RHO-LD--143

DE82 005425

RHO-LD-143
Informal Report

RECEIVED BY TIG JAN 4 1982

First-Year Evaluation of Low-Level Waste Management Stabilization Techniques

MASTER

G.R. Cox

Prepared for the United States
Department of Energy
Under Contract DE-AC06-77RL01030

Rockwell International

Rockwell Hanford Operations
Energy Systems Group
Richland, WA 99352

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Rockwell International

Rockwell Hanford Operations
Energy Systems Group
Richland, WA 99352

PRELIMINARY REPORT

This report contains information of a preliminary nature. It is subject to revision or correction and therefore does not represent a final report. It was prepared primarily for internal use within Rockwell Hanford Operations. Any expressed views and opinions are those of the author and not necessarily of the Company.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

RHO-LD-143

FIRST-YEAR EVALUATION OF LOW-LEVEL WASTE
MANAGEMENT STABILIZATION TECHNIQUES

G. R. Cox

Environmental Analysis and Monitoring
Health, Safety and Environment

December 1981

Prepared for the United States
Department of Energy under
Contract DE-AC06-77RL01030

Rockwell International

Rockwell Hanford Operations
Energy Systems Group
P.O. Box 800
Richland, Washington 99352

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

peg

Title: FIRST-YEAR EVALUATION OF
LOW-LEVEL WASTE MANAGEMENT
STABILIZATION TECHNIQUES

Document
Number RHO-LD-143

Issue Approval:

G. R. Cox G. R. Cox
Author

September 22, 1981
Date

R. M. Mitchell R. M. Mitchell
Issuing Manager

9/25/81
Date

W. H. Price W. H. Price
Concurring Approval

9/22/81
Date

M. A. Christie M. A. Christie
Program Representative

9.28.81
Date

W. F. Heine W. F. Heine
Program Office

9/23/81
Date

Rockwell International

**Rockwell Hanford Operations
Energy Systems Group**

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

EXECUTIVE SUMMARY

The objective of interim stabilization was to eliminate surface contamination and isolate buried radionuclides from intrusion and transport by wind, animals, and plants. The required duration of interim stabilization applications is a minimum of 2 decades or until long-term stabilization of buried waste is initiated. The goal of this 3-year test was to optimize interim stabilization techniques. Various test combinations were applied on selected burial ground trenches and integrated into operational schedules. Upon completion of this test, the data collected will help select the appropriate stabilization technique to apply to a candidate site with its unique requirements.

The original test was designed to evaluate three biobarriers, five perennial grass species, one annual grass species, two soil depths over biobarriers, and three herbicides. Combinations of these materials were installed in the 218-W-2a and 218-E-12a Burial Grounds (216-W-2a and 218-E-12a). Observations were directed primarily toward the individual plant species and selective herbicide applications. Only a cursory evaluation of biobarrier effects was possible due principally to the unavailability of Radiation Monitoring support. Observations made thus far were based on data collected under the unusual environmental conditions encountered during this period (abnormally high rainfall and a major volcanic eruption).

Cheatgrass (*Bromus tectorum*) initially produced more plants and biomass than any other perennial species planted. However, by the second year, this trend had reversed and the perennial wheatgrasses surpassed cheatgrass in biomass production. The natural control of Russian thistle (*Salsola kali*) in the second year was indeterminate due to the effectiveness of selective herbicide applications. Nonetheless, observations of 3- to 5-year-old revegetated sites indicated that a combination of perennial species can be effective in the stabilization of soil and the natural exclusion of Russian thistle.

Cheatgrass, although ubiquitous to most of eastern Washington, has been classified a common weed and is no longer legally available for sale in the State of Washington (Washington State Department of Agriculture Order No. 1604). A new hybrid seed cross (Wintergraze) exhibiting the desirable characteristics of cheatgrass (rapid establishment and low moisture requirement) is currently available, but unlike cheatgrass, will not compete as a weed species in subsequent years because no viable seed is produced.

Of the three perennial wheatgrasses tested, crested wheatgrass (*Agropyron desertorium*) appeared to provide the best initial establishment. Thickspike wheatgrass (*Agropyron dasytachyum*), however, exhibited poor initial establishment, yet increased dramatically in plant occurrence and biomass production going into the second year. This increase may be attributed to the plant's rhizomatous characteristic (the ability to send out new plants from one central plant via underground stems) which allowed it to "fill in" between other established plants.

Early fall seeding combined with nitrogen fertilizer applied at a rate of 140 kg/ha increased all plant species stand density and biomass production.

Early and late spring applications of 2,4-D amine/Dicamba herbicides were effective in the control of Russian thistle. Data collected to date indicated that all grass species tested in combination with applications of 2,4-D amine/Dicamba resulted in plant stands adequate to stabilize a given site. When 2,4-D amine/Dicamba was applied to cheatgrass stands during the preflower stage, it reduced the number of seed set and subsequent percent germination. Treatments of 2,4-D amine/Dicamba resulted in increased biomass accumulation for all perennial species stands by reducing the occurrence and competition normally attributed to Russian thistle and other annual broadleaf plants.

Treflan, a root toxin tested alone as a biobarrier, was undetectable in subsurface soil samples analyzed in 1980. Although an examination of several soil profiles indicated that Treflan was preventing root

penetration as planned, insufficient data were available from which to draw valid conclusions. No additional sampling or visual observations have been planned for 1981.

Plastic biobarriers impeded the downward movement of moisture and limited the profile depth from which plant available moisture could be drawn. Thus, the plants grown on restricted soil profiles (due to the presence of a plastic biobarrier) produced less biomass than plants grown on unrestricted profiles. Insufficient data exist from which any conclusions may be drawn regarding the effectiveness of biobarriers in preventing the upward movement of radionuclides.

Ureabor and Krovar, soil sterilants used on roads in the burial grounds and along roads in the 200 Areas, were less than effective in preventing the growth of Russian thistle. As a result, the use of these sterilants on 218-W-2a and 218-E-12a will be replaced by applications of 2,4-D amine/Dicamba. This alternate approach should prove effective and allow treatment of the entire burial ground at one time with the same equipment and materials.

