RRTAC FUTURE RESEARCH NEEDS PROJECT - SUMMARY

by

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for

ALBERTA LAND CONSERVATION AND RECLAMATION COUNCIL
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1. INTRODUCTION

Concord Scientific Corporation was contracted to design a questionnaire program to determine the reclamation research needs of organizations/industries in Alberta that are involved with industrial disturbances. The company was also responsible for analyzing the questionnaire results and prioritizing the research needs.

This report is a summary of the work, and is a condensed version of the final project report prepared by Judith Smith, Concord Scientific Corporation, for the Reclamation Research Technical Advisory Committee (RRTAC). The report has been produced and distributed to the people who participated in the project. RRTAC would like to thank the participants for their time and assistance in this project.

The results of this study will be used by RRTAC to assist in establishing the direction to be taken in funding government reclamation research over the next several years.

2. METHODOLOGY

2.1 PREPARATION AND DISTRIBUTION OF QUESTIONNAIRE

A list of organizations/industries involved with reclamation in Alberta was developed with the assistance of RRTAC. This mailing list included members of industry, consulting firms, and the Provincial and Federal governments.

The multi-disciplinary study team of four consultants, with the assistance of RRTAC, prepared a detailed questionnaire to determine reclamation research needs in the province. The questionnaire was designed so that the research needs could be described by a combination of alphanumeric codes (Appendix 2). The following information was requested for each research need identified:

1. the geographic location within the province of Alberta,
2. the type of disturbance to be reclaimed,
3. the proposed end land use, and
4. the main and modifier codes to define the research.

The main code identified the primary research concern. For example, a respondent concerned about how to determine levels of sludge and wastes for landspreading would have put S6 as the main research topic. If he/she was also interested in whether, or how, salts or other toxic constituents in sludges might move in the soil once spread, he/she would have added S14 as a modifier. Each respondent was asked to list up to ten research areas and to prioritize them from most to least important, with priority rating 1 representing the most important research need and priority rating 10 representing the least important research need.

The questionnaire was pre-tested with three participants who work in the reclamation field: Al Fedkenhueur of NOVA Corporation of Alberta, Phil Lulman of TransAlta Utilities Corporation, and Dean Mutrie of Tera Environmental

Consultants. The participants were asked to review the questionnaire and assess the following items: completeness of the questionnaire in covering relevant reclamation topics, clarity and readability of the instructions and code options, and ease of use of the questionnaire. The participants were interviewed and the questionnaire was modified based on their recommendations.

A total of 221 questionnaires were mailed. The approximate distribution of the questionnaire by organization/industry affiliation was 51% to government, 37% to industry, and 12% to consulting firms.

2.2 DATA TABULATION AND ANALYSIS

Information from the questionnaires was entered onto a MacIntosh computer system, and the Excel spreadsheet program was used to catalogue the data. One hundred and nineteen questionnaires were returned, however a number of these contained combined responses from several people. Altogether, the results constitute the ideas of 142 people. Some respondents identified fewer than 10 needs, while others provided more. Altogether, 1214 needs were identified by the 142 respondents.

Most of the 1214 needs were issues identified by more than one respondent. In all, 222 separate research needs were identified. Of these 222 needs, 126 were added by respondents to the original list. This is important because all respondents were not given the chance to select these "new" research needs. There may have been more votes for those needs had they been on the original list, and they may have shown up as higher priorities.

2.2.1 Analysis for Top Ten Reclamation Research Topics

The selection of the top ten reclamation research topics was based on a frequency/priority ranking analysis of the main research topics identified by respondents. The steps used in this analysis were as follows:

1. The number of times each main research topic was identified by respondents (frequency) was tabulated. The 34 most frequently referenced topics were selected for analysis; these 34 topics accounted for almost 50% of the total number of responses received (i.e., 602 responses/1214 total responses). The 34 topics were ranked, with rank 1 assigned to the most frequently identified research topic and rank 30 assigned to the least frequently identified topic. Research topics with the same frequency response were given the same rank.

2. The priority ratings assigned by the respondents to each of the 34 research topics were averaged. These priority rating averages were ranked, with rank 1 assigned to the lowest average priority (the most important topic as identified by the respondents) and rank 32 assigned to the highest average priority (the least important topic). Research topics with the same average priority rating were given the same rank.

3. The frequency rank and the priority rank for each research topic were added. Therefore, frequency and priority rankings were given equal weighting in determining the most important research topics. The ten lowest total ranks represented the top reclamation research needs identified by the respondents.

Modifier research codes were used to further define and delineate the ten main research topics identified through the frequency/priority ranking analysis. Disturbance types associated with each of the topics were identified.

2.2.2 Analysis for Top Research Topics Associated with the Four RRTAC Program Areas

The main research topics associated with RRTAC's four current program areas were determined through frequency/priority ranking analyses. The steps in each analysis were similar to those described in Section 2.2.1.

The RRTAC program areas are: Plains Coal, Mountains/Foothills, Oil Sands, and Oil and Gas. For the Plains Coal Program area, all research topics associated with the coal mine disturbance type category within the following geographic regions: plains, northwest, northeast and all of Alberta were analyzed. For the Mountains/Foothills Program area, all research topics associated with the coal disturbance type category within the following geographic regions: mountains/foothills, northwest, northeast and all of Alberta were analyzed. For the Oil Sands Program area, all research topics associated with the oil sands mine disturbance type category were analyzed. For the Oil and Gas Program area, all research topics associated with the disposal well, in-situ oil sands, multi-well pad, pipeline, sump and well site disturbance type categories were analyzed.

In addition, research topics associated with the "several disturbance types" category were allocated by RRTAC to the program area(s) where they would most likely be addressed:

1. The following research topics under "several disturbance types" were included in the Oil and Gas Program: D18, D60, S03, S05, S06, S28, S29, S37, V15, V17 and V30.

2. The following research topics under "several disturbance types" were included in the Oil Sands Program: V15, V16, V17 and V30.

3. The following research topics under "several disturbance types" were included in the Plains Coal Program: V15, V17, V30 and V33.

4. The following research topics under "several disturbance types" were included in the Mountains/Foothills Program: V15, V16, V17 and V30.

Modifier research codes were used to further delineate the main research topics within each of the four program areas.

For the disturbance types that were identified more than 30 times in the research responses, the most common main research topics were determined:

1. Several Disturbance Types
   - Weed growth/control on reclaimed sites; and
   - Reclamation of soil sterilant affected sites.

2. Coal Mine
   - Determine time frames required to meet reclamation objectives and end land use;
   - Replacement depth of topsoil/subsoil/regolith over spoil; and
   - Reconstructed soil development.

3. Pipeline
   - Methods to alleviate deep compaction.

4. Well Site
   - Methods to alleviate deep compaction; and
   - Reclamation of soil sterilant affected sites.

5. Industrial Site
   - Reclamation of soil sterilant affected sites; and
   - Oily waste disposal options.

6. Oil Sands Mine
   - Reclamation of tailings pond.

7. Logging Operation
   - Germination and seedling emergence as affected by soil properties.

8. Sand and Gravel Operation
   - Design of ponds/lakes.

9. Chemical Disturbance
   - Determine levels of sludge and wastes for landspreading; and
   - Reclamation of soil sterilant affected sites.

10. Highway
    - Evaluate stream relocation/construction methods;
    - Develop/refine methods for stream crossings; and
    - Water erosion control techniques.

11. Sump
    - Determine levels of sludge and wastes for landspreading.

12. Transmission and Seismic Line
    - No dominant research topic.

13. Landfill
    - Controls to prevent groundwater contamination.

3.1.3 Land Use

Respondents were allowed to identify up to three end land uses for each research need. Assuming the land uses were identified in order of priority, the most commonly identified first priority end land use was either several types of use or agriculture (each about 32% of end land uses identified). The next most commonly identified uses were wildlife/fisheries habitat and forestry (between 11% and 13% of uses identified).

The most commonly identified second priority end land use was either wildlife/fisheries habitat or forestry, while the most commonly identified third priority use was recreation.

3.2 TOP TEN RESEARCH NEEDS

The top ten main research topics identified based on frequency/priority ranking are:

1. Replacement depth of topsoil/subsoil/regolith over spoil
2. Oily waste disposal options
3. Selection, evaluation and multiplication of native grass, legume and forb species
4. Methods to alleviate deep compaction
5. Determine levels of sludge and wastes for landspreading
6. Reconstructed soil development
7. Management practices for the establishment and maintenance of native species
8. Salt and/or toxic soil constituent mobility
9. Optimum seed mixes and rates of application for grasses and legumes
10. Soil handling methods

Six of the reclamation research topics are related to soils, although there is considerable overlap between two of the soils topics S6 and S14, and the miscellaneous topic D18. S6 is most frequently identified as a research need associated chemical disturbances, S14 with well sites disturbances, and D18 with industrial and well site disturbances.

Three of the main research topics within the top ten are vegetation issues. The first two topics (V15 and V17) overlap in content and relate to the use of native species in revegetation. However, V15 is most frequently identified as a research need associated with well site disturbances and V17 with pipeline disturbances.

The number of times the top ten main research topics were used by respondents as modifier research codes in defining needs are as follows: S17 (19 times), D18 (11), V15 (17), S22 (21), S6 (23), S9 (22), V17 (19), S14 (18), V1 (41), and S23 (29). This further indicates the importance of those research needs to the respondents.

3.3 FOUR RRTAC PROGRAM AREAS

3.3.1 Oil and Gas

For the Oil and Gas Program, the top 15 research topics are listed below:

1. Determine levels of sludge and wastes for landspreading
2. Selection, evaluation and multiplication of native grass, legume and forb species
3. Methods to alleviate deep compaction
4. Soil handling methods
5. Sod salvage versus topsoil salvage in native pasture
6. Analytical methods for characterization of waste types
7. Oily waste disposal options
8. Reclamation of soil sterilant affected sites
9. Reclamation of sandy soils
10. Analytical methods for physical characterization of soil and subsoil materials
11. Effect of storage on topsoil quality
12. Salt and/or toxic soil constituent mobility
13. Management practices for the establishment and maintenance of native species
14. Alternates to chemical fertilizers (i.e., organic wastes, peat)
15. Nutrient cycling in reclaimed soil

Nine of the topics are related to soils, three to waste management, two to vegetation, and one to fertilization.

3.3.2 Mountains/Foothills

The top 11 research topics for the Mountains/Foothills Program are listed below.

1. Selection, evaluation and multiplication of native grass, legume and forb species
2. Determine "time frames" required to meet reclamation objectives and end land use
3. Monitoring long-term performance of woody species in reclaimed areas
4. Evaluate long-term use of terrestrial and aquatic reclaimed areas by wildlife
5. Alternate tree/shrub planting methods
6. Reclamation of tailings ponds
7. Evaluation of tree/shrub and grass/legume growth
8. Selection, evaluation and multiplication of native tree and shrub species

9. Management practices for the establishment and maintenance of native species
10. Maximum angle of repose suitable for revegetation
11. Reconstruction soil development

Seven of the topics are related to vegetation, two to miscellaneous topics, one to water and one to soils.

