ESTABLISHMENT OF NATIVE VEGETATION AT ST. JOHNS LANDFILL:

VEGETATION MAINTENANCE

[WORK TASKS D & E]

<u>WORKING DRAFT</u>

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August 1998

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*= new pages

A. Previous Testplot Work

Summary of Past Work (1992-1998)

Overview
Since the initiation of SJL final closure work in 1992, four series of vegetative testplots were established in 1992, 1994, 1995 and 1996. Specific information about each test plot is summarized in **Table 1: Native Grass Testplots 1992-1996** (revised from: M.G. Wilson, *SJL Vegetation Maintenance Program: Task Two- Native Grassland Management Plan*, 1997). To date, none of the established testplots have been replicated. Each test plot was established using different combinations of site preparation manipulations and seeding methods. While some testplots were successful in the short term, the results obtained from each plot were incomplete and therefore could not be fully analyzed.

Testplot Results- 1992-1997
Of the twelve total plots seeded, six were abandoned by the 1997 growing season. In five of the six abandoned plots, the seedings of native grasses failed, primarily due to competition from un-seeded non-native grasses in the seedbank or from a seeded covercrop. The sixth plot was abandoned due to depradation by waterfowl grazing. It should be noted that of the six grassland plots abandoned, four were on plots that had no site (or soil) preparation manipulation prior to seeding.

Several other factors contributed to the failure of test plots from 1992 through 1996:

- When the final closure soils and composts were placed, heavy road building equipment was used, resulting in soil compaction.
- The use of recycled soil (from the temporary soil cover) and imported soil containing weeds has resulted in contaminated soil seedbanks.
- The yard debris compost was poorly mixed with the cover soil.
- The seeding rate of native grasses was not sufficient for good stand establishment in the 1995-1996 plots.
- All testplots were sown with out of area seed.

Testplot Results- 1998
By the beginning of 1998 there were six remaining testplots: 4 in Subarea 1 and 2 in Subarea 5 & 5A [See Table A]. After the consultant surveyed each of the plots and consulted with Metro SJL staff, five of the plots were abandoned due to poor native grass performance, leaving only Testplot Number 3A in Subarea 1. Unfortunately, all the Subarea 1 plots were allowed to be grazed by sheep beginning in the early spring of 1998.

Factors that contributed to the failure of the six remaining test plots included:

- When the final closure soils and composts were placed, heavy road building equipment was used resulting in soil compaction.
- The use of recycled soil (from the temporary soil cover) and imported soil containing weeds has resulted in contaminated soil seedbanks.

- The yard debris compost was poorly mixed with the cover soil.
- The seeding rate of native grasses was not sufficient for good stand establishment in the 1995-1996 plots.
- The use of "cooked" soil in the Subarea 5 testplots resulted in stands of native grasses that exibited symptoms of very poor nutrition.
- All testplots were sown with out of area seed.

At this time all native grassland plots established in 1992, 1994, 1995 and 1996 have been abandoned.

What has been learned from previous testplot failure?

1. Native grass testplots cannot be successfully established in one growing season due to great amount of non-native seed (primarily ryegrass) in the soil seedbank. It would appear that it is necessary to spend a minimum of one growing season prior to seeding on site/soil preparation activities designed to reduce the affect of a contaminated seedbank.
2. The cover soils in many of the areas tested in the spring of 1998 exibited evidence of inconsistent soil/compost/sand mixing and poor infiltration. Although most of the soil testing was done on Subareas 2 & 3 only, inferences can be made about the condition of soils throughout the landfill. [see Appendix 3 for additional information].
3. Hydroseeding is a poor method of establishing native grasses and forbs.
4. Native grass seeding rates of approximately 8 lbs and 16 lbs per acre are not adequate to insure good stand establishment.
5. The native grass, Idaho fescue (*Festuca idahoensis*) and forbs supplied from producers in California and east of the Cascades perform poorly in western Oregon.
6. The use of cooked soil on the Subarea 5 testplots resulted in sterile seedbanks, but vegetation that exhibited symptoms of very poor nutrition. Extensive soil fertility testing and followup fertilization before seeding are recommended if sterile soils are used in the future.

TABLE A: SJL Native Grass Testplots 1992-1997

Location/Size	Site Prep.	Date/Method	Species	App. Rate	Status
Mesic Plots: SA-1 4 Acres total	None	9/92 - Track & Broadcast Hydroseed	covercrop + 4 grasses 7 forbs	variable (mix)	abandoned: failure
Xeric Plots: SA-1 4.5 Acres total	None	9/92 - Track & Broadcast Hydroseed	covercrop + 4 grasses 3 forbs	variable (mix)	abandoned: failure
Plot 1A: SA-1 .5 Acre	Herbicide-Tillage	9/94 No-till drill	BRca & FEid	8.5 #/Acre equal mix	abandoned: failure
Plot 1B: SA-1 .6 Acre	Herbicide-No Tillage	9/94 No-till drill	BRca & FEid	8.5 #/Acre equal mix	abandoned: failure (spring '98)
Plot 2A: SA-1 .10 Acre	Solarization	9/94 No-till drill	BRca & FEid	8.5 #/Acre equal mix	abandoned: failure (spring '98)
Plot 2B: SA-1 .25 Acre	Tillage only	9/94 No-till drill	BRca & FEid	8.5 #/Acre equal mix	abandoned: failure (spring '98)
Plot 3A: SA-1 .6 Acre	Tillage only	9/94 No-till drill	BRca & FEid	16.3 #/Acre equal mix	abandoned: grazing damage (summer 98)
Plot 3B: SA-1 .55 Acre	Acid pH	9/94 No-till drill	BRca & FEid	16.3 #/Acre equal mix	abandoned: failure
Plot 4: SA-2 1.5 Acres	None	9/94 No-till drill	BRca & Feid	16.3 #/Acre equal mix	abandoned: failure
Plot A: SA-4 1 Acre	None	9/95 - Track & Broadcast	ELgl	30 #/Acre	abandoned: waterfowl depredation
Plot B: SA-5 1 Acre	Sterile Soil	9/96 - Track & Broadcast	BRca & ELgl	30 #/Acre equal mix	abandoned: failure (spring '98)
Plot C: SA-5a 6 Acres	Sterile Soil	9/96 - Track & Broadcast	BRca & ELgl	30 #/Acre equal mix	abandoned: failure (spring '98)

Species: BRca=Bromus carinatus/FEid=Festuca idahoensis/ELgl=Elymus glaucus

C. Experimental Testplots

Future Testplot Maintenance & Cost Estimates (Fall 1998 through Winter 1999)

The WBW project design team recommends that only minimal maintenance work be performed on the experimental testplots to be seeded in the fall of 1998. The use of herbicides is not recommended after seeding, due to the possibility of damage to the native species. High mowing and hoeing are proposed as maintenance activities. The timing of these maintenance practices will be determined by regularly scheduled testplot monitoring visits by the project design team.

Testplot Maintenance Cost Estimates (February 1999 through July 1999)

Task/Season	Equipment/Supplies	Hours/Cost Estimate	Staff
High mowing (winter→summer)	tractor/sidecutter	24 hrs./$800.00	Metro
Hoeing (winter→summer)	supplied by contractor	24 hrs./$800.00	contractor

Spring 1998 Soil Microbiology and Physical Properties Testing: Experimental plots and reference areas

Soils were tested for total bacterial and fungal biomass; percent colonization of roots by mycorrhizae; infiltration rate; penetrability; and percent moisture. Samples for testing were taken from: 1) the 1998 experimental plots; 2) the stand of *Bromus carinatus* in 1994 experimental plot 3A in Subarea 1; and 3) a native prairie reference site near Corvallis. Results from microbiological and physical tests of soils in the 1998-99 experimental plots and reference areas are presented in detail in Appendix 3.

Microbiological tests showed generally low mycorrhizal colonization and low bacterial biomass in landfill soils compared to the native prairie reference site.

Physical tests revealed challenging conditions for plant growth at many of the sample sites. Infiltration rates (permeability) varied widely from one sample site to the next, ranging from a rate typical of a very poorly drained natural clay soil (a hydric soil), to a rate much higher than that of an excessively drained natural soil. This variability was due to poor mixing of the surface compost material with the underlying clay soil. The clay layer showed low permeability, and would perch the water table during the growing season, creating anaerobic conditions in the rooting zone. By contrast, the surface compost layer was extremely permeable and would store very little moisture, resulting in drought in early summer. Where sand was mixed into the clay layer, permeability was often very high. The admixed sand probably carries water out of the reach of plant roots into the deeper sand layer above the geomembrane.

In summary, at many of the sample sites, conditions are difficult for plant growth. Soils are anaerobic and saturated in winter, and droughty in summer. These same conditions have undoubtedly limited development of a healthy soil microflora. The use of mycorrhizal inoculum to attempt to provide better nutrition for native grass seedlings appears to be justified. As described in previous reports, mycorrhizae are particularly important to native grasses, and can help provide water and nutrients to plants growing in a challenging physical environment.

E. Landfill Integrated Vegetation Management Plan (IVM)

Introduction

Vegetation Monitoring & Surveying (1997 & 1998)
The existing vegetation on the 3 one acre testplots was characterized in the summer of 1997 and has been monitored at regular intervals until the present time. In the spring and summer of 1998, the vegetation on the landfill was surveyed to determine if current vegetation maintenance practices are meeting management goals.

Generally speaking, populations of invasive non-native plants at SJL have increased during this one year period particularly in areas grazed by sheep and along un-mowed/un-grazed methane well pipelines and ditches throughout the landfill. In some areas of the landfill it appears that poor grazing management practices have led to overgrazing and increased bare ground; reduction of vegetative cover has resulted in opportunities for the establishment of undesirable and invasive vegetation.

The WBW project design team has two general vegetation management suggestions:

1. Review the document: Sheep Grazing Guidelines, prepared for Metro R.E.M. by M.G. Wilson in February, 1997. Formulate a grazing policy and convene a follow-up meeting with Metro SJL managers/staff and sheepherder to address grazing issues.
2. During the growing season survey all pipelines and ditches for growth of undesirable and invasive vegetation [see **Species of Concern** below]. Schedule regular vegetation maintenance work as needed.
3. Assign [an existing Metro SJL employee] or establish a SJL Vegetation Manger position and hire a qualified person. This positon should only be responsible for: grazing management; undesirable/invasive vegetation surveying and integrated vegetation management and monitoring. } can we contract this?

Vegetation Species of Concern
The following species have been found on the capped portion of the landfill or on adjacent properties and are State of Oregon listed weeds:

"T" list designated weeds-
Senecio jacobaea (tansy ragwort)

"A" list designated weeds-
none found

"B" list designated weeds-
Centaurea maculosa (spotted knapweed)
Cirsium arvense (Canada thistle)
Cirsium vulgare (bull thistle)

Conium maculatum (poison hemlock)
Cytisus scoparius (Scotch broom)
Equisetum arvense (western horsetail)
Equisetum telmateia (giant horsetail)
Hypericum perforatum (St. Johnswort) [Klamath weed]
Silybum marianum (milk thistle)

In addition, the following species have been found on the capped portion of the landfill or on adjacent properties and are listed as <u>Nuisance Plant Species or Prohibited Plant Species by Metro and the City of Portland</u>:

Buddleia davidii (butterfly bush)
Chrysanthemum leucanthemum (ox-eye daisy)
Convovulvus seppium (lady's nightcap)
Daucus carota (Queen Anne's lace)
Dipacus sylvestris (common teasel)*
Erodium circutarium (crane's bill geranium)
Phalaris arundinacea (reed canary grass)*
Poa annua (annual blue grass)
Rubus discolor (Himalayan blackberry)*
Solanum dulcamara (blue bindweed)
Taraxacum officianale (common dandelion)

Significant populations of the * species above have been found on the capped portion of the landfill or on adjacent lands. Integrated Vegetation Plans for the * species and the State of Oregon listed species are on the following pages:

<u>NOTE</u>: Some of the following IVM Plans have been adapted from: St. Johns Landfill 1997 Vegetation Maintenance Program, Task One: Integrated Vegetation Management Plan for Species of Concern (Mark G. Wilson, April 1997). Cited references are available on request.