Maintenance to be performed during the second year of this test include reseeding and mulching portions of selected trenches in 218-W-2a and selective herbicide applications in 218-W-2a and 218-E-12a. Although detailed cost information associated with these maintenance actions was not included in the 1981 report, these costs will be addressed in the final, third-year report.

The recommendations pertaining to current field practices are to:

- Continue to increase the use of a perennial grass mix [Siberian (*Agropyron sibiricum*) and/or crested wheatgrass in combination with thickspike wheatgrass] for control of Russian thistle and the establishment of a self-sustaining grass stand
- Continue the 2,4-D amine/Dicamba spray program to minimize the occurrence of Russian thistle and assist in the establishment of the desired grass species by lessening the competition from other undesirable plants

- Continue straw mulching during the revegetation process and mulch or apply a soil fixative to any area expected to be left bare for an extended period of time
- Schedule revegetation to coincide with optimum fall planting period. (September to early November)
- Eliminate rocked roadways between trenches in burial grounds by stabilizing the entire area since the trenches are identified by concrete marker posts designating center lines
- Continue the revised practice of planting perennial grass species at recommended depth (1.25 to 1.9 centimeters) using a seed drill
- Schedule the final, third-year test report for completion at the end of next fiscal year. This will allow data collection to continue throughout the length of next year's growing season and permit an evaluation of plant response to the environmental conditions encountered during that entire period. (Past scheduling of the first- and second-year test reports have resulted in data collection and evaluation based on only a portion of the current year's growing season.)
- Revise current work procedures for burial ground stabilization to reflect the recommendations above
- Continue collecting plant count and biomass data for the final test report
- Continue collecting soil moisture data on selected trenches (biobarrier test trenches vs. control)
- Continue visual observations and photographic documentation of plant condition and trend
- Continue monitoring ongoing field practices for problems and improvements
- Continue observations for erosion losses and initiate corrective actions as warranted

- Continue monitoring the 2,4-D amine/Dicamba herbicide spray program and collecting data to establish effectiveness
- Perform a comprehensive radiological survey of the trenches in 218-E-12a and 218-W-2a to determine whether any contamination has reached the surface during the course of this test
[Particular attention should be given to the remaining control strips (areas where selective herbicides were not applied) crossing those trenches where biobarriers were installed.]
- Conduct a "cold" test of biobarriers to determine effective lifetime and potential modes of failure, including biological intrusion. Cold testing will allow yearly detailed examinations and eliminate the restrictions imposed on tests conducted in radiation zones
- Exhume and examine sections of biobarriers previously installed.

CONTENTS

Introduction	1
Materials and Methods	3
Results and Discussion	9
Effectiveness of Revegetation in 218-W-2a	9
Effectiveness of Biobarrier Revegetation Combinations in 218-E-12a	14
Conclusions	19
Bibliography	43
Appendices:	
A. The 27-Year Average and 1979/1980 Actual Monthly Precipitation	A-1
B. The 27-Year Average and 1979/1980 Actual Monthly Temperature	B-1

FIGURES:

1. Plant Stand Count When No Herbicide is Applied	23
2. Russian Thistle Found on Area Seeded With No Herbicide Treatment	23
3. Biomass Accumulation When No Herbicide is Applied	24
4. Plant Stand Count After 2,4-D amine/Dicamba Herbicide Treatment	24
5. Russian Thistle After 2,4-D amine/Dicamba Herbicide Treatment	25
6. Biomass Accumulation with 2,4-D amine/Dicamba Herbicide Treatment	25
7. Plant Stand Count as a Function of Planting Date	26
8. Biomass Accumulation as a Function of Planting Date	26
9. All Seeded Species Plant Stand Count With and Without Herbicide Treatment	27
10. Biomass Accumulation as a Function of Herbicide Effect	27
11. Plant Stand Count as a Function of Annual vs. Perennial Species	28
12. Biomass Accumulation as a Function of Annual vs. Perennial Species	28
13. Plant Stand Count of Cheatgrass Seeded in 218-W-2a and 218-E-12a	29
14. Biomass Accumulation as a Function of Cheatgrass Seeded in 218-W-2a or 218-E-12a	29
15. Plant Stand Count of Cheatgrass Seeded on Four Planting Dates	30
16. Biomass Accumulation as a Function of Planting Date	30

FIGURES (Continued):

17.	Plant Stand Count as a Function of Soil Backfill Depth Over Plastic Barrier in 218-E-12a	31
18.	Russian Thistle Found on Area Seeded Over Plastic Barrier in 218-E-12a	31
19.	Biomass Accumulation as a Function of Backfill Depth	32
20.	Soil Moisture Profile for 218-E-12a by Species Planted and Backfill Depth	32
21.	Soil Moisture Profile for 218-W-2a by Species Planted	33
22.	Plant Stand Count of Cheatgrass, Including Drought- Stricken Plants	33
23.	Plant Stand Count of Annual Grasses as a Function of Backfill Depth With and Without Plastic Barrier	34
24.	Biomass Accumulation as a Function of Backfill Depth With and Without Plastic Barrier	34
25.	Plant Stand Count of Annual Grasses as a Function of Backfill Depth and Fertilizer in 218-E-12a	35
26.	Biomass Accumulation as a Function of Backfill Depth and Fertilizer Rate in 218-E-12a	35
27.	Plant Stand Count of Perennial Grasses as a Function of Planting Date and One Soil Backfill Depth Over Plastic Barrier	36
28.	Biomass Accumulation as a Function of Planting Date and One Soil Backfill Depth Over Plastic Barrier	36
29.	Plant Stand Count of Perennial Grasses as a Function of Planting Date and One Soil Backfill Depth Over Plastic Barrier	37
30.	Biomass Accumulation as a Function of Planting Date and One Soil Backfill Depth Over Plastic Barrier	37
31.	Plant Stand Count of Perennial Grasses Planted on 10/12/79 Over Two Soil Backfill Depths	38
32.	Biomass Accumulation of Perennial Grasses Planted on 10/12/79 With Two Soil Backfill Depths Over a Plastic Barrier	38
33.	Plant Stand Count of Perennial Grasses Planted on 11/7/79 With Two Soil Backfill Depths Over Plastic Barrier	39
34.	Biomass Accumulation of Perennial Grasses Planted on 11/7/79 With Two Soil Backfill Depths Over Plastic Barrier	39
35.	Plant Stand Count of Perennial Grasses Planted in 30 cm of Soil Backfill and Unlimited Soil Backfill	40
36.	Russian Thistle Found on Area Seeded With Perennial Grasses in 30 cm of Soil Backfill and Unlimited Soil Backfill	40

