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# SOIL EXTRACTIONS FOR DETERMINING HEAVY METAL BIOAVAILABILITY IN MINING WASTE

Contract JO278005  
Schafer and Associates

BUREAU OF MINES  
UNITED STATES DEPARTMENT OF THE INTERIOR



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| 16. Abstract (Limit: 200 words)<br><p>Forage plots were established on agricultural lands contaminated by acid mining waste. The acid produced through oxidation of pyrite and other sulfides caused elevated solubility and plant availability of copper, zinc, and arsenic which killed vegetation and polluted surface and groundwater. Soil amendments including agricultural lime (<math>\text{CaCO}_3</math>), hydrated lime (<math>\text{Ca(OH)}_2</math>), phosphorus, and organic matter were used to reduce the toxicity of metals. Several acid-tolerant grasses were used to vegetate the amended soils. Various soil extraction techniques were used to see which best correlated with vegetation performance. The extractions corresponded to three "forms" of metals in soil including soluble (water-saturation extract); plant-available/weakly adsorbed (DTPA extract); and total (<math>\text{HNO}_3/\text{H}_2\text{O}_2</math> extract). Of the extractants tested the DTPA levels appeared to correlate best with metal levels in plant tissue. The DTPA soil extractant serves as a useful tool in predicting potential phytotoxicity of mine waste materials.</p> |               |                                                  |                                                        |
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## FOREWORD

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Financial support was also received from the Mile High Conservation District (southwestern Montana) through a grant from the 1985 Montana legislature of Resource Indemnity Trust (RIT) Fund monies. Portions of the work completed under this project were administered by the Headwaters Resource Conservation and Development (R.C. & D.) Agency (USDA). The purpose of these grants are to improve areas impacted by mining. Generous time-sharing support was received from the Powell County Soil Conservation Service, the Montana Cooperative Extension Service, and from the Soil Conservation Service / Montana State office. A companion study is being conducted by the Montana Bureau of Mines and Geology on ground water chemistry.

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## EXECUTIVE SUMMARY

The purpose of this investigation was to develop and test cost-effective techniques for reclamation of lands contaminated by sulfide-rich base metal mine waste and to test the effectiveness of a variety of soil extractions for predicting plant toxicity. Evaluation of different chemical fixation and neutralization techniques as a means of alleviating acid and metal solubility problems and selection of appropriate forage species for growth on metal-enriched acid soil were the objectives of the study. Chemical fixation and neutralization refer to the use of soil amendments to counteract acidity or reduce the mobility of toxic constituents.

Advantages of this approach include reduced metal solubility and reduced ground water recharge resulting in an abatement of metal movement to surface and ground water. Reduction in fugitive dust also resulted from the enhanced vegetative cover. Finally, a productive agricultural use was re-established.

Soil amendments evaluated included lime, phosphorous, and organic matter. Soil extractions used to test for phytotoxicity included 1) a saturated paste of soil and water to simulate the soluble fraction of metals, 2) a DTPA (diethylene triamine pentaacetic acid) solution to simulate the exchangeable or "bioavailable" fraction, 3) a nitric acid and hydrogen peroxide digest to analyse "total" soil metal levels, and 4) a microbial bioassay technique.

### Plant Performance

Several species were evaluated in the multi-year experiment for their performance on acid, sulfide-rich mine waste contaminated soils. Of the species tested streambank wheatgrass, basin wildrye, and russian wildrye appeared best-suited for use in reclamation. Poor performers included western wheatgrass, crested wheatgrass, legumes, and pubescent wheatgrass. Another species that showed promising preliminary response included Altai wildrye.

### Soil Amendments

Use of 4 to 6 tons/acre of lime appeared to improve soil pH levels substantially. On some soils with shallow zones of contamination, tillage alone increased soil pH and improved vegetation performance. All soil treatments tested improved plant performance, but differences between treatments were generally minor and inconsistent.

Soil treatments greatly reduced the solubility of key metals (Cu, Zn). Use of phosphorus in combination with lime reduced metal levels to a similar degree as lime used alone. Use of manure, phosphorus, and lime increased Cu solubility when compared to use of lime alone, while the addition of manure further decreased Zn solubility relative to lime alone. Soil amendments had inconsistent effects on extractable metal levels.

### Soil Extractions

Three soil extractions were tested to see which correlated best with plant performance and metal uptake. The extractions corresponded to three "forms" of metals in soil including soluble (water-saturation extract); plant-available/weakly adsorbed (DTPA extract); and total ( $\text{HNO}_3/\text{H}_2\text{O}_2$  extract). Of the extractants tested the DTPA levels appeared to correlate best with metal levels in plant tissue. Yields of several forage species were also correlated with DTPA metal levels. For other forage species yields were not related in a straight-forward manner to soil metal levels thus no extractable metal levels correlated well with yield. Copper and zinc seemed to most commonly limit yield in the forage plots evaluated. Critical levels of copper and zinc where yield reduction was noted corresponded to roughly 20 to 24 mg/kg plant Cu and 100 to 150 mg/kg plant Zn. The extractable DTPA levels in soils causing this level of uptake were roughly 100 mg/kg Cu and 70 to 100 mg/kg extractable Zn. Combinations of high levels of Cu and Zn appeared to affect plant performance more adversely than presence of one element alone. The DTPA soil extractant serves as a useful tool in predicting potential phytotoxicity of mine waste materials. Development of exact criteria for determining phytotoxic levels of DTPA extractable metals is not yet possible due to differences in metal tolerances between forage species and due to interactions of toxic metals when more than one are present at higher-than-normal concentrations.

A microbial bioassay technique was used to evaluate phytotoxicity of amended soils. The microtox test was adapted for testing contaminated soils by directly exposing the light-emitting bacteria to a soil suspension. Extensive color correction was required to interpret the results. The microtox test shows promise for predicting phytotoxic response, especially in mixed waste systems where more than one potentially toxic metal (or other contaminant) is present. Further development of this bioassay is necessary to standardize the test method and to correlate the results with observed phytotoxicity before its widespread use can be recommended.

### Lysimeter Chemistry

Suction lysimeters were installed in selected plots to determine the effects of soil amendments on mobility of metals and to note the correlation of different soil extractions with metals in pore water.

The metal levels in pore water samples did not vary consistently across lime rate treatments. The saturated paste (soluble) soil extraction (saturation extract) appears to correlate well with metal levels in pore water. In general, metal levels declined as soil pH increased with the exception of As which had elevated solubility at pH levels above 8.0.

## 1.0 INTRODUCTION

### 1.1 STUDY OBJECTIVES

This project received joint sponsorship from two funding sources including the U.S. Bureau of Mines with funding from their Abandoned Mined Lands research program and the Mile High Conservation District with funding from the Montana Resource Indemnity Trust (RIT) Fund. The RIT grant was provided for developing and testing methods of establishing forage on lands affected by mining and smelting for base metals in southwestern Montana. The Bureau funding was provided to evaluate the use of various soil extractions for testing the bioavailability of heavy metals. Research plots testing various soil amendments and plant species were established to meet the objectives of the joint project funding sources.

The purpose of this investigation was to develop and test cost-effective techniques for reclamation of contaminated lands for forage production. Evaluation of different chemical fixation and neutralization techniques as a means of alleviating acid and metal solubility problems and selection of appropriate forage species were the objectives of the study. Chemical fixation and neutralization refer to the use of amendments to counteract acidity or reduce the mobility of toxic constituents. Soil amendments evaluated included lime, phosphorus, and organic matter.

Advantages of this approach include reduced metal solubility and reduced ground water recharge resulting in an abatement of metal movement to surface and ground water. Reduction in fugitive dust would also result from the enhanced vegetative cover. Finally, a productive agricultural use would be re-established helping to bolster the local economy.

Primary disadvantages of the approach might include metal uptake by plants and accumulation in livestock, expense outweighing benefits, and solubilization of arsenic. Metal levels in plant tissue and soil arsenic levels were monitored in the investigation, treatments were chosen to keep overall reclamation costs as low as possible. Although treatments developed are not expected to be cost-effective for an individual farm enterprise, the additional public benefits justify payment of project costs by a public entity (State of Montana) or a responsible polluter through cost recovery under the Superfund or through other Federal legislation.

## 1.2 STUDY LOCATION

The area chosen for this investigation was said to have over 100 active dairy operations at the turn of the century. Now it is mostly barren ground contributing to a regional fugitive dust problem. Plants growing in the area are noxious weeds like leafy spurge, russian knapweed, canada thistle, field bindweed, and hoary cress.

The research area is located about 5 miles east of Anaconda, Montana on the Hazel Spangler ranch, a large dairy operation (Figure 1). The area was contaminated when old surface irrigation systems brought Silver Bow Creek water onto low terraces and alluvial fans. The area now an EPA superfund site, has several thousand acres of land where agricultural production is no longer possible, or where yields are reduced. Vegetative cover averages less than 10 percent and consists primarily of weedy species. Precipitation totals about 14 inches annually most of which falls from April to June. In recent years, numerous landowners have experienced crop and livestock losses in the area due to metal contamination. Zinc toxicity has most often been cited as the cause of crop failure with copper toxicity occasionally cited.

The research area is typical of land affected by mining waste from base metal extraction processes. Tailings ponds, waste rock piles, dump leach areas, and lands in the vicinity of smelters often have acid soil conditions in association with elevated levels of toxic metals. Hence, research conducted on this site should have wide applicability to other areas affected by mining.

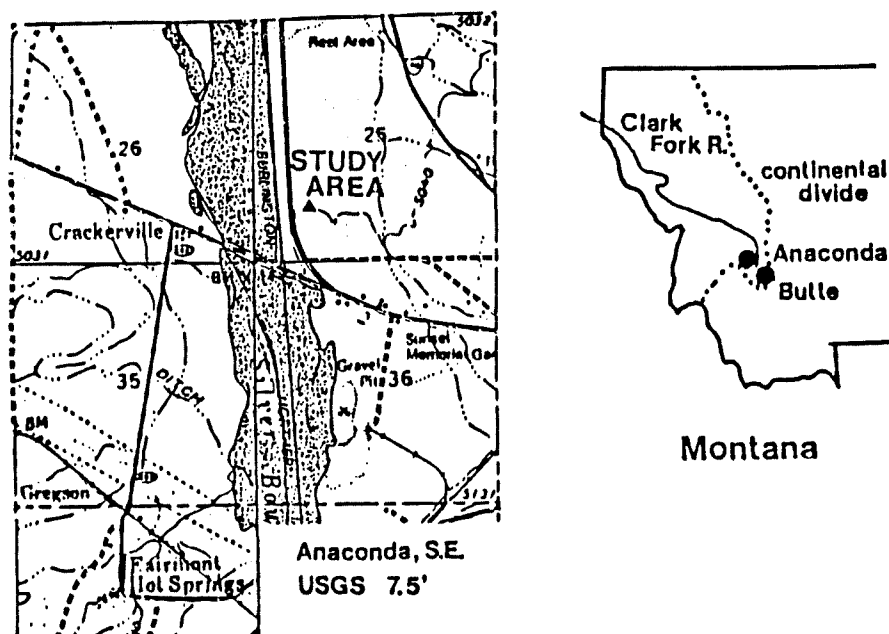


Figure 1. Location of the forage establishment study in the upper Clark Fork River drainage.

### 1.3 SITE HISTORY

#### Mining History

Numerous smelters operated in the Butte area around the turn of the century to concentrate the mined ores (Smith 1952). Early smelting processes generally consisted of pulverizing the ore to silt, sand, or small gravel-sized particles and then using gravity methods to separate the particles high in metal content from the waste rock or mill tailings (Smith 1952). A summary of key historic events in the upper Clark Fork drainage are shown in Figure 2.

Mill tailings were typically deposited behind dams located in adjacent drainages or were discharged directly to Silver Bow Creek. Locations of mill tailing deposits from early mining and milling activities in Butte are evident on maps and photographs contained in Weed (1897, 1912), and Meinzer (1914). Tailing dams along Silver Bow Creek would occasionally fail, and large quantities of tailings were carried downstream of Butte (GCM Services 1983).

#### Agriculture

Agricultural development began in the region in the 1860's as the mining camps provided a ready market for beef, small grains, and vegetables. Irrigation development flourished due to the abundance of surface water, availability of suitable dryland benches, and due to the shortage of adequate seasonal precipitation.

Flooding of Silver Bow Creek and the upper Clark Fork River was intensified by the abundance of tailings and waste dumped into Silver Bow Creek by mining operations in Butte. During flood events, tailings laden-water was spread over many of the irrigated areas. The mine wastes deposited were high in toxic metals and subsequently acidified agricultural soils.

In the 1890's livestock of all types began dieing. The symptoms were bleeding from the nose and mouth, and staggering followed by death. These symptoms indicated arsenic poisoning. Emissions from the Anaconda smelter had contaminated pastureland as far north as Garrison (Horstman 1984). Construction of a taller stack, and a new smelter and reduction works built in the early 1900's alleviated the problem of massive livestock deaths by diluting the emissions. Continuing low level contamination from the stack affected agricultural soils until the smelter closure in the 1980's.

Droughts between 1915 and 1920 and again in the 1930's caused the Upper Clark Fork drainage to be severely damaged by over-grazing (Horstman 1984). Since some areas had elevated metal levels they never became revegetated, as a result excessive soil erosion occurred.



### Site Clean-up

With passage of the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund), studies in support of clean-up of the Upper Clark Fork River were initiated. A National Priorities List of the nations worst abandoned hazardous waste sites listed Silver Bow Creek as 21st of more than 600 sites initially listed. Separate Superfund sites have been identified along Silver Bow Creek, the Upper Clark Fork River, on Butte Hill, at the Anaconda Smelter, and at Milltown Reservoir. Most of these studies are in the remedial investigation (RI) and feasibility study (FS) phase. Engineering design plans will be developed after completion of each RI/FS and selected remedial measures will then be initiated. Superfund has been criticized because of its inherently slow pace of clean-up. In 1986, passage of the Superfund Reauthorization (SARA) provided additional funding for clean-up activities but narrowed the scope of clean-up goals to exclude public welfare, hence only public health and environmental concerns are now addressed. Montana has become concerned that clean-up of the Clark Fork under Superfund may not address the valid concerns of landowners claiming that agricultural production has been impaired due to historical pollution. The State has filed a Natural Resources Damage Claim which may be able to provide funding to address public welfare clean-up goals like agricultural land reclamation.

In recognition of the need for evaluation of measures for reestablishment of forages on agricultural lands along the Upper Clark Fork River, the 1985 legislature provided funding of a Resource Indemnity Trust Fund (RIT) proposal to evaluate forage establishment techniques. Additional funding was received from the U.S. Bureau of Mines to evaluate various soil extractants for determining the bioavailability of metals in metal-contaminated soils and AML sites.

### 1.4 GEOLOGIC SETTING

The geology around the study area is very diverse with soil parent materials ranging from Cretaceous intrusives to Quaternary alluvium. Rocks in the Butte area are largely siliceous with zones containing valuable sulfide minerals and other associated sulfide deposits. The Deer Lodge Valley is bounded to the west by the Anaconda-Pintlar and Flint Creek Ranges which contain a significant section of exposed sedimentary rocks including an abundance of carbonates. East of the study area lies the Boulder Batholith which is composed primarily of highly mineralized quartz monzonite. This lithologic difference is reflected in soil character and surface and ground water chemistry. The soils in the study area vary with the origin of the alluvial parent material.

Soils in the area are in the Beaverell and Tally series. The Beaverell soils are loamy-skeletal, mixed, Aridic Argiborolls. These soils have loam to loamy-sand A1 horizons which are truncated by wind erosion in places. The argillic extends from 6 to 14 inches and is loam in texture. Rock fragments in the base of the argillic and the C horizon average 40 to 50 percent by

volume. The Tally soils are coarse-loamy, mixed Typic Haploborolls. These soils are similar except in lacking a significant clay accumulation. A weak accumulation of carbonates are found below the argillic with some effervescence in the argillic observed occasionally. Both soils are cool variants (cryic) as mapped locally.

## 2.0 LITERATURE REVIEW

Generation of acidity from oxidation of sulfide-rich mine waste is a commonly observed environmental problem. (Caruccio 1968, Sobek and others 1978). Acidification of natural soils through fluvial deposition of sulfidic materials has seldom been described, however the problem is identical in nature to other mine wastes. Although a number of potential remedies for acid generation have been proposed (Kabata-Pendias and Pendias 1984, Smith and others 1974), lime neutralization is the most commonly practiced remedial approach.

Several methods have been devised for determining the lime required to neutralize acidity. For most soils, the lime requirement is the amount necessary to neutralize the "active acidity" which is a function of the soil pH and its buffering capacity. Methods based on measurement of titratable acidity (McLean and others 1966, McLean 1982, Peech 1965) have been used to predict lime requirement for most natural soils. The SMP Buffer method (Shoemaker and others 1961) has received wide acceptance as a standard method for measuring titratable acidity.

Sulfide-rich soils also have "residual acidity" which may be released over many years. Oxidation of pyrite and other sulfides forms sulfuric acid. Research on coal overburden in the Eastern U.S. indicated that residual acidity is a function of sulfide sulfur and to an extent organic sulfur. Sulfate is already oxidized thus does not contribute to acid generation. More recently, organic sulfur was shown to be less acid-producing than inorganic sulfur (Sullivan and Sobek 1982). The pathway (Caruccio 1984) and kinetics (Geidel 1979) of sulfide oxidation is complex. A number of factors have been shown to affect the rate of acid formation including crystalline form (Caruccio and others 1976), oxygen supply, moisture content, and microbial populations (Caruccio 1980). The "acid-base accounting" method has been used to calculate potential acid release from sulfide-rich materials (Smith and others 1976, Sobek and others 1978, Sturey and others 1982). These methods have often been criticized as overestimating lime requirements because coarse sulfide materials are not reactive or may be coated with iron oxides (Burt and Caruccio 1986).

Tailings material is unlike coal overburden in being low in organic sulfur. Therefore sulfide sulfur gives a good indication of maximum residual acidity. Sobek and others (1978) noted that lime required in tons per acre to neutralize residual acidity is percent sulfide sulfur times 31.25.

Most acid soils and overburden materials suppress plant growth due to increased bioavailability of manganese or aluminum ion in low pH soil solution (below 4.5). Reclamation of tailings and smelter contaminated soils is further complicated by the abundance of heavy metals like copper, zinc, cadmium, lead, and arsenic which often causes phytotoxic effects at higher pH levels (soil pH 5.5 to 6.0). Liming has often been recommended as the best technique for improvement of tailings and other metal-enriched mine waste because solubility of the metals decreases with increasing pH. Arsenic solubility, however, is much like phosphorus in having a maximum solubility at neutral pH and under reducing conditions.

Research on the use of lime to reduce metal uptake was recently conducted on this site in a previous investigation (Schafer 1986). Four different forage grasses and alfalfa were planted on acid and metal-enriched soils amended at three rates of lime plus a control. Liming increased soil pH to desired levels and reduced levels of soluble Cu, Zn, Cd, Al, and Mn. Despite this response, vegetative response was limited. Many species displayed Zn or Cu toxicity symptoms and had accumulated phytotoxic levels of Zn. Soils had elevated levels of DTPA extractable (plant available) Zn and Cu even on soils where pH had risen to above 7.0 due to liming. Thus liming alone was not effective in reducing the plant availability of certain phytotoxic metals.

Other workers have used high rates of phosphorus or manure (Kabata Pendias and Pendias 1984 and Watkin and Winch 1974) in conjunction with lime to reduce plant uptake of metals. Although limited information is available, the results appear to be successful on sites high in Zn and Cu.

Several plant species have been evaluated for their adaptation to low soil pH or elevated soil metal levels (Bradshaw and Chadwick 1980). Locally, colonial bentgrass (Agrostis tenuis), and tufted hairgrass (Deschampsia caespitosa) have been found to survive on acid tailings areas. Local seed sources have been documented to exhibit copper and zinc tolerance (Surbrugg 1982). Discussion with local farmers managing these grasses for hay and pasture indicated that toxic metal levels in forage, poor production, low palatability, and high water requirement all preclude the widespread use of these grasses if restoration of agricultural use is desired.

Traditional agricultural forage species vary in their ability to tolerate elevated metals or low pH (Bradshaw and Chadwick 1980). Plant species selected must also be drought tolerant and winter hardy to survive in the region. Additionally, metal uptake by the plant must be determined so that toxic metal accumulation by livestock is prevented (NAS 1980). Fortunately, most species will die before accumulating sufficient metal to cause problems for livestock (Parr and others 1983). Some grasses may accumulate metals (especially copper and arsenic) in root and crown portions of the plant while maintaining moderate levels in plant tops. In some grazing systems, however, metal uptake by livestock can be partly or largely a function of metal in soil or root and crown tissue (Ian Thornton, personal communication) thus prevention of uptake by plant tops alone will not preclude livestock metal toxicity.

### 3.0 METHODS

#### 3.1 SITE SELECTION

A research site was chosen on a metal-contaminated soil located about 5 miles east of Anaconda, Montana on the Hazel Spangler ranch, a large dairy operation (see Figure 1). Several thousand acres of soils contaminated by both smelter emissions and deposition of tailings in irrigation water are found in the vicinity where old surface irrigation systems brought Silver Bow Creek water onto low terraces and alluvial fans.

### 3.2 EXPERIMENTAL DESIGN

Two separate forage trial experiments were conducted on the Spangler site. A Liming study was established in 1985 with three lime rates, and four plant species replicated in a split-plot experimental design. Detailed results of the Liming study are contained in reports by Schafer (1987). A second study was seeded in 1987 to evaluate the ability of lime and other soil amendments to "fix" metals into insoluble and biologically unavailable forms. The "Fixation study" tested lime, lime with phosphorus, and lime-phosphorus-manure treatments against four mixtures of adapted metal-tolerant agronomic grasses and forbes.

#### Liming Study Plot Construction

For the liming study a uniform barren area was selected which had a pH of 5.5 to 5.7 and an EC of 0.3 to 0.4 mmhos/cm. The sodium bicarbonate extractable phosphorus was 64 ppm and extractable arsenic was 34 ppm. The area had been used at one time for irrigated alfalfa production. Many of the old irrigation ditches were still evident in the fields. Only sparse weeds grew in the area due to the accumulation of heavy metals.

#### Plot Layout and Experimental Treatments

The lime study plots were designed to test the effects of liming and species selection on forage establishment. A two factor split block design was used so that species could be drill seeded in one pass through an entire block (Little and Hills 1972). On the lime-species plots, three lime rates and a control were used. Lime rates were designed at 0.5, 1.0, and 2.0 times the lime requirement adjusted for lime purity. An SMP buffer lime test (Shoemaker and others, 1961) predicted that the lime rate necessary to raise the pH to 6.5 was 4.3 tons per acre. Preliminary soil analyses indicated that no measurable sulfide sulfur remained in the soils indicating that only the "active" acidity needed to be neutralized. Rates of 0, 2.15, 4.3, and 8.6 tons of lime per acre were used.

The four forage treatments included three perennial grasses and a grass/legume mixture. Ladak 65 alfalfa (Medicago sativa) and Nordan crested wheatgrass (Agropyron cristatum) were seeded in alternate rows. This treatment represented the traditional mixture used in the past by many area ranchers. Additional forage species included Yindall russian wildrye (Elymus junceus), Mandan 759 pubescent wheatgrass (A. trichophorum), and Sodar streambank wheatgrass (A. riparian). All seeding rates were adjusted for purity and germination to yield 30 pure live seeds per foot of row.

A 0.6 acre site (132 feet by 196 feet) was sprayed in late 1984 with glyphosate to eradicate as many perennial weeds as possible. The research area was then staked into 64 plots (4 replicates). Each plot was 12 by 20 feet in size. The plot diagram is shown below.

SPLIT BLOCK DESIGN  
 STUDY AREA 132' X 136'

|                            |               |
|----------------------------|---------------|
| S1 = ALFALFA/CRESTED       | L0 = CONTROL  |
| S2 = RUSSIAN WILDRYE       | L1 = 2.15 T/A |
| S3 = PUBESCENT WHEATGRASS  | L2 = 4.3 T/A  |
| S4 = STREAMWICK WHEATGRASS | L3 = 8.6 T/A  |

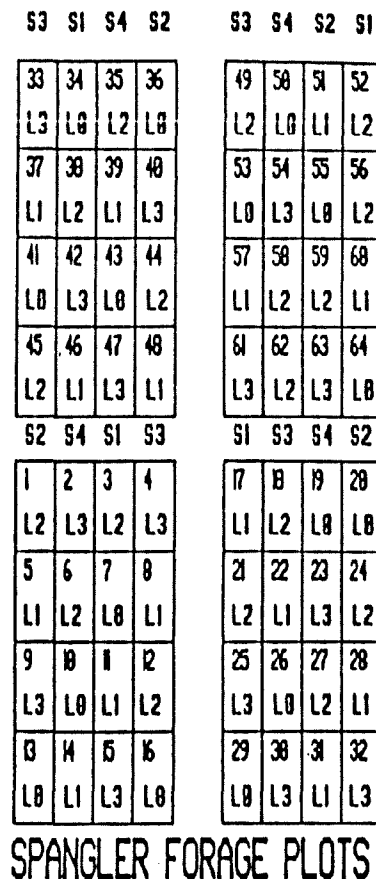


Figure 3. Liming study plot diagram.

#### One-row plots

In addition to the replicated treatments described above, a single row of a number of selected species were planted across all lime rates adjacent to one of the four experimental species used. Vigor and stand ratings were made of all species on 5 June 1986. Since lime rate appeared to have little differential influence on species response, no effort was made to evaluate the effects of liming.

#### Plot Installation

Agricultural lime (calcium carbonate) ground to less than 200 mesh was applied at a rate equivalent to 2.15, 4.3, and 8.6 tons per acre of pure calcium carbonate. Material used was rated at 94 percent effectiveness. Due to the powdery nature of the lime, and windy conditions encountered, lime was mixed with wet sandy soil from the plot prior to double spreading by hand over the plot area.

Ammonium phosphate fertilizer (11-55-0) was surface applied to supply 80 pounds  $P_2O_5$  and 20 pounds of N. Phosphorus was added primarily to counteract

an excessive level of arsenic. After spreading lime, the plots were plowed to a depth of 5 inches (moldboard), surface rocks were removed, and the seedbed packed before restaking on the lime study plots.

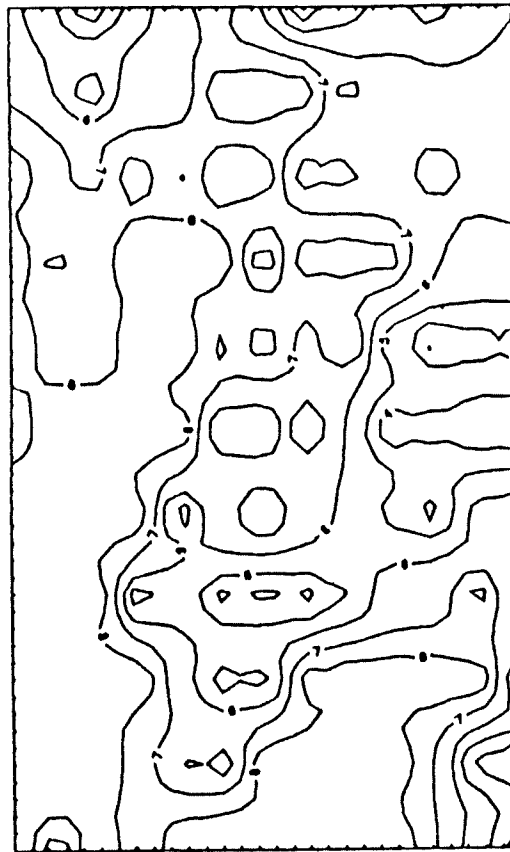
Plots were seeded in mid-April of 1985. A 7 foot double-disk drill was used. All species were seeded at 12 inch row spacing except for Russian wildrye which has 24 inch spacing. Unseasonably windy, hot, and dry conditions followed during the summer of 1985 making the months of January through July the driest on record. Wind erosion filled in and crusted over many of the drill rows causing patchy germination due to trapping of seedlings below the crust. The fall of 1985 had above-normal rainfall while 1986 was a near average rainfall year. While 1987 was a near-normal year, 1988 was one of the hottest and driest on record.

Early plant performance including germination measured in early July of 1985 and establishment measured in June of 1986 was described in a previous report (Schafer 1987). Yields in 1987 were also measured and tissue samples were obtained from the pubescent wheatgrass and crested wheatgrass treatments where sufficient plant material was available.

## Fixation study plot construction

### Plot Selection

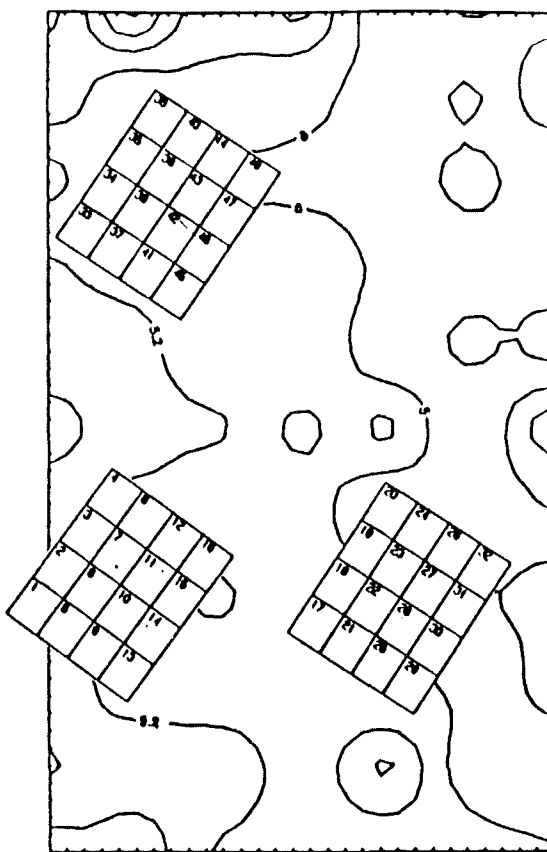
A detailed assessment of soil depth and pH was conducted to find uniform areas for placement of research plots. Three individual plot areas were selected for study. These were areas with soil depth to gravel of more than 6 inches, and surface soil pH of from 4.8 to 5.4. Soils were uniform and barren in appearance. Soil depth (Figure 4) and surface pH (Figure 5) of the plot vicinity, and location of the plots are shown below. The plots are located approximately 75 yards north of the liming study plots. The three plots were used to replicate the experimental treatments and are treated as blocks in the statistical design.



SPANGLER PLOT DEPTH

Scale: 1 inch = 70 feet

Figure 4. Soil depth contours in the vicinity of the research plots.



SPANGLER PLOT pH

Scale: 1 inch = 70 feet

Figure 5. Surface soil pH in the vicinity of the research plots.

### Plot Layout and Experimental Treatments

#### Installation

Experimental soil amendment treatments selected included an 1) experimental control, 2) lime added to counteract active and potential acidity, 3) lime plus phosphorus, and 4) lime plus phosphorus plus manure (Figure 6). The lime rate required for neutralization of acidity was inferred from the previous investigation. A safety factor of fifty percent was used to allow for spatial variations in acidity and lack of mixing. The lime rate selected was 6 tons per acre. Two-thirds of the lime requirement was added as  $\text{CaCO}_3$  (31 pounds per plot) with the remaining one-third supplied by  $\text{Ca}(\text{OH})_2$  (12.75 pounds per plot). Fertilizer triple super phosphate (0-45-0) was used to supply phosphorus. Manure was obtained from corrals used by the Spangler ranch for feeding dairy cattle.

During the week of October 16, 1986 agricultural feed grade lime (calcium carbonate) ground to less than 60 mesh was applied by hand at a rate equivalent of 4 tons per acre to the amended plots. Type S lime ( $\text{Ca}(\text{OH})_2$ ) at a rate of 2 tons/acre was mixed with the agricultural lime before application

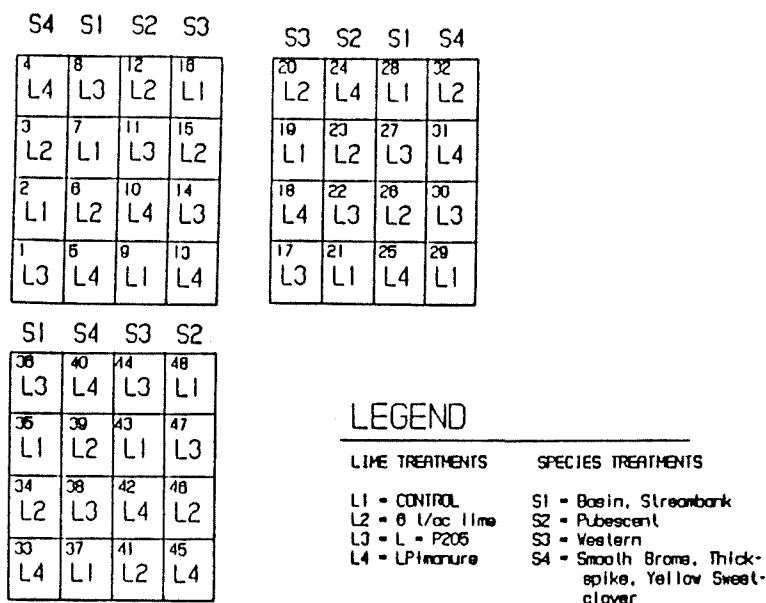


Figure 6. Experimental design of the forage establishment plots.

to make it easier to reduce dust losses of amendment. Phosphorus was applied by hand at the rate of 750 pounds  $\text{P}_2\text{O}_5$  per acre using 6.12 pounds of triple super-phosphate (0-45-0, 45%  $\text{P}_2\text{O}_5$ ) per plot. Manure was applied at the rate of roughly 25 tons per acre on a dry weight basis. A pull-type manure spreader wagon with a ground-driven flail and belt delivery system was used to apply manure to the plots. Considerable handwork was required to evenly distribute manure along the plot margins.

Ammonium nitrate fertilizer (34-0-0) was surface-applied to provide 20 pounds of N. After spreading amendments, the plots were plowed to a depth of 5 inches (moldboard). In order to improve the mixing of amendments plots were plowed a second time in the opposite direction. Surface rocks were removed, and the amendments were allowed to equilibrate over the winter before seeding in the spring.

Plots were seeded in mid-April of 1987. Weighed portions of seed were sown by hand onto plots that were roughened first by harrowing. Species mixtures selected for evaluation are shown in Table 1. Seed for each row of four plots (split-block design) were separated into two halves and each half was spread uniformly to insure good coverage with seed. After seeding, the plots were rolled to provide good seed coverage and soil-seed contact.

Table 1. Seed mixtures designed for evaluation in the forage establishment study.

| Treatment | Species<br>( <u>Latin name</u> )                        | seeds/<br>ft <sup>2</sup> | seeds/lb<br>1000's | purity<br>(%) | germ.<br>(%) | g/plot |
|-----------|---------------------------------------------------------|---------------------------|--------------------|---------------|--------------|--------|
| S1        | Basin wildrye<br>( <u>Elymus cinereus</u> )             | 50                        | 135                | 95.3          | 89           | 31.71  |
|           | Streambank Wheatgrass<br>( <u>Agropyron riparium</u> )  | 50                        | 160                | 90.5          | 97           | 25.84  |
| S2        | Pubescent wheatgrass<br>( <u>Ag. pubescens</u> )        | 100                       | 90                 | 93.2          | 93           | 93.00  |
| S3        | Western wheatgrass<br>( <u>Ag. smithii</u> )            | 100                       | 81                 | 93.7          | 99           | 96.58  |
| S4        | Smooth brome<br>( <u>Bromus inermis</u> )               | 40                        | 137                | 96.4          | 87           | 24.70  |
|           | Thickspike wheatgrass<br>( <u>Ag. dasystachyum</u> )    | 40                        | 145                | 96.7          | 96           | 21.57  |
|           | Yellow Sweetclover<br>( <u>Melilotus officianalus</u> ) | 20                        | 260                | 99.3          | 94           | 5.99   |

Germination and seedling vigor was measured on the 27th and 28th of June, 1987. A qualitative estimate of plant vigor was made of each plot by ranking vigor ranging from 1 for excellent to 9 for very poor vigor.

#### Soil and Plant Tissue Analyses

##### Soil sampling procedure

Soil samples were collected from every plot of both experiments in early August of 1987. Each sample was taken from the 0 to 5 inch layer, which was the depth of lime incorporation, and was expected to be the zone most affected by metal contamination. Samples were a composite of several subsamples taken from the central portion of each plot with an Oakfield corer.

##### Soil sample preparation

All samples were dried at 30 degrees C for 48 hours. They were then sifted through a 2 millimeter sieve, the soil aggregates retained on the sieve were ground and rocks discarded. Each sample was then poured through a splitter where two subsamples of approximately 800 grams were put into two plastic lined bags. The remainder of the sample was archived in a plastic bag.

### Plant sampling procedure

Lime-study plots were drill-seeded on 12 inch spacing so sampling two rows of each species provided a known area to sample. The upper two-thirds of the forage was harvested for determination of yield and to provide a sample for metal analysis on 28 June, 1987. Fixation study plots were seeded in mid-April 1987, making it necessary to wait until September 25 1987, just before senescence to get enough sample from most of the plots. Fixation study plots were broadcast seeded so a random forage sampling method was used for these plots. A diagonal tape was layed corner to corner across each plot and one-square-foot wire frames were placed at 5,8, and 14 feet. The vegetation inside the frame was then clipped in the same manner as experiment one. The vegetation was sorted by species and put in separate bags. Samples were used to measure yield and to analyze the forage metal levels.

### Plant tissue sample preparation

Plant samples for both experiments were dried at 30 degrees C. for 48 hours. The dried samples were then ground and stored in glass jars.

### Soil sample analysis methods

Three methods were used to determine soluble, extractable and total metals. A saturated paste extract from 200 grams of soil was used to obtain soluble metals. For extractable metals (plant-available) a DTPA extraction buffered at 7.3 was utilized. A total dissolution of one gram of soil using nitric acid and hydrogen peroxide was used to measure total metals in soil. The ammonium acetate method discussed in the proposal was found to be equivalent to the DTPA extraction on earlier studies. Schafer (1986) found that both DTPA and ammonium acetate extracts correlated with plant metal levels. The soil and plant analytical methods are outlined in Appendix F. Extracts from each method were shipped to the USBM Spokane Research Center for analysis by inductively-coupled plasma-emission spectrometry. Results are shown in Appendix E.

Additional soil analyses were performed including pH, electrical conductivity (EC), texture, organic matter, cation exchange capacity (CEC), and calcium carbonate percentage (Table 2).

Table 2. Methods of analysis for soil chemical determinations.

| Parameter    | Procedure                                                | Reference               |
|--------------|----------------------------------------------------------|-------------------------|
| pH           | electrode in paste                                       | U.S. Salinity Lab 1954  |
| EC           | saturation paste extract                                 | Sandoval and Power 1977 |
| sol. metals  | soluble, satn. extract                                   | U.S. Salinity Lab 1954  |
| extr. metals | DTPA-TEA extract                                         | Baker and Amacher 1982  |
| Total metals | Total / HNO <sub>3</sub> - H <sub>2</sub> O <sub>2</sub> |                         |

A subsample of each plot sample from both experiments was made into a 1:4 soil to water paste for determination of pH (Appendix H).

The extra 800 gram split of each sample from both experiments was prepared for shipment to Intermountain Laboratories in Sheridan, Wyoming. as follows: A split of each sample not containing manure as an amendment, within a block was composited producing one bulk sample per block for analysis of texture, organic matter (OM), and cation exchange capacity (CEC). The remaining sample from every plot was analyzed for electrical conductivity (EC) and percent carbonate. The samples from plots containing manure were also analyzed for organic matter (OM) and cation exchange capacity (CEC). Data are shown in Appendix E and F.

#### Plant sample analysis method

A plant sample consisted of one species from one plot. Two grams of plant sample from every plot in both experiments was digested using a nitric acid method. The method is described in Appendix A. The digested samples were sent to the USBM Spokane Research Center for metal analysis.

### Suction Lysimeters

Lysimeters were installed in plots 51, 55, 59 and 63 of the lime study. This design enabled the sampling of all four lime rates across one species. The lysimeters were installed at depths of 4 inches, 10 inches and 16 inches for a total of 12 lysimeters. Due to the dry years of 1987-88 and subsequent low soil moisture levels, the only samples collected for analysis were taken on May 14 1988.

Lysimeters were installed in a slurry of 270 mesh pure silica sand. Bentonite grout was placed over the silica sand pack to prevent vertical movement of solution from surface horizons.

### Microtox Bioassay

#### Study Objectives

The purpose of this experiment was to test the Microtox Model 2055 Toxicity Analyzer for determining toxic levels of tailings affected soils and see if it is an easy, fast and cost-effective method to determine phytotoxicity. This system makes use of luminescent marine bacteria for the bioassay. As the bacteria is exposed to toxic materials, the luminosity declines or drops to zero. Light emitted by the bacteria exposed to an unknown sample are compared to light readings from bacteria in a nutrient solution. The Microtox Analyzer was chosen because it allows the bacteria to interact directly with the soil particles during the test. It is believed that the soils may be more phytotoxic than an analysis of a saturated paste extract indicates due to the interaction of roots with soil colloids and the synergistic effects of toxic metals. The Microtox data are compared against plant yield and metal levels in the results section.

For this test 12 soils from experiment two of known metal content and phytotoxicity were used. The samples selected were taken from plots with four soil amendments replicated three times. All plots were seeded to the same species. Appendix B discusses the principles of microtox operation, methods of analysis, and data reduction methods in more detail.

#### AML Site Sampling

A coal waste site at Red Lodge Montana was amended and direct seeded, similar to this project. The site was sampled to determine if soil extractions correlated with vegetation success as in the forage study along Silver Bow Creek. Five stands of Western wheatgrass (Agropyron smithii) were identified on the site. Soil and vegetation samples were taken at each of the five locations. One additional soil sample (#6) was taken in a nonvegetated spot near the center of the site. Plant tissue analyses were compared to DTPA extractable metal levels.

#### Statistical Data Analysis

Analysis of variance for a split-block design was used to verify the significance of forage response to soil amendments, and response of soil chemical parameters to chemical treatments (Snedecor and Cochran 1978). For species or chemical properties indicating a significant response in the analysis of variance, a Neuman-Keuls mean separation test was used to evaluate differences between treatments. Further, simple linear regression was also used to show significant data trends especially between soil and plant metal levels.

## 4.0 RESULTS

### 4.1 QUALITY ASSURANCE

A quality assurance program was utilized to evaluate the data quality for soil and plant extractions. Where possible, reference materials (National Bureau of Standards Tomato Leaves, EPA ICAP Standard Solutions, Appendix H) were used to evaluate the accuracy of measurements. In addition blind replicate samples were submitted to the laboratory to evaluate the precision obtainable. Error in the precision measurement is a reflection of subsampling, extraction, and analytical sources of error. Reagent blanks were also submitted to identify potential sources of contamination or bias. A quality assurance report (Appendix H) was developed for each element analyzed. Procedures for calculating precision and accuracy are found in Appendix H.

Data for manganese, sulfur, iron, zinc, lead, copper, and calcium were with few exceptions of adequate quality (accuracy 80% to 120%, precision  $\pm$  20% relative percent difference at 90% confidence level). Arsenic data were unusable due to very low recovery (<30%). Aluminum accuracy was low due to instrument interferences. The amount of Al reported in reference samples was higher than the known Al concentration. The soluble and DTPA extracts indicated Al contamination, or interference in the ICP analysis. Many calcium values were reported over-range on the ICP and were not re-run after making dilutions rendering much of the data unusable. Iron recoveries were less than 60% in concentrated solutions (plant extracts). Iron contamination or interference was noted in one of the three DTPA and  $\text{HNO}_3/\text{H}_2\text{O}_2$  blanks. The concentration of Ca, Mg, K, and S are of course meaningless, in the DTPA extract. This solution is only used for trace element extraction.

The discussion of study results is limited to those elements that have adequate accuracy, and precision, and that are free of significant levels of contamination. Instrument detection limits (IDL) for each element were found by plotting solution concentrations against the relative standard deviation of replicated readings taken from the inductively coupled plasma (ICP) output. Where the trend line appeared to cross 20% relative standard deviation was taken as the IDL for that element (Appendix H).

### 4.2 LIMING STUDY - SOIL RESPONSE

Results of the Liming study are discussed in detail in a previous report by Schafer (1986). A summary of the results is provided to assist the reader in interpreting results of the soil extract and plant tissue metal level determinations. Soil analysis data from the liming study are contained in Appendix E.

After amendment incorporation, two of the four blocks attained higher pH values due to mixing better subsoil with the surface (Schafer 1986). This alone caused a significant increase in yield over those two blocks. Since the soil response varied so substantially over the blocks analysis of variance

could not be performed for the liming study. Multiple linear regression analyses were used to identify critical relationships between soil chemical parameters, species performance, and plant tissue metal levels discussed in section 4.3.

The average pH levels of the plowed but unamended liming study plots is shown in Figure 7. In the south half of the study area (plots 1 to 32) pH levels were over 7.0 due to tillage. Acid soil conditions were still prevalent in the north half of the plots. Vegetation performance closely paralleled the pH response. Figure 8 shows the average pH levels of the liming study plot area with 2.1, 4.3, and 8.6 tons per acre of applied lime. Average pH levels in the north half of the plots increased substantially with the addition of lime (Table 3).

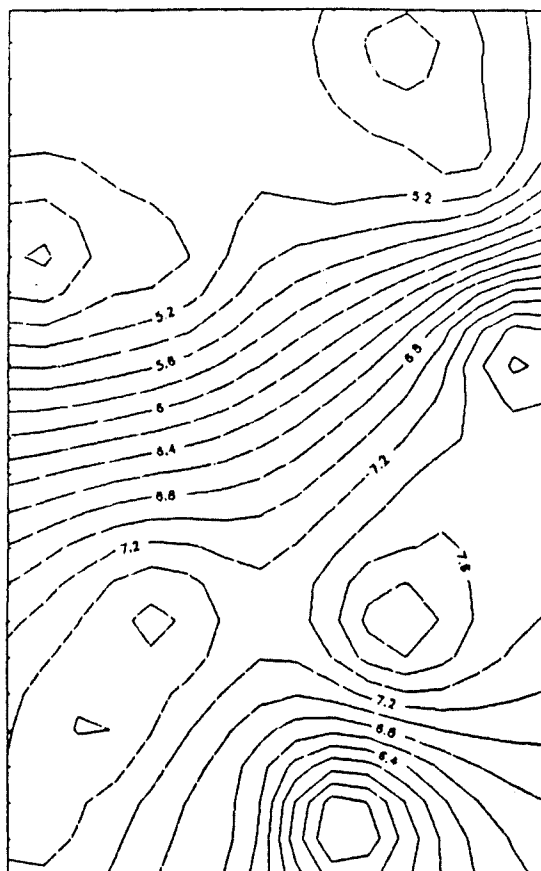
Table 3. Analysis of variance and comparison of soil pH (0-6 inches) of lime study plots 33 to 64.

| <u>Source</u> | <u>DF</u> | <u>F</u> | <u>p</u> |
|---------------|-----------|----------|----------|
| Blocks        | 1         | 7.17     | .0036    |
| Lime          | 3         | .69      | .58      |
| Species       | 3         | .80      | .63      |
| L x S         | 9         |          |          |
| Residual      | 15        |          |          |

| <u>LIME RATE</u><br>(tons/acre) | <u>SOIL pH</u> |
|---------------------------------|----------------|
| 0                               | 4.93 A *       |
| 2.1                             | 5.27 A B       |
| 4.3                             | 5.54 B C       |
| 8.6                             | 5.87 C         |

\* - numbers followed by the same letter are not significantly different at p=.05.