Centaurea maculosa
(spotted knapweed)

DESCRIPTION & ACTUAL/POTENTIAL THREATS
Spotted knapweed is a highly invasive biennial or short lived perennial found on disturbed xeric and mesic soils. It has a stout taproot and is usually from 1-3 feet tall with pinkish-purple, thistle like flowers. There is evidence that many species of the *Centaurea* genus hybridize and also release chemical substances that inhibit surrounding vegetation. Spotted knapweed's range has been primarily east of the Cascades and southern Oregon, but according to the Oregon Department of Agriculture (ODA), several small infestations have been found in the past few years along the Columbia River in Portland and on Port of Portland Property near the Columbia Slough. The ODA has designated spotted knapweed as a "T" (target) species and identified it for control efforts by the department's Weed Control Program. During the summer 1998 vegetation survey of the landfill, <u>one</u> plant was found in the vicinity of the railroad crossing on the landfill entry road. The plant, just coming into bloom, was pulled and destroyed. Here this year - city cut it down

DISCUSSION OF MANAGEMENT OPTIONS
No Action: The one plant found at SJL summer 1998 does not constitute an immediate threat. However, knapweeds wind disperse great numbers of viable seed, and taking no action would have most likely result in an increased infestation.

Manual/Mechanical Control: Small populations of knapweed can be controlled by hand pulling when the ground is soft in the fall and spring. The entire plant should be pulled, bagged and destroyed.

Cultural Control: No known cultural controls exist, but minimizing bare and or soil disturbance will minimize infestation and spread.

Chemical Control: Many herbicides are approved for control of spotted knapweed. Consult the current edition of The PNW Weed Control Handbook for herbicide recommendations and application rates.

Biological Control: In areas of large infestations biological control may be effective. Twelve insect species have been released in Oregon. Contact ODA for information.

RECOMMENDATIONS
<u>Contact the ODA regarding the finding of the single plant at SJL.</u>
Monitoring: As only one plant has been found at SJL to date, surveying during the growing season should be done several times yearly, especially near the location of the found plant and along travel corridors. Found plants should be pulled and destroyed.

Cirsium arvense
(Canada thistle)

DESCRIPTION & ACTUAL/POTENTIAL THREATS
Cirsium arvense is a rhizomatous herbaceous perennial found on mesic soils in disturbed areas such as roadsides, old fields and overgrazed or abandoned pastures throughout the Portland metro area. The Oregon Department of Agriculture (ODA) classifies Canada Thistle as a "B" list noxious weed; as such it is subject to intensive control on a case by case basis. Populations of Canada thistle at SJL are especially common along methane pipes.

DISCUSSION OF MANAGEMENT OPTIONS
No Action: No control effort will result in the continued spread and establishment of thistle throughout the upland grasslands of SJL especially within the path of the prevailing winds.

Mechanical Control: Mowing/String line trimming- A single mowing/trimming of thistle at the early bud stage weakens the plant at a time when root carbohydrate reserves are at a yearly low (Hodgson 1968). Mowing should be timed to coincide with the period between the early flower bud stage and the first sign of purple bloom. As Canada thistle is a long day plant flowering has been observed only in daylengths of 14 to 18 hours (Hunter and Smith 1972); monitoring of the site to determine a mowing schedule should thus begin in early June.

Cultural Control: Although the term is no longer used, smother crops of grasses continue to be used in integrated pest management systems for Canada thistle (Hodgson 1968). Shading with appropriate native shrubs and trees will prevent seedling establishment and may prevent the spread of existing patches (Hodgson 1968). Small areas of early successional woodlands planted to grasses, would be good locations for monitoring the long term effect of this thistle control method. (McLendon 1987) speculates that some change in soil processes or characteristics occurs during plant succession and that this is what eventually may push Canada thistle out of an area. The management of all riparian areas on or adjacent to the landfill in such a way as to hasten their succession to wet, mesic and xeric woodlands may control Canada thistle over time. Soil solarization may also be used to control small patches of thistle if solarizing plastic sheeting is placed after cultivating the affected area.

Chemical Control: Canada thistle control using herbicides is difficult due to the plant's deep, well-developed root system. Most herbicides that would be used to control broad-leaved perennial do not translocate easily into the root system (Baradari et al. 1980, Marriage 1981). Effectiveness of phenoxy herbicides (2,4-D) is greatest when root carbohydrate reserves are low in late spring/early summer (Marriage 1981). Consult the current edition of The Pacific Northwest Weed Control Handbook for specific recommendations.

Biological Control: Coombs (1995) of the Oregon Department of Agriculture report that a European insect, the crown weevil (*Ceutorhynchus litura*) is establishing well in six counties in Oregon (Miller, personal communication). Although the insect has not provided total thistle control in other release areas in the western U.S., it does weaken and damage the plants by mining the stem pith (Peschken and Wilkinson 1981, Coombs 1995). Other useful thistle biocontrol agents established in Oregon include the stem gall fly (*Urophora cardui*) which is locally abundant in Benton County and the seed head weevil (*Rhinocyllus conicus*) which also attacks thistle in several counties (Coombs 1995). The native painted lady butterfly (*Vanessa cadui*) occasionally defoliates Canada thistle. During some years the damage is quite severe, but it does not control the plant.

In addition, a plant rust species (*Puccinia punctiformis*) is a possible thistle biological control agent in Oregon; especially for thistles growing in wet areas (Coombs 1993). Again, the damage inflicted does not seem to be sufficient to control thistle on its own (Ososki et al 1979, Turner et al. 1980) but preliminary results in England suggest that the rust can be used in conjunction with 2,4-D in an integrated program of thistle control (Haggar et al. 1986). In Ontario there appears to be a synergistic relationship between the rust (*Puccinia puntiformis*) and the weevil (*Ceutorhynchus litura*); 87% of rust infected thistles were mined by the weevil compared with 32% of uninfected shoots (Peschken and Beecher 1973). Similar results were not obtained in trails conducted in western Canada however (Peschken and Wilkinson 1981). No information has been found regarding the tolerance of the weevil to herbicides other than the 2,4-D study above (Haggar et al. 1986). The USDA is presently evaluating the use of the rust as a bio-control agent. Contact Eric Coombs at the Oregon State Department of Agriculture for additional information.

RECOMMENDATIONS

Cirsium arvense is a good candidate for an integrated weed management program that uses a combination of control treatments. Populations of Canada thistle growing in grasslands on the capped portion of SJL should be controlled by timely mowing (or string line trimming) of the plants in the early summer when the plants are between the flower bud and bloom stage. Low mowing in such a way as to scrape or scarify the ground should be avoided; bare ground is an ideal substrate for thistle seed. In areas where thistle is intermixed with successful herbaceous and woody plantings, soil solarization or early summer flaming with a propane torch followed by fall reseeding with noninvasive or native grasses to control regrowth should be attempted. Optional spot treatment with either wick applied or back pack applied herbicides enriched with nitrogen and phosphorus fertilizers should be applied before the plant flowers and mowing begins. In the long term encouraging the rapid succession of all areas of the landfill to a combination of riparian woodlands and upland grasslands may minimize the kinds of open canopy disturbed habitats Canada thistle prefers. The State of Oregon Department of Agriculture should be contacted in the spring of 1997 in order to determine the suitability of the site as a Canada thistle biocontrol test site.

Monitoring

All Canada thistle control efforts should be thoroughly documented and then monitored for at least three years thereafter.

Cirsium vulgare
(bull thistle)

DESCRIPTION & ACTUAL/POTENTIAL THREATS

Cirsium vulgare is an herbaceous biennial with a short fleshy taproot. First year growth is limited to a rosette of leaves; the second year, the rosette develops a 2-5 foot tall flowering stalk. Bull thistle is differentiated from Canada thistle by examining the leaves. Bull thistle leaves are prickly-hairy above and cottony below. Canada thistle leaves are smooth above and smooth or hairy beneath. It is found on mesic soils in disturbed areas such as roadsides, old fields and overgrazed or abandoned pastures throughout the Portland metro area. The Oregon Department of Agriculture (ODA) classifies bull thistle as a "B" list noxious weed; as such it is subject to intensive control on a case by case basis. Bull thistle populations have increased since sheep grazing has been used to control grasses at SJL.

DISCUSSION OF MANAGEMENT OPTIONS

No Action: No control effort will result in the continued spread and establishment of thistle throughout the upland grasslands of SJL especially within the path of the prevailing winds.

Mechanical Control: The careful hand hoeing of first year rosettes will slow the spread of the plant. Ground disturbance should be minimized. The ground around the base of mature plants should be checked for rosette seedlings. Mowing or string line trimming of mature (second year) plants will also produce some control. If the stalk is removed in July or August at the 6 inch height after flower formation (at the first sign of color) but before full bloom, the plant will not send up another flower stalk. The flower stalk should be bagged and destroyed carefully as thistle seed after-ripens.

Cultural Control: Although the term is no longer used, smother crops of grasses continue to be used in integrated pest management systems for bull thistle (Hodgson 1968). Shading with appropriate native shrubs and trees will prevent seedling establishment and may prevent the spread of existing patches (Hodgson 1968). Small areas of early successional woodlands planted to grasses, would be good locations for monitoring the long term effect of this thistle control method. (McLendon 1987) speculates that some change in soil processes or characteristics occurs during plant succession and that this is what eventually may push bull thistle out of an area. Soil solarization may also be used to control small patches of first year thistle rosettes.

Chemical Control:
Consult the current edition of The Pacific Northwest Weed Control Handbook for specific herbicide recommendations and application rates.

Biological Control: The Oregon Department of Agriculture (ODA) has released the seedhead gall fly (*Urophora stylata*) in the Willamette Valley for control of bull thistle. This seed eating insect has provided some measure of control in dense stands.

RECOMMENDATIONS

Effective sheep grazing management techniques such as timely field rotation will minimize ground disturbance, which favors the spread of bull thistle. Timely manual and mechanical means of thistle control during the growing season, should keep infestations of bull thistle at SJL in check.

Monitoring

Given the large seed production of each thistle plant and it's attractiveness to seed eating birds such as finches and goldfinches, monitoring of manual/mechanical control efforts should be carried out several times during the growing season.

Conium maculatum
(poison hemlock)

DESCRIPTION & ACTUAL/POTENTIAL THREATS
Poison hemlock is a biennial that grows 6-10 feet tall. Stems are purple spotted and ridged. Flowers are white and umbrella shaped. All parts of the plant are poisonous. It occurs on poorly drained soils throughout the Portland metro area and the population at SJL is found on lower slopes on the edge of the capped portion of the landfill and in the riparian fringe adjacent to the Columbia Slough. The current population is sizable but easily controllable.

DISCUSSION OF MANAGEMENT OPTIONS
No Action: The current population will spread to all mesic soil areas on the perimeter of the landfill if not controlled.

Manual/Mechanical Control: The existing population should be pulled when the ground is soft in spring and fall. Several years of pulling will be necessary to eradicate the existing stands.

Cultural Control: none known

Chemical Control: not appropriate

Biological Control: The leaf tying moth *Agonopterix alstromeriana* is widespread throughout Oregon. Although the moth severely defoliates the plants, stand reduction has not been documented.

RECOMMENDATIONS
Hand pull all plants during the spring and fall of each year. Initiate grazing practices that minimize ground disturbance.
Monitoring: Survey mesic soil areas of the landfill for two years after control. Focus particularly on areas where the plant has formerly grown.

Cytisus scoparius
(Scotch broom)

DESCRIPTION & ACTUAL/POTENTIAL THREATS

Cytisus scoparius is a widespread woody perennial pest plant found throughout the Pacific Northwest on disturbed xeric to mesic soils. Scotch broom actively invades overgrazed pastures, cultivated fields, grasslands, roadsides and the dikes and berms along many streams in the Portland metro area. Its spread has been encouraged by its production and sale in Oregon nurseries, old plantings in ornamental landscapes and former use along freeway right-of-ways. Its success is due to its tolerance of many soil types and conditions; its ability to fix nitrogen and grow most of the year; and its production of seeds that remain viable for many years. The State of Oregon Department of Agriculture classifies Scotch broom as a "B" list noxious weed; as such it is subject to intensive control on a case by case basis. Scotch broom at the landfill can potentially become the most serious long term pest plant unless control measures are carried out several times yearly.