3.3.3 Plains Coal

The Plains Coal Program top 10 research topics are listed below:

1. Replacement depth of topsoil/subsoil/regolith over spoil
2. Selection, evaluation and multiplication of native grass, legume and forb species
3. Determine "time frames" required to meet reclamation objectives and end land use
4. Evaluate long-term use of terrestrial and aquatic reclaimed areas by wildlife
5. Selection, evaluation and multiplication of native tree and shrub species
6. Reconstructed soil development
7. Management practices for the establishment and maintenance of native species
8. Effects of vegetation types on movement of saline groundwater into the rootzone
9. Selection of plant species for saline, sodic and/or saline/sodic soil conditions
10. Ecological succession as a factor in the design of reclamation programs

Six of the topics are related to vegetation, two to miscellaneous topics and two to soils.

3.3.4 Oil Sands

The top 10 research topics for the Oil Sands Program are listed below:

1. Selection, evaluation and multiplication of native grass, legume and forb species
2. Management practices for the establishment and maintenance of native species
3. Monitoring long-term performance of woody species in reclaimed areas
4. Reclamation of tailings ponds
5. Detoxification of tailings pond water
6. Evaluate long-term use of terrestrial and aquatic reclaimed areas by wildlife

7. Selection, evaluation and multiplication of native tree and shrub species
8. Reconstructed soil development
9. Ecological succession as a factor in the design of reclamation programs
10. Replacement depth of topsoil/subsoil/regolith over spoil

Five of the topics are related to vegetation, two to water, two to soil and one to miscellaneous.

3.4 NUMBER OF RESPONSES BY THE ORGANIZATION/INDUSTRY AFFILIATION

Recommendations for research topics in the Oil and Gas Program came dominantly from government (58% of all responses), those for the Mountains/Foothills Program came equally and dominantly from government and industry (41 to 45%), those for the Plains Coal Program also came equally and dominantly from government and industry (40%), and those associated with the Oil Sands Program came primarily from government (55%).

4. CONCLUSIONS

The main conclusions from the analyses of the reclamation needs questionnaire results are summarized below:

1. Broken down by geographic region, 66% of the research topics were identified for the entire province or for the plains area of Alberta. The remaining one third of the responses were equally distributed amongst the mountain/foothills, northeast and northwest regions.

2. The disturbance types, other than the several disturbance types category, that account for at least 5% of the research topic responses are, in decreasing order of importance: coal mines, pipelines, well sites, industrial sites, oil sands mines, logging operations, sand and gravel operations, and chemical disturbances.

3. The commonly identified first, second and third priority end land uses associated with the reclamation research topics are: first priority - several types of uses and agriculture; second priority - wildlife/fisheries habitat and forestry; and third priority - recreation.

4. The top ten main research topics identified based on frequency/priority ranking are:

   - Replacement depth of topsoil/subsoil/regolith over spoil
   - Oily waste disposal options
   - Selection, evaluation and multiplication of native grass, legume and forb species

- o Methods to alleviate deep compaction
- o Determine levels of sludge and wastes for landspreading
- o Reconstructed soil development
- o Management practices for the establishment and maintenance of native species
- o Salt and/or toxic soil constituent mobility
- o Optimum seed mixes and rates of application for grasses and legumes
- o Soil handling methods

5. The top research needs associated with the four RRTAC research areas are:

- o Oil and Gas Program (15 topics)
  - Determine levels of sludge and wastes for landspreading
  - Selection, evaluation and multiplication of native grass, legume and forb species
  - Methods to alleviate deep compaction
  - Soil handling methods
  - Sod salvage versus topsoil salvage in native pasture
  - Analytical methods for characterization of waste types
  - Oily waste disposal options
  - Reclamation of soil sterilant affected sites
  - Reclamation of sandy soils
  - Analytical methods for physical characterization of soil and subsoil materials
  - Effect of storage on topsoil quality
  - Salt and/or toxic soil constituent mobility
  - Management practices for the establishment and maintenance of native species
  - Alternates to chemical fertilizers (i.e., organic wastes, peat)
  - Nutrient cycling in reclaimed soil

- o Mountains/Foothills Program (11 topics)
  - Selection, evaluation and multiplication of native grass, legume and forb species
  - Determine "time frames" required to meet reclamation objectives and end land use
  - Monitoring long-term performance of woody species in reclaimed areas
  - Evaluate long-term use of terrestrial and aquatic reclaimed areas by wildlife
  - Alternate tree/shrub planting methods
  - Reclamation of tailings ponds
  - Evaluation of tree/shrub and grass/legume growth
  - Selection, evaluation and multiplication of native tree and shrub species

- Management practices for the establishment and maintenance of native species
- Maximum angle of repose suitable for revegetation
- Reconstruction soil development

o Plains Coal Program (10 topics)
- Replacement depth of topsoil/subsoil/regolith over spoil
- Selection, evaluation and multiplication of native grass, legume and forb species
- Determine "time frames" required to meet reclamation objectives and end land use
- Evaluate long-term use of terrestrial and aquatic reclaimed areas by wildlife
- Selection, evaluation and multiplication of native tree and shrub species
- Reconstructed soil development
- Management practices for the establishment and maintenance of native species
- Effects of vegetation types on movement of saline groundwater into the rootzone
- Selection of plant species for saline, sodic and/or saline/sodic soil conditions
- Ecological succession as a factor in the design of reclamation programs

o Oil Sands Program (10 topics)
- Selection, evaluation and multiplication of native grass, legume and forb species
- Management practices for the establishment and maintenance of native species
- Monitoring long-term performance of woody species in reclaimed areas
- Reclamation of tailings ponds
- Detoxification of tailings pond water
- Evaluate long-term use of terrestrial and aquatic reclaimed areas by wildlife
- Selection, evaluation and multiplication of native tree and shrub species
- Reconstructed soil development
- Ecological succession as a factor in the design of reclamation programs
- Replacement depth of topsoil/subsoil/regolith over spoil

5. APPENDIX 1

The lists contained in this section are expanded versions of those in the main body of the report. They include the main research topics as well as the modifiers noted by the respondents. The modifiers were meant to further define the research needs by providing more specific areas of interest.

The number in front of each modifier code indicates the number of times the code was identified by respondents.

5.1 TOP TEN RESEARCH NEEDS

The top ten overall research topics with their associated modifier codes are listed below.

S17 REPLACEMENT DEPTH OF TOPSOIL/SUBSOIL/REGOLITH OVER SPOIL.

3-S19 Surface mulches, stabilizers and barriers for erosion control.
3-S23 Soil handling methods.
2-S1 Analytical methods for physical characterization of soil and subsoil materials.
2-S20 Reclamation of sandy soils.
2-S22 Methods to alleviate deep compaction.
2-S25 Use of ash as an amendment.
1-D9 Use of water budget models to predict the fate of reclaimed soils.
1-D57 Consolidate existing research information; improve dissemination of information.
1-F1 Initial fertilizer requirements.
1-F8 Optimization of topsoil and/or fertilizer for long-term reclamation success.
1-G1 Baseline hydrogeological studies (i.e., groundwater occurrence, flow conditions, hydraulic properties of aquifers and aquicludes, groundwater quality).
1-S4 Analytical methods for detection of soil sterilants.
1-S7 Relationship of soil properties to erosion potential.
1-S8 Effects of storage on topsoil quality.
1-S9 Reconstructed soil development.
1-S10 Weathering of replaced spoil/subsoil.
1-S14 Salt and/or toxic soil constituent mobility.
1-S16 Methods to increase rate of pedogenesis of reclaimed soils.
1-S18 Amendment techniques for sand tailings.
1-S34 Instrument requirements for assessing compaction.
1-V1 Optimum seed mixes and rates of application for grasses and legumes.
1-V3 Seed bed preparation.
1-V17 Management practices for the establishment and maintenance of native species.
1-V18 Productivity evaluation and equivalency with pre-disturbed plant cover.
1-V21 Guidelines to evaluate successful establishment of plant species and/or communities to meet end land use.

D18 OILY WASTE DISPOSAL OPTIONS.

13-S6 Determine levels of sludge and wastes for landspreading.
11-S3 Analytical methods for characterization of waste types.
4-M7 Use of bioreclamation for hydrocarbon spill clean-up (i.e., bacteria).
1-D54 Establish acceptable guidelines for landfilling and/or land spreading (oily wastes) i.e., cleaned sands.
1-D55 Determine optimum treatment techniques for reclamation sites treated with invert based muds.
1-S16 Methods to increase rate of pedogenesis of reclaimed soils.
1-S45 Impact of different waste application rates on major soil types in Alberta.
1-V49 Impact of different industrial waste application rates on plant/crops.

V15 SELECTION, EVALUATION AND MULTIPLICATION OF NATIVE GRASS, LEGUME AND FORB SPECIES.

6-V1 Optimum seed mixes and rates of application for grasses and legumes.
3-V3 Seed bed preparation.
3-V4 Germination and seedling emergence as affected by soil properties.
3-V17 Management practices for the establishment and maintenance of native species.
3-V26 Spring vs summer vs fall vs winter seeding and planting.
3-V38 Selection of plant species for saline, sodic and/or saline/sodic soil conditions.
2-F5 Establishment of nutrient self-sufficiency.
2-M5 Monitoring establishment of microbiota in reclaimed soil over long-term.
2-S7 Relationship of soil properties to erosion potential.
2-S11 Nutrient cycling in reclaimed soil.
2-S16 Methods to increase rate of pedogenesis of reclaimed soils.
2-V2 Evaluate seeding techniques of herbaceous species.
2-V31 Competition as a factor in the selection of species for reclamation.
2-V39 Species tolerance to toxicities (salt, etc.).
1-D7 Value of wildlife and fish populations and habitat in assessing productivity of reclaimed site.
1-D19 Topographic and vegetation considerations for wildlife habitat.
1-D20 Range management practices for reclaimed lands.
1-D25 Evaluate long-term use of terrestrial and aquatic reclaimed areas by wildlife.
1-D26 Monitor changes in composition of wildlife species with ecosystem succession.
1-D27 Field verification of methods to assess success of wildlife habitat reclamation for certification.
1-F1 Initial fertilizer requirements.
1-M1 Interactions between bacteria, actinorrhizae, and mycorrhizae and their plant symbionts.
1-M2 Develop mycorrhizal inoculation techniques.
1-M3 Relationship between fertilizers and mycorrhizae.

1-M4	Need for inoculation of mesofauna (earthworms, arthropods, small vertebrates) into reclaimed areas.
1-S5	Reclamation of soil sterilant affected sites.
1-S20	Reclamation of sandy soils.
1-S26	Wind erosion control techniques.
1-S27	Water erosion control techniques.
1-S29	Sod salvage versus topsoil salvage in native pasture.
1-V51	Determine effects of high pH on herbaceous and woody species.
1-V23	Suitability of herbaceous and woody plants as wildlife forage/browse (i.e., forage value, productivity, tolerance to grazing/trampling).
1-V25	Weed growth/control on reclaimed sites.
1-V30	Ecological succession as a factor in the design of reclamation programs.

S22 METHODS TO ALLEVIATE DEEP COMPACTION.