SPANGLER pH OF CONTROL

Figure 7. Original pH of the Spangler liming study forage plots near Anaconda, Montana.

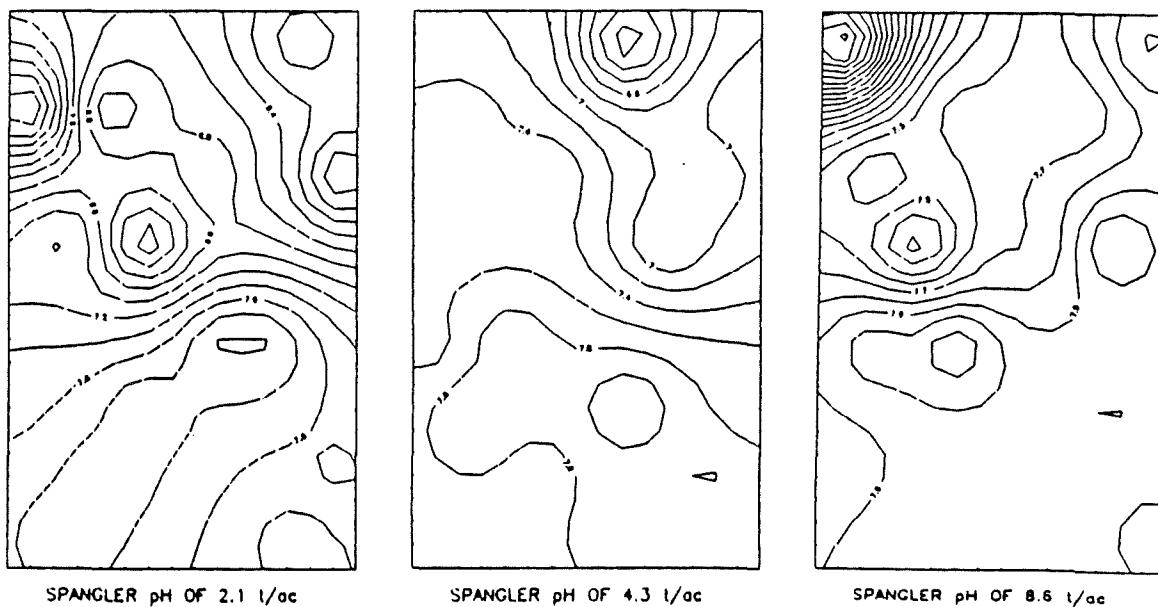


Figure 8 Spangler site soil pH at 2.1, 4.3, and 8.6 tons, lime.

#### 4.3 FIXATION STUDY - SOIL RESPONSE

Soil pH responded to chemical amendments when measured in April, 1987, and August, 1987. The magnitude of pH change due to addition of amendments was also gauged by comparing April, 1987 pH levels to pre-amendment levels (Table 4).

Table 4. Analysis of variance and comparison of mean soil pH values measured in April, 1987; August, 1987; and change in pH due to addition of amendments (April, 1987 - October, 1987).

Soil pH April, 1987

| Source   | DF | F    | p     |
|----------|----|------|-------|
| Blocks   | 2  | -    | -     |
| Lime     | 3  | 5.59 | .0039 |
| Species  | 3  | .23  | .88   |
| L x S    | 9  | .56  | .82   |
| Residual | 30 | -    | -     |

| LIME RATE  | soil pH<br>4/87 | soil pH<br>8/87 | pH change<br>10/86-4/87 |
|------------|-----------------|-----------------|-------------------------|
| 0          | 6.15 a*         | 5.51 a          | 1.08 a                  |
| 6 t/a      | 6.51 b          | 5.84 ab         | 1.53 b                  |
| L + P      | 6.53 b          | 5.68 ab         | 1.40 ab                 |
| L+P+manure | 6.70 b          | 5.97 b          | 1.69 b                  |

\* - Amounts followed by the same letter are not significantly different at  $p=.05$ .

Tillage alone caused a significant increase in soil pH due to mixing of less acid material at depth with contaminated surface soil. Addition of soil amendments further increased soil pH. It is not known if the apparent decrease in pH between April and August is real or an effect of pH meter calibration or pH measurement differences. Relative differences in pH remained the same on the later measurement date.

Addition of lime and phosphorus appeared to increase the soil salinity levels (Table 5) slightly but not enough to affect vegetation response. The EC of the manure plots was significantly higher than the other plots partially explaining the initial slightly poorer vegetative performance of the manure plots.

Table 5. Analysis of variance and comparison of mean soil EC values measured in August, 1987.

| Soil EC August, 1987 |    |      |       |
|----------------------|----|------|-------|
| Source               | DF | F    | p     |
| Blocks               | 2  | -    | -     |
| Lime                 | 3  | 8.66 | .0001 |
| Species              | 3  | .690 | .569  |
| L x S                | 9  | .811 | .611  |
| Residual             | 30 | -    | -     |

| SOIL AMENDMENT | soil EC (mmhos/cm)<br>8/87 |
|----------------|----------------------------|
| O              | .428 a*                    |
| 6 t/a          | .704 a                     |
| L + P          | .502 a                     |
| L+P+manure     | 1.23 b                     |

\* - Amounts followed by the same letter are not significantly different at p=.05.

Analysis of variance was used to investigate the changes in soluble, DTPA extractable, and total metal levels as a function of soil amendments and plant species. Of course no significant changes in soil parameters are expected in response to differences in seeded species. It was hoped that application of different soil amendments might affect soil levels of metals. In order to simplify the results of the analysis of variance, Table 6 indicates which soil properties varied significantly for each experimental factor (soil amendment, plant species, soil by plant interaction). The level of probability that the relationship is random is shown. A probability (P-value) less than 0.05 indicates that a change in metal content in soil was due to the effect of an experimental treatment. Table 7 lists the mean metal levels in mg/kg for the treatments which were significantly correlated with metal reduction.

Table 6. Fixation study - Analysis of Variance for metal levels in soil against soil treatment and vegetation treatment (P-values).

| VARIABLE                       | SOIL (1)<br>AMENDMENT | SPECIES (2) | 1x2 |
|--------------------------------|-----------------------|-------------|-----|
| <u>TOTAL METALS</u>            |                       |             |     |
| Cu - TOT                       | NS                    | .01         | NS  |
| Zn - TOT                       | NS                    | .004        | NS  |
| Mn - TOT                       | NS                    | NS          | NS  |
| Al - TOT                       | NS                    | NS          | NS  |
| Cd - TOT                       | NS                    | NS          | NS  |
| pH - 4/87                      | .001                  | NS          | NS  |
| pH - 8/87                      | .004                  | NS          | NS  |
| pH - 1988                      | NS                    | NS          | NS  |
| EC                             | <.001                 | NS          | NS  |
| <u>DTPA EXTRACTABLE METALS</u> |                       |             |     |
| Cu                             | NS                    | .01         | NS  |
| Zn                             | NS                    | .004        | NS  |
| Mn                             | NS                    | .02         | NS  |
| Al                             | .02                   | NS          | NS  |
| Cd                             | NS                    | NS          | NS  |
| <u>SOLUBLE METALS</u>          |                       |             |     |
| Cu                             | .00                   | NS          | NS  |
| Zn                             | .10                   | NS          | NS  |
| Mn                             | NS                    | NS          | NS  |
| Al                             | NS                    | NS          | NS  |
| Cd                             | NS                    | NS          | NS  |

Table 7. Mean values of variables that were significantly affected by soil amendment treatments or that varied across plant species treatments.

| SOIL AMENDMENT                | EC   | EXTRACTABLE<br>Al | SOLUBLE<br>Cu | SOLUBLE<br>Zn |
|-------------------------------|------|-------------------|---------------|---------------|
| Control                       | .43  | 1.876             | 0.2493        | 1.071         |
| Lime                          | .70  | 1.299             | 0.1687        | 0.5223        |
| Lime + Phosphorus             | .50  | 1.60              | 0.1885        | 0.8578        |
| Lime + Phosphorus +<br>Manure | 1.23 | 0.8828            | 0.3804        | 0.4348        |

| PLANT SPECIES                                              | TOTAL<br>Cu | TOTAL<br>Zn | -----EXTRACTABLE----- |       |       |
|------------------------------------------------------------|-------------|-------------|-----------------------|-------|-------|
|                                                            |             |             | Cu                    | Zn    | Mn    |
| Basin Wildrye<br>( <i>Elymus cinerius</i> )                | 252.5       | 226.0       | 109.4                 | 71.79 | 20.14 |
| Streambank Wheatgrass<br>( <i>Agropyron riparium</i> )     |             |             |                       |       |       |
| Pubescent Wheatgrass<br>( <i>Agropyron trichophorum</i> )  | 192.9       | 188.9       | 95.14                 | 60.66 | 29.84 |
| Western Wheatgrass<br>( <i>Agropyron smithii</i> )         | 169.5       | 167.6       | 70.62                 | 43.66 | 25.46 |
| Smooth Brome<br>( <i>Bromus inermis</i> )                  | 212.0       | 215.5       | 92.1                  | 64.44 | 18.77 |
| Thickspike Wheatgrass<br>( <i>Agropyron dasystachyum</i> ) |             |             |                       |       |       |
| Yellow Sweetclover<br>( <i>Melilotus officianalus</i> )    |             |             |                       |       |       |

Use of different soil amendments did not significantly affect total metal levels as expected. The intent of soil amendments is not to remove metals but to reduce their bioavailability and uptake. Total copper and zinc levels did vary by plant species which is assumed to be a random occurrence rather than an actual influence of plant species on total soil metal levels. This variation in total metals across species may influence the interpretation of plant performance data.

Only DTPA extractable Al was significantly affected by soil amendments. All amendments reduced levels of extractable Al but the manure treatment provided the most striking reduction in extractable Al. Extractable levels of Cu, Zn, and Mn varied across plant species with Basin wildrye having the highest extractable metal levels and western wheatgrass having the lowest. This trend should be considered when evaluating differences in plant success.

Significant differences were noted in soluble copper and zinc levels across soil amendments. While both lime and phosphorus treatments decreased soluble Cu, addition of manure increased soluble Cu. This result was surprising in that Cu is known to bind strongly to organic complexing sites in soils so that lower Cu solubility was expected in manure plots. It appears likely that a considerable quantity of soluble organic matter may have been in solution thus increasing the apparent "soluble" fraction of Cu, when in fact the copper was complexed to soluble organic matter. Soluble zinc was lowest with the lime and manure treatments. Addition of phosphorus increased soluble zinc levels but not as high as the levels found in unamended soils.

Reduction in soluble and extractable Cu and solubility is thought to be essential to encourage improved plant performance on these soils.

#### 4.4 LIMING STUDY - VEGETATIVE RESPONSE

Yield and vigor of lime study plots are reported in Appendix C. As noted in section 4.1, soil pH and soil chemistry was improved over one-half of the study area simply through mixing of less contaminated subsoil with metal-enriched topsoil. Hence, the vegetation established was much better over the blocks that had better subsoil mixed with the surface. As a consequence the analysis of variance tests used to delineate the effects of lime rate on plant performance (yield) were applied only to blocks 3 and 4 (plots 33 to 64) where unamended soils were acid.

Analysis of variance was performed on yield of blocks 3 and 4 but with only 1 degree of freedom for blocks, treatment effects are likely to be obscured (Table 8).

Table 8. Analysis of variance and comparison of fresh weight yields of lime study plots 33 to 64 measured in July, 1987.

| <u>Source</u> | <u>DF</u> | <u>F</u> | <u>p</u> |
|---------------|-----------|----------|----------|
| Blocks        | 1         |          |          |
| Lime          | 3         | 2.03     | .15      |
| Species       | 3         | .15      | .92      |
| L x S         | 9         | .63      | .75      |
| Residual      | 15        |          |          |

| <u>LIME RATE</u><br>(tons/acre) | <u>FRESH WEIGHT YIELD</u><br>(g/ft <sup>2</sup> ) |
|---------------------------------|---------------------------------------------------|
| 0                               | 4.5 A*                                            |
| 2.1                             | 7.1 A                                             |
| 4.3                             | 14.5 A                                            |
| 8.6                             | 12.0 A                                            |

\* - numbers followed by the same letter are not significantly different at p=.05.

Due to the seemingly large increase in yield with added lime, it is expected that these differences would have been significant with additional replication (Table 9).

Table 9. The acid lime study plots (33 to 64) showed no significant effect of increasing lime due to the within - block variability and the limited number of repetitions. Obvious differences in yield are apparent however.

| <u>LIME RATE</u><br>(tons/acre) | <u>YIELD</u><br>(fresh weight g/ft <sup>2</sup> ) |                    |                         |                          |
|---------------------------------|---------------------------------------------------|--------------------|-------------------------|--------------------------|
|                                 | crested<br>wheatgrass                             | russian<br>wildrye | pubescent<br>wheatgrass | streambank<br>wheatgrass |
| 0                               | 3.3                                               | 4.8                | 3.8                     | 6.6                      |
| 2.1                             | 13.9                                              | 11.3               | 1.2                     | 2.4                      |
| 4.3                             | 7.8                                               | 14.0               | 20.0                    | 16.6                     |
| 8.6                             | 6.9                                               | 13.8               | 13.7                    | 14.7                     |

Vigor of vegetation in the plots showed a similar response in that lime rates were correlated with vigor ( $p=.16$ ) while species and vigor were also correlated ( $p=.04$ ). Differences in vigor are shown in Table 10.

Table 10. Differences in vigor across lime rates and species in the lime study plots 33 to 64.

| <u>LIME RATE</u><br>(tons/acre) | <u>VIGOR*</u> | <u>SPECIES</u>        | <u>VIGOR</u> |
|---------------------------------|---------------|-----------------------|--------------|
| 0                               | 9.0           | crested wheatgrass    | 8.25         |
| 2.1                             | 8.5           | russian wildrye       | 7.25         |
| 4.3                             | 8.3           | pubescent wheatgrass  | 9.25         |
| 8.6                             | 7.5           | streambank wheatgrass | 8.5          |

\* - Vigor ratings vary from 0 = excellent to 9 = poor.

Russian wildrye and streambank wheatgrass appeared to be the most successful species seeded on the lime study plots.

Linear regression analysis was used to see if metal levels in the plant tissue of each species correlated with some combination of soil properties. If such correlations were to exist for several species it might indicate a cause and effect relationship between soil chemistry and plant uptake. Results of multiple linear regression analyses using the concentration of various metal levels in the soil as independent variables and plant metal levels as the dependent variable is summarized in Table 11. It was expected that plant metal uptake (Appendix E) would correlate with soluble or extractable soil metal levels. The only two cases where such a relationship was found are shown.

Table 11. Liming Study: Multiple linear regression of metal levels in soils to plant metal uptake.

|                                                           | Metal<br>Form | Regression<br>Equation              | R <sup>2</sup> Values |
|-----------------------------------------------------------|---------------|-------------------------------------|-----------------------|
| <hr/>                                                     |               |                                     |                       |
| CRESTED WHEATGRASS<br>( <u>Agropyron cristatum</u> )      |               |                                     |                       |
| Cu-Val                                                    | DTPA extr     | 27.21 + 0.119 (Cu/DTPA) - 2.87 (pH) | R <sup>2</sup> = .642 |
|                                                           | Soluble       | NS                                  |                       |
|                                                           | Total         | NS                                  |                       |
| <hr/>                                                     |               |                                     |                       |
| PUBESCENT WHEATGRASS<br>( <u>Agropyron trichophorum</u> ) |               |                                     |                       |
| Cd-Val                                                    | DTPA extr     | .8313 - 223 (Cd/DTPA) + .242 (EC)   | R <sup>2</sup> = .602 |
|                                                           | Soluble       | NS                                  |                       |
|                                                           | Total         | NS                                  |                       |

**NOTE:** All other vegetation treatments had non-significant responses to metals from DTPA, Soluble, and Total extraction types.

NS = no significant correlation @ P < .05  
 x/Val = metal level in vegetation (mg/kg)  
 x/DTPA = extractable metal level in soil (mg/kg)  
 x/Soluble = metal level in soil (mg/kg)  
 x/Total = metal level in soil (mg/kg)

It appeared that increasing levels of DTPA Cu or decreasing levels of pH served to increase plant uptake of Cu in Crested wheatgrass. Levels of Cd in Pubescent wheatgrass increased with rising salinity but declined with increasing extractable Cd, an unexpected result.

#### 4.5 FIXATION STUDY - VEGETATIVE RESPONSE

Vegetative response was measured by assessment of germination, and vigor in June of 1987, and measurement of yield and cover in September, 1987 and July, 1988 (Appendix D). Differences in germination for different species was noted but not for different soil amendments (Table 12). Mean germination ranged from 9.9 percent for yellow sweetclover and 13.5 percent for western wheatgrass to 47.6 and 48.6 percent for thickspike and streambank wheatgrass.

Table 12. Analysis of variance and for germination of the forage establishment plots.

| <u>Source</u> | <u>DF</u> | <u>F</u> | <u>p</u> |
|---------------|-----------|----------|----------|
| Blocks        | 2         | -        | -        |
| Lime          | 3         | 1.03     | .38      |
| Species       | 3         | 62.15    | .0001    |
| Replicates    | 2         | .74      | .08      |
| L x S         | 9         | 2.63     | .67      |
| L x R         | 6         | .31      | .93      |
| S x R         | 6         | 1.19     | .32      |
| LxSxR         | 18        | .30      | .99      |
| Residual      | 94        | -        | -        |

Plant vigor was rated from 0 (excellent) to 10 (very poor). Unlike germination, plant vigor responded to soil chemical amendments (Table 13). Vigor was best (lowest number) on the manure treatment and worst on the control.

Table 13. Analysis of variance and comparison of mean vigor of vegetation in late June, 1987.

| Plant Vigor June, 1987 |    |      |       |
|------------------------|----|------|-------|
| Source                 | DF | F    | p     |
| Blocks                 | 2  | -    | -     |
| Lime                   | 3  | 5.71 | .0035 |
| Species                | 3  | 4.42 | .011  |
| L x S                  | 9  | .28  | .90   |
| Residual               | 30 | -    | -     |

| SOIL AMENDMENT | Vigor<br>Rating 8/87 |
|----------------|----------------------|
| O              | 5.08 a               |
| 6 t/a          | 4.17 a               |
| L + P          | 3.67 a               |
| L+P+manure     | 2.75 a               |

Amounts followed by the same letter are not significantly different at  $p=.05$ .

Both plant cover and yield (Table 14) measured in September, 1987 showed a significant response to both chemical amendments and manure. Yields were not increased by liming alone but addition of phosphorus or manure did increase yield. Species varied in their pattern of response with less aggressive species showing maximum yields for the lime plus phosphorus treatments (Figure 9). Aggressive species like Smooth brome had the highest yields for the nutrient-rich manure treatment. Cover was highest in the manure treatments partly due to the increased canopy of weeds (Table 15, Figure 10) but plant cover data in general showed the same pattern as did yield.

Table 14. Analysis of variance and comparison of mean yield of vegetation in September, 1987.

| Plant yield (g/m <sup>2</sup> ) September, 1987 |           |          |          |
|-------------------------------------------------|-----------|----------|----------|
| <u>Source</u>                                   | <u>DF</u> | <u>F</u> | <u>p</u> |
| Blocks                                          | 2         | -        | -        |
| Lime                                            | 3         | 6.42     | .0007    |
| Species                                         | 3         | 5.92     | .0011    |
| L x S                                           | 9         | 1.93     | .052     |
| Residual                                        | 30        | -        | -        |

| <u>SOIL AMENDMENT</u> | <u>Yield (g/ft<sup>2</sup>)</u><br><u>8/87</u> |
|-----------------------|------------------------------------------------|
| O                     | 4.16 a                                         |
| 6 t/a                 | 5.45 a                                         |
| L + P                 | 8.76 b                                         |
| L+P+manure            | 8.25 b                                         |

Amounts followed by the same letter are not significantly different at  $p=.05$ .

Table 15. Analysis of variance and comparison of mean cover of vegetation in September, 1987.

| Plant cover (%) September, 1987 |    |       |       |
|---------------------------------|----|-------|-------|
| Source                          | DF | F     | p     |
| Blocks                          | 2  | -     | -     |
| Lime                            | 3  | 3.85  | .0117 |
| Species                         | 3  | 14.72 | .0001 |
| L x S                           | 9  | 2.32  | .019  |
| Residual                        | 30 | -     | -     |

| SOIL AMENDMENT | VEGETATION COVER (%) |
|----------------|----------------------|
|                | 8/87                 |
| O              | 18.86 a              |
| 6 t/a          | 24.14 ab             |
| L + P          | 27.89 ab             |
| L+P+manure     | 34.28 b              |

Amounts followed by the same letter are not significantly different at  $p=.05$ .

# SPANGLER RIT PLOT

## 1987 Yield

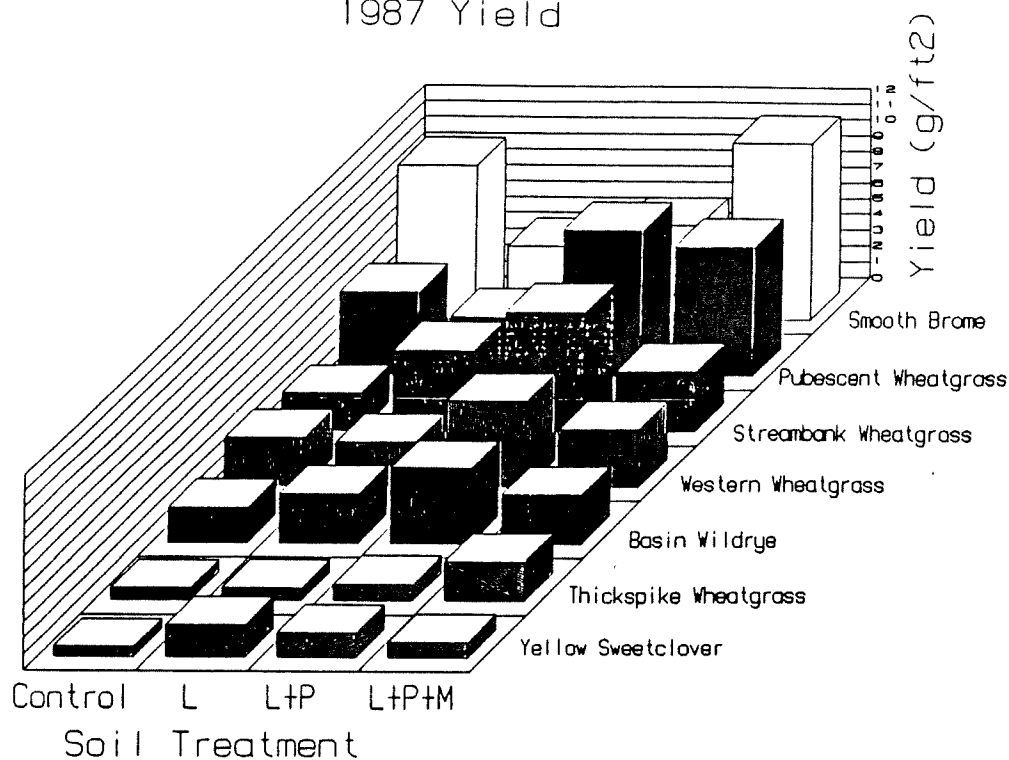


Figure 9. Yield of individual species (measured 9/87) seeded in the Spangler Fixation study plots.

## 1987 Cover

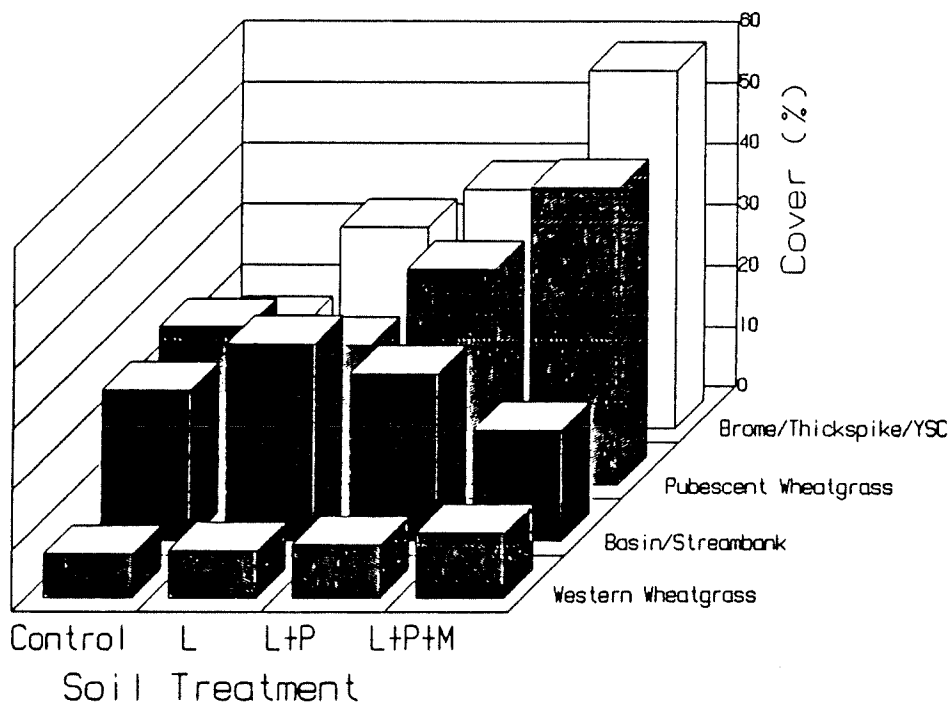


Figure 10. Percent cover of vegetative treatments in the Spangler Fixation study plots.

Yields measured in the second year after seeding showed more marked response to soil treatments, but no differences between treatments. The basin wildrye/streambank wheatgrass seed mixture appeared to out-produce all others while western wheatgrass performed the most poorly (Table 16, Figure 11).

Table 16. Analysis of variance and comparison of mean 1988 yield (dry weight) of forage in the Spangler Fixation study plots.

| <u>Source</u>      | <u>DF</u> | <u>F</u> | <u>p</u> |
|--------------------|-----------|----------|----------|
| Blocks             | 2         |          |          |
| Species            | 3         | 4.12     | .066     |
| Error              | 6         |          |          |
| Soil Amendment     | 3         | 6.35     | .0009    |
| Spec x Soil        | 9         | 1.03     | .42      |
| Location           | 2         | 1.36     | .26      |
| Spec x Location    | 6         | 2.06     | .065     |
| Soil x Location    | 6         | 1.15     | .34      |
| Spec x Soil x Loc. | 18        | 0.77     | .72      |
| Error              | 88        |          |          |

# SPANGLER FIXATION STUDY

## 1988 YIELD

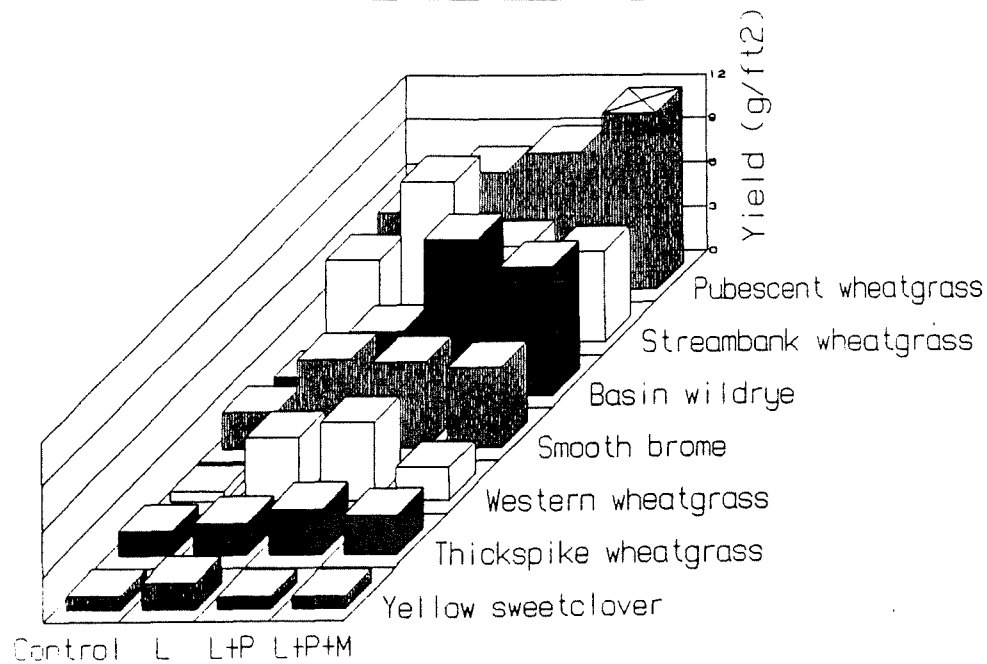


Figure 11. Yield of individual species (measured 6/88) seeded in the Spangler Fixation study plots.

An analysis of variance was performed on plant tissue metal levels to see if particular metal levels varies across soil amendments. A summary of the results is shown (Table 17).

Table 17. Fixation study - Analysis of variance results (probability) for plant metal levels over four different soil amendments.

| METALS | SMOOTH<br>BROME<br>(Br.inermis) | STREAMBANK<br>WHEATGRASS<br>(Ag.riparium) | YELLOW<br>SWEETCLOVER<br>(Melilotus<br>officianalus) | WESTERN<br>WHEATGRASS<br>(Ag.smithii) | THICKSPIKE<br>WHEATGRASS<br>(Ag.dasys-<br>tachyum) | PUBESCENT<br>WHEATGRASS<br>(Ag.tricho-<br>phorum) | BASIN WILD<br>RYE<br>(E.cinereus) |
|--------|---------------------------------|-------------------------------------------|------------------------------------------------------|---------------------------------------|----------------------------------------------------|---------------------------------------------------|-----------------------------------|
| Ca     | NS                              | NS                                        | NS                                                   | NS                                    | NS                                                 | NS                                                | NS                                |
| Mg     | .07                             | NS                                        | NS                                                   | NS                                    | NS                                                 | NS                                                | NS                                |
| K      | NS                              | .02                                       | NS                                                   | .10                                   | NS                                                 | NS                                                | NS                                |
| S      | NS                              | NS                                        | NS                                                   | NS                                    | NS                                                 | NS                                                | NS                                |
| Cu     | .09                             | NS                                        | NS                                                   | NS                                    | NS                                                 | NS                                                | NS                                |
| Zn     | .04                             | NS                                        | NS                                                   | NS                                    | NS                                                 | NS                                                | NS                                |
| Mn     | NS                              | NS                                        | NS                                                   | NS                                    | .02                                                | .004                                              | NS                                |
| Al     | NS                              | NS                                        | NS                                                   | NS                                    | NS                                                 | NS                                                | NS                                |
| Cd     | .09                             | NS                                        | NS                                                   | NS                                    | NS                                                 | NS                                                | .001                              |

NOTE: NS = no significant correlation  
Data are found in Appendix H.

Levels of Cu, Zn, and Cd in Smooth Brome varied significantly across soil amendments. Significant differences in plant tissue levels of Mn in Thickspike and Pubescent wheatgrass was noted across soil amendments. Differences in plant Cd was seen in Basin wildrye.

Linear regressions models were developed for each species to see if metal levels in plant tissue could be predicted from soil metal levels and other soil parameters (pH and EC). Tables 18-24 summarize the correlations.

Table 18. Fixation study - Regression Equations for Basin Wildrye  
(*Elymus cinereus*)

|        | Metal<br>Types | Regression<br>Equation                           | R <sup>2</sup> Values |
|--------|----------------|--------------------------------------------------|-----------------------|
| Cu-Val | DTPA extr      | NS                                               |                       |
|        | Soluble        | NS                                               |                       |
|        | Total          | NS                                               |                       |
| Zn-Val | DTPA extr      | 21.21 + 1.80 (Zn/DTPA)                           | R <sup>2</sup> = .499 |
|        | Soluble        | NS                                               |                       |
|        | Total          | -54.99 + .9097 (Zn/Total)                        | R <sup>2</sup> = .364 |
| Mn-Val | DTPA extr      | 201.5 - 2.70 (Mn/DTPA) - 16.56 pH<br>+ .830 (EC) | R <sup>2</sup> = .903 |
|        | Soluble        | 88.5 - 26.21 (Mn/Soluble)                        | R <sup>2</sup> = .357 |
|        | Total          | 189.2 - .223 (Mn/Total)                          | R <sup>2</sup> = .435 |
| Al-Val | DTPA extr      | NS                                               |                       |
|        | Soluble        | NS                                               |                       |
|        | Total          | NS                                               |                       |
| Cd-Val | DTPA extr      | -1.38 + 1.45 (Cd/DTPA) + 1.31 (EC)               | R <sup>2</sup> = .498 |
|        | Soluble        | NS                                               |                       |
|        | Total          | -1.40 + 1.49 (Cd/Total)                          | R <sup>2</sup> = .387 |

NS = no significant correlation @ P < .05  
x/Val = metal level in vegetation (mg/kg)  
x/DTPA = extractable metal level in soil (mg/kg)  
x/Soluble = metal level in soil (mg/kg)  
x/Total = metal level in soil (mg/kg)

Data found in Appendix H

Table 19. Fixation study - Regression Equations for Streambank Wheatgrass  
(Agropyron riparium)

|        | Metal<br>Types | Regression<br>Equation  | R <sup>2</sup> Values |
|--------|----------------|-------------------------|-----------------------|
| Cu-Val | DTPA extr      | 8.43 + .049 (Cu/DTPA)   | R <sup>2</sup> = .332 |
|        | Soluble        | NS                      |                       |
|        | Total          | 7.75 + .024 (Cu/Total)  | R <sup>2</sup> = .315 |
| Zn-Val | DTPA extr      | 25.22 + 2.07 (Zn/DTPA)  | R <sup>2</sup> = .479 |
|        | Soluble        | NS                      |                       |
|        | Total          | -72.9 + 1.09 (Zn/Total) | R <sup>2</sup> = .405 |
| Mn-Val | DTPA extr      | NS                      |                       |
|        | Soluble        | NS                      |                       |
|        | Total          | NS                      |                       |
| Al-Val | DTPA extr      | NS                      |                       |
|        | Soluble        | NS                      |                       |
|        | Total          | 729.4 - .041 (Al/Total) | R <sup>2</sup> = .389 |
| Cd-Val | DTPA extr      | NS                      |                       |
|        | Soluble        | NS                      |                       |
|        | Total          | NS                      |                       |

NS = no significant correlation @ P < .05

x/Val = metal level in vegetation (mg/kg)

x/DTPA = extractable metal level in soil (mg/kg)

x/Soluble = metal level in soil (mg/kg)

x/Total = metal level in soil (mg/kg)

Data found in Appendix H

Table 20. Fixation study - Regression Equations for Pubescent Wheatgrass  
(*Agropyron trichophorum*)

|        | Metal<br>Types | Regression<br>Equation               | R <sup>2</sup> Values |
|--------|----------------|--------------------------------------|-----------------------|
| Cu-Val | DTPA extr      | NS                                   |                       |
|        | Soluble        | NS                                   |                       |
|        | Total          | -2.20 + .098 (Cu/Total)              | R <sup>2</sup> = .513 |
| Zn-Val | DTPA extr      | 32.17 + 1.40 (Zn/DTPA)               | R <sup>2</sup> = .456 |
|        | Soluble        | -434.2 + 143.9 (Zn/Sol) + 83.58 (pH) | R <sup>2</sup> = .662 |
|        | Total          | -24.8 + .747 (Zn/Total)              | R <sup>2</sup> = .630 |
| Mn-Val | DTPA extr      | NS                                   |                       |
|        | Soluble        | NS                                   |                       |
|        | Total          | NS                                   |                       |
| Al-Val | DTPA extr      | NS                                   |                       |
|        | Soluble        | NS                                   |                       |
|        | Total          | NS                                   |                       |
| Cd-Val | DTPA extr      | -1.058 + 1.69 (Cd/DTPA) + .822 (EC)  | R <sup>2</sup> = .888 |
|        | Soluble        | NS                                   |                       |
|        | Total          | NS                                   |                       |

NS = no significant correlation @ P < .05

x/Val = metal level in vegetation (mg/kg)

x/DTPA = extractable metal level in soil (mg/kg)

x/Soluble = metal level in soil (mg/kg)

x/Total = metal level in soil (mg/kg)

Table 21. Fixation study - Regression Equations for Western Wheatgrass  
(*Agropyron smithii*)

|        | Metal<br>Types | Regression<br>Equation                               | R <sup>2</sup> Values |
|--------|----------------|------------------------------------------------------|-----------------------|
| Cu-Val | DTPA extr      | NS                                                   |                       |
|        | Soluble        | 7.15 + 16.18 (Cu/Sol)                                | R <sup>2</sup> = .568 |
|        | Total          | NS                                                   |                       |
| Zn-Val | DTPA extr      | NS                                                   |                       |
|        | Soluble        | 120.1 + 26.52 (Zn/Sol)                               | R <sup>2</sup> = .293 |
|        | Total          | NS                                                   |                       |
| Mn-Val | DTPA extr      | -2324 + 27.29 (Mn/DTPA) + 379.3<br>(pH) - 401.7 (EC) | R <sup>2</sup> = .660 |
|        | Soluble        | -1118 + 224.7 (Mn/Sol) + 211.3<br>(pH) - 186.8 (EC)  | R <sup>2</sup> = .449 |
|        | Total          | NS                                                   |                       |
| Al-Val | DTPA extr      | NS                                                   |                       |
|        | Soluble        | NS                                                   |                       |
|        | Total          | NS                                                   |                       |
| Cd-Val | DTPA extr      | NS                                                   |                       |
|        | Soluble        | NS                                                   |                       |
|        | Total          | 10.41 - 3.91 (Cd/Total)                              | R <sup>2</sup> = .274 |

NS = no significant correlation @ P < .05

x/Val = metal level in vegetation (mg/kg)

x/DTPA = extractable metal level in soil (mg/kg)

x/Soluble = metal level in soil (mg/kg)

x/Total = metal level in soil (mg/kg)

Table 22. Fixation study - Regression Equations for Smooth Brome  
(*Bromus inermis*)

|        | Metal<br>Types | Regression<br>Equation                            | R <sup>2</sup> Values |
|--------|----------------|---------------------------------------------------|-----------------------|
| Cu-Val | DTPA extr      | NS                                                |                       |
|        | Soluble        | NS                                                |                       |
|        | Total          | NS                                                |                       |
| Zn-Val | DTPA extr      | 68.71 + 2.00 (Zn/DTPA) - 59.18 (EC)               | R <sup>2</sup> = .686 |
|        | Soluble        | 93.4 + 93.63 (Zn/Sol)                             | R <sup>2</sup> = .467 |
|        | Total          | -1.35 + .973 (Zn/Total) - 72.45 (EC)              | R <sup>2</sup> = .598 |
| Mn-Val | DTPA extr      | NS                                                |                       |
|        | Soluble        | NS                                                |                       |
|        | Total          | NS                                                |                       |
| Al-Val | DTPA extr      | NS                                                |                       |
|        | Soluble        | NS                                                |                       |
|        | Total          | NS                                                |                       |
| Cd-Val | DTPA extr      | 10.21 - 1.11 (Cd/DTPA) - 1.22<br>(pH) + .479 (EC) | R <sup>2</sup> = .687 |
|        | Soluble        | NS                                                |                       |
|        | Total          | NS                                                |                       |

NS = no significant correlation @ P < .05  
 x/Val = metal level in vegetation (mg/kg)  
 x/DTPA = extractable metal level in soil (mg/kg)  
 x/Soluble = metal level in soil (mg/kg)  
 x/Total = metal level in soil (mg/kg)

Table 23. Fixation study - Regression Equations for Yellow Sweetclover  
(*Melilotus officianalus*)

|        | Metal<br>Types | Regression<br>Equation                    | R <sup>2</sup> Values |
|--------|----------------|-------------------------------------------|-----------------------|
| Cu-Val | DTPA extr      | 6.14 + 0.078 (Cu/DTPA) - 3.03 (EC)        | R <sup>2</sup> = .577 |
|        | Soluble        | NS                                        |                       |
|        | Total          | 6.07 + .035 (Cu/Total) - 3.26 (EC)        | R <sup>2</sup> = .552 |
| Zn-Val | DTPA extr      | -25.24 + 1.456 (Zn/DTPA)                  | R <sup>2</sup> = .721 |
|        | Soluble        | 33.38 + 63.16 (Zn/Sol)                    | R <sup>2</sup> = .684 |
|        | Total          | -70.52 + .7464 (Zn/Total) -<br>25.05 (EC) | R <sup>2</sup> = .683 |
| Mn-Val | DTPA extr      | 466.8 - 60.65 (pH)                        | R <sup>2</sup> = .351 |
|        | Soluble        | 129.0 + 96.92 (Mn/Sol) - 86.21 (EC)       | R <sup>2</sup> = .300 |
|        | Total          | 757.8 - .410 (Mn/Total) - 73.03 (pH)      | R <sup>2</sup> = .628 |
| Al-Val | DTPA extr      | NS                                        |                       |
|        | Soluble        | NS                                        |                       |
|        | Total          | -165.8 + .024 (Al/Total)                  | R <sup>2</sup> = .34  |
| Cd-Val | DTPA extr      | NS                                        |                       |
|        | Soluble        | NS                                        |                       |
|        | Total          | NS                                        |                       |

NS = no significant correlation @ P < .05

x/Val = metal level in vegetation (mg/kg)

x/DTPA = extractable metal level in soil (mg/kg)

x/Soluble = metal level in soil (mg/kg)

x/Total = metal level in soil (mg/kg)

Table 24. Fixation study - Regression Equations for Thickspike Wheatgrass  
(*Agropyron dasystachyum*)

|        | Metal<br>Types | Regression<br>Equation                | R <sup>2</sup> Values |
|--------|----------------|---------------------------------------|-----------------------|
| Cu-Val | DTPA extr      | 6.58 + 0.05 (Cu/DTPA)                 | R <sup>2</sup> = .472 |
|        | Soluble        | NS                                    |                       |
|        | Total          | 5.77 + .025 (Cu/Total)                | R <sup>2</sup> = .570 |
| Zn-Val | DTPA extr      | 30.41 + 2.02 (Zn/DTPA) - 31.53 (EC)   | R <sup>2</sup> = .772 |
|        | Soluble        | 79.78 + 94.05 (Zn/Sol)                | R <sup>2</sup> = .720 |
|        | Total          | -43.82 + .999 (Zn/Total) - 45.05 (EC) | R <sup>2</sup> = .650 |
| Mn-Val | DTPA extr      | NS                                    |                       |
|        | Soluble        | 71.3 + 21.69 (Mn/Sol)                 | R <sup>2</sup> = .419 |
|        | Total          | 71.3 + 14.32 (Mn/Total)               | R <sup>2</sup> = .389 |
| Al-Val | DTPA extr      | NS                                    |                       |
|        | Soluble        | 224.2 - 184.5 (Al/Sol)                | R <sup>2</sup> = .394 |
|        | Total          | NS                                    |                       |
| Cd-Val | DTPA extr      | NS                                    |                       |
|        | Soluble        | NS                                    |                       |
|        | Total          | NS                                    |                       |

NS = no significant correlation @ P < .05

x/Val = metal level in vegetation (mg/kg)

x/DTPA = extractable metal level in soil (mg/kg)

x/Soluble = metal level in soil (mg/kg)

x/Total = metal level in soil (mg/kg)

Levels of Zn, Cu, and Mn and infrequently Cd were most commonly correlated with metal levels in soils. Although significant correlations were often found with all three soil fractions (soluble, extractable, total), the extractable metal fraction was most frequently the most highly correlated with metal uptake. In many cases the soil pH or EC levels also affected metal uptake with, in general, increasing pH causing a decline in metal level while increasing salinity had the same effect.

Multiple regression analysis was also used to see if either plant or soil levels of metals correlated with overall plant growth as measured by yield (Table 25). Although yield was strongly affected by soil amendment, little correlation existed between yield and plant or soil metal levels. Though this result is surprising, it may suggest that a complex interaction of many potentially toxic metals may be affecting plant performance on these soils. Also it is clear that different species respond to elevated levels of various metals and to different soil amendments differently. Visual metal toxicity symptoms were noted on a number of individual plants in the field plots especially on the unamended control plots, so toxic metal levels are inhibiting vegetative production on unamended soils.

Table 25. Fixation study - Significant Regression Equation for Plant Yield.

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**YIELD AGAINST PLANT TISSUE LEVELS**

Thickspike Wheatgrass  
(*Agropyron dasystachum*)

$$\text{yield} = -0.1699 + 0.4266 (\text{plant tissue Cu}) - 0.016 (\text{plant tissue Zn}) \quad R^2 = 0.447$$


---

**YIELD AGAINST SOIL DTPA EXTR Cu, SOIL DTPA EXTR Zn,  
SOIL pH, AND SOIL LAB EC**

Western Wheatgrass  
(*Agropyron smithii*)

$$\text{yield} = -7.357 + 2.237 (\text{pH}) \quad R^2 = 0.3817$$


---

**YIELD AGAINST SOIL SOLUBLE Cu, SOIL SOLUBLE Zn,  
SOIL Ph, AND SOIL LAB EC**

Streambank Wheatgrass  
(*Agropyron riparion*)

$$\text{yield} = 10.55 - 25.34 (\text{soil soluble Cu}) + 1.082 (\text{soil lab EC}) \quad R^2 = 0.6214$$

Western Wheatgrass  
(*Agropyron Smithii*)

$$\text{yield} = -7.357 + 2.237 (\text{pH}) \quad R^2 = 0.3817$$


---

#### 4.6 LYSIMETER CHEMISTRY RESPONSE

Lysimeters were installed in the fixation study plots by the Montana Bureau of Mines and Geology (MBMG). Results of lysimeter samples collected by the MBMG are presented in Appendix I. Lysimeters were installed at 8, 16, and 24 inches in depth in plots 5, 6, 7, 8, 11, and 15 in block 1. Samples for metal analysis were collected on 6/22/87 and 8/5/87. Comparison of the lysimeter data did not indicate any consistent differences in leachate chemistry due to the use of chemical amendments. This lack of consistent results may be due to any of a number of factors including 1) variability in initial leachate chemistry masking changes in final chemical concentrations, 2) treatments had little effect on leachate chemistry, 3) installation techniques using a slurry of excavated soil as backfill may have masked chemical response.