FIGURES (Continued):

37.	Biomass Accumulation of Perennial Grasses Planted With and Without Herbicide Application	41
38.	Plant Stand Count of Annual Grasses Planted in Two Soil Depths and Unlimited Soil Backfill	41
39.	Russian Thistle Found on Area Planted With Annual Grasses in Two Soil Depths and Unlimited Soil Backfill	42
40.	Biomass Accumulation of Annual Grasses Planted in Two Soil Depths and Unlimited Soil Backfill	42

TABLES:

1.	Vegetation and Selective Herbicide Techniques Tested in 218-W-2a	5
2.	Biobarrier, Soil Depth, and Vegetation Techniques Tested in 218-E-12a	6
3.	Seed Set of Cheatgrass	11
4.	Seed Germination of Cheatgrass	11

INTRODUCTION

The 1981 report on the effectiveness of revegetation and biobarriers was based on observations from two separate experiments on two sites, the 218-W-2a and 218-E-12a Burial Grounds (216-W-2a and 218-E-12a). Some treatment observations were common to both sites. These data represented observations over 1 year and, thus, are valid only under the environmental conditions encountered during that period (Appendices A and B). Anomalies included a major volcanic eruption (May 18, 1980) and one of the wettest (149% of normal) years on record. Based on the data collected this first year, preliminary observations will be reported which may or may not be valid after 3 complete years of testing. However, these data should be valuable in the selection of appropriate techniques to apply at other candidate low-level nuclear waste sites.

The objectives of interim site stabilization are to minimize surface contamination, isolate buried radionuclides from intrusion by animals and plants, and prevent potential transport offsite by wind. The estimated lifetime of interim stabilization applications is about two decades or until long-term stabilization of buried waste is initiated. Revegetation and the use of biobarriers represent two techniques which will accomplish these objectives.

The goal of these investigations was to optimize interim stabilization techniques such as biobarriers and revegetation and to determine their effectiveness in mitigating problems associated with the safe storage of shallow-buried low-level radioactive waste. The problems included soil erosion by wind and water, which might expose buried radioactive waste to atmospheric interaction and transport; and biological intrusion by both plants and animals, which is well documented as a significant factor in the failure of waste containment (Maxfield, 1979).

MATERIALS AND METHODS

To achieve the stated goals, the effects of the following factors were investigated:

- Plant species
- Planting date
- Fertilizer rate
- Ability of plant species to limit Russian thistle (*Salsola kali*)
- Selective herbicide effect
- Backfill depth over various biobarriers.

The parameters measured to evaluate these factors included plant density by species, biomass by species, and moisture profile data.

Plant density was obtained by counts of live plants made on 0.2-m² grids randomly arrayed on the test trenches. Two subsamples per grid were combined to make up four replicates per trench. These plant density counts were also estimated by the Daubenmire (1959) canopy cover class method of species analysis for comparison purposes (these data are not presented at this time).

Biomass data were collected at the end of the active growing season in early July. All plants were cut off at ground level, segregated by species, and then dried for 12 hours at 60°C. The dry weight was then recorded. Moisture data were obtained by collecting soil samples at depths of 0, 15, and 30 centimeters on 30 centimeters of backfill and depths of 0, 15, 30, 45, and 60 centimeters on 60 centimeters of backfill sites through the profile. The soil samples were then oven dried at 100°C for 12 hours.

The following materials were selected for testing to evaluate their relative performance in accomplishing these goals.

- Herbicides
  - Ureabor, a soil sterilant, toxic to all vegetation
(tested in combination with plastic as a biobarrier)

- Treflan, a mitotic root inhibitor which forms a vapor barrier preventing further downward growth of roots (tested alone as a biobarrier)
- 2,4-D amine/Dicamba mixture, a selective herbicide toxic to broadleaf vegetation, i.e., Russian thistle (tested as a selective surface vegetation enhancement treatment).
- Plastics
  - 10-mil polyethylene sheeting
  - 20-mil nylon-reinforced polyvinyl chloride (PVC) pond liner.
- Grass species utilized in revegetation
  - Annuals, such as cheatgrass (*Bromus tectorum*)
  - Perennials, such as:
    - Siberian wheatgrass (*Agropyron sibiricum*)
    - Thickspike wheatgrass (*Agropyron dasytachyum*)
    - Crested wheatgrass (*Agropyron desertorium*)
    - Perennial Mix [Siberian wheatgrass, thickspike wheatgrass, Indian ricegrass (*Oryzopsis hymenoides*) and sand dropseed (*Sporobolus cryptandrus*)].
- Soil depth for grasses
  - 30 centimeters of backfill above biobarrier
  - 60 centimeters of backfill above biobarrier.
- Moisture addition to aid germination and establishment of grasses
  - Fall and spring applications
  - Fall-only application.

The materials were arrayed in various combinations: to test biobarriers, species planted, their effectiveness in limiting Russian thistle and preventing other forms of biologic intrusion in 218-E-12a; and to test the various grass species planted and selective herbicides applied for effectiveness in limiting Russian thistle and other biologic intrusions in 218-W-2a. The vegetation and selective herbicide combinations tested in 218-W-2a are listed in Table 1. The biobarrier, soil depth, and vegetation combinations tested in 218-E-12a are listed in Table 2.