18-V27	Effects of compaction on root growth.
13-S34	Instrument requirements for assessing compaction.
5-D13	Design/modification to improve reclamation equipment.
4-D1	Determine "time frames" required to meet reclamation objectives and end land use.
4-S37	Develop field criteria for shut-down point in wet weather or with frozen soils.
3-S21	Mechanical soil mixing methods (i.e., disc, chisel plow, etc.).
3-S33	Pre-disturbance inventories, design and densities, material availability calculations for large scale salvage.
2-D12	Economics of reclamation.
2-G7	Groundwater contamination clean-up methods.
2-S1	Analytical methods for physical characterization of soil and subsoil materials.
2-S9	Reconstructed soil development.
2-V1	Optimum seed mixes and rates of application for grasses and legumes.
2-V3	Seed bed preparation.
2-V4	Germination and seedling emergence as affected by soil properties.
2-V21	Guidelines to evaluate successful establishment of plant species and/or communities to meet end land use.
2-V48	Plants to alleviate compaction.
1-D18	Oily waste disposal options.
1-M7	Use of bioreclamation for hydrocarbon spill clean-up (i.e., bacteria).
1-S23	Soil handling methods.
1-S27	Water erosion control techniques.
1-S50	Reclamation on sites which lack or are deficient in topsoil; alternate organic sources i.e., manure, straw, mulch, etc.; building soil.
1-V11	Evaluation of tree/shrub and grass/legume growth.
1-V25	Weed growth/control on reclaimed sites.
1-V26	Spring vs summer vs fall vs winter seeding and planting.
1-V30	Ecological succession as a factor in the design of reclamation programs.
1-V47	Effects of composition on plant performance.

S6 DETERMINE LEVELS OF SLUDGE AND WASTES FOR LANDSPREADING.

5-S3 Analytical methods for characterization of waste types.
4-D18 Oily waste disposal options.
4-F1 Initial fertilizer requirements.
3-S1 Analytical methods for physical characterization of soil and subsoil materials.
3-S2 Analytical methods for chemical evaluation of soil and subsoil materials.
3-S53 Methods (not necessarily analytical [i.e., computer]) for determining site-specific clean-up criteria for soils.
3-V1 Optimum seed mixes and rates of application for grasses and legumes.
2-F3 Application methods.
2-M7 Use of bioreclamation for hydrocarbon spill clean-up (i.e., bacteria).
2-S14 Salt and/or toxic soil constituent mobility.
2-V26 Spring vs summer vs fall vs winter seeding and planting.
2-V39 Species tolerance to toxicities (salt, etc.).
1-D12 Economics of reclamation.
1-F2 Maintenance fertilizer requirements.
1-F5 Establishment of nutrient self-sufficiency.
1-F9 Alternates to chemical fertilizers (i.e., organic wastes, peat).
1-M3 Relationship between fertilizers and mycorrhizae.
1-S16 Methods to increase rate of pedogenesis of reclaimed soils.
1-S21 Mechanical soil mixing methods (i.e., disc, chisel plow, etc.).
1-S45 Impact of different waste application rates on major soil types in Alberta.
1-V3 Seed bed preparation.
1-V24 Rodent control methods to minimize woody plant damage.
1-V49 Impact of different industrial waste application rates on plants/crops.
1-W19 Evaluate the effects of rock drains on benthic invertebrate movement.

S9 RECONSTRUCTED SOIL DEVELOPMENT.

5-S23 Soil handling methods.
3-F5 Establishment of nutrient self-sufficiency.
3-M8 Rates and mechanisms of organic matter decomposition.
3-S10 Weathering of replaced spoil/subsoil.
3-S13 Predictive models for soil processes.
3-S15 Long-term study of pedogenesis of reclaimed salt affected soils.
3-S17 Replacement depth of topsoil/subsoil/regolith over spoil.
2-S36 Soil monitoring methodology.
2-V1 Optimum seed mixes and rates of application for grasses and legumes.
2-V13 Monitoring long-term performance of woody species in reclaimed areas.
2-V18 Productivity evaluation and equivalency with pre-disturbed plant cover.
2-V25 Weed growth/control on reclaimed sites.
1-F8 Optimization of topsoil and/or fertilizer for long-term reclamation success.
1-M5 Monitoring establishment of microbiota in reclaimed soil over long-term.

1-S11	Nutrient cycling in reclaimed soil.
1-S12	Barriers to adverse soil constituent movement.
1-S16	Methods to increase rate of pedogenesis of reclaimed soils.
1-S20	Reclamation of sandy soils.
1-S22	Methods to alleviate deep compaction.
1-S34	Instrument requirements for assessing compaction.
1-S37	Develop field criteria for shut-down point in wet weather or with frozen soils.
1-S50	Reclamation on sites which lack or are deficient in topsoil; alternate organic sources i.e., manure, straw, mulch, etc.; building soil.
1-S59	Affects of sump fluids on soil quality and/or productivity.
1-V15	Selection, evaluation and multiplication of native grass, legume and forb species.

V17 MANAGEMENT PRACTICES FOR THE ESTABLISHMENT AND MAINTENANCE OF NATIVE SPECIES.

5-D25	Evaluate long-term use of terrestrial and aquatic reclaimed areas by wildlife.
4-F1	Initial fertilizer requirements.
4-V15	Selection, evaluation and multiplication of native grass, legume and forb species.
4-V25	Weed growth/control on reclaimed sites.
4-V30	Ecological succession as a factor in the design of reclamation programs.
3-F2	Maintenance fertilizer requirements.
3-F3	Application methods.
2-F4	Timing of fertilization.
2-F5	Establishment of nutrient self-sufficiency.
2-V16	Selection, evaluation and multiplication of native tree and shrub species.
1-D7	Value of wildlife and fish populations and habitat in assessing productivity of reclaimed site.
1-D9	Use of water budget models to predict the fate of reclaimed soils.
1-D19	Topographic and vegetation considerations for wildlife habitat.
1-D20	Range management practices for reclaimed lands.
1-D26	Monitor changes in composition of wildlife species with ecosystem succession.
1-D27	Field verification of methods to assess success of wildlife habitat reclamation for certification.
1-F6	N-contribution of nodulated woody species.
1-F7	Fertilizer effects on plant community composition.
1-F8	Optimization of topsoil and/or fertilizer for long-term reclamation success.
1-M1	Interactions between bacteria, actinorrhizae, and mycorrhizae and their plant symbionts.
1-M2	Develop mycorrhizal inoculation techniques.
1-M3	Relationship between fertilizers and mycorrhizae.

1-M4	Need for inoculation of mesofauna (earthworms, arthropods, small vertebrates) into reclaimed areas.
1-M5	Monitoring establishment of microbiota in reclaimed soil over long-term.
1-S7	Relationship of soil properties to erosion potential.
1-S11	Nutrient cycling in reclaimed soil.
1-S18	Amendment techniques for sand tailings.
1-S19	Surface mulches, stabilizers and barriers for erosion control.
1-S26	Wind erosion control techniques.
1-S27	Water erosion control techniques.
1-S29	Sod salvage versus topsoil salvage in native pasture.
1-V1	Optimum seed mixes and rates of application for grasses and legumes.
1-V3	Seed bed preparation.
1-V4	Germination and seedling emergence as affected by soil properties.
1-V6	Alternate tree/shrub planting methods.
1-V12	Establishment of woody species in grasslands.
1-V21	Guidelines to evaluate successful establishment of plant species and/or communities to meet end land use.
1-V23	Suitability of herbaceous and woody plants as wildlife forage/browse (i.e., forage value, productivity, tolerance to grazing/trampling).
1-V26	Spring vs summer vs fall vs winter seeding and planting.
1-V38	Selection of plant species for saline, sodic and/or saline/sodic soil conditions.
1-V44	Develop a method for stripping native sod and replacing it over a disturbed area.
1-V45	Develop a method for stockpiling and storing native sod to be used to revegetate a disturbed area.

S14 SALT AND/OR TOXIC SOIL CONSTITUENT MOBILITY.

7-S3	Analytical methods for characterization of waste types.
5-G2	Controls to prevent groundwater contamination.
5-S36	Soil monitoring methodology.
4-S15	Long-term study of pedogenesis of reclaimed salt affected soils.
3-M5	Monitoring establishment of microbiota in reclaimed soil over long-term.
3-S6	Determine levels of sludge and wastes for landspreading.
3-S12	Barriers to adverse soil constituent movement.
3-V33	Effects of vegetation types on movement of saline groundwater into the rootzone.
2-G6	Movement of contaminated groundwater into adjacent aquifers, surface water bodies or water supply wells.
2-S16	Methods to increase rate of pedogenesis of reclaimed soils.
2-V38	Selection of plant species for saline, sodic and/or saline/sodic soil conditions.
2-V39	Species tolerance to toxicities (salt, etc.).
1-D10	Compilation of reclamation guidelines, methodologies, etc.
1-D12	Economics of reclamation.

1-D24	Effects of toxic elements from plants on reclaimed lands on herbivorous wildlife.
1-G4	Contaminant plume development.
1-G11	Movement of saline water into the plant rootzone.
1-S32	Soil sampling designs (densities/patterns) for characterization of soil materials.
1-V17	Management practices for the establishment and maintenance of native species.
1-V34	Develop/refine methods for plant chemistry analyses.
1-V35	Analytical methods to quantify plant available nutrients in reclaimed soils.

V1 OPTIMUM SEED MIXES AND RATES OF APPLICATION FOR GRASSES AND LEGUMES.

6-V3	Seed bed preparation.
4-V15	Selection, evaluation and multiplication of native grass, legume and forb species.
4-V17	Management practices for the establishment and maintenance of native species.
3-V2	Evaluate seeding techniques of herbaceous species.
2-D3	Reclamation for non-consumptive recreational use - tourism, aesthetics.
2-D20	Range management practices for reclaimed lands.
2-D22	Effects and control of grazing, browsing and trampling on reclaimed lands.
2-D59	Gracialfluvial brunisolic xeric sites with jack pine forest cover.
2-V25	Wood growth/control on reclaimed sites.
2-V26	Spring vs summer vs fall vs winter seeding and planting.
1-F1	Initial fertilizer requirements.
1-F2	Maintenance fertilizer requirements.
1-F3	Application methods.
1-V4	Germination and seedling emergence as affected by soil properties.
1-V5	Effects of fertilization on inter-specific plant competition.
1-V22	Methods to improve the quality and production of forage plants (i.e., fertilizer, species mixes).
1-V23	Suitability of herbaceous and woody plants as wildlife forage/browse (i.e., forage value, productivity, tolerance to grazing/trampling).
1-V30	Ecological succession as a factor in the design of reclamation programs.
1-V31	Competition as a factor in the selection of species for reclamation.
1-V39	Species tolerance to toxicities (salt, etc.).

S23 SOIL HANDLING METHODS.

3-S24	Soil storage methods.
3-S29	Sod salvage versus topsoil salvage in native pasture.
2-S17	Replacement depth of topsoil/subsoil/regolith over spoil.
1-S7	Relationship of soil properties to erosion potential.
1-S8	Effects of storage on topsoil quality.
1-S9	Reconstructed soil development.

1-S22 Methods to alleviate deep compaction.
1-S35 Refine/extend soil and overburden quality rating system.
1-S37 Develop field criteria for shut-down point in wet weather or with frozen soils.
1-S38 Subsoil and topsoil mixing-methods for determining adverse effects on growth and methods for correcting conditions.
1-S47 Soils associated with forested lands in white and green zones with summer/winter.
1-S61 Topsoil salvage guidelines.
1-S64 Soil handling procedures to be used for solonetzic soils during pipeline construction.
1-S67 Impact of handling on soil chemical properties.
1-V1 Optimum seed mixes and rates of application for grasses and legumes.
1-V11 Evaluation of tree/shrub and grass/legume growth.
1-V28 Management practices under unseasonal climatic conditions.

5.2 TOP RESEARCH NEEDS FOR THE OIL AND GAS PROGRAM

For the Oil and Gas Program, the top 15 research topics with their associated modifier codes are listed below.

S06 DETERMINE LEVELS OF SLUDGE AND WASTES FOR LANDSPREADING.