Liming appeared to cause an increase in soluble calcium at all depths. Addition of phosphorus also caused an increase of phosphorus at all depths. Zinc and manganese concentrations appeared to decrease at all depth in the lime/phosphorus and lime/phosphorus/manure plots. Strontium and arsenic concentrations appeared to increase in all chemical treatments. No consistent differences were noted for other metals.

Lysimeters were installed in the lime study plots in August of 1987. Four plots were selected that included three rates of lime and a control (plots 51, 55, 59, and 63). Due to dry soil conditions during the period of study, lysimeters could only be successfully sampled on 5/14/88. Data for the lysimeter chemistry as well as soil analyses from the 0-6" layer are presented (Table 26).

Soluble metal levels detected in lysimeter samples appeared to decline little if at all with depth. Total metal levels decrease by 50% or more between 6 and 20 inches (Table 27). The soluble and weakly adsorbed fraction of Cu and Zn may be in equilibrium throughout the upper 20 inches of soil while surface layers have an abundance of less chemically active metal forms thus accounting for their higher metal content. We propose that downward leaching and diffusion has transported soluble Cu, Zn, and other metals from surface layers over decades thus accounting for the elevated levels of these metals of depth.

Table 26. Lime study lysimeter data sampled 5/14/88.

| Soil Treatment | Plot#-Depth (in) | pH   | Lysimeter/Soluble |             |             |           | Total (Soil) |     |
|----------------|------------------|------|-------------------|-------------|-------------|-----------|--------------|-----|
|                |                  |      | EC mmhos          | Cu (mg/l)   | Zn (mg/l)   | As (mg/l) | Cu (mg/kg)   | Zn  |
| CONTROL        |                  |      |                   |             |             |           |              |     |
| Soil (0-6"):55 |                  | 4.7  | 0.48              | 0.13(mg/kg) | 0.56(mg/kg) | --        | 190          | 167 |
| Lysimeter:     | 55-4             | 7.26 | 1.24              | 0.03        | 0.99        | 0.240     | --           | --  |
|                | 55-10            | 7.49 | 5.45              | 0.04        | 0.17        | 0.155     | --           | --  |
|                | 55-16            | 7.43 | 7.82              | 0.06        | 0.32        | 0.380     | --           | --  |
| LIME: 2 t/ac   |                  |      |                   |             |             |           |              |     |
| Soil (0-6"):51 |                  | 4.6  | 0.85              | 0.32(mg/kg) | 1.12(mg/kg) | --        | 270          | 203 |
| Lysimeter:     | 51-4             | 6.8  | 1.02              | 0.10        | 2.04        | 0.095     | --           | --  |
|                | 51-10            | 8.0  | 6.92              | 0.04        | 0.28        | 0.50      | --           | --  |
|                | 51-16            | 7.2  | 4.36              | 0.05        | 2.02        | 0.315     | --           | --  |
| LIME: 4 t/ac   |                  |      |                   |             |             |           |              |     |
| Soil (0-6"):59 |                  | 5.9  | 0.90              | 0.04(mg/kg) | 0.10(mg/kg) | --        | 228          | 211 |
| Lysimeter:     | 59-4             | 7.35 | 0.53              | 0.06        | 0.36        | 0.570     | --           | --  |
|                | 59-10            | 8.10 | 3.22              | 0.04        | 0.15        | 0.550     | --           | --  |
|                | 59-16            | 8.0  | 3.79              | 0.04        | 0.14        | 0.250     | --           | --  |
| LIME: 8 t/ac   |                  |      |                   |             |             |           |              |     |
| Soil (0-6"):63 |                  | 5.7  | 0.38              | 0.09(mg/kg) | 0.33(mg/kg) | --        | 370          | 241 |
| Lysimeter:     | 63-4             | --   | --                | --          | --          | --        | --           | --  |
|                | 63-10            | 7.6  | 2.64              | 0.15        | 0.32        | 0.060     | --           | --  |
|                | 63-16            | 7.9  | 1.90              | 0.15        | 0.11        | 0.090     | --           | --  |

Table 27. Total and soluble metal levels in a soil profile sampled near the Spangler forage plots (Multitech, 1986).

| HORIZON | DEPTH<br>(in) | TOTAL (mg/kg) |     |     |      | SOL  |     |
|---------|---------------|---------------|-----|-----|------|------|-----|
|         |               | As            | Cu  | Zn  | Cd   | Cu   | Zn  |
| A1      | 0-6           | 189           | 321 | 249 | 3.6  | .17  | .74 |
| B2t     | 6-14          | 61.2          | 130 | 283 | 3.5  | <.09 | .13 |
| C1      | 14-26         | 68.2          | 136 | 144 | <1.4 | <.06 | .02 |

Metal levels appeared to be correlated to pH levels. In general, lower Cu and Zn and higher As were related to higher leachate pH. The pH was not well correlated to liming rate. The highest soluble As levels (>0.5 mg/l) were found where pH was near or above 8.0. The plot with the highest lime rate (plot 63) also had the highest levels of Cu in leachate. While this may have been due in part to the anomalously high levels of total Cu in this plot, the high lime rate may have increased the abundance of the soluble organic matter fraction. Organic matter is known to break-down at alkaline pH levels. Hence, the Cu may be transported partially as a chelated fraction.

#### 4.7 MICROTOX RESULTS

##### Sample Toxicity Values

Traditionally, Microtox assays are used to compare toxicity between samples by determining the weakest sample dilution in Microtox reagent (at a standard elapsed time interval) where 50 percent of the bacteria (compared to the nutrient blank) die. To find the point where half of the bacteria die, data from various sample dilutions are graphed to get the effective concentration (EC) where 50 percent light loss occurs. This is called the EC 50 value. For this experiment the EC 50 value for every sample in appendix F is simply listed out (Table 28). If no EC 50 value occurred for a sample, the most toxic dilution, time and percent light loss value for that time was recorded. The samples are listed in order of increasing toxicity.

Replicate assays were conducted on most of the samples. The replicate values differed little so they were averaged together to get the corrected percent light loss results.

Table 28. Samples in order of decreasing toxicity.

| SAMPLE<br>NUM. | TREAT-<br>MENT | CONCENTRATION | TIME<br>MIN | EC 50 or<br>% LIGHT LOSS |
|----------------|----------------|---------------|-------------|--------------------------|
| N2             | L1             | 1/20          | 20          | EC 50                    |
| N37            | L1             | 1/10          | 10          | EC 50                    |
| N38            | L3             | 1/10          | 30          | EC 50                    |
| N29            | L1             | 1/5           | 25          | EC 50                    |
| N1             | L3             | 1/5           | 30          | EC 50                    |
| N39            | L2             | 1/5           | 30          | EC 50                    |
| N32            | L2             | 1/5           | 30          | 34                       |
| N3             | L2             | 1/5           | 30          | 25                       |
| N40            | L4             | 1/5           | 30          | 21                       |
| N31            | L4             | 1/5           | 30          | 18                       |
| N4             | L4             | 1/5           | 30          | 16                       |
| N30            | L3             | 1/5           | 30          |                          |

#### PLOT TREATMENT

L1 = CONTROL

L2 = 6 TONS/ACRE LIME

L3 = L2 + 800#  $P_2O_5$

L4 = L3 + MANURE

Metal content data from three different soil extraction methods were compared to the Microtox data. The methods were: saturated paste extract to determine soluble metals, DTPA extraction to determine extractable metals, and a total nitric acid/hydrogen peroxide digest to determine total metals. Metal levels are listed below in the same order of decreasing toxicity as identified by the Microtox results (Table 29).

Table 29. Soluble, extractable, and total metal levels listed in order of decreasing toxicity as determined by Microtox readings.

| SAMPLE<br>NUM.                        | TREAT-<br>MENT | Cu     | Pb<br>SOLUBLE | As<br>METAL | Zn<br>LEVELS | Cd<br>(mg/kg) | Mn     | SUM OF<br>METALS |
|---------------------------------------|----------------|--------|---------------|-------------|--------------|---------------|--------|------------------|
| N2                                    | L1             | 0.183  | 0.022         | 0.032       | 1.765        | 0.032         | 0.480  | 2.514            |
| N37                                   | L1             | 0.147  | 0.021         | 0.029       | 0.805        | 0.029         | 0.267  | 1.298            |
| N38                                   | L3             | 0.160  | 0.022         | 0.038       | 0.720        | 0.032         | 0.406  | 1.378            |
| N29                                   | L1             | 0.174  | 0.024         | 0.123       | 0.429        | 0.035         | 0.405  | 1.19             |
| N1                                    | L3             | 0.154  | 0.022         | 0.083       | 1.532        | 0.031         | 0.636  | 2.458            |
| N39                                   | L2             | 0.169  | 0.024         | 0.034       | 0.549        | 0.034         | 0.388  | 1.198            |
| N32                                   | L2             | 0.211  | 0.30          | 0.092       | 0.049        | 0.042         | 0.107  | .801             |
| N3                                    | L2             | 0.162  | 0.023         | 0.032       | 0.165        | 0.032         | 0.281  | .695             |
| N40                                   | L4             | 0.816  | 0.026         | 0.391       | 0.210        | 0.037         | 1.479  | 2.959            |
| N31                                   | L4             | 0.272  | 0.030         | 0.116       | 0.095        | 0.044         | 0.625  | 1.182            |
| N4                                    | L4             | 0.326  | 0.024         | 0.056       | 0.559        | 0.035         | 1.448  | 2.448            |
| N30                                   | L3             | 0.196  | 0.027         | 0.185       | 0.074        | 0.039         | 0.186  | .71              |
| DTPA EXTRACTABLE METAL LEVELS (mg/kg) |                |        |               |             |              |               |        |                  |
| N2                                    | L1             | 162.30 | 4.33          | 0.20        | 113.57       | 1.99          | 20.49  | 302.8            |
| N37                                   | L1             | 98.75  | 5.81          | 0.20        | 63.96        | 1.46          | 18.14  | 188.3            |
| N38                                   | L3             | 84.55  | 3.42          | 0.29        | 59.77        | 1.54          | 18.18  | 167.8            |
| N29                                   | L1             | 73.18  | 9.89          | 0.81        | 38.99        | 1.33          | 18.24  | 142.4            |
| N1                                    | L3             | 107.32 | 4.64          | 0.77        | 100.04       | 1.88          | 16.42  | 231.1            |
| N39                                   | L2             | 84.70  | 3.87          | 0.24        | 51.90        | 1.22          | 14.17  | 156.1            |
| N32                                   | L2             | 69.40  | 9.49          | 0.78        | 43.47        | 1.17          | 12.34  | 136.7            |
| N3                                    | L2             | 78.74  | 2.90          | 0.20        | 67.24        | 1.39          | 12.21  | 162.7            |
| N40                                   | L4             | 129.78 | 11.42         | 2.22        | 61.82        | 1.98          | 29.42  | 236.6            |
| N31                                   | L4             | 71.58  | 9.39          | 0.93        | 41.07        | 1.53          | 30.96  | 155.5            |
| N4                                    | L4             | 89.68  | 3.40          | 0.41        | 91.14        | 1.57          | 22.65  | 208.9            |
| N30                                   | L3             | 55.25  | 8.82          | 1.15        | 40.34        | 1.18          | 12.04  | 118.8            |
| TOTAL METAL LEVELS (mg/kg)            |                |        |               |             |              |               |        |                  |
| N2                                    | L1             | 342.70 | 70.80         | 26.40       | 291.80       | 2.00          | 671.70 | 1405.4           |
| N37                                   | L1             | 220.10 | 72.00         | 27.20       | 206.30       | 2.00          | 530.70 | 1058.3           |
| N38                                   | L3             | 203.20 | 48.50         | 28.90       | 168.30       | 2.00          | 467.70 | 918.6            |
| N29                                   | L1             | 178.20 | 54.40         | 32.40       | 169.40       | 2.00          | 514.20 | 950.6            |
| N1                                    | L3             | 275.10 | 60.40         | 21.60       | 278.30       | 2.20          | 513.30 | 1150.9           |
| N39                                   | L2             | 158.00 | 37.30         | 16.00       | 173.90       | 2.00          | 418.20 | 805.4            |
| N32                                   | L2             | 182.30 | 71.00         | 40.60       | 202.50       | 2.60          | 563.60 | 1062.3           |
| N3                                    | L2             | 182.10 | 39.20         | 16.00       | 209.10       | 2.00          | 500.30 | 948.7            |
| N40                                   | L4             | 306.10 | 96.10         | 43.30       | 225.90       | 2.00          | 485.90 | 1159.3           |
| N31                                   | L4             | 150.40 | 45.00         | 29.00       | 166.60       | 2.90          | 590.60 | 984.5            |
| N4                                    | L4             | 199.20 | 48.00         | 16.00       | 283.20       | 2.20          | 565.50 | 1114.1           |
| N30                                   | L3             | 146.80 | 48.50         | 28.90       | 168.30       | 2.00          | 467.70 | 862.2            |

Review of the relative toxicity of samples indicated that the control plots were more highly toxic than any amended plots. Plant yield, vigor, and cover data support this trend. The manure plots appeared to have the lowest toxicity but the nutrient enhancement provided by manure may mask any real effects of metal levels on bacteria.

Most of the metal levels from the saturated paste extract are below the instrument detection limits. No single metal level from any of the analyses display highly phytotoxic levels. Reviews of the plant establishment and vigor data from the plots sampled showed the controls (L1) to be phytotoxic with vigor and crop cover increasing from treatment L2 to L4.

It is believed that combinations of metals with levels below toxic limits could cause toxic responses. The Microtox bioassay did show toxic responses in the samples with high levels of more than one metal. Because it is a bioassay method it is not possible to define the type or quantity of toxic elements. There is no strong consistent pattern of increasing toxicity with increasing metal level though many of the most toxic samples did have higher levels of soluble and extractable Zn.

#### Microtox Statistical Analysis

Linear regression was used to find any correlation between percent light loss (L) and different metal levels. The statistically significant metals are summarized in Table 30. Increasing levels of Zn and Al appeared to increase toxicity.

Table 30. Regression equations between Microtox light loss and selected metal levels.

---

|                                                                              |             |
|------------------------------------------------------------------------------|-------------|
| $L = 15.72 - 27.88 (\text{Cu/TOT}) + .2247 (\text{EC})$                      | $R^2 = .76$ |
| $L = 74.46 + 50.8 (\text{Zn/Sol}) - .30 (\text{Zn/TOT})$                     | $R^2 = .72$ |
| $L = 206.1 + .55 (\text{Al/Sol}) + 20.5 (\text{Al/DTPA}) - 31.6 (\text{pH})$ | $R^2 = .82$ |
| $L = 268.4 - 39.2 (\text{pH})$                                               | $R^2 = .67$ |

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L = Light loss (%)

To find any correlation between toxicity and plant yield, and toxicity and plant cover linear regressions were run. The correlation between toxicity and plant yield produced a P-value of 0.166 and an R-squared of 0.1825. The correlation between toxicity and plant cover produced a P-value of 0.119 and an R-squared of 0.2252. The plant cover, which included weeds obtained a better correlation with the toxicity of the soil to bacteria than yield did.

### Microtox Discussion

Although no samples were lethal to the bacteria they did display a toxic response closely correlating to the treatments. An initial test allowing the assay to proceed for over an hour showed a steady consistent downward drift of light. This was the characteristic toxic response varying with treatment over time. For convenience and standardization, all assays were terminated after 30 minutes.

It was felt that cumulative metal content may reflect toxicity. Cumulative metal levels summarized in Table 29 indicates no direct correlation with toxicity. Use of Microtox for bioassay requires extension color correction and turbidity correction and standardization to derive meaningful values.

Even with the color correction procedure it is still a rapid bioassay for determining toxicity. Most bioassay use a small number of animals subjected to a toxin over a period of hours or days. Microtox tests use millions of individual organisms and data are obtained in hours. The Microtox analyzer is quite useful for rapidly screening samples to determine the most toxic ones. Of course, information on specific contaminants or of the amount or level of toxins in a sample are not provided.

Bioassay methods like microtox are especially useful where complex mixtures of potentially toxic contaminants exist in a sample. Organisms can be affected by toxins at lower threshold concentrations when two or more toxins are present (synergistic effect). Presence of two contaminants may also cause the reverse where higher contaminant levels may be tolerated (antagonistic effects). Bioassays can provide a better index of biological toxicity than merely analyzing metal concentration.

#### 4.8 AML Site Analysis

Soil and vegetation was sampled at six locations at a coal and waste AML site as outlined in the methods section. Three soil samples and two vegetation samples were analyzed. Soil-6 was the nonvegetated sample site. The other sites had sparse stands of western wheatgrass directly seeded into limed coal waste.

Table 31. Data from a coal waste site.

| Sample &<br>Loc. #            | pH  | EC<br>mmhos/cm | Cu<br>mg/kg | Mn<br>mg/kg | Zn<br>mg/kg |
|-------------------------------|-----|----------------|-------------|-------------|-------------|
| -----DTPA extraction-----     |     |                |             |             |             |
| Soil-1                        | 4.4 | 2.49           | 4.78        | 5.06        | 11.50       |
| Soil-3                        | 3.9 | 2.61           | 3.64        | 4.26        | 3.70        |
| Soil-6                        | 4.6 | 3.33           | 1.60        | 4.30        | 2.52        |
| -----Plant tissue levels----- |     |                |             |             |             |
| Veg-1                         | --- | ----           | 0.24        | 1.96        | 0.86        |
| Veg-3                         | --- | ----           | 0.26        | 3.16        | 0.94        |

None of the samples (soil or plant) had metal levels indicative of toxicity. The low pH of the site suggests that poor vegetative performance would be expected. Excessive levels of Cu and Zn were not found as in the hard-rock mine waste study sites (Spangler) because these elements are not typically found in coal waste. Manganese and aluminum toxicity most frequently cause phytotoxicity in acid soils where Cu and Zn are not elevated. The DTPA Mn levels did not appear to correlate with plant Mn levels, nor was Mn toxicity suspected on the AML samples.

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## **APPENDIX A**

### **Soil Extractions and Digestion Methods**

#### A.1 SATURATION EXTRACT

Weigh 200 to 400g of air-dry soil of known water content into a plastic container having a snaptight lid. Weigh the container plus contents. Add distilled water to the soil with stirring until it is nearly saturated. Allow the mixture to stand covered for several hours to permit the soil to imbibe the water, and then add more water to achieve a uniformly saturated soil-water paste. At this point, which is generally reproducible to within  $\pm 5\%$ , the soil paste glistens as it reflects light, flows slightly when the container is tipped, slides freely and cleanly off a spatula, and consolidates easily by tapping or jarring the container after a trench is formed in the paste with the side of the spatula. After mixing, allow the sample to stand (preferably overnight, but at least 4 hours), and then recheck the criteria for saturation. Free water should not collect on the soil surface, nor should the paste stiffen markedly or lose its glisten. If the paste is too wet, add additional dry soil to the paste mixture. Upon attainment of saturation, reweigh the container plus contents. Record the increase in weight, which is the amount of water added. Calculate the saturation water percentage from the weight of over-dry soil and the sum of the weights of water added and that initially present in the air-dry sample. After allowing the saturated soil paste to stand 4 or more hours, transfer it to a Buchner or Richards (1949) filter funnel fitted with highly retentive filter paper. Apply vacuum, and collect the filtrate in a test tube or bottle. If the initial filtrate is turbid, refilter or discard it. Terminate the filtration when air begins to pass through the filter. Add 1 drop of  $0.1\%$   $(\text{NaPO}_3)_6$  solution for each 25 ml of extract.

#### A.2 DTPA EXTRACTION

##### Reagents:

Diethylenetriaminepentaacetic acid (DTPA) extracting solution - 0.005M calcium chloride ( $\text{CaCl}_2$ ), and 0.1M triethanolamine [ $\text{TEA}$ ,  $\text{HOCH}_2\text{CH}_2)_3\text{N}$ ] adjusted to pH 7.30 with hydrochloric ( $\text{HCl}$ ): To prepare 10 liters of this solution, dissolve 149.2g of reagent-grade TEA, 19.67g of DTPA, and 14.7g of  $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$  in approximately 200 ml of pure water (10 Megaohms specific resistance or greater). Allow sufficient time for the DTPA to dissolve, and dilute to approximately 9 liters. Adjust the pH to  $7.3 \pm 0.05$  with  $1\text{N HCl}$  while stirring, and dilute to 10 liter. This solution is stable for several months.

##### Extracting procedure:

To 10g of air-dried soil in a 125-ml conical flask, add 10 ml of the DTPA extraction solution. Cover each flask with stretchable parafilm or polyethylene stoppers, and secure upright on a horizontal shaker with a stroke off 8.0 cm and a speed of 120 cycles/min. After exactly 2 hours of shaking, filter the suspensions by gravity through Whatman no. 42 filter paper. The time of shaking is very important because extraction is not complete after 2 hours, the labile and nonlabile quantities of the trace metals will continue to dissolve. The filtrate may be analyzed for the trace metals Fe, Zn, Cu, Ni, and Cd by AAS and appropriate standards as indicated under section 19-2.29 (Methods of Soil Analysis, 1986).

### A.3 ACID DIGESTION OF SEDIMENTS, SLUDGES, AND SOILS

#### 1. Scope and Application

- 1.1 This method is an acid digestion procedure used to prepare sediments, sludges, and soil samples for analysis by flame or furnace atomic absorption spectroscopy (AAS) or by inductively coupled argon plasma spectroscopy (ICP). Samples prepared by this method may be analyzed by AAS or ICP for the following metals:

|           |           |          |
|-----------|-----------|----------|
| Aluminum  | Chromium  | Selenium |
| Antimony  | Cobalt    | Silver   |
| Arsenic   | Copper    | Sodium   |
| Barium    | Iron      | Thallium |
| Beryllium | Lead      | Tin      |
| Cadmium   | Magnesium | Vanadium |
| Calcium   | Manganese | Zinc     |
|           | Nickel    |          |
|           | Potassium |          |

#### 2. Summary of Method

NOTE: A separate digestion procedure is required for furnace AA/ICP analysis.

- 2.1 A representative 1g (wet weight) sample is digested in nitric acid and hydrogen peroxide. The digestate is then refluxed with either nitric acid or hydrochloric acid. Hydrochloric acid is used as the final reflux acid for the furnace AA analysis of Sb and Sn, the flame AA or ICP analysis of Al, Sb, Ba, Be, Ca, Cd, Cr, Co, Cu, Fe, Pb, Mg, Mn, Ni, K, Ag, Na, Tl, Sn, V, and Zn. Nitric acid is employed as the final reflux acid for the furnace AA analysis of As, Be, Cd, Cr, Co, Cu, Fe, Pb, Mn, Ni, Se, Ag, Tl, V, and Zn. A separate sample shall be dried for a total solids determination (Exhibit D, Attachment 9).

#### 3. Apparatus and Materials

- 3.1 Conical beakers - 250 ml Phillips beaker or other appropriate vessel.
- 3.2 Watch glasses
- 3.3 Thermometer that covers range of 0° to 200°C
- 3.4 Whatman No. 42 filter paper or equivalent

#### 4. Reagents

- 4.1 ASTM Type II water (ASTM D1193): Water must be monitored
- 4.2 Concentrated Nitric Acid (sp. gr. 1.41)
- 4.3 Concentrated Hydrochloride Acid (sp. gr. 1.19)
- 4.4 Hydrogen Peroxide (30%): Tin-free grade.

## 5. Sample Preservation, and Handling

5.1 Non-aqueous samples must be refrigerated upon receipt until analysis.

## 6. Procedure

- 6.1 Mix the sample thoroughly to achieve homogeneity. For each digestion procedure, weigh and transfer to a conical beaker a 1.0g portion (to the nearest 0.01 gms) of sample.
- 6.2 Add 10ml of 1:1 nitric acid ( $\text{HNO}_3$ ), mix the slurry and cover with a watch glass. Heat the sample to  $95^\circ\text{C}$  and reflux for 10 minutes without boiling. Allow the sample to cool, add 5 ml of concentrated  $\text{HNO}_3$ , replace the watch glass, and reflux for 30 minutes. Do not allow the volume to be reduced to less than 5ml while maintaining a covering of solution over the bottom of the beaker.
- 6.3 After the second reflux step has been completed and the sample has cooled, add 2ml of Type II water and 3ml of 30% hydrogen peroxide ( $\text{H}_2\text{O}_2$ ). Return the beaker to the hot plate for warming to start the peroxide reaction. Care must be taken to ensure that losses do not occur due to excessively vigorous effervescence. Heat until effervescence subsides, and cool the beaker.
- 6.4 Continue to add 30%  $\text{H}_2\text{O}_2$  in 1ml aliquots with warming until the effervescence is minimal or until the general sample appearance is unchanged. (NOTE: Do not add more than a total of 10ml 30%  $\text{H}_2\text{O}_2$ ).
- 6.5 If the sample is being prepared for the furnace AA analysis of Sn and Sb, the flame AA or ICP analysis of Al, Sb, Ba, Be, Ca, Cd, Cr, Co, Cu, Fe, Pb, Mg, Mn, Ni, K, Ag, Na, Tl, Sn, V, and Zn, add 5ml of 1:1 HCl and 10ml of Type II water, return the covered beaker to the hot plate, and heat for an additional 10 minutes. After cooling, filter through Whatman No. 42 filter paper (or equivalent) and dilute to 100ml with Type II water (or centrifuge the sample - see Note 1). The diluted sample has an approximate acid concentration of 2.5% (v/v) HCl and 5% (v/v)  $\text{HNO}_3$ . Dilute the digestate 1:5 with the deionized water. The sample is now ready for analysis.
- 6.6 If the sample is being prepared for the furnace analysis of As, Be, Cd, Cr, Co, Cu, Fe, Pb, Mn, Ni, Se, Ag, Tl, V, and Zn, continue heating the acid-peroxide digestate until the volume has been reduced to approximately 2ml, add 10ml of Type II water, and warm the mixture. After cooling, filter through Whatman No. 42 filter paper (or equivalent - see Note 1) and dilute to 100ml with Type II water (or centrifuge the sample). The diluted digestate solution contains approximately 2% (v/v)  $\text{HNO}_3$ . Dilute the digestate 1:5 with deionized water. For analysis, withdraw aliquots of appropriate volume, and add any required reagent or matrix modifier. The sample is now ready for analysis (.EPA Test Methods for Evaluating Solid Waste, 1982).

#### A.4 PLANT NITRIC ACID (HNO<sub>3</sub>) DIGEST

##### Procedure:

2.000g of ground plant sample were added to a test tube, then 20 ml. of concentrated nitric acid was added. The samples were stirred and set aside to predigest for several hours (over night). After that the samples were boiled at 130° C for 4 hours. When cooling was completed they were filtered in a Buchner funnel using #42 Whatman filter paper and diluted to 100 ml. by washing distilled deionized water through the filter apparatus.

Samples were then bottled, labeled, and sent off for metal analysis.

## **APPENDIX B**

Microtox Analyzer  
Methods of Operation  
and Data Analysis

## B.2 ABSORBANCE CORRECTION MEASUREMENTS

Highly colored aqueous samples like soil dilutions cause reductions in light levels when analyzed. These light level reductions cannot be distinguished from those caused by toxins in the standard toxicity assay (Microtox). A specially designed Absorbance Correction Cuvette (ACC) is used to measure the amount of color interference in a sample. The ACC is a double walled cuvette illustrated in figure 6. When used the ACC contains reconstituted bacteria in the center and the dilution to be tested in the outer chamber. The light lost from the bacteria due to interference in the dilution is then recorded over a period of time. These values are then used to mathematically correct the results from the standard toxicity assay.

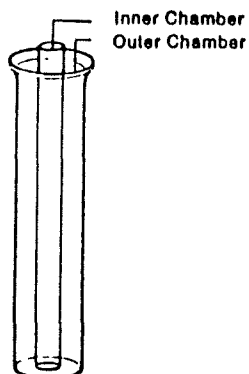


Figure B-1. Absorbance Correction Cuvette.

### B.3 REAGENTS AND SOLUTIONS REQUIRED

#### MICROTOX REAGENT

The Microtox Reagent is a lyophilized strain of marine luminescent bacteria most closely resembling *Photobacterium phosphoreum* in its characteristics. This particular strain was selected because of its suitable light output and its desirable sensitivity to a wide variety of toxicants. The bacterium has not been found to be pathogenic to man.

#### MICROTOX RECONSTITUTION SOLUTION

Microtox Reconstitution Solution is specially purified water which is used to reconstitute the Microtox Reagent.

#### MICROTOX DILUENT

The Microtox Diluent consists of specially purified water containing 2% sodium chloride (NaCl). The Diluent is used to make dilutions of the test sample and of the reconstituted Reagent before testing. It is also used as a non-toxic control (Reagent Blank).

#### MICROTOX OSMOTIC ADJUSTING SOLUTION

Microtox Osmotic Adjusting Solution consists of specially purified water containing 22% NaCl. It is used to adjust the osmolality of a test sample to 2% NaCl or other appropriate salinity (Microtox).

#### B.4 SAMPLE SELECTION

Upon reviewing the vegetation responses to the amendments, the Smooth Brome, Thickspike, Yellow Sweetclover plots were chosen for analysis with the Microtox analyzer. A subsample was taken from the soil samples taken earlier from each of the chosen plots, giving three replicates of each of the four treatments for a total of 12 samples.

#### B.5 MICROTOX ANALYZER SET UP

The analyzer should be turned on a minimum of one hour before use to allow all cooling wells to come to equilibrium. For these tests the temperature of the incubator and turret wells was set at 15 degrees C. The temperature of the precooling well is set at a constant 3 degrees C. The analyzer is zeroed out and set up as outlined in the Microtox System Operating Manual. All wells are loaded with cuvettes. Figure 7 shows location of wells.

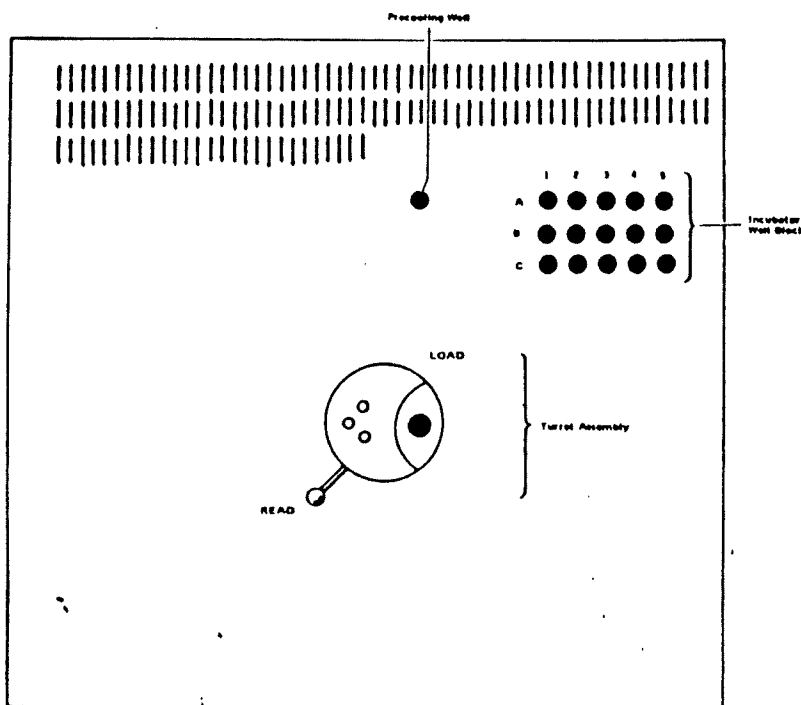


Figure B-2. Top view of Microtox Analyzer.

## B.6 SAMPLE DILUTION

Since the toxicity of the samples to the bacteria was unknown, a range of dilutions were initially tested to find the concentrations that would yield a detectable light loss. It was found that a dilution of less than 1/5 soil to water was impractical. Dilutions from 1/5 to 1/10000 were tested for a toxic response. It was found that any dilution over 1/100 showed no response. All tests were run using dilutions between 1/5 and 1/100. The water used for dilution was a 2% NaCl solution. All dilutions were allowed to equilibrate for several hours before testing.

## B.7 STANDARD ASSAY PROCEDURE

The general procedure used for this experiment will be outlined in this section. Step by step instructions are found in the Microtox Manual.

The initial step is to reconstitute the bacteria in the precooling well. The bacteria needs 15 minutes to revive. While waiting the other wells are loaded. Well A1 is loaded with 1.5 ml of diluent to be used for blanks (Figure 7). Wells A2 through A5 contain the chosen dilutions, 1/5, 1/10, 1/20, and 1/50 for this experiment. The remaining incubator wells in rows B and C are then loaded with 1/2 a milliliter of Diluent. These are allowed to equilibrate for 5 minutes. The next step is to add 10 microliters of reconstituted bacteria to each of the cuvettes in rows B and C. Each cuvette is mixed by pipetting and aspirating the solution five times. After equilibrating for five minutes each cuvette in rows B and C are transferred to the turret well and the light readings are recorded. This is to get a pre-sample light reading so any differences in light can be normalized. The final step is to transfer 0.5 ml of sample from A1 to B1 then again from A1 to C1, being sure to mix the sample well before pipetting and then mixing well when its added to the bacteria in B and C. This is repeated from A2 to A5. This step effectively dilutes the initial concentration by 1/2. Light readings are then recorded for all cuvettes in rows B and C every five minutes for thirty minutes (Appendix A). This method gives replicate data simultaneously. A sample of the raw data is shown below (Table 2).

Table B-1. Example Raw light readings for various soil dilutions.

| PLOT: N1      |     |     |      |     |      |     |      |     |     |     |
|---------------|-----|-----|------|-----|------|-----|------|-----|-----|-----|
| TIME/<br>MIN. | B   |     | 1/50 |     | 1/20 |     | 1/10 |     | 1/5 |     |
|               | b   | c   | b    | c   | b    | c   | b    | c   | b   | c   |
| - SOIL        | 154 | 167 | 157  | 162 | 148  | 169 | 153  | 154 | 150 | 174 |
| + SOIL        |     |     |      |     |      |     |      |     |     |     |
| 5             | 100 | 113 | 91   | 102 | 72   | 84  | 62   | 65  | 40  | 47  |
| 10            | 88  | 102 | 82   | 92  | 66   | 77  | 59   | 61  | 39  | 45  |
| 15            | 81  | 95  | 74   | 85  | 60   | 70  | 54   | 54  | 36  | 40  |
| 20            | 75  | 89  | 68   | 77  | 54   | 62  | 47   | 48  | 31  | 34  |
| 25            | 72  | 84  | 64   | 74  | 50   | 57  | 44   | 44  | 27  | 31  |
| 30            | 67  | 80  | 60   | 69  | 45   | 51  | 38   | 38  | 23  | 26  |

## B.8 ANALYZER COLOR CORRECTION PROCEDURE

Row A is set up the same as mentioned in the standard assay procedure. Row B will now contain Absorbance Correction Cuvettes (ACC). Reconstituted bacteria is pipetted into the center chamber of the ACC and Diluent is pipetted into the outer chamber. An initial light reading is recorded on all ACC's and then the Diluent in the outer chamber is aspirated out and sample is loaded. Light levels are recorded every five minutes for thirty minutes. These light readings are used to correct standard readings for light lost due to cloudiness and changes in light output due to particulate settling (Appendix B).

## B.9 DATA REDUCTION

The raw data in appendix A is converted to % light lost at that given time compared to light emitted from the blank at that given time using equation A.

Equation A:      Initial Blank/Before Soil Reading for specific  
                    dilution \* Soil Reading at time T/Blank at time T  
                    \* 100

The first part of this equation normalizes the initial light outputs between the blank and the cuvette that will contain the soil dilution. The rest of the equation then compares the light output of the soil dilution to the light output of the blank on a percentage basis. These values are shown in Appendix C.

Reviewing these data it became clear that correcting the values due to interference from the cloudy dilution was necessary.

## B.10 CORRECTION FOR ABSORBANCE DUE TO COLOR

The data obtained from the Absorbance Correction Cuvettes in appendix B was used in this section. Due to geometric differences due to color, the equation for absorbance due to color is:

$$A_c = 3.1 \ln(I_0/I_f)$$

where  $I_0$  is the initial light reading for that dilution and  $I_f$  is the light reading of the desired time, giving a corrected value for change in light due to time.

Transmittance is the amount of light that passed through the dilution, with a value of 1 being 100%. The equation for Transmittance is:

$$T_x = (1 - e^{-A_c})/A_c.$$

Since all the soils tested had the same texture, the absorbance due to color was calculated on only two soils. The Ac and Tx values for every dilution at all time intervals for both soils are listed in appendix D. Appendix E graphically displays percent transmittance vs. concentration for both soils tested. Since the data for both soils were very similar one line was fit for both soils at every time interval. All lines were fit on one graph so transmittance values could be used to correct the light readings obtained in the standard assay procedure (Figure 8).

Transmittance vs Concentration  
for Absorbance Correction Cuvettes

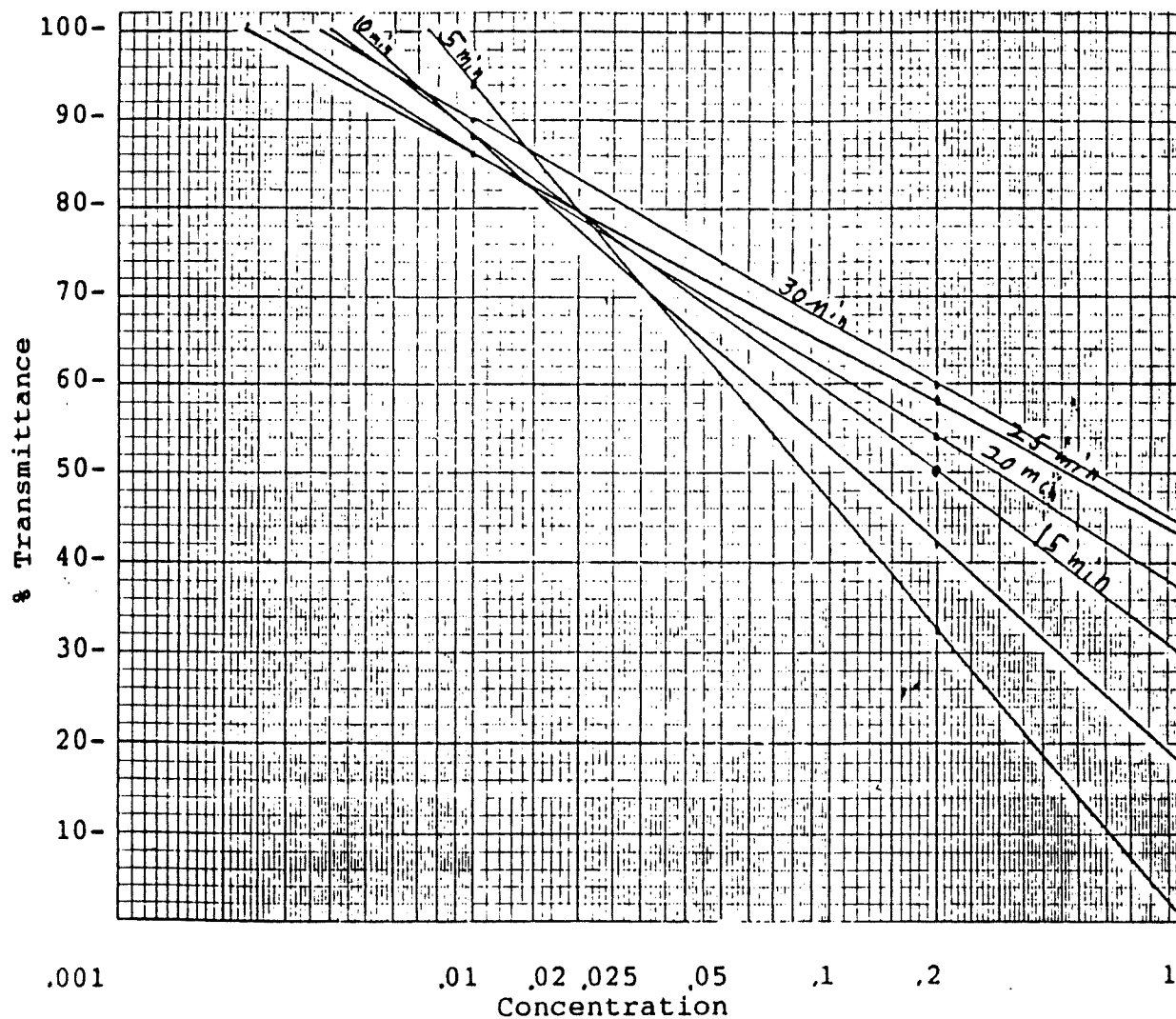


Figure B-3. Transmittance vs. concentration for the ACC's on a semi-log scale.

All values in appendix C are corrected for light loss due to color and converted to percent light loss in relation to a blank due to toxicity by the equation:

$$1 - [(I_{\text{light}})/T_x] = \text{Light loss}$$

where  $I_{\text{light}}$  is the value for a given concentration at a given time from appendix B.  $T_x$  is taken off of Figure 9 at the appropriate concentration and time. It must be noted that in the standard assay procedure the soil dilutions are further diluted, changing a 1/5 soil dilution to a 1/10, so that a 1/10 transmittance value at that time is used in the above equation. This is true for all concentrations. These final corrected percent light loss due to toxicity values are shown in appendix F. A negative percent light loss value shows a gain in light as compared with a blank.

## APPENDIX C

### Yield and Vigor Data from the Lime Study Plots

Table C-1. Vigor and stand ratings (6/5/86), germination (%) (7/85), and establishment (6/86) of vegetation planted on the Lime study plots.

USBM/RCD FORAGE PLOTS  
LIME STUDY  
1985 VEGETATION EVALUATION

| PLOT<br>NUMBER                          | SOIL<br>AMENDMENT<br>CODE | VIGOR<br>RATING<br>(1=GOOD,<br>9=POOR) | STAND<br>RATING<br>(1=GOOD,<br>9=POOR) | GERMINATION<br>(%) | ESTABLISHMENT<br>(%) |
|-----------------------------------------|---------------------------|----------------------------------------|----------------------------------------|--------------------|----------------------|
| ** SPECIES CODE: 1 (Crested wheatgrass) |                           |                                        |                                        |                    |                      |
| 3                                       | 3                         | 3                                      | 7                                      | 23.0               | 1.5                  |
| 7                                       | 1                         | 3                                      | 5                                      | 13.0               | 1.3                  |
| 11                                      | 2                         | 7                                      | 7                                      | 23.0               | 5.8                  |
| 15                                      | 4                         | 6                                      | 7                                      | 21.0               | 11.3                 |
| 17                                      | 2                         | 2                                      | 1                                      | 25.0               | 28.8                 |
| 21                                      | 3                         | 3                                      | 4                                      | 22.0               | 21.0                 |
| 25                                      | 4                         | 6                                      | 5                                      | 35.0               | 11.8                 |
| 29                                      | 1                         | 8                                      | 9                                      | 32.0               | 1.8                  |
| 34                                      | 1                         | 7                                      | 9                                      | 24.0               | 0.0                  |
| 38                                      | 3                         | 5                                      | 9                                      | 13.0               | 0.3                  |
| 42                                      | 4                         | 7                                      | 9                                      | 6.0                | 0.3                  |
| 46                                      | 2                         | 6                                      | 8                                      | 14.0               | 1.3                  |
| 52                                      | 4                         | 7                                      | 8                                      | 48.0               | 0.0                  |
| 56                                      | 3                         | 5                                      | 9                                      | 25.0               | 0.0                  |
| 60                                      | 2                         | 5                                      | 8                                      | 21.0               | 1.0                  |
| 64                                      | 1                         | 4                                      | 5                                      | 27.0               | 13.5                 |

Table C-1. (Continued).

USBM/RCD FORAGE PLOTS  
LIME STUDY  
1985 VEGETATION EVALUATION

| PLOT<br>NUMBER                       | SOIL<br>AMENDMENT<br>CODE | VIGOR<br>RATING<br>(1=GOOD,<br>9=POOR) | STAND<br>RATING<br>(1=GOOD,<br>9=POOR) | GERMINATION<br>(%) | ESTABLISHMENT<br>(%) |
|--------------------------------------|---------------------------|----------------------------------------|----------------------------------------|--------------------|----------------------|
| ** SPECIES CODE: 2 (Russian wildrye) |                           |                                        |                                        |                    |                      |
| 1                                    | 3                         | 5                                      | 9                                      | 7.0                | 15.0                 |
| 5                                    | 2                         | 5                                      | 9                                      | 9.0                | 2.3                  |
| 9                                    | 4                         | 5                                      | 7                                      | 11.0               | 5.8                  |
| 13                                   | 1                         | 5                                      | 4                                      | 14.0               | 13.8                 |
| 20                                   | 1                         | 6                                      | 8                                      | 5.0                | 0.5                  |
| 24                                   | 3                         | 5                                      | 8                                      | 15.0               | 2.0                  |
| 28                                   | 2                         | 7                                      | 8                                      | 18.0               | 4.5                  |
| 32                                   | 4                         | 6                                      | 8                                      | 11.0               | 2.0                  |
| 36                                   | 1                         | 7                                      | 9                                      | 4.0                | 0.3                  |
| 40                                   | 4                         | 7                                      | 8                                      | 11.0               | 0.8                  |
| 44                                   | 3                         | 7                                      | 7                                      | 7.0                | 3.0                  |
| 48                                   | 2                         | 7                                      | 8                                      | 5.0                | 0.0                  |
| 51                                   | 2                         | 7                                      | 9                                      | 12.0               | 0.3                  |
| 55                                   | 1                         | 7                                      | 8                                      | 10.0               | 3.5                  |
| 59                                   | 3                         | 6                                      | 7                                      | 10.0               | 0.5                  |
| 63                                   | 4                         | 7                                      | 8                                      | 5.0                | 1.0                  |

Table C-1. (Continued).

