ESTABLISHMENT OF NATIVE VEGETATION AT ST. JOHNS LANDFILL:

APPENDICES

to the

FINAL REPORT

Prepared for:

REGIONAL ENVIRONMENTAL MANAGEMENT DIVISION
METROPOLITAN SERVICES DISTRICT
600 NE GRAND AVENUE
PORTLAND, OR 97232

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APPENDICES

APPENDIX 1: USE OF HERBICIDES AT ST. JOHNS LANDFILL

Rationale for the Use of Glyphosate Herbicide for Site Preparation on Experimental Plots at St. Johns Landfill

Summary
Use of the low-toxicity herbicide glyphosate (commercial formulations: "Roundup", "Roundup Pro", "Rodeo") is recommended for control of existing undesired vegetation on experimental test plots at the St. Johns Landfill. Glyphosate is the recommended option because it offers the highest chance of success with the lowest environmental and health risk. One other option (repeated tillage) was considered feasible and economically acceptable, but repeated tillage is not recommended due to potential damage to soil structure and removal of surface plant residue, resulting in increased erosion potential. This document presents a rationale for the use of glyphosate at the test plots on the landfill, following the guidelines of Metro's Executive Order Number 60 (Metro, 1995).

Life Cycle and Characteristics of Pest
Perennial ryegrass (*Lolium perenne*, or LOPR) is the dominant species in the existing undesired vegetation community on the proposed experimental plot area. LOPR is a short-lived perennial grass introduced from Europe, cultivated worldwide and escaped from cultivation in many areas. Seed for LOPR is grown almost exclusively in the Willamette Valley. LOPR is a cool-season grass with a bunch-type growth habit, expanding from individual crowns with basal innovations similar to the tillers of wheat plants. LOPR readily crosses with *Lolium multiflorum* (annual or Italian ryegrass) and with the genus *Festuca* (fescue), forming natural hybrids (Heath et al, 1985).

LOPR grows vigorously in fertile soils, particularly soils with high available nitrogen. The optimum soil pH is 6 to 7. If the available nitrogen in the substrate is not continually replenished (either by fertilization, or through slow decomposition of nitrogen-rich composts or sludge), the cover of LOPR generally declines after a few years as the nitrogen level drops (Dr. Ray William, pers. comm., 8/15/97). LOPR is considered a less persistent forage than certain other perennial cool-season forage species such as tall fescue (*Festuca arundinacea*), timothy (*Phleum pratense*), and orchardgrass (*Dactylis glomerata*).

Although LOPR grows best on well-drained, fertile soils, it can persist in areas where soils are too wet for many other cool-season perennial grasses. Where adapted, it is extremely competitive with other grass and forb species, and its vigorous growth may prevent the establishment of desired legumes. The crowns of LOPR easily survive fire, and fire is often used as a management tool to control fungal diseases and weeds and to remove residue after seed harvest in commercial ryegrass fields.

Other Potential Pests

LOPR is expected to decline as available nitrogen declines on the landfill due to compost decomposition and starter fertilizer depletion. This is likely to occur during the next 2-3 years. As LOPR declines, the weed community is expected to change for the worse, moving from dominance by perennial ryegrass to dominance by perennial, noxious, and highly invasive weeds such as knapweed, starthistle, ripgut brome, cheatgrass, medusa-head, thistles, prickly lettuce, Himalayan blackberry, and Scot's broom. All of these species will be far more difficult to control than perennial ryegrass. The risk of noxious weed invasion is much higher if persistent native or native-dominant vegetation has not yet become established during the decline of LOPR. Therefore, to reduce the risk of noxious weed invasion, **rapid establishment of native vegetation is a high priority.** Undesired vegetation must be controlled thoroughly and rapidly, and the control method must maximize the early development of native species plantings while simultaneously minimizing soil erosion. Glyphosate meets these requirements.

Damage Caused by *Lolium perenne*

The competitiveness of LOPR at this time makes establishment of native grass species very difficult. LOPR covers 60 to 65% of the ground surface on much of the proposed experimental plot area. If native grasses or forbs were overseeded directly into the LOPR stand, they would have low germination rates (due to shading), and those that germinated would grow very slowly (due to competition for nutrients, water, and light).

Intended Use of the Landscape

The landscape on which herbicide use is recommended consists of the areas shown in the map entitled "Proposed Test Plot Locations" in the Phase I document (Wilson, Brophy and Wilson, 1997b). These test plots will provide information needed for long-term establishment of native vegetation at the landfill.