TABLE 1. Vegetation and Selective Herbicide Techniques Tested in 218-W-2a.^a

Trench	Vegetation	Selective herbicide
1 through 4	Cheatgrass	None
5 and 6	Cheatgrass	2,4-D amine/ Dicamba
7 and 8	Siberian wheatgrass	None
9 and 10	Siberian wheatgrass	2,4-D amine/ Dicamba
20 and 21	Thickspike wheatgrass	None
22 and 23	Thickspike wheatgrass	2,4-D amine/ Dicamba
24	Crested wheatgrass	2,4-D amine/ Dicamba
27 and cell coverblock mound	Crested wheatgrass	None

^aNo biobarrier used. Radiologically clean soil/sand used at a depth of 30 centimeters.

TABLE 2. Biobarrier, Soil Depth, and Vegetation Techniques Tested in 218-E-12a.

Trench	Biobarrier	Plastic	Radiologically clean soil depth (cm) ^a	Vegetation
3, 12, 15, 16				
Northwest quarter	Treflan	None	30	Perennial ^b
Southwest quarter	Treflan	None	60	Perennial
Northeast quarter	Treflan	None	30	Cheatgrass
Southeast quarter	Treflan	None	60	Cheatgrass
13				
Northwest quarter	Ureabor	20-mil PVC	30	Cheatgrass
Southwest quarter	Ureabor	20-mil PVC	60	Cheatgrass
Northeast quarter	Ureabor	20-mil PVC	30	Perennial
Southeast quarter	Ureabor	20-mil PVC	60	Perennial
14	Ureabor	10-mil poly-ethylene	60	Perennial
17	Ureabor	10-mil poly-ethylene	60	Cheatgrass
18	Ureabor	10-mil poly-ethylene	60	Cheatgrass
19	Ureabor	10-mil poly-ethylene	60	Perennial
20	Ureabor	10-mil poly-ethylene	60	Cheatgrass
21	Ureabor	10-mil poly-ethylene	30	Perennial
22	Ureabor	10-mil poly-ethylene	30	Cheatgrass
23	Ureabor	10-mil poly-ethylene	30	Perennial
24	Ureabor	10-mil poly-ethylene	30	Cheatgrass
25	Ureabor	10-mil poly-ethylene	60	Cheatgrass

^aDepth is ± 15 centimeters.^bPerennial consisted of a mixture of Siberian and thickspike wheat-grasses, Indian ricegrass, and sand dropseed.

Three types of biobarriers, five perennial grass species (singularly and in combinations), one annual grass species, two soil depths over the biobarriers, and three herbicides (two as buried biobarriers and one as a selective control of surface vegetation) were evaluated. Combinations of these materials were installed using established procedures (i.e., mulch, crimp, seed, water, etc.) in 218-W-2a (see Table 1) and 218-E-12a (see Table 2).

The experiment was designed originally so that major treatment effects could be compared directly. Due to time constraints during the implementation of the test, some comparisons may no longer be valid. Calibration of the equipment in the field produced variations which hinder the interpretation of the treatment effects, such as unplanned seed and fertilizer rate differences.

RESULTS AND DISCUSSION

EFFECTIVENESS OF REVEGETATION IN 218-W-2a

The experimental design of 218-W-2a allowed direct comparisons among three perennials (Siberian, crested, and thickspike wheatgrasses) and one annual (cheatgrass) species. Figures 1 and 2 indicate that the trenches seeded to cheatgrass produced significantly more plants and biomass than any of the three perennial species; however, at the same time, the highest counts of Russian thistle also occurred (Figure 3).^{*} Furthermore, when the cheatgrass matured, set seed, and died in early June (as indicated by the decrease in live healthy plants), the number, and more importantly, the plant biomass (i.e., size) of the Russian thistle increased dramatically. Figures 1 and 3 also indicate that the end of the cheatgrass annual cycle (as outlined above) allowed Russian thistle to continue its growth. This illustrated the basic difference between a winter annual (cheatgrass) and a summer annual (Russian thistle). The winter annual required vernalization (cold treatment of the young plant) before it would flower and set seed, whereas the summer annual did not. The 218-E-5a site demonstrated the result of seeding cheatgrass in the spring; i.e., the plants remained rosette in growth and set no seed, which resulted in the failure of cheatgrass to make a stand the next year.

Of the three perennials, only the crested wheatgrass initial stand approached the stand count of cheatgrass (Figure 1). Perennial species might go dormant and cease active growth during extended drought periods, but did not die when properly established. They were able to break dormancy when conditions conducive to plant growth resumed, thereby providing competition against the Russian thistle. In well-established, mature, perennial grass stands, few resources remained available for Russian thistle establishment, and, thus, its exclusion was encouraged, as evidenced by observations of previous revegetation sites (e.g., - 216-S-17 Pond, 200 West Garage). Furthermore, the perennial grasses

---

^{*} Figures are placed behind text to aid readability.

regenerated each year from a crown located just below the soil surface. This rendered the plant essentially immune to fire, an attribute not ascribed to annual grasses.

The data summarized in Figures 4, 5, and 6 demonstrated the following:

- When 2,4-D amine/Dicamba was applied to cheatgrass stands, Russian thistle occurrence was significantly decreased.
- After the cheatgrass matured, set seed, and died, it no longer provided competition and Russian thistle was free to increase in number and utilize all remaining resources, unless another herbicide application was made.

Thus, without herbicide treatment, it is doubtful that cheatgrass could provide long-term Russian thistle control after a loss of institutional control. The herbicide treatment also had two other effects; one on the number of seeds set (Table 3), and the other on subsequent seed germination (Table 4). A Duncan's multiple range test was performed to evaluate significant differences among treatments (Steele and Torrie, 1960). The herbicide 2,4-D amine is a plant growth regulator which, when applied during flowering, would cause a hormonal reaction which simulated pollination and induced parthenocarpy (i.e., seedlessness); but if applied after flowering and pollination (seed set), it would augment natural hormones and increase the number of seed set and their subsequent germination. Time constraints during application on the Hanford Site could result in application during the preflower stage, possibly resulting in a reduction of the cheatgrass stand the following year. Cheatgrass was an invader weed species, much like Russian thistle (except that it was a winter annual and less mobile) whose seed would be present in backfill soil in significant numbers whether it was planted or not. The rapid initial establishment of cheatgrass and subsequent surface soil stabilization might be used to advantage when seeding a perennial species for more permanent control of Russian thistle.

TABLE 3. Seed Set of Cheatgrass.