USBM/RCD FORAGE PLOTS  
LIME STUDY  
1985 VEGETATION EVALUATION

| PLOT<br>NUMBER                            | SOIL<br>AMENDMENT<br>CODE | VIGOR<br>RATING<br>(1=GOOD,<br>9=POOR) | STAND<br>RATING<br>(1=GOOD,<br>9=POOR) | GERMINATION<br>(%) | ESTABLISHMENT<br>(%) |
|-------------------------------------------|---------------------------|----------------------------------------|----------------------------------------|--------------------|----------------------|
| ** SPECIES CODE: 3 (Pubescent wheatgrass) |                           |                                        |                                        |                    |                      |
| 4                                         | 4                         | 2                                      | 2                                      | 22.0               | 9.0                  |
| 8                                         | 2                         | 5                                      | 5                                      | 25.0               | 11.8                 |
| 12                                        | 3                         | 4                                      | 4                                      | 18.0               | 6.8                  |
| 16                                        | 1                         | 5                                      | 9                                      | 24.0               | 11.3                 |
| 18                                        | 2                         | 6                                      | 7                                      | 25.0               | 9.5                  |
| 22                                        | 1                         | 5                                      | 4                                      | 24.0               | 5.0                  |
| 26                                        | 3                         | 4                                      | 6                                      | 26.0               | 5.5                  |
| 30                                        | 4                         | 7                                      | 8                                      | 13.0               | 1.3                  |
| 33                                        | 4                         | 6                                      | 9                                      | 8.0                | 0.3                  |
| 37                                        | 2                         | 8                                      | 9                                      | 16.0               | 1.5                  |
| 41                                        | 1                         | 7                                      | 9                                      | 13.0               | 0.0                  |
| 45                                        | 3                         | 7                                      | 9                                      | 16.0               | 2.3                  |
| 49                                        | 3                         | 6                                      | 6                                      | 33.0               | 5.0                  |
| 53                                        | 1                         | 6                                      | 7                                      | 45.0               | 1.5                  |
| 57                                        | 2                         | 4                                      | 8                                      | 38.0               | 0.5                  |
| 61                                        | 4                         | 6                                      | 8                                      | 29.0               | 0.8                  |

Table C-1. (Continued).

USBM/RCD FORAGE PLOTS  
LIME STUDY  
1985 VEGETATION EVALUATION

| PLOT<br>NUMBER                             | SOIL<br>AMENDMENT<br>CODE | VIGOR<br>RATING<br>(1=GOOD,<br>9=POOR) | STAND<br>RATING<br>(1=GOOD,<br>9=POOR) | GERMINATION<br>(%) | ESTABLISHMENT<br>(%) |
|--------------------------------------------|---------------------------|----------------------------------------|----------------------------------------|--------------------|----------------------|
| ** SPECIES CODE: 4 (Streambank wheatgrass) |                           |                                        |                                        |                    |                      |
| 2                                          | 4                         | 5                                      | 5                                      | 15.0               | 4.3                  |
| 6                                          | 3                         | 4                                      | 4                                      | 19.0               | 14.5                 |
| 10                                         | 1                         | 8                                      | 8                                      | 14.0               | 4.0                  |
| 14                                         | 2                         | 5                                      | 6                                      | 19.0               | 13.5                 |
| 19                                         | 1                         | 7                                      | 7                                      | 17.0               | 7.8                  |
| 23                                         | 4                         | 6                                      | 7                                      | 23.0               | 6.5                  |
| 27                                         | 3                         | 7                                      | 8                                      | 15.0               | 4.3                  |
| 31                                         | 2                         | 7                                      | 8                                      | 12.0               | 3.0                  |
| 35                                         | 3                         | 7                                      | 9                                      | 5.0                | 0.0                  |
| 39                                         | 2                         | 7                                      | 9                                      | 10.0               | 0.3                  |
| 43                                         | 1                         | 6                                      | 9                                      | 6.0                | 0.8                  |
| 47                                         | 4                         | 7                                      | 9                                      | 10.0               | 1.8                  |
| 50                                         | 1                         | 6                                      | 7                                      | 29.0               | 0.8                  |
| 54                                         | 4                         | 6                                      | 7                                      | 22.0               | 1.3                  |
| 58                                         | 2                         | 4                                      | 9                                      | 11.0               | 0.0                  |
| 62                                         | 3                         | 5                                      | 8                                      | 14.0               | 1.0                  |

Table C-2. Fresh weight yields of forage in the Spangler Lime study plots in 1987.

USBM/RCD SPANGLER FORAGE STUDY  
LIME STUDY PLOTS  
1987 YIELD (FRESH WEIGHT)

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| PLOT NUMBER | LIME RATE CODE | YIELD FRESH WEIGHT (g/ft <sup>2</sup> ) |
|-------------|----------------|-----------------------------------------|
|-------------|----------------|-----------------------------------------|

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\*\* SPECIES CODE: 1  
Crested wheatgrass

|    |   |        |
|----|---|--------|
| 3  | 2 | 56.72  |
| 7  | 0 | 56.15  |
| 11 | 1 | 21.92  |
| 15 | 3 | 65.97  |
| 17 | 1 | 116.20 |
| 21 | 2 | 103.37 |
| 25 | 3 | 56.93  |
| 29 | 0 | 0.40   |
| 34 | 0 | 1.55   |
| 38 | 2 | 9.38   |
| 42 | 3 | 5.20   |
| 46 | 1 | 14.70  |
| 52 | 3 | 8.38   |
| 56 | 2 | 5.64   |
| 60 | 1 | 13.02  |
| 64 | 0 | 121.77 |

\*\* SPECIES CODE: 2  
Russian wildrye

|    |   |        |
|----|---|--------|
| 1  | 2 | 31.33  |
| 5  | 1 | 41.52  |
| 9  | 3 | 56.17  |
| 13 | 0 | 113.35 |
| 20 | 0 | 122.92 |
| 24 | 2 | 26.40  |
| 28 | 1 | 54.33  |
| 32 | 3 | 39.18  |
| 36 | 0 | 3.77   |
| 40 | 3 | 15.60  |
| 44 | 2 | 14.52  |
| 48 | 1 | 14.17  |
| 51 | 1 | 8.20   |
| 55 | 0 | 5.54   |
| 59 | 2 | 13.17  |
| 63 | 3 | 11.48  |

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Table C-2. (Continued).

USBM/RCD SPANGLER FORAGE STUDY  
LIME STUDY PLOTS  
1987 YIELD (FRESH WEIGHT)

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| PLOT<br>NUMBER | LIME<br>RATE<br>CODE | YIELD<br>FRESH<br>WEIGHT<br>(g/ft <sup>2</sup> ) |
|----------------|----------------------|--------------------------------------------------|
|----------------|----------------------|--------------------------------------------------|

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\*\* SPECIES CODE: 3  
Pubescent wheatgrass

|    |   |        |
|----|---|--------|
| 4  | 3 | 125.63 |
| 8  | 1 | 124.15 |
| 12 | 2 | 128.98 |
| 16 | 0 | 131.55 |
| 18 | 2 | 103.63 |
| 22 | 1 | 136.72 |
| 26 | 0 | 108.48 |
| 30 | 3 | 67.73  |
| 33 | 3 | 0.50   |
| 37 | 1 | 0.28   |
| 41 | 0 | 1.84   |
| 45 | 2 | 1.61   |
| 49 | 2 | 38.40  |
| 53 | 0 | 5.32   |
| 57 | 1 | 1.93   |
| 61 | 3 | 26.20  |

\*\* SPECIES CODE: 4  
Streambank wheatgrass

|    |   |        |
|----|---|--------|
| 2  | 3 | 67.93  |
| 6  | 2 | 68.97  |
| 10 | 0 | 45.53  |
| 14 | 1 | 66.53  |
| 19 | 0 | 118.72 |
| 23 | 3 | 107.82 |
| 27 | 2 | 56.82  |
| 31 | 1 | 35.87  |
| 35 | 2 | 2.85   |
| 39 | 1 | 2.76   |
| 43 | 0 | 1.80   |
| 47 | 3 | 15.65  |
| 50 | 0 | 11.30  |
| 54 | 3 | 13.23  |
| 58 | 1 | 1.77   |
| 62 | 2 | 30.27  |

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## APPENDIX D

### Forage Performance in the Spangler Fixation Study Plots

Table D-1. Germination (6/87) of forage seeded in the Spangler Fixation study plots.

USBM/RCD FORAGE YIELD STUDY  
1987 GERMINATION

| Plot<br>Number                                            | SOIL<br>AMENDMENT<br>CODE | SAMPLE<br>LOCATION | GERMINATION<br>SPECIES 1<br>(plants/<br>ft2) | GERMINATION<br>SPECIES 2<br>(plants/<br>ft2) | GERMINATION<br>SPECIES 3<br>(plants/<br>ft2) | GERMINATION<br>SPECIES 1<br>(%) | GERMINATION<br>SPECIES 2<br>(%) | GERMINATION<br>SPECIES 3<br>(%) |
|-----------------------------------------------------------|---------------------------|--------------------|----------------------------------------------|----------------------------------------------|----------------------------------------------|---------------------------------|---------------------------------|---------------------------------|
| ** SPECIES CODE: 1 (Basin wildrye, Streambank wheatgrass) |                           |                    |                                              |                                              |                                              |                                 |                                 |                                 |
| 5                                                         | 4                         | 5                  | 8                                            | 14                                           | 0                                            | 16.0                            | 28.0                            | 0.0                             |
| 5                                                         | 4                         | 8                  | 8                                            | 39                                           | 0                                            | 16.0                            | 78.0                            | 0.0                             |
| 5                                                         | 4                         | 14                 | 5                                            | 19                                           | 0                                            | 10.0                            | 38.0                            | 0.0                             |
| 6                                                         | 2                         | 5                  | 7                                            | 44                                           | 0                                            | 14.0                            | 88.0                            | 0.0                             |
| 6                                                         | 2                         | 8                  | 1                                            | 26                                           | 0                                            | 2.0                             | 52.0                            | 0.0                             |
| 6                                                         | 2                         | 14                 | 6                                            | 33                                           | 0                                            | 12.0                            | 66.0                            | 0.0                             |
| 7                                                         | 1                         | 5                  | 35                                           | 22                                           | 0                                            | 70.0                            | 44.0                            | 0.0                             |
| 7                                                         | 1                         | 8                  | 1                                            | 25                                           | 0                                            | 2.0                             | 50.0                            | 0.0                             |
| 7                                                         | 1                         | 14                 | 9                                            | 31                                           | 0                                            | 18.0                            | 62.0                            | 0.0                             |
| 8                                                         | 3                         | 5                  | 4                                            | 27                                           | 0                                            | 8.0                             | 54.0                            | 0.0                             |
| 8                                                         | 3                         | 8                  | 8                                            | 35                                           | 0                                            | 16.0                            | 70.0                            | 0.0                             |
| 8                                                         | 3                         | 14                 | 11                                           | 29                                           | 0                                            | 22.0                            | 58.0                            | 0.0                             |
| 25                                                        | 4                         | 5                  | 11                                           | 23                                           | 0                                            | 22.0                            | 46.0                            | 0.0                             |
| 25                                                        | 4                         | 8                  | 8                                            | 27                                           | 0                                            | 16.0                            | 54.0                            | 0.0                             |
| 25                                                        | 4                         | 14                 | 8                                            | 31                                           | 0                                            | 16.0                            | 62.0                            | 0.0                             |
| 26                                                        | 2                         | 5                  | 7                                            | 11                                           | 0                                            | 14.0                            | 22.0                            | 0.0                             |
| 26                                                        | 2                         | 8                  | 23                                           | 39                                           | 0                                            | 46.0                            | 78.0                            | 0.0                             |
| 26                                                        | 2                         | 14                 | 9                                            | 32                                           | 0                                            | 18.0                            | 64.0                            | 0.0                             |
| 27                                                        | 3                         | 5                  | 16                                           | 19                                           | 0                                            | 32.0                            | 38.0                            | 0.0                             |
| 27                                                        | 3                         | 8                  | 22                                           | 31                                           | 0                                            | 44.0                            | 62.0                            | 0.0                             |
| 27                                                        | 3                         | 14                 | 7                                            | 33                                           | 0                                            | 14.0                            | 66.0                            | 0.0                             |
| 28                                                        | 1                         | 5                  | 7                                            | 16                                           | 0                                            | 14.0                            | 32.0                            | 0.0                             |
| 28                                                        | 1                         | 8                  | 27                                           | 12                                           | 0                                            | 54.0                            | 24.0                            | 0.0                             |
| 28                                                        | 1                         | 14                 | 18                                           | 37                                           | 0                                            | 36.0                            | 74.0                            | 0.0                             |
| 33                                                        | 4                         | 5                  | 9                                            | 24                                           | 0                                            | 18.0                            | 48.0                            | 0.0                             |
| 33                                                        | 4                         | 8                  | 11                                           | 29                                           | 0                                            | 22.0                            | 58.0                            | 0.0                             |
| 33                                                        | 4                         | 14                 | 2                                            | 20                                           | 0                                            | 4.0                             | 40.0                            | 0.0                             |
| 34                                                        | 2                         | 5                  | 18                                           | 31                                           | 0                                            | 36.0                            | 62.0                            | 0.0                             |
| 34                                                        | 2                         | 8                  | 12                                           | 34                                           | 0                                            | 24.0                            | 68.0                            | 0.0                             |
| 34                                                        | 2                         | 14                 | 5                                            | 22                                           | 0                                            | 10.0                            | 44.0                            | 0.0                             |
| 35                                                        | 1                         | 5                  | 1                                            | 4                                            | 0                                            | 2.0                             | 8.0                             | 0.0                             |
| 35                                                        | 1                         | 8                  | 6                                            | 18                                           | 0                                            | 12.0                            | 36.0                            | 0.0                             |
| 35                                                        | 1                         | 14                 | 0                                            | 0                                            | 0                                            | 0.0                             | 0.0                             | 0.0                             |
| 36                                                        | 3                         | 5                  | 14                                           | 14                                           | 0                                            | 28.0                            | 28.0                            | 0.0                             |
| 36                                                        | 3                         | 8                  | 16                                           | 19                                           | 0                                            | 32.0                            | 38.0                            | 0.0                             |
| 36                                                        | 3                         | 14                 | 6                                            | 5                                            | 0                                            | 12.0                            | 10.0                            | 0.0                             |

Table D-1. (Continued).

 USBM/RCD FORAGE YIELD STUDY  
 1987 GERMINATION

| Plot<br>Number                            | SOIL<br>AMENDMENT<br>CODE | SAMPLE<br>LOCATION | GERMINATION<br>SPECIES 1<br>(plants/<br>ft <sup>2</sup> ) | GERMINATION<br>SPECIES 2<br>(plants/<br>ft <sup>2</sup> ) | GERMINATION<br>SPECIES 3<br>(plants/<br>ft <sup>2</sup> ) | GERMINATION<br>SPECIES 1<br>(%) | GERMINATION<br>SPECIES 2<br>(%) | GERMINATION<br>SPECIES 3<br>(%) |
|-------------------------------------------|---------------------------|--------------------|-----------------------------------------------------------|-----------------------------------------------------------|-----------------------------------------------------------|---------------------------------|---------------------------------|---------------------------------|
| ** SPECIES CODE: 2 (Pubescent wheatgrass) |                           |                    |                                                           |                                                           |                                                           |                                 |                                 |                                 |
| 9                                         | 1                         | 5                  | 7                                                         | 0                                                         | 0                                                         | 7.0                             | 0.0                             | 0.0                             |
| 9                                         | 1                         | 8                  | 21                                                        | 0                                                         | 0                                                         | 21.0                            | 0.0                             | 0.0                             |
| 9                                         | 1                         | 14                 | 29                                                        | 0                                                         | 0                                                         | 29.0                            | 0.0                             | 0.0                             |
| 10                                        | 4                         | 5                  | 71                                                        | 0                                                         | 0                                                         | 71.0                            | 0.0                             | 0.0                             |
| 10                                        | 4                         | 8                  | 46                                                        | 0                                                         | 0                                                         | 46.0                            | 0.0                             | 0.0                             |
| 10                                        | 4                         | 14                 | 42                                                        | 0                                                         | 0                                                         | 42.0                            | 0.0                             | 0.0                             |
| 11                                        | 3                         | 5                  | 29                                                        | 0                                                         | 0                                                         | 29.0                            | 0.0                             | 0.0                             |
| 11                                        | 3                         | 8                  | 27                                                        | 0                                                         | 0                                                         | 27.0                            | 0.0                             | 0.0                             |
| 11                                        | 3                         | 14                 | 23                                                        | 0                                                         | 0                                                         | 23.0                            | 0.0                             | 0.0                             |
| 12                                        | 2                         | 5                  | 41                                                        | 0                                                         | 0                                                         | 41.0                            | 0.0                             | 0.0                             |
| 12                                        | 2                         | 8                  | 45                                                        | 0                                                         | 0                                                         | 45.0                            | 0.0                             | 0.0                             |
| 12                                        | 2                         | 14                 | 37                                                        | 0                                                         | 0                                                         | 37.0                            | 0.0                             | 0.0                             |
| 21                                        | 1                         | 5                  | 20                                                        | 0                                                         | 0                                                         | 20.0                            | 0.0                             | 0.0                             |
| 21                                        | 1                         | 8                  | 26                                                        | 0                                                         | 0                                                         | 26.0                            | 0.0                             | 0.0                             |
| 21                                        | 1                         | 14                 | 49                                                        | 0                                                         | 0                                                         | 49.0                            | 0.0                             | 0.0                             |
| 22                                        | 3                         | 5                  | 27                                                        | 0                                                         | 0                                                         | 27.0                            | 0.0                             | 0.0                             |
| 22                                        | 3                         | 8                  | 57                                                        | 0                                                         | 0                                                         | 57.0                            | 0.0                             | 0.0                             |
| 22                                        | 3                         | 14                 | 33                                                        | 0                                                         | 0                                                         | 33.0                            | 0.0                             | 0.0                             |
| 23                                        | 2                         | 5                  | 43                                                        | 0                                                         | 0                                                         | 43.0                            | 0.0                             | 0.0                             |
| 23                                        | 2                         | 8                  | 45                                                        | 0                                                         | 0                                                         | 45.0                            | 0.0                             | 0.0                             |
| 23                                        | 2                         | 14                 | 37                                                        | 0                                                         | 0                                                         | 37.0                            | 0.0                             | 0.0                             |
| 24                                        | 4                         | 5                  | 28                                                        | 0                                                         | 0                                                         | 28.0                            | 0.0                             | 0.0                             |
| 24                                        | 4                         | 8                  | 58                                                        | 0                                                         | 0                                                         | 58.0                            | 0.0                             | 0.0                             |
| 24                                        | 4                         | 14                 | 21                                                        | 0                                                         | 0                                                         | 21.0                            | 0.0                             | 0.0                             |
| 45                                        | 4                         | 5                  | 21                                                        | 0                                                         | 0                                                         | 21.0                            | 0.0                             | 0.0                             |
| 45                                        | 4                         | 8                  | 47                                                        | 0                                                         | 0                                                         | 47.0                            | 0.0                             | 0.0                             |
| 45                                        | 4                         | 14                 | 37                                                        | 0                                                         | 0                                                         | 37.0                            | 0.0                             | 0.0                             |
| 46                                        | 2                         | 5                  | 45                                                        | 0                                                         | 0                                                         | 45.0                            | 0.0                             | 0.0                             |
| 46                                        | 2                         | 8                  | 56                                                        | 0                                                         | 0                                                         | 56.0                            | 0.0                             | 0.0                             |
| 46                                        | 2                         | 14                 | 30                                                        | 0                                                         | 0                                                         | 30.0                            | 0.0                             | 0.0                             |
| 47                                        | 3                         | 5                  | 53                                                        | 0                                                         | 0                                                         | 53.0                            | 0.0                             | 0.0                             |
| 47                                        | 3                         | 8                  | 52                                                        | 0                                                         | 0                                                         | 52.0                            | 0.0                             | 0.0                             |
| 47                                        | 3                         | 14                 | 39                                                        | 0                                                         | 0                                                         | 39.0                            | 0.0                             | 0.0                             |
| 48                                        | 1                         | 5                  | 43                                                        | 0                                                         | 0                                                         | 43.0                            | 0.0                             | 0.0                             |
| 48                                        | 1                         | 8                  | 72                                                        | 0                                                         | 0                                                         | 72.0                            | 0.0                             | 0.0                             |
| 48                                        | 1                         | 14                 | 21                                                        | 0                                                         | 0                                                         | 21.0                            | 0.0                             | 0.0                             |

Table D-1. (continued).

 USBM/RCD FORAGE YIELD STUDY  
 1987 GERMINATION

| Plot<br>Number                          | SOIL<br>AMENDMENT<br>CODE | SAMPLE<br>LOCATION | GERMINATION<br>SPECIES 1<br>(plants/<br>ft2) | GERMINATION<br>SPECIES 2<br>(plants/<br>ft2) | GERMINATION<br>SPECIES 3<br>(plants/<br>ft2) | GERMINATION<br>SPECIES 1<br>(%) | GERMINATION<br>SPECIES 2<br>(%) | GERMINATION<br>SPECIES 3<br>(%) |
|-----------------------------------------|---------------------------|--------------------|----------------------------------------------|----------------------------------------------|----------------------------------------------|---------------------------------|---------------------------------|---------------------------------|
| ** SPECIES CODE: 3 (Western wheatgrass) |                           |                    |                                              |                                              |                                              |                                 |                                 |                                 |
| 13                                      | 4                         | 5                  | 12                                           | 0                                            | 0                                            | 12.0                            | 0.0                             | 0.0                             |
| 13                                      | 4                         | 8                  | 8                                            | 0                                            | 0                                            | 8.0                             | 0.0                             | 0.0                             |
| 13                                      | 4                         | 14                 | 20                                           | 0                                            | 0                                            | 20.0                            | 0.0                             | 0.0                             |
| 14                                      | 3                         | 5                  | 12                                           | 0                                            | 0                                            | 12.0                            | 0.0                             | 0.0                             |
| 14                                      | 3                         | 8                  | 29                                           | 0                                            | 0                                            | 29.0                            | 0.0                             | 0.0                             |
| 14                                      | 3                         | 14                 | 4                                            | 0                                            | 0                                            | 4.0                             | 0.0                             | 0.0                             |
| 15                                      | 2                         | 5                  | 15                                           | 0                                            | 0                                            | 15.0                            | 0.0                             | 0.0                             |
| 15                                      | 2                         | 12                 | 15                                           | 0                                            | 0                                            | 15.0                            | 0.0                             | 0.0                             |
| 15                                      | 2                         | 14                 | 4                                            | 0                                            | 0                                            | 4.0                             | 0.0                             | 0.0                             |
| 16                                      | 1                         | 5                  | 1                                            | 0                                            | 0                                            | 1.0                             | 0.0                             | 0.0                             |
| 16                                      | 1                         | 8                  | 8                                            | 0                                            | 0                                            | 8.0                             | 0.0                             | 0.0                             |
| 16                                      | 1                         | 14                 | 3                                            | 0                                            | 0                                            | 3.0                             | 0.0                             | 0.0                             |
| 17                                      | 3                         | 5                  | 21                                           | 0                                            | 0                                            | 21.0                            | 0.0                             | 0.0                             |
| 17                                      | 3                         | 8                  | 25                                           | 0                                            | 0                                            | 25.0                            | 0.0                             | 0.0                             |
| 17                                      | 3                         | 14                 | 39                                           | 0                                            | 0                                            | 39.0                            | 0.0                             | 0.0                             |
| 18                                      | 4                         | 5                  | 5                                            | 0                                            | 0                                            | 5.0                             | 0.0                             | 0.0                             |
| 18                                      | 4                         | 8                  | 12                                           | 0                                            | 0                                            | 12.0                            | 0.0                             | 0.0                             |
| 18                                      | 4                         | 14                 | 11                                           | 0                                            | 0                                            | 11.0                            | 0.0                             | 0.0                             |
| 19                                      | 1                         | 5                  | 22                                           | 0                                            | 0                                            | 22.0                            | 0.0                             | 0.0                             |
| 19                                      | 1                         | 8                  | 12                                           | 0                                            | 0                                            | 12.0                            | 0.0                             | 0.0                             |
| 19                                      | 1                         | 14                 | 1                                            | 0                                            | 0                                            | 1.0                             | 0.0                             | 0.0                             |
| 20                                      | 2                         | 5                  | 15                                           | 0                                            | 0                                            | 15.0                            | 0.0                             | 0.0                             |
| 20                                      | 2                         | 8                  | 18                                           | 0                                            | 0                                            | 18.0                            | 0.0                             | 0.0                             |
| 20                                      | 2                         | 14                 | 7                                            | 0                                            | 0                                            | 7.0                             | 0.0                             | 0.0                             |
| 41                                      | 2                         | 5                  | 14                                           | 0                                            | 0                                            | 14.0                            | 0.0                             | 0.0                             |
| 41                                      | 2                         | 8                  | 11                                           | 0                                            | 0                                            | 11.0                            | 0.0                             | 0.0                             |
| 41                                      | 2                         | 14                 | 18                                           | 0                                            | 0                                            | 18.0                            | 0.0                             | 0.0                             |
| 42                                      | 4                         | 5                  | 18                                           | 0                                            | 0                                            | 18.0                            | 0.0                             | 0.0                             |
| 42                                      | 4                         | 8                  | 9                                            | 0                                            | 0                                            | 9.0                             | 0.0                             | 0.0                             |
| 42                                      | 4                         | 14                 | 16                                           | 0                                            | 0                                            | 16.0                            | 0.0                             | 0.0                             |
| 43                                      | 1                         | 5                  | 7                                            | 0                                            | 0                                            | 7.0                             | 0.0                             | 0.0                             |
| 43                                      | 1                         | 8                  | 15                                           | 0                                            | 0                                            | 15.0                            | 0.0                             | 0.0                             |
| 43                                      | 1                         | 14                 | 26                                           | 0                                            | 0                                            | 26.0                            | 0.0                             | 0.0                             |
| 44                                      | 3                         | 5                  | 4                                            | 0                                            | 0                                            | 4.0                             | 0.0                             | 0.0                             |
| 44                                      | 3                         | 8                  | 13                                           | 0                                            | 0                                            | 13.0                            | 0.0                             | 0.0                             |
| 44                                      | 3                         | 14                 | 17                                           | 0                                            | 0                                            | 17.0                            | 0.0                             | 0.0                             |

Table D-1. (Continued).

 USBM/RCD FORAGE YIELD STUDY  
 1987 GERMINATION

| Plot<br>Number                                                               | SOIL<br>AMENDMENT<br>CODE | SAMPLE<br>LOCATION | GERMINATION<br>SPECIES 1<br>(plants/<br>ft2) | GERMINATION<br>SPECIES 2<br>(plants/<br>ft2) | GERMINATION<br>SPECIES 3<br>(plants/<br>ft2) | GERMINATION<br>SPECIES 1<br>(%) | GERMINATION<br>SPECIES 2<br>(%) | GERMINATION<br>SPECIES 3<br>(%) |
|------------------------------------------------------------------------------|---------------------------|--------------------|----------------------------------------------|----------------------------------------------|----------------------------------------------|---------------------------------|---------------------------------|---------------------------------|
| ** SPECIES CODE: 4 (Smooth brome, thickspike wheatgrass, yellow sweetclover) |                           |                    |                                              |                                              |                                              |                                 |                                 |                                 |
| 1                                                                            | 3                         | 5                  | 12                                           | 25                                           | 1                                            | 30.0                            | 62.5                            | 5.0                             |
| 1                                                                            | 3                         | 8                  | 8                                            | 16                                           | 0                                            | 20.0                            | 40.0                            | 0.0                             |
| 1                                                                            | 3                         | 14                 | 8                                            | 43                                           | 0                                            | 20.0                            | 107.5                           | 0.0                             |
| 2                                                                            | 1                         | 5                  | 2                                            | 21                                           | 3                                            | 5.0                             | 52.5                            | 15.0                            |
| 2                                                                            | 1                         | 8                  | 6                                            | 19                                           | 2                                            | 15.0                            | 47.5                            | 10.0                            |
| 2                                                                            | 1                         | 14                 | 8                                            | 4                                            | 2                                            | 20.0                            | 10.0                            | 10.0                            |
| 3                                                                            | 2                         | 5                  | 6                                            | 17                                           | 3                                            | 15.0                            | 42.5                            | 15.0                            |
| 3                                                                            | 2                         | 8                  | 11                                           | 24                                           | 3                                            | 27.5                            | 60.0                            | 15.0                            |
| 3                                                                            | 2                         | 14                 | 17                                           | 29                                           | 8                                            | 42.5                            | 72.5                            | 40.0                            |
| 4                                                                            | 4                         | 5                  | 19                                           | 37                                           | 1                                            | 47.5                            | 92.5                            | 5.0                             |
| 4                                                                            | 4                         | 8                  | 7                                            | 9                                            | 1                                            | 17.5                            | 22.5                            | 5.0                             |
| 4                                                                            | 4                         | 14                 | 16                                           | 18                                           | 5                                            | 40.0                            | 45.0                            | 25.0                            |
| 29                                                                           | 1                         | 5                  | 3                                            | 22                                           | 2                                            | 7.5                             | 55.0                            | 10.0                            |
| 29                                                                           | 1                         | 8                  | 3                                            | 13                                           | 0                                            | 7.5                             | 32.5                            | 0.0                             |
| 29                                                                           | 1                         | 14                 | 17                                           | 26                                           | 2                                            | 42.5                            | 65.0                            | 10.0                            |
| 30                                                                           | 3                         | 5                  | 16                                           | 21                                           | 3                                            | 40.0                            | 52.5                            | 15.0                            |
| 30                                                                           | 3                         | 8                  | 9                                            | 22                                           | 5                                            | 22.5                            | 55.0                            | 25.0                            |
| 30                                                                           | 3                         | 14                 | 8                                            | 37                                           | 3                                            | 20.0                            | 92.5                            | 15.0                            |
| 31                                                                           | 4                         | 5                  | 7                                            | 8                                            | 0                                            | 17.5                            | 20.0                            | 0.0                             |
| 31                                                                           | 4                         | 8                  | 10                                           | 24                                           | 2                                            | 25.0                            | 60.0                            | 10.0                            |
| 31                                                                           | 4                         | 14                 | 21                                           | 38                                           | 3                                            | 52.5                            | 95.0                            | 15.0                            |
| 32                                                                           | 2                         | 5                  | 8                                            | 8                                            | 0                                            | 20.0                            | 20.0                            | 0.0                             |
| 32                                                                           | 2                         | 8                  | 24                                           | 39                                           | 2                                            | 60.0                            | 97.5                            | 10.0                            |
| 32                                                                           | 2                         | 14                 | 4                                            | 9                                            | 0                                            | 10.0                            | 22.5                            | 0.0                             |
| 37                                                                           | 1                         | 5                  | 8                                            | 5                                            | 1                                            | 20.0                            | 12.5                            | 5.0                             |
| 37                                                                           | 1                         | 8                  | 25                                           | 39                                           | 0                                            | 62.5                            | 97.5                            | 0.0                             |
| 37                                                                           | 1                         | 14                 | 5                                            | 5                                            | 0                                            | 12.5                            | 12.5                            | 0.0                             |
| 38                                                                           | 3                         | 5                  | 9                                            | 12                                           | 0                                            | 22.5                            | 30.0                            | 0.0                             |
| 38                                                                           | 3                         | 8                  | 7                                            | 5                                            | 3                                            | 17.5                            | 12.5                            | 15.0                            |
| 38                                                                           | 3                         | 14                 | 10                                           | 20                                           | 1                                            | 25.0                            | 50.0                            | 5.0                             |
| 39                                                                           | 2                         | 5                  | 22                                           | 22                                           | 4                                            | 55.0                            | 55.0                            | 20.0                            |
| 39                                                                           | 2                         | 8                  | 11                                           | 15                                           | 4                                            | 27.5                            | 37.5                            | 20.0                            |
| 39                                                                           | 2                         | 14                 | 12                                           | 14                                           | 5                                            | 30.0                            | 35.0                            | 25.0                            |
| 40                                                                           | 4                         | 5                  | 7                                            | 7                                            | 0                                            | 17.5                            | 17.5                            | 0.0                             |
| 40                                                                           | 4                         | 8                  | 9                                            | 7                                            | 2                                            | 22.5                            | 17.5                            | 10.0                            |
| 40                                                                           | 4                         | 14                 | 3                                            | 5                                            | 0                                            | 7.5                             | 12.5                            | 0.0                             |

Table D-2. First-year yield (September, 1987) from the Spangler Fixation study plots.

USBM/RCD FORAGE YIELD STUDY  
1987 YIELDS

| Plot<br>Number                                        | SOIL<br>AMENDMENT<br>CODE | SAMPLE<br>LOCATION | YIELD<br>SPECIES<br>1<br>(g/ft2) | YIELD<br>SPECIES<br>2<br>(g/ft2) | YIELD<br>SPECIES<br>3<br>(g/ft2) | GROSS<br>YIELD<br>(g/ft2) | COVER<br>(%) |
|-------------------------------------------------------|---------------------------|--------------------|----------------------------------|----------------------------------|----------------------------------|---------------------------|--------------|
| ** SPECIES CODE: Basin wildrye, Streambank wheatgrass |                           |                    |                                  |                                  |                                  |                           |              |
| 5                                                     | 4                         | 5                  | 1.64                             | 1.79                             | 0.00                             | 3.42                      | 25.00        |
| 5                                                     | 4                         | 8                  | 0.00                             | 2.83                             | 0.00                             | 2.83                      | 5.00         |
| 5                                                     | 4                         | 14                 | 0.00                             | 1.86                             | 0.00                             | 1.86                      | 4.00         |
| 6                                                     | 2                         | 5                  | 0.00                             | 0.85                             | 0.00                             | 0.85                      | 4.00         |
| 6                                                     | 2                         | 8                  | 2.00                             | 4.89                             | 0.00                             | 6.90                      | 25.00        |
| 6                                                     | 2                         | 14                 | 4.79                             | 2.26                             | 0.00                             | 7.04                      | 20.00        |
| 7                                                     | 1                         | 5                  | 0.48                             | 0.20                             | 0.00                             | 0.68                      | 10.00        |
| 7                                                     | 1                         | 8                  | 0.00                             | 1.39                             | 0.00                             | 1.39                      | 10.00        |
| 7                                                     | 1                         | 14                 | 0.00                             | 2.92                             | 0.00                             | 2.92                      | 15.00        |
| 8                                                     | 3                         | 5                  | 4.22                             | 13.35                            | 0.00                             | 17.57                     | 20.00        |
| 8                                                     | 3                         | 8                  | 2.45                             | 6.64                             | 0.00                             | 9.09                      | 35.00        |
| 8                                                     | 3                         | 14                 | 0.00                             | 9.74                             | 0.00                             | 9.74                      | 35.00        |
| 25                                                    | 4                         | 5                  | 1.77                             | 2.07                             | 0.00                             | 3.84                      | 5.00         |
| 25                                                    | 4                         | 8                  | 6.92                             | 11.12                            | 0.00                             | 18.05                     | 35.00        |
| 25                                                    | 4                         | 14                 | 1.05                             | 2.37                             | 0.00                             | 3.42                      | 7.00         |
| 26                                                    | 2                         | 5                  | 5.18                             | 2.56                             | 0.00                             | 7.74                      | 15.00        |
| 26                                                    | 2                         | 8                  | 2.59                             | 9.10                             | 0.00                             | 11.70                     | 75.00        |
| 26                                                    | 2                         | 14                 | 5.19                             | 7.50                             | 0.00                             | 12.69                     | 75.00        |
| 27                                                    | 3                         | 5                  | 5.59                             | 4.80                             | 0.00                             | 10.39                     | 25.00        |
| 27                                                    | 3                         | 8                  | 16.83                            | 11.18                            | 0.00                             | 28.02                     | 50.00        |
| 27                                                    | 3                         | 14                 | 3.46                             | 11.20                            | 0.00                             | 14.66                     | 20.00        |
| 28                                                    | 1                         | 5                  | 1.29                             | 5.63                             | 0.00                             | 6.92                      | 60.00        |
| 28                                                    | 1                         | 8                  | 5.90                             | 5.44                             | 0.00                             | 11.34                     | 50.00        |
| 28                                                    | 1                         | 14                 | 11.46                            | 5.84                             | 0.00                             | 17.30                     | 80.00        |
| 33                                                    | 4                         | 5                  | 9.01                             | 1.18                             | 0.00                             | 10.19                     | 40.00        |
| 33                                                    | 4                         | 8                  | 5.75                             | 7.32                             | 0.00                             | 13.07                     | 30.00        |
| 33                                                    | 4                         | 14                 | 1.15                             | 3.81                             | 0.00                             | 4.95                      | 15.00        |
| 34                                                    | 2                         | 5                  | 6.61                             | 7.73                             | 0.00                             | 14.34                     | 30.00        |
| 34                                                    | 2                         | 8                  | 0.84                             | 9.80                             | 0.00                             | 10.64                     | 40.00        |
| 34                                                    | 2                         | 14                 | 0.00                             | 0.99                             | 0.00                             | 0.99                      | 10.00        |
| 35                                                    | 1                         | 5                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 35                                                    | 1                         | 8                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 35                                                    | 1                         | 14                 | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 36                                                    | 3                         | 5                  | 8.03                             | 2.43                             | 0.00                             | 10.46                     | 30.00        |
| 36                                                    | 3                         | 8                  | 0.00                             | 6.64                             | 0.00                             | 6.64                      | 20.00        |
| 36                                                    | 3                         | 14                 | 1.31                             | 1.55                             | 0.00                             | 2.86                      | 15.00        |

Table D-2. (Continued).

USBM/RCD FORAGE YIELD STUDY  
1987 YIELDS

| Plot<br>Number                        | SOIL<br>AMENDMENT<br>CODE | SAMPLE<br>LOCATION | YIELD<br>SPECIES<br>1<br>(g/ft2) | YIELD<br>SPECIES<br>2<br>(g/ft2) | YIELD<br>SPECIES<br>3<br>(g/ft2) | GROSS<br>YIELD<br>(g/ft2) | COVER<br>(%) |
|---------------------------------------|---------------------------|--------------------|----------------------------------|----------------------------------|----------------------------------|---------------------------|--------------|
| ** SPECIES CODE: Pubescent wheatgrass |                           |                    |                                  |                                  |                                  |                           |              |
| 9                                     | 1                         | 5                  | 4.78                             | 0.00                             | 0.00                             | 4.78                      | 35.00        |
| 9                                     | 1                         | 8                  | 6.31                             | 0.00                             | 0.00                             | 6.31                      | 30.00        |
| 9                                     | 1                         | 14                 | 2.37                             | 0.00                             | 0.00                             | 2.37                      | 30.00        |
| 10                                    | 4                         | 5                  | 11.43                            | 0.00                             | 0.00                             | 11.43                     | 80.00        |
| 10                                    | 4                         | 8                  | 15.90                            | 0.00                             | 0.00                             | 15.90                     | 60.00        |
| 10                                    | 4                         | 14                 | 2.64                             | 0.00                             | 0.00                             | 2.64                      | 20.00        |
| 11                                    | 3                         | 5                  | 5.04                             | 0.00                             | 0.00                             | 5.04                      | 35.00        |
| 11                                    | 3                         | 8                  | 5.30                             | 0.00                             | 0.00                             | 5.30                      | 25.00        |
| 11                                    | 3                         | 14                 | 3.19                             | 0.00                             | 0.00                             | 3.19                      | 20.00        |
| 12                                    | 2                         | 5                  | 3.09                             | 0.00                             | 0.00                             | 3.09                      | 30.00        |
| 12                                    | 2                         | 8                  | 1.69                             | 0.00                             | 0.00                             | 1.69                      | 10.00        |
| 12                                    | 2                         | 14                 | 0.88                             | 0.00                             | 0.00                             | 0.88                      | 20.00        |
| 21                                    | 1                         | 5                  | 1.68                             | 0.00                             | 0.00                             | 1.68                      | 10.00        |
| 21                                    | 1                         | 8                  | 8.31                             | 0.00                             | 0.00                             | 8.31                      | 40.00        |
| 21                                    | 1                         | 14                 | 22.93                            | 0.00                             | 0.00                             | 22.93                     | 90.00        |
| 22                                    | 3                         | 5                  | 29.63                            | 0.00                             | 0.00                             | 29.63                     | 90.00        |
| 22                                    | 3                         | 8                  | 23.55                            | 0.00                             | 0.00                             | 23.55                     | 70.00        |
| 22                                    | 3                         | 14                 | 15.05                            | 0.00                             | 0.00                             | 15.05                     | 80.00        |
| 23                                    | 2                         | 5                  | 11.46                            | 0.00                             | 0.00                             | 11.46                     | 60.00        |
| 23                                    | 2                         | 8                  | 5.12                             | 0.00                             | 0.00                             | 5.12                      | 40.00        |
| 23                                    | 2                         | 14                 | 9.18                             | 0.00                             | 0.00                             | 9.18                      | 35.00        |
| 24                                    | 4                         | 5                  | 10.03                            | 0.00                             | 0.00                             | 10.03                     | 80.00        |
| 24                                    | 4                         | 8                  | 19.92                            | 0.00                             | 0.00                             | 19.92                     | 90.00        |
| 24                                    | 4                         | 14                 | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 45                                    | 4                         | 5                  | 2.68                             | 0.00                             | 0.00                             | 2.68                      | 12.00        |
| 45                                    | 4                         | 8                  | 8.47                             | 0.00                             | 0.00                             | 8.47                      | 85.00        |
| 45                                    | 4                         | 14                 | 1.58                             | 0.00                             | 0.00                             | 1.58                      | 15.00        |
| 46                                    | 2                         | 5                  | 0.38                             | 0.00                             | 0.00                             | 0.38                      | 2.00         |
| 46                                    | 2                         | 8                  | 1.01                             | 0.00                             | 0.00                             | 1.01                      | 10.00        |
| 46                                    | 2                         | 14                 | 0.25                             | 0.00                             | 0.00                             | 0.25                      | 1.00         |
| 47                                    | 3                         | 5                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 47                                    | 3                         | 8                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 47                                    | 3                         | 14                 | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 48                                    | 1                         | 5                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 48                                    | 1                         | 8                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 48                                    | 1                         | 14                 | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |

Table D-2. (Continued).

USBM/RCD FORAGE YIELD STUDY  
1987 YIELDS

| Plot<br>Number                      | SOIL<br>AMENDMENT<br>CODE | SAMPLE<br>LOCATION | YIELD<br>SPECIES<br>1<br>(g/ft2) | YIELD<br>SPECIES<br>2<br>(g/ft2) | YIELD<br>SPECIES<br>3<br>(g/ft2) | GROSS<br>YIELD<br>(g/ft2) | COVER<br>(%) |
|-------------------------------------|---------------------------|--------------------|----------------------------------|----------------------------------|----------------------------------|---------------------------|--------------|
| ** SPECIES CODE: Western wheatgrass |                           |                    |                                  |                                  |                                  |                           |              |
| 13                                  | 4                         | 5                  | 2.92                             | 0.00                             | 0.00                             | 2.92                      | 5.00         |
| 13                                  | 4                         | 8                  | 2.27                             | 0.00                             | 0.00                             | 2.27                      | 5.00         |
| 13                                  | 4                         | 14                 | 2.87                             | 0.00                             | 0.00                             | 2.87                      | 5.00         |
| 14                                  | 3                         | 5                  | 1.50                             | 0.00                             | 0.00                             | 1.50                      | 10.00        |
| 14                                  | 3                         | 8                  | 7.55                             | 0.00                             | 0.00                             | 7.55                      | 20.00        |
| 14                                  | 3                         | 14                 | 5.66                             | 0.00                             | 0.00                             | 5.66                      | 15.00        |
| 15                                  | 2                         | 5                  | 0.11                             | 0.00                             | 0.00                             | 0.11                      | 2.00         |
| 15                                  | 2                         | 12                 | 0.37                             | 0.00                             | 0.00                             | 0.37                      | 3.00         |
| 15                                  | 2                         | 14                 | 0.94                             | 0.00                             | 0.00                             | 0.94                      | 4.00         |
| 16                                  | 1                         | 5                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 16                                  | 1                         | 8                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 16                                  | 1                         | 14                 | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 17                                  | 3                         | 5                  | 9.95                             | 0.00                             | 0.00                             | 9.95                      | 10.00        |
| 17                                  | 3                         | 8                  | 12.11                            | 0.00                             | 0.00                             | 12.11                     | 10.00        |
| 17                                  | 3                         | 14                 | 9.95                             | 0.00                             | 0.00                             | 9.95                      | 7.00         |
| 18                                  | 4                         | 5                  | 8.29                             | 0.00                             | 0.00                             | 8.29                      | 25.00        |
| 18                                  | 4                         | 8                  | 4.00                             | 0.00                             | 0.00                             | 4.00                      | 15.00        |
| 18                                  | 4                         | 14                 | 0.95                             | 0.00                             | 0.00                             | 0.95                      | 10.00        |
| 19                                  | 1                         | 5                  | 11.20                            | 0.00                             | 0.00                             | 11.20                     | 20.00        |
| 19                                  | 1                         | 8                  | 9.03                             | 0.00                             | 0.00                             | 9.03                      | 15.00        |
| 19                                  | 1                         | 14                 | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 20                                  | 2                         | 5                  | 6.56                             | 0.00                             | 0.00                             | 6.56                      | 25.00        |
| 20                                  | 2                         | 8                  | 5.23                             | 0.00                             | 0.00                             | 5.23                      | 15.00        |
| 20                                  | 2                         | 14                 | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 41                                  | 2                         | 5                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 41                                  | 2                         | 8                  | 5.71                             | 0.00                             | 0.00                             | 5.71                      | 15.00        |
| 41                                  | 2                         | 14                 | 6.08                             | 0.00                             | 0.00                             | 6.08                      | 5.00         |
| 42                                  | 4                         | 5                  | 1.02                             | 0.00                             | 0.00                             | 1.02                      | 4.00         |
| 42                                  | 4                         | 8                  | 6.18                             | 0.00                             | 0.00                             | 6.18                      | 15.00        |
| 42                                  | 4                         | 14                 | 4.45                             | 0.00                             | 0.00                             | 4.45                      | 12.00        |
| 43                                  | 1                         | 5                  | 1.74                             | 0.00                             | 0.00                             | 1.74                      | 10.00        |
| 43                                  | 1                         | 8                  | 1.44                             | 0.00                             | 0.00                             | 1.44                      | 10.00        |
| 43                                  | 1                         | 14                 | 4.18                             | 0.00                             | 0.00                             | 4.18                      | 10.00        |
| 44                                  | 3                         | 5                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 44                                  | 3                         | 8                  | 1.41                             | 0.00                             | 0.00                             | 1.41                      | 4.00         |
| 44                                  | 3                         | 14                 | 0.68                             | 0.00                             | 0.00                             | 0.68                      | 3.00         |

Table D-2. (Continued).