4-D18 Oily waste disposal options.
4-S3 Analytical methods for characterization of waste types.
3-F1 Initial fertilizer requirements.
2-M7 Use of bioreclamation for hydrocarbon spill clean-up (i.e., bacteria).
2-S1 Analytical methods for physical characterization of soil and subsoil materials.
2-S2 Analytical methods for chemical evaluation of soil and subsoil materials.
2-S14 Salt and/or toxic soil constituent mobility.
2-V1 Optimum seed mixes and rates of application for grasses and legumes.
2-V26 Spring vs summer vs fall vs winter seeding and planting.
1-F2 Maintenance fertilizer requirements.
1-F9 Alternates to chemical fertilizers (i.e., organic wastes, peat).
1-M3 Relationship between fertilizers and mycorrhizae.
1-S45 Impact of different waste application rates on major soil types in Alberta.
1-V24 Rodent control methods to minimize woody plant damage.
1-V39 Species tolerance to toxicities (salt, etc.).
1-V49 Impact of different industrial waste application rates on plants/crops.
1-W19 Evaluate the effects of rock drains on benthic invertebrate movement.

V15 SELECTION, EVALUATION AND MULTIPLICATION OF NATIVE GRASS, LEGUME AND FORB SPECIES.

2-F5 Establishment of nutrient self-sufficiency.
2-M5 Monitoring establishment of microbiota in reclaimed soil over long-term.
2-S11 Nutrient cycling in reclaimed soil.
2-S16 Methods to increase rate of pedogenesis of reclaimed soils.
2-V1 Optimum seed mixes and rates of application for grasses and legumes.
2-V2 Evaluate seeding techniques of herbaceous species.
2-V3 Seed bed preparation.
2-V4 Germination and seedling emergence as affected by soil properties.
2-V17 Management practices for the establishment and maintenance of native species.
1-M1 Interactions between bacteria, actinorrhizae, and mycorrhizae and their plant symbionts.
1-M2 Develop mycorrhizal inoculation techniques.
1-M3 Relationship between fertilizers and mycorrhizae.
1-M4 Need for inoculation of mesofauna (earthworms, arthropods, small vertebrates) into reclaimed areas.
1-S5 Reclamation of soil sterilant affected sites.
1-S7 Relationship of soil properties to erosion potential.
1-S20 Reclamation of sandy soils.
1-S29 Sod salvage versus topsoil salvage in native pasture.
1-V5 Effects of fertilization on inter-specific plant competition.
1-V25 Weed growth/control on reclaimed sites.
1-V30 Ecological succession as a factor in the design of reclamation programs.
1-V31 Competition as a factor in the selection of species for reclamation.
1-V39 Species tolerance to toxicities (salt, etc.).

S22 METHODS TO ALLEVIATE DEEP COMPACTION.

10-V27 Effects of compaction on root growth.
7-S34 Instrument requirements for assessing compaction.
4-D13 Design/modification to improve reclamation equipment.
3-D1 Determine "time frames" required to meet reclamation objectives and end land use.
2-D12 Economics of reclamation.
2-S9 Reconstructed soil development.
2-S37 Develop field criteria for shut-down point in wet weather or with frozen soils.
2-V4 Germination and seedling emergence as affected by soil properties.
2-V48 Plants to alleviate compaction.
1-D18 Oily waste disposal options.
1-G7 Groundwater contamination clean-up methods.
1-M7 Use of bioreclamation for hydrocarbon spill clean-up (i.e., bacteria).
1-S33 Pre-disturbance inventories, design and densities, material availability calculations for large scale salvage.

1-S50 Reclamation on sites which lack or are deficient in topsoil; alternate organic sources i.e., manure, straw, mulch, etc.; building soil.
1-V1 Optimum seed mixes and rates of application for grasses and legumes.
1-V3 Seed bed preparation.
1-V11 Evaluation of tree/shrub and grass/legume growth.
1-V21 Guidelines to evaluate successful establishment of plant species and/or communities to meet end land use.
1-V25 Weed growth/control on reclaimed sites.
1-V30 Ecological succession as a factor in the design of reclamation programs.

S23 SOIL HANDLING METHODS.

1-S7 Relationship of soil properties to erosion potential.
1-S8 Effects of storage on topsoil quality.
1-S9 Reconstructed soil development.
1-S22 Methods to alleviate deep compaction.
1-S24 Soil storage methods.
1-S29 Sod salvage versus topsoil salvage in native pasture.
1-S37 Develop field criteria for shut-down point in wet weather or with frozen soils.
1-S47 Soils associated with forested lands in white and green zones with summer/winter.
1-S61 Topsoil salvage guidelines.
1-S64 Soil handling procedures to be used for solonetzic soils during pipeline construction.
1-S67 Impact of handling on soil chemical properties.
1-V11 Evaluation of tree/shrub and grass/legume growth.

S29 SOD SALVAGE VERSUS TOPSOIL SALVAGE IN NATIVE PASTURE.

2-D1 Determine "time frames" required to meet reclamation objectives and end land use.
2-M5 Monitoring establishment of microbiota in reclaimed soil over long-term.
2-S7 Relationship of soil properties to erosion potential.
2-S19 Surface mulches, stabilizers and barriers for erosion control.
2-S20 Reclamation of sandy soils.
2-S23 Soil handling methods.
2-S24 Soil storage methods.
1-F1 Initial fertilizer requirements.
1-S11 Nutrient cycling in reclaimed soil.
1-S16 Methods to increase rate of pedogenesis of reclaimed soils.
1-S30 Evaluate mechanical moisture retention treatments (i.e., stubble, furrow, etc.).
1-V1 Optimum seed mixes and rates of application for grasses and legumes.
1-V7 Transplanting methods and success.
1-V11 Evaluation of tree/shrub and grass/legume growth.

S03 ANALYTICAL METHODS FOR CHARACTERIZATION OF WASTE TYPES.

2-S6 Determine levels of sludge and wastes for landspreading.
1-S4 Analytical methods for detection of soil sterilants.
1-S45 Impact of different waste application rates on major soil types in Alberta.
1-V34 Develop/refine methods for plant chemistry analyses.

D18 OILY WASTE DISPOSAL OPTIONS.

3-S3 Analytical methods for characterization of waste types.
3-S6 Determine levels of sludge and wastes for landspreading.
2-M7 Use of bioreclamation for hydrocarbon spill clean-up (i.e., bacteria).
1-D54 Establish acceptable guidelines for landfilling and/or land spreading (oily wastes) i.e., cleaned sands.
1-D55 Determine optimum treatment techniques for reclamation sites treated with invert based muds.
1-S16 Methods to increase rate of pedogenesis of reclaimed soils.
1-S45 Impact of different waste application rates on major soil types in Alberta.
1-V49 Impact of different industrial waste application rates on plants/crops.

S05 RECLAMATION OF SOIL STERILANT AFFECTED SITES.

7-S4 Analytical methods for detection of soil sterilants.
5-S31 Develop effective short-term soil sterilant.
4-V39 Species tolerance to toxicities (salt, etc.).
2-S14 Salt and/or toxic soil constituent mobility.
2-S15 Long-term study of pedogenesis of reclaimed salt affected soils.
2-S22 Methods to alleviate deep compaction.
1-D1 Determine "time frames" required to meet reclamation objectives and end land use.
1-D4 Standardize requirements for reclamation certification.
1-D5 Compare end land use capability with pre-reclamation objectives.
1-D10 Compilation of reclamation guidelines, methodologies, etc.
1-D12 Economics of reclamation.
1-D15 Micro-climatic considerations to enhance reclamation.
1-D18 Oily waste disposal options.
1-F1 Initial fertilizer requirements.
1-F8 Optimization of topsoil and/or fertilizer for long-term reclamation success.
1-S1 Analytical methods for physical characterization of soil and subsoil materials.
1-V1 Optimum seed mixes and rates of application for grasses and legumes.
1-V21 Guidelines to evaluate successful establishment of plant species and/or communities to meet end land use.
1-V24 Rodent control methods to minimize woody plant damage.
1-V38 Selection of plant species for saline, sodic and/or saline/sodic soil conditions.
1-V43 Species tolerance to herbicides.

S20 RECLAMATION OF SANDY SOILS.

5-V1 Optimum seed mixes and rates of application for grasses and legumes.
5-S26 Wind erosion control techniques.
4-S19 Surface mulches, stabilizers and barriers for erosion control.
4-V3 Seed bed preparation.
2-F8 Optimization of topsoil and/or fertilizer for long-term reclamation success.
2-F10 Susceptibility of common fertilizers to leaching (into groundwater).
2-V2 Evaluate seeding techniques of herbaceous species.
2-V22 Methods to improve the quality and production of forage plants (i.e., fertilizer, species mixes).
1-D5 Compare end land use capability with pre-reclamation objectives.
1-D10 Compilation of reclamation guidelines, methodologies, etc.
1-S11 Nutrient cycling in reclaimed soil.
1-S23 Soil handling methods.
1-S29 Sod salvage versus topsoil salvage in native pasture.
1-S37 Develop field criteria for shut-down point in wet weather or with frozen soils.
1-V4 Germination and seedling emergence as affected by soil properties.
1-V11 Evaluation of tree/shrub and grass/legume growth.
1-V28 Management practices under unseasonal climatic conditions.

S01 ANALYTICAL METHODS FOR PHYSICAL CHARACTERIZATION OF SOIL AND SUBSOIL MATERIALS.

2-S17 Replacement depth of topsoil/subsoil/regolith over spoil.
1-D5 Compare end land use capability with pre-reclamation objectives.
1-D6 Methods of evaluating capability.
1-S4 Analytical methods for detection of soil sterilants.
1-S29 Sod salvage versus topsoil salvage in native pasture.
1-S32 Soil sampling designs (densities/patterns) for characterization of soil materials.
1-S44 Susceptibility of sodium/salt to move from mixed B and C horizons into stripped topsoil which has been replaced.

S08 EFFECTS OF STORAGE ON TOPSOIL QUALITY.

5-S24 Soil storage methods.
4-S23 Soil handling methods.
1-S9 Reconstructed soil development.
1-S17 Replacement depth of topsoil/subsoil/regolith over spoil.
1-S36 Soil monitoring methodology.
1-S48 Storage of topsoil in pits or above ground sites.
1-V25 Weed growth/control on reclaimed sites.

S14 SALT AND/OR TOXIC SOIL CONSTITUENT MOBILITY.

5-S3 Analytical methods for characterization of waste types.
3-G2 Controls to prevent groundwater contamination.
2-M5 Monitoring establishment of microbiota in reclaimed soil over long-term.
2-S15 Long-term study of pedogenesis of reclaimed salt affected soils.
2-S36 Soil monitoring methodology.
2-V38 Selection of plant species for saline, sodic and/or saline/sodic soil conditions.
2-V39 Species tolerance to toxicities (salt, etc.).
1-D10 Compilation of reclamation guidelines, methodologies, etc.
1-G6 Movement of contaminated groundwater into adjacent aquifers, surface water bodies or water supply wells.
1-G11 Movement of saline water into the plant rootzone.
1-S6 Determine levels of sludge and wastes for landspreading.
1-S12 Barriers to adverse soil constituent movement.
1-S16 Methods to increase rate of pedogenesis of reclaimed soils.
1-V17 Management practices for the establishment and maintenance of native species.
1-V33 Effects of vegetation types on movement of saline groundwater into the rootzone.

V17 MANAGEMENT PRACTICES FOR THE ESTABLISHMENT AND MAINTENANCE OF NATIVE SPECIES.