An experimental plot is designed to test a the effect of a small number of controllable factors on a variable of interest (in this case, growth of native species). For the 1998 experimental plot plantings, the controllable factors will include such factors as seeding method, fertility, soil amendments, and species mixtures. As on any experimental farm or on-farm trial, existing undesirable vegetation must be controlled **before** beginning the experiment, to eliminate the effect of variation in weed cover on experimental results. In other words, effective initial control of undesirable vegetation is a prerequisite to successful testing of native vegetation establishment methods.

Monitoring Program

The approach that will be used for vegetation monitoring in the test plots is described in the document, "Establishment of Native Vegetation at St. Johns Landfill" (Work Plan, Task 5) (Wilson, Brophy and Wilson, 1997a). Monitoring will be quantitative and statistically valid, and will be designed to maximize accuracy, precision and repeatability of measurements. Frequency of monitoring will be at least once per growing season; more frequent monitoring may be conducted if required due to plant community changes during the native species establishment period. Preliminary quantitative data on vegetation cover were collected in July 1997 (Wilson, Brophy and Wilson, 1997b) and will be used for comparison to post-treatment data.

Options for Control

The options for control of LOPR and other existing vegetation are shown in Table A-1, with comments on their feasibility at the landfill site.

Table A-1. Options for control of existing vegetation

Option	Feasibility
Biological controls	Not feasible due to commercial culture of LOPR. Any effective biological control would have unacceptable economic impact.
Fertility management	Not feasible. LOPR will decline naturally over time as available N declines, but action is very slow, preventing early establishment of native species and allowing invasion of noxious weeds as LOPR declines.
Water management	Not feasible. LOPR and other undesirable species are well-adapted to natural water regime.
Burning	Not feasible; LOPR survives burning
Mulching	Not feasible. Used to prevent weed growth; cannot be used to eliminate well-established stands
Solarization	Feasible, but expensive
Mowing	Not feasible; evidently unsuccessful at SJL in past years.
Tillage	Feasible and could be effective. However, repeated tillage would be needed, and this would damage soil structure in existing poorly-aggregated soils
Soil-applied herbicide	Not feasible; residual activity would damage native plantings and active herbicide could be carried offsite if erosion occurred
Foliar-applied herbicide - selective	Not feasible. No herbicide is available that could selectively remove LOPR from native grasses, even if native grasses could first be established in the LOPR stand.
Foliar-applied herbicide - nonselective, translocated	**Feasible and **RECOMMENDED**. No soil residual activity; creates "safe sites" for seedling establishment; leaves plant material on soil surface for erosion control. Low-toxicity materials are readily available. See text for specifics.

Feasible options therefore include solarization, tillage, and foliar-applied, nonselective, translocated herbicide. The recommended option is the herbicide, for the reasons outlined below:

Solarization
Solarization has been successful on Subarea 1 (Demonstration Plot 2) in the past. However, its cost (about $2600/A) makes it unacceptable for use on the entire experimental plot area. In addition, even if this method might be appropriate for the experimental plots, it could not feasibly be applied to the entire landfill.

Tillage
Tillage has been fairly successful on Subarea 1 (Demonstration Plot 3A). However, tillage has two undesirable effects that could cause problems at the landfill: damage to soil structure, and removal of surface residue.

> ***Disadvantage: Damage to soil structure.***
> Repeated tillage (probably 4 to 6 tillage operations during the growing season) would be required to sufficiently reduce competition from undesirable vegetation. This amount of tillage would be very likely to cause damage to the soil structure on the proposed experimental plot area. The silt loams and loams found on the proposed test plot area are already compacted and poorly-aggregated, and are vulnerable to further compaction and loss of soil structure with repeated tillage. Compacted, poorly-aggregated soils are particularly vulnerable to erosion, which is a major concern at the landfill.

> ***Disadvantage: Surface residue ("mulch") removal.***
> Surface residue (dead plant material, or "mulch") is the most important factor in erosion control. Tillage removes mulch by turning the material under the soil surface. Repeated tillage leaves very little mulch on the surface, leaving the soil vulnerable to erosion -- a definite risk on the sloping proposed test plot areas (and similarly on the majority of the landfill). Mulch (if not excessive) also aids in seedling establishment and growth, by providing protected "safe sites" where seedlings are protected from desiccation and wind.

Herbicide
Use of a foliar-applied, non-selective, translocated herbicide (specifically, glyphosate) is recommended for control of undesired vegetation on the test plots for the following reasons:
low toxicity; minimal chronic health effects; environmental safety; no soil residual action; effectiveness on weed species of concern; and maintenance of mulch.

