught. 2002. Carbon biomass storage opportunities from pulp and paper sludge applications in the forest. March, 2002.

<u>Objective:</u>

- To determine the actual total cumulative CO_2 sequestered in sludge amended forest areas with emphasis on the CO_2 stored in trees
    - New expansion factors used for calculating total above ground biomass from stem wood height and diameter were determined
    - Data were interpreted to determine potential sequestration from "Kyoto forests" or carbon sequestered during 2008 to 2012 from forests established since January, 1990.

Summary:

The work conducted relative to the effect of pulp mill sludge application on CO_2 sequestration and ecosystem carbon levels has demonstrated positive results. The combined carbon storage in the above ground (stem wood, bark, branches, and foliage), understory plants, and below ground (roots) vegetation component was substantially higher for the sludge amended treatments compared to the controls in the forest. The flux measurements in the forest indicated that photosynthetic efficiency (CO_2 uptake per gram biomass) was generally higher in sludge amended sites than control sites.

The new expansion factors developed for calculating total above ground biomass from stem wood height and diameter data for pine were 2.27 for the control trees and 2.82 for the sludge amended trees compared to a literature value of 1.57. The data indicated that the needles sequester about the same amount of CO_2 as the stem wood and somewhat more than the branches.

The expansion factor data indicated that estimates of CO_2 storage based on the literature factor are somewhat lower than the estimates based on the actual or calculated expansion factor.

A linear fit of the yearly rate of CO_2 sequestration per hectare was determined for the different treatments at the experimental sites. The data was extrapolated to determine the total amounts that could be sequestered in the period 2008 to 2012 as allowed in the Kyoto agreement. At the cutblock experimental site established in 1993, the total amount of CO_2 sequestration projected for pine ranged from a low of 10t CO_2/ha for the D3 (30 t/ha) treatment. The total amount projected for white spruce ranged from 2.7t CO_2/ha for the control treatment to 12.2t CO_2/ha for the D10 (100 t/ha) treatment.

At the juvenile pine site established in 1998, the control treatment was projected to result in the storage of 20.6t CO_2/ha compared to 64.6t CO_2/ha for the sludge amended forest for the four year Kyoto period.

Similarly, initial results from the full scale or operational spreading program conducted by Alberta Newsprint Company in 2000 and 2001 will result in the potential for the sludge amended pine treatments to store three times the amount stored by the control treatment.

Conclusions:

The combined carbon storage in the above ground (stem wood, bark, branches, and foliage), understory plants, and below ground (roots) vegetation component was substantially higher for the sludge amended treatments than the controls in the forest.

- The amount of CO_2 stored based on actual weight of the stem wood, needles, and branches is about 1.5 times higher than the value calculated from wood volume data. The calculation based on wood volume involves measurements of tree height and diameter to determine volume which is then multiplied by a literature expansion value to account for needles and branches. Actual expansion values of 2.27 for control treatment pine and 2.82 for sludge amended pine were determined from field measurements and are somewhat higher than the literature value of 1.57.

- Growth data was extrapolated to determine the total projected amounts of CO_2 that could be sequestered in the period 2008 to 2012 as allowed under Article 3.3 of the Kyoto protocol. The results obtained from the experimental trial areas and the full scale operational spreading program demonstrated the potential for the sludge amended pine treatments to store three times the amount stored by the control treatment. At a juvenile pine site established in 1998 with five year old trees, the control is projected to result in the storage of 20.6t CO_2/ha compared to 64.6t CO_2/ha for the sludge amended forest for the four year Kyoto period.

Macyk, T.M. and R.L. Faught. 2003. Carbon biomass storage opportunities from pulp and paper sludge applications in the forest. March, 2003.

<u>Objective:</u>

- To determine the actual total cumulative CO_2 sequestered in sludge amended forest areas compared to control areas with emphasis on the CO_2 stored in trees.
    - To determine net ecosystem productivity in recently harvested poplar and white spruce forests with sludge amended and control treatments
    - To determine the contribution of understory and "competing" cover to total biomass generated in lodgepole pine and white spruce cover including different sludge application rates and control treatments

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<u>Conclusion:</u>

The summary and conclusion statement are based on measurements completed in 2002.