4-V15 Selection, evaluation and multiplication of native grass, legume and forb species.
3-F1 Initial fertilizer requirements.
3-F3 Application methods.
3-F4 Timing of fertilization.
2-D25 Evaluate long-term use of terrestrial and aquatic reclaimed areas by wildlife.
2-F2 Maintenance fertilizer requirements.
2-F5 Establishment of nutrient self-sufficiency.
2-V16 Selection, evaluation and multiplication of native tree and shrub species.
1-F6 N-contribution of nodulated woody species.
1-F7 Fertilizer effects on plant community composition.
1-F8 Optimization of topsoil and/or fertilizer for long-term reclamation success.
1-M1 Interactions between bacteria, actinorrhizae, and mycorrhizae and their plant symbionts.
1-M2 Develop mycorrhizal inoculation techniques.
1-M3 Relationship between fertilizers and mycorrhizae.
1-M4 Need for inoculation of mesofauna (earthworms, arthropods, small vertebrates) into reclaimed areas.
1-M5 Monitoring establishment of microbiota in reclaimed soil over long-term.

1-S11 Nutrient cycling in reclaimed soil.
1-S19 Surface mulches, stabilizers and barriers for erosion control.
1-S29 Sod salvage versus topsoil salvage in native pasture.
1-V4 Germination and seedling emergence as affected by soil properties.
1-V6 Alternate tree/shrub planting methods.
1-V25 Weed growth/control on reclaimed sites.
1-V30 Ecological succession as a factor in the design of reclamation programs.
1-V44 Develop a method for stripping native sod and replacing it over a disturbed area.
1-V45 Develop a method for stockpiling and storing native sod to be used to revegetate a disturbed area.

F09 ALTERNATES TO CHEMICAL FERTILIZERS (I.E., ORGANIC WASTES, PEAT).

2-D51 Evaluate long-term importance of various soil amendments.
2-V4 Germination and seedling emergence as affected by soil properties.

S11 NUTRIENT CYCLING IN RECLAIMED SOIL.

2-S16 Methods to increase rate of pedogenesis of reclaimed soils.
1-S1 Analytical methods for physical characterization of soil and subsoil materials.
1-S17 Replacement depth of topsoil/subsoil/regolith over spoil.
1-V3 Seed bed preparation.
1-V27 Effects of compaction on root growth.

5.3 TOP RESEARCH NEEDS FOR THE MOUNTAINS/FOOTHILLS PROGRAM

The top 11 research topics for the Mountains/Foothills Program with their associated modifier codes are listed below.

V15 SELECTION, EVALUATION AND MULTIPLICATION OF NATIVE GRASS, LEGUME AND FORB SPECIES.

3-V1 Optimum seed mixes and rates of application for grasses and legumes.
3-V4 Germination and seedling emergence as affected by soil properties.
2-V2 Evaluate seeding techniques of herbaceous species.
2-V3 Seed bed preparation.
2-V17 Management practices for the establishment and maintenance of native species.
1-F5 Establishment of nutrient self-sufficiency.
1-M1 Interactions between bacteria, actinorrhizae, and mycorrhizae and their plant symbionts.
1-M2 Develop mycorrhizal inoculation techniques.
1-M3 Relationship between fertilizers and mycorrhizae.

1-M4	Need for inoculation of mesofauna (earthworms, arthropods, small vertebrates) into reclaimed areas.
1-M5	Monitoring establishment of microbiota in reclaimed soil over long-term.
1-S11	Nutrient cycling in reclaimed soil.
1-S16	Methods to increase rate of pedogenesis of reclaimed soils.
1-V5	Effects of fertilization on inter-specific plant competition.

D01 DETERMINE "TIME FRAMES" REQUIRED TO MEET RECLAMATION OBJECTIVES AND END LAND USE.

2-D6	Methods of evaluating capability.
2-V21	Guidelines to evaluate successful establishment of plant species and/or communities to meet end land use.
1-D7	Value of wildlife and fish populations and habitat in assessing productivity of reclaimed site.
1-S26	Wind erosion control techniques.
1-S27	Water erosion control techniques.
1-V18	Productivity evaluation and equivalency with pre-disturbed plant cover.

V13 MONITORING LONG-TERM PERFORMANCE OF WOODY SPECIES IN RECLAIMED AREAS.

1-F5	Establishment of nutrient self-sufficiency.
1-S9	Reconstructed soil development.
1-S11	Nutrient cycling in reclaimed soil.
1-V11	Evaluation of tree/shrub and grass/legume growth.
1-V18	Productivity evaluation and equivalency with pre-disturbed plant cover.
1-V20	Methods for assessing productivity (tree growth, regeneration, etc.).

D25 EVALUATE LONG-TERM USE OF TERRESTRIAL AND AQUATIC RECLAIMED AREAS BY WILDLIFE.

2-D26	Monitor changes in composition of wildlife species with ecosystem succession.
2-D27	Field verification of methods to assess success of wildlife habitat reclamation for certification.
1-D19	Topographic and vegetation considerations for wildlife habitat.
1-D20	Range management practices for reclaimed lands.
1-D29	Further development of habitat modelling to meet reclamation objectives.
1-V17	Management practices for the establishment and maintenance of native species.

V06 ALTERNATE TREE/SHRUB PLANTING METHODS.

1-F7 Fertilizer effects on plant community composition.
1-S8 Effects of storage on topsoil quality.
1-S9 Reconstructed soil development.
1-S17 Replacement depth of topsoil/subsoil/regolith over spoil.
1-S19 Surface mulches, stabilizers and barriers for erosion control.

W18 RECLAMATION OF TAILINGS PONDS.

2-D16 Alternate methods for dewatering and reclaiming tailings sludge.
1-D2 Determine potential for alternate end land uses.
1-D11 Bioengineering techniques.
1-W5 Monitor ecosystem development within waterbodies on reclaimed land over long-term.

V11 EVALUATION OF TREE/SHRUB AND GRASS/LEGUME GROWTH.

1-M2 Develop mycorrhizal inoculation techniques.
1-M3 Relationship between fertilizers and mycorrhizae.
1-S17 Replacement depth of topsoil/subsoil/regolith over spoil.

V16 SELECTION, EVALUATION AND MULTIPLICATION OF NATIVE TREE AND SHRUB SPECIES.

3-V6 Alternate tree/shrub planting methods.
3-V11 Evaluation of tree/shrub and grass/legume growth.
2-V7 Transplanting methods and success.
2-V8 Effects of container characteristics on tree/shrub growth/survival.
2-V9 Container versus bareroot plantings.
2-V10 Methods for collecting, handling and planting cuttings.
2-V12 Establishment of woody species in grasslands.
2-V13 Monitoring long-term performance of woody species in reclaimed areas.
1-M1 Interactions between bacteria, actinorrhizae, and mycorrhizae and their plant symbionts.
1-M2 Develop mycorrhizal inoculation techniques.
1-M3 Relationship between fertilizers and mycorrhizae.
1-M4 Need for inoculation of mesofauna (earthworms, arthropods, small vertebrates) into reclaimed areas.
1-M5 Monitoring establishment of microbiota in reclaimed soil over long-term.
1-V17 Management practices for the establishment and maintenance of native species.

V17 MANAGEMENT PRACTICES FOR THE ESTABLISHMENT AND MAINTENANCE OF NATIVE SPECIES.

3-V15 Selection, evaluation and multiplication of native grass, legume and forb species.
2-F1 Initial fertilizer requirements.
2-F2 Maintenance fertilizer requirements.
2-F3 Application methods.
2-F4 Timing of fertilization.
2-F5 Establishment of nutrient self-sufficiency.
1-F6 N-contribution of nodulated woody species.
1-F7 Fertilizer effects on plant community composition.
1-F8 Optimization of topsoil and/or fertilizer for long-term reclamation success.
1-M1 Interactions between bacteria, actinorrhizae, and mycorrhizae and their plant symbionts.
1-M2 Develop mycorrhizal inoculation techniques.
1-M3 Relationship between fertilizers and mycorrhizae.
1-M4 Need for inoculation of mesofauna (earthworms, arthropods, small vertebrates) into reclaimed areas.
1-M5 Monitoring establishment of microbiota in reclaimed soil over long-term.
1-S11 Nutrient cycling in reclaimed soil.
1-S19 Surface mulches, stabilizers and barriers for erosion control.
1-S29 Sod salvage versus topsoil salvage in native pasture.
1-V4 Germination and seedling emergence as affected by soil properties.
1-V6 Alternate tree/shrub planting methods.
1-V16 Selection, evaluation and multiplication of native tree and shrub species.

V29 MAXIMUM ANGLE OF REPOSE SUITABLE FOR REVEGETATION.

1-D19 Topographic and vegetation considerations for wildlife habitat.

S09 RECONSTRUCTED SOIL DEVELOPMENT.

1-F5 Establishment of nutrient self-sufficiency.
1-M8 Rates and mechanisms of organic matter decomposition.
1-S10 Weathering of replaced spoil/subsoil.
1-S13 Predictive models for soil processes.
1-S15 Long-term study of pedogenesis of reclaimed salt affected soils.
1-S17 Replacement depth of topsoil/subsoil/regolith over spoil.
1-S23 Soil handling methods.
1-V13 Monitoring long-term performance of woody species in reclaimed areas.
1-V18 Productivity evaluation and equivalency with pre-disturbed plant cover.

5.4 TOP RESEARCH NEEDS FOR THE PLAINS COAL PROGRAM

The Plains Coal Program top 10 research topics with their associated modifier codes are listed below.

S17 REPLACEMENT DEPTH OF TOPSOIL/SUBSOIL/REGOLITH OVER SPOIL.

2-S25 Use of ash as an amendment.
1-D9 Use of water budget models to predict the fate of reclaimed soils.
1-D57 Consolidate existing research information; improve dissemination of information.
1-G1 Baseline hydrogeological studies (i.e., groundwater occurrence, flow conditions, hydraulic properties of aquifers and aquicludes, groundwater quality).
1-S8 Effects of storage on topsoil quality.
1-S9 Reconstructed soil development.
1-S14 Salt and/or toxic soil constituent mobility.
1-S16 Methods to increase rate of pedogenesis of reclaimed soils.
1-S22 Methods to alleviate deep compaction.

V15 SELECTION, EVALUATION AND MULTIPLICATION OF NATIVE GRASS, LEGUME AND FORB SPECIES.

1-F5 Establishment of nutrient self-sufficiency.
1-S11 Nutrient cycling in reclaimed soil.
1-S16 Methods to increase rate of pedogenesis of reclaimed soils.
1-S20 Reclamation of sandy soils.
1-S29 Sod salvage versus topsoil salvage in native pasture.
1-V1 Optimum seed mixes and rates of application for grasses and legumes.
1-V2 Evaluate seeding techniques of herbaceous species.
1-V3 Seed bed preparation.
1-V4 Germination and seedling emergence as affected by soil properties.
1-V17 Management practices for the establishment and maintenance of native species.

D01 DETERMINE "TIME FRAMES" REQUIRED TO MEET RECLAMATION OBJECTIVES AND END LAND USE.

3-D6 Methods of evaluating capability.

D25 EVALUATE LONG-TERM USE OF TERRESTRIAL AND AQUATIC RECLAIMED AREAS BY WILDLIFE.

1-D19 Topographic and vegetation considerations for wildlife habitat.
1-D20 Range management practices for reclaimed lands.
1-D26 Monitor changes in composition of wildlife species with ecosystem succession.