> ***Advantage: Low toxicity***
> Glyphosate is assigned by the EPA to the category IV (least toxic). Its oral LD50 (a measure of acute toxicity if a material is ingested orally) is about 5000 mg/kg. For comparison, the chlorinated hydrocarbons and organophosphate insecticides that first created public awareness of pesticide toxicity in the 1970's are 100 to 1000 times more toxic than glyphosate. Since spray personnel are unlikely to ingest glyphosate, dermal (skin) absorption is a more appropriate measure of toxicity. Glyphosate apparently causes little or no skin irritation and is absorbed through human skin at a very low rate (<2%) (Wester et al, 1991). In a 21-day study of 346 human volunteers, the level of irritation caused by undiluted Roundup

(a glyphosate formulation) on the skin was less than that caused by baby shampoo or liquid dishwashing detergent (Maibach, 1986).

Advantage: Minimal chronic health effects
Acute toxicity is not the only concern for human health; carcinogenicity (potential to cause cancer) and teratogenicity (potential to cause birth defects) and must be evaluated. EPA has classified glyphosate as Group E (evidence of non-carcinogenicity for humans), indicating that studies have not shown evidence that glyphosate causes cancer. Franz et al (1997) summarized studies on rats and rabbits, which showed that the lowest level of glyphosate in the diet that caused observable birth defects ranged from 176 mg/kg/day (about a half-ounce per day for a 150-lb human) to 3500 mg/kg/day (about a half-pound per day for a 150-lb human). Many studies have shown that glyphosate is rapidly excreted from mammals, and does not leave detectable residues in their tissues (Franz et al, 1997).

Advantage: Environmental safety
An intensive study in the Pacific Northwest Coast Range showed no bioaccumulation of glyphosate, and all animals tested excreted glyphosate faster than they absorbed it from their food (Newton et al, 1984). Other studies have shown no toxicity and no repellent effect on beetles or earthworms in the field (Eysackers, 1985; Brust, 1990; Clements et al, 1990). In field tests, soil fungal and bacterial populations were lower 2 months after application of Roundup herbicide, but returned to normal after 6 months (Chakravarty et al, 1990a). Other studies showed increases in bacterial and fungal propagules in glyphosate-treated areas (Grossbard, 1985; Carlisle, 1988). A review of several studies (Olson et al, 1991) concluded that Roundup herbicide does not reduce nitrification in sandy or silt loam agricultural soils, even at 10 times normal field rates. In a review, Grossbard (1985) concluded that Roundup herbicide generally either had no effect on straw decomposition, or enhanced straw decomposition, and other studies showed that Roundup did not inhibit mycorrhizal colonization or development on trees (Chakravarty et al, 1990b; Palmer et al, 1980; Schoenholtz, 1987).

Advantage: No soil residual activity
Glyphosate is rapidly adsorbed and tightly bound to the cation exchange complex in soils, and therefore has no significant activity after it reaches the soil surface. A review of several studies on agricultural and forest soils showed that glyphosate did not leach out of soils to which it was applied to any appreciable extent, even on steep (8%) slopes with sandy soils (Franz et al, 1997).

Advantage: Effectiveness on target species
The undesired vegetation cover at St. Johns Landfill consists mainly of LOPR; some areas have fairly high cover of colonial bentgrass (*Agrostis tenuis*). According to the Pacific Northwest Weed Control Handbook (1997), LOPR is susceptible to glyphosate, as are annual and perennial grasses in general. Annual

weeds are also a concern in the test plots; glyphosate is considered effective on the predominant annual weeds observed on the 1994 test plots (*Cardamine* spp., *Poa annua*, and *Veronica persica*).

Advantage: Maintenance of mulch
Since erosion is a major concern at the landfill, a mulch layer should be maintained on the soil surface as long as possible during establishment of the native cover. Use of herbicide allows the killed weed cover to be left in place as mulch, reducing erosion and providing good conditions for seed germination and seedling development.

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APPENDIX 2: VEGETATION MONITORING & SURVEYING

Summer 1997 Vegetation Monitoring Results

Summary

In July 1997 Laura Brophy and Loverna Wilson visited the landfill to obtain soil samples and describe the existing plant communities at three locations we selected as possible locations for our test plots. We examined one location on Subarea 2 (covering proposed test plot 2E), and two locations on Subarea 3 (proposed test plots 3N and 3S). All three areas have a dense cover of mixed grasses, especially ryegrass, plus a variety of scattered forbs. The following is a description of the communities on these sites.

Subarea 2, mid-slope

This site is currently dominated by three grass species:

Perennial ryegrass (*Lolium perenne*)	60 percent cover
Colonial bentgrass (*Agrostis tenuis*)	30 percent cover
Velvetgrass (*Holcus lanatus*)	10 percent cover

There are small amounts of other species scattered across the site, such as bull thistle (*Cirsium vulgare*), prickly lettuce (*Lactuca serriola*), prickly sow-thistle (*Sonchus asper*), rough hawksbeard (*Crepis setosa*), white clover (*Trifolium repens*), red clover (*Trifolium pratense*), common vetch (*Vicia sativa*), curly dock (*Rumex crispus*), clustered dock (*Rumex conglomeratus*), soft cheat (*Bromus mollis*), and timothy (*Phleum pratense*).