USBM/RCD FORAGE YIELD STUDY  
1987 YIELDS

| Plot<br>Number                                                              | SOIL<br>AMENDMENT<br>CODE | SAMPLE<br>LOCATION | YIELD<br>SPECIES<br>1<br>(g/ft2) | YIELD<br>SPECIES<br>2<br>(g/ft2) | YIELD<br>SPECIES<br>3<br>(g/ft2) | GROSS<br>YIELD<br>(g/ft2) | COVER<br>(%) |
|-----------------------------------------------------------------------------|---------------------------|--------------------|----------------------------------|----------------------------------|----------------------------------|---------------------------|--------------|
| ** SPECIES CODE: Smooth brome, thickspike wheatgrass,<br>yellow sweetclover |                           |                    |                                  |                                  |                                  |                           |              |
| 1                                                                           | 3                         | 5                  | 1.39                             | 0.00                             | 0.85                             | 2.23                      | 20.00        |
| 1                                                                           | 3                         | 8                  | 3.45                             | 0.06                             | 0.46                             | 3.98                      | 25.00        |
| 1                                                                           | 3                         | 14                 | 2.23                             | 0.00                             | 0.38                             | 2.61                      | 15.00        |
| 2                                                                           | 1                         | 5                  | 0.00                             | 0.82                             | 0.33                             | 1.15                      | 8.00         |
| 2                                                                           | 1                         | 8                  | 0.23                             | 0.00                             | 0.20                             | 0.43                      | 4.00         |
| 2                                                                           | 1                         | 14                 | 1.45                             | 0.00                             | 0.48                             | 1.94                      | 10.00        |
| 3                                                                           | 2                         | 5                  | 2.14                             | 0.00                             | 1.51                             | 3.65                      | 15.00        |
| 3                                                                           | 2                         | 8                  | 9.60                             | 1.84                             | 1.94                             | 13.38                     | 60.00        |
| 3                                                                           | 2                         | 14                 | 7.87                             | 1.65                             | 0.92                             | 10.44                     | 60.00        |
| 4                                                                           | 4                         | 5                  | 15.41                            | 1.81                             | 0.00                             | 17.22                     | 90.00        |
| 4                                                                           | 4                         | 8                  | 11.74                            | 2.54                             | 0.00                             | 14.28                     | 65.00        |
| 4                                                                           | 4                         | 14                 | 3.12                             | 8.70                             | 1.24                             | 13.06                     | 50.00        |
| 29                                                                          | 1                         | 5                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 29                                                                          | 1                         | 8                  | 2.01                             | 0.00                             | 0.83                             | 2.84                      | 10.00        |
| 29                                                                          | 1                         | 14                 | 9.85                             | 4.94                             | 2.57                             | 17.36                     | 55.00        |
| 30                                                                          | 3                         | 5                  | 9.47                             | 0.00                             | 2.26                             | 11.73                     | 50.00        |
| 30                                                                          | 3                         | 8                  | 7.29                             | 6.38                             | 0.38                             | 14.06                     | 75.00        |
| 30                                                                          | 3                         | 14                 | 8.76                             | 1.85                             | 5.85                             | 16.46                     | 60.00        |
| 31                                                                          | 4                         | 5                  | 11.96                            | 7.44                             | 0.00                             | 19.41                     | 60.00        |
| 31                                                                          | 4                         | 8                  | 6.92                             | 0.99                             | 2.58                             | 10.49                     | 45.00        |
| 31                                                                          | 4                         | 14                 | 31.77                            | 0.00                             | 2.62                             | 34.38                     | 95.00        |
| 32                                                                          | 2                         | 5                  | 1.71                             | 0.00                             | 3.29                             | 5.00                      | 25.00        |
| 32                                                                          | 2                         | 8                  | 7.54                             | 3.14                             | 5.93                             | 16.61                     | 70.00        |
| 32                                                                          | 2                         | 14                 | 0.31                             | 0.09                             | 0.19                             | 0.59                      | 5.00         |
| 37                                                                          | 1                         | 5                  | 3.39                             | 0.00                             | 0.00                             | 3.39                      | 15.00        |
| 37                                                                          | 1                         | 8                  | 2.40                             | 0.00                             | 0.23                             | 2.64                      | 12.00        |
| 37                                                                          | 1                         | 14                 | 3.74                             | 0.93                             | 0.87                             | 5.54                      | 40.00        |
| 38                                                                          | 3                         | 5                  | 8.29                             | 0.66                             | 1.46                             | 10.42                     | 45.00        |
| 38                                                                          | 3                         | 8                  | 6.35                             | 0.00                             | 0.34                             | 6.70                      | 25.00        |
| 38                                                                          | 3                         | 14                 | 5.72                             | 0.00                             | 1.60                             | 7.32                      | 40.00        |
| 39                                                                          | 2                         | 5                  | 6.46                             | 0.00                             | 2.23                             | 8.69                      | 35.00        |
| 39                                                                          | 2                         | 8                  | 1.12                             | 0.00                             | 0.00                             | 1.12                      | 8.00         |
| 39                                                                          | 2                         | 14                 | 4.00                             | 0.00                             | 1.83                             | 5.83                      | 20.00        |
| 40                                                                          | 4                         | 5                  | 7.62                             | 0.00                             | 1.60                             | 9.22                      | 50.00        |
| 40                                                                          | 4                         | 8                  | 9.20                             | 0.00                             | 0.29                             | 9.49                      | 50.00        |
| 40                                                                          | 4                         | 14                 | 2.00                             | 0.00                             | 0.33                             | 2.33                      | 25.00        |

Table D-3. Vigor rating of species planted in the Spangler  
Fixation study (July, 1988).

USBM/RCD FORAGE STUDY  
1988 VIGOR  
FIXATION STUDY

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| PLOT<br>NUMBER | SOIL<br>AMENDMENT<br>CODE | VIGOR<br>RATING<br>(1=GOOD,<br>9=POOR) |
|----------------|---------------------------|----------------------------------------|
|----------------|---------------------------|----------------------------------------|

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\*\* SPECIES CODE: Basin, streambank

|    |   |   |
|----|---|---|
| 5  | 4 | 2 |
| 6  | 2 | 4 |
| 7  | 1 | 4 |
| 8  | 3 | 4 |
| 25 | 4 | 3 |
| 26 | 2 | 5 |
| 27 | 3 | 2 |
| 28 | 1 | 4 |
| 33 | 4 | 4 |
| 34 | 2 | 6 |
| 35 | 1 | 8 |
| 36 | 3 | 6 |

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Table D-3. (Continued).

USBM/RCD FORAGE STUDY  
1988 VIGOR  
FIXATION STUDY

| PLOT<br>NUMBER             | SOIL<br>AMENDMENT<br>CODE | VIGOR<br>RATING<br>(1=GOOD,<br>9=POOR) |
|----------------------------|---------------------------|----------------------------------------|
| ** SPECIES CODE: Pubescent |                           |                                        |
| 9                          | 1                         | 3                                      |
| 10                         | 4                         | 2                                      |
| 11                         | 3                         | 2                                      |
| 12                         | 2                         | 3                                      |
| 21                         | 1                         | 5                                      |
| 22                         | 3                         | 1                                      |
| 23                         | 2                         | 3                                      |
| 24                         | 4                         | 2                                      |
| 45                         | 4                         | 3                                      |
| 46                         | 2                         | 4                                      |
| 47                         | 3                         | 7                                      |
| 48                         | 1                         | 5                                      |

Table D-3. (Continued).

USBM/RCD FORAGE STUDY  
1988 VIGOR  
FIXATION STUDY

| PLOT<br>NUMBER           | SOIL<br>AMENDMENT<br>CODE | VIGOR<br>RATING<br>(1=GOOD,<br>9=POOR) |
|--------------------------|---------------------------|----------------------------------------|
| ** SPECIES CODE: Western |                           |                                        |
| 13                       | 4                         | 5                                      |
| 14                       | 3                         | 3                                      |
| 15                       | 2                         | 6                                      |
| 16                       | 1                         | 8                                      |
| 17                       | 3                         | 4                                      |
| 18                       | 4                         | 2                                      |
| 19                       | 1                         | 3                                      |
| 20                       | 2                         | 6                                      |
| 41                       | 2                         | 5                                      |
| 42                       | 4                         | 3                                      |
| 43                       | 1                         | 7                                      |
| 44                       | 3                         | 7                                      |

Table D-3. (Continued).

USBM/RCD FORAGE STUDY  
1988 VIGOR  
FIXATION STUDY

| PLOT<br>NUMBER                                                                 | SOIL<br>AMENDMENT<br>CODE | VIGOR<br>RATING<br>(1=GOOD,<br>9=POOR) |
|--------------------------------------------------------------------------------|---------------------------|----------------------------------------|
| ** SPECIES CODE: Smooth brome,<br>thickspike wheatgrass,<br>yellow sweetclover |                           |                                        |
| 1                                                                              | 3                         | 3                                      |
| 2                                                                              | 1                         | 6                                      |
| 3                                                                              | 2                         | 2                                      |
| 4                                                                              | 4                         | 1                                      |
| 29                                                                             | 1                         | 4                                      |
| 30                                                                             | 3                         | 2                                      |
| 31                                                                             | 4                         | 1                                      |
| 32                                                                             | 2                         | 3                                      |
| 37                                                                             | 1                         | 4                                      |
| 38                                                                             | 3                         | 3                                      |
| 39                                                                             | 2                         | 3                                      |
| 40                                                                             | 4                         | 5                                      |

Table D-4. Second year yield (July, 1988) of the Spangler Fixation Study plots.

USBM/RCD FORAGE YIELD STUDY  
1988 YIELDS

| Plot<br>Number                                        | SOIL<br>AMENDMENT<br>CODE | SAMPLE<br>LOCATION | YIELD<br>SPECIES<br>1<br>(g/ft2) | YIELD<br>SPECIES<br>2<br>(g/ft2) | YIELD<br>SPECIES<br>3<br>(g/ft2) | GROSS<br>YIELD<br>(g/ft2) | COVER<br>(%) |
|-------------------------------------------------------|---------------------------|--------------------|----------------------------------|----------------------------------|----------------------------------|---------------------------|--------------|
| ** SPECIES CODE: Basin wildrye, streambank wheatgrass |                           |                    |                                  |                                  |                                  |                           |              |
| 5                                                     | 4                         | 5                  | 8.14                             | 2.08                             | 0.00                             | 10.22                     | 35.00        |
| 5                                                     | 4                         | 8                  | 11.18                            | 4.82                             | 0.00                             | 16.00                     | 0.00         |
| 5                                                     | 4                         | 14                 | 11.39                            | 4.58                             | 0.00                             | 15.97                     | 0.00         |
| 6                                                     | 2                         | 5                  | 5.95                             | 7.80                             | 0.00                             | 13.75                     | 25.00        |
| 6                                                     | 2                         | 8                  | 0.74                             | 15.77                            | 0.00                             | 16.51                     | 0.00         |
| 6                                                     | 2                         | 14                 | 13.78                            | 2.18                             | 0.00                             | 15.96                     | 0.00         |
| 7                                                     | 1                         | 5                  | 0.79                             | 13.30                            | 0.00                             | 14.09                     | 30.00        |
| 7                                                     | 1                         | 8                  | 1.18                             | 10.38                            | 0.00                             | 11.56                     | 0.00         |
| 7                                                     | 1                         | 14                 | 0.00                             | 1.14                             | 0.00                             | 1.14                      | 0.00         |
| 8                                                     | 3                         | 5                  | 4.39                             | 18.37                            | 0.00                             | 22.76                     | 50.00        |
| 8                                                     | 3                         | 8                  | 18.00                            | 5.15                             | 0.00                             | 23.15                     | 0.00         |
| 8                                                     | 3                         | 14                 | 14.35                            | 11.11                            | 0.00                             | 25.46                     | 0.00         |
| 25                                                    | 4                         | 5                  | 3.30                             | 5.77                             | 0.00                             | 9.07                      | 40.00        |
| 25                                                    | 4                         | 8                  | 3.37                             | 5.73                             | 0.00                             | 9.10                      | 0.00         |
| 25                                                    | 4                         | 14                 | 12.85                            | 8.66                             | 0.00                             | 21.51                     | 0.00         |
| 26                                                    | 2                         | 5                  | 4.09                             | 7.77                             | 0.00                             | 11.86                     | 40.00        |
| 26                                                    | 2                         | 8                  | 2.75                             | 7.79                             | 0.00                             | 10.54                     | 0.00         |
| 26                                                    | 2                         | 14                 | 4.95                             | 14.58                            | 0.00                             | 19.53                     | 0.00         |
| 27                                                    | 3                         | 5                  | 7.24                             | 4.30                             | 0.00                             | 11.54                     | 50.00        |
| 27                                                    | 3                         | 8                  | 13.25                            | 6.85                             | 0.00                             | 20.10                     | 0.00         |
| 27                                                    | 3                         | 14                 | 2.12                             | 7.96                             | 0.00                             | 10.08                     | 0.00         |
| 28                                                    | 1                         | 5                  | 2.72                             | 8.04                             | 0.00                             | 10.76                     | 28.00        |
| 28                                                    | 1                         | 8                  | 3.00                             | 4.74                             | 0.00                             | 7.74                      | 0.00         |
| 28                                                    | 1                         | 14                 | 0.90                             | 8.08                             | 0.00                             | 8.98                      | 0.00         |
| 33                                                    | 4                         | 5                  | 14.18                            | 3.01                             | 0.00                             | 17.19                     | 42.00        |
| 33                                                    | 4                         | 8                  | 8.53                             | 16.09                            | 0.00                             | 24.62                     | 0.00         |
| 33                                                    | 4                         | 14                 | 5.92                             | 4.67                             | 0.00                             | 10.59                     | 0.00         |
| 34                                                    | 2                         | 5                  | 3.42                             | 17.45                            | 0.00                             | 20.87                     | 25.00        |
| 34                                                    | 2                         | 8                  | 2.09                             | 21.84                            | 0.00                             | 23.93                     | 0.00         |
| 34                                                    | 2                         | 14                 | 0.61                             | 3.93                             | 0.00                             | 4.54                      | 0.00         |
| 35                                                    | 1                         | 5                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 6.00         |
| 35                                                    | 1                         | 8                  | 0.00                             | 0.37                             | 0.00                             | 0.37                      | 0.00         |
| 35                                                    | 1                         | 14                 | 3.11                             | 5.10                             | 0.00                             | 8.21                      | 0.00         |
| 36                                                    | 3                         | 5                  | 6.35                             | 3.12                             | 0.00                             | 9.47                      | 30.00        |
| 36                                                    | 3                         | 8                  | 30.08                            | 1.29                             | 0.00                             | 31.37                     | 0.00         |
| 36                                                    | 3                         | 14                 | 0.00                             | 0.87                             | 0.00                             | 0.87                      | 0.00         |

Table D-4 (Continued).

USBM/RCD FORAGE YIELD STUDY  
1988 YIELDS

| Plot<br>Number                        | SOIL<br>AMENDMENT<br>CODE | SAMPLE<br>LOCATION | YIELD<br>SPECIES<br>1<br>(g/ft2) | YIELD<br>SPECIES<br>2<br>(g/ft2) | YIELD<br>SPECIES<br>3<br>(g/ft2) | GROSS<br>YIELD<br>(g/ft2) | COVER<br>(%) |
|---------------------------------------|---------------------------|--------------------|----------------------------------|----------------------------------|----------------------------------|---------------------------|--------------|
| ** SPECIES CODE: Pubescent wheatgrass |                           |                    |                                  |                                  |                                  |                           |              |
| 9                                     | 1                         | 5                  | 10.15                            | 0.00                             | 0.00                             | 10.15                     | 25.00        |
| 9                                     | 1                         | 8                  | 18.89                            | 0.00                             | 0.00                             | 18.89                     | 0.00         |
| 9                                     | 1                         | 14                 | 4.41                             | 0.00                             | 0.00                             | 4.41                      | 0.00         |
| 10                                    | 4                         | 5                  | 18.65                            | 0.00                             | 0.00                             | 18.65                     | 32.00        |
| 10                                    | 4                         | 8                  | 15.73                            | 0.00                             | 0.00                             | 15.73                     | 0.00         |
| 10                                    | 4                         | 14                 | 26.89                            | 0.00                             | 0.00                             | 26.89                     | 0.00         |
| 11                                    | 3                         | 5                  | 6.42                             | 0.00                             | 0.00                             | 6.42                      | 25.00        |
| 11                                    | 3                         | 8                  | 17.74                            | 0.00                             | 0.00                             | 17.74                     | 0.00         |
| 11                                    | 3                         | 14                 | 7.66                             | 0.00                             | 0.00                             | 7.66                      | 0.00         |
| 12                                    | 2                         | 5                  | 19.56                            | 0.00                             | 0.00                             | 19.56                     | 20.00        |
| 12                                    | 2                         | 8                  | 8.65                             | 0.00                             | 0.00                             | 8.65                      | 0.00         |
| 12                                    | 2                         | 14                 | 15.72                            | 0.00                             | 0.00                             | 15.72                     | 0.00         |
| 21                                    | 1                         | 5                  | 3.07                             | 0.00                             | 0.00                             | 3.07                      | 18.00        |
| 21                                    | 1                         | 8                  | 6.44                             | 0.00                             | 0.00                             | 6.44                      | 0.00         |
| 21                                    | 1                         | 14                 | 4.63                             | 0.00                             | 0.00                             | 4.63                      | 0.00         |
| 22                                    | 3                         | 5                  | 8.72                             | 0.00                             | 0.00                             | 8.72                      | 22.00        |
| 22                                    | 3                         | 8                  | 24.46                            | 0.00                             | 0.00                             | 24.46                     | 0.00         |
| 22                                    | 3                         | 14                 | 16.14                            | 0.00                             | 0.00                             | 16.14                     | 0.00         |
| 23                                    | 2                         | 5                  | 5.00                             | 0.00                             | 0.00                             | 5.00                      | 20.00        |
| 23                                    | 2                         | 8                  | 1.24                             | 0.00                             | 0.00                             | 1.24                      | 0.00         |
| 23                                    | 2                         | 14                 | 21.16                            | 0.00                             | 0.00                             | 21.16                     | 0.00         |
| 24                                    | 4                         | 5                  | 4.15                             | 0.00                             | 0.00                             | 4.15                      | 25.00        |
| 24                                    | 4                         | 8                  | 2.24                             | 0.00                             | 0.00                             | 2.24                      | 0.00         |
| 24                                    | 4                         | 14                 | 3.88                             | 0.00                             | 0.00                             | 3.88                      | 0.00         |
| 45                                    | 4                         | 5                  | 6.00                             | 0.00                             | 0.00                             | 6.00                      | 8.00         |
| 45                                    | 4                         | 8                  | 13.12                            | 0.00                             | 0.00                             | 13.12                     | 0.00         |
| 45                                    | 4                         | 14                 | 23.12                            | 0.00                             | 0.00                             | 23.12                     | 0.00         |
| 46                                    | 2                         | 5                  | 0.66                             | 0.00                             | 0.00                             | 0.66                      | 2.00         |
| 46                                    | 2                         | 8                  | 0.18                             | 0.00                             | 0.00                             | 0.18                      | 0.00         |
| 46                                    | 2                         | 14                 | 0.45                             | 0.00                             | 0.00                             | 0.45                      | 0.00         |
| 47                                    | 3                         | 5                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 1.00         |
| 47                                    | 3                         | 8                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 47                                    | 3                         | 14                 | 3.04                             | 0.00                             | 0.00                             | 3.04                      | 0.00         |
| 48                                    | 1                         | 5                  | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 2.00         |
| 48                                    | 1                         | 8                  | 1.20                             | 0.00                             | 0.00                             | 1.20                      | 0.00         |
| 48                                    | 1                         | 14                 | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |

Table D-4. (Continued).

USBM/RCD FORAGE YIELD STUDY  
1988 YIELDS

| Plot<br>Number                      | SOIL<br>AMENDMENT<br>CODE | SAMPLE<br>LOCATION | YIELD<br>SPECIES<br>1<br>(g/ft2) | YIELD<br>SPECIES<br>2<br>(g/ft2) | YIELD<br>SPECIES<br>3<br>(g/ft2) | GROSS<br>YIELD<br>(g/ft2) | COVER<br>(%) |
|-------------------------------------|---------------------------|--------------------|----------------------------------|----------------------------------|----------------------------------|---------------------------|--------------|
| ** SPECIES CODE: Western wheatgrass |                           |                    |                                  |                                  |                                  |                           |              |
| 13                                  | 4                         | 5                  | 2.06                             | 0.00                             | 0.00                             | 2.06                      | 12.00        |
| 13                                  | 4                         | 8                  | 1.33                             | 0.00                             | 0.00                             | 1.33                      | 0.00         |
| 13                                  | 4                         | 14                 | 3.06                             | 0.00                             | 0.00                             | 3.06                      | 0.00         |
| 14                                  | 3                         | 5                  | 3.56                             | 0.00                             | 0.00                             | 3.56                      | 22.00        |
| 14                                  | 3                         | 8                  | 6.76                             | 0.00                             | 0.00                             | 6.76                      | 0.00         |
| 14                                  | 3                         | 14                 | 5.60                             | 0.00                             | 0.00                             | 5.60                      | 0.00         |
| 15                                  | 2                         | 5                  | 3.84                             | 0.00                             | 0.00                             | 3.84                      | 10.00        |
| 15                                  | 2                         | 12                 | 1.20                             | 0.00                             | 0.00                             | 1.20                      | 0.00         |
| 15                                  | 2                         | 14                 | 4.78                             | 0.00                             | 0.00                             | 4.78                      | 0.00         |
| 16                                  | 1                         | 5                  | 1.00                             | 0.00                             | 0.00                             | 1.00                      | 2.00         |
| 16                                  | 1                         | 8                  | 1.15                             | 0.00                             | 0.00                             | 1.15                      | 0.00         |
| 16                                  | 1                         | 14                 | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 17                                  | 3                         | 5                  | 8.58                             | 0.00                             | 0.00                             | 8.58                      | 45.00        |
| 17                                  | 3                         | 8                  | 6.40                             | 0.00                             | 0.00                             | 6.40                      | 0.00         |
| 17                                  | 3                         | 14                 | 17.45                            | 0.00                             | 0.00                             | 17.45                     | 0.00         |
| 18                                  | 4                         | 5                  | 4.99                             | 0.00                             | 0.00                             | 4.99                      | 40.00        |
| 18                                  | 4                         | 8                  | 8.55                             | 0.00                             | 0.00                             | 8.55                      | 0.00         |
| 18                                  | 4                         | 14                 | 6.42                             | 0.00                             | 0.00                             | 6.42                      | 0.00         |
| 19                                  | 1                         | 5                  | 15.22                            | 0.00                             | 0.00                             | 15.22                     | 35.00        |
| 19                                  | 1                         | 8                  | 3.76                             | 0.00                             | 0.00                             | 3.76                      | 0.00         |
| 19                                  | 1                         | 14                 | 5.36                             | 0.00                             | 0.00                             | 5.36                      | 0.00         |
| 20                                  | 2                         | 5                  | 8.82                             | 0.00                             | 0.00                             | 8.82                      | 30.00        |
| 20                                  | 2                         | 8                  | 3.94                             | 0.00                             | 0.00                             | 3.94                      | 0.00         |
| 20                                  | 2                         | 14                 | 0.00                             | 0.00                             | 0.00                             | 0.00                      | 0.00         |
| 41                                  | 2                         | 5                  | 6.67                             | 0.00                             | 0.00                             | 6.67                      | 28.00        |
| 41                                  | 2                         | 8                  | 3.97                             | 0.00                             | 0.00                             | 3.97                      | 0.00         |
| 41                                  | 2                         | 14                 | 8.33                             | 0.00                             | 0.00                             | 8.33                      | 0.00         |
| 42                                  | 4                         | 5                  | 8.92                             | 0.00                             | 0.00                             | 8.92                      | 24.00        |
| 42                                  | 4                         | 8                  | 7.14                             | 0.00                             | 0.00                             | 7.14                      | 0.00         |
| 42                                  | 4                         | 14                 | 3.43                             | 0.00                             | 0.00                             | 3.43                      | 0.00         |
| 43                                  | 1                         | 5                  | 5.51                             | 0.00                             | 0.00                             | 5.51                      | 10.00        |
| 43                                  | 1                         | 8                  | 2.36                             | 0.00                             | 0.00                             | 2.36                      | 0.00         |
| 43                                  | 1                         | 14                 | 2.68                             | 0.00                             | 0.00                             | 2.68                      | 0.00         |
| 44                                  | 3                         | 5                  | 2.94                             | 0.00                             | 0.00                             | 2.94                      | 8.00         |
| 44                                  | 3                         | 8                  | 4.43                             | 0.00                             | 0.00                             | 4.43                      | 0.00         |
| 44                                  | 3                         | 14                 | 3.11                             | 0.00                             | 0.00                             | 3.11                      | 0.00         |

Table D-4. (Continued).

USBM/RCD FORAGE YIELD STUDY  
1988 YIELDS

| Plot<br>Number                                                              | SOIL<br>AMENDMENT<br>CODE | SAMPLE<br>LOCATION | YIELD<br>SPECIES<br>1<br>(g/ft2) | YIELD<br>SPECIES<br>2<br>(g/ft2) | YIELD<br>SPECIES<br>3<br>(g/ft2) | GROSS<br>YIELD<br>(g/ft2) | COVER<br>(%) |
|-----------------------------------------------------------------------------|---------------------------|--------------------|----------------------------------|----------------------------------|----------------------------------|---------------------------|--------------|
| ** SPECIES CODE: Smooth brome, thickspike wheatgrass,<br>yellow sweetclover |                           |                    |                                  |                                  |                                  |                           |              |
| 1                                                                           | 3                         | 5                  | 5.20                             | 1.12                             | 0.78                             | 7.10                      | 15.00        |
| 1                                                                           | 3                         | 8                  | 0.78                             | 1.52                             | 0.00                             | 2.30                      | 0.00         |
| 1                                                                           | 3                         | 14                 | 5.88                             | 8.24                             | 0.00                             | 14.12                     | 0.00         |
| 2                                                                           | 1                         | 5                  | 0.20                             | 0.09                             | 5.13                             | 5.42                      | 8.00         |
| 2                                                                           | 1                         | 8                  | 1.10                             | 0.64                             | 0.00                             | 1.74                      | 0.00         |
| 2                                                                           | 1                         | 14                 | 3.72                             | 0.92                             | 0.00                             | 4.64                      | 0.00         |
| 3                                                                           | 2                         | 5                  | 2.75                             | 3.07                             | 0.00                             | 5.82                      | 45.00        |
| 3                                                                           | 2                         | 8                  | 8.30                             | 1.29                             | 2.97                             | 12.56                     | 0.00         |
| 3                                                                           | 2                         | 14                 | 12.11                            | 1.96                             | 11.46                            | 25.53                     | 0.00         |
| 4                                                                           | 4                         | 5                  | 10.60                            | 0.49                             | 0.00                             | 11.09                     | 40.00        |
| 4                                                                           | 4                         | 8                  | 1.33                             | 1.50                             | 0.00                             | 2.83                      | 0.00         |
| 4                                                                           | 4                         | 14                 | 15.80                            | 9.77                             | 0.95                             | 26.52                     | 0.00         |
| 29                                                                          | 1                         | 5                  | 3.02                             | 1.09                             | 0.00                             | 4.11                      | 15.00        |
| 29                                                                          | 1                         | 8                  | 2.90                             | 1.71                             | 1.95                             | 6.56                      | 0.00         |
| 29                                                                          | 1                         | 14                 | 2.24                             | 7.35                             | 0.00                             | 9.59                      | 0.00         |
| 30                                                                          | 3                         | 5                  | 7.66                             | 1.17                             | 0.00                             | 8.83                      | 16.00        |
| 30                                                                          | 3                         | 8                  | 6.60                             | 2.02                             | 0.00                             | 8.62                      | 0.00         |
| 30                                                                          | 3                         | 14                 | 7.47                             | 8.04                             | 0.00                             | 15.51                     | 0.00         |
| 31                                                                          | 4                         | 14                 | 1.38                             | 0.31                             | 0.00                             | 1.69                      | 0.00         |
| 31                                                                          | 4                         | 8                  | 0.91                             | 3.43                             | 0.00                             | 4.34                      | 0.00         |
| 31                                                                          | 4                         | 5                  | 3.12                             | 0.74                             | 0.00                             | 3.86                      | 22.00        |
| 32                                                                          | 2                         | 5                  | 3.59                             | 1.06                             | 0.00                             | 4.65                      | 20.00        |
| 32                                                                          | 2                         | 8                  | 1.55                             | 2.21                             | 0.00                             | 3.76                      | 0.00         |
| 32                                                                          | 2                         | 14                 | 6.35                             | 2.09                             | 0.00                             | 8.44                      | 0.00         |
| 37                                                                          | 1                         | 5                  | 2.88                             | 0.54                             | 0.65                             | 4.07                      | 15.00        |
| 37                                                                          | 1                         | 8                  | 2.64                             | 1.15                             | 0.00                             | 3.79                      | 0.00         |
| 37                                                                          | 1                         | 14                 | 4.00                             | 1.06                             | 0.00                             | 5.06                      | 0.00         |
| 38                                                                          | 3                         | 5                  | 7.94                             | 0.00                             | 0.59                             | 8.53                      | 22.00        |
| 38                                                                          | 3                         | 8                  | 1.99                             | 0.38                             | 5.82                             | 8.19                      | 0.00         |
| 38                                                                          | 3                         | 14                 | 8.25                             | 4.13                             | 0.00                             | 12.38                     | 0.00         |
| 39                                                                          | 2                         | 5                  | 3.00                             | 1.24                             | 0.00                             | 4.24                      | 18.00        |
| 39                                                                          | 2                         | 8                  | 9.00                             | 1.00                             | 0.00                             | 10.00                     | 0.00         |
| 39                                                                          | 2                         | 14                 | 7.70                             | 4.72                             | 0.74                             | 13.16                     | 0.00         |
| 40                                                                          | 4                         | 5                  | 6.92                             | 1.74                             | 0.00                             | 8.66                      | 20.00        |
| 40                                                                          | 4                         | 8                  | 2.63                             | 3.82                             | 4.09                             | 10.54                     | 0.00         |
| 40                                                                          | 4                         | 14                 | 5.71                             | 2.00                             | 1.87                             | 9.58                      | 0.00         |

## APPENDIX E

Total Metals, Extractable Metals, Soluble Metals,  
and Forage Metal levels from the  
Spangler Lime Study Plots

Table E-1. Chemical and physical properties of soils and total metal levels in the old Spangler Lime study plots.

SPANGLER FORAGE ESTABLISHMENT STUDY  
OLD RCAC PLOTS

CHEMICAL & PHYSICAL PROPERTIES

| SAMPLE<br>NUMBER                       | PLOT | VEG PASTE<br>TREAT-<br>MENT | pH   | EC (mmhos/<br>cm) | CaCO <sub>3</sub><br>(%) | ORGANIC<br>MATTER<br>(%) | CEC<br>(meq/<br>100g) | SAND<br>(%) | SILT<br>(%) | CLAY<br>(%) | TOTAL<br>Al<br>(mg/<br>kg) | TOTAL<br>Fe<br>(mg/<br>kg) | TOTAL<br>Ca<br>(mg/<br>kg) | TOTAL<br>Mg<br>(mg/<br>kg) | TOTAL<br>K<br>(mg/<br>kg) | TOTAL<br>S<br>(mg/<br>kg) |
|----------------------------------------|------|-----------------------------|------|-------------------|--------------------------|--------------------------|-----------------------|-------------|-------------|-------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|---------------------------|
| ** SOIL TREATMENT = 1 (Control)        |      |                             |      |                   |                          |                          |                       |             |             |             |                            |                            |                            |                            |                           |                           |
| 07( 0- 5)                              | 7    | 1                           | 6.81 | 0.74              | 0.6                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 13460.00                   | 18102.10                   | 4645.30                    | 4616.60                    | 3956.70                   | 232.00                    |
| 029( 0- 5)                             | 29   | 1                           | 5.03 | 0.36              | 0.2                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 15080.00                   | 18622.00                   | 2749.50                    | 3671.60                    | 3312.20                   | 112.00                    |
| 034( 0- 5)                             | 34   | 1                           | 4.78 | 0.64              | 0.1                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 11500.00                   | 14048.90                   | 2152.20                    | 2732.80                    | 2841.20                   | 175.00                    |
| 064( 0- 5)                             | 64   | 1                           | 6.21 | 0.72              | 0.3                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 12370.00                   | 16708.30                   | 3594.90                    | 4295.90                    | 4071.70                   | 175.00                    |
| 020( 0- 5)                             | 20   | 2                           | 6.07 | 0.47              | 0.4                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 13880.00                   | 19651.20                   | 2342.30                    | 4169.30                    | 3870.60                   | 143.00                    |
| 013( 0- 5)                             | 13   | 2                           | 6.04 | 0.34              | 0.3                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 9880.00                    | 15856.20                   | 2507.00                    | 3249.40                    | 3026.60                   | 178.00                    |
| 036( 0- 5)                             | 36   | 2                           | 4.83 | 0.96              | 0.2                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 14300.00                   | 18951.00                   | 1783.20                    | 3271.60                    | 2652.00                   | 141.00                    |
| 055( 0- 5)                             | 55   | 2                           | 4.70 | 0.48              | 0.2                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 11020.00                   | 14480.60                   | 1764.40                    | 2532.30                    | 2558.20                   | 126.00                    |
| 022( 0- 5)                             | 22   | 3                           | 6.62 | 0.66              | 0.5                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 13840.00                   | 17871.60                   | 3188.60                    | 4847.20                    | 4074.90                   | 128.00                    |
| 016( 0- 5)                             | 16   | 3                           | 6.80 | 0.42              | 0.3                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 11800.00                   | 17225.00                   | 2883.10                    | 3939.30                    | 3891.60                   | 149.00                    |
| 041( 0- 5)                             | 41   | 3                           | 4.53 | 0.94              | 0.2                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 9170.00                    | 11400.60                   | 1773.70                    | 2499.60                    | 2341.60                   | 156.00                    |
| 053( 0- 5)                             | 53   | 3                           | 4.82 | 0.57              | 0.3                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 13220.00                   | 15644.50                   | 2305.20                    | 2941.60                    | 2739.60                   | 108.00                    |
| 019( 0- 5)                             | 19   | 4                           | 6.28 | 0.86              | 0.4                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 12720.00                   | 17051.10                   | 3333.60                    | 4197.70                    | 4001.70                   | 158.00                    |
| 010( 0- 5)                             | 10   | 4                           | 6.47 | 0.49              | 0.4                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 12070.00                   | 19673.00                   | 3340.80                    | 4227.30                    | 3692.00                   | 216.00                    |
| 043( 0- 5)                             | 43   | 4                           | 4.72 | 1.21              | 0.2                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 9560.00                    | 15657.70                   | 1855.20                    | 2435.30                    | 2231.20                   | 133.00                    |
| 050( 0- 5)                             | 50   | 4                           | 4.83 | 0.57              | 0.4                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 10740.00                   | 16794.80                   | 2015.10                    | 3086.80                    | 2608.10                   | 111.00                    |
| ** SOIL TREATMENT = 2 (2.1 tons/ acre) |      |                             |      |                   |                          |                          |                       |             |             |             |                            |                            |                            |                            |                           |                           |
| 017( 0- 5)                             | 17   | 1                           | 6.48 | 0.48              | 0.4                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 12190.00                   | 17422.80                   | 3567.70                    | 4126.00                    | 4012.80                   | 182.00                    |
| 011( 0- 5)                             | 11   | 1                           | 6.23 | 0.44              | 0.3                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 12950.00                   | 19127.20                   | 3508.70                    | 4645.80                    | 3977.30                   | 174.00                    |
| 046( 0- 5)                             | 46   | 1                           | 5.93 | 1.73              | 0.7                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 9870.00                    | 14524.40                   | 3738.70                    | 2599.70                    | 2322.10                   | 155.00                    |
| 060( 0- 5)                             | 60   | 1                           | 5.02 | 0.49              | 0.3                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 11400.00                   | 15505.50                   | 2591.60                    | 3128.30                    | 2945.70                   | 121.00                    |
| 05( 0- 5)                              | 5    | 2                           | 5.52 | 0.60              | 0.4                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 12650.00                   | 17956.90                   | 3124.50                    | 3949.10                    | 3679.30                   | 200.00                    |
| 028( 0- 5)                             | 28   | 2                           | 5.94 | 0.60              | 0.3                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 11440.00                   | 15099.30                   | 3515.30                    | 3560.10                    | 3356.30                   | 149.00                    |
| 048( 0- 5)                             | 48   | 2                           | 5.25 | 1.26              | 0.4                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 11780.00                   | 14595.10                   | 2402.10                    | 3067.10                    | 2677.00                   | 121.00                    |
| 051( 0- 5)                             | 51   | 2                           | 4.54 | 0.85              | 0.3                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 11000.00                   | 15347.20                   | 2023.90                    | 2676.40                    | 2592.40                   | 154.00                    |
| 08( 0- 5)                              | 8    | 3                           | 6.29 | 0.48              | 0.3                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 12730.00                   | 15145.00                   | 3659.70                    | 3868.00                    | 3687.00                   | 194.00                    |
| 018( 0- 5)                             | 18   | 3                           | 6.21 | 0.54              | 0.3                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 14460.00                   | 20667.80                   | 3335.50                    | 5032.60                    | 4300.70                   | 223.00                    |
| 037( 0- 5)                             | 37   | 3                           | 5.42 | 2.12              | 0.4                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 11330.00                   | 15653.50                   | 3653.20                    | 2966.00                    | 2831.20                   | 163.00                    |
| 057( 0- 5)                             | 57   | 3                           | 5.35 | 0.90              | 0.4                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 11260.00                   | 13961.80                   | 3051.40                    | 2858.40                    | 2682.50                   | 152.00                    |
| 014( 0- 5)                             | 14   | 4                           | 6.34 | 0.41              | 0.3                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 12870.00                   | 18063.10                   | 2909.50                    | 4087.40                    | 3859.80                   | 151.00                    |
| 058( 0- 5)                             | 58   | 4                           | 5.14 | 0.91              | 0.3                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 11630.00                   | 15004.00                   | 1592.50                    | 2570.00                    | 2547.80                   | 116.00                    |
| 031( 0- 5)                             | 31   | 4                           | 5.67 | 0.38              | 0.2                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 10930.00                   | 16994.20                   | 2748.50                    | 3379.20                    | 3097.30                   | 152.00                    |
| 039( 0- 5)                             | 39   | 4                           | 5.50 | 1.07              | 0.3                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 10510.00                   | 16910.70                   | 2682.10                    | 2924.90                    | 2494.90                   | 151.00                    |

Table E-1. (continued).

| SAMPLE<br>NUMBER                      | PLOT | VEG<br>TREAT-<br>MENT | PASTE<br>pH | EC<br>(mmhos/<br>cm) | CaCO <sub>3</sub><br>(%) | ORGANIC<br>MATTER<br>(%) | CEC<br>(meq/<br>100g) | SAND<br>(%) | SILT<br>(%) | CLAY<br>(%) | TOTAL<br>Al<br>(mg/<br>kg) | TOTAL<br>Fe<br>(mg/<br>kg) | TOTAL<br>Ca<br>(mg/<br>kg) | TOTAL<br>Mg<br>(mg/<br>kg) | TOTAL<br>K<br>(mg/<br>kg) | TOTAL<br>S<br>(mg/<br>kg) |
|---------------------------------------|------|-----------------------|-------------|----------------------|--------------------------|--------------------------|-----------------------|-------------|-------------|-------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|---------------------------|
| ** SOIL TREATMENT = 3 (4.3 tons/acre) |      |                       |             |                      |                          |                          |                       |             |             |             |                            |                            |                            |                            |                           |                           |
| 0 3( 0- 5)                            | 3    | 1                     | 6.48        | 0.66                 | 0.4                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 14200.00                   | 18643.80                   | 3649.80                    | 4158.40                    | 3342.20                   | 209.00                    |
| 021( 0- 5)                            | 21   | 1                     | 6.75        | 0.72                 | 0.5                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 13610.00                   | 17360.40                   | 2897.70                    | 4710.50                    | 4064.90                   | 103.00                    |
| 038( 0- 5)                            | 38   | 1                     | 5.42        | 1.72                 | 0.3                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 9130.00                    | 12181.90                   | 2681.00                    | 2537.80                    | 2392.40                   | 152.00                    |
| 056( 0- 5)                            | 56   | 1                     | 5.17        | 0.53                 | 0.3                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 11250.00                   | 16666.50                   | 2305.20                    | 3071.00                    | 2745.50                   | 132.00                    |
| 0 1( 0- 5)                            | 1    | 2                     | 5.23        | 1.13                 | 0.3                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 11390.00                   | 15269.80                   | 2246.00                    | 3102.40                    | 3103.40                   | 161.00                    |
| 024( 0- 5)                            | 24   | 2                     | 5.48        | 0.39                 | 0.3                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 14740.00                   | 20039.90                   | 3231.10                    | 4121.50                    | 3788.60                   | 180.00                    |
| 044( 0- 5)                            | 44   | 2                     | 5.65        | 1.17                 | 0.5                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 9850.00                    | 16178.70                   | 3042.40                    | 2630.30                    | 2377.50                   | 137.00                    |
| 059( 0- 5)                            | 59   | 2                     | 5.89        | 0.90                 | 0.5                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 12660.00                   | 17051.70                   | 2738.60                    | 3109.60                    | 2850.80                   | 101.00                    |
| 012( 0- 5)                            | 12   | 3                     | 6.12        | 0.34                 | 0.3                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 9480.00                    | 14253.10                   | 2589.90                    | 3671.60                    | 3345.60                   | 152.00                    |
| 026( 0- 5)                            | 26   | 3                     | 5.57        | 0.68                 | 0.1                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 10680.00                   | 17224.60                   | 2727.10                    | 3538.40                    | 3362.30                   | 165.00                    |
| 049( 0- 5)                            | 49   | 3                     | 5.35        | 0.45                 | 0.2                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 12510.00                   | 19201.90                   | 2799.80                    | 3543.40                    | 3096.90                   | 137.00                    |
| 045( 0- 5)                            | 45   | 3                     | 5.76        | 1.56                 | 0.7                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 9650.00                    | 13098.60                   | 3192.10                    | 2397.30                    | 2380.90                   | 150.00                    |
| 027( 0- 5)                            | 27   | 4                     | 6.17        | 0.68                 | 0.4                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 11380.00                   | 16066.70                   | 3068.30                    | 3487.70                    | 3051.50                   | 169.00                    |
| 0 6( 0- 5)                            | 6    | 4                     | 6.21        | 0.44                 | 0.4                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 8950.00                    | 13012.20                   | 2996.50                    | 3704.80                    | 3206.50                   | 201.00                    |
| 035( 0- 5)                            | 35   | 4                     | 6.05        | 1.42                 | 1.4                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 12060.00                   | 13800.70                   | 8389.40                    | 2545.90                    | 2609.70                   | 166.00                    |
| 062( 0- 5)                            | 62   | 4                     | 5.07        | 1.48                 | 0.4                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 10240.00                   | 14641.90                   | 2355.30                    | 2975.80                    | 2711.40                   | 152.00                    |
| ** SOIL TREATMENT = 4 (8.5 tons/acre) |      |                       |             |                      |                          |                          |                       |             |             |             |                            |                            |                            |                            |                           |                           |
| 015( 0- 5)                            | 15   | 1                     | 6.01        | 0.63                 | 0.5                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 10850.00                   | 16910.90                   | 4762.60                    | 4049.30                    | 3968.30                   | 188.00                    |
| 025( 0- 5)                            | 25   | 1                     | 6.10        | 0.34                 | 0.3                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 15340.00                   | 18962.70                   | 3532.60                    | 4480.30                    | 3843.60                   | 144.00                    |
| 042( 0- 5)                            | 42   | 1                     | 6.52        | 1.61                 | 1.2                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 12180.00                   | 17978.20                   | 5743.00                    | 2693.50                    | 2774.50                   | 240.00                    |
| 052( 0- 5)                            | 52   | 1                     | 5.64        | 0.65                 | 0.5                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 11290.00                   | 17368.90                   | 2567.20                    | 2797.20                    | 2431.30                   | 137.00                    |
| 0 9( 0- 5)                            | 9    | 2                     | 6.28        | 0.72                 | 1.2                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 10850.00                   | 13258.10                   | 5877.10                    | 3272.70                    | 3311.00                   | 198.00                    |
| 032( 0- 5)                            | 32   | 2                     | 5.79        | 0.93                 | 0.4                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 9840.00                    | 13315.00                   | 4599.20                    | 3217.20                    | 2968.30                   | 161.00                    |
| 040( 0- 5)                            | 40   | 2                     | 6.07        | 1.16                 | 0.8                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 10190.00                   | 16939.80                   | 5790.80                    | 2751.10                    | 2504.50                   | 160.00                    |
| 063( 0- 5)                            | 63   | 2                     | 5.69        | 0.38                 | 0.4                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 13730.00                   | 18015.70                   | 2104.60                    | 3948.80                    | 3353.10                   | 107.00                    |
| 0 4( 0- 5)                            | 4    | 3                     | 6.96        | 0.57                 | 0.6                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 15790.00                   | 22872.30                   | 4768.90                    | 4920.40                    | 4224.10                   | 197.00                    |
| 030( 0- 5)                            | 30   | 3                     | 5.44        | 0.67                 | 0.3                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 13380.00                   | 19613.80                   | 2513.10                    | 3676.30                    | 3558.20                   | 129.00                    |
| 033( 0- 5)                            | 33   | 3                     | 6.02        | 2.34                 | 1.1                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 10190.00                   | 14538.10                   | 6792.10                    | 2467.90                    | 2477.60                   | 165.00                    |
| 061( 0- 5)                            | 61   | 3                     | 5.36        | 2.18                 | 0.5                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 11100.00                   | 17578.90                   | 3008.30                    | 2921.60                    | 2816.40                   | 201.00                    |
| 023( 0- 5)                            | 23   | 4                     | 5.99        | 0.38                 | 0.3                      | 0.8                      | 26.8                  | 55.6        | 31.3        | 13.1        | 12700.00                   | 19042.10                   | 3181.80                    | 4120.40                    | 4007.70                   | 174.00                    |
| 0 2( 0- 5)                            | 2    | 4                     | 5.87        | 0.73                 | 0.4                      | 0.9                      | 27.4                  | 54.7        | 32.2        | 13.1        | 11450.00                   | 16596.70                   | 2844.20                    | 3459.90                    | 3198.30                   | 181.00                    |
| 054( 0- 5)                            | 54   | 4                     | 5.81        | 0.90                 | 0.5                      | 0.6                      | 21.8                  | 57.5        | 31.2        | 11.3        | 10680.00                   | 15818.30                   | 3454.70                    | 2935.00                    | 2687.20                   | 138.00                    |
| 047( 0- 5)                            | 47   | 4                     | 5.84        | 1.19                 | 0.7                      | 0.8                      | 21.0                  | 60.2        | 30.3        | 9.5         | 11940.00                   | 16414.00                   | 4792.30                    | 2914.20                    | 2753.70                   | 156.00                    |

Table E-2. Total metals ( $\text{HNO}_3/\text{H}_2\text{O}_2$ ) in the Spangler Lime study plots.