1-D27	Field verification of methods to assess success of wildlife habitat reclamation for certification.
1-V17	Management practices for the establishment and maintenance of native species.
V16	SELECTION, EVALUATION AND MULTIPLICATION OF NATIVE TREE AND SHRUB SPECIES.
2-V6	Alternate tree/shrub planting methods.
2-V7	Transplanting methods and success.
2-V8	Effects of container characteristics on tree/shrub growth/survival.
2-V9	Container versus bareroot plantings.
2-V10	Methods for collecting, handling and planting cuttings.
2-V11	Evaluation of tree/shrub and grass/legume growth.
2-V12	Establishment of woody species in grasslands.
2-V13	Monitoring long-term performance of woody species in reclaimed areas.
1-M1	Interactions between bacteria, actinorrhizae, and mycorrhizae and their plant symbionts.
1-M2	Develop mycorrhizal inoculation techniques.
1-M3	Relationship between fertilizers and mycorrhizae.
1-M4	Need for inoculation of mesofauna (earthworms, arthropods, small vertebrates) into reclaimed areas.
1-M5	Monitoring establishment of microbiota in reclaimed soil over long-term.
S09	RECONSTRUCTED SOIL DEVELOPMENT.
2-M8	Rates and mechanisms of organic matter decomposition.
1-M5	Monitoring establishment of microbiota in reclaimed soil over long-term.
1-S10	Weathering of replaced spoil/subsoil.
1-S11	Nutrient cycling in reclaimed soil.
1-S13	Predictive models for soil processes.
1-S15	Long-term study of pedogenesis of reclaimed salt affected soils.
1-S17	Replacement depth of topsoil/subsoil/regolith over spoil.
1-S22	Methods to alleviate deep compaction.
1-S23	Soil handling methods.
1-S37	Develop field criteria for shut-down point in wet weather or with frozen soils.
1-S50	Reclamation on sites which lack or are deficient in topsoil; alternate organic sources i.e., manure, straw, mulch, etc.; building soil.
1-V1	Optimum seed mixes and rates of application for grasses and legumes.
1-V25	Weed growth/control on reclaimed sites.

V17 MANAGEMENT PRACTICES FOR THE ESTABLISHMENT AND MAINTENANCE OF NATIVE SPECIES.

3-V15 Selection, evaluation and multiplication of native grass, legume and forb species.
2-F1 Initial fertilizer requirements.
2-F2 Maintenance fertilizer requirements.
2-F3 Application methods.
2-F4 Timing of fertilization.
2-F5 Establishment of nutrient self-sufficiency.
1-D25 Evaluate long-term use of terrestrial and aquatic reclaimed areas by wildlife.
1-M1 Interactions between bacteria, actinorrhizae, and mycorrhizae and their plant symbionts.
1-M2 Develop mycorrhizal inoculation techniques.
1-M3 Relationship between fertilizers and mycorrhizae.
1-M4 Need for inoculation of mesofauna (earthworms, arthropods, small vertebrates) into reclaimed areas.
1-M5 Monitoring establishment of microbiota in reclaimed soil over long-term.
1-F6 N-contribution of nodulated woody species.
1-F7 Fertilizer effects on plant community composition.
1-F8 Optimization of topsoil and/or fertilizer for long-term reclamation success.
1-S11 Nutrient cycling in reclaimed soil.
1-S19 Surface mulches, stabilizers and barriers for erosion control.
1-S29 Sod salvage versus topsoil salvage in native pasture.
1-V4 Germination and seedling emergence as affected by soil properties.
1-V16 Selection, evaluation and multiplication of native tree and shrub species.

V33 EFFECTS OF VEGETATION TYPES ON MOVEMENT OF SALINE GROUNDWATER INTO THE ROOTZONE.

2-G11 Movement of saline water into the plant rootzone.
1-S14 Salt and/or toxic soil constituent mobility.
1-V15 Selection, evaluation and multiplication of native grass, legume and forb species.
1-V39 Species tolerance to toxicities (salt, etc.).

V38 SELECTION OF PLANT SPECIES FOR SALINE, SODIC AND/OR SALINE/SODIC SOIL CONDITIONS.

1-V27 Effects of compaction on root growth.
1-V33 Effects of vegetation types on movement of saline groundwater into the rootzone.

V30 ECOLOGICAL SUCCESSION AS A FACTOR IN THE DESIGN OF RECLAMATION PROGRAMS.

3-V5 Effects of fertilization on inter-specific plant competition.
2-F2 Maintenance fertilizer requirements.
2-F7 Fertilizer effects on plant community composition.
2-V17 Management practices for the establishment and maintenance of native species.
2-V31 Competition as a factor in the selection of species for reclamation.
1-F8 Optimization of topsoil and/or fertilizer for long-term reclamation success.
1-S11 Nutrient cycling in reclaimed soil.
1-S33 Pre-disturbance inventories, design and densities, material availability calculations for large scale salvage.
1-V15 Selection, evaluation and multiplication of native grass, legume and forb species.
1-V22 Methods to improve the quality and production of forage plants (i.e., fertilizer, species mixes).
1-V28 Management practices under unseasonal climatic conditions.

5.5 TOP RESEARCH NEEDS FOR THE OIL SANDS PROGRAM

The top 10 research topics with their associated modifier codes for the Oil Sands Program are listed below.

V15 SELECTION, EVALUATION AND MULTIPLICATION OF NATIVE GRASS, LEGUME AND FORB SPECIES.

2-F5 Establishment of nutrient self-sufficiency.
2-S11 Nutrient cycling in reclaimed soil.
2-S16 Methods to increase rate of pedogenesis of reclaimed soils.
2-V2 Evaluate seeding techniques of herbaceous species.
2-V3 Seed bed preparation.
2-V4 Germination and seedling emergence as affected by soil properties.
2-V17 Management practices for the establishment and maintenance of native species.
1-M1 Interactions between bacteria, actinorrhizae, and mycorrhizae and their plant symbionts.
1-M2 Develop mycorrhizal inoculation techniques.
1-M3 Relationship between fertilizers and mycorrhizae.
1-M4 Need for inoculation of mesofauna (earthworms, arthropods, small vertebrates) into reclaimed areas.
1-M5 Monitoring establishment of microbiota in reclaimed soil over long-term.
1-S20 Reclamation of sandy soils.
1-S29 Sod salvage versus topsoil salvage in native pasture.
1-V1 Optimum seed mixes and rates of application for grasses and legumes.
1-V5 Effects of fertilization on inter-specific plant competition.

V17 MANAGEMENT PRACTICES FOR THE ESTABLISHMENT AND MAINTENANCE OF NATIVE SPECIES.

4-V15 Selection, evaluation and multiplication of native grass, legume and forb species.
2-F1 Initial fertilizer requirements.
2-F2 Maintenance fertilizer requirements.
2-F3 Application methods.
2-F4 Timing of fertilization.
2-F5 Establishment of nutrient self-sufficiency.
2-V16 Selection, evaluation and multiplication of native tree and shrub species.
1-D9 Use of water budget models to predict the fate of reclaimed soils.
1-D25 Evaluate long-term use of terrestrial and aquatic reclaimed areas by wildlife.
1-F6 N-contribution of nodulated woody species.
1-F7 Fertilizer effects on plant community composition.
1-F8 Optimization of topsoil and/or fertilizer for long-term reclamation success.
1-M1 Interactions between bacteria, actinorrhizae, and mycorrhizae and their plant symbionts.
1-M2 Develop mycorrhizal inoculation techniques.
1-M3 Relationship between fertilizers and mycorrhizae.
1-M4 Need for inoculation of mesofauna (earthworms, arthropods, small vertebrates) into reclaimed areas.
1-M5 Monitoring establishment of microbiota in reclaimed soil over long-term.
1-S11 Nutrient cycling in reclaimed soil.
1-S18 Amendment techniques for sand tailings.
1-S19 Surface mulches, stabilizers and barriers for erosion control.
1-S29 Sod salvage versus topsoil salvage in native pasture.
1-V4 Germination and seedling emergence as affected by soil properties.
1-V6 Alternate tree/shrub planting methods.

V13 MONITORING LONG-TERM PERFORMANCE OF WOODY SPECIES IN RECLAIMED AREAS.

1-D25 Evaluate long-term use of terrestrial and aquatic reclaimed areas by wildlife.
1-V11 Evaluation of tree/shrub and grass/legume growth.
1-V18 Productivity evaluation and equivalency with pre-disturbed plant cover.
1-V20 Methods for assessing productivity (tree growth, regeneration, etc.).
1-V24 Rodent control methods to minimize woody plant damage.

W18 RECLAMATION OF TAILINGS PONDS.

5-W17 Detoxification of tailings pond water.
4-D16 Alternate methods for dewatering and reclaiming tailings sludge.
1-S18 Amendment techniques for sand tailings.
1-S26 Wind erosion control techniques.

1-V39	Species tolerance to toxicities (salt, etc.).
1-W2	Design of ponds/lakes.
1-W9	Develop/refine surface water quality models.
W17	DETOXIFICATION OF TAILINGS POND WATER.
1-W3	Evaluate long-term use of reclaimed waterbodies by fish.
D25	EVALUATE LONG-TERM USE OF TERRESTRIAL AND AQUATIC RECLAIMED AREAS BY WILDLIFE.
1-D26	Monitor changes in composition of wildlife species with ecosystem succession.
1-V17	Management practices for the establishment and maintenance of native species.
V16	SELECTION, EVALUATION AND MULTIPLICATION OF NATIVE TREE AND SHRUB SPECIES.
3-V6	Alternate tree/shrub planting methods.
3-V11	Evaluation of tree/shrub and grass/legume growth.
2-V7	Transplanting methods and success.
2-V8	Effects of container characteristics on tree/shrub growth/survival.
2-V9	Container versus bareroot plantings.
2-V10	Methods for collecting, handling and planting cuttings.
2-V12	Establishment of woody species in grasslands.
2-V13	Monitoring long-term performance of woody species in reclaimed areas.
2-V17	Management practices for the establishment and maintenance of native species.
1-V23	Suitability of herbaceous and woody plants as wildlife forage/browse (i.e., forage value, productivity, tolerance to grazing/trampling).
1-M1	Interactions between bacteria, actinorrhizae, and mycorrhizae and their plant symbionts.
1-M2	Develop mycorrhizal inoculation techniques.
1-M3	Relationship between fertilizers and mycorrhizae.
1-M4	Need for inoculation of mesofauna (earthworms, arthropods, small vertebrates) into reclaimed areas.
1-M5	Monitoring establishment of microbiota in reclaimed soil over long-term.
S09	RECONSTRUCTED SOIL DEVELOPMENT.
1-F5	Establishment of nutrient self-sufficiency.
1-M8	Rates and mechanisms of organic matter decomposition.
1-S10	Weathering of replaced spoil/subsoil.
1-S13	Predictive models for soil processes.
1-S15	Long-term study of pedogenesis of reclaimed salt affected soils.

1-S17 Replacement depth of topsoil/subsoil/regolith over spoil.
1-S20 Reclamation of sandy soils.
1-S23 Soil handling methods.
1-V13 Monitoring long-term performance of woody species in reclaimed areas.
1-V18 Productivity evaluation and equivalency with pre-disturbed plant cover.

V30 ECOLOGICAL SUCCESSION AS A FACTOR IN THE DESIGN OF RECLAMATION PROGRAMS.