Subarea 3, north side

This site is dominated by three grasses and one forb:

Perennial and Italian (*L. multiflorum*) ryegrass	65 percent cover
White clover	20 percent cover
Spike bentgrass (*Agrostis exarata*)	15 percent cover

Other scattered species include rough hawksbeard, Mayweed (*Anthemis cotula*), red clover, least hop clover (*Trifolium dubium*), hairy vetch (*Vicia hirsuta*), soft rush (*Juncus effusus*), tall fescue (*Festuca arundinacea*), and winter bentgrass (*Agrostis scabra*).

Subarea 3, south side

This location is dominated by three grass species:

Colonial bentgrass	60 percent cover
Perennial ryegrass and Italian ryegrass	40 percent cover

This site has the lowest number of associated species. They include Mayweed, red clover, curly dock, timothy, and spike bentgrass.

Summer 1998 Vegetation Surveying

Summary
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.

Map Key
Figure 1 is a drawing of the landfill. The following key defines the notations, and how they relate to the discussion in this report. 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:

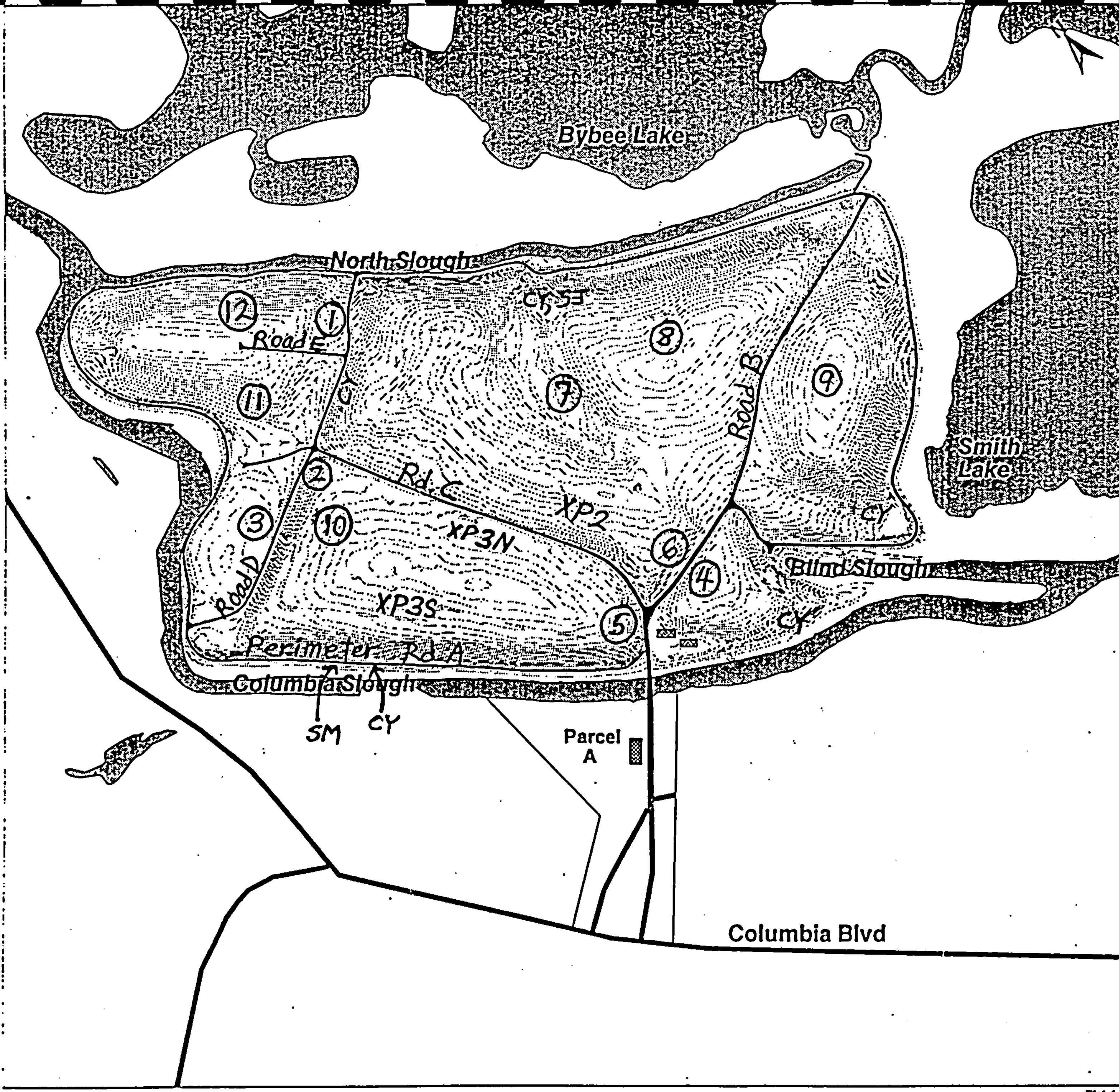
- Perimeter Road A - circles the edges of the study area:
- Road C - is the East-West road crossing the site;
- Road B - is the north-south road on the east side of the site;
- Road D - is the north-south road along the powerline corridor on the west side of the site.