DISCUSSION OF MANAGEMENT OPTIONS

No Action: Broom will spread and become established on the upland grasslands, and on berms, dikes, and along roadways at SJL, if no control action is taken.

Manual/Mechanical Control: Research by Williams (1983) suggests that Scotch broom is an early successional plant which can be replaced by later seral stages if a desirable groundlayer plant community is left undisturbed when the plant is removed. Any soil disturbance should be kept to a minimum as bare soil provides an ideal rooting substrate for Scotch broom seedlings. Manual methods of *Cytisus* control range from the use of the "Weed Wrench" tool or cutting for the removal of large plants, to hand pulling or mowing for the control of small seedlings. The Bradley Method (Fuller and Barbe 1985) is a systematic method of hand pulling. This method consists of hand weeding small areas of infestation in a specific sequence, starting with the best stands of desirable vegetation and working towards those stands with the worst pest plant infestation. Initially, outlier pest plants that occur singly or in small groups at the edge of large patches of infestation should be eliminated. The next areas to work on are those containing pest plants growing intermixed with desirable vegetation. Finally, work should focus on clearing the most dense pest plant patches. The following manual control guidelines are suggested by Miller: (Broom/Gorse Quarterly 1992)

> Cut all broom with stem diameters of greater than 1" in late summer during time of maximum drought stress; regrowth should be limited. Broom plants with stems less than 1" in diameter it should be pulled out or cut and then treated with an herbicide.

Cultural Control: The green stems of broom are able to photosynthesize during mild winter days and are also able to fix nitrogen throughout the winter (Wheeler et al. 1979). However, Broom's nitrogen fixation is limited by soil pH due to the fact that the *Rhizobium* bacterium on the plants root nodules require much less acidity than is found in many Western Oregon soils (Wheeler et al. 1987). Also, Williams (1981) found that phosphorus and sulfur availability strongly influences broom growth.

Chemical Control: Consult the current edition of The Pacific Northwest Weed Control Handbook for specific herbicide recommendations and application rates.

Biological Control: Thus far, the population of broom at SJL is small and manageable. Biological control of broom would only be feasible at SJL if the site had a very large population of plants and if all other control methods fail. Miller (1993 personal communication) states that: ..."All we have at this time [for broom biocontrol] is the seed feeding weevil *Apion fuscirostre*. It eats a lot of seeds but the effect is impossible to measure. It is useful when all else is hopeless." For an up to date analysis of current broom biocontrol efforts and possibilities see the Oregon Department of Agriculture publication: Broom/Gorse Quarterly or the subsequent publication: Weed Watchers Guide. The ODA also was a sponsor of an international broom symposium in April 1996; proceedings are not yet available.

RECOMMENDATIONS

Broom plants growing on the site should be relatively easy to eradicate using manual treatments. Adult plants can be pulled (or "Weed Wrench"ed) when they are in bloom during the months of May and June. The area around the adult plants should be checked for seedlings, which should be easy to pull by hand if the ground is moist.

Monitoring

A yearly surveying and monitoring program is necessary given broom's invasive tendencies. Surveying should focus on all upland grassland areas on the capped portion of the landfill and at the edge of the riparian forest on the perimeter during the flowering season. Monitoring should document the results of eradication efforts.

Dipacus sylvestris
(common teasel)

DESCRIPTION & ACTUAL/POTENTIAL THREATS

Dipsacus is a wide spread biennial or short lived perennial that grows on mesic to hydric soils on the edges of agricultural fields, roadsides, old fields and overgrazed pastures. In the Portland metro area it is a commonly found pest plant along dikes and berms, railroad right-of-ways, and on the edges of wetlands. The State of Oregon Department of Agriculture does <u>not</u> classify Common Teasel as a noxious weed.

DISCUSSION OF MANAGEMENT OPTIONS

No Action: If controls are not implemented teasel will continue spread and establish throughout the riparian areas along the Columbia Slough and on mesic upland areas at SJL. As teasel is suspected of also being able to water disperse, seed may be also move off the project site to adjacent areas.

Manual/Mechanical Control: <u>Mowing/Cutting</u> Repeated mowing and cutting has proven to be an effective method of controlling teasel (Werner 1979). The timing of these operations is critical. Flowering stalks should be cut at ground level once flowering has initiated. In teasel, flowering begins in a ring around the center of the flowerhead and then progresses both upward and downward (Ferguson 1965). If plants are cut at this time most plants should not reflower and will die at the end of the season. If flower stalks are cut before flowering begins, the plant will respond by sending up several flowering stalks. All cut flower stalks should be removed from the field because immature seeds can produce viable seed on the stem even after cutting. Solecki (1989) has found that seed shaken from cut stalks of teasel had a 95% germination rate in a laboratory setting seven months after cutting (teasel samples were cut at the same flowering stage as described above). After cutting some plants may reflower if the stalks were not cut low enough the first time. Areas of infestation should be checked one additional time after cutting for this reason. Mowing should <u>not</u> be done with a flail mower as the mowing action will shatter the seedheads. A sidecutter mower, attached to the PTO and 3 point of a tractor will lay down the seed stalks and minimize seed shatter. Suitable cutting tools include: "Weed Wacker" hand tool or gas powered "Weedeater" string line trimmer (fitted with blade for old stands). Small hand tools may be the most effective means of removing the cut stems from the site. As teasel seed is viable for up to two years, mowing/cutting may need to be repeated for several years.

Cultural Control: Werner (1975) found that *Dipsacus sylvestris* seed did not require cold treatment, scarification or a specific period of light or dark to germinate. But, Werner also reports (Ibid) a negative correlation between teasel seed germination and the percent cover of leaf and stem litter. Teasel germination may be hindered by heavy litter cover such as that found on prairies that have not been burned or mowed (Solecki 1989). The use of prescribed fire is a very successful method of removing large dense patches of standing dead teasel stalks; however, followup cutting or herbicide treatment is necessary (Wilson 1993). <u>Soil solarization</u> of one year old seedlings and rosettes should be attempted in areas where non selective control is appropriate.

Chemical Control: Consult the current edition of The Pacific Northwest Weed Control Handbook for specific herbicide recommendations and application rates.

Biological Control: None available.

RECOMMENDATIONS

With persistence and the use of good timing, teasel on and adjacent to the site could eventually be controlled using mowing/cutting techniques. If cutting timing is off herbicide application may be required; early spring or fall application is the preferred method. Soil solarization should be tried on small infestations. Minimizing bare ground and any soil disturbance will reduce preferred teasel habitat. Encouraging the rapid succession of all upland areas to grasslands may minimize the kinds of disturbed habitats common teasel prefers.

Monitoring

All teasel control efforts should be thoroughly documented and then surveyed and monitored for at least three years thereafter.

Equisetum arvense
(western horsetail)
and
Equisetum telmateia
: (giant horsetail)

DESCRIPTION & ACTUAL/POTENTIAL THREATS
Both species are aggressive Pacific Northwest native plants that have extensive shallow tuber forming roots. *Equisetum* stands are very competitive due to the shallowness of the extensive root system. Both species favor mesic soils with high water tables. Stands at SJL are small in size and are restricted to poorly drained soils on the cap and in ditches.

DISCUSSION OF MANAGEMENT OPTIONS
No Action: In poorly drained areas that pose no threat to the cap, no control action is recommended.

Manual/Mechanical Control:
In steep areas, where winter vegetative cover is desirable to control erosion, hand or mechanical excavation followed by correction of the drainage problem is recommended. The excavated *Equisetum* should be destroyed and weed free, replacement soil should be used for fill.

Cultural Control: Correct poor drainage [see above]

Chemical Control: Not recommended. Chemical control is difficult due to the smallness of the leaf surface and the ability of the plant to block systemic herbicide translocation.

Biological Control: none known

RECOMMENDATIONS
No action except in areas where cap damage may result.
Monitoring
Survey low spots and drainage areas of SJL during the wet times of year to determine need for control action.

Hypericum perforatum

(St. Johnswort) [Klamath weed]

DESCRIPTION & ACTUAL/POTENTIAL THREATS

Klamath weed is a 1-3 foot perennial that grows on dry soils throughout the west. Grazing is often associated with it's spread, due to the reduction and trampling of competitive grass. The plant has numerous branches covered with opposite leaves with no petiole. The small, oval leaves are covered with tiny transparent dots. Flowers are ¾" in diameter and have 5 yellow petals. The weed contains a toxic substance which affects white haired animals. Affected animals often loose weight and develop a skin irritation when exposed to sunlight. The population at SJL is sparse but distributed widely, especially on the dryer ridge slopes.

DISCUSSION OF MANAGEMENT OPTIONS

No Action: To date Klamath weed populations are fairly low and no action is justified. Future monitoring of the population is recommended however, especially if sheep grazing continues to be used for grass control.

Manual/Mechanical Control: not needed

Cultural Control: none known

Chemical Control: Many herbicides are approved for Klamath weed control. Consult the current edition of The Pacific Northwest Weed Control Handbook for specific herbicide recommendations and application rates.

Biological Control: Defoliation of the plant by the Klamath weed beetles, *Chrysolina* spp., has resulted in spectacular control since their release in the late 1940's. The two beetle species are widespread throughout Oregon, but in the last several years their populations have declined, allowing the host plants to increase in local areas. The ODA should be asked to sample the SJL population to determine if a reintroduction is warranted.

RECOMMENDATIONS

No action other than contacting ODA to determine if existing populations would support reintroduction of the biocontrol beetles. Practice good grazing management in order to avoid overgrazing (severe reduction of grass cover).

Monitoring

Yearly surveying of SJL during the growing season is recommended to determine if populations are greatly increasing.

Phalaris arundinacea
(reed canary grass)

DESCRIPTION & ACTUAL/POTENTIAL THREATS

Phalaris arundinacea is a perennial grass that reproduces from rhizomes and seed. The U.S. Fish and Wildlife Service classifies *Phalaris* as a facultative wetland plant (a plant that grows 66% of the time in wetlands and 33% of the time on uplands). *Phalaris* is found throughout the Pacific Northwest on disturbed sites such as: urban stream floodplains, irrigation canals, old pastures, and in ditches along roadsides; it also actively invades natural wetlands especially wet prairies and emergent marshes. The spread of the species is intensified along stream courses which serve as dispersal corridors; proliferation is enhanced greatly because seeds have no dormancy requirements and germinate immediately after ripening (Piper 1924). The State of Oregon Department of Agriculture does <u>not</u> classify *Phalaris* as a noxious weed. However, it is considered an invasive weed in wetlands.

The taxonomy of *Phalaris* is unclear; some authorities, including Hitchcock and Cronquist (1973), classify it as a north American native, other as an exotic. If it is native it seems unlikely that it is indigenous to the Pacific Northwest; its rampant growth here is a product of the twentieth century. *Phalaris* is now widely represented in the U.S. through its introduction for agricultural purposes (Anderson 1961). Until the 1960's *Phalaris* was promoted by several federal agencies as a forage crop and for use in erosion control (Wilkins and Hugh 1932). Some have suggested that *Phalaris* was not in the Portland metro area until it was planted along dikes for erosion control. *Phalaris arundinacea* is often confused with a closely related species *Phalaris aquatalis* (Harding Grass) which is also fairly common in the metro area. The difference between the two species is in the lengths of the sterile lemmas; *arundinacea* has 1 mm lemmas, *aquatilis* 1.5 mm lemmas (Peterson/TNC E.S.A. 1988). Harding grass also seems to favor slightly drier soil conditions.

DISCUSSION OF MANAGEMENT OPTIONS

No Action: It is unclear, at this time, if the populations of *Phalaris* on capped portions of SJL will continue to spread due to their upland position. The unchecked spread of *Phalaris* in the riparian fringe (on the perimeter of the landfill) may, however, endanger the existing native plantings and subsequent succession in the emergent wetlands and riparian areas along the Columbia Slough.