Date collected	Control ^a	2,4-D amine/Dicamba treatment ^a	
		Preflower	Postflower
6/15/80	7076b ^b	5016a	7193b

^aSeed per 100 plants.

^bMeans followed by the same letter within a row are not significantly different at the 0.05 level of probability according to Duncan's multiple range test.

TABLE 4. Seed Germination of Cheatgrass.

Date of germination	Control, %	2,4-D amine/Dicamba treatment, % ^a	
		Preflower	Postflower
8/01/80	0	0	0
8/06/80	41.3a ^a	41.3a	53.3b
8/41/80	72.b	68.0a	74.0b

^aMeans followed by the same letter within a column are not significantly different at the 0.05 level of probability according to Duncan's multiple range test.

These data also suggested that the 2,4-D amine/Dicamba herbicide applications reduced competition from other weed species and allowed those resources to be used by the desired planted species. Since water is the most limiting of the resources on the Hanford Site, the use of the straw mulch further conserves this resource. Based on observations from 218-W-2a and 218-E-12a, 25 centimeters of mulch provided the optimum benefit. Orientation of the trench design to run at right angles to the prevailing winds (west-northwest) also helped hold the straw in place and conserve moisture.

Independent examination of each species indicated that a 2,4-D amine/Dicamba herbicide application complicated the resulting interpretation of the data. For instance, only two trenches were seeded with crested wheatgrass and they were planted approximately 2 weeks apart (Figures 7 and 8). One trench received the 2,4-D amine/Dicamba herbicide treatment; it was hard to discern whether the resulting plant stand effect was due to the planting date or the selective herbicide (Figures 7 and 8). Data and observations suggested that the selective herbicide was the major influence. Furthermore, under conditions of no herbicide treatment, the crested wheatgrass compared favorably to the cheatgrass in plant count (but not biomass since this was not a mature stand) while significantly decreasing the occurrence of Russian thistle (Figures 1, 3, 4, and 6). Although crested wheatgrass appeared to be the most promising perennial species investigated, the literature suggests it is the least drought tolerant of the three perennial wheatgrasses (Dewey, 1960), not commonly found native to Hanford plant communities (Daubenmire, 1959), and in an average precipitation year (less moisture than received in 1979) may not establish or survive as well (Herbel and Sosebee, 1969). Continued observations are warranted and, with supplemental moisture additions or use of other drought-tolerant varieties, these concerns may eventually be overcome in obtaining initial grass establishment and survival. A new variety of crested wheatgrass (Fairway) was recently released for commercial use which incorporated the rhizomatous (sod forming) characteristic and will be investigated in next year's seedings.

In comparing Siberian wheatgrass (Figures 1 through 6) to cheatgrass, the perennial characteristics appeared more desirable because they decreased the occurrence of Russian thistle. While cheatgrass may have had 3 to 10 times as many plants per 0.2 m^2 , the biomass (dry weight of aboveground plant material) and the percentage of relative plant cover for an established perennial may have been 3 to 4 times that of the annual cheatgrass. This was due, in part, to the fact that two of the perennial grasses tested were bunch types, which produce many leaves and few seed heads, as opposed to the annual grass, which produced many seed heads with few leaves. Thus, once the perennial

was established, it provided a maximum plant cover, capable of excluding Russian thistle and providing stabilization of the surface soil from erosion. Currently, this is not the case, but should develop as a mature stand of perennial grass is established.

These data also indicated that the 2,4-D amine/Dicamba selective herbicide treatment on those trenches seeded to Siberian wheatgrass (Figures 4, 5, and 6) appeared to be detrimental to the initial establishment of the wheatgrass. Further observation to determine why this occurred revealed that the plants were treated early (2- to 5-leaf stage) in their development and were partly susceptible to the herbicide. This was a short-lived phenomenon and should not hinder future development of the grass.

Examination of the effects of thickspike wheatgrass (Figures 4, 5, and 6) indicated that it was not a promising species for revegetation as a single species planting at its present level of development. The thickspike wheatgrass did not suppress Russian thistle occurrence and its plant population and biomass production remained at low levels. Treatment with herbicides (Figures 4, 5, and 6) appeared to decrease further initial thickspike wheatgrass establishment while also suppressing Russian thistle. Thickspike wheatgrass was not a bunch grass per se, but rather it possessed a rhizomatous characteristic (the ability to establish new plants from one central plant via underground stems) and is classified as a sod former which allows it to "fill in" between other perennial plant species. Recent observations indicated that the grass indeed sent out rhizomes and filled in the stands.

Observations made on 3- to 5-year-old revegetated sites (216-S-17 and 200 West Garage) indicated that a combination of Siberian and thickspike wheatgrass is effective for stabilization of the soil and elimination of Russian thistle. Data obtained in this experiment suggest that crested wheatgrasses may be a promising species to try in combination with thickspike wheatgrass (Figures 1, 2, and 3). If the rhizomatous crested variety (Fairway) turned out to be acceptable, a mixture with Siberian wheatgrass may be preferable.

It appeared that treatment with 2,4-D amine/Dicamba tended to help crested wheatgrass increase its plant stand significantly, while decreasing Russian thistle occurrence for all perennials (Figures 4, 5, and 6). In general, the selective herbicide tended to stabilize the stand of planted species by reducing the competition from Russian thistle (Figures 9 and 10) and thus, freed resources for use by desirable species.

EFFECTIVENESS OF BIOBARRIER REVEGETATION COMBINATIONS IN 218-E-12a

The perennial mix planted on 218-E-12a consisted of varying proportions of Siberian wheatgrass and thickspike wheatgrass, with small amounts of Indian ricegrass and sand dropseed. Comparison of the data from 218-E-12a and 218-W-2a indicated that the cheatgrass produced three to four times as many plants and significantly more biomass (as a function of its increased numbers) than the perennial mix at the end of a 1-year growing season (Figures 11 and 12). The relative number of cheatgrass plants on 218-E-12a was initially 4 to 5 times that found on 218-W-2a (Figures 13 and 14), but equal to 218-W-2a at maturation. This indicated that an early seeding date (Figures 15 and 16) for cheatgrass resulted in a larger plant stand. This might lead to the conclusion that cheatgrass will fulfill the goals outlined in the introduction of this report. However, cheatgrass would not control adequately the occurrence of Russian thistle without a supplemental 2,4-D amine/Dicamba herbicide program applied at least twice a year. Furthermore, as an annual, cheatgrass must reseed and establish itself each year, thereby rendering it susceptible to adverse environmental changes and/or herbicide damage as previously described.