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.



R L I S

REGIONAL LAND INFORMATION SYSTEM

St Johns Landfill

0 400 800 1200 Feet

1" = 800 feet

METRO

600 NE Grand Ave.
Portland, OR 97232-2736
503 797-1742 FAX 503 797-1909
Email: drc@metro.dst.or.us

Plot date: Apr 21, 1998; /disc/disc2/sw/proj/98038/dennis2.apr

Plant Communities

Summary

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 Road D

This is a small area along Road D 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 Road C and Road D

This is a small wet spot where runoff from the Road C 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 Road D

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 Road B
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 Road B
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.

Subarea 1 Testplots:

1995 Testplot 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).

Subarea 2, 1998 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 1998 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 1998 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.

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 — f\SJL98.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: SOIL TESTING

Summer 1997 Soil Testing

Soil chemistry tests -- results

Soil chemistry test results for sample areas within the proposed test plot areas are summarized on the chart labeled SJLSOILS.XLS found on the next page. Soil tests verified that soils are appropriate for experimental plot use (soil textures, macro- and micronutrient levels, salinity and pH are within normal range for agricultural soils). A sample from a native upland prairie site near Corvallis ("GS" on Chart) provides reference data.

St. John's Landfill Soil Test Results, 8/12/97

Sample Site	pH	Sol.salt mmhos	OM %	P ppm	K ppm	Ca meq	Mg meq	NO3 #/A	NH4 #/A	S ppm	B ppm	Zn ppm	Mn ppm	Cu ppm	Fe ppm	Total bases	SMP buf.pH	sand	% silt	clay	Textural class
SA2-ED	6.3	0.08	3.8	41	113	5.0	1.7	3	5	3.0	0.3	12.4	11	6.8	186	7.0	7.0	59.0	30.4	10.6	sandy loam
SA2-EM	6.7	0.16	6.0	26	224	10.7	4.1	6	14	3.6	0.3	9.6	35	4.5	193	15.4	6.6	38.4	51.8	9.8	silt loam
SA3-N	6.5	0.22	12.0	33	370	15.8	4.0	8	18	5.0	1.0	22.6	55	4.7	295	20.7	6.4	27.0	62.2	10.8	silt loam
SA3-SD	6.3	0.14	3.9	16	129	8.1	3.6	6	8	2.0	0.4	4.7	34	4.9	215	12.0	6.6	32.0	47.2	20.8	loam
SA3-SM	6.4	0.12	6.0	20	189	10.4	4.4	6	9	4.5	0.5	5.0	28	4.7	219	15.3	6.7	27.8	53.6	18.6	silt loam
Native prairie	6.3	0.20	10.2	11	276	21.3	10.4	3	24	4.0	0.6	2.4	27	9.4	221	32.4	6.3	11.4	51.6	37.0	silty clay loam

Results of seed bank testing (seeds/lb):

	Lolium sp.	Festuca myuros	Others
SA2-ED	-0-	27	none
SA2-EM	153	27	9 Poa sp., 18 Trifolium dubium
SA3-N	18	-0-	none
SA3-SD	126	9	9 Glyceria sp., 9 Polygonum aviculare
SA3-SM	27	18	81 Agrostis sp.

Chemical analysis done by Agri-Check, Umatilla, OR

Extraction methods used:

P: Weak Bray extraction

K: Acetate extraction

Micronutrients: DTPA extraction

Organic matter: Walkley-Black method

Winter 1998 Soil Testing

Soil Microbiology testing -- 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*).

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

Microbiological tests -- results

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

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
882	SA2-LS1	LOPR+	146	48	3.1
883	SA2-LS2	LOPR+	60	67	0.9
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

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

Soil Physical Properties 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 Properties tests -- results
Infiltration rates determined by cylinder infiltrometer are shown in Table 4.

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

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

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

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

Infiltration rates -- discussion

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.