Mechanical Control: On the capped portion of SJL, the <u>digging</u> of small isolated plants can slow the spread of *Phalaris*, but total control is difficult due to the improbability of removing all rhizome pieces. <u>Removing seed heads</u> by clipping after anthesis but before seed dehiscence will slow the spread of new plants from seed. <u>Mowing</u> alone will delay anthesis but won't provide control. Mowing can be more affective when combined with herbicide wicking. *Phalaris* growing along the riparian perimeter of SJL should be mowed or string line trimmed several times during each growing season in order to slow it's rank growth and reduce seed formation. Mowing *Phalaris* will lessen its ability to compete with the established woody vegetation for water and nutrients.

Cultural Control: Controlled burning of monoculture stands of *Phalaris* in selected areas on the perimeter of SJL along the Columbia Slough should be explored. Connelly and Kauffman (1991) in a review of the role of fire in wetland and riparian areas, suggest that wetland burning can be useful for the enhancement of waterfowl forage and habitat and for the management of threatened and endangered plant species. The burning of *Phalaris* in wet prairies in early spring as well as in early fall has been tried in control attempts in the United Kingdom, the Midwest U.S. as well as in Western Oregon. The flooding of *Phalaris* has also been attempted. At the Oaks Bottom Urban Natural Area in Portland, a water control structure was constructed to raise the water level in an area of willow (*Salix* spp.) and *Phalaris*. After 9 months of inundation during the growing season (January through September), the *Phalaris* appeared dead and a stand of sedge (*Carex aperta*) has reestablished (Rogers, personal communication). Prolonged flooding is necessary for success; and if possible, *Phalaris* should be mowed before flooding to a level higher than the apical meristem of the plant (Wilson, personal experience). The control of *Phalaris* by solarization with clear plastic sheeting has recently been attempted on a project at Fern Ridge Lake (Fishman, Wilson, et al., unpublished). Using ideas proposed by Bainbridge (1990) a small un-replicated test plot was setup in the summer of 1992 to compare the efficacy of four pest plant eradication techniques: prescribed burning, tillage, tillage with herbicide, and solarization. After one year, preliminary observations verified that solarization provided more effective *Phalaris* control than the other three methods tried. By the summer of 1995, however, *Phalaris* rhizomes had reinvaded the small 300 square foot test plot from the untreated edges.. Shading has also been tried as a method of control for small isolated patches, using black plastic sheeting to prevent the plant from photosynthesizing (Alverson, personal communication).

Chemical Control: The most effective herbicide for the control of *Phalaris* is either Roundup or Rodeo (glyphosate) (Comes et al. 1981, Apfelbaum 1991, M.G. Wilson 1993). The 1997 Pacific Northwest Weed Control Handbook also recommends Roundup or Rodeo.

Biological Control: None available

RECOMMENDATIONS

There are significant infestations of *Phalaris* in three different settings on (or adjacent to) SJL:

1. *Phalaris* growing as a monoculture stand on large open floodplains of the Columbia Slough and Smith and Bybee Lakes at the perimeter of SJL.
2. *Phalaris* growing as understory to native woody trees and shrubs (e.g. Oregon Ash (*Fraxinus latifolia*) and Willow (*Salix* spp.) on the banks of the Columbia Slough.
3. *Phalaris* growing as a co-dominant intermixed with desirable upland grasses on the capped portion of the landfill (primarily in Subarea 1).

Following are prescriptions for each of these settings:

Non selective Control on floodplains using herbicide and flooding or prescribed fire:

Spring/Summer- Apply herbicide as a spray to the entire infested area before seedhead emergence. Repeat application three weeks later. Mow the standing dead *Phalaris*.

Fall-. After fall regrowth of the *Phalaris* has begun, reapply herbicide as a spray. If water impoundment is not possible, prescribe burn the herbicide killed *Phalaris* to destroy the seedbank.

Late Fall- If water impoundment is possible, adjust control structure as needed to insure that the water level is higher than the herbicide killed and mowed *Phalaris* through the winter and into the late spring.

Repeat yearly until *Phalaris* control is achieved. Plant with wetland emergent plugs and reseed with native/non-native grasses.

Selective Management in existing woodlands, emergent marshes, or wet prairies:

Late summer- Mow or string line trim areas to be treated. Repeat monthly. Maintain *Phalaris* as a low growing grass until desirable woody plantings provide total canopy coverage.

Early spring and fall- Apply optional herbicide to woodland, marsh or prairie infestations using the wicking method. Repeat as needed. Reseed/replant with desirable vegetation.

CAUTION: Herbicide should not be applied on or near desirable woodland trees, shrubs or herbaceous plants unless they are dormant.

Fall- After control (using herbicides) is achieved, plant groundlayer with wetland emergent plugs or reseed with desirable emergents or native or non invasive grasses.

Selective Control on upland grasslands:

Remove seed heads to prevent spread of plant. Repeated shallow tillage during the growing season has proven somewhat beneficial (Wilson, personal experience). Monthly discing during two successive growing seasons has proven necessary to kill *Phalaris* rhizomes or seedbank. At the end of the first growing season, seed a non-invasive grass to control erosion during the winter. The soil solarization or the shading with black plastic of small isolated patches of *Phalaris* during the growing season will also provide some control. After control is achieved, dense seedings of native/non-native grasses should be made.

Monitoring and Maintenance

After *Phalaris* control has been implemented, surveying and monitoring of the site should be conducted monthly during the following three growing seasons in the years thereafter. Monitor to determine the level of sustained maintenance effort needed to control the spread of the plant.

Rubus discolor
(Himalayan blackberry)

ACTUAL/POTENTIAL THREATS
Rubus discolor (procerus) is a widespread woody perennial pest plant found throughout the Pacific Northwest on disturbed mesic soils. This introduced blackberry actively invades overgrazed pastures, hedgerows, woodland edges and the dikes and berms along seasonal waterways throughout the Portland metro area. It's success is due to it's tolerance of many soil types and conditions, and it's ability to propagate readily from seed, tip runners and underground rhizomes. The fruits of this species are very attractive to several species of wildlife and birds and localized infestations are often associated with perching trees or shrubs. The State of Oregon Department of Agriculture classifies Himalayan blackberry as a noxious weed; however it is not considered a priority "target" weed for the focus of state control efforts.

DISCUSSION OF MANAGEMENT OPTIONS
No Action: Continued spread and establishment on upland areas of SJL. particularly on the edges of mesic riparian woodland areas.

Mechanical and Manual Control: Mechanical removal with tractor mounted flail mower, brush cutters, power saws, machetes, and burning may be the most effective method of removing mature canes; but followup treatments are necessary as the root crown will simply resprout and produce more canes. Harris (1992), Miller (personal communication) and Wilson (personal experience) report success with repeated mowings with a flail mower (2-3 times per year) or weedeater trimmer affixed with a cutting blade or string line. If only a single mowing can be done, the best time is when the plants are in flower as the plant is its weakest. If mowing is done before seed set the piles of debris may be left for enhancement of wildlife habitat or burned; debris can also be chipped and used for mulch for revegetation plantings. Care should be taken to prevent vegetative reproduction of cuttings, however, which root readily. Harris (1992) also reports success with repeated mowing followed by hand grubbing of the root crowns with a claw mattox. Hand grubbing of seedlings should be done after a rain when the soil is loose. Hand hoeing is effective in areas where desirable vegetation prevents mowing. The goal of hoeing is to cut off the resprouts or seedlings at ground level without going too deeply into the soil. Hoeing several times during the growing season will gradually weaken the plant but removal of mature canes alone will not control blackberry. If repeated tillage is used a means of control, repeating for 2-3 growing seasons is necessary (Wilson personal experience).

Cultural Control: Blackberries growing in full sun produce good seed crops nearly every year. Amor (1974) reports that birds disperse the seed and that the passage of seed through their digestive tracts improves germination. Trees and large shrubs at edges of sunny openings, are often infested with blackberries due to the spread of seed by perching birds. Blackberry is somewhat intolerant of shading by overhead trees with a dense canopy, particularly evergreens (Wilson, personal experience). In Australia, Amor (1974) found that blackberry seedlings receiving less than 44% of full sunlight did not survive. The susceptibility of seedlings to shading suggests that few seedlings will survive in dense grasslands or conifer forests; seedling establishment is more common in open habitats such as land neglected after cultivation or along eroded stream banks.

Chemical Control: Treatment with herbicides following burning or mechanical removal of the canes should be conducted cautiously for several reasons: 1) the herbicide may be translocated to unforeseen locations by running water and 2) some herbicides promote vegetative regrowth from lateral roots. When applying herbicides a dye should be used in the chemical mix in order to identify treated plants. Consult the current edition of the Pacific Northwest Weed Control Manual for specific herbicide recommendations and application rates.

Biological Control: None available. To date the ODA will not support introductions of bio-control agents due to their potential threat to commercially important *Rubus* species.

RECOMMENDATIONS

Most probably the combination of mechanical and chemical treatments will be necessary to control blackberry on the SJL site. In the spring of the growing season flail mow or use blade trimmer or other hand tools to remove top growth; repeat as required. Before berry set, paint freshly cut stems with herbicide. On highly disturbed flat ground shallow tillage with a disc for 2-3 growing seasons followed by the dense seeding of a nonpersistant cereal will provide control to small patches of blackberry (Wilson personal experience).

Monitoring

All Himalayan blackberry control efforts should be thoroughly documented and then monitored for at least three years thereafter. Project sites should be monitored twice yearly for reinfestation.

Senecio jacobaea
(tansy ragwort)

DESCRIPTION & ACTUAL/POTENTIAL THREATS
Tansy ragwort is a biennial or short lived perennial. The plant is 1-6 feet tall with numerous yellow, daisy like, flower heads in terminal clusters. The plant is widespread throughout the northwest and California and is very toxic to horses and cattle. The population at SJL is small but widely distributed, particularly along travel corridors and roads.

DISCUSSION OF MANAGEMENT OPTIONS
No Action: No action, other than monitoring the existing population, is recommended at this time.

Manual/Mechanical Control: If future monitoring indicates that the population of tansy is increasing, hand pulling during the late spring when the soil is still moist and the plant is just beginning to flower can be used to prevent spread of the plant. A followup removal of the flower heads of missed plants will prevent seeding.

Cultural Control: Promote growth and retention of grass cover to encourage competition. Continuous grazing using sheep, which are not affected by the plant toxin, will keep tansy vegetative and prevent it from going to seed. Practice sound grazing management practices to insure good field rotation.

Chemical Control: Not recommended at this time.

Biological Control: Three insects have been released by ODA as tansy biocontrol agents. The ragwort flea beetle, *Longitarsus jacobaeae*; the seed head fly, *Pegohylemyia seniciella*; and the cinnabar moth, *Tyria jacobaeae*. The combination of flea beetle and cinnabar moth have nearly eliminated flowering ragwort in many areas and ODA makes collections of the insects on an as needed basis. Contact ODA for further information regarding required minimum population densities for tansy for biocontrol success.

RECOMMENDATIONS
No control action is recommended at this time. Contact ODA for biocontrol information.
Monitoring
The landfill should be surveyed several times during the growing season to determine if the existing population increases.

Silybum marianum
(milk thistle)

ACTUAL/POTENTIAL THREATS

Milk thistle is a biennial or winter annual that prefers moist soil conditions and can reach 6 feet in height. The plant has ridged stems and the leaves have spiny margins with distinctive white marbling on the leaf veins. The flowers are red-purple. Milk thistle is infrequently found in the Portland metro area and only one plant was found at SJL during the summer 1998 vegetation inventory. Because of its invasive tendencies, it is a plant to monitor.

DISCUSSION OF MANAGEMENT OPTIONS

No Action: No action, other than flower removal [see below] is recommended at this time.

Manual/Mechanical Control: The one existing plant at SJL was found in a ditch midway along the south side of the east-west road that bisects subareas 2 and 3. When the plant shows sign of bloom, the flowering stalk should be removed as close to the ground as possible. Check again a few weeks later to be sure that the plant has not sent up another flowering stalk.