When the data were compared by planting date and depth of backfill (30 centimeters vs. 60 centimeters), a detailed explanation of the effects became necessary (Figures 17, 18, and 19). Figure 20 indicates that on March 27, 1979, a moisture profile of approximately 10% at the surface and 15% at 60 centimeters existed in the soil. By mid-July, this profile had changed to less than 3% at the surface and about 8% at

60 centimeters. In contrast, Figure 21 indicates that 218-W-2a, which essentially drew moisture from a deeper profile, had 1% moisture at the surface to about 5% moisture at 60 centimeters. This indicated that the biobarrier impeded the downward movement of moisture, keeping it close to the surface and available to the plants. This could account for the dramatic increase in the number of cheatgrass plants initially present on the 218-E-12a site. The 218-W-2a data indicated that moisture tended to move down into the soil profile to a greater depth and became available more uniformly, as needed from this larger volume storage reservoir.

A dramatic decrease in cheatgrass numbers occurred in early May. This coincided with the advent of warmer weather and less precipitation, and suggested that the total amount of moisture present in 30 or 60 centimeters of backfill (regardless of percentage, which is not volume dependent) may not be sufficient to support this number of established plants. This was further supported by the following:

- 218-W-2a cheatgrass plant densities which did not exhibit decrease in number (Figures 13 and 14)
- The large number of dead plants observed on 218-E-12a cheatgrass trenches (Figure 22)
- The greater biomass present at maturation in 218-W-2a (Figures 23 and 24).

Late October to early November appeared to be an optimal time for planting the perennial mix, but a poor time to plant cheatgrass. Since cheatgrass had only 1 year in which to complete its life cycle, it did not root deeply, but rather concentrated its resources on late fall and early winter germination, winter root development, spring shoot growth, and seed set. It produced much more seed than was necessary to insure its survival through time. This was an abnormally moist year (Appendix A) although temperatures remained fairly normal (Appendix B). In a normal year, less moisture would have been available in 30 or 60 centimeters of backfill, and the dessication of cheatgrass observed in May 1980

could have occurred prior to seed set and resulted in stand failure the following year. Observations over the next 2 years will be important in this respect, particularly if they are dry years.

Preliminary observations of the data presented in Figures 17 and 18 suggested moisture utilization differences may have existed between cheatgrass and perennials. Cheatgrass was relatively shallow rooted, while perennials tended to be deeper rooted. Examination of the data indicated that cheatgrass on 30 centimeters of backfill produced more plants than on 60 centimeters of backfill, but the opposite was true for perennials; 60 centimeters of backfill produced twice as many plants by count as on 30 centimeters of backfill. Table 2 moisture data seemed to support this notion, but there were insufficient data points to prove this conclusively. Moisture utilization will be investigated more closely in the future to provide a better understanding of this interaction.

An interaction which requires further investigation is the effect of fertilization on plant stand and biomass production (Figures 25 and 26). While it appeared that 30 centimeters of backfill tended to favor cheatgrass establishment, the fertility of the soil may have had an effect as well. Using the optimum planting dates (late September or early October), it appeared that 140 kg/ha of nitrogen fertilizer greatly increased the plant stand and biomass production. It is proposed that future fertility trials be conducted with the perennials to define better this interaction. The data presented in Figures 27 through 30 implied that minor differences may have existed between planting dates and backfill depths. However, 2 to 3 perennial plants per square meter may have made a difference between the success and failure of a stand.

Due to the low organic matter content and the sandy nature of Hanford soils, the cation exchange capacity was very low. As a result, conventionally applied fertilizers moved rapidly through the soil profile. Next year, dilute liquid fertilizer will be applied in the herbicide solution. This technique has the advantage of being in an active form and available for the direct use of the plants.

Figure 31 indicates that 60 centimeters of backfill resulted in more perennials and fewer Russian thistle than 30 centimeters of backfill. The first-year biomass data (Figure 32) did not fully support this; however, this was not a mature stand of grass and within 3 to 5 years these data may change. Note that only 30 and 60 centimeters of backfill depth were tested. Figures 33 and 34 support the conclusion that when the proper planting date was employed, plant stands were almost doubled and biomass increased significantly; at the same time, Russian thistle biomass decreased. Backfill depths of greater than 90 centimeters should be evaluated in the future, as the one 3- to 5-year-old site in place (241-B-43 through 241-B-50 Cribs) was unsuccessful in accomplishing the goals outlined in the introduction and it employed 60 centimeters of backfill over a plastic biobarrier.

The data indicated (Figures 35 to 40) that the 2,4-D amine/Dicamba herbicide treatment would control Russian thistle occurrence and biomass size while favoring increase of species planted (numbers) and biomass size by reducing competition from weed species. This is desirable because it would eliminate the major problem of radionuclide uptake and potential movement out of the zone of containment by Russian thistle. It also would enhance the initial stand of the perennial grass species and decrease the time required to achieve a self-sustaining perennial grass community. Since this was the most successful aspect of the site stabilization program, a full effort in vegetation control is planned for next year.

As the result of the observations made during studies of 218-W-2a, it is recommended that the roadways in this area be eliminated for the following reasons:

- Russian thistle flourishes at the edge of the roadways where there is no biobarrier and/or herbicide treatment. The roots may penetrate laterally down into the buried waste.
- Vehicular traffic stirs up dust, including Ureabor, which settles and acts as a herbicide on the revegetated trenches.

- Road use allows rill erosion down the slope of the road.
- The wind erodes the road and "blasts" sand on to the revegetated trench.
- The roadways prevent favorable trench orientation against prevailing winds.