APPENDIX 4: MONITORING DATA SHEET

Establishment of Native Vegetation at St. Johns Landfill
1997-1998 Testplots: Data Sheet for Vegetative Monitoring

Obs.#	Rep.	Mainplot	Subplot	Quadrat Location	% cover BRca	% cover ELgl	% cover Lopu	% cover other species

R1

ESTABLISHMENT OF NATIVE VEGETATION AT ST. JOHNS LANDFILL:

APPENDICES

to the

FINAL REPORT

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APPENDIX 3: SOIL TESTING

Summer 1997 Soil Testing

Soil chemistry tests -- results

Soil chemistry test results for sample areas within the proposed test plot areas are summarized on the chart labeled SJLSOILS.XLS found on the next page. Soil tests verified that soils are appropriate for experimental plot use (soil textures, macro- and micronutrient levels, salinity and pH are within normal range for agricultural soils). A sample from a native upland prairie site near Corvallis ("GS" on Chart) provides reference data.

St. John's Landfill Soil Test Results, 8/12/97

Sample Site	pH	Sol.salt mmhos	OM %	P ppm	K ppm	Ca meq	Mg meq	NO3 #/A	NH4 #/A	S ppm	B ppm	Zn ppm	Mn ppm	Cu ppm	Fe ppm	Total bases	SMP buf.pH	sand	% silt	clay	Textural class
SA2-ED	6.3	0.08	3.8	41	113	5.0	1.7	3	5	3.0	0.3	12.4	11	6.8	186	7.0	7.0	59.0	30.4	10.6	sandy loam
SA2-EM	6.7	0.16	6.0	26	224	10.7	4.1	6	14	3.6	0.3	9.6	35	4.5	193	15.4	6.6	38.4	51.8	9.8	silt loam
SA3-N	6.5	0.22	12.0	33	370	15.8	4.0	8	18	5.0	1.0	22.6	55	4.7	295	20.7	6.4	27.0	62.2	10.8	silt loam
SA3-SD	6.3	0.14	3.9	16	129	8.1	3.6	6	8	2.0	0.4	4.7	34	4.9	215	12.0	6.6	32.0	47.2	20.8	loam
SA3-SM	6.4	0.12	6.0	20	189	10.4	4.4	6	9	4.5	0.5	5.0	28	4.7	219	15.3	6.7	27.8	53.6	18.6	silt loam
Native prairie	6.3	0.20	10.2	11	276	21.3	10.4	3	24	4.0	0.6	2.4	27	9.4	221	32.4	6.3	11.4	51.6	37.0	silty clay loam

Results of seed bank testing (seeds/lb):

	Lolium sp.	Festuca myuros	Others
SA2-ED	-0-	27	none
SA2-EM	153	27	9 Poa sp., 18 Trifolium dubium
SA3-N	18	-0-	none
SA3-SD	126	9	9 Glyceria sp., 9 Polygonum aviculare
SA3-SM	27	18	81 Agrostis sp.

Chemical analysis done by Agri-Check, Umatilla, OR
Extraction methods used:
P: Weak Bray extraction
K: Acetate extraction
Micronutrients: DTPA extraction
Organic matter: Walkley-Black method

Landfill cap soil properties and landfill leachate irrigation potential on the St. Johns Landfill, Portland, OR

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Oregon Graduate Institute

Research Funded by Metro

Table of Contents

EXECUTIVE SUMMARIES

I. Soil properties, Subarea 1

In general, soil properties measured on Subarea 1 two years after development were in the range necessary for good plant growth. Salinity and zinc levels were much higher in the surface than in the subsoils, but not likely to cause problems for plant growth. Variations among sites were also highest for salinity and zinc, both of which are related to related to sewage sludge additions. These results suggest that the addition of sludge was very uneven, and may result in areas that are excessively high in heavy metals and salinity, at least initially. The long-term impacts of uneven distribution are less clear. In addition, while most weedy species are not especially sensitive to these factors, native species may be more sensitive, adding to problems of establishment in these soils.

II. Native species establishment, Subarea 1

The large seed bank of weedy species, combined with the high nitrogen availability in the soils amended with sewage sludge compost, resulted in excessive competition with the native species on the site.

Keeping soil fertility low should allow the natives, which are slower growing but better adapted to low nitrogen soils, to establish and persist even with some competition from the ryegrass and other weedy species on the site. Use of high nitrogen amendments such as sewage sludge compost encourages too much growth of weedy species.

III. Leachate irrigation of landfill cover

Regreen growth in low nitrogen soils is greatly enhanced by the addition of leachate constituting up to 33% of the total irrigation water volume. The enhancement is probably primarily through the increased bioavailability of nitrogen to the plant. At the highest rate of leachate addition, potentially toxic symptoms of salinity and/or excess ammonium were noted.