Cultural Control: none known

Chemical Control: Consult the current edition of the Pacific Northwest Weed Control Manual for herbicide recommendations and application rates.

Biological Control: A seed head weevil, *Rhinocyllus conicus* was introduced by the ODA in the late 1970's but its ability to control the plant is questionable.

RECOMMENDATIONS

Remove flower stalk from the one plant found [see manual control above].

Monitoring

Survey SJL several times during the growing season to identify additional plants.

F. APPENDICES

APPENDIX 2

SUMMER 1998 VEGETATION SURVEY

In July 1998 Laura Brophy and Loverna Wilson visited the landfill to obtain information on the presence and location of any noxious weeds and to describe the existing plant communities on the various subareas and the three new experimental plot locations. Most of the landfill has a dense cover of mixed grasses, especially perennial ryegrass, plus a variety of scattered forbs. There are a few smaller areas with somewhat different species composition, usually reflecting recent disturbance or more hydric conditions than the majority of the site. After examining the study area for two seasons, it is apparent that the impermeable substrate created by the landfill sealing cap, plus the shallow soil depths (8 to 18 inches), amplifies the effect of rainfall, slope, and aspect on the plant communities on site.

Figure 1 is a 1998 aerial photograph of the landfill. The following key defines the notations, and how they relate to the discussion in this report.

I. AERIAL PHOTO MAP KEY

The compass directions given for the map and in the text are not based on true north; instead, the North slough at the top of the photo is "north" and Columbia Slough at the bottom is "south".

Road Names

We named each road to simplify locations of our observation areas:

- Perimeter Rd - circles the edges of the study area:
- E-W Rd - is the East-West road crossing the site;
- E Rd - is the north-south road on the east side of the site;
- PLC Rd - is the north-south road along the powerline corridor on the west side of the site.

Experimental Test Plots

- XP2 - is the experimental plot in subarea 2;
- XP3N - is the northern experimental plot in subarea 3;
- XP3S - is the southern experimental plot in subarea 3.

Noxious Weeds

Patches of noxious weeds are noted by two-letter codes:

cy = Cytisus scoparius (Scot's broom)
sj = Senecio jacobaea (tansy ragwort)
sm = Silybum marianum (blessed milk thistle)

Circled Numbers

Circled numbers are the designations of the observational areas (OAs) we examined during the July 1998 field visit. Species composition for each OA is described in the following community descriptions.

II. PLANT COMMUNITIES

Over most of the landfill, the dominant species is perennial ryegrass (Lolium perenne). Colonial bentgrass (Agrostis tenuis) is the most frequently occurring subdominant species. Other grasses that are often present are barren brome (Bromus sterilis), rat-tail fescue (Festuca myuros), velvetgrass (Holcus lanatus), and California brome (Bromus carinatus). In addition to describing the plant communities, this field visit was also focused on identifying any noxious weeds present on the site. Therefore, any sites that looked different from the typical grasslands were also visited and described. A list of all plant species identified on the study area are provided in a list at the end of this report.

OA 1: Subarea 1, north end of PLC Road

This is a small area along PLC Road and under the powerline. It was heavily disturbed some time during the last year. Surface soil is rocky and extremely compacted, and shows evidence of ponded water in the spring. The community is a mixture of forbs, many of which grow in vernally wet areas and the rest of which are weedy pioneer species. The dominant species is:

perennial ryegrass

Water-loving species include curve-pod watercress (Rorippa curvisiliqua), low cudweed (Gnaphalium uliginosum), orchardgrass (Echinochloa crusgalli), celery-leaved buttercup (Ranunculus sceleratus), lady's-thumb (Polygonum persicaria), and annual rabbit-foot grass (Polypogon monspeliensis). The most common pioneer species are mayweed (Anthemis cotula), shepherd's-purse (Capsella bursa-pastoris), English plantain (Plantago lanceolata), pineappleweed (Matricaria matricarioides), prostrate knotweed (Polygonum aviculare), and hedge mustard (Sisymbrium officinale).

OA 2: Subarea 3, SE corner of PLC Rd and E-W Rd

This is a small wet spot where runoff from the E-W Rd ditch collects in the low area at the corner of the intersection. There is a patch of reed canarygrass (Phalaris arundinacea) in the lowest spot, with autumn willow-weed (Epilobium paniculatum), Himalayan blackberry (Rubus discolor), Canada thistle (Cirsium arvense), common horsetail (Equisetum arvense), poison-hemlock (Conium maculatum), St. John's wort (Hypericum perforatum), curly dock (Rumex crispus), hedge bindweed (Convolvulus sepium), and one black cottonwood (Populus trichocarpa) sapling also present.

Upslope along the drier edges were tall fescue (Festuca arundinacea), velvetgrass, sweet vernalgrass (Anthoxanthum odoratum), teasel (Dipsacus sylvestris), burdock (Arctium sp.), Colonial bentgrass, and sand plantain (Plantago psyllium).

OA 3: South end of powerline corridor, west side of PLC Rd

This is a flat site that evidently retains considerable water in the spring, because there is a diverse wetland community developing on a large part of the area. Some of the soils may have come from wetland sites, providing seed sources for some of the species. Species on OA3 classified as wetland plants are marked with *. Dominant species are:

perennial ryegrass
Colonial bentgrass*
sweet vernalgrass
rough-stalk bentgrass* (Poa trivialis)

Other common species are soft rush* (Juncus effusus), slender rush* (Juncus tenuis), meadow foxtail* (Alopecurus pratensis), spike bentgrass* (Agrostis exarata), thick-headed sedge* (Carex pachystachya), green-sheathed sedge* (Carex feta), one-sided sedge* (Carex unilateralis), clustered dock* (Rumex conglomeratus), oxeye daisy (Chrysanthemum leucanthemum), Canada thistle, and yellow parentucellia (Parentucellia viscosa).

OA 4: Subarea 5, south end; east side of E Rd.

The dominant species in this area are:

white clover (Trifolium repens)
perennial ryegrass

Other grasses include California brome, velvetgrass, tall fescue, rabbit-foot grass, timothy (Phleum pratense), and creeping velvetgrass (Holcus mollis). Forbs on the site include red clover (Trifolium pratense), rabbit-foot clover (Trifolium arvense), hop clover (Trifolium procumbens), cat peas (Vicia cracca), bird's-foot trefoil (Lotus corniculatus), curly dock, bitterdock (Rumex obtusifolius), bull thistle (Cirsium vulgare), yellow parentucellia, and hairy hawkbit (Leontodon nudicaulis).

Along the unmowed south edge of the site there are additional species including sheep sorrel (Rumex acetosella), prickly lettuce (Lactuca serriola), Queen Anne's lace (Daucus carota), St. John's wort, blue wildrye (Elymus glaucus), English plantain, prickly sow-thistle (Sonchus asper), mayweed, and common evening-primrose (Oenanthe strigosa).

Upslope, in a wet spot created by a water outfall, is a patch of reed canarygrass, spike bentgrass, lady's-thumb, beggars-tick (Bidens sp.), common sow-thistle (Sonchus oleraceus), and mannagrass (Glyceria sp.).

OA 5: Subarea 3, east end; across road from gas plant.

This site has been mowed this year, but there has been some regrowth. Identifiable species include perennial ryegrass, Colonial bentgrass, California brome, velvetgrass, soft brome (Bromus mollis), hairy hawkbit, bull thistle, white clover, dandelion (Taraxacum officinale), smooth hawksbeard (Crepis capillaris), and rough hawksbeard (Crepis setosa).

In the ditch along the road is soft rush, velvetgrass, curly dock, moth mullein (Verbascum blattaria), chicory (Cichorium intybus), sand plantain, evening-primrose, and rabbit-foot grass.

OA 6: Subarea 4, southeast corner; west side of E Rd.

This site was planted with blue wildrye. It has been very recently mowed. Mowing, coupled with the dense thatch, makes species identification and dominance assessment difficult during this field visit.

OA 7: Subarea 2, north side of ridge; west side of ravine.

We walked this site from OA 6, moving northward above the ravine. There is a large concave wet area in the middle of this subarea with drier convex sites at either end. At the south end, the dry community is typical of the study area, dominated by:

perennial ryegrass
Colonial bentgrass

There is scattered Canada thistle as well.

Moving toward the wetter area, there is an increase in Colonial bentgrass and Canada thistle, plus velvetgrass, tall fescue, quackgrass (Agropyron repens), and sweet vernalgrass. There is also a large patch of bull thistle. The wettest portion is dominated by:

Colonial bentgrass

The most common associated species are soft rush, Canada thistle, and scattered clumps of reed canarygrass. Teasel increases at the bottom of the slope toward the ravine. Willows line the bottom of the ravine, and include Sitka willow (Salix sitchensis), Hooker's willow (Salix hookeriana--previously called Salix piperi), Scouler's willow (Salix scouleriana), and a fourth unidentified willow.

Beyond the wet area, the dominant species is:

Colonial bentgrass

Other species are perennial ryegrass, soft brome, barren brome, rip-gut brome (Bromus rigidus), velvetgrass, tall fescue, and white clover.

At the check dam near the bottom of the ravine, the area is dominated by:

perennial ryegrass

There are three undesirable species in the vicinity: Scot's broom (one very large fruiting shrub, and several young seedlings), poison-hemlock (Conium maculatum), and tansy ragwort. Other species include Himalayan blackberry, tall fescue, Canada thistle, and one red elderberry (Sambucus racemosa).

OA 8: Subarea 4, north slope

This grass community had been recently mowed. Although few species were identifiable, composition is probably a typical mix of perennial ryegrass, Colonial bentgrass, velvetgrass, bromes, and fescues. A patch of white campion (Lychnis alba) was growing along one of the gas pipelines.

OA 9: Subarea 5

This site is dominated by:

perennial ryegrass

Colonial ryegrass is subdominant in some areas. There are the usual bromes and fescues, plus fox-tail barley (Hordeum jubatum), orchardgrass (Dactylis glomerata), sweet vernalgrass, smooth hawksbeard, hairy cat's-ear (Hypochaeris radicata), curly dock, bitterdock, clustered dock, and alfalfa (Medicago sativa). Toward the north end, there is a large area that has English plantain as one of the dominant species. The individual plants are extremely tall and robust, with flowering stems up to three feet in height.

OA 10: Subarea 3, west end

This is a flat area with lush vegetation. The dominant species are:

perennial ryegrass
Colonial bentgrass
tall fescue

Other grasses include California brome, velvetgrass, meadow foxtail, and spreading bentgrass (Agrostis stolonifera). Common forbs are hairy hawksbeard, oxeye daisy, Canada thistle, bull thistle, hairy cat's-ear, red clover, white clover, alsike clover (Trifolium hybridum), and least hop clover (Trifolium dubium). There is also one tuft of soft rush.

OA 11: Subarea 1, south slope

The dominant species on this site are:

perennial ryegrass
rat-tail fescue
barren brome

Additional grasses are California brome, soft brome, Mediterranean barley (Hordeum geniculatum), tall fescue, and quackgrass. Forbs include bull thistle, English plantain, wild radish (Raphanus sativus), hedge mustard, and dovefoot geranium (Geranium molle).

The plant community described above is the one outside the original five test plots established in 1995. Vegetation on these earlier test plots is described in the next section of this report.

OA 12: Subarea 1, north slope

The plant community on this site is similar in composition to OA 11 on the south side of the ridge, except the vegetation is greener and more lush on the north side of the ridge, and there are additional species present including blue wildrye, mouse barley (Hordeum murinum), reed canarygrass, creeping velvetgrass, cut-leaf geranium (Geranium dissectum), Canada thistle, and yarrow (Achillea millefolium). There is also much more meadow foxtail on this site, and is some spots it is dominant.

III. CURRENT VEGETATION, 1995 TEST PLOTS IN SUBAREA 1

1995 Plot 1-A

Dominant species: perennial ryegrass.
Other grasses include Colonial bentgrass, rat-tail fescue, barren brome, rip-gut brome, velvetgrass, and meadow foxtail. There are some patches of water foxtail (Alopecuris geniculatus) in vernally wet spots. Scattered forbs include dovefoot geranium, field mustard (Brassica campestris), and bull thistle.