SPANGLER FORAGE ESTABLISHMENT STUDY  
OLD RCAC PLOTS

TOTAL METALS

| SAMPLE<br>NUMBER                      | PLOT | VEG<br>TREAT-<br>MENT | TOTAL<br>Cu<br>(mg/<br>kg) | TOTAL<br>Zn<br>(mg/<br>kg) | TOTAL<br>Pb<br>(mg/<br>kg) | TOTAL<br>Mn<br>(mg/<br>kg) | TOTAL<br>Cd<br>(mg/<br>kg) | TOTAL<br>As<br>(mg/<br>kg) | TOTAL<br>Ni<br>(mg/<br>kg) | TOTAL<br>Hg<br>(mg/<br>kg) | TOTAL<br>Cr<br>(mg/<br>kg) | TOTAL<br>V<br>(mg/<br>kg) |
|---------------------------------------|------|-----------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|
| ** SOIL TREATMENT = 1 (control)       |      |                       |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| 0 7( 0- 5)                            | 7    | 1                     | 433.40                     | 358.50                     | 110.10                     | 555.00                     | 2.00 B                     | 41.90                      | 9.40                       | 10.10                      | 21.10                      | 30.50                     |
| 029( 0- 5)                            | 29   | 1                     | 257.90                     | 212.60                     | 42.80                      | 473.70                     | 2.00 B                     | 21.10                      | 8.10                       | 4.00 B                     | 19.90                      | 32.40                     |
| 034( 0- 5)                            | 34   | 1                     | 391.90                     | 254.20                     | 89.40                      | 693.00                     | 2.00 B                     | 42.20                      | 6.00 B                     | 6.20                       | 15.70                      | 23.70                     |
| 064( 0- 5)                            | 64   | 1                     | 337.60                     | 294.90                     | 97.40                      | 526.80                     | 2.30                       | 37.80                      | 8.80                       | 4.00 B                     | 20.10                      | 28.10                     |
| 020( 0- 5)                            | 20   | 2                     | 304.90                     | 284.30                     | 78.50                      | 555.60                     | 2.00 B                     | 35.20                      | 9.80                       | 4.00 B                     | 21.80                      | 35.80                     |
| 013( 0- 5)                            | 13   | 2                     | 298.80                     | 260.00                     | 87.40                      | 416.60                     | 2.00 B                     | 39.00                      | 6.80                       | 4.00 B                     | 16.10                      | 29.40                     |
| 036( 0- 5)                            | 36   | 2                     | 188.60                     | 215.00                     | 63.00                      | 576.60                     | 2.00 B                     | 31.20                      | 8.50                       | 4.00 B                     | 21.10                      | 35.80                     |
| 055( 0- 5)                            | 55   | 2                     | 190.40                     | 166.80                     | 48.00                      | 502.00                     | 2.00 B                     | 28.40                      | 6.80                       | 4.00                       | 16.20                      | 27.50                     |
| 022( 0- 5)                            | 22   | 3                     | 289.00                     | 239.80                     | 57.60                      | 509.10                     | 2.00 B                     | 26.60                      | 10.70                      | 4.00 B                     | 21.10                      | 30.10                     |
| 016( 0- 5)                            | 16   | 3                     | 292.90                     | 237.30                     | 65.30                      | 543.00                     | 2.20                       | 32.50                      | 7.80                       | 4.00 B                     | 20.40                      | 30.20                     |
| 041( 0- 5)                            | 41   | 3                     | 309.20                     | 206.20                     | 74.40                      | 546.50                     | 3.80                       | 41.60                      | 6.00 B                     | 10.00                      | 12.10                      | 19.30                     |
| 053( 0- 5)                            | 53   | 3                     | 249.60                     | 215.60                     | 54.00                      | 454.20                     | 2.00 B                     | 23.40                      | 7.40                       | 4.50                       | 17.60                      | 29.30                     |
| 019( 0- 5)                            | 19   | 4                     | 316.50                     | 245.10                     | 65.90                      | 530.20                     | 2.00 B                     | 33.40                      | 10.00                      | 4.00 B                     | 18.80                      | 29.20                     |
| 010( 0- 5)                            | 10   | 4                     | 431.50                     | 367.10                     | 131.50                     | 535.10                     | 3.50                       | 50.00                      | 10.50                      | 7.00                       | 21.30                      | 33.90                     |
| 043( 0- 5)                            | 43   | 4                     | 258.50                     | 241.00                     | 79.40                      | 511.30                     | 2.40                       | 35.60                      | 6.00 B                     | 4.70                       | 15.80                      | 30.60                     |
| 050( 0- 5)                            | 50   | 4                     | 180.20                     | 199.40                     | 48.10                      | 517.40                     | 2.00                       | 19.60                      | 8.60                       | 4.00 B                     | 18.80                      | 30.90                     |
| ** SOIL TREATMENT = 2 (2.1 tons/acre) |      |                       |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| 017( 0- 5)                            | 17   | 1                     | 308.50                     | 244.50                     | 76.70                      | 509.30                     | 2.00 B                     | 37.70                      | 7.40                       | 4.00 B                     | 20.80                      | 31.20                     |
| 011( 0- 5)                            | 11   | 1                     | 381.30                     | 320.10                     | 86.60                      | 560.70                     | 2.00 B                     | 30.20                      | 10.30                      | 5.20                       | 20.20                      | 32.10                     |
| 046( 0- 5)                            | 46   | 1                     | 235.20                     | 219.00                     | 78.60                      | 495.40                     | 3.90                       | 39.70                      | 6.90                       | 5.30                       | 15.40                      | 24.70                     |
| 060( 0- 5)                            | 60   | 1                     | 214.20                     | 232.60                     | 51.60                      | 589.90                     | 2.10                       | 18.40                      | 8.50                       | 4.00 B                     | 18.10                      | 27.60                     |
| 0 5( 0- 5)                            | 5    | 2                     | 374.90                     | 332.10                     | 115.80                     | 505.10                     | 3.80                       | 48.30                      | 8.00                       | 7.50                       | 21.20                      | 31.10                     |
| 028( 0- 5)                            | 28   | 2                     | 355.90                     | 353.70                     | 78.10                      | 606.20                     | 3.40                       | 28.80                      | 8.10                       | 6.90                       | 17.50                      | 24.70                     |
| 048( 0- 5)                            | 48   | 2                     | 205.30                     | 256.00                     | 38.90                      | 610.00                     | 2.00 B                     | 16.00 B                    | 7.10                       | 7.10                       | 17.00                      | 26.00                     |
| 051( 0- 5)                            | 51   | 2                     | 270.30                     | 203.00                     | 73.30                      | 457.90                     | 2.00 B                     | 40.90                      | 6.70                       | 4.00 B                     | 18.40                      | 28.60                     |
| 0 8( 0- 5)                            | 8    | 3                     | 381.50                     | 298.20                     | 94.60                      | 507.70                     | 3.40                       | 37.70                      | 7.90                       | 7.40                       | 16.30                      | 24.80                     |
| 018( 0- 5)                            | 18   | 3                     | 449.20                     | 392.10                     | 83.30                      | 683.90                     | 2.60                       | 27.60                      | 11.00                      | 4.00 B                     | 21.60                      | 34.00                     |
| 037( 0- 5)                            | 37   | 3                     | 278.70                     | 229.90                     | 72.20                      | 520.20                     | 3.50                       | 36.60                      | 6.60                       | 8.60                       | 17.90                      | 28.20                     |
| 057( 0- 5)                            | 57   | 3                     | 315.20                     | 238.90                     | 67.00                      | 567.60                     | 2.00 B                     | 32.80                      | 6.60                       | 4.00                       | 15.60                      | 24.80                     |
| 014( 0- 5)                            | 14   | 4                     | 308.40                     | 293.10                     | 89.60                      | 513.20                     | 2.00 B                     | 33.30                      | 9.80                       | 4.30                       | 20.40                      | 33.20                     |
| 058( 0- 5)                            | 58   | 4                     | 250.60                     | 203.50                     | 79.50                      | 564.40                     | 2.00 B                     | 37.80                      | 6.00 B                     | 4.00 B                     | 16.30                      | 27.80                     |
| 031( 0- 5)                            | 31   | 4                     | 375.40                     | 302.60                     | 85.90                      | 538.00                     | 3.30                       | 38.50                      | 8.20                       | 4.00 B                     | 18.10                      | 29.50                     |
| 039( 0- 5)                            | 39   | 4                     | 251.70                     | 238.00                     | 83.50                      | 621.00                     | 2.70                       | 40.20                      | 8.20                       | 4.00 B                     | 18.80                      | 31.40                     |

Table E-2. (continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
OLD RCAC PLOTS

## TOTAL METALS

| SAMPLE<br>NUMBER                      | PLOT | VEG<br>TREAT-<br>MENT | TOTAL<br>Cu<br>(mg/<br>kg) | TOTAL<br>Zn<br>(mg/<br>kg) | TOTAL<br>Pb<br>(mg/<br>kg) | TOTAL<br>Mn<br>(mg/<br>kg) | TOTAL<br>Cd<br>(mg/<br>kg) | TOTAL<br>As<br>(mg/<br>kg) | TOTAL<br>Ni<br>(mg/<br>kg) | TOTAL<br>Hg<br>(mg/<br>kg) | TOTAL<br>Cr<br>(mg/<br>kg) | TOTAL<br>V<br>(mg/<br>kg) |
|---------------------------------------|------|-----------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|
| ** SOIL TREATMENT = 3 (4.3 tons/acre) |      |                       |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| 0 3( 0- 5)                            | 3    | 1                     | 334.60                     | 325.40                     | 96.00                      | 495.20                     | 3.80                       | 36.70                      | 8.00                       | 4.00 B                     | 22.90                      | 33.00                     |
| 021( 0- 5)                            | 21   | 1                     | 203.90                     | 181.90                     | 46.20                      | 540.10                     | 2.00 B                     | 16.80                      | 9.60                       | 5.10                       | 19.20                      | 30.90                     |
| 038( 0- 5)                            | 38   | 1                     | 326.60                     | 246.10                     | 79.70                      | 614.40                     | 2.60                       | 38.50                      | 6.50                       | 4.00 B                     | 12.20                      | 21.10                     |
| 056( 0- 5)                            | 56   | 1                     | 362.90                     | 249.30                     | 57.80                      | 571.40                     | 2.30                       | 22.00                      | 8.00                       | 4.00 B                     | 18.30                      | 30.10                     |
| 0 1( 0- 5)                            | 1    | 2                     | 252.90                     | 246.80                     | 126.80                     | 581.20                     | 2.00 B                     | 43.90                      | 6.80                       | 4.00 B                     | 16.40                      | 27.70                     |
| 024( 0- 5)                            | 24   | 2                     | 503.00                     | 345.30                     | 83.30                      | 631.90                     | 2.00 B                     | 37.90                      | 8.70                       | 4.00 B                     | 22.90                      | 32.90                     |
| 044( 0- 5)                            | 44   | 2                     | 223.70                     | 201.90                     | 67.60                      | 788.00                     | 3.70                       | 38.40                      | 9.10                       | 4.00 B                     | 18.40                      | 33.40                     |
| 059( 0- 5)                            | 59   | 2                     | 228.40                     | 210.60                     | 64.90                      | 565.90                     | 2.00 B                     | 28.30                      | 6.90                       | 4.00 B                     | 19.20                      | 32.50                     |
| 012( 0- 5)                            | 12   | 3                     | 278.10                     | 254.60                     | 72.30                      | 503.10                     | 3.00                       | 31.50                      | 7.70                       | 4.10                       | 15.90                      | 24.30                     |
| 026( 0- 5)                            | 26   | 3                     | 300.90                     | 237.40                     | 87.30                      | 489.90                     | 3.50                       | 42.10                      | 7.90                       | 7.70                       | 19.10                      | 30.60                     |
| 049( 0- 5)                            | 49   | 3                     | 261.30                     | 270.30                     | 58.80                      | 543.30                     | 2.00 B                     | 19.70                      | 9.80                       | 4.00 B                     | 20.90                      | 36.00                     |
| 045( 0- 5)                            | 45   | 3                     | 260.50                     | 189.50                     | 96.00                      | 460.50                     | 2.30                       | 47.60                      | 6.00 B                     | 4.00 B                     | 12.50                      | 24.30                     |
| 027( 0- 5)                            | 27   | 4                     | 364.80                     | 301.70                     | 69.10                      | 521.00                     | 2.00 B                     | 31.40                      | 8.20                       | 6.90                       | 18.30                      | 27.20                     |
| 0 6( 0- 5)                            | 6    | 4                     | 335.60                     | 338.80                     | 108.10                     | 496.10                     | 3.80                       | 40.40                      | 7.60                       | 6.80                       | 12.80                      | 21.00                     |
| 035( 0- 5)                            | 35   | 4                     | 294.70                     | 223.20                     | 73.90                      | 483.60                     | 3.10                       | 36.50                      | 6.50                       | 4.00 B                     | 14.60                      | 25.40                     |
| 062( 0- 5)                            | 62   | 4                     | 209.90                     | 212.80                     | 57.60                      | 547.70                     | 2.30                       | 23.90                      | 8.60                       | 4.00 B                     | 17.00                      | 24.20                     |
| ** SOIL TREATMENT = 4 (8.5 tons/acre) |      |                       |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| 015( 0- 5)                            | 15   | 1                     | 365.90                     | 270.50                     | 81.60                      | 532.50                     | 3.40                       | 37.50                      | 7.90                       | 6.70                       | 19.90                      | 30.60                     |
| 025( 0- 5)                            | 25   | 1                     | 318.50                     | 260.30                     | 49.30                      | 535.40                     | 2.00 B                     | 17.60                      | 9.50                       | 4.00 B                     | 21.40                      | 33.30                     |
| 042( 0- 5)                            | 42   | 1                     | 372.50                     | 272.00                     | 119.50                     | 2196.10                    | 2.00 B                     | 47.70                      | 7.10                       | 4.90                       | 25.60                      | 34.90                     |
| 052( 0- 5)                            | 52   | 1                     | 235.80                     | 207.00                     | 52.10                      | 555.90                     | 2.10                       | 21.40                      | 7.90                       | 4.00 B                     | 10.00 B                    | 32.40                     |
| 0 9( 0- 5)                            | 9    | 2                     | 334.00                     | 261.20                     | 97.90                      | 417.80                     | 2.50                       | 43.60                      | 6.10                       | 4.00 B                     | 14.40                      | 23.40                     |
| 032( 0- 5)                            | 32   | 2                     | 420.90                     | 310.00                     | 89.90                      | 499.10                     | 3.70                       | 33.00                      | 6.90                       | 8.10                       | 14.70                      | 22.30                     |
| 040( 0- 5)                            | 40   | 2                     | 336.50                     | 233.90                     | 97.30                      | 611.70                     | 2.00 B                     | 49.50                      | 7.30                       | 4.00                       | 17.30                      | 31.60                     |
| 063( 0- 5)                            | 63   | 2                     | 370.90                     | 241.40                     | 50.80                      | 541.50                     | 2.00 B                     | 17.60                      | 8.80                       | 4.00 B                     | 22.10                      | 32.70                     |
| 0 4( 0- 5)                            | 4    | 3                     | 518.40                     | 371.20                     | 105.80                     | 623.60                     | 2.00 B                     | 32.00                      | 10.20                      | 4.00 B                     | 26.10                      | 38.20                     |
| 030( 0- 5)                            | 30   | 3                     | 320.80                     | 304.00                     | 92.30                      | 566.50                     | 2.00 B                     | 30.80                      | 8.90                       | 4.00 B                     | 21.20                      | 35.70                     |
| 033( 0- 5)                            | 33   | 3                     | 218.30                     | 188.70                     | 60.20                      | 493.90                     | 2.00 B                     | 33.10                      | 6.60                       | 4.00 B                     | 14.30                      | 26.90                     |
| 061( 0- 5)                            | 61   | 3                     | 338.00                     | 276.40                     | 64.40                      | 587.10                     | 3.00                       | 24.00                      | 7.60                       | 4.00 B                     | 18.10                      | 32.10                     |
| 023( 0- 5)                            | 23   | 4                     | 392.00                     | 273.10                     | 83.40                      | 538.70                     | 2.00 B                     | 39.10                      | 10.20                      | 4.40                       | 20.60                      | 31.60                     |
| 0 2( 0- 5)                            | 2    | 4                     | 337.40                     | 297.80                     | 94.70                      | 538.90                     | 2.00 B                     | 38.70                      | 7.10                       | 4.00 B                     | 17.40                      | 29.40                     |
| 054( 0- 5)                            | 54   | 4                     | 328.60                     | 242.00                     | 93.40                      | 618.90                     | 2.50                       | 35.50                      | 7.20                       | 4.10                       | 15.50                      | 28.80                     |
| 047( 0- 5)                            | 47   | 4                     | 285.20                     | 238.20                     | 74.40                      | 594.60                     | 2.00 B                     | 32.90                      | 6.80                       | 4.00 B                     | 19.00                      | 30.50                     |

Table E-3. Extractable metal levels (DTPA) in soils from the Spangler Lime study.

SPANGLER FORAGE ESTABLISHMENT STUDY  
RCAC PLOTS

DTPA EXTRACTABLE METALS

| SAMPLE<br>NUMBER                      | PLOT | VEG<br>TREAT-<br>MENT | DTPA<br>AL<br>(mg/<br>kg) | DTPA<br>Fe<br>(mg/<br>kg) | DTPA<br>Ca<br>(mg/<br>kg) | DTPA<br>Mg<br>(mg/<br>kg) | DTPA<br>K<br>(mg/<br>kg) | DTPA<br>S<br>(mg/<br>kg) |
|---------------------------------------|------|-----------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|--------------------------|
| ** SOIL TREATMENT = 1 (control)       |      |                       |                           |                           |                           |                           |                          |                          |
| 0 7( 0- 5)                            | 7    | 1                     | 1.20                      | 22.05                     | 1593.43                   | 179.77                    | 210.07                   | 13.70                    |
| 029( 0- 5)                            | 29   | 1                     | 2.00                      | 37.24                     | 1329.40                   | 163.82                    | 159.01                   | 13.84                    |
| 034( 0- 5)                            | 34   | 1                     | 2.40                      | 58.14                     | 921.62                    | 76.54                     | 120.21                   | 17.72                    |
| 064( 0- 5)                            | 64   | 1                     | 0.34 B                    | 31.92                     | 1325.55                   | 142.92                    | 223.16                   | 12.42                    |
| 013( 0- 5)                            | 13   | 2                     | 2.20                      | 34.04                     | 1307.85                   | 137.70                    | 228.01                   | 11.98                    |
| 020( 0- 5)                            | 20   | 2                     | 0.34 B                    | 31.40                     | 1341.81                   | 171.07                    | 253.74                   | 10.76                    |
| 036( 0- 5)                            | 36   | 2                     | 0.69                      | 49.16                     | 1014.17                   | 91.98                     | 84.55                    | 20.38                    |
| 055( 0-5)                             | 55   | 2                     | 3.20                      | 54.78                     | 912.37                    | 71.06                     | 130.98                   | 19.06                    |
| 016( 0- 5)                            | 16   | 3                     | 0.48                      | 45.52                     | 1158.72                   | 143.23                    | 255.52                   | 10.32                    |
| 022( 0- 5)                            | 22   | 3                     | 1.40                      | 19.19                     | 1539.78                   | 221.65                    | 209.62                   | 12.56                    |
| 053( 0- 5)                            | 53   | 3                     | 0.64                      | 39.99                     | 1073.20                   | 101.23                    | 94.91                    | 6.96                     |
| 041( 0- 5)                            | 41   | 3                     | 3.00                      | 58.92                     | 862.19                    | 65.05                     | 123.95                   | 19.54                    |
| 019( 0- 5)                            | 19   | 4                     | 1.00                      | 27.22                     | 1327.33                   | 171.11                    | 249.12                   | 13.52                    |
| 010( 0- 5)                            | 10   | 4                     | 2.00                      | 24.86                     | 1480.62                   | 182.73                    | 241.63                   | 13.24                    |
| 050( 0- 5)                            | 50   | 4                     | 2.20                      | 33.79                     | 1082.79                   | 117.06                    | 111.47                   | 11.00                    |
| 043( 0- 5)                            | 43   | 4                     | 1.07                      | 56.72                     | 992.76                    | 69.72                     | 101.35                   | 18.98                    |
| ** SOIL TREATMENT = 2 (2.1 tons/acre) |      |                       |                           |                           |                           |                           |                          |                          |
| 017( 0- 5)                            | 17   | 1                     | 0.34 B                    | 28.13                     | 1287.21                   | 146.86                    | 276.00                   | 7.94                     |
| 011( 0- 5)                            | 11   | 1                     | 0.34 B                    | 20.22                     | 1401.97                   | 200.59                    | 214.97                   | 5.96                     |
| 046( 0- 5)                            | 46   | 1                     | 2.60                      | 36.12                     | 1228.61                   | 67.66                     | 107.79                   | 23.32                    |
| 060( 0- 5)                            | 60   | 1                     | 0.61                      | 37.22                     | 1149.99                   | 102.15                    | 144.15                   | 11.80                    |
| 0 5( 0- 5)                            | 5    | 2                     | 0.48                      | 56.29                     | 1192.32                   | 128.15                    | 205.37                   | 11.68                    |
| 028( 0- 5)                            | 28   | 2                     | 0.53                      | 1.00 B                    | 154.59                    | 22.54                     | 54.23                    | 22.40                    |
| 048( 0- 5)                            | 48   | 2                     | 0.34 B                    | 26.36                     | 1196.32                   | 133.08                    | 104.34                   | 16.24                    |
| 051( 0- 5)                            | 51   | 2                     | 2.60                      | 61.02                     | 967.55                    | 68.48                     | 123.39                   | 20.82                    |
| 0 8( 0- 5)                            | 8    | 3                     | 0.34 B                    | 29.73                     | 1448.34                   | 155.23                    | 220.49                   | 9.40                     |
| 018( 0- 5)                            | 18   | 3                     | 2.00                      | 21.69                     | 1342.67                   | 240.68                    | 206.78                   | 11.80                    |
| 057( 0- 5)                            | 57   | 3                     | 0.38                      | 38.03                     | 1130.28                   | 87.96                     | 88.50                    | 11.66                    |
| 037( 0- 5)                            | 37   | 3                     | 2.20                      | 40.18                     | 1173.81                   | 79.09                     | 125.10                   | 20.82                    |
| 031( 0- 5)                            | 32   | 4                     | 0.40                      | 35.99                     | 1600.00 A                 | 106.25                    | 155.66                   | 10.90                    |
| 014( 0- 5)                            | 14   | 4                     | 0.34 B                    | 28.11                     | 1405.09                   | 159.73                    | 236.49                   | 10.06                    |
| 058( 0- 5)                            | 58   | 4                     | 2.40                      | 51.14                     | 1005.22                   | 65.85                     | 117.05                   | 18.62                    |
| 039( 0- 5)                            | 39   | 4                     | 0.51                      | 45.18                     | 1131.91                   | 70.99                     | 92.00                    | 18.12                    |

Table E-3. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RCAC PLOTS

## DTPA EXTRACTABLE METALS

| SAMPLE<br>NUMBER                      | PLOT | VEG<br>TREAT-<br>MENT | DTPA<br>AL<br>(mg/<br>kg) | DTPA<br>Fe<br>(mg/<br>kg) | DTPA<br>Ca<br>(mg/<br>kg) | DTPA<br>Mg<br>(mg/<br>kg) | DTPA<br>K<br>(mg/<br>kg) | DTPA<br>S<br>(mg/<br>kg) |
|---------------------------------------|------|-----------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|--------------------------|
| ** SOIL TREATMENT = 3 (4.3 tons/acre) |      |                       |                           |                           |                           |                           |                          |                          |
| 021( 0- 5)                            | 21   | 1                     | 0.34 B                    | 23.35                     | 1438.93                   | 272.82                    | 245.25                   | 8.84                     |
| 0 3( 0- 5)                            | 3    | 1                     | 0.34 B                    | 21.91                     | 1443.84                   | 158.95                    | 192.61                   | 7.40                     |
| 056( 0- 5)                            | 56   | 1                     | 2.20                      | 34.30                     | 1087.82                   | 98.92                     | 93.52                    | 15.98                    |
| 038( 0- 5)                            | 38   | 1                     | 0.40                      | 28.77                     | 1600.00 A                 | 110.24                    | 160.39                   | 11.00                    |
| 0 1( 0- 5)                            | 1    | 2                     | 2.40                      | 54.26                     | 1105.63                   | 97.01                     | 201.84                   | 15.58                    |
| 024( 0- 5)                            | 24   | 2                     | 0.34 B                    | 34.67                     | 1241.74                   | 139.75                    | 156.97                   | 11.58                    |
| 044( 0- 5)                            | 44   | 2                     | 1.40                      | 35.76                     | 1123.87                   | 76.83                     | 110.18                   | 15.20                    |
| 059( 0- 5)                            | 59   | 2                     | 0.34 B                    | 33.25                     | 1256.88                   | 106.87                    | 125.57                   | 13.20                    |
| 012( 0- 5)                            | 12   | 3                     | 1.20                      | 32.25                     | 1247.00                   | 151.01                    | 235.01                   | 11.54                    |
| 026( 0- 5)                            | 26   | 3                     | 2.20                      | 50.01                     | 1154.93                   | 122.08                    | 239.85                   | 15.08                    |
| 049( 0- 5)                            | 49   | 3                     | 2.00                      | 32.09                     | 1253.98                   | 138.37                    | 134.41                   | 11.28                    |
| 045( 0- 5)                            | 45   | 3                     | 2.80                      | 45.46                     | 1069.68                   | 53.69                     | 133.20                   | 23.38                    |
| 0 6( 0- 5)                            | 6    | 4                     | 2.20                      | 27.54                     | 1401.60                   | 178.75                    | 224.85                   | 12.10                    |
| 027( 0- 5)                            | 27   | 4                     | 1.47                      | 31.80                     | 1330.45                   | 150.16                    | 239.57                   | 9.70                     |
| 035( 0- 5)                            | 35   | 4                     | 0.34 B                    | 31.95                     | 1228.18                   | 71.62                     | 95.31                    | 13.44                    |
| 062( 0- 5)                            | 62   | 4                     | 1.40                      | 42.32                     | 1080.95                   | 92.15                     | 154.34                   | 21.54                    |
| ** SOIL TREATMENT = 4 (8.5 tons/acre) |      |                       |                           |                           |                           |                           |                          |                          |
| 025( 0- 5)                            | 25   | 1                     | 0.34 B                    | 22.09                     | 1415.94                   | 210.90                    | 179.05                   | 12.30                    |
| 015( 0- 5)                            | 15   | 1                     | 0.34 B                    | 36.24                     | 1263.66                   | 139.71                    | 265.61                   | 8.76                     |
| 052( 0- 5)                            | 52   | 1                     | 1.60                      | 35.16                     | 1239.84                   | 77.43                     | 87.35                    | 13.52                    |
| 042( 0- 5)                            | 42   | 1                     | 1.00                      | 28.47                     | 1307.93                   | 14.08                     | 101.55                   | 15.86                    |
| 0 9( 0- 5)                            | 9    | 2                     | 0.34 B                    | 42.05                     | 1315.99                   | 141.71                    | 253.59                   | 11.82                    |
| 032( 0- 5)                            | 32   | 2                     | 0.34 B                    | 42.93                     | 1217.90                   | 106.90                    | 148.48                   | 11.94                    |
| 040( 0- 5)                            | 40   | 2                     | 1.40                      | 1.00 B                    | 1406.31                   | 64.63                     | 109.04                   | 16.34                    |
| 063( 0- 5)                            | 63   | 2                     | 2.20                      | 22.17                     | 1210.76                   | 180.85                    | 155.05                   | 11.00                    |
| 030( 0- 5)                            | 30   | 3                     | 0.34 B                    | 34.63                     | 1203.66                   | 118.42                    | 206.54                   | 11.04                    |
| 033( 0- 5)                            | 33   | 3                     | 0.36                      | 36.91                     | 1268.53                   | 61.64                     | 126.45                   | 25.42                    |
| 061( 0- 5)                            | 61   | 3                     | 0.35                      | 34.84                     | 1225.86                   | 90.99                     | 131.91                   | 25.20                    |
| 023( 0- 5)                            | 23   | 4                     | 0.34 B                    | 34.71                     | 1313.71                   | 184.10                    | 244.75                   | 11.34                    |
| 0 2( 0- 5)                            | 2    | 4                     | 0.34 B                    | 37.04                     | 1228.90                   | 125.74                    | 192.27                   | 7.38                     |
| 047( 0- 5)                            | 47   | 4                     | 0.44                      | 35.89                     | 1211.82                   | 80.82                     | 114.85                   | 13.76                    |
| 054( 0- 5)                            | 54   | 4                     | 2.20                      | 37.06                     | 1183.86                   | 74.18                     | 36.70                    | 14.44                    |
| 0 4( 0- 5)                            | 4    | 8                     | 2.00                      | 16.40                     | 1510.85                   | 170.67                    | 162.65                   | 11.76                    |

Table E-4. Extractable metal levels (DTPA) in soils from the Spangler Lime Study Plots.

SPANGLER FORAGE ESTABLISHMENT STUDY  
RCAC PROJECT

## DTPA METALS

| SAMPLE<br>NUMBER                      | PLOT | VEG<br>TREAT-<br>MENT | DTPA<br>Cu<br>(mg/<br>kg) | DTPA<br>Zn<br>(mg/<br>kg) | DTPA<br>Pb<br>(mg/<br>kg) | DTPA<br>Mn<br>(mg/<br>kg) | DTPA<br>Cd<br>(mg/<br>kg) | DTPA<br>As<br>(mg/<br>kg) | DTPA<br>Ni<br>(mg/<br>kg) | DTPA<br>Hg<br>(mg/<br>kg) | DTPA<br>Cr<br>(mg/<br>kg) | DTPA<br>V<br>(mg/<br>kg) |
|---------------------------------------|------|-----------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|
| ** SOIL TREATMENT = 1 (control)       |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| 0 7( 0- 5)                            | 7    | 1                     | 126.53                    | 72.12                     | 11.19                     | 4.72                      | 1.50                      | 0.75                      | 0.29                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| 029( 0- 5)                            | 29   | 1                     | 107.99                    | 57.40                     | 5.00                      | 28.26                     | 1.29                      | 0.20 B                    | 1.08                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 034( 0- 5)                            | 34   | 1                     | 208.92                    | 95.11                     | 10.38                     | 33.01                     | 2.16                      | 0.39                      | 0.63                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 064( 0- 5)                            | 64   | 1                     | 141.42                    | 69.25                     | 9.12                      | 5.94                      | 1.36                      | 0.56                      | 0.43                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| 013( 0- 5)                            | 13   | 2                     | 146.80                    | 69.57                     | 11.06                     | 7.32                      | 1.57                      | 0.73                      | 0.42                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| 020( 0- 5)                            | 20   | 2                     | 208.63                    | 101.64                    | 8.45                      | 9.68                      | 1.91                      | 0.61                      | 0.55                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| 036( 0- 5)                            | 36   | 2                     | 132.17                    | 87.67                     | 7.73                      | 42.04                     | 1.96                      | 0.20 B                    | 0.87                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 055( 0- 5)                            | 55   | 2                     | 101.08                    | 56.24                     | 8.12                      | 67.23                     | 1.50                      | 0.26                      | 0.65                      | 0.13                      | 0.02                      | 0.03                     |
| 016( 0- 5)                            | 16   | 3                     | 151.33                    | 63.85                     | 7.49                      | 15.42                     | 1.31                      | 0.38                      | 0.65                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 022( 0- 5)                            | 22   | 3                     | 111.57                    | 50.60                     | 3.59                      | 4.86                      | 0.93                      | 0.36                      | 0.31                      | 0.20 B                    | 0.08 B                    | 0.06                     |
| 053( 0- 5)                            | 53   | 3                     | 137.12                    | 82.57                     | 7.63                      | 16.13                     | 1.67                      | 0.20 B                    | 0.77                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 041( 0- 5)                            | 41   | 3                     | 175.10                    | 78.29                     | 9.90                      | 52.15                     | 1.93                      | 0.26                      | 0.57                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 019( 0- 5)                            | 19   | 4                     | 118.81                    | 50.47                     | 6.83                      | 6.11                      | 1.12                      | 0.61                      | 0.30                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| 010( 0- 5)                            | 10   | 4                     | 231.90                    | 102.71                    | 12.37                     | 5.25                      | 1.92                      | 0.74                      | 0.38                      | 0.20 B                    | 0.08 B                    | 0.06                     |
| 050( 0- 5)                            | 50   | 4                     | 99.04                     | 56.93                     | 5.60                      | 25.72                     | 1.35                      | 0.20 B                    | 0.81                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 043( 0- 5)                            | 43   | 4                     | 163.97                    | 103.33                    | 10.99                     | 44.21                     | 2.14                      | 0.40                      | 0.74                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| ** SOIL TREATMENT = 2 (2.1 tons/acre) |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| 017( 0- 5)                            | 17   | 1                     | 130.94                    | 52.81                     | 8.36                      | 6.15                      | 1.07                      | 0.68                      | 0.24                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| 011( 0- 5)                            | 11   | 1                     | 195.20                    | 88.23                     | 5.42                      | 5.06                      | 1.34                      | 0.34                      | 0.42                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 046( 0- 5)                            | 46   | 1                     | 115.37                    | 57.28                     | 8.29                      | 12.24                     | 1.50                      | 0.59                      | 0.37                      | 0.20 B                    | 0.13                      | 0.04 B                   |
| 060( 0- 5)                            | 60   | 1                     | 111.83                    | 59.62                     | 5.27                      | 23.12                     | 1.50                      | 0.20 B                    | 0.77                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 0 5( 0- 5)                            | 5    | 2                     | 174.97                    | 85.86                     | 13.64                     | 12.71                     | 1.83                      | 0.58                      | 0.52                      | 0.20 B                    | 0.08                      | 0.04 B                   |
| 028( 0- 5)                            | 28   | 2                     | 0.68                      | 1.41                      | 0.02                      | 0.33                      | -0.01                     | 0.21                      | 0.20 B                    | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 048( 0- 5)                            | 48   | 2                     | 113.94                    | 94.40                     | 4.78                      | 14.90                     | 1.65                      | 0.20 B                    | 0.80                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 051( 0- 5)                            | 51   | 2                     | 105.08                    | 52.66                     | 11.38                     | 57.02                     | 1.48                      | 0.24                      | 0.64                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 0 8( 0- 5)                            | 8    | 3                     | 182.34                    | 81.24                     | 9.98                      | 5.50                      | 1.50                      | 0.58                      | 0.37                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 018( 0- 5)                            | 18   | 3                     | 188.83                    | 82.02                     | 2.47                      | 9.83                      | 1.22                      | 0.30                      | 0.49                      | 0.20 B                    | 0.08 B                    | 0.04                     |
| 057( 0- 5)                            | 57   | 3                     | 164.32                    | 82.60                     | 7.51                      | 14.42                     | 1.67                      | 0.22                      | 0.62                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 037( 0- 5)                            | 37   | 3                     | 127.85                    | 68.93                     | 7.71                      | 14.16                     | 1.59                      | 0.44                      | 0.44                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 031( 0- 5)                            | 32   | 4                     | 192.97                    | 74.10                     | 7.38                      | 8.62                      | 1.40                      | 0.32                      | 0.49                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 014( 0- 5)                            | 14   | 4                     | 182.55                    | 92.21                     | 8.37                      | 5.15                      | 1.46                      | 0.39                      | 0.38                      | 0.20 B                    | 0.08 B                    | 0.04                     |
| 058( 0- 5)                            | 58   | 4                     | 171.21                    | 77.05                     | 10.56                     | 27.37                     | 1.85                      | 0.32                      | 0.52                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 039( 0- 5)                            | 39   | 4                     | 127.46                    | 68.59                     | 9.50                      | 12.03                     | 1.60                      | 0.43                      | 0.46                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |

Table E-4. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RCAC PROJECT

## DTPA METALS

| SAMPLE<br>NUMBER                      | PLOT | VEG<br>TREAT-<br>MENT | DTPA<br>Cu<br>(mg/<br>kg) | DTPA<br>Zn<br>(mg/<br>kg) | DTPA<br>Pb<br>(mg/<br>kg) | DTPA<br>Mn<br>(mg/<br>kg) | DTPA<br>Cd<br>(mg/<br>kg) | DTPA<br>As<br>(mg/<br>kg) | DTPA<br>Ni<br>(mg/<br>kg) | DTPA<br>Hg<br>(mg/<br>kg) | DTPA<br>Cr<br>(mg/<br>kg) | DTPA<br>V<br>(mg/<br>kg) |
|---------------------------------------|------|-----------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|
| ** SOIL TREATMENT = 3 (4.3 tons/acre) |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| 021( 0- 5)                            | 21   | 1                     | 119.61                    | 51.78                     | 3.74                      | 6.65                      | 0.86                      | 0.34                      | 0.37                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| 0 3( 0- 5)                            | 3    | 1                     | 167.23                    | 98.37                     | 10.30                     | 4.16                      | 1.75                      | 0.63                      | 0.36                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| 056( 0- 5)                            | 56   | 1                     | 220.46                    | 93.96                     | 3.96                      | 22.02                     | 1.83                      | 0.20 B                    | 0.62                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 038( 0- 5)                            | 38   | 1                     | 164.21                    | 90.60                     | 6.34                      | 7.58                      | 1.84                      | 0.29                      | 0.53                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 0 1( 0- 5)                            | 1    | 2                     | 157.93                    | 81.38                     | 11.05                     | 19.54                     | 1.87                      | 0.55                      | 0.59                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 024( 0- 5)                            | 24   | 2                     | 262.45                    | 111.22                    | 7.67                      | 11.28                     | 1.96                      | 0.25                      | 0.73                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 044( 0- 5)                            | 44   | 2                     | 104.60                    | 54.65                     | 8.51                      | 9.55                      | 1.44                      | 0.43                      | 0.40                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 059( 0- 5)                            | 59   | 2                     | 159.28                    | 79.36                     | 5.37                      | 10.82                     | 1.70                      | 0.20 B                    | 0.50                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 012( 0- 5)                            | 12   | 3                     | 125.49                    | 51.97                     | 7.77                      | 6.45                      | 1.11                      | 0.63                      | 0.30                      | 0.20 B                    | 0.08 B                    | 0.06                     |
| 026( 0- 5)                            | 26   | 3                     | 146.50                    | 52.49                     | 9.77                      | 23.67                     | 1.35                      | 0.53                      | 0.50                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| 049( 0- 5)                            | 49   | 3                     | 137.80                    | 85.89                     | 7.84                      | 12.71                     | 1.70                      | 0.21                      | 0.86                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 045( 0- 5)                            | 45   | 3                     | 153.94                    | 59.38                     | 9.29                      | 21.26                     | 1.46                      | 0.53                      | 0.33                      | 0.20 B                    | 0.14                      | 0.04 B                   |
| 0 6( 0- 5)                            | 6    | 4                     | 162.06                    | 86.73                     | 13.13                     | 7.36                      | 2.01                      | 0.73                      | 0.37                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| 027( 0- 5)                            | 27   | 4                     | 226.08                    | 107.52                    | 9.49                      | 5.47                      | 1.84                      | 0.59                      | 0.54                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 035( 0- 5)                            | 35   | 4                     | 149.75                    | 48.24                     | 7.79                      | 6.95                      | 1.70                      | 0.52                      | 0.36                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 062( 0- 5)                            | 62   | 4                     | 102.84                    | 53.67                     | 5.36                      | 32.81                     | 1.39                      | 0.20 B                    | 0.66                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| ** SOIL TREATMENT = 4 (8.5 tons/acre) |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| 025( 0- 5)                            | 25   | 1                     | 151.66                    | 82.25                     | 2.44                      | 7.39                      | 1.31                      | 0.20 B                    | 0.64                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 015( 0- 5)                            | 15   | 1                     | 166.47                    | 68.93                     | 6.99                      | 7.93                      | 1.31                      | 0.60                      | 0.35                      | 0.20 B                    | 0.09                      | 0.05                     |
| 052( 0- 5)                            | 52   | 1                     | 87.43                     | 49.15                     | 5.74                      | 11.02                     | 1.35                      | 0.36                      | 0.43                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 042( 0- 5)                            | 42   | 1                     | 133.74                    | 59.49                     | 8.76                      | 4.30                      | 1.63                      | 0.52                      | 0.20 B                    | 0.20 B                    | 0.08 B                    | 0.04                     |
| 0 9( 0- 5)                            | 9    | 2                     | 171.27                    | 80.36                     | 12.00                     | 8.15                      | 1.68                      | 0.64                      | 0.39                      | 0.20 B                    | 0.08 B                    | 0.04                     |
| 032( 0- 5)                            | 32   | 2                     | 242.56                    | 109.88                    | 11.03                     | 6.62                      | 2.02                      | 0.36                      | 0.65                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 040( 0- 5)                            | 40   | 2                     | 143.08                    | 58.03                     | 11.42                     | 8.82                      | 1.73                      | 0.51                      | 0.24                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| 063( 0-5)                             | 63   | 2                     | 284.98                    | 103.23                    | 2.00                      | 7.69                      | 1.54                      | 0.20 B                    | 0.66                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 030( 0- 5)                            | 30   | 3                     | 237.00                    | 126.01                    | 7.00                      | 14.76                     | 2.11                      | 0.30                      | 0.87                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 033( 0- 5)                            | 33   | 3                     | 118.94                    | 60.04                     | 5.74                      | 25.92                     | 1.37                      | 0.35                      | 0.38                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 061( 0- 5)                            | 61   | 3                     | 200.76                    | 109.96                    | 7.45                      | 18.09                     | 2.27                      | 0.20                      | 0.59                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 023( 0- 5)                            | 23   | 4                     | 176.02                    | 61.54                     | 7.96                      | 8.86                      | 1.24                      | 0.36                      | 0.44                      | 0.20 B                    | 0.08 B                    | 0.04                     |
| 0 2( 0- 5)                            | 2    | 4                     | 161.57                    | 80.50                     | 10.51                     | 8.09                      | 1.69                      | 0.52                      | 0.40                      | 0.20 B                    | 0.08                      | 0.04 B                   |
| 047( 0- 5)                            | 47   | 4                     | 118.05                    | 62.01                     | 7.39                      | 11.65                     | 1.46                      | 0.41                      | 0.43                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 054( 0- 5)                            | 54   | 4                     | 155.78                    | 66.78                     | 8.03                      | 11.65                     | 1.63                      | 0.33                      | 0.40                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| 0 4( 0- 5)                            | 4    | 8                     | 173.40                    | 76.36                     | 6.85                      | 3.47                      | 1.33                      | 0.44                      | 0.27                      | 0.20 B                    | 0.08 B                    | 0.06                     |

Table E-5. Soluble metal levels (saturation extract) from soils in the Spangler Lime study plots.