- All treatments evaluated had a negative flux indicating that CO_2 was being removed from the atmosphere or that photosynthesis was greater than respiration.
- The highest gross primary production or gross photosynthesis (GPP) values were reported for the grass cover that has thrived in the 80 t/ha sludge treatment. The GPP values reported for raspberry were also relatively high and can be attributed to the large leaf area associated with the species.
- The lowest GPP values were reported for the honeysuckle, which had a relatively small leaf area.
- The largest amounts of CO_2 sequestered per year occurred with the grass and raspberry with the lowest amount sequestered by the honeysuckle.
- The contribution of the grass and herbaceous cover is significant in the overall context of carbon storage, or the potential sink creation in the early stages of

reestablishment of a forest cover following tree harvesting. This potential is increased significantly by sludge application.

- The data generated by completing understory biomass measurements indicated that the competing species that occur in juvenile pine or spruce stands make a significant contribution to the total carbon and CO_2 equivalent pool. This contribution is enhanced by sludge application.

T.M. Macyk, T.C. Richens and R.L. Faught. Executive Summary from "Pulp and Paper Research Program Sludge Utilization Field Plot Trials in the Forest". Alberta Research Council, 2004.

EXECUTIVE SUMMARY

The research described in this report was initiated in 1992 under the auspices of the Alberta Research Council (ARC) and Alberta Newsprint Company (ANC) Joint Research Venture and is continuing with financial support from the Mechanical Pulping Consortium Pulp and Paper Research Program.

The objective of the forest cut-block field trials is to determine the impact of the addition of different rates of both conventional and de-ink sludge on soils and plants. The results of this work are providing the basis for development of environmentally acceptable sludge application rates, a basis for making predictions regarding long-term productivity increases, determining the economic benefits of sludge application, and a basis for developing operational landspreading guidelines.

The forest cut-block experiment was established in the latter portion of May, 1993. The treatments included control, 3 cm sludge, 5 cm sludge, and 10 cm sludge for the conventional and de-ink sludges. Each of these treatments was replicated six times to allow for planting of both spruce and pine seedlings. Post-application sampling was completed about two days after sludge incorporation and annually thereafter.

A neutron access tube was installed in each of the C0 (conventional sludge 0 cm application rate), C3, C5, and C10 plot treatments as well as in each of the D5 (de-ink sludge 5 cm rate) treatments. Soil moisture and soil density were measured approximately once monthly during the growing seasons in 1993 to 1996 inclusive, three times in 1997 and once in 1998. No measurements have been conducted since 1998.

Climate monitoring equipment was installed to provide continuous measurement of precipitation, air temperature, soil temperature, soil moisture, solar radiation, and relative humidity.

The total soil carbon, soil nitrogen, and plant available nitrogen levels in 2003 continued to show higher levels in the sludge amended plots and continue to reflect differences that relate to the initial sludge application rate in 1993. These results support the prediction that the trees in the sludge amended treatments will continue to demonstrate better growth than the trees in the control plots or open areas.

Tree growth data are available for ten years for the white spruce and nine years for the lodgepole pine at the cut-block plots. The 2003 data indicated that there were significant differences in mean height and diameter between the sludge amended treatments and the controls for both spruce and pine but no differences between the different sludge rates. Height/age relationship curves were prepared for pine and spruce grown in the de-ink sludge treatments. By projecting the growth of pine over the next 50 to 60 years on a linear basis, the results suggest that a tree in a D10 treatment would achieve a height of 25 m in about 58 years compared to about 77 years for a D0 or control treatment.

The tree height data were assessed in the context of the minimum height requirements to achieve establishment and performance standards. The data indicated that establishment guidelines for spruce and pine were achieved one year sooner in the sludge amended than the control treatments and that performance standards were achieved two to three years sooner in the sludge amended treatments.

The disturbed forest trial was established in June, 1994 with the completion of the summer treatment plots followed by completion of the winter treatments in November. A total of fourteen 5 m x 10 m plots were established on a chip site haul road with treatments including control (0 t/ha) and 60 and 100 t/ha application rates of sludge.

Pine growth was significantly better in the sludge amended plots than the controls at the disturbed forest site. Native herbaceous cover establishment important for reclamation and erosion control purposes was substantially better at the sludge amended than the control plots.

The results obtained to date indicate that the sludges are beneficial soil amendments resulting in enhanced tree growth. The sludge amended treatments have produced a 2.5 to 3 fold volume increase in pine and a 2 to 3 fold increase in the volume of spruce produced at the cut-block site to date. The plant available nitrogen levels remained considerably higher in the sludge amended compared to control treatments indicating that the enhanced growth will continue in the sludge amended plots.