1995 Plot 1-B

Dominant species: perennial ryegrass.

Other grasses include velvetgrass, rat-tail fescue, soft brome, rip-gut brome, and California brome. Scattered forbs include bull thistle, field mustard, dovefoot geranium, and bur chervil (Anthriscus scandicina).

1995 Plot 2-B

Dominant species: perennial ryegrass.

Other grasses include California brome (dominant in some spots), rat-tail fescue, velvetgrass, Colonial bentgrass, tall fescue, soft brome, and rip-gut brome. Scattered forbs include hedge mustard and field mustard.

1995 Plot 3-A

Dominant species: perennial ryegrass, California brome.

Other species include scattered Colonial bentgrass, soft brome, dovefoot geranium, wild radish, and bull thistle.

1995 Plot 3-B

Dominant species: perennial ryegrass.

Additional grasses include California brome, ryebrome (Bromus secalinus), soft brome, barren brome, Colonial bentgrass, rat-tail fescue, velvetgrass, and meadow foxtail. Forbs include bull thistle, wild radish, dovefoot geranium, field mustard, hedge mustard, shepherd's-purse, sheep sorrel, poison-hemlock, and field garlic (Allium vineale).

IV. CURRENT VEGETATION, 1998 EXPERIMENTAL PLOTS

Subarea 2, Experimental Plot (XP2 in Fig. 1)

Dominant species: bitterdock seedlings, perennial ryegrass, bull thistle.

Other species are Colonial bentgrass, bull thistle, curly dock, cut-leaf geranium, nippleseed plantain (Plantago major), common groundsel (Senecio vulgaris), and hairy hawkbit.

Subarea 3, North Experimental Plot (XPN3)

Dominant species: willow-weed (Epilobium sp.).

Grasses include perennial ryegrass, annual fescue, water foxtail (in vernally wet spots), and rabbit-foot grass. There is less perennial ryegrass on this plot than on XP2, but many more forb species. These include curve-pod watercress, common groundsel, nippleseed plantain, marsh cudweed (Gnaphalium palustre), mayweed, prickly lettuce, hairy hawkbit, hop clover, and white clover.

Outside the southwest corner of the plot, along a gas pipeline, is a wet spot supporting spike bentgrass and slender hairgrass (Deschampsia elongata).

Subarea 3, South Experimental Plot (XPS3)

Dominant species: perennial ryegrass.

In addition to the ryegrass, there are scattered young forbs such as dovefoot geranium, mayweed, autumn willow-weed, and common groundsel.

V. PRELIMINARY VASCULAR PLANT LIST

Please see following 5 pages.

Preliminary Vascular Plant List for St. John's Landfill Study Area,

Portland, Oregon, for METRO Parks and Greenspaces
Prepared by Loverna Wilson and Laura Brophy,
from observations July 1998

CODES

F = Forbs
G = Graminoids (grasses, sedges, and rushes)
W = Woody species (shrubs and trees)

* = non-native species, introduced after European settlement
134 records: 42 native species; 92 introduced species

ΛSJL98.spp

ALPHABETIZED BY SCIENTIFIC NAME

LAYER	*SCIENTIFIC NAME*	COMMON NAME
F	*Achillea millefolium*	yarrow
F	*Allium vineale**	field garlic
F	*Anthemis cotula**	mayweed
F	*Anthriscus scandicina**	bur chervil
F	*Arctium**	burdock
F	*Bidens*	beggars-tick
F	*Brassica campestris**	field mustard
F	*Capsella bursa-pastoris**	shepherd's-purse
F	*Chenopodium album**	lambsquarter; white goosefoot
F	*Chenopodium botrys**	Jerusalem-oak
F	*Chrysanthemum leucanthemum**	ox-eye daisy
F	*Cichorium intybus**	chicory
F	*Cirsium arvense**	Canada thistle
F	*Cirsium vulgare**	bull thistle
F	*Conium maculatum**	poison-hemlock
F	*Convolvulus sepium**	hedge bindweed
F	*Crepis capillaris**	smooth hawksbeard
F	*Crepis setosa**	rough hawksbeard
F	*Daucus carota**	Queen Anne's lace
F	*Dipsacus sylvestris**	teasel
F	*Epilobium angustifolium*	fireweed

LAYER	*SCIENTIFIC NAME*	COMMON NAME
F	*Epilobium paniculatum*	autumn willow-weed
F	*Epilobium watsonii*	Watson's willow-weed
F	*Equisetum arvense*	common horsetail
F	*Erodium cicutarium**	filaree
F	*Galium parisiense**	wall bedstraw
F	*Geranium dissectum**	cut-leaf geranium
F	*Geranium molle**	dovefoot geranium
F	*Gnaphalium palustre*	marsh cudweed
F	*Gnaphalium uliginosum**	low cudweed
F	*Hypericum perforatum**	St. John's wort
F	*Hypochaeris radicata**	hairy cat's-ear
F	*Lactuca serriola**	prickly lettuce
F	*Leontodon nudicaulis**	hairy hawkbit
F	*Lichnis alba**	white campion
F	*Lotus corniculatus**	bird's-foot trefoil
F	*Lotus purshianus*	Spanish clover
F	*Madia sativa*	coast tarweed
F	*Matricaria matricarioides*	pineappleweed
F	*Medicago sativa**	alfalfa
F	*Melilotus alba**	white sweet-clover
F	*Oenothera strigosa*	common evening-primrose
F	*Parentucellia viscosa**	yellow parentucellia
F	*Phacelia nemoralis*	woodland phacelia
F	*Plantago lanceolata**	English plantain
F	*Plantago major**	nippleseed plantain
F	*Plantago psillium**	sand plantain
F	*Polygonum aviculare*	prostrate knotweed
F	*Polygonum persicaria*	lady's-thumb
F	*Ranunculus sceleratus*	celery-leaved buttercup
F	*Raphanus sativus**	wild radish
F	*Rorippa curvisiliqua*	curve-pod watercress

LAYER	*SCIENTIFIC NAME*	COMMON NAME
F	*Rumex acetosella**	sheep sorrel
F	*Rumex conglomeratus**	clustered dock
F	*Rumex crispus**	curly dock
F	*Rumex obtusifolius**	bitterdock
F	*Senecio jacobaea**	tansy ragwort
F	*Senecio vulgaris**	common groundsel
F	*Silybum marianum**	blessed thistle; milk thistle
F	*Sisymbrium officinale**	hedge mustard
F	*Solidago canadensis*	Canada goldenrod
F	*Sonchus asper**	prickly sow-thistle
F	*Sonchus oleraceus**	common sow-thistle
F	*Tanacetum vulgare**	common tansy
F	*Taraxacum officinale**	dandelion
F	*Trifolium arvense**	rabbit-foot clover
F	*Trifolium dubium**	least hop clover
F	*Trifolium fragiferum**	strawberry clover
F	*Trifolium hybridum**	alsike clover
F	*Trifolium pratense**	red clover
F	*Trifolium procumbens**	hop clover
F	*Trifolium repens**	white clover
F	*Urtica dioica**	stinging nettle
F	*Verbascum blattaria**	moth mullein
F	*Verbascum thapsus**	flannel mullein
F	*Veronica arvensis**	common speedwell
F	*Vicia cracca**	cat peas
F	*Vicia hirsuta**	hairy vetch; tiny vetch
F	*Vicia sativa**	common vetch
G	*Agropyron repens**	quackgrass
G	*Agrostis exarata*	spike bentgrass
G	*Agrostis scabra*	winter bentgrass; ticklegrass

LAYER	*SCIENTIFIC NAME*	COMMON NAME
G	*Agrostis stolonifera**	spreading bentgrass
G	*Agrostis tenuis**	Colonial bentgrass
G	*Alopecurus geniculatus*	water foxtail
G	*Alopecurus pratensis**	meadow foxtail
G	*Anthoxanthum odoratum**	sweet vernalgrass
G	*Bromus carinatus*	California brome
G	*Bromus mollis**	soft brome
G	*Bromus rigidus**	rip-gut brome
G	*Bromus secalinus**	ryebrome
G	*Bromus sterilis**	barren brome
G	*Bromus tectorum**	cheat grass
G	*Carex feta*	green-sheathed sedge
G	*Carex pachystachya*	thick-headed sedge
G	*Carex unilateralis*	one-sided sedge
G	*Dactylis glomerata**	orchardgrass
G	*Deschampsia cespitosa*	tufted hairgrass
G	*Echinochloa crusgalli**	barnyard grass
G	*Elymus glaucus*	blue wildrye
G	*Festuca arundinacea**	tall fescue
G	*Festuca megalura**	fox-tail fescue
G	*Festuca myuros**	rat-tail fescue
G	*Glyceria*	mannagrass
G	*Holcus lanatus**	common velvetgrass
G	*Holcus mollis**	creeping velvetgrass
G	*Hordeum geniculatum**	Mediterranean barley
G	*Hordeum jubatum*	fox-tail barley
G	*Hordeum murinum**	mouse barley
G	*Juncus bufonius*	toad rush
G	*Juncus effusus*	soft rush
G	*Juncus tenuis*	slender rush
G	*Lolium multiflorum**	Italian ryegrass

LAYER	*SCIENTIFIC NAME*	COMMON NAME
G	*Lolium perenne**	perennial ryegrass
G	*Phalaris arundinacea*	reed canarygrass
G	*Phleum pratense**	timothy
G	*Poa annua**	annual bluegrass
G	*Poa pratensis**	Kentucky bluegrass
G	*Poa trivialis**	rough bluegrass
G	*Polypogon monspeliensis**	rabbit-foot grass
W	*Acer macrophyllum*	big-leaf maple
W	*Alnus rubra*	red alder
W	*Buddleja davidii**	butterfly-bush
W	*Cytisus scoparius**	Scot's broom
W	*Populus alba**	white poplar; silver poplar
W	*Populus trichocarpa*	black cottonwood
W	*Rubus discolor**	Himalayan blackberry
W	*Salix hookeriana*	Hooker willow
W	*Salix lasiandra*	Pacific willow
W	*Salix scouleriana*	Scouler willow
W	*Salix sessilifolia*	northwest willow
W	*Salix sitchensis*	Sitka willow
W	*Sambucus racemosa*	red elderberry
W	*Solanum dulcamara**	climbing nightshade

APPENDIX 3

Spring 1998 Soil Microbiology and Physical Properties Testing: 1998 experimental plots and reference areas

Microbiological tests -- methods

Soils in plot areas and reference areas were tested for total fungal and bacterial biomass. These values are considered general indicators of soil health. Roots of grasses in these areas were tested for percent colonization by mycorrhizae.

Table 1 describes soil and root samples used for microbiological tests. Soil samples for microbiological testing were collected from just below the mat of grass roots at the soil surface (i.e., about 2" deep). Sampling areas were based on visually apparent differences within the area of interest. For instance, in each experimental plot, there was at least one area that was noticeably wetter than the rest of the plot. These wetter areas were sampled separately from the remainder of the plot. Samples were also taken from areas adjacent to the experimental plots, to determine possible effects of herbicide treatment, from the successful 1995 *Bromus carinatus* plot (1995 plot 3A) and from a native prairie reference site near Corvallis.

Small soil samples (approx. 100 ml) were taken from 5 to 10 locations within each sampling area. These samples were bulked together, mixed thoroughly, and a subsample of about 250 ml total was delivered to Soil Foodweb, Inc. for analysis.

Root samples for analysis of mycorrhizal colonization were taken from the dominant grass species present in each soil sampling area (*Lolium perenne* on all experimental plots and adjacent areas; *Bromus carinatus* on 1995 plot 3A; *Bromus carinatus* and *Elymus glaucus* from the native prairie reference site). Roots were bulked from 5 to 10 individual plants and a subsample extracted, as for the soil samples above. For comparison, a root sample was also collected from a weedy annual fescue found in plot SA2 (*Vulpia myuros*).

Microbiological tests -- results and discussion

Results of microbiological tests on the '98 test plot areas are shown in Tables 2 and 3.