| SPANGLER FORAGE ESTABLISHMENT STUDY<br>RIT PROJECT |      |                    |                                 |                           |                           |                           |                           |                          |                          |
|----------------------------------------------------|------|--------------------|---------------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|--------------------------|
| SOLUBLE METALS                                     |      |                    |                                 |                           |                           |                           |                           |                          |                          |
| SAMPLE<br>NUMBER                                   | PLOT | VEG TREAT-<br>MENT | SATURATION<br>PERCENTAGE<br>(%) | SOL.<br>Al<br>(mg/<br>kg) | SOL.<br>Fe<br>(mg/<br>kg) | SOL.<br>Ca<br>(mg/<br>kg) | SOL.<br>Mg<br>(mg/<br>kg) | SOL.<br>K<br>(mg/<br>kg) | SOL.<br>S<br>(mg/<br>kg) |
| ** SOIL TREATMENT = 1 (Control)                    |      |                    |                                 |                           |                           |                           |                           |                          |                          |
| 0 7( 0- 5)                                         | 7    | 1                  | 40.4                            | 0.131                     | 0.150                     | 40.779                    | 7.453                     | 14.179                   | 5.32                     |
| 029( 0- 5)                                         | 29   | 1                  | 29.9                            | 0.084                     | 0.140                     | 9.881                     | 2.236                     | 6.296                    | 2.71                     |
| 034( 0- 5)                                         | 34   | 1                  | 27.6                            | 0.096                     | 0.079                     | 20.236                    | 3.375                     | 8.571                    | 4.36                     |
| 064(0-5)                                           | 64   | 1                  | 31.6                            | 0.443                     | 0.231                     | 25.469                    | 5.450                     | 14.527                   | 6.20                     |
| 020( 0- 5)                                         | 20   | 2                  | 29.4                            | 0.055                     | 0.181                     | 11.510                    | 3.438                     | 8.331                    | 4.94                     |
| 013( 0- 5)                                         | 13   | 2                  | 31.1                            | 0.137                     | 0.166                     | 100.912 A                 | 7.182                     | 13.413                   | 14.31                    |
| 055( 0- 5)                                         | 55   | 2                  | 26.5                            | 0.265                     | 0.108                     | 7.961                     | 1.545                     | 5.618                    | 5.04                     |
| 036( 0- 5)                                         | 36   | 2                  | 27.9                            | 0.056                     | 0.025 B                   | 28.735                    | 6.951                     | 6.121                    | 5.09                     |
| 022( 0- 5)                                         | 22   | 3                  | 38.2                            | 0.065 B                   | 0.099                     | 37.229                    | 8.373                     | 13.639                   | 4.23                     |
| 016( 0- 5)                                         | 16   | 3                  | 29.1                            | 0.052                     | 0.102                     | 9.397                     | 2.175                     | 10.389                   | 3.07                     |
| 053( 0- 5)                                         | 53   | 3                  | 27.4                            | 0.137                     | 0.054                     | 8.530                     | 1.841                     | 3.452                    | 1.92                     |
| 041( 0- 5)                                         | 41   | 3                  | 25.2                            | 0.191                     | 0.106                     | 23.575                    | 3.830                     | 9.780                    | 3.65                     |
| 019( 0- 5)                                         | 19   | 4                  | 33.9                            | 0.058                     | 0.088                     | 31.751                    | 6.560                     | 17.537                   | 4.75                     |
| 010( 0- 5)                                         | 10   | 4                  | 36.8                            | 0.100                     | 0.118                     | 24.457                    | 4.410                     | 12.584                   | 3.44                     |
| 043( 0- 5)                                         | 43   | 4                  | 24.7                            | 0.042 B                   | 0.022 B                   | 0.025 B                   | 0.025 B                   | 0.025 B                  | 0.12 B                   |
| 050( 0- 5)                                         | 50   | 4                  | 25.4                            | 0.051                     | 0.024                     | 11.025                    | 2.947                     | 4.912                    | 1.86                     |
| ** SOIL TREATMENT = 2 (2.1 tons/acre)              |      |                    |                                 |                           |                           |                           |                           |                          |                          |
| 011( 0- 5)                                         | 11   | 1                  | 33.0                            | 0.121                     | 0.173                     | 13.411                    | 3.181                     | 9.538                    | 2.42                     |
| 060( 0- 5)                                         | 60   | 1                  | 28.6                            | 0.143                     | 0.054                     | 12.256                    | 2.358                     | 7.134                    | 4.13                     |
| 046( 0- 5)                                         | 46   | 1                  | 25.6                            | 0.095                     | 0.101                     | 83.038 A                  | 7.146                     | 7.915                    | 11.33                    |
| 0 5( 0- 5)                                         | 5    | 2                  | 30.9                            | 0.053                     | 0.085                     | 22.646                    | 4.033                     | 11.661                   | 4.95                     |
| 028( 0- 5)                                         | 28   | 2                  | 33.8                            | 0.089                     | 0.111                     | 26.086                    | 3.804                     | 9.152                    | 3.78                     |
| 051( 0- 5)                                         | 51   | 2                  | 24.1                            | 0.114                     | 0.101                     | 17.201                    | 2.764                     | 7.145                    | 4.65                     |
| 048( 0- 5)                                         | 48   | 2                  | 28.6                            | 0.049 B                   | 0.080                     | 92.950 A                  | 7.987                     | 7.734                    | 6.74                     |
| 0 8( 0- 5)                                         | 8    | 3                  | 32.5                            | 0.061                     | 0.126                     | 20.995                    | 3.736                     | 10.661                   | 2.91                     |
| 018( 0- 5)                                         | 18   | 3                  | 34.9                            | 0.419                     | 0.261                     | 8.425                     | 2.520                     | 6.038                    | 3.63                     |
| 057( 0- 5)                                         | 57   | 3                  | 25.3                            | 0.253                     | 0.135                     | 0.200                     | 6.406                     | 5.212                    | 6.96                     |
| 037( 0- 5)                                         | 37   | 3                  | 23.1                            | 0.046                     | 0.021                     | 73.834                    | 11.202                    | 9.059                    | 9.36                     |
| 014( 0- 5)                                         | 14   | 4                  | 34.3                            | 0.314                     | 0.264                     | 19.172                    | 3.854                     | 11.573                   | 2.88                     |
| 039( 0- 5)                                         | 39   | 4                  | 26.1                            | 0.088                     | 0.121                     | 84.825 A                  | 4.815                     | 5.216                    | 5.46                     |
| 058( 0- 5)                                         | 58   | 4                  | 24.4                            | 0.110                     | 0.161                     | 79.462 A                  | 3.712                     | 8.290                    | 6.05                     |
| 031( 0- 5)                                         | 31   | 4                  | 32.3                            | 0.096                     | 0.149                     | 14.279                    | 2.367                     | 7.715                    | 3.14                     |

A - above instrument range

B - below detection limit

Table E-5. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RIT PROJECT

## SOLUBLE METALS

| SAMPLE<br>NUMBER                      | PLOT | VEG<br>TREAT-<br>MENT | SATURATION<br>PERCENTAGE<br>(%) | SOL.<br>Al<br>(mg/<br>kg) | SOL.<br>Fe<br>(mg/<br>kg) | SOL.<br>Ca<br>(mg/<br>kg) | SOL.<br>Mg<br>(mg/<br>kg) | SOL.<br>K<br>(mg/<br>kg) | SOL.<br>S<br>(mg/<br>kg) |
|---------------------------------------|------|-----------------------|---------------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|--------------------------|
| ** SOIL TREATMENT = 3 (4.3 tons/acre) |      |                       |                                 |                           |                           |                           |                           |                          |                          |
| 0 3( 0- 5)                            | 3    | 1                     | 34.4                            | 0.058 B                   | 0.074                     | 28.329                    | 4.888                     | 10.642                   | 2.81                     |
| S21( 0- 5)                            | 21   | 1                     | 36.1                            | 0.145                     | 0.096                     | 25.887                    | 9.399                     | 13.918                   | 6.15                     |
| 056( 0- 5)                            | 56   | 1                     | 26.5                            | 0.298                     | 0.297                     | 14.140                    | 2.529                     | 4.658                    | 4.65                     |
| 038( 0- 5)                            | 38   | 1                     | 28.3                            | 0.509                     | 0.259                     | 48.993                    | 1.296                     | 6.452                    | 11.38                    |
| 0 1( 0- 5)                            | 1    | 2                     | 30.9                            | 0.052 B                   | 0.081                     | 100.263 A                 | 5.580                     | 14.374                   | 5.33                     |
| 024( 0- 5)                            | 24   | 2                     | 29.6                            | 0.059                     | 0.051                     | 11.923                    | 2.580                     | 5.821                    | 3.37                     |
| 044( 0- 5)                            | 44   | 2                     | 25.6                            | 0.043 B                   | 0.023 B                   | 0.026 B                   | 0.026 B                   | 0.026 B                  | 0.13 B                   |
| 059( 0- 5)                            | 59   | 2                     | 26.5                            | 0.089                     | 0.114                     | 26.703                    | 4.251                     | 6.463                    | 5.28                     |
| 012( 0- 5)                            | 12   | 3                     | 29.4                            | 0.764                     | 0.428                     | 8.552                     | 1.920                     | 6.791                    | 3.44                     |
| 026( 0- 5)                            | 26   | 3                     | 28.1                            | 0.169                     | 0.092                     | 20.544                    | 4.684                     | 12.308                   | 5.73                     |
| 049( 0- 5)                            | 49   | 3                     | 28.2                            | 0.068                     | 0.095                     | 14.052                    | 2.777                     | 6.117                    | 2.22                     |
| 045( 0- 5)                            | 45   | 3                     | 24.4                            | 0.042 B                   | 0.022 B                   | 0.024 B                   | 0.024 B                   | 0.024 B                  | 0.12 B                   |
| 027( 0- 5)                            | 27   | 4                     | 33.8                            | 0.057 B                   | 0.087                     | 28.918                    | 5.025                     | 14.065                   | 3.18                     |
| 0 6( 0- 5)                            | 6    | 4                     | 35.6                            | 0.061 B                   | 0.032 B                   | 15.045                    | 3.154                     | 10.648                   | 3.01                     |
| 035( 0- 5)                            | 35   | 4                     | 27.6                            | 0.047 B                   | 0.083                     | 89.538 A                  | 6.616                     | 7.423                    | 8.79                     |
| 062( 0- 5)                            | 62   | 4                     | 27.2                            | 0.050                     | 0.080                     | 88.562 A                  | 7.249                     | 14.034                   | 7.59                     |
| ** SOIL TREATMENT = 4 (8.5 tons/acre) |      |                       |                                 |                           |                           |                           |                           |                          |                          |
| 015( 0- 5)                            | 15   | 1                     | 31.9                            | 0.064                     | 0.090                     | 25.844                    | 4.800                     | 15.523                   | 3.51                     |
| 025( 0- 5)                            | 25   | 1                     | 32.6                            | 0.131                     | 0.067                     | 10.017                    | 2.563                     | 6.889                    | 2.32                     |
| 052( 0- 5)                            | 52   | 1                     | 25.4                            | 0.483                     | 0.237                     | 15.278                    | 1.841                     | 2.743                    | 4.17                     |
| 042( 0- 5)                            | 42   | 1                     | 23.4                            | 0.129                     | 0.145                     | 75.888 A                  | 5.053                     | 7.041                    | 5.41                     |
| 0 9( 0- 5)                            | 9    | 2                     | 35.7                            | 0.074                     | 0.105                     | 36.412                    | 6.790                     | 17.184                   | 5.07                     |
| 040( 0- 5)                            | 40   | 2                     | 20.9                            | 0.691                     | 0.336                     | 33.954                    | 4.075                     | 4.860                    | 5.66                     |
| 032( 0- 5)                            | 32   | 2                     | 32.3                            | 0.711                     | 0.372                     | 22.155                    | 3.291                     | 6.428                    | 5.07                     |
| 063(0-5)                              | 63   | 2                     | 32.6                            | 0.261                     | 0.131                     | 10.996                    | 3.374                     | 7.074                    | 2.54                     |
| 0 4( 0- 5)                            | 4    | 3                     | 32.1                            | 0.193                     | 0.090                     | 16.429                    | 4.963                     | 9.277                    | 3.18                     |
| 030( 0- 5)                            | 30   | 3                     | 30.4                            | 0.052 B                   | 0.088                     | 19.537                    | 3.249                     | 11.105                   | 4.06                     |
| 033( 0- 5)                            | 33   | 3                     | 24.1                            | 0.074                     | 0.088                     | 78.163 A                  | 7.161                     | 10.403                   | 10.60                    |
| 061( 0- 5)                            | 61   | 3                     | 23.7                            | 0.118                     | 0.078                     | 76.006                    | 12.985                    | 9.575                    | 9.27                     |
| 023( 0- 5)                            | 23   | 4                     | 29.4                            | 0.050 B                   | 0.083                     | 11.300                    | 2.655                     | 9.401                    | 3.39                     |
| 0 2( 0- 5)                            | 2    | 4                     | 31.0                            | 0.107                     | 0.127                     | 24.164                    | 4.116                     | 11.217                   | 3.56                     |
| 054( 0- 5)                            | 54   | 4                     | 26.0                            | 0.728                     | 0.349                     | 20.946                    | 2.587                     | 3.744                    | 5.46                     |
| 047( 0- 5)                            | 47   | 4                     | 23.6                            | 0.053                     | 0.074                     | 76.862 A                  | 4.361                     | 5.693                    | 6.17                     |

A - above instrument range

B - below detection limits

Table E-6. Soluble metal levels (saturation extract) from soils in the Spangler Lime study.

SPANGLER FORAGE ESTABLISHMENT STUDY  
RCAC PROJECT

## SOLUBLE METALS

| SAMPLE<br>NUMBER                      | PLOT | VEG<br>TREAT-<br>MENT | SOL.<br>Cu<br>(mg/<br>kg) | SOL.<br>Zn<br>(mg/<br>kg) | SOL.<br>Pb<br>(mg/<br>kg) | SOL.<br>Mn<br>(mg/<br>kg) | SOL.<br>Cd<br>(mg/<br>kg) | SOL.<br>As<br>(mg/<br>kg) | SOL.<br>Ni<br>(mg/<br>kg) | SOL.<br>Hg<br>(mg/<br>kg) | SOL.<br>Cr<br>(mg/<br>kg) | SOL.<br>V<br>(mg/<br>kg) |
|---------------------------------------|------|-----------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|
| ** SOIL TREATMENT = 1 (Control)       |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| 0 7( 0- 5)                            | 7    | 1                     | 0.221                     | 0.066                     | 0.028 B                   | 0.040 B                   | 0.040 B                   | 0.189                     | 0.028 B                   | 0.040 B                   | 0.016 B                   | 0.008 B                  |
| 029( 0- 5)                            | 29   | 1                     | 122.795                   | 0.427                     | 0.021 B                   | 0.198                     | 0.030 B                   | 0.030 B                   | 0.021 B                   | 0.030 B                   | 0.012 B                   | 0.006 B                  |
| 034( 0- 5)                            | 34   | 1                     | 0.358                     | 1.556                     | 0.019 B                   | 0.673                     | 0.028 B                   | 0.028 B                   | 0.019 B                   | 0.028 B                   | 0.011 B                   | 0.006 B                  |
| 064( 0- 5)                            | 64   | 1                     | 0.149                     | 0.063                     | 0.022 B                   | 0.032 B                   | 0.032 B                   | 0.307                     | 0.022 B                   | 0.032 B                   | 0.013 B                   | 16.268                   |
| 020( 0- 5)                            | 20   | 2                     | 0.141                     | 0.107                     | 0.021 B                   | 0.051                     | 0.029 B                   | 0.111                     | 0.021 B                   | 0.029 B                   | 0.012 B                   | 0.006 B                  |
| 013( 0- 5)                            | 13   | 2                     | 0.095                     | 0.365                     | 0.022 B                   | 0.687                     | 0.031 B                   | 0.031 B                   | 0.022 B                   | 0.031 B                   | 0.012 B                   | 0.006 B                  |
| 055( 0- 5)                            | 55   | 2                     | 0.126                     | 0.562                     | 0.019 B                   | 0.898                     | 0.027 B                   | 0.061                     | 0.019 B                   | 0.027 B                   | 0.011 B                   | 0.005 B                  |
| 036( 0- 5)                            | 36   | 2                     | 0.169                     | 1.574                     | 0.020 B                   | 0.973                     | 0.028 B                   | 0.050                     | 0.020 B                   | 0.028 B                   | 0.011 B                   | 0.006 B                  |
| 022( 0- 5)                            | 22   | 3                     | 0.127                     | 0.038 B                   | 0.027 B                   | 0.038 B                   | 0.038 B                   | 0.067                     | 0.027 B                   | 0.038 B                   | 0.015 B                   | 0.008 B                  |
| 016( 0- 5)                            | 16   | 3                     | 0.162                     | 0.240                     | 0.020 B                   | 0.093                     | 0.029 B                   | 0.084                     | 0.020 B                   | 0.029 B                   | 0.012 B                   | 0.006 B                  |
| 053( 0- 5)                            | 53   | 3                     | 0.087                     | 0.658                     | 0.019 B                   | 0.285                     | 0.027 B                   | 0.060                     | 0.019 B                   | 0.027 B                   | 0.011 B                   | 0.005 B                  |
| 041( 0- 5)                            | 41   | 3                     | 0.589                     | 2.092                     | 0.018 B                   | 1.503                     | 0.032                     | 0.025 B                   | 0.018 B                   | 0.025 B                   | 0.010 B                   | 0.005 B                  |
| 019( 0- 5)                            | 19   | 4                     | 0.158                     | 0.077                     | 0.024 B                   | 0.034 B                   | 0.034 B                   | 0.057                     | 0.024 B                   | 0.034 B                   | 0.014 B                   | 0.007 B                  |
| 010( 0- 5)                            | 10   | 4                     | 0.221                     | 0.076                     | 0.026 B                   | 0.037 B                   | 0.037 B                   | 0.156                     | 0.026 B                   | 0.037 B                   | 0.015 B                   | 0.007 B                  |
| 043( 0- 5)                            | 43   | 4                     | 0.025 B                   | 0.025 B                   | 0.017 B                   | 0.025 B                   | 0.025 B                   | 0.025 B                   | 0.017 B                   | 0.025 B                   | 0.010 B                   | 0.005 B                  |
| 050( 0- 5)                            | 50   | 4                     | 0.082                     | 0.428                     | 0.018 B                   | 0.282                     | 0.025 B                   | 0.055                     | 0.018 B                   | 0.025 B                   | 0.010 B                   | 0.005 B                  |
| ** SOIL TREATMENT = 2 (2.1 tons/acre) |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| 011( 0- 5)                            | 11   | 1                     | 0.111                     | 0.088                     | 0.023 B                   | 0.033 B                   | 0.033 B                   | 0.044                     | 0.023 B                   | 0.033 B                   | 0.013 B                   | 0.007 B                  |
| 060( 0- 5)                            | 60   | 1                     | 0.089                     | 0.413                     | 0.020 B                   | 0.226                     | 0.029 B                   | 0.098                     | 0.020 B                   | 0.029 B                   | 0.011 B                   | 0.006 B                  |
| 046( 0- 5)                            | 46   | 1                     | 0.057                     | 0.152                     | 0.018 B                   | 0.202                     | 0.026 B                   | 0.026 B                   | 0.018 B                   | 0.026 B                   | 0.010 B                   | 0.005 B                  |
| 0 5( 0- 5)                            | 5    | 2                     | 0.184                     | 0.339                     | 0.022 B                   | 0.124                     | 0.031 B                   | 0.088                     | 0.022 B                   | 0.031 B                   | 0.012 B                   | 0.006 B                  |
| 028( 0- 5)                            | 28   | 2                     | 0.115                     | 0.239                     | 0.024 B                   | 0.056                     | 0.034 B                   | 0.035                     | 0.024 B                   | 0.034 B                   | 0.014 B                   | 0.007 B                  |
| 051( 0- 5)                            | 51   | 2                     | 0.324                     | 1.123                     | 0.017 B                   | 1.152                     | 0.024 B                   | 0.024 B                   | 0.017 B                   | 0.024 B                   | 0.010 B                   | 0.005 B                  |
| 048( 0- 5)                            | 48   | 2                     | 0.092                     | 1.321                     | 0.020 B                   | 0.341                     | 0.029 B                   | 0.029 B                   | 0.020 B                   | 0.029 B                   | 0.011 B                   | 0.006 B                  |
| 0 8( 0- 5)                            | 8    | 3                     | 0.147                     | 0.061                     | 0.023 B                   | 0.033 B                   | 0.033 B                   | 0.101                     | 0.023 B                   | 0.033 B                   | 0.013 B                   | 0.007 B                  |
| 018( 0- 5)                            | 18   | 3                     | 0.092                     | 0.209                     | 0.024 B                   | 0.038                     | 0.035 B                   | 0.090                     | 0.024 B                   | 0.035 B                   | 0.014 B                   | 0.007 B                  |
| 057( 0- 5)                            | 57   | 3                     | 0.049                     | 0.329                     | 0.018 B                   | 0.192                     | 0.025 B                   | 0.062                     | 0.018 B                   | 0.025 B                   | 0.010 B                   | 0.005 B                  |
| 037( 0- 5)                            | 37   | 3                     | 0.041                     | 0.343                     | 0.016 B                   | 0.297                     | 0.023 B                   | 0.060                     | 0.016 B                   | 0.023 B                   | 0.009 B                   | 6.235                    |
| 014( 0- 5)                            | 14   | 4                     | 0.184                     | 0.111                     | 0.024 B                   | 0.034 B                   | 0.034 B                   | 0.089                     | 0.024 B                   | 0.034 B                   | 0.014 B                   | 0.007 B                  |
| 039( 0- 5)                            | 39   | 4                     | 0.054                     | 0.291                     | 0.018 B                   | 0.177                     | 0.026 B                   | 0.028                     | 0.018 B                   | 0.026 B                   | 0.010 B                   | 0.005 B                  |
| 058( 0- 5)                            | 58   | 4                     | 0.162                     | 1.198                     | 0.017 B                   | 0.625                     | 0.024 B                   | 0.024 B                   | 0.017 B                   | 0.024 B                   | 0.010 B                   | 0.005 B                  |
| 031( 0- 5)                            | 31   | 4                     | 0.188                     | 0.297                     | 0.023 B                   | 0.068                     | 0.032 B                   | 0.066                     | 0.023 B                   | 0.032 B                   | 0.013 B                   | 0.006 B                  |

Table E-6. (continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RCAC PROJECT

SOLUBLE METALS

| SAMPLE<br>NUMBER                      | PLOT | VEG<br>TREAT-<br>MENT | SOL.<br>Cu<br>(mg/<br>kg) | SOL.<br>Zn<br>(mg/<br>kg) | SOL.<br>Pb<br>(mg/<br>kg) | SOL.<br>Mn<br>(mg/<br>kg) | SOL.<br>Cd<br>(mg/<br>kg) | SOL.<br>As<br>(mg/<br>kg) | SOL.<br>Ni<br>(mg/<br>kg) | SOL.<br>Hg<br>(mg/<br>kg) | SOL.<br>Cr<br>(mg/<br>kg) | SOL.<br>V<br>(mg/<br>kg) |
|---------------------------------------|------|-----------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|
| ** SOIL TREATMENT = 3 (4.3 tons/acre) |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| 0 3( 0- 5)                            | 3    | 1                     | 0.105                     | 0.061                     | 0.024 B                   | 0.034 B                   | 0.034 B                   | 0.115                     | 0.024 B                   | 0.034 B                   | 0.014 B                   | 0.007 B                  |
| S21( 0- 5)                            | 21   | 1                     | 0.157                     | 0.358                     | 0.025 B                   | 0.036 B                   | 0.036 B                   | 0.222                     | 0.025 B                   | 0.036 B                   | 0.014 B                   | 0.007 B                  |
| 056( 0- 5)                            | 56   | 1                     | 0.196                     | 0.865                     | 0.019 B                   | 0.295                     | 0.027 B                   | 0.027 B                   | 0.019 B                   | 0.027 B                   | 0.011 B                   | 0.005 B                  |
| 038( 0- 5)                            | 38   | 1                     | 0.059                     | 0.226                     | 0.020 B                   | 0.201                     | 0.028 B                   | 0.056                     | 0.020 B                   | 0.028 B                   | 0.011 B                   | 0.006 B                  |
| 0 1( 0- 5)                            | 1    | 2                     | 0.126                     | 0.526                     | 0.022 B                   | 0.324                     | 0.031 B                   | 0.032                     | 0.022 B                   | 0.031 B                   | 0.012 B                   | 0.006 B                  |
| 024( 0- 5)                            | 24   | 2                     | 0.080                     | 0.420                     | 0.021 B                   | 0.071                     | 0.030 B                   | 0.091                     | 0.021 B                   | 0.030 B                   | 0.012 B                   | 0.006 B                  |
| 044( 0- 5)                            | 44   | 2                     | 0.026 B                   | 0.026 B                   | 0.018 B                   | 0.026 B                   | 0.026 B                   | 0.026 B                   | 0.018 B                   | 0.026 B                   | 0.010 B                   | 0.005 B                  |
| 059( 0- 5)                            | 59   | 2                     | 0.039                     | 0.099                     | 0.019 B                   | 0.064                     | 0.027 B                   | 0.027 B                   | 0.019 B                   | 0.027 B                   | 0.011 B                   | 0.005 B                  |
| 012( 0- 5)                            | 12   | 3                     | 0.195                     | 0.035                     | 0.021 B                   | 0.065                     | 0.029 B                   | 0.461                     | 0.021 B                   | 0.029 B                   | 0.012 B                   | 0.006 B                  |
| 026( 0- 5)                            | 26   | 3                     | 0.139                     | 0.079                     | 0.020 B                   | 0.185                     | 0.028 B                   | 0.154                     | 0.020 B                   | 0.028 B                   | 0.011 B                   | 0.006 B                  |
| 049( 0- 5)                            | 49   | 3                     | 0.075                     | 0.480                     | 0.020 B                   | 0.112                     | 0.028 B                   | 0.029                     | 0.020 B                   | 0.028 B                   | 0.011 B                   | 0.006 B                  |
| 045( 0- 5)                            | 45   | 3                     | 0.024 B                   | 0.024 B                   | 0.017 B                   | 0.024 B                   | 0.024 B                   | 0.024 B                   | 0.017 B                   | 0.024 B                   | 0.010 B                   | 0.005 B                  |
| 027( 0- 5)                            | 27   | 4                     | 0.142                     | 0.145                     | 0.024 B                   | 0.036                     | 0.034 B                   | 0.068                     | 0.024 B                   | 0.034 B                   | 0.014 B                   | 0.007 B                  |
| 0 6( 0- 5)                            | 6    | 4                     | 0.189                     | 0.041                     | 0.025 B                   | 0.036 B                   | 0.036 B                   | 0.164                     | 0.025 B                   | 0.036 B                   | 0.014 B                   | 0.007 B                  |
| 035( 0- 5)                            | 35   | 4                     | 0.081                     | 0.241                     | 0.019 B                   | 0.085                     | 0.028 B                   | 0.028 B                   | 0.019 B                   | 0.028 B                   | 0.011 B                   | 0.006 B                  |
| 062( 0- 5)                            | 62   | 4                     | 0.116                     | 1.050                     | 0.019 B                   | 0.966                     | 0.027 B                   | 0.027 B                   | 0.019 B                   | 0.027 B                   | 0.011 B                   | 0.005 B                  |
| ** SOIL TREATMENT = 4 (8.5 tons/acre) |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| 015( 0- 5)                            | 15   | 1                     | 0.159                     | 0.107                     | 0.022 B                   | 0.041                     | 0.032 B                   | 0.058                     | 0.022 B                   | 0.032 B                   | 0.013 B                   | 0.006 B                  |
| 025( 0- 5)                            | 25   | 1                     | 0.066                     | 0.056                     | 0.023 B                   | 0.033 B                   | 0.033 B                   | 0.107                     | 0.023 B                   | 0.033 B                   | 0.013 B                   | 0.007 B                  |
| 052( 0- 5)                            | 52   | 1                     | 0.036                     | 0.041                     | 0.018 B                   | 0.048                     | 0.025 B                   | 0.025 B                   | 0.018 B                   | 0.025 B                   | 0.010 B                   | 0.005 B                  |
| 042( 0- 5)                            | 42   | 1                     | 0.057                     | 0.138                     | 0.016 B                   | 0.039                     | 0.023 B                   | 0.023 B                   | 0.016 B                   | 0.023 B                   | 0.009 B                   | 0.005 B                  |
| 0 9( 0- 5)                            | 9    | 2                     | 0.216                     | 0.106                     | 0.025 B                   | 0.051                     | 0.036 B                   | 0.110                     | 0.025 B                   | 0.036 B                   | 0.014 B                   | 0.007 B                  |
| 040( 0- 5)                            | 40   | 2                     | 0.072                     | 0.069                     | 0.015 B                   | 0.078                     | 0.021 B                   | 0.094                     | 0.015 B                   | 0.021 B                   | 0.008 B                   | 0.004 B                  |
| 032( 0- 5)                            | 32   | 2                     | 0.074                     | 0.055                     | 0.023 B                   | 0.045                     | 0.032 B                   | 0.128                     | 0.023 B                   | 0.032 B                   | 0.013 B                   | 0.006 B                  |
| 063(0-5)                              | 63   | 2                     | 0.086                     | 0.326                     | 0.023 B                   | 0.059                     | 0.033 B                   | 0.050                     | 0.023 B                   | 0.033 B                   | 0.013 B                   | 7.814                    |
| 0 4( 0- 5)                            | 4    | 3                     | 0.093                     | 0.039                     | 0.022 B                   | 0.032                     | 0.032 B                   | 0.169                     | 0.022 B                   | 0.032 B                   | 0.013 B                   | 0.006 B                  |
| 030( 0- 5)                            | 30   | 3                     | 0.162                     | 0.615                     | 0.021 B                   | 0.150                     | 0.030 B                   | 0.036                     | 0.021 B                   | 0.030 B                   | 0.012 B                   | 0.006 B                  |
| 033( 0- 5)                            | 33   | 3                     | 0.063                     | 0.177                     | 0.017 B                   | 0.540                     | 0.024 B                   | 0.024 B                   | 0.017 B                   | 0.024 B                   | 0.010 B                   | 0.005 B                  |
| 061( 0- 5)                            | 61   | 3                     | 0.047                     | 0.645                     | 0.017 B                   | 0.443                     | 0.024 B                   | 0.024 B                   | 0.017 B                   | 0.024 B                   | 0.009 B                   | 0.005 B                  |
| 023( 0- 5)                            | 23   | 4                     | 0.189                     | 0.096                     | 0.021 B                   | 0.042                     | 0.029 B                   | 0.072                     | 0.021 B                   | 0.029 B                   | 0.012 B                   | 0.006 B                  |
| 0 2( 0- 5)                            | 2    | 4                     | 0.122                     | 0.149                     | 0.022 B                   | 0.050                     | 0.031 B                   | 0.064                     | 0.022 B                   | 0.031 B                   | 0.012 B                   | 0.006 B                  |
| 054( 0- 5)                            | 54   | 4                     | 0.054                     | 0.044                     | 0.018 B                   | 0.060                     | 0.026 B                   | 0.072                     | 0.018 B                   | 0.026 B                   | 0.010 B                   | 0.005 B                  |
| 047( 0- 5)                            | 47   | 4                     | 0.037                     | 0.090                     | 0.017 B                   | 0.084                     | 0.024 B                   | 0.024 B                   | 0.017 B                   | 0.024 B                   | 0.009 B                   | 0.005 B                  |

Table E-7. Plant tissue metal levels in forage from the Spangler Lime study.

SPANGLER FORAGE ESTABLISHMENT STUDY  
RCAC PROJECT

PLANT TISSUE LEVELS

| SAMPLE<br>NUMBER               | PLOT | SOIL<br>TREAT-<br>MENT | PLANT<br>Al<br>(mg/<br>kg) | PLANT<br>Fe<br>(mg/<br>kg) | PLANT<br>Ca<br>(mg/<br>kg) | PLANT<br>Mg<br>(mg/<br>kg) | PLANT<br>K<br>(mg/<br>kg) | PLANT<br>S<br>(mg/<br>kg) |
|--------------------------------|------|------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|---------------------------|
| ** VEGETATION TREATMENT = 1    |      |                        |                            |                            |                            |                            |                           |                           |
| * SPECIES = Crested wheatgrass |      |                        |                            |                            |                            |                            |                           |                           |
| P29C                           | 29   | 1                      | 565.000                    | 417.200                    | 3455.000                   | 415.500                    | 9050.000                  | 1570.000                  |
| P 7C                           | 7    | 1                      | 75.000                     | 81.650                     | 3548.000                   | 421.000                    | 13505.000                 | 2610.000                  |
| P34C                           | 34   | 1                      | 255.000                    | 219.800                    | 2977.500                   | 686.000                    | 11930.000                 | 1445.000                  |
| P64C                           | 64   | 1                      | 120.000                    | 136.300                    | 3189.500                   | 1068.500                   | 12380.000                 | 2165.000                  |
| P17C                           | 17   | 2                      | 85.000                     | 98.000                     | 4750.500                   | 549.000                    | 14440.000                 | 2990.000                  |
| P60C                           | 60   | 2                      | 160.000                    | 171.100                    | 3672.000                   | 977.500                    | 11285.000                 | 2220.000                  |
| P46C                           | 46   | 2                      | 150.000                    | 168.250                    | 2898.000                   | 319.500                    | 10405.000                 | 1560.000                  |
| P11C                           | 11   | 2                      | 185.000                    | 160.850                    | 3766.500                   | 1353.000                   | 13060.000                 | 2315.000                  |
| P 3C                           | 3    | 3                      | 5.000 B                    | 25.000 B                   | 459.500                    | 25.000 B                   | 8570.000                  | 25.000 B                  |
| P21C                           | 21   | 3                      | 115.000                    | 109.450                    | 2757.000                   | 1395.500                   | 10380.000                 | 1435.000                  |
| P56C                           | 56   | 3                      | 200.000                    | 200.500                    | 2997.000                   | 801.000                    | 11480.000                 | 1820.000                  |
| P38C                           | 38   | 3                      | 180.000                    | 205.800                    | 2742.500                   | 719.000                    | 10285.000                 | 2010.000                  |
| P15C                           | 15   | 4                      | 190.000                    | 188.800                    | 3964.000                   | 1527.500                   | 15015.000                 | 2455.000                  |
| P42C                           | 42   | 4                      | 180.000                    | 188.000                    | 2879.000                   | 871.000                    | 10280.000                 | 1760.000                  |
| P52C                           | 52   | 4                      | 140.000                    | 164.050                    | 3128.000                   | 950.500                    | 11720.000                 | 2085.000                  |
| P25C                           | 25   | 4                      | 65.000                     | 74.550                     | 3284.000                   | 1107.000                   | 12310.000                 | 2255.000                  |
| ** VEGETATION TREATMENT = 2    |      |                        |                            |                            |                            |                            |                           |                           |
| * SPECIES = Russian wildre     |      |                        |                            |                            |                            |                            |                           |                           |
| P13R                           | 13   | 1                      | 80.000                     | 72.400                     | 2088.050                   | 838.700                    | 18447.100                 | 1739.500                  |
| P55R                           | 55   | 1                      | 210.000                    | 166.650                    | 2569.500                   | 1106.500                   | 16665.000                 | 2145.000                  |
| P36R                           | 36   | 1                      | 180.000                    | 132.650                    | 2730.500                   | 1499.500                   | 16380.000                 | 1640.000                  |
| P20R                           | 20   | 1                      | 30.000                     | 46.400                     | 1842.000                   | 929.500                    | 21045.000                 | 2135.000                  |
| P28R                           | 28   | 2                      | 55.000                     | 38.000                     | 1390.500                   | 619.000                    | 13265.000                 | 1080.000                  |
| P48R                           | 48   | 2                      | 190.000                    | 141.400                    | 3170.000                   | 1421.000                   | 17190.000                 | 2080.000                  |
| P51R                           | 51   | 2                      | 200.000                    | 125.350                    | 2973.500                   | 1349.500                   | 18565.000                 | 2570.000                  |
| P 5R                           | 5    | 2                      | 75.000                     | 39.300                     | 2014.000                   | 1176.500                   | 18690.000                 | 2340.000                  |
| P24R                           | 24   | 3                      | 130.000                    | 94.750                     | 3918.000                   | 1648.500                   | 18885.000                 | 3115.000                  |
| P 1R                           | 1    | 3                      | 70.000                     | 51.300                     | 3167.000                   | 1444.500                   | 19160.000                 | 1955.000                  |
| P59R                           | 59   | 3                      | 270.000                    | 213.300                    | 3944.000                   | 1325.500                   | 18750.000                 | 2320.000                  |
| P44R                           | 44   | 3                      | 115.000                    | 82.200                     | 2263.500                   | 1345.000                   | 16800.000                 | 1850.000                  |
| P32R                           | 32   | 4                      | 90.000                     | 77.800                     | 3790.000                   | 1392.000                   | 21285.000                 | 2705.000                  |
| P40R                           | 40   | 4                      | 150.000                    | 134.600                    | 3009.000                   | 1539.500                   | 20835.000                 | 2175.000                  |
| P 9R                           | 9    | 4                      | 50.000                     | 49.650                     | 1974.500                   | 1243.000                   | 17635.000                 | 2280.000                  |
| P63R                           | 63   | 4                      | 165.000                    | 127.150                    | 3663.400                   | 1613.450                   | 17443.300                 | 2688.500                  |

Table E-7. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RCAC PROJECT

PLANT TISSUE LEVELS

| SAMPLE<br>NUMBER                 | PLOT | SOIL<br>TREAT-<br>MENT | PLANT<br>Al<br>(mg/<br>kg) | PLANT<br>Fe<br>(mg/<br>kg) | PLANT<br>Ca<br>(mg/<br>kg) | PLANT<br>Mg<br>(mg/<br>kg) | PLANT<br>K<br>(mg/<br>kg) | PLANT<br>S<br>(mg/<br>kg) |
|----------------------------------|------|------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|---------------------------|
| ** VEGETATION TREATMENT = 3      |      |                        |                            |                            |                            |                            |                           |                           |
| * SPECIES = Meadow brome         |      |                        |                            |                            |                            |                            |                           |                           |
| P22BR                            | 22   | 1                      | 65.000                     | 80.500                     | 2021.000                   | 1336.500                   | 14730.000                 | 1425.000                  |
| P18BR                            | 18   | 2                      | 35.000                     | 58.750                     | 4189.500                   | 1130.500                   | 17550.000                 | 2175.000                  |
| P26BR                            | 26   | 3                      | 55.000                     | 74.650                     | 3764.000                   | 1569.000                   | 19445.000                 | 2145.000                  |
| P30BR                            | 30   | 4                      | 170.000                    | 176.100                    | 3472.000                   | 1723.500                   | 18760.000                 | 2310.000                  |
| * SPECIES = Pubescent wheatgrass |      |                        |                            |                            |                            |                            |                           |                           |
| P53P                             | 53   | 1                      | 165.000                    | 154.700                    | 2462.500                   | 1082.500                   | 14320.000                 | 1475.000                  |
| P22P                             | 22   | 1                      | 35.000                     | 58.700                     | 2808.500                   | 1273.000                   | 18360.000                 | 1655.000                  |
| P41P                             | 41   | 1                      | 140.000                    | 161.400                    | 2555.000                   | 1049.000                   | 15885.000                 | 1635.000                  |
| P16P                             | 16   | 1                      | 60.000                     | 68.950                     | 2748.650                   | 889.700                    | 18705.550                 | 1260.000                  |
| P37P                             | 37   | 2                      | 210.000                    | 174.650                    | 3950.000                   | 1697.000                   | 14805.000                 | 1810.000                  |
| P57P                             | 57   | 2                      | 110.000                    | 106.350                    | 2501.500                   | 971.500                    | 17780.000                 | 1315.000                  |
| P 8P                             | 8    | 2                      | 50.000                     | 66.050                     | 3239.500                   | 1091.500                   | 18110.000                 | 2140.000                  |
| P18P                             | 18   | 2                      | 40.000                     | 60.650                     | 2690.500                   | 1673.000                   | 20520.000                 | 1935.000                  |
| P12P                             | 12   | 3                      | 35.000                     | 59.400                     | 2882.500                   | 1389.000                   | 22510.000                 | 2255.000                  |
| P49P                             | 49   | 3                      | 145.000                    | 154.100                    | 3367.500                   | 1187.500                   | 15775.000                 | 1885.000                  |
| P26P                             | 26   | 3                      | 110.000                    | 110.850                    | 3277.000                   | 1373.000                   | 21430.000                 | 1910.000                  |
| P45P                             | 45   | 3                      | 170.000                    | 175.250                    | 2745.500                   | 947.500                    | 11575.000                 | 2000.000                  |
| P 4P                             | 4    | 4                      | 75.000                     | 79.350                     | 3689.500                   | 1343.500                   | 15545.000                 | 1975.000                  |
| P30P                             | 30   | 4                      | 85.000                     | 100.850                    | 3221.500                   | 1322.500                   | 19120.000                 | 1920.000                  |
| P33P                             | 33   | 4                      | 630.000                    | 604.450                    | 4898.500                   | 1222.500                   | 14455.000                 | 1755.000                  |
| P61P                             | 61   | 4                      | 140.000                    | 133.050                    | 3688.500                   | 1035.000                   | 18035.000                 | 2195.000                  |

Table E-7. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RCAC PROJECT

PLANT TISSUE LEVELS

| SAMPLE<br>NUMBER                  | PLOT | SOIL<br>TREAT-<br>MENT | PLANT<br>Al<br>(mg/<br>kg) | PLANT<br>Fe<br>(mg/<br>kg) | PLANT<br>Ca<br>(mg/<br>kg) | PLANT<br>Mg<br>(mg/<br>kg) | PLANT<br>K<br>(mg/<br>kg) | PLANT<br>S<br>(mg/<br>kg) |
|-----------------------------------|------|------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|---------------------------|
| ** VEGETATION TREATMENT = 4       |      |                        |                            |                            |                            |                            |                           |                           |
| * SPECIES = Altai wilrye          |      |                        |                            |                            |                            |                            |                           |                           |
| P50A                              | 50   | 1                      | 170.000                    | 151.350                    | 3445.000                   | 1043.000                   | 16685.000                 | 2160.000                  |
| P58A                              | 58   | 2                      | 135.000                    | 130.450                    | 4244.500                   | 1376.000                   | 22365.000                 | 3705.000                  |
| P62A                              | 62   | 3                      | 120.000                    | 119.000                    | 3653.000                   | 1230.000                   | 24525.000                 | 2665.000                  |
| P54A                              | 54   | 4                      | 155.000                    | 142.850                    | 3032.400                   | 873.300                    | 19635.000                 | 1997.500                  |
| * SPECIES = Basin wildrye         |      |                        |                            |                            |                            |                            |                           |                           |
| P10B                              | 10   | 1                      | 135.000                    | 132.800                    | 3278.500                   | 1360.500                   | 25870.000                 | 3185.000                  |
| P14B                              | 14   | 2                      | 90.000                     | 95.050                     | 2440.500                   | 1005.500                   | 21945.000                 | 2330.000                  |
| P 6B                              | 6    | 3                      | 320.000                    | 308.150                    | 3630.000                   | 1374.500                   | 25690.000                 | 2470.000                  |
| P 2B                              | 2    | 4                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                     | 0.000                     |
| * SPECIES = Streambank wheatgrass |      |                        |                            |                            |                            |                            |                           |                           |
| P43S                              | 43   | 1                      | 200.000                    | 162.450                    | 2446.500                   | 545.500                    | 10400.000                 | 985.000                   |
| P10S                              | 10   | 1                      | 85.000                     | 86.300                     | 3032.500                   | 977.500                    | 13815.000                 | 1580.000                  |
| P50S                              | 50   | 1                      | 130.000                    | 103.600                    | 1666.500                   | 655.000                    | 9670.000                  | 1170.000                  |
| P19S                              | 19   | 1                      | 105.000                    | 102.500                    | 3099.000                   | 1670.000                   | 14700.000                 | 1235.000                  |
| P58S                              | 58   | 2                      | 300.000                    | 269.650                    | 3025.800                   | 670.700                    | 11810.000                 | 1348.500                  |
| P14S                              | 14   | 2                      | 70.000                     | 73.150                     | 2571.500                   | 746.000                    | 12200.000                 | 1360.000                  |
| P31S                              | 31   | 2                      | 180.000                    | 168.650                    | 2995.500                   | 922.500                    | 14295.000                 | 1690.000                  |
| P39S                              | 39   | 2                      | 220.000                    | 193.800                    | 2670.500                   | 1026.000                   | 12410.000                 | 1260.000                  |
| P62S                              | 62   | 3                      | 220.000                    | 179.900                    | 3231.500                   | 980.000                    | 13560.000                 | 1520.000                  |
| P 6S                              | 6    | 3                      | 100.000                    | 89.950                     | 3128.500                   | 1103.000                   | 12550.000                 | 1565.000                  |
| P27S                              | 27   | 3                      | 150.000                    | 165.850                    | 3965.500                   | 1628.000                   | 16440.000                 | 2260.000                  |
| P35S                              | 35   | 3                      | 280.000                    | 220.900                    | 2959.000                   | 637.000                    | 11130.000                 | 1315.000                  |
| P54S                              | 54   | 4                      | 280.000                    | 235.450                    | 3858.000                   | 1108.500                   | 14610.000                 | 1765.000                  |
| P23S                              | 23   | 4                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                     | 0.000                     |
| P47S                              | 47   | 4                      | 210.000                    | 120.900                    | 2693.000                   | 848.000                    | 11315.000                 | 1505.000                  |
| P 2S                              | 2    | 4                      | 335.000                    | 299.850                    | 4112.500                   | 1511.000                   | 14865.000                 | 2185.000                  |
| * SPECIES = Western wheatgrass    |      |                        |                            |                            |                            |                            |                           |                           |
| P10W                              | 10   | 1                      | 165.000                    | 167.750                    | 2886.500                   | 746.500                    | 15850.000                 | 2190.000                  |
| P14W                              | 14   | 2                      | 160.000                    | 165.100                    | 3081.500                   | 1025.500                   | 15935.000                 | 1885.000                  |
| P 6W                              | 6    | 3                      | 100.000                    | 101.600                    | 2876.500                   | 1117.000                   | 16945.000                 | 2200.000                  |
| P 2W                              | 2    | 4                      | 150.000                    | 164.000                    | 3833.000                   | 1736.000                   | 21255.000                 | 3210.000                  |

Table E-8. Plant tissue metal levels in forage from the Spangler Lime study plots.