Although N concentrations in the drainage water were not monitored, the response of the plants suggests that most of the added N was utilized effectively by the plants at 17% and 33% leachate in the irrigation water. However, at 50% leachate in the irrigation water, essentially none of the additional N was taken up by the plant, making it susceptible to leaching from the site.

Phosphorus concentrations in the drainage water increased over time for columns receiving leachate. Increases were greater with higher amounts of leachate added. In the case of the 50% leachate treatment some samples exceeded 0.1 mg P/L in the leachate waters.

Leachate could be used for limited irrigation on the site, if mixed with fresh water. Ratios of leachate to fresh water should probably not exceed 20%, both for plant growth and for quality of drainage water. Judicious use of the leachate could supplement soil N supplies, but could also encourage weedy plant growth. Its use would be more appropriate in areas where weeds are not a problem, or where rapid growth is desired. Leaching

IV. Use of common plant species reed canary grass as indicator of leachate seeps

Reed canary grass (RCG) is relatively ubiquitous in some areas of the landfill, especially near the slough. Analysis of one cluster of the grass indicated that lush growth and green to blue-green color, associated with high N and Cl in stems of the grass, may indicate the presence of a leachate seep.

Further "prospecting" for seeps, using as indicators dark green to bluish green color of RCG plants (due to high ammonium and salinity), may provide a rapid method for determining the location of seeps, even partially submerged seeps. Results could be confirmed with tissue analysis for nitrogen and chloride. Although there may be false positives due to other nitrogen sources, most excess N on the site is expected to be derived from the leachate.

I. Soil properties, Subarea 1, 1994

Properties of soils across the landfill cover may vary depending upon the materials used, initial conditions (method and uniformity of installation), and processes occurring in the soil, including erosion, settling, and organic matter decomposition. The following study was undertaken to assess the general soil properties and their variability across the landscape in Subarea 1.

Materials and Methods

Soil samples were collected at nine sites across Subarea 1 two years after establishment (Summer 1994). Horizon depths were recorded in the field. Samples were returned to Oregon Graduate Institute and air-dried in a greenhouse.

Soils were ground in a stainless steel mill. Salinity (electrical conductivity) and pH of 1:1 water:soil extract were determined. Soils were extracted with ammonium bicarbonate - DTPA, and phosphorus, calcium, potassium, magnesium, sodium, and zinc determined on the extract.

Results and Discussion

Results are presented in Table I.1. Horizons listed include surface soil (A), subsoil (B), and a transition layer (AB) where it was apparent. Means are presented, along with coefficients of variation (CV; 100*standard deviation/mean), to indicate the degree of heterogeneity among the sample sites. This heterogeneity may be a result of non-uniform application of the sludge materials.

Salinity and pH

Soluble salts concentrations decreased with depth, indicating that the surface layer was probably still significantly more saline than deeper layers. However, none of the values found are particularly high. The CV indicates considerable variation across the sites at all depths, probably indicating changes in leaching as well as heterogeneity in mixing.

The soil pH increased slightly with depth. The pH's fell within an acceptable range for all samples, and the relatively small CV (<5%) indicates that there were few high or low pH sites.

Cations

Calcium varied little among all sites, and was within desired ranges. Sodium likewise varied relatively little and was low, as expected in these soils. Magnesium and potassium were within normal ranges. However, K was enriched in the surface compared with samples at depth, while Mg was depleted in surface soils compared with subsoils.

The effects of Mg and K often occur when manures are added, since they are high in K and relatively low in Mg. However, sewage sludges usually are also low in K (most of it leaves with the wastewater), so reasons for K enrichment in surface soils on these sites is not apparent. We do not believe that they were fertilized with K-containing materials. Alternatively, the soil used as surface material may have entered the site enriched in K. In any case, concentrations of K are high but probably not toxic in the surface soil, except for species that might be especially sensitive.

Zinc

Zinc was selected as an indicator metal for two reasons: firstly, it is relatively enriched in sewage sludges; and secondly, it was found in relatively high concentrations in the leachate waters from the leachate experiment (See Section III, Leachate Irrigation).

There was a very clear enrichment in the surface soil, probably due to sludge compost additions. In addition, the CV was high in all instances, suggesting that the application patterns were very non-uniform across the area.

Summary

Soils were typically in relatively fertile condition, but there was great evidence of substantial variations in soil quality from site to site across the landscape. This may actually provide beneficial diversity in soil properties, as long as the desired effects are observed.

The relatively high zinc concentrations in surface soils, presumably derived from sludge compost, may affect the growth of some of the desired native plant species, although certainly the weedier types appeared to be unaffected.