Mycorrhizal colonization. Soil tests showed that VAM (vesicular-arbuscular mycorrhizal) colonization of plant roots in experimental plots was variable and often lower than the level needed for optimum growth of native grasses (Table 2). A minimum of 40% VAM colonization is considered adequate for stimulation of native grass growth (Elaine Ingham, 1998, personal communication). Only two root samples from the landfill, one of *Lolium perenne* from an area just outside experimental plot SA2 and one from *Vulpia myuros* within plot SA2, showed VAM colonization above 40%. The stand of *Bromus carinatus* in the 1995 experimental plot 3A showed no VAM colonization. By contrast, the two native grass species sampled at the native prairie reference site showed 45-50% VAM colonization.

Native grasses are stimulated by VAM colonization to a greater degree than are the opportunistic non-native grasses that currently dominate the landfill cover community. Although non-native grasses such as *Lolium perenne* may be colonized by VAM, the native grasses are more responsive to VAM colonization. Therefore, addition of VAM inoculum may provide the competitive edge needed by native grasses to outcompete non-natives (Ted St. John, 1998, personal communication).

The need for VAM colonization may be especially high where growing conditions are harsh, such as in thin droughty soils, compacted soils, or soils that are saturated for long periods during the winter. April 1998 tests (see **Physical tests** below) showed that the landfill cover soils show several of these characteristics.

Bacterial biomass. Bacterial biomass (Table 3) was generally low in landfill samples, under 100 μg per g of soil in most cases. 100 μg bacterial biomass per g of soil is considered a minimum adequate level. By contrast, bacterial biomass in the native prairie soil was exceptionally high -- 2208 μg per g of soil, over twenty times the highest value from the landfill. This native prairie soil sample was a bulked sample, minimizing the potential for sample error. However, lack of replication leaves open some possibility that an error could have occurred during sample processing or analysis. A few more samples should be taken from the native prairie in the future to verify the high bacterial biomass.

Fungal biomass. Fungal biomass (Table 3) varied from 40 to 200 μg per g of soil, but was generally over 100 μg per g of soil, considered an adequate level. In most cases fungal biomass was higher than bacterial biomass, resulting in a ratio of fungal to bacterial biomass that was greater than 1 in most samples. Interpretation of these results was difficult. Bacterial biomass can be increased through the use of no-till agricultural practices, addition of compost, or use of cover crops (E. Ingham, personal communication, 1998). All of these practices are already in place on the landfill. Most likely, some unusual characteristic of the landfill cover soils retards the development of the soil bacterial community. This seems particularly likely since the cover soils are unnatural in many respects (see **Physical tests** below).

Physical tests -- methods

Several facts influenced the choice of soil physical test methods for the landfill. First, the landfill soil is highly artificial. Above the geomembrane, a layer of sand is the lowest element of the soil profile that influences plant growth. On top of this sand, a plant growth substrate was spread after closure, using heavy machinery. This substrate consists of varying qualities of subsoil and topsoil. The final application was a layer of compost. Specifications called for this compost to be mixed with the soil below, but mixing was often inadequate (see **results** below). The final depth of soil above the sand varies from about 2 feet to only 8 or 10 inches.

With the soil tests described in this report, we intended to discover the nature of the landfill's soil as a physical medium for plant growth. With limited time and budget, we searched for test methods that would provide rapid information about soil compaction, soil structure, and the nature of the soil profile.

One of the best indicators of soil quality for plant growth is the rate at which water percolates into the soil. This rate incorporates the effects of many factors, including soil structure, soil aggregation, soil compaction, soil texture, and the nature of the soil profile. Moderately rapid infiltration benefits plants by moving water into storage in the root zone; relatively slow infiltration can show high water-holding capacity and good potential fertility. Very slow infiltration can lead to runoff and erosion; very rapid infiltration can indicate poor water-holding capacity and low fertility.

The rate at which water percolates into the soil is called the infiltration rate; this rate can be tested with a device called a cylinder infiltrometer. A simple infiltrometer was used at the landfill, consisting of a coffee can which was kept filled with water. The water level and elapsed time were recorded at intervals, and water was added to keep the level approximately the same during the testing period.

In addition to cylinder infiltrometer readings, a Lang soil penetrometer was used to provide an estimate of soil hardness and compaction. Penetrability readings are expressed as the average of 10 to 30 test probes. In each area tested for penetrability, percent moisture was determined using a pocket moisture meter (conductivity meter), since soil moisture level is generally correlated with soil penetrability.

Physical tests -- results and discussion

Infiltration rates

Infiltration rates determined by cylinder infiltrometer are shown in Table 4. Infiltration in plot SA3-S was fairly predictable, ranging from 1 to 8 cm/hr. This infiltration rate shows that the loam and silt loam soils present on plot SA3-S are well-drained, but not excessively drained.

Infiltration rates in plot SA3-N and parts of plot SA2 varied widely due to the extreme layering and/or patchy mixing of the surface soil profile. The exact position of the base of the infiltrometer relative to the soil layers or sandy patches determined the infiltration rate. The surface soil profile often consisted of a surface layer of light-textured organic material (compost) and a heavy clay layer at a depth of a few inches. The clay layer showed low permeability; in some areas infiltration was less than 0.5 cm/hr, similar to that of poorly-drained natural clay soils. By contrast, the surface compost layer was in most cases excessively drained: infiltration into this layer was sometimes over 150 cm/hr. For comparison, 35 cm/hr is considered a high infiltration rate in a natural soil.

The depth to the low-permeability clay layer varied widely within plots SA3N and SA2. In some cases the clay layer began just 2 to 3" below the soil surface. In these cases, the clay layer was not mixed with the surface compost, and nearly all fine plant roots were found in the surface compost layer.

In some cases, the clay layer appeared to be mixed with sand. In these spots, water drained very rapidly from the infiltrometer. This patchy mixing of the surface soil layer with the lower sand layer led to highly variable soil characteristics within a small area.

The extreme layering of the soil profile in much of plot SA3N and parts of SA2 results from inadequate mixing of the compost layer with the soil layer below. The layering produces a stressful environment for plants. In winter when rainfall is heavy, the clay layer perches the water table, saturating surface soils and leading to anaerobic conditions. The presence in plot SA3-N of plant species tolerant of flooding (e.g., *Juncus effusus)* suggests soils do become anaerobic during the growing season]. In early summer, the surface compost layer dries very rapidly due to its low water-holding capacity. Plants must rely on deeper roots in the clay layer for their water supply. Where the clay layer is relatively impermeable to plant roots, plants undergo drought stress in summer as well as anaerobic stress in winter.

The soil layers observed in plots SA3-N and parts of SA2 create a challenge for plant growth that is seldom found in a natural soil. In most natural soils in the dry-summer climate of western Oregon, deeper soil layers hold water later into the summer. These deeper soil layers have been formed by natural processes, rather than having been placed by heavy machinery. As a result they are less compacted and have better structure, making them more accessible to plant roots. In addition, the landfill soils simply don't have deep water-storage capacity, due to their shallow depth and the sand layer below the soil, which would tend to drain away any excess water rather than storing it.

Natural soils also generally have a much better water-holding capacity in the surface few inches than is present in the landfill's compost layer. Where surface soils are saturated in winter and during the growing season, they generally dry slowly, extending plant growth into the summer.

Other physical soil characteristics -- results and discussion

Penetrometer readings for experimental plots and reference areas are shown in Table 5. Sample area descriptions are provided in Table 1 above.

Across all samples, penetration resistance was not related to soil moisture, probably due to the widely varying soil types tested. For example, the organic compost layer found at the surface of the bare patches on SA3N and SA3S showed low penetration resistance, regardless of moisture level. Moisture level would be expected to correlate more closely with penetrability only within a given soil type.

Penetration resistance was high in plot SA3S in general, with the exception of the organic layer at the surface of the bare patch (sample SA3S-B). Plot SA3S is the only plot with a fairly well-mixed surface soil, and a mineral layer rather than a compost layer over most of the soil surface. Over time, establishment of native vegetation and/or a healthy soil ecosystem may lead to better soil tilth and lower penetration resistance in this experimental plot.

Table 1.
St. John's Landfill 1998 experimental plots and reference sites
Sample descriptions: Soil microbiological testing, April 1998
Analysis by Soil Foodweb Incorporated, Corvallis, OR

SFI Sample ID	GPS Sample ID	Sample type*	Sample description
863	SA2-L	VAM	*Lolium perenne* in experimental plot SA2
864	SA2-F	VAM	*Vulpia myuros* in experimental plot SA2
865	SA2-UA	VAM	*Lolium perenne* just outside N edge of exptl. plot SA2
866	SA2-LA	VAM	*Lolium perenne* just outside S edge of exptl. plot SA2
862	SA3N-G	VAM	*Lolium perenne* in experimental plot SA3-N
867	SA3S-L	VAM	*Lolium perenne* in experimental plot SA3S
868	SA3S-NA	VAM	*Lolium perenne* just outside N edge of exptl. plot SA3S
869	SA3S-SA	VAM	*Lolium perenne* just outside S edge of exptl. plot SA3S
861	BRCA	VAM	*Bromus carinatus* (dominant) in 1995 Plot 3A
1489	OS-BC	VAM	*Bromus carinatus* in native prairie at Benton Co. Open Space Park
1490	OS-EG	VAM	*Elymus glaucus* in native prairie at Benton Co. Open Space Park
877	SA2-SP1	TB/TF	Seepage area in experimental plot SA2 -- sample 1
878	SA2-SP2	TB/TF	Seepage area in experimental plot SA2 -- sample 2
879	SA2-US	TB/TF	Upper slope, experimental plot SA2
882	SA2-LS1	TB/TF	Lower slope, experimental plot SA2 -- sample 1
883	SA2-LS2	TB/TF	Lower slope, experimental plot SA2 -- sample 2
880	SA2-UA	TB/TF	Area just outside N edge of experimental plot SA2
881	SA2-LA	TB/TF	Area just outside S edge of experimental plot SA2
875	SA3N-B	TB/TF	Bare ground (wet area) in experimental plot SA3-N
876	SA3N-G	TB/TF	Area of *Lolium perenne* regrowth in experimental plot SA3-N
870	SA3S-B	TB/TF	Bare ground (wet area) in experimental plot SA3-S
871	SA3S-G	TB/TF	Area of *Lolium perenne* regrowth in experimental plot SA3-S
872	SA3S-NA	TB/TF	Area just outside N edge of experimental plot SA3-S
873	SA3S-SA	TB/TF	Area just outside S edge of experimental plot SA3-S
874	BRCA	TB/TF	1995 plot 3A (*Bromus carinatus* dominant)
1491	OS-BC	TB/TF	Native prairie at Benton County Open Space Park

* VAM = root sample for analysis of percent colonization by mycorrhizae
TB/TF= soil sample for analysis of total bacterial and fungal biomass

Table 2.
St. John's Landfill 1998 experimental plots and reference sites
Percent mycorrhizal colonization of roots: April 1998
Analysis by Soil Foodweb Incorporated, Corvallis, OR

SFI Sample ID	GPS Sample ID	Species	%VAM colonization	VAM notes
863	SA2-L	LOPR	4	good feeder roots, very low VAM
864	SA2-F	VUMY	41	good VAM development
865	SA2-UA	LOPR	53	good VAM structures
866	SA2-LA	LOPR	9	poor feeder roots
862	SA3N-G	LOPR	12	limited VAM, small and short feeder roots
867	SA3S-L	LOPR	5	few secondary roots, many root hairs
868	SA3S-NA	LOPR	15	limited VAM
869	SA3S-SA	LOPR	2	low VAM
861	BRCA	BRCA	0	roots in poor condition
1489	OS-BC	BRCA	48	good VAM development
1490	OS-EG	ELGL	46	good VAM development

by glyphosate treatment:
1) not treated:

861	BRCA	BRCA	0	roots in poor condition
865	SA2-UA	LOPR	53	good VAM structures
866	SA2-LA	LOPR	9	poor feeder roots, low VAM
868	SA3S-NA	LOPR	15	limited VAM
869	SA3S-SA	LOPR	2	low VAM
1489	OS-BC	BRCA	48	good VAM development
1490	OS-EG	ELGL	46	good VAM development