2-V5 Effects of fertilization on inter-specific plant competition.
2-V31 Competition as a factor in the selection of species for reclamation.
2-F7 Fertilizer effects on plant community composition.
1-F2 Maintenance fertilizer requirements.
1-S11 Nutrient cycling in reclaimed soil.
1-S33 Pre-disturbance inventories, design and densities, material availability calculations for large scale salvage.
1-V13 Monitoring long-term performance of woody species in reclaimed areas.
1-V15 Selection, evaluation and multiplication of native grass, legume and forb species.
1-V17 Management practices for the establishment and maintenance of native species.

S17 REPLACEMENT DEPTH OF TOPSOIL/SUBSOIL/REGOLITH OVER SPOIL.

1-S18 Amendment techniques for sand tailings.
1-S23 Soil handling methods.

6. APPENDIX 2

6. Appendix 2 Alphanumeric code list for geographic regions, disturbance types, end land use and reclamation research topics. Italicized codes are codes recommended by respondents.

1. Geographic Region Codes:

A	All of Alberta	NE	Northeast Alberta
MF	Mountains/Foothills	P	Plains
NW	Northwest Alberta		

2. Disturbance Type Codes:

CC	*Cultivation*	OM	Other Mines (minerals, etc.)
CD	Chemical Disturbance (oil, salt, sulphur, biocides)	OS	Oil Sands Mine
		PC	*Pesticide Container Collection Site*
CM	Coal Mine	PL	Pipeline
DW	*Disposal Wells*	RS	Recreational Site
FR	*Prescribed or Wild Fire*	SG	Sand/Gravel Operations
GP	Gas Plant	SL	Seismic Line
GTP	*Gypsum Tailing Pond*	SP	Sump
HW	Highway/Road	TL	Transmission Line
IC	Irrigation Canals	US	Urban Sites
IOS	*In-Situ Oil Sands*	*WE*	*Water Extraction for Waterflood of Oil Reservoirs*
IS	Industrial Site		
LF	Landfill	WI	Water Impoundment
LO	Logging Operation	WS	Well Site
MP	*Meat Packing Plant*	ZZ	Several Disturbance Types
MW	Multi-well Pad		

3. End Land Use Codes:

A	Agriculture	*PG*	*Phosphogypsum Ponds*
C	*Conservation*	R	Recreation
F	Forestry	U	Urban
H	Wildlife/Fisheries Habitat	Z	Several End Land Uses
I	Industry		
L	*Rangeland*		

4. Reclamation Research Topic Codes:

MISCELLANEOUS TOPICS

D1 Determine ***"time frames"*** required to ***meet reclamation objectives*** and end land use.
D2 Determine potential for ***alternate end land uses.***
D3 Reclamation for ***non-consumptive recreational use*** - tourism, aesthetics.
D4 Standardize requirements for ***reclamation certification.***
D5 Compare ***end land use capability*** with ***pre-reclamation objectives.***
D6 Methods of ***evaluating capability.***
D7 Value of wildlife and fish ***populations and habitat*** in ***assessing productivity*** of reclaimed site.
D8 Contouring reclaimed area to ***manage/predict soil water movement*** and discharge.

D9 Use of ***water budget models*** to predict the fate of reclaimed soils.
D10 Compilation of ***reclamation guidelines, methodologies***, etc.
D11 ***Bioengineering*** techniques.
D12 ***Economics*** of reclamation.
D13 Design/modification to improve ***reclamation equipment.***
D15 ***Micro-climatic considerations*** to enhance reclamation.
D16 Alternate methods for dewatering and reclaiming ***tailings sludge.***
D17 Sawmill ***sawdust pile*** reclamation.
D18 ***Oily waste disposal*** options.
D19 Topographic and vegetation considerations for ***wildlife habitat.***
D20 ***Range management*** practices for reclaimed lands.
D21 Delineate ***stocking rates*** and/or ***carrying capacities*** of reclaimed land for wildlife.
D22 ***Effects*** and ***control*** of ***grazing, browsing and trampling*** on reclaimed lands.
D23 ***Forage requirements*** (e.g., nutrients, energy) of large herbivores.
D24 ***Effects of toxic elements*** from plants on reclaimed lands on herbivorous ***wildlife***.
D25 Evaluate ***long-term use*** of terrestrial and aquatic ***reclaimed areas*** by ***wildlife.***
D26 Monitor ***changes*** in composition of ***wildlife species*** with ***ecosystem succession***.
D27 Field verification of ***methods*** to ***assess success of wildlife habitat reclamation*** for certification.
D29 Further development of ***habitat modelling*** to meet reclamation objectives.
D30 Determine the most cost-effective method of recontouring final pit highwalls.
D31 Rehabilitation of gravel borrow pits utilizing construction wastes.
D32 Decommissioning sites with emphasis on soils and groundwater.
D33 Evaluate use of non-palatable species.
D34 Determine minimum buffer between a river and surface mine. Consider minimum width and height above the river water to protect river bank stability and maximize resource recovery near the river bank.
D35 Refine remote sensing analytical methods for evaluating reclamation success.
D36 Relationship of land and climate to erosion potential.
D37 Evaluation of differential settlement impact on land use.
D38 Wildlife habitat design.
D39 Climate monitoring techniques to provide guidance for reclamation strategies.
D40 Subsidence problems related to sump disposal.
D41 Species-specific behavioural requirements in determining habitat suitability of reclaimed sites (traditional use, social behaviour etc.).
D42 Site-specific forage requirements.
D43 Operational costs of poor reclamation (e.g. erosion, remedial repairs etc.) determined from operation/maintenance budgets.
D44 Evaluate individual well site spacing versus multi-well pads in relationship to future restoration (e.g. too much industrial activity versus agriculturally productive lands). Heavy oil development in Wainwright-Provost-Consort areas.
D45 Compare performance, durability to overwintering, required rates of application etc., of tackifiers and mulches that are available.
D46 Monitor and evaluate numerous well site gas leaks and ways to solve the problem (e.g. hold-ups in issuing reclamation certificates).
D47 Communicate reclamation policies and activities to public through information programs.
D48 Identify methods to reclaim mined-out areas adjacent to rivers in order to restore wildlife habitat and aesthetics.
D49 Applications of biotechnology to reclamation.

D50 *In-situ removal and collection of surface soil contaminants (soil, brine).*
D51 *Evaluate long-term importance of various soil amendments.*
D52 *Evaluate construction equipment to be used for topsoil stripping during frozen soil conditions.*
D53 *Methods of evaluating productivity and capability for pipeline rights-of-way prior to returning security deposits and issuing reclamation certificates.*
D54 *Establish acceptable guidelines for landfilling and/or land spreading (oily wastes) e.g. cleaned sands.*
D55 *Determine optimum treatment techniques for reclamation sites treated with invert based muds.*
D56 *Develop equipment for the detection of buried materials.*
D57 *Consolidate existing research information; improve dissemination of information.*
D58 *Reclamation of subalpine and alpine areas.*
D59 *Glaciofluvial brunisolic xeric sites with jack pine forest cover.*
D60 *Improve methods for disposal of drilling mud; dry spread versus tank.*
D61 *Physical methodology for reclaiming drilling sump.*
D62 *If the greenhouse effect becomes a reality, reclaiming "more" xeric environments will be a concern.*
D63 *Effects of logging "slash" burning on soil fertility and reforestation.*
D64 *Salt-spill site reclamation in the boreal forest, specifically in treed muskeg environments in northern Alberta.*
D65 *Tailings management and long-term reclamation.*
D66 *Visual integration of reclaimed sites with adjacent environment.*
D67 *Techniques for reclaiming phosphogypsum stacks.*
D68 *Compare mining methods in terms of materials handling sequence to determine cost effectiveness in achieving final required soil/subsoil/spoil configurations.*

FERTILIZERS

F1 ***Initial*** fertilizer ***requirements.***
F2 ***Maintenance*** fertilizer ***requirements.***
F3 ***Application*** methods
F4 ***Timing*** of fertilization.
F5 Establishment of ***nutrient self-sufficiency.***
F6 ***N-contribution*** of nodulated woody species.
F7 Fertilizer effects on ***plant community composition.***
F8 Optimization of topsoil and/or fertilizer for ***long-term*** reclamation ***success.***
F9 ***Alternates*** to chemical fertilizers (e.g., organic wastes, peat).
F10 ***Susceptibility*** of common fertilizers to ***leaching*** (into groundwater).
F11 *Product testing - data availability*

GROUNDWATER

G1 ***Baseline*** hydrogeological ***studies*** (e.g., groundwater occurrence, flow conditions, hydraulic properties of aquifers and aquicludes, groundwater quality).
G2 ***Controls to prevent*** groundwater ***contamination.***
G3 ***Contamination*** of ***near-surface aquifers*** by industrial, agricultural and municipal activities.
G4 ***Contaminant plume*** development
G5 Attenuation capacity of common geologic deposits with respect to ***contaminated groundwater.***
G6 ***Movement of contaminated groundwater*** into adjacent aquifers, surface water bodies or water supply wells.
G7 Groundwater ***contamination clean-up methods.***

G8 Groundwater ***monitoring*** methodology (construction, testing and sampling).
G9 Geophysical sounding and other ***non-intrusive detection techniques*** for groundwater contamination.
G10 Tracer studies and ***intrusive detection techniques*** for groundwater contamination.
G11 ***Movement of saline water*** into the plant rootzone.
G12 Aquifer recharge.
G13 Evaluate ***deep-well injection*** methodology and effects.
G14 Refine and test existing groundwater ***models*** for Alberta setting (flow and quality).
G15 Artificial ***recharge of aquifers.***
G16 ***Aquifer depletion*** resulting from overpumping or dewatering operations.
G17 Re-establishment of groundwater/soil interaction.
G18 Sump fluid migration in sandy soils and how this may pollute groundwater aquifers.
G19 Pre-determining suitability of soils for sump fluid containment.
G20 Influence of pipelines on soil alkalinity in sideslope conditions.
G21 Re-establishment of groundwater regime.

MICRO/MESOBIOLOGY

M1 Interactions between ***bacteria, actinorrhizae***, and ***mycorrhizae*** and their plant symbionts.
M2 Develop mycorrhizal ***inoculation techniques.***
M3 Relationship between ***fertilizers*** and ***mycorrhizae.***
M4 Need for ***inoculation of mesofauna*** (earthworms, arthropods, small vertebrates) into reclaimed areas.
M5 ***Monitoring*** establishment of ***microbiota*** in reclaimed soil over long-term.
M6 Fate of ***pathogens*** introduced via ***sewage sludge*** used in reclamation.
M7 Use of ***bioreclamation*** for hydrocarbon spill clean-up (e.g., bacteria).
M8 Rates and mechanisms of ***organic matter decomposition.***
M9 Means to increase levels of stable organic matter.
M10 Bioreclamation of contaminated soils other than spills.