II. Native species establishment, Subarea 1

Several research plots were established on the Subarea 1 site. The research plots were planted with native species, while the remainder of the site was planted with Regreen, a sterile wheatgrass hybrid.

Field sample collection and analysis

On April 6, 1994, the plots were inspected. Germination and establishment of the native species was very erratic spatially. In many cases the weedy ryegrass had overgrown the native species, and seemed destined to shade and generally outcompete the slower growing natives.

At that time it appeared relatively meaningless to assess the distribution of species, since native establishment was so erratic.

Instead, soil samples were collected from two contrasting areas:

Area 2 supported a lush stand of weedy ryegrass and wild mustard, while Area 1 contained many native seedlings, and the ryegrass and mustard plants, while present, appeared to be nutrient deficient. The stunting of the weeds lowered their competitiveness, and allowed the less nutrient-demanding natives an opportunity to become established.

Area 1 soil was collected in three layers:

A: silt loam soil mixed with organic material; B: silt loam soil with no organic amendment; C: sand.

Area 2 soil was coated with a layer of organic material that appeared to be sewage sludge compost, which was designated the "O" layer. Otherwise, the profile appeared similar to that of Area 1.

The hypothesis was tested that the soils with a better ratio of native cover to exotic plant cover would be lower in nutrients, particularly nitrogen.

Soil Analysis

After air-drying and grinding to pass a 2mm sieve, the following analyses were run on the soil samples:

Soil pH: 1:2 soil:water, glass electrode

Extractable ions: ammonium bicarbonate - DTPA extract for Ca, Mg, Na, K, Zn, Mn, Cu, Fe, and P

Total C and N: combustion/gas chromatography on Carlo-Erba CNS analyzer.

Results and Discussion

Soil analysis results are reported on Table II.1.

Area 1 reflected a healthy but not excessively nutrient-rich composition. Nutrient content decreased with depth in a manner typical of natural soils. Soil pH was almost perfect for many of the native species, between 6.5 and 7.5

In contrast, Area 2 had a generally lower pH. The organic layer on the surface was obviously sewage-sludge influenced. The high nitrogen and phosphorus concentrations, along with the metals, indicated that this was nutrient-rich compost, not typical of pure yard debris materials.

As a result of this enrichment, non-native weedy species found an ideal soil substrate for rapid growth, and quickly overtopped and shaded the native species. Presumably the same competition was occurring below ground, and the weedy sites likely dried out earlier than the low nutrient, less weedy areas.

Conclusions

These results support the hypothesis that native species, at least in the early stages where exotic weedy species are present, are more likely to become established where soil nutrient concentrations are low. This especially applies to soil nitrogen availability. In the future, sites of modest fertility may provide the best long-term plant cover.

Table I.1. Soil analysis by layer for nine cores from Subarea 1, collected September 1994, two years after installation.

Horizon (layer)		Calcium	Magnesium	Potassium	Sodium	Zinc	pH	EC
		----------		mg/kg	----------			µS/m
A	Mean	241	155	306	20	56.7	6.40	199.10
	CV	18	16	27	16	55.2	3.58	47.59
AB	AB	258	243	180	20	11.1	6.68	52.85
	CV	15	5	51	25	129.9	4.13	47.23
B	B	258	281	171	28	2.0	6.72	43.60
	CV	9	15	21	14	87.7	2.59	34.60

Table II.1. Soil analysis from two sites in Subarea 1, collected Spring 1993. / 1 was covered with a scattered growth of exotic, weedy species, numerous seedlings of planted native species. Area 2 supported tall, lush green growth ryegrass and some vetch, with very few, spindly seedlings of planted natives.

					Macrocations					Metals			
Area	Layer	pH	Total C	Total N	Ca	Mg	K	Na	P	Fe	Mn	Cu	Zn
			.-------%------		.-------- meq/100g -------				mg/kg	.----------- mg/kg ----------			
1	A	6.82	3.98	0.21	0.61	2.20	0.82	0.11	28.4	338	29	13.4	20.2
	B	6.68	1.28	0.09	0.46	2.65	0.49	0.15	11.5	246	192	10.7	3.4
	C	7.16	0.39	0.02	1.13	2.47	0.54	0.14	6.9	116	20	2.5	2.2
2	O	5.70	9.92	0.50	0.53	1.36	0.83	0.10	67.1	279	61	61.0	101.0
	A	5.99	1.41	0.06	0.43	1.79	0.45	0.11	21.5	194	212	6.2	9.2
	B	6.22	2.63	0.17	0.60	2.29	0.41	0.16	32.4	156	256	41.0	55.4
	C	6.64	0.32	0.01	0.91	2.52	0.56	0.15	12.9	125	48	6.3	7.4