2) treated:

862	SA3N-G	LOPR	12	limited VAM, small and short feeder roots
863	SA2-L	LOPR	4	good feeder roots, very low VAM
864	SA2-F	VUMY	41	good VAM development
867	SA3S-L	LOPR	5	few secondary roots, low VAM

*LOPR = *Lolium perenne*; BRCA = *Bromus carinatus*;
ELGL = *Elymus glaucus*;
VUMY = *Vulpia myuros*

Table 3.
St. John's Landfill 1998 experimental plots and reference sites
Fungal and bacterial biomass, April 1998
Analysis by Soil Foodweb, Inc., Corvallis, OR

SFI Sample ID	GPS Sample ID	Plant community*	A=fungal biomass (µg/g of soil)	B=bacterial biomass (µg/g of soil)	Ratio A:B
877	SA2-SP1	LOPR+	129	48	2.7
878	SA2-SP2	LOPR+	126	42	3.0
879	SA2-US	LOPR+	67	43	1.6
882	SA2-LS1	LOPR+	146	48	3.1
883	SA2-LS2	LOPR+	60	67	0.9
880	SA2-UA	LOPR+	84	90	0.9
881	SA2-LA	LOPR+	92	43	2.1
875	SA3N-B	none	102	50	2.0
876	SA3N-G	LOPR+	117	39	3.0
870	SA3S-B	none	190	53	3.6
871	SA3S-G	LOPR+	43	32	1.3
872	SA3S-NA	LOPR+	135	33	4.1
873	SA3S-SA	LOPR+	195	33	5.9
874	BRCA	BRCA+	39	109	0.4
1491	OS-BC	BRCA+	151	2208	0.1

by glyphosate treatment:

1) not treated:

880	SA2-UA	LOPR+	84	90	0.9
881	SA2-LA	LOPR+	92	43	2.1
872	SA3S-NA	LOPR+	135	33	4.1
873	SA3S-SA	LOPR+	195	33	5.9
874	BRCA	BRCA+	39	109	0.4
1491	OS-BC	BRCA+	151	2208	0.1

2) treated:

877	SA2-SP1	LOPR+	129	48	2.7
878	SA2-SP2	LOPR+	126	42	3.0
879	SA2-US	LOPR+	67	43	1.6
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871	SA3S-G	LOPR+	43	32	1.3

* LOPR+: plant community at time of soil sampling dominated by LOPR;
BRCA+: plant community at time of soil sampling dominated by BRCA

Table 4.
St. John's Landfill 1998 experimental plots and reference sites
Infiltration rates, April 1998

Experimental plot ID	Cylinder #	Avg. infiltrattion rate (cm/hr)	Comments
SA2	1	1.2	in clay layer in seepage area
SA2	2	7.7	just above seepage area
SA2	3	9.2	rocky area at top of plot
SA2	4	0.8	in clay layer
SA2	5	22.0	in compost layer
SA3-N	1	0.2	in clay layer; in LOPR regrowth
SA3-N	2a	60.0	in sandy patch; bare ground
SA3-N	2b	50.6	in sandy patch; bare ground
SA3-S	1	0.9	in LOPR regrowth
SA3-S	2	1.3	"
SA3-S	3	7.8	"
SA3-S	4	4.8	"
SA3-S	5	4.8	"
BRCA	1	150.0	sandy loam soil

Table 5.
St. John's Landfill 1998 experimental plots and reference sites
Lang Penetrometer readings and soil moisture, April 1998

Sample area	Average penetration resistance*	Soil moisture (%)	Comments
SA2-SP1	6.7	82	seepage area; still moist
SA2-SP2	7.0	55	drier portion of seepage area
SA2-US	8.7	65	fairly dry
SA2-LS1	6.6	80	moist lower slope
SA2-LS2	4.7	80	moist lower slope
SA2-UA	12.3	68	hard, sandy soil
SA2-LA	--	--	no readings taken*
SA3N-B	7.3	95	bare ground, still moist
SA3N-G	9.9	70	LOPR regrowth, drier than bare area
SA3S-B	6.7	55	bare ground, very dry surface
SA3S-G	15.2	78	LOPR regrowth
SA3S-NA	10.9	50	dry, hard soil
SA3S-SA	14.9	73	hard dry soil on S-facing ditch bank
BRCA	--	--	no readings taken
OS-BC	--	--	no readings taken

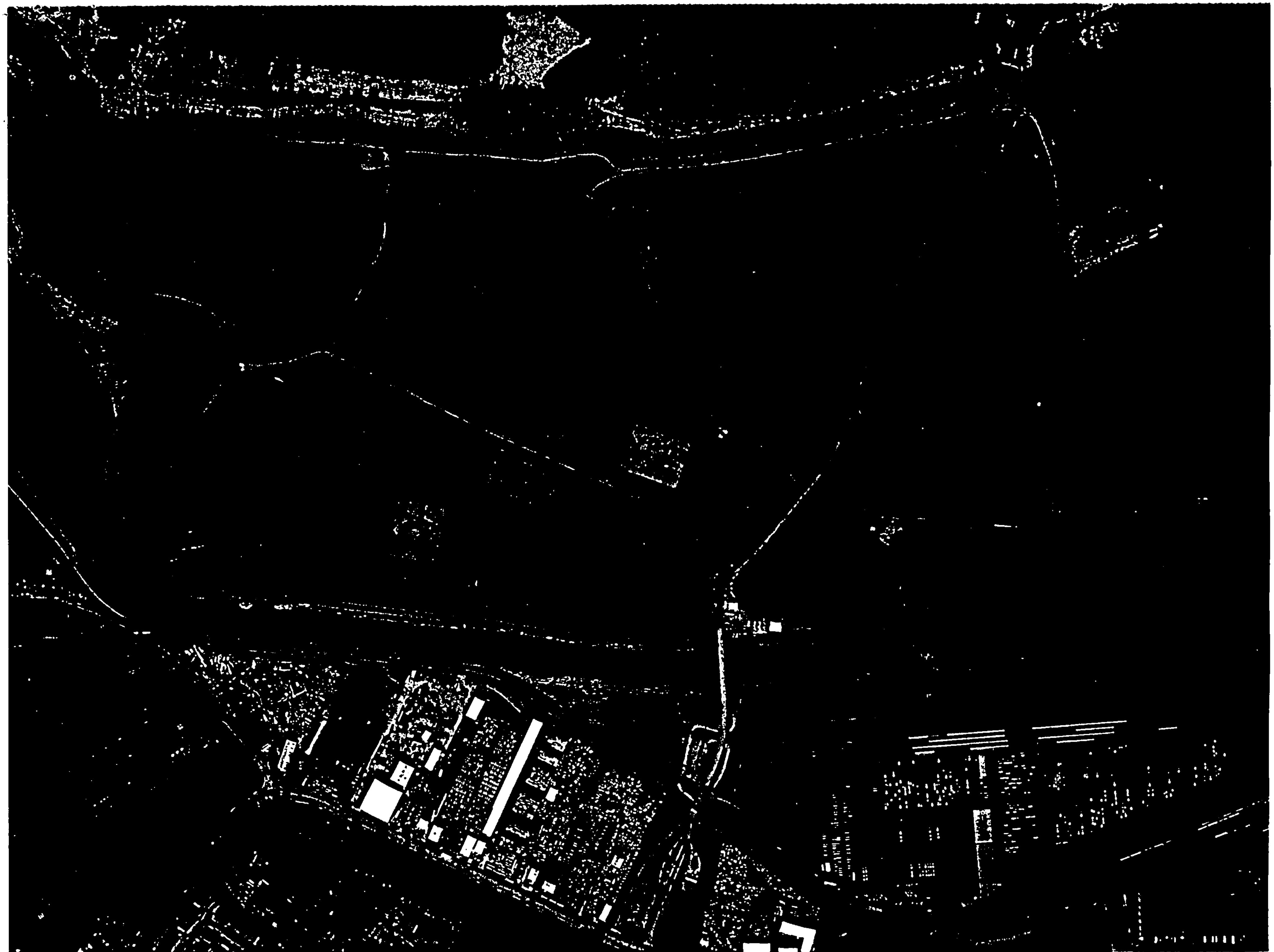

FIG. 1

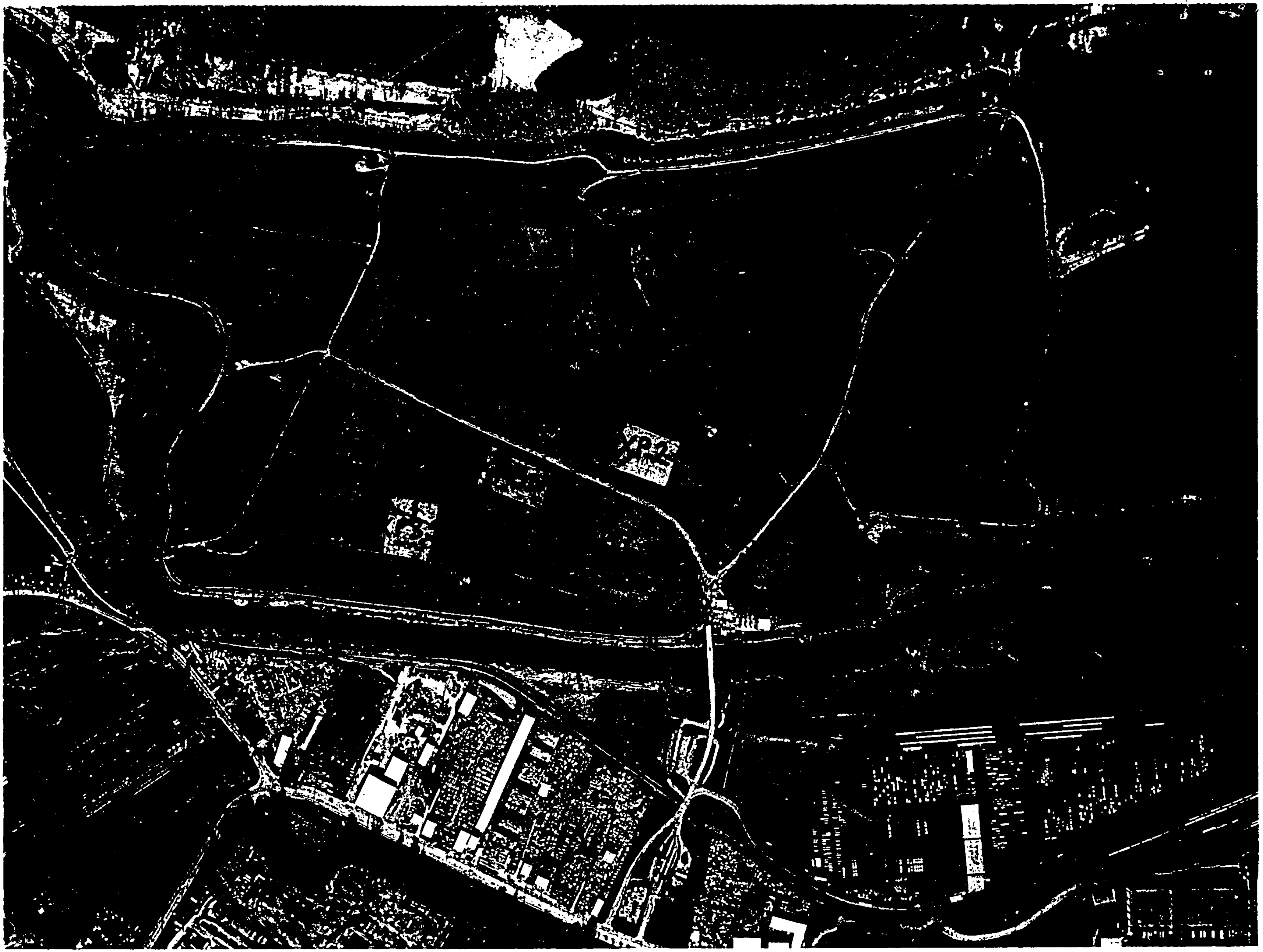

FIG. 1