SOILS

S1 Analytical methods for ***physical characterization*** of soil and subsoil ***materials.***
S2 Analytical methods for ***chemical evaluation*** of soil and subsoil ***materials.***
S3 Analytical methods for ***characterization of waste types.***
S4 Analytical methods for ***detection of soil sterilants.***
S5 Reclamation of ***soil sterilant*** affected sites.
S6 Determine levels of ***sludge and wastes*** for landspreading.
S7 Relationship of soil properties to ***erosion potential.***
S8 Effects of ***storage*** on topsoil ***quality.***
S9 Reconstructed ***soil development.***
S10 ***Weathering*** of replaced spoil/subsoil.
S11 ***Nutrient cycling*** in reclaimed soil.
S12 Barriers to adverse ***soil constituent movement.***
S13 Predictive models for ***soil processes.***
S14 ***Salt*** and/or ***toxic*** soil ***constituent*** mobility.
S15 Long-term study of ***pedogenesis*** of reclaimed ***salt affected soils.***
S16 Methods to ***increase rate of pedogenesis*** of reclaimed soils.
S17 ***Replacement depth*** of topsoil/subsoil/regolith over spoil.
S18 Amendment techniques for ***sand tailings.***

S19 Surface mulches, stabilizers and barriers for ***erosion control***.
S20 Reclamation of ***sandy soils***.
S21 Mechanical ***soil mixing methods*** (e.g., disc, chisel plow, etc.).
S22 Methods to alleviate deep ***compaction***.
S23 Soil ***handling*** methods.
S24 Soil ***storage*** methods.
S25 Use of ***ash*** as an amendment.
S26 ***Wind erosion*** control techniques.
S27 ***Water erosion*** control techniques.
S28 Triple ***handling***.
S29 ***Sod salvage*** versus topsoil salvage in native pasture.
S30 Evaluate mechanical ***moisture retention*** treatments (e.g. stubble, furrow, etc.).
S31 Develop effective short-term soil ***sterilant***.
S32 Soil ***sampling designs*** (densities/patterns) for characterization of soil materials.
S33 Pre-disturbance inventories, design and densities, material availability calculations for ***large scale salvage***.
S34 ***Instrument*** requirements for assessing ***compaction***.
S35 Refine/extend soil and overburden ***quality rating system***.
S36 Soil ***monitoring*** methodology.
S37 Develop ***field criteria*** for shut-down point in wet weather or with frozen soils.
S38 Subsoil and topsoil mixing-methods for determining adverse effects on growth and methods for correcting conditions.
S39 Reclamation of pesticide container collection sites.
S40 Define impact on agricultural or forested soils.
S41 Reclamation of soils affected by gas seepage.
S42 Topsoil stripping during winter versus summer on well sites.
S43 Evaluate moisture retention in rooting zone of disturbed and undisturbed soil.
S44 Susceptibility of sodium/salt to move from mixed B and C horizons into stripped topsoil which has been replaced.
S45 Impact of different waste application rates on major soil types in Alberta.
S46 Reclamation of natural angle of repose slopes.
S47 Soils associated with forested lands in white and green zones with summer/winter.
S48 Storage of topsoil in pits or above ground sites.
S49 Evaluate methods of reducing high soil pH.
S50 Reclamation on sites which lack or are deficient in topsoil; alternate organic sources i.e. manure, straw, mulch, etc.; building soil .
S51 Determine acceptable levels of organics/metals in soil.
S52 Determine mixture of muskeg, overburden and oil sand tailings sand for vegetation production for wildlife habitat and forestry.
S53 Methods (not necessarily analytical ([e.g. computer]) for determining site-specific clean -up criteria for soils.
S54 Methods for determining site-specific clean-up criteria for groundwater.
S55 Follow-up assessments of soil quality.
S56 Topsoil salvage under frozen conditions.
S57 Effect of refined hydrocarbon contamination on subsoil.
S58 Microsite enhancement to increase seedling survival and growth rate.
S59 Affects of sump fluids on soil quality and/or productivity.
S60 Sand/gravel excavation effects on stability of river breaks (particularly the subsurface water movement after excavations within or above river breaks).
S61 Topsoil salvage guidelines.
S62 Develop standards and limits for soil disturbances (e.g. where topsoil should be stripped in the province).
S63 Determine the importance of maintaining topsoil and subsoil quality and quantity.

S64 *Soil handling procedures to be used for solonetzic soils during pipeline construction.*
S65 *Impacts of compaction on soils to be reclaimed (topsoil and subsoil).*
S66 *Relationship of soil properties to slumping; at what percentage does slumping occur with different soil types.*
S67 *Impact of handling on soil chemical properties.*
S68 *Optimal sump fluid loading rates.*
S69 *Long -term effects of topsoil disturbance.*
S70 *Determining best and most cost-effective type of equipment for topsoil salvage.*
S71 *Evaluate effect of subsoil over topsoil at various thicknesses.*
S72 *Develop mine soil design parameters for reclamation objectives (to replace the undefinable equal capacity concept).*
S73 *Soil landscape modelling for reclamation planning.*
S74 *Soil reconstruction of oil sands mining waste.*
S75 *Use of Phosphogypsum as a soil amendment/fertilizer*

VEGETATION

V1 Optimum ***seed mixes*** and ***rates of application*** for grasses and legumes.
V2 Evaluate seeding ***techniques*** of herbaceous species.
V3 ***Seed bed*** preparation.
V4 ***Germination*** and ***seedling emergence*** as affected by soil properties.
V5 ***Effects of fertilization*** on interspecific plant competition.
V6 Alternate tree/shrub ***planting methods***.
V7 ***Transplanting methods*** and success.
V8 ***Effects of container*** characteristics on tree/shrub growth/survival.
V9 ***Container versus bareroot*** plantings.
V10 Methods for collecting, handling and planting ***cuttings***.
V11 ***Evaluation*** of tree/shrub and grass/legume ***growth***.
V12 Establishment of ***woody species in grasslands***.
V13 Monitoring ***long-term performance*** of ***woody species*** in reclaimed areas.
V14 Vegetation types and planting methods for ***waterbodies***.
V15 ***Selection, evaluation and multiplication*** of native grass, legume and forb species.
V16 ***Selection, evaluation and multiplication*** of native tree and shrub species.
V17 ***Management practices*** for the establishment and maintenance of ***native species***.
V18 ***Productivity evaluation*** and equivalency with pre-disturbed plant cover.
V19 Standard methods of ***evaluating pre-disturbed plant communities/forests*** for establishing reclamation objectives.
V20 Methods for ***assessing productivity*** (tree growth, regeneration, etc.)
V21 ***Guidelines*** to evaluate successful ***establishment of plant species and/or communities*** to meet end land-use.
V22 Methods to improve the quality and production of ***forage plants*** (e.g., fertilizer, species mixes)
V23 Suitability of herbaceous and woody ***plants*** as ***wildlife forage/browse*** (e.g., forage value, productivity, tolerance to grazing/ trampling).
V24 ***Rodent control methods*** to minimize woody plant damage.
V25 ***Weed growth/control*** on reclaimed sites.
V26 Spring vs summer vs fall vs winter ***seeding and planting***.
V27 Effects of ***compaction*** on root growth.
V28 ***Management practices*** under ***unseasonal climatic*** conditions.
V29 Maximum ***angle of repose*** suitable for revegetation.
V30 ***Ecological succession*** as a factor in the design of reclamation programs.

V31 ***Competition*** as a factor in the selection of species for reclamation.
V32 Crop ***rotation strategies*** for reclaimed land.
V33 Effects of vegetation types on ***movement of saline groundwater*** into the rootzone.
V34 Develop/refine ***methods for plant chemistry*** analyses.
V35 Analytical methods to ***quantify plant available nutrients*** in reclaimed soils.
V36 ***Irrigation*** for establishment of herbaceous and/or woody species.
V37 Effects and ***reclamation of trampling*** due to recreation.
V38 ***Selection of plant species*** for saline, sodic and/or saline/sodic soil conditions.
V39 Species ***tolerance to toxicities*** (salt, etc.).
V40 Evaluate the effect of aspect on plant species selection for reclamation.
V41 Forest cover establishment on reclaimed sites.
V42 Aquatic vegetation management/culture.
V43 Species tolerance to herbicides.
V44 Develop a method for stripping native sod and replacing it over a disturbed area.
V45 Develop a method for stockpiling and storing native sod to be used to revegetate a disturbed area.
V46 Seismic programs on waterbodies (using airguns, water cannons, drilling shot points).
V47 Effects of composition on plant performance.
V48 Plants to alleviate compaction.
V49 Impact of different industrial waste application rates on plants/crops.
V50 Direct seeding of trees/shrubs.
V51 Determine effects of high pH on herbaceous and woody species.
V52 Effects of livestock/wildlife grazing on reclaimed sites-sandy soils (i.e., fenced exclosures versus free range locations).
V53 Use of nurse crops during revegetation.
V54 Mechanical methods for collecting native seed and grass rhizomes.
V55 Mechanical seeding methods.
V56 Standard methods of evaluating post-disturbance plant communities on reclaimed sites.
V57 Vegetative response characteristics from sulphur and nitrogen emissions.
V58 Reclaiming to native prairie conditions.
V59 Determine stocking of reforested areas through remote sensing.
V60 The effect of inoculated legumes on disturbed sites versus non-inoculated legumes in fixing of nitrogen or adding nitrogen to the soil.
V61 Using bare legume seed and coated pre-inoculated legume seed.
V62 New methods to reduce damage by livestock to reclaimed sites i.e. chemical deterrent; odour producing substance in spray or solid form.
V63 Affects of ammonium sulphate on plant species.
V64 Evaluate effect of topsoil loss and/or topsoil/subsoil mixing on crop productivity.
V65 Visual fit of reclaimed area with surroundings.

SURFACE WATER

W1 Prediction of ***sediment loading*** in waterbodies.
W2 ***Design*** of ***ponds/lakes***.
W3 Evaluate ***long-term use*** of reclaimed ***waterbodies*** by ***fish***.
W4 Design of ***sediment ponds*** to enhance reclamation.
W5 Monitor ***ecosystem development*** within ***waterbodies*** on reclaimed land over long-term.
W6 Develop/refine ***methods*** for ***stream crossings***.
W7 Evaluate ***impacts*** of ***stream crossings***.
W8 Evaluate ***stream relocation/construction methods***.

W9 Develop/refine surface water quality ***models***.
W10 Effectiveness of in-stream ***sediment control devices***.
W11 Evaluate/refine surface water quality ***monitoring methods***.
W12 ***Effects*** of ***ponds/lakes*** on ***groundwater*** recharge and chemistry.
W13 Effects of rock drains on ***water quality***.
W14 Evaluate ***flocculents*** for sediment ponds.
W15 ***Clean-up methods*** for contaminated surface waters.
W16 ***Guide for use of water*** (e.g. irrigation, livestock) from reclaimed areas.
W17 ***Detoxification*** of ***tailings*** pond ***water***.
W18 ***Reclamation*** of ***tailings ponds***.
W19 Evaluate the effects of rock drains on benthic invertebrate movement.
W20 Stabilization of reservoir flood plains.
W21 Management of phytoplankton growth in ponds.
W22 Design specifications for a potential waterbody (waterfowl enhancement) created as a result of borrow material removal.
W23 Design to reduce annual "maintenance" at crossings.
W24 Discharge of decanted tailing water.
W25 Downstream area of influence.
W26 Evaluate different levels of disturbance, e.g. TDS>15000 vs. 5000
W27 Impact of well pad construction in shallow or intermittent waterbodies.
W28 Siting of tailing ponds for least long-term impact on groundwater and surface water.
W29 Technology options to render coal tailings "safe" for disposal/stockpiling (i.e. no chemical additives for cleaning/preparation.
W30 Evaluate cost-effectiveness and success of stream habitat enhancement measures/structures.
W31 Develop techniques for restoration of natural slumps and cutbanks along streams and rivers.
W32 Erosion at stream crossings related to seasonal/temporary logging roads.
W33 Water development for agricultural and domestic uses.
W34 Surface drainage methods.