CONCLUSIONS

The first year of observation for effectiveness of biobarriers and herbicides in revegetation efforts demonstrated that certain practices will result in successful site stabilization. These practices include the following:

- Proper orientation of burial trench to reduce erosion
- Utilization of mulches to conserve moisture
- Seeding mixed perennial or annual grass species at the proper time for optimization of establishment and growth
- Applying 2,4-D amine/Dicamba selective herbicide at the optimum time for enhancement of desirable grasses and reduction of competition from other species.

The ultimate success or failure of a revegetation operation depends in part on the availability of equipment and manpower, weather conditions, and engineering feasibility. The data indicated that perennial grasses offered advantages over annual grasses and that the 2,4-D amine/Dicamba herbicide spray program was successful and should be expanded for next year. However, programmatic decisions should not be based on the data for 1 year, but should be based on data gathered over the full 3 years of the project.

RHO-LD-143

FIGURES

FIGURE 1. Plant Stand Count When No Herbicide is Applied.

FIGURE 2. Russian Thistle Found on Area Seeded With No Herbicide Treatment.

FIGURE 3. Biomass Accumulation When No Herbicide is Applied.

FIGURE 4. Plant Stand Count After 2,4-D amine/Dicamba Herbicide Treatment.

FIGURE 5. Russian Thistle After 2,4-D amine/Dicamba Herbicide Treatment.

FIGURE 6. Biomass Accumulation With 2,4-D amine/Dicamba Herbicide Treatment.

FIGURE 7. Plant Stand Count as a Function of Planting Date.

FIGURE 8. Biomass Accumulation as a Function of Planting Date.

FIGURE 9. All Seeded Species Plant Stand Count With and Without Herbicide Treatment.

FIGURE 10. Biomass Accumulation as a Function of Herbicide Effect.

FIGURE 11. Plant Stand Count as a Function of Annual vs. Perennial Species.

FIGURE 12. Biomass Accumulation as a Function of Annual vs. Perennial Species.

FIGURE 13. Plant Stand Count of Cheatgrass Seeded in 218-W-2a and 218-E-12a.

FIGURE 14. Biomass Accumulation as a Function of Cheatgrass Seeded in 218-W-2a or 218-E-12a.

FIGURE 15. Plant Stand Count of Cheatgrass Seeded on Four Planting Dates.

FIGURE 16. Biomass Accumulation as a Function of Planting Date.

FIGURE 17. Plant Stand Count as a Function of Soil Backfill Depth Over Plastic Barrier in 218-E-12a.

FIGURE 18. Russian Thistle Found on Area Seeded Over Plastic Barrier in 218-E-12a.

FIGURE 19. Biomass Accumulation as a Function of Backfill Depth.

FIGURE 20. Soil Moisture Profile for 218-E-12a by Species Planted and Backfill Depth.

FIGURE 21. Soil Moisture Profile for 218-W-2a by Species Planted.

FIGURE 22. Plant Stand Count of Cheatgrass, Including Drought-Stricken Plants.

FIGURE 23. Plant Stand Count of Annual Grasses as a Function of Backfill Depth With and Without Plastic Barrier.

FIGURE 24. Biomass Accumulation as a Function of Backfill Depth With and Without Plastic Barrier.

FIGURE 25. Plant Stand Count of Annual Grasses as a Function of Backfill Depth and Fertilizer in 218-E-12a.

FIGURE 26. Biomass Accumulation as a Function of Backfill Depth and Fertilizer Rate in 218-E-12a.

FIGURE 27. Plant Stand Count of Perennial Grasses as a Function of Planting Date and One Soil Backfill Depth Over Plastic Barrier.

FIGURE 28. Biomass Accumulation as a Function of Planting Date and One Soil Backfill Depth Over Plastic Barrier.

FIGURE 29. Plant Stand Count of Perennial Grasses as a Function of Planting Date and One Soil Backfill Depth Over Plastic Barrier.

FIGURE 30. Biomass Accumulation as a Function of Planting Date and One Soil Backfill Depth Over Plastic Barrier.

FIGURE 31. Plant Stand Count of Perennial Grasses Planted on 10/12/79 Over Two Soil Backfill Depths.

FIGURE 32. Biomass Accumulation of Perennial Grasses Planted on 10/12/79 With Two Soil Backfill Depths Over a Plastic Barrier.

FIGURE 33. Plant Stand Count of Perennial Grasses Planted on 11/7/79 With Two Soil Backfill Depths Over Plastic Barrier.

FIGURE 34. Biomass Accumulation of Perennial Grasses Planted on 11/7/79 With Two Soil Backfill Depths Over Plastic Barrier.

FIGURE 35. Plant Stand Count of Perennial Grasses Planted in 30 cm of Soil Backfill and Unlimited Soil Backfill.

FIGURE 36. Russian Thistle Found on Area Seeded with Perennial Grasses in 30 cm of Soil Backfill and Unlimited Soil Backfill.

FIGURE 37. Biomass Accumulation of Perennial Grasses Planted With and Without Herbicide Application.

FIGURE 38. Plant Stand Count of Annual Grasses Planted in Two Soil Depths and Unlimited Soil Backfill.

FIGURE 39. Russian Thistle Found on Area Planted With Annual Grasses in Two Soil Depths and Unlimited Soil Backfill.

FIGURE 40. Biomass Accumulation of Annual Grasses Planted in Two Soil Depths and Unlimited Soil Backfill.

BIBLIOGRAPHY

- Beutner, E. L. and D. Anderson (1944), "A Method of Seedbed Preparation and Reseeding Deteriorated Rangelands," J. Am. Soc. Agron. 35, pp. 171-172.
- Blaisdel, J. P. and W. F. Mueggler (1965), "Effect of 2,4-D on Forbs and Shrubs Associated with Big Sagebrush," J. Range Mgmt. 9, pp. 30-40.
- Daubenmire, R. (1940), "Plant Succession Due to Overgrazing in the *Agropyron* Bunchgrass Prairie of Southeastern Washington," Ecol. 21, pp. 55-65.
- Daubenmire, R. (1959), "A Canopy-Cover Method of Vegetational Analysis," Northwest. Sci. 33, pp. 43-64.
- Dewey, R. (1960), "Salt Tolerance of Twenty-Five Strains of *Agropyron*," Agron. J. 52, pp. 631-635.
- Douglas, D. S., A. L. Hafenrichter, and K. H. Klages (1960), "Cultural Methods and Their Relationship to Establishment of Native and Exotic Grasses in Range Seedings," J. Range Mgmt. 13, pp. 53-57.
- Harris, G. A. (1967), "Some Competitive Relationships Between *Agropyron spicatum* and *Bromus tectorum*," Ecol. Mono. 37, pp. 89-111.
- Herbel, C. E. and E. Sosebee (1969), "Moisture and Temperature Effects on Emergence and Initial Growth of Two Range Grasses," Agron. J. 61, pp. 628-631.
- Hulbert, L. C. (1955), "Ecological Studies of *Bromus tectorum* and Other Annual Bromegrasses," Ecol. Mono. 25, pp. 181-213.
- Hull A. C. (1964), "Emergence of Cheatgrass and Three Wheatgrasses from Four Seeding Depths," J. Range Mgmt. 21, pp. 140-144.
- Hurd, R. M. (1955), "Effect of 2,4-D on Some Herbaceous Range Plants," J. Range Mgmt. 8, pp. 126-128.
- Hyder, D. N., F. A. Sneva, and W. A. Sawyer (1955), "Soil Firming May Improve Range Seeding Operations," J. Range Mgmt. 8, pp. 159-163.
- Kay, B. L. and R. A. Evans (1965), "Effects of Fertilization on a Mixed Stand of Cheatgrass and Intermediate Wheatgrass," J. Range Mgmt. 21, pp. 213-216.
- Klomp, G. J. and A. C. Hull, Jr. (1968), "Effects of 2,4-D on Emergence and Seedling Growth of Range Grasses," J. Range Mgmt. 21, pp. 67-70.

- Maxfield, H. L. (1979), Handbook - 200 Areas Waste Sites, RHO-CD-673, Vol. II, Rockwell Hanford Operations, Richland, Washington.
- Mueggler, W. F. and J. P. Blaisdel (1955), "Effects of Seeding Rate Upon Establishment and Yield of Crested Wheatgrass," J. Range Mgmt. 8, pp. 74-76.
- Robocker, W. C. (1961), "The Influence of Perennial Vegetation and Precipitation on Occurrence of *Halogeton glomeratus* and *Bromus tectorum* in Arid and Semi-Arid Regions," J. Range Mgmt. 14, pp. 28-34.
- Robocker, W. C., D. Gates, and H. D. Kerr (1965), "Effects of Herbicides, Burning and Seeding Date in Reseeding an Arid Range," J. Range Mgmt. 18, pp. 114-118.
- Rummell, S. (1946), "Some Effects of Competition from Cheatgrass *Bromus* on Crested Wheatgrass and Bluestem Wheatgrass (*A. smithii*)," Ecol. 27, pp. 159-167.
- Shown, L. M., R. F. Miller, and F. A. Branson (1969), "Sagebrush Conversion to Grassland as Affected by Precipitation, Soil and Cultural Practices," J. Range Mgmt. 22, pp. 303-311.
- Smika, D. E., H. J. Haas, and G. A. Rogler (1963), "Native Grass and Crested Wheatgrass Production as Influenced by Fertilizer Placement and Weed Control," J. Range Mgmt. 16, pp. 5-8.
- Sosebee, R. E. and C. E. Herbel (1969), "Effects of High Temperatures on Emergence and Initial Growth of Range Plants," Agron. J. 61, pp. 621-624.
- Steele, R. G. D. and J. N. Torrie (1960), Principles and Procedures of Statistics, McGraw-Hill Book Company Inc., Toronto, Ontario.

APPENDIX A

THE 27-YEAR AVERAGE AND 1979/1980 ACTUAL MONTHLY PRECIPITATION

RCP8111-65

A-1 (A-2 blank)

RHO-LD-143

APPENDIX B

THE 27-YEAR AVERAGE AND 1979/1980 ACTUAL MONTHLY TEMPERATURE

RCP8111-64

RHO-LD-143

DO NOT MICROFILM
DISTRIBUTION

Number of copies

OFFSITE

1

Los Alamos National Scientific Laboratory
Environmental Science Group
P.O. Box 1663/MS 495
Los Alamos, New Mexico 87545
G. I. De Poorter

1

Rockwell International - Rocky Flats Plant
Environmental Analysis and Control Department
P. O. Box 464
Golden, Colorado 80401
D. D. Hornbacker

2

U.S. Department of Energy
Technical Information Center
P.O. Box 62
Oak Ridge, Tennessee 37830

1

Washington State University
Seed Technology Laboratory
Pullman, Washington 99164
Dr. J. D. Maguire

1

Washington State University
Western Washington Research
and Extension Center
Puyallup, Washington 98371
Dr. R. L. Gabrielson

1

University of California - Davis
326 Mills Drive
Davis, California 95616
Dr. B. Kay

1

U.S. Department of Energy
Low-Level Waste Management Program
550 Second Street
Idaho Falls, Idaho 83401
M. J. Barainca

1

EG&G
Waste Management Operations
P.O. Box 1625
Idaho Falls, Idaho 83401
G. Levin

ONSITE

3

Pacific Northwest Laboratory
Arid Land Ecology Unit
Richland, Washington 99352
J. F. Cline

Land and Water Resource Department
Richland, Washington 99352

T. L. Jones
R. R. Kirkham

45

Rockwell Hanford Operations

M. A. Christie
G. R. Cox (10)
J. L. Deichman
R. D. Fox
M. R. Fuchs
A. N. Gallegos
A. W. Graves
W. F. Heine
W. P. Kunkel
L. E. Kusler
P. G. Lorenzini
C. W. Manry
H. E. McGuire
R. M. Mitchell (5)
J. D. Molnaa
W. L. Nees
S. M. O'Tuole
W. H. Price
R. C. Routson
H. P. Shaw
W. J. Waugh
R. E. Wheeler
S. A. Wiegman
J. A. Winterhalder
D. L. Uhl
Document Control (3)
Report Coordination and Production (4)