SPANGLER FORAGE ESTABLISHMENT STUDY  
RCAC PROJECT

## PLANT TISSUE METALS

| SAMPLE<br>NUMBER               | PLOT | SOIL<br>TREAT-<br>MENT | PLANT<br>Cu<br>(mg/<br>kg) | PLANT<br>Zn<br>(mg/<br>kg) | PLANT<br>Pb<br>(mg/<br>kg) | PLANT<br>Mn<br>(mg/<br>kg) | PLANT<br>Cd<br>(mg/<br>kg) | PLANT<br>As<br>(mg/<br>kg) | PLANT<br>Ni<br>(mg/<br>kg) | PLANT<br>Hg<br>(mg/<br>kg) | PLANT<br>Cr<br>(mg/<br>kg) | PLANT<br>V<br>(mg/<br>kg) |
|--------------------------------|------|------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|
| ** VEGETATION TREATMENT = 1    |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| * SPECIES = Crested wheatgrass |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| P29C                           | 29   | 1                      | 27.400                     | 249.000                    | 3.000 B                    | 55.000                     | 1.350                      | 5.000 B                    | 2.000                      | 5.000 B                    | 2.350                      | 5.000 B                   |
| P 7C                           | 7    | 1                      | 8.650                      | 79.500                     | 3.000 B                    | 36.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P34C                           | 34   | 1                      | 15.250                     | 79.000                     | 3.000 B                    | 28.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P64C                           | 64   | 1                      | 8.150                      | 62.500                     | 3.000 B                    | 44.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P17C                           | 17   | 2                      | 8.450                      | 84.500                     | 3.000 B                    | 51.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P60C                           | 60   | 2                      | 10.650                     | 112.000                    | 3.000 B                    | 37.000                     | 0.700                      | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P46C                           | 46   | 2                      | 5.800                      | 84.500                     | 3.000 B                    | 18.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P11C                           | 11   | 2                      | 9.550                      | 117.500                    | 3.000 B                    | 64.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.600                      | 5.000 B                   |
| P 3C                           | 3    | 3                      | 2.500 B                    | 5.000 B                    | 3.000 B                    | 5.000 B                    | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P21C                           | 21   | 3                      | 5.550                      | 51.000                     | 3.000 B                    | 45.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P56C                           | 56   | 3                      | 13.050                     | 146.000                    | 3.000 B                    | 33.500                     | 0.900                      | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P38C                           | 38   | 3                      | 10.200                     | 85.000                     | 3.000 B                    | 23.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P15C                           | 15   | 4                      | 15.050                     | 108.500                    | 3.000 B                    | 53.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P42C                           | 42   | 4                      | 12.050                     | 88.500                     | 3.000 B                    | 19.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P52C                           | 52   | 4                      | 8.650                      | 92.000                     | 3.000 B                    | 23.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P25C                           | 25   | 4                      | 17.700                     | 75.500                     | 3.000 B                    | 47.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| ** VEGETATION TREATMENT = 2    |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| * SPECIES = Russian wildrye    |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| P13R                           | 13   | 1                      | 5.750                      | 51.300                     | 3.000 B                    | 16.200                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P55R                           | 55   | 1                      | 14.700                     | 104.500                    | 3.300                      | 22.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P36R                           | 36   | 1                      | 8.650                      | 114.500                    | 3.000 B                    | 20.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P20R                           | 20   | 1                      | 4.450                      | 53.500                     | 3.000 B                    | 16.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P28R                           | 28   | 2                      | 4.800                      | 44.500                     | 3.000 B                    | 5.000 B                    | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P48R                           | 48   | 2                      | 9.750                      | 121.500                    | 3.000 B                    | 23.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P51R                           | 51   | 2                      | 12.900                     | 105.500                    | 3.000 B                    | 19.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P 5R                           | 5    | 2                      | 2.500 B                    | 60.500                     | 3.000 B                    | 11.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P24R                           | 24   | 3                      | 8.350                      | 92.500                     | 3.000 B                    | 14.500                     | 0.800                      | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P 1R                           | 1    | 3                      | 20.850                     | 73.500                     | 3.000 B                    | 19.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P59R                           | 59   | 3                      | 11.250                     | 95.500                     | 3.000 B                    | 27.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P44R                           | 44   | 3                      | 8.750                      | 87.000                     | 3.000 B                    | 14.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P32R                           | 32   | 4                      | 7.150                      | 75.500                     | 3.000 B                    | 15.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P40R                           | 40   | 4                      | 10.450                     | 85.500                     | 3.000 B                    | 20.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P 9R                           | 9    | 4                      | 6.850                      | 70.500                     | 3.000 B                    | 15.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.800                      | 5.000 B                   |
| P63R                           | 63   | 4                      | 11.250                     | 122.650                    | 3.000 B                    | 39.450                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |

Table E-8. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RCAC PROJECT

PLANT TISSUE METALS

| SAMPLE<br>NUMBER                 | PLOT | SOIL<br>TREAT-<br>MENT | PLANT<br>Cu<br>(mg/<br>kg) | PLANT<br>Zn<br>(mg/<br>kg) | PLANT<br>Pb<br>(mg/<br>kg) | PLANT<br>Mn<br>(mg/<br>kg) | PLANT<br>Cd<br>(mg/<br>kg) | PLANT<br>As<br>(mg/<br>kg) | PLANT<br>Ni<br>(mg/<br>kg) | PLANT<br>Hg<br>(mg/<br>kg) | PLANT<br>Cr<br>(mg/<br>kg) | PLANT<br>V<br>(mg/<br>kg) |
|----------------------------------|------|------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|
| ** VEGETATION TREATMENT = 3      |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| * SPECIES = Meadow brome         |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| P22BR                            | 22   | 1                      | 8.950                      | 38.000                     | 3.000 B                    | 75.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P18BR                            | 18   | 2                      | 12.600                     | 44.500                     | 3.000 B                    | 106.500                    | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 2.400                      | 5.000 B                   |
| P26BR                            | 26   | 3                      | 6.350                      | 38.500                     | 3.000 B                    | 31.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P30BR                            | 30   | 4                      | 15.750                     | 56.500                     | 3.000 B                    | 57.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| * SPECIES = Pubescent wheatgrass |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| P53P                             | 53   | 1                      | 12.250                     | 113.000                    | 3.000 B                    | 28.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P22P                             | 22   | 1                      | 6.200                      | 36.500                     | 3.000 B                    | 63.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P41P                             | 41   | 1                      | 11.250                     | 65.000                     | 3.000 B                    | 30.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 2027.500                  |
| P16P                             | 16   | 1                      | 5.550                      | 27.800                     | 3.000 B                    | 45.300                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P37P                             | 37   | 2                      | 18.450                     | 171.500                    | 3.000 B                    | 48.000                     | 0.850                      | 5.000 B                    | 2.500                      | 5.000 B                    | 1.900                      | 5.000 B                   |
| P57P                             | 57   | 2                      | 14.350                     | 61.500                     | 3.000 B                    | 17.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P 8P                             | 8    | 2                      | 2.500 B                    | 36.500                     | 3.000 B                    | 29.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P18P                             | 18   | 2                      | 7.700                      | 41.000                     | 3.000 B                    | 79.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P12P                             | 12   | 3                      | 2.600                      | 45.000                     | 3.000 B                    | 57.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P49P                             | 49   | 3                      | 10.200                     | 81.000                     | 3.000 B                    | 28.000                     | 0.650 B                    | 5.150                      | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P26P                             | 26   | 3                      | 6.850                      | 37.000                     | 3.000 B                    | 39.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.700                      | 5.000 B                   |
| P45P                             | 45   | 3                      | 14.200                     | 78.500                     | 3.000 B                    | 30.000                     | 0.800                      | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P 4P                             | 4    | 4                      | 17.950                     | 35.500                     | 3.000 B                    | 40.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P30P                             | 30   | 4                      | 8.000                      | 42.500                     | 3.000 B                    | 28.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P33P                             | 33   | 4                      | 35.100                     | 164.500                    | 3.150                      | 73.000                     | 1.450                      | 5.000 B                    | 2.500                      | 5.000 B                    | 3.650                      | 5.000 B                   |
| P61P                             | 61   | 4                      | 11.300                     | 82.500                     | 3.000 B                    | 34.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |

Table E-8. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RCAC PROJECT

## PLANT TISSUE METALS

| SAMPLE<br>NUMBER                  | PLOT | SOIL<br>TREAT-<br>MENT | PLANT<br>Cu<br>(mg/<br>kg) | PLANT<br>Zn<br>(mg/<br>kg) | PLANT<br>Pb<br>(mg/<br>kg) | PLANT<br>Mn<br>(mg/<br>kg) | PLANT<br>Cd<br>(mg/<br>kg) | PLANT<br>As<br>(mg/<br>kg) | PLANT<br>Ni<br>(mg/<br>kg) | PLANT<br>Hg<br>(mg/<br>kg) | PLANT<br>Cr<br>(mg/<br>kg) | PLANT<br>V<br>(mg/<br>kg) |
|-----------------------------------|------|------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|
| ** VEGETATION TREATMENT = 4       |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| * SPECIES = Altai wildrye         |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| P50A                              | 50   | 1                      | 9.300                      | 117.500                    | 3.000 B                    | 22.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P58A                              | 58   | 2                      | 8.850                      | 133.000                    | 3.000 B                    | 18.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P62A                              | 62   | 3                      | 8.350                      | 104.000                    | 3.000 B                    | 32.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P54A                              | 54   | 4                      | 7.250                      | 66.100                     | 3.000 B                    | 23.450                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| * SPECIES = Basin wildrye         |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| P10B                              | 10   | 1                      | 10.250                     | 73.500                     | 3.000 B                    | 41.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P14B                              | 14   | 2                      | 8.750                      | 60.500                     | 3.000 B                    | 30.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P 6B                              | 6    | 3                      | 15.050                     | 78.500                     | 20.200                     | 40.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P 2B                              | 2    | 4                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                     |
| * SPECIES = Streambank wheatgrass |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| P43S                              | 43   | 1                      | 15.000                     | 81.000                     | 3.000 B                    | 22.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P10S                              | 10   | 1                      | 20.450                     | 41.000                     | 3.000 B                    | 23.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P50S                              | 50   | 1                      | 7.950                      | 67.000                     | 3.000 B                    | 22.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P19S                              | 19   | 1                      | 6.750                      | 42.500                     | 3.000 B                    | 45.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P58S                              | 58   | 2                      | 17.150                     | 89.800                     | 3.000 B                    | 33.300                     | 0.650 B                    | 5.000 B                    | 2.500                      | 5.000 B                    | 2.400                      | 5.000 B                   |
| P14S                              | 14   | 2                      | 7.450                      | 40.500                     | 3.000 B                    | 26.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P31S                              | 31   | 2                      | 9.050                      | 47.000                     | 3.000 B                    | 20.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P39S                              | 39   | 2                      | 28.950                     | 61.500                     | 3.000 B                    | 21.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P62S                              | 62   | 3                      | 14.000                     | 55.000                     | 3.000 B                    | 41.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 2.100                      | 5.000 B                   |
| P 6S                              | 6    | 3                      | 7.450                      | 36.000                     | 3.000 B                    | 20.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P27S                              | 27   | 3                      | 8.750                      | 48.000                     | 3.000 B                    | 44.000                     | 0.650 B                    | 5.000 B                    | 3.000                      | 5.000 B                    | 7.150                      | 5.000 B                   |
| P35S                              | 35   | 3                      | 15.250                     | 83.000                     | 3.000 B                    | 20.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P54S                              | 54   | 4                      | 20.250                     | 63.500                     | 3.000 B                    | 35.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 2.350                      | 5.000 B                   |
| P23S                              | 23   | 4                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                     |
| P47S                              | 47   | 4                      | 12.250                     | 54.000                     | 3.000 B                    | 25.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P 2S                              | 2    | 4                      | 53.650                     | 65.500                     | 3.000 B                    | 34.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.950                      | 5.000 B                   |
| * SPECIES = Western wheatgrass    |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| P10W                              | 10   | 1                      | 10.100                     | 56.500                     | 3.000 B                    | 41.000                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P14W                              | 14   | 2                      | 15.750                     | 53.000                     | 3.000 B                    | 42.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P 6W                              | 6    | 3                      | 19.400                     | 48.500                     | 3.000 B                    | 27.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| P 2W                              | 2    | 4                      | 11.250                     | 50.000                     | 3.000 B                    | 36.500                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |

## APPENDIX F

Total Metals, Extractable Metals, Soluble Metals,  
and Forage Metal levels from the  
Spangler Fixation Study Plots

Table F-1. Chemical and physical properties of soils in the Spangler Fixation study plots.

| SPANGLER FORAGE ESTABLISHMENT STUDY<br>RIT PROJECT |      |                             |      |                   |                          |                          |                       |             |             |             |                            |                            |                            |                            |                           |                           |
|----------------------------------------------------|------|-----------------------------|------|-------------------|--------------------------|--------------------------|-----------------------|-------------|-------------|-------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|---------------------------|
| CHEMICAL & PHYSICAL PROPERTIES                     |      |                             |      |                   |                          |                          |                       |             |             |             |                            |                            |                            |                            |                           |                           |
| SAMPLE<br>NUMBER                                   | PLOT | VEG PASTE<br>TREAT-<br>MENT | pH   | EC (mmhos/<br>cm) | CaCO <sub>3</sub><br>(%) | ORGANIC<br>MATTER<br>(%) | CEC<br>(meq/<br>100g) | SAND<br>(%) | SILT<br>(%) | CLAY<br>(%) | TOTAL<br>AL<br>(mg/<br>kg) | TOTAL<br>Fe<br>(mg/<br>kg) | TOTAL<br>Ca<br>(mg/<br>kg) | TOTAL<br>Mg<br>(mg/<br>kg) | TOTAL<br>K<br>(mg/<br>kg) | TOTAL<br>S<br>(mg/<br>kg) |
| ** SOIL TREATMENT = 1 (Control)                    |      |                             |      |                   |                          |                          |                       |             |             |             |                            |                            |                            |                            |                           |                           |
| N28( 0- 5)                                         | 28   | 1                           | 6.72 | 3.50              | 1.4                      | 1.0                      | 28.2                  | 52.9        | 35.8        | 11.3        | 13610.00                   | 14743.90                   | 6656.00                    | 4327.80                    | 3955.00                   | 230.00                    |
| N 7( 0- 5)                                         | 7    | 1                           | 5.63 | 0.92              | 0.5                      | 0.8                      | 25.6                  | 58.4        | 31.2        | 10.4        | 10850.00                   | 14064.30                   | 2412.10                    | 3155.40                    | 2611.70                   | 126.00                    |
| N35( 0- 5)                                         | 35   | 1                           | 4.89 | 1.05              | 0.3                      | 0.9                      | 24.8                  | 56.5        | 31.3        | 12.2        | 12470.00                   | 17130.10                   | 2421.90                    | 3187.90                    | 2985.50                   | 174.00                    |
| N 9( 0- 5)                                         | 9    | 2                           | 6.01 | 4.31              | 0.6                      | 0.8                      | 25.6                  | 58.4        | 31.2        | 10.4        | 11770.00                   | 14648.00                   | 4348.90                    | 3350.30                    | 3034.60                   | 173.00                    |
| N21( 0- 5)                                         | 21   | 2                           | 6.67 | 1.22              | 0.7                      | 1.0                      | 28.2                  | 52.9        | 35.8        | 11.3        | 12700.00                   | 17134.10                   | 3948.60                    | 4145.80                    | 3628.10                   | 173.00                    |
| N48( 0- 5)                                         | 48   | 2                           | 4.51 | 1.31              | 0.2                      | 0.9                      | 24.8                  | 56.5        | 31.3        | 12.2        | 10380.00                   | 13953.80                   | 1497.20                    | 2717.90                    | 2581.90                   | 103.00                    |
| N16( 0- 5)                                         | 16   | 3                           | 4.85 | 1.05              | 0.3                      | 0.8                      | 25.6                  | 58.4        | 31.2        | 10.4        | 12270.00                   | 14641.80                   | 2534.20                    | 3868.60                    | 3189.80                   | 183.00                    |
| N19( 0- 5)                                         | 19   | 3                           | 6.36 | 1.81              | 0.7                      | 1.0                      | 28.2                  | 52.9        | 35.8        | 11.3        | 12670.00                   | 15146.50                   | 3176.20                    | 4202.40                    | 3489.40                   | 141.00                    |
| N43( 0- 5)                                         | 43   | 3                           | 4.87 | 1.48              | 0.4                      | 0.9                      | 24.8                  | 56.5        | 31.3        | 12.2        | 12040.00                   | 16959.60                   | 2526.70                    | 3739.70                    | 2956.70                   | 151.00                    |
| N 2( 0- 5)                                         | 2    | 4                           | 5.13 | 9.15              | 0.3                      | 0.8                      | 25.6                  | 58.4        | 31.2        | 10.4        | 13610.00                   | 18757.00                   | 2681.80                    | 3389.00                    | 3251.50                   | 148.00                    |
| N37( 0- 5)                                         | 37   | 4                           | 5.15 | 0.82              | 0.4                      | 0.9                      | 24.8                  | 56.5        | 31.3        | 12.2        | 12460.00                   | 15897.40                   | 2420.70                    | 3232.80                    | 3039.30                   | 142.00                    |
| N29( 0- 5)                                         | 29   | 4                           | 5.28 | 1.40              | 0.5                      | 0.0                      | 0.0                   | 52.9        | 35.8        | 11.3        | 12420.00                   | 15522.90                   | 3135.60                    | 3960.90                    | 3079.40                   | 176.00                    |
| ** SOIL TREATMENT = 2 (Lime)                       |      |                             |      |                   |                          |                          |                       |             |             |             |                            |                            |                            |                            |                           |                           |
| N 6( 0- 5)                                         | 6    | 1                           | 5.62 | 1.72              | 0.5                      | 0.8                      | 25.6                  | 58.4        | 31.2        | 10.4        | 12360.00                   | 15829.00                   | 3128.70                    | 3940.80                    | 3057.00                   | 177.00                    |
| N26( 0- 5)                                         | 26   | 1                           | 5.08 | 1.82              | 0.4                      | 1.0                      | 28.2                  | 52.9        | 35.8        | 11.3        | 13500.00                   | 15235.20                   | 2949.70                    | 3382.70                    | 3259.50                   | 146.00                    |
| N34( 0- 5)                                         | 34   | 1                           | 6.16 | 4.40              | 0.9                      | 0.9                      | 24.8                  | 56.5        | 31.3        | 12.2        | 11940.00                   | 15361.80                   | 4922.50                    | 3721.00                    | 2918.50                   | 208.00                    |
| N23( 0- 5)                                         | 23   | 2                           | 5.80 | 2.97              | 0.7                      | 1.0                      | 28.2                  | 52.9        | 35.8        | 11.3        | 10740.00                   | 15266.80                   | 4566.10                    | 3948.80                    | 3238.00                   | 174.00                    |
| N12( 0- 5)                                         | 12   | 2                           | 5.93 | 2.21              | 0.5                      | 0.8                      | 25.6                  | 58.4        | 31.2        | 10.4        | 11730.00                   | 15142.00                   | 3281.50                    | 3737.30                    | 3032.80                   | 118.00                    |
| N46( 0- 5)                                         | 46   | 2                           | 5.40 | 4.09              | 0.5                      | 0.9                      | 24.8                  | 56.5        | 31.3        | 12.2        | 12240.00                   | 15754.60                   | 3525.80                    | 3492.40                    | 3063.20                   | 134.00                    |
| N20( 0- 5)                                         | 20   | 3                           | 6.73 | 2.83              | 0.9                      | 1.0                      | 28.2                  | 52.9        | 35.8        | 11.3        | 14350.00                   | 15219.30                   | 4735.80                    | 4655.80                    | 3828.30                   | 149.00                    |
| N15( 0- 5)                                         | 15   | 3                           | 5.42 | 1.79              | 0.5                      | 0.8                      | 25.6                  | 58.4        | 31.2        | 10.4        | 11960.00                   | 14153.30                   | 3076.10                    | 3976.00                    | 3045.80                   | 159.00                    |
| N41( 0- 5)                                         | 41   | 3                           | 5.49 | 2.68              | 0.6                      | 0.9                      | 24.8                  | 56.5        | 31.3        | 12.2        | 13360.00                   | 16950.50                   | 3892.90                    | 4095.30                    | 3354.70                   | 179.00                    |
| N 3( 0- 5)                                         | 3    | 4                           | 6.19 | 4.29              | 0.8                      | 0.8                      | 25.6                  | 58.4        | 31.2        | 10.4        | 12260.00                   | 15496.10                   | 4162.30                    | 3752.30                    | 3312.30                   | 226.00                    |
| N32( 0- 5)                                         | 32   | 4                           | 6.66 | 2.32              | 0.9                      | 1.0                      | 28.2                  | 52.9        | 35.8        | 11.3        | 12990.00                   | 19023.80                   | 5083.90                    | 5081.90                    | 4016.10                   | 185.00                    |
| N39( 0- 5)                                         | 39   | 4                           | 5.58 | 1.96              | 0.4                      | 0.9                      | 24.8                  | 56.5        | 31.3        | 12.2        | 11730.00                   | 15108.30                   | 3137.60                    | 3767.50                    | 2912.80                   | 137.00                    |
| ** SOIL TREATMENT = 3 (Lime + Phosphourus)         |      |                             |      |                   |                          |                          |                       |             |             |             |                            |                            |                            |                            |                           |                           |
| N 8( 0- 5)                                         | 8    | 1                           | 6.09 | 1.52              | 0.6                      | 0.8                      | 25.6                  | 58.4        | 31.2        | 10.4        | 11710.00                   | 13005.80                   | 3378.70                    | 3590.70                    | 2994.60                   | 115.00                    |
| N27( 0- 5)                                         | 27   | 1                           | 6.14 | 2.86              | 0.7                      | 1.0                      | 28.2                  | 52.9        | 35.8        | 11.3        | 12310.00                   | 17935.30                   | 4430.70                    | 4412.60                    | 3539.20                   | 157.00                    |
| N36( 0- 5)                                         | 36   | 1                           | 5.07 | 2.78              | 0.4                      | 0.9                      | 24.8                  | 56.5        | 31.3        | 12.2        | 11720.00                   | 15820.50                   | 3693.20                    | 3122.00                    | 2940.20                   | 151.00                    |
| N22( 0- 5)                                         | 22   | 2                           | 5.30 | 1.68              | 0.5                      | 1.0                      | 28.2                  | 52.9        | 35.8        | 11.3        | 11720.00                   | 15966.40                   | 2907.30                    | 3177.30                    | 3139.70                   | 175.00                    |
| N11( 0- 5)                                         | 11   | 2                           | 6.14 | 1.57              | 0.5                      | 0.8                      | 25.6                  | 58.4        | 31.2        | 10.4        | 13540.00                   | 16277.40                   | 4746.20                    | 4183.20                    | 3016.90                   | 179.00                    |
| N47( 0- 5)                                         | 47   | 2                           | 4.86 | 2.54              | 0.6                      | 0.9                      | 24.8                  | 56.5        | 31.3        | 12.2        | 12870.00                   | 15103.90                   | 3473.80                    | 3314.70                    | 2829.70                   | 144.00                    |
| N14( 0- 5)                                         | 14   | 3                           | 5.33 | 1.72              | 0.4                      | 0.8                      | 25.6                  | 58.4        | 31.2        | 10.4        | 11210.00                   | 14113.10                   | 2982.10                    | 3371.70                    | 2805.30                   | 126.00                    |
| N17( 0- 5)                                         | 17   | 3                           | 6.24 | 2.58              | 0.6                      | 1.0                      | 28.2                  | 52.9        | 35.8        | 11.3        | 12680.00                   | 18137.50                   | 4066.10                    | 3788.00                    | 3657.90                   | 145.00                    |
| N44( 0- 5)                                         | 44   | 3                           | 5.23 | 4.89              | 1.2                      | 0.9                      | 24.8                  | 56.5        | 31.3        | 12.2        | 11600.00                   | 15976.30                   | 3570.80                    | 3278.30                    | 2894.50                   | 192.00                    |
| N 1( 0- 5)                                         | 1    | 4                           | 5.74 | 2.56              | 0.7                      | 0.8                      | 25.6                  | 58.4        | 31.2        | 10.4        | 12910.00                   | 14559.80                   | 3578.30                    | 3273.80                    | 2936.70                   | 145.00                    |
| N38( 0- 5)                                         | 38   | 4                           | 5.47 | 1.35              | 0.4                      | 0.9                      | 24.8                  | 56.5        | 31.3        | 12.2        | 13470.00                   | 17118.80                   | 2976.80                    | 4001.30                    | 3101.30                   | 173.00                    |
| N30( 0- 5)                                         | 30   | 4                           | 6.60 | 2.57              | 1.0                      | 1.0                      | 28.2                  | 52.9        | 35.8        | 11.3        | 13290.00                   | 16770.00                   | 4845.70                    | 4516.60                    | 3703.10                   | 157.00                    |

Table F-1. (continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RIT PROJECT

CHEMICAL & PHYSICAL PROPERTIES

| SAMPLE<br>NUMBER                                   | PLOT | VEG PASTE<br>TREAT-<br>MENT | pH   | EC (mmhos/<br>cm) | CaCO <sub>3</sub><br>(%) | ORGANIC<br>MATTER<br>(%) | CEC<br>(meq/<br>100g) | SAND<br>(%) | SILT<br>(%) | CLAY<br>(%) | TOTAL<br>Al<br>(mg/<br>kg) | TOTAL<br>Fe<br>(mg/<br>kg) | TOTAL<br>Ca<br>(mg/<br>kg) | TOTAL<br>Mg<br>(mg/<br>kg) | TOTAL<br>K<br>(mg/<br>kg) | TOTAL<br>S<br>(mg/<br>kg) |
|----------------------------------------------------|------|-----------------------------|------|-------------------|--------------------------|--------------------------|-----------------------|-------------|-------------|-------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|---------------------------|
| ** SOIL TREATMENT = 4 (Lime + Phosphorus + Manure) |      |                             |      |                   |                          |                          |                       |             |             |             |                            |                            |                            |                            |                           |                           |
| N 5( 0- 5)                                         | 5    | 1                           | 5.69 | 0.56              | 0.6                      | 1.0                      | 25.4                  | 58.4        | 31.2        | 10.4        | 11980.00                   | 13424.40                   | 3130.80                    | 3189.30                    | 2806.40                   | 154.00                    |
| N25( 0- 5)                                         | 25   | 1                           | 6.51 | 5.73              | 1.2                      | 1.9                      | 31.0                  | 52.9        | 35.8        | 11.3        | 12960.00                   | 16087.90                   | 7027.80                    | 4381.10                    | 3914.60                   | 321.00                    |
| N33( 0- 5)                                         | 33   | 1                           | 5.68 | 5.37              | 0.7                      | 2.1                      | 25.8                  | 56.5        | 31.3        | 12.2        | 14280.00                   | 16231.50                   | 4043.80                    | 3632.50                    | 3797.20                   | 226.00                    |
| N10( 0- 5)                                         | 10   | 2                           | 6.11 | 4.12              | 0.7                      | 1.1                      | 25.0                  | 58.4        | 31.2        | 10.4        | 9840.00                    | 11527.40                   | 3052.70                    | 2940.10                    | 2698.30                   | 173.00                    |
| N24( 0- 5)                                         | 24   | 2                           | 5.78 | 5.78              | 0.6                      | 1.7                      | 27.8                  | 52.9        | 35.8        | 11.3        | 13000.00                   | 16345.30                   | 4217.90                    | 3955.60                    | 3996.90                   | 213.00                    |
| N45( 0- 5)                                         | 45   | 2                           | 6.24 | 8.19              | 0.8                      | 1.9                      | 27.8                  | 56.5        | 31.3        | 12.2        | 11070.00                   | 14784.90                   | 5228.10                    | 3669.70                    | 4005.60                   | 263.00                    |
| N13( 0- 5)                                         | 13   | 3                           | 4.80 | 1.75              | 2.6                      | 0.8                      | 24.8                  | 58.4        | 31.2        | 10.4        | 12700.00                   | 15526.10                   | 2988.70                    | 3465.10                    | 2989.90                   | 142.00                    |
| N18( 0- 5)                                         | 18   | 3                           | 6.72 | 7.05              | 1.3                      | 2.2                      | 27.6                  | 52.9        | 35.8        | 11.3        | 10900.00                   | 14948.40                   | 6449.90                    | 4622.10                    | 4264.50                   | 376.00                    |
| N42( 0- 5)                                         | 42   | 3                           | 5.97 | 6.85              | 0.8                      | 1.7                      | 26.2                  | 56.5        | 31.3        | 12.2        | 10540.00                   | 13212.10                   | 3836.80                    | 3632.10                    | 3549.40                   | 291.00                    |
| N 4( 0- 5)                                         | 4    | 4                           | 6.17 | 7.91              | 0.7                      | 1.4                      | 25.8                  | 58.4        | 31.2        | 10.4        | 11360.00                   | 16010.50                   | 4238.70                    | 3892.00                    | 3717.70                   | 213.00                    |
| N31( 0- 5)                                         | 31   | 4                           | 6.14 | 4.08              | 1.0                      | 1.6                      | 34.4                  | 52.9        | 35.8        | 11.3        | 15030.00                   | 19036.10                   | 4848.00                    | 5210.80                    | 4321.80                   | 272.00                    |
| N40( 0- 5)                                         | 40   | 4                           | 5.91 | 8.01              | 1.0                      | 3.1                      | 26.2                  | 56.5        | 31.3        | 12.2        | 10650.00                   | 16619.70                   | 4264.40                    | 3457.90                    | 4054.90                   | 322.00                    |

Table F-2. Total metals ( $\text{HNO}_3/\text{H}_2\text{O}_2$ ) in the Spangler Fixation study plots.

| SPANGLER FORAGE ESTABLISHMENT STUDY<br>RIT PROJECT |      |                       |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
|----------------------------------------------------|------|-----------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|
| TOTAL METALS                                       |      |                       |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| SAMPLE<br>NUMBER                                   | PLOT | VEG<br>TREAT-<br>MENT | TOTAL<br>Cu<br>(mg/<br>kg) | TOTAL<br>Zn<br>(mg/<br>kg) | TOTAL<br>Pb<br>(mg/<br>kg) | TOTAL<br>Mn<br>(mg/<br>kg) | TOTAL<br>Cd<br>(mg/<br>kg) | TOTAL<br>As<br>(mg/<br>kg) | TOTAL<br>Ni<br>(mg/<br>kg) | TOTAL<br>Hg<br>(mg/<br>kg) | TOTAL<br>Cr<br>(mg/<br>kg) | TOTAL<br>V<br>(mg/<br>kg) |
| ** SOIL TREATMENT = 1 (Control)                    |      |                       |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| N28( 0- 5)                                         | 28   | 1                     | 183.90                     | 145.30                     | 69.60                      | 413.30                     | 2.00 B                     | 41.60                      | 8.50                       | 4.00 B                     | 16.40                      | 24.50                     |
| N 7( 0- 5)                                         | 7    | 1                     | 205.70                     | 257.60                     | 33.90                      | 512.70                     | 2.00 B                     | 16.00 B                    | 7.80                       | 4.00 B                     | 14.90                      | 24.60                     |
| N35( 0- 5)                                         | 35   | 1                     | 426.20                     | 300.80                     | 109.70                     | 614.00                     | 2.00 B                     | 38.10                      | 8.40                       | 4.00 B                     | 18.30                      | 29.40                     |
| N 9( 0- 5)                                         | 9    | 2                     | 240.80                     | 232.90                     | 39.00                      | 533.50                     | 2.00 B                     | 16.00 B                    | 7.30                       | 5.00                       | 17.10                      | 26.20                     |
| N21( 0- 5)                                         | 21   | 2                     | 135.30                     | 122.60                     | 46.50                      | 458.40                     | 2.00 B                     | 21.50                      | 10.20                      | 4.00 B                     | 19.30                      | 29.50                     |
| N48( 0- 5)                                         | 48   | 2                     | 173.40                     | 136.30                     | 56.20                      | 390.20                     | 2.00 B                     | 40.60                      | 6.30                       | 4.00 B                     | 14.80                      | 25.90                     |
| N16( 0- 5)                                         | 16   | 3                     | 246.20                     | 205.00                     | 69.80                      | 544.60                     | 2.60                       | 39.20                      | 7.60                       | 4.00 B                     | 16.30                      | 24.00                     |
| N19( 0- 5)                                         | 19   | 3                     | 110.40                     | 136.60                     | 25.20                      | 500.60                     | 2.20                       | 21.40                      | 7.90                       | 4.00 B                     | 17.10                      | 26.00                     |
| N43( 0- 5)                                         | 43   | 3                     | 221.70                     | 176.70                     | 56.50                      | 472.50                     | 2.00                       | 27.70                      | 6.90                       | 4.00 B                     | 18.00                      | 29.80                     |
| N 2( 0- 5)                                         | 2    | 4                     | 342.70                     | 291.80                     | 70.80                      | 671.70                     | 2.00 B                     | 26.40                      | 7.60                       | 4.00 B                     | 21.50                      | 33.10                     |
| N37( 0- 5)                                         | 37   | 4                     | 220.10                     | 206.30                     | 72.00                      | 530.70                     | 2.00 B                     | 27.20                      | 7.80                       | 4.00 B                     | 17.50                      | 27.20                     |
| N29( 0- 5)                                         | 29   | 4                     | 178.20                     | 169.40                     | 54.40                      | 514.20                     | 2.00 B                     | 32.40                      | 7.10                       | 4.00 B                     | 18.10                      | 25.50                     |
| ** SOIL TREATMENT = 2 (Lime)                       |      |                       |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| N 6( 0- 5)                                         | 6    | 1                     | 323.80                     | 271.30                     | 78.10                      | 550.60                     | 2.70                       | 22.50                      | 7.20                       | 6.80                       | 18.60                      | 27.10                     |
| N26( 0- 5)                                         | 26   | 1                     | 181.10                     | 158.30                     | 43.60                      | 496.70                     | 2.00 B                     | 30.10                      | 6.90                       | 4.00 B                     | 16.60                      | 25.60                     |
| N34( 0- 5)                                         | 34   | 1                     | 297.80                     | 237.60                     | 86.20                      | 496.70                     | 2.60                       | 32.60                      | 6.60                       | 4.00 B                     | 17.20                      | 26.10                     |
| N23( 0- 5)                                         | 23   | 2                     | 127.80                     | 139.30                     | 47.80                      | 478.60                     | 2.80                       | 27.20                      | 7.70                       | 7.00                       | 16.60                      | 26.40                     |
| N12( 0- 5)                                         | 12   | 2                     | 258.50                     | 290.00                     | 37.70                      | 632.50                     | 2.50                       | 16.00 B                    | 6.90                       | 4.00 B                     | 16.30                      | 25.60                     |
| N46( 0- 5)                                         | 46   | 2                     | 222.20                     | 194.30                     | 74.40                      | 635.20                     | 2.00 B                     | 40.30                      | 7.10                       | 4.00 B                     | 17.40                      | 27.60                     |
| N20( 0- 5)                                         | 20   | 3                     | 112.20                     | 111.90                     | 36.00                      | 447.00                     | 2.00 B                     | 18.10                      | 8.20                       | 4.00 B                     | 17.40                      | 24.90                     |
| N15( 0- 5)                                         | 15   | 3                     | 132.90                     | 155.60                     | 32.30                      | 431.00                     | 2.00 B                     | 18.50                      | 8.20                       | 9.20                       | 16.80                      | 24.30                     |
| N41( 0- 5)                                         | 41   | 3                     | 195.40                     | 211.10                     | 43.70                      | 587.50                     | 2.30                       | 19.60                      | 7.20                       | 4.00 B                     | 18.20                      | 28.50                     |
| N 3( 0- 5)                                         | 3    | 4                     | 182.10                     | 209.10                     | 39.20                      | 500.30                     | 2.00 B                     | 16.00 B                    | 8.80                       | 4.00 B                     | 22.10                      | 26.40                     |
| N32( 0- 5)                                         | 32   | 4                     | 182.30                     | 202.50                     | 71.00                      | 563.60                     | 2.60                       | 40.60                      | 9.60                       | 4.30                       | 20.90                      | 32.40                     |
| N39( 0- 5)                                         | 39   | 4                     | 158.00                     | 173.90                     | 37.30                      | 418.20                     | 2.00 B                     | 16.00 B                    | 7.60                       | 4.00 B                     | 17.50                      | 25.00                     |
| ** SOIL TREATMENT = 3 (Lime + Phosphorus)          |      |                       |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| N 8( 0- 5)                                         | 8    | 1                     | 179.50                     | 255.30                     | 31.70                      | 525.80                     | 2.00 B                     | 16.00 B                    | 8.30                       | 4.00 B                     | 14.40                      | 23.70                     |
| N27( 0- 5)                                         | 27   | 1                     | 127.30                     | 141.30                     | 47.40                      | 444.60                     | 2.00 B                     | 26.30                      | 9.60                       | 6.40                       | 20.30                      | 30.40                     |
| N36( 0- 5)                                         | 36   | 1                     | 388.30                     | 258.60                     | 75.20                      | 641.20                     | 2.00 B                     | 30.60                      | 7.70                       | 4.00 B                     | 17.30                      | 28.90                     |
| N22( 0- 5)                                         | 22   | 2                     | 133.50                     | 141.00                     | 42.30                      | 624.60                     | 2.00 B                     | 26.90                      | 7.70                       | 4.00 B                     | 17.10                      | 28.90                     |
| N11( 0- 5)                                         | 11   | 2                     | 219.50                     | 307.20                     | 30.90                      | 541.00                     | 2.60                       | 16.00 B                    | 8.80                       | 4.00 B                     | 19.30                      | 27.00                     |
| N47( 0- 5)                                         | 47   | 2                     | 239.30                     | 174.40                     | 53.40                      | 459.40                     | 2.00 B                     | 28.80                      | 6.80                       | 4.30                       | 17.30                      | 27.10                     |
| N14( 0- 5)                                         | 14   | 3                     | 91.20                      | 126.10                     | 23.40                      | 460.30                     | 2.00 B                     | 16.00 B                    | 7.10                       | 5.10                       | 16.40                      | 25.00                     |
| N17( 0- 5)                                         | 17   | 3                     | 138.90                     | 129.90                     | 51.00                      | 424.40                     | 2.00 B                     | 30.80                      | 8.60                       | 4.00 B                     | 21.10                      | 33.60                     |
| N44( 0- 5)                                         | 44   | 3                     | 276.50                     | 232.50                     | 60.40                      | 517.00                     | 2.00 B                     | 31.80                      | 7.90                       | 4.00 B                     | 17.30                      | 28.50                     |
| N 1( 0- 5)                                         | 1    | 4                     | 275.10                     | 278.30                     | 60.40                      | 513.30                     | 2.20                       | 21.60                      | 6.70                       | 4.00 B                     | 16.00                      | 25.50                     |
| N38( 0- 5)                                         | 38   | 4                     | 203.20                     | 210.60                     | 46.60                      | 562.50                     | 2.50                       | 19.90                      | 8.00                       | 6.80                       | 18.90                      | 29.10                     |
| N30( 0- 5)                                         | 30   | 4                     | 146.80                     | 168.30                     | 48.50                      | 467.70                     | 2.00 B                     | 28.90                      | 8.20                       | 4.00 B                     | 19.20                      | 28.10                     |

Table F-2. (continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RIT PROJECT

TOTAL METALS

| SAMPLE<br>NUMBER                                   | PLOT | VEG<br>TREAT-<br>MENT | TOTAL<br>Cu<br>(mg/<br>kg) | TOTAL<br>Zn<br>(mg/<br>kg) | TOTAL<br>Pb<br>(mg/<br>kg) | TOTAL<br>Mn<br>(mg/<br>kg) | TOTAL<br>Cd<br>(mg/<br>kg) | TOTAL<br>As<br>(mg/<br>kg) | TOTAL<br>Ni<br>(mg/<br>kg) | TOTAL<br>Hg<br>(mg/<br>kg) | TOTAL<br>Cr<br>(mg/<br>kg) | TOTAL<br>V<br>(mg/<br>kg) |
|----------------------------------------------------|------|-----------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|
| ** SOIL TREATMENT = 4 (Lime + Phosphorus + Manure) |      |                       |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| N 5( 0- 5)                                         | 5    | 1                     | 243.70                     | 227.70                     | 46.50                      | 458.60                     | 2.00 B                     | 16.00 B                    | 20.90                      | 4.00 B                     | 15.70                      | 23.80                     |
| N25( 0- 5)                                         | 25   | 1                     | 145.60                     | 167.90                     | 45.30                      | 476.20                     | 2.00 B                     | 31.10                      | 7.80                       | 6.10                       | 19.90                      | 27.40                     |
| N33( 0- 5)                                         | 33   | 1                     | 327.20                     | 289.80                     | 67.60                      | 618.20                     | 3.10                       | 28.70                      | 7.70                       | 4.00 B                     | 18.70                      | 28.50                     |
| N10( 0- 5)                                         | 10   | 2                     | 229.70                     | 194.40                     | 43.20                      | 523.20                     | 2.00 B                     | 16.00 B                    | 6.90                       | 7.20                       | 12.30                      | 20.20                     |
| N24( 0- 5)                                         | 24   | 2                     | 135.00                     | 126.60                     | 32.80                      | 469.90                     | 2.00 B                     | 25.20                      | 7.00                       | 6.70                       | 18.90                      | 27.90                     |
| N45( 0- 5)                                         | 45   | 2                     | 199.50                     | 207.70                     | 45.70                      | 516.00                     | 2.00 B                     | 21.90                      | 7.30                       | 10.50                      | 17.60                      | 27.80                     |
| N13( 0- 5)                                         | 13   | 3                     | 185.70                     | 185.30                     | 35.90                      | 600.90                     | 2.00 B                     | 26.50                      | 7.00                       | 6.70                       | 17.70                      | 26.50                     |
| N18( 0- 5)                                         | 18   | 3                     | 147.10                     | 145.40                     | 57.70                      | 449.90                     | 2.10                       | 34.80                      | 7.80                       | 4.00 B                     | 19.10                      | 26.40                     |
| N42( 0- 5)                                         | 42   | 3                     | 175.40                     | 194.70                     | 50.70                      | 450.90                     | 2.00 B                     | 19.70                      | 6.80                       | 4.00 B                     | 15.50                      | 24.00                     |
| N 4( 0- 5)                                         | 4    | 4                     | 199.20                     | 283.20                     | 48.00                      | 565.50                     | 2.20                       | 16.00 B                    | 8.80                       | 4.00                       | 17.00                      | 28.90                     |
| N31( 0- 5)                                         | 31   | 4                     | 150.40                     | 166.60                     | 45.00                      | 590.60                     | 2.90                       | 29.00                      | 8.70                       | 4.00 B                     | 22.00                      | 30.80                     |
| N40( 0- 5)                                         | 40   | 4                     | 306.10                     | 225.90                     | 96.10                      | 485.90                     | 2.00 B                     | 43.30                      | 8.00                       | 4.00 B                     | 17.90                      | 30.70                     |

Table F-3. Extractable metals (DTPA) from the Spangler Fixation study plots.

| SPANGLER FORAGE ESTABLISHMENT STUDY<br>RIT PROJECT |      |                       |                           |                           |                           |                           |                          |                          |
|----------------------------------------------------|------|-----------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|--------------------------|
| DTPA EXTRACTABLE METALS                            |      |                       |                           |                           |                           |                           |                          |                          |
| SAMPLE<br>NUMBER                                   | PLOT | VEG<br>TREAT-<br>MENT | DTPA<br>Al<br>(mg/<br>kg) | DTPA<br>Fe<br>(mg/<br>kg) | DTPA<br>Ca<br>(mg/<br>kg) | DTPA<br>Mg<br>(mg/<br>kg) | DTPA<br>K<br>(mg/<br>kg) | DTPA<br>S<br>(mg/<br>kg) |
| ** SOIL TREATMENT = 1 (control)                    |      |                       |                           |                           |                           |                           |                          |                          |
| N28( 0- 5)                                         | 28   | 1                     | 2.60                      | 40.39                     | 1540.00 A                 | 275.08                    | 277.71                   | 34.94                    |
| N 7( 0- 5)                                         | 7    | 1                     | 1.40                      | 20.53                     | 1301.53                   | 166.00                    | 139.43                   | 18.82                    |
| N35( 0- 5)                                         | 35   | 1                     | 1.40                      | 54.22                     | 1540.00 A                 | 120.11                    | 131.23                   | 18.36                    |
| N 9( 0- 5)                                         | 9    | 2                     | 1.00                      | 19.99                     | 1540.00 A                 | 226.57                    | 232.70                   | 30.94                    |
| N21( 0- 5)                                         | 21   | 2                     | 1.60                      | 30.97                     | 1363.13                   | 219.31                    | 194.94                   | 15.66                    |
| N48( 0- 5)                                         | 48   | 2                     | 3.51                      | 78.82                     | 1540.00 A                 | 89.95                     | 139.28                   | 25.24                    |
| N16( 0- 5)                                         | 16   | 3                     | 2.00                      | 52.45                     | 1149.75                   | 135.61                    | 173.49                   | 17.22                    |
| N19( 0- 5)                                         | 19   | 3                     | 1.40                      | 26.13                     | 1416.45                   | 223.00                    | 253.91                   | 19.20                    |
| N43( 0- 5)                                         | 43   | 3                     | 1.60                      | 52.37                     | 1540.00 A                 | 145.07                    | 152.61                   | 18.08                    |
| N 2( 0- 5)                                         | 2    | 4                     | 2.00                      | 33.47                     | 1540.00 A                 | 108.19                    | 99.92                    | 12.18                    |
| N29( 0- 5)                                         | 29   | 4                     | 2.80                      | 52.73                     | 1540.00 A                 | 191.79                    | 160.63                   | 17.56                    |
| N37( 0- 5)                                         | 37   | 4                     | 1.20                      | 41.44                     | 1540.00 A                 | 123.72                    | 142.23                   | 14.18                    |
| ** SOIL TREATMENT = 2 (Lime)                       |      |                       |                           |                           |                           |                           |                          |                          |
| N 6( 0- 5)                                         | 6    | 1                     | 1.00                      | 29.94                     | 1540.00 A                 | 46.81                     | 131.81                   | 18.08                    |
| N26( 0- 5)                                         | 26   | 1                     | 1.60                      | 30.50                     | 1540.00 A                 | 123.83                    | 141.87                   | 13.20                    |
| N34( 0- 5)                                         | 34   | 1                     | 1.40                      | 27.21                     | 1540.00 A                 | 252.81                    | 195.67                   | 21.88                    |
| N23( 0- 5)                                         | 23   | 2                     | 0.40 B                    | 34.93                     | 1540.00 A                 | 251.44                    | 246.24                   | 26.40                    |
| N12( 0- 5)                                         | 12   | 2                     | 2.40                      | 18.87                     | 1540.00 A                 | 246.13                    | 144.70                   | 17.50                    |
| N46( 0- 5)                                         | 46   | 2                     | 1.40                      | 41.78                     | 1540.00 A                 | 243.66                    | 176.76                   | 28.68                    |
| N15( 0- 5)                                         | 15   | 3                     | 0.40 B                    | 34.06                     | 1540.00 A                 | 170.14                    | 151.13                   | 12.12                    |
| N20( 0- 5)                                         | 20   | 3                     | 0.40 B                    | 25.96                     | 1540.00 A                 | 349.38                    | 239.97                   | 16.62                    |
| N41( 0- 5)                                         | 41   | 3                     | 1.00                      | 27.70                     | 1540.00 A                 | 45.52                     | 226.27                   | 20.74                    |
| N 3( 0- 5)                                         | 3    | 4                     | 1.00                      | 14.11                     | 1441.86                   | 216.49                    | 215.43                   | 21.54                    |
| N39( 0- 5)                                         | 39   | 4                     | 2.60                      | 26.43                     | 1540.00 A                 | 198.95                    | 136.79                   | 16.36                    |
| N32( 0- 5)                                         | 32   | 4                     | 2.40                      | 35.48                     | 1540.00 A                 | 301.96                    | 226.78                   | 23.16                    |
| ** SOIL TREATMENT = 3 (Lime + Phosphorus)          |      |                       |                           |                           |                           |                           |                          |                          |
| N27( 0- 5)                                         | 27   | 1                     | 1.20                      | 31.41                     | 1540.00 A                 | 284.17                    | 221.28                   | 20.72                    |
| N 8( 0- 5)                                         | 8    | 1                     | 2.40                      | 14.12                     | 1540.00 A                 | 232.05                    | 138.00                   | 27.22                    |
| N36( 0- 5)                                         | 36   | 1                     | 1.40                      | 39.78                     | 1540.00 A                 | 161.52                    | 152.51                   | 18.32                    |
| N11( 0- 5)                                         | 11   | 2                     | 1.20                      | 15.12                     | 1389.94                   | 216.89                    | 129.27                   | 17.46                    |
| N22( 0- 5)                                         | 22   | 2                     | 2.80                      | 36.63                     | 1540.00 A                 | 166.80                    | 191.23                   | 18.96                    |
| N47( 0- 5)                                         | 47   | 2                     | 1.20                      | 58.63                     | 1540.00 A                 | 214.15                    | 129.18                   | 27.80                    |
| N14( 0- 5)                                         | 14   | 3                     | 1.20                      | 22.30                     | 1540.00 A                 | 37.58                     | 114.22                   | 18.74                    |
| N17( 0- 5)                                         | 17   | 3                     | 2.60                      | 34.01                     | 1540.00 A                 | 204.73                    | 195.69                   | 18.14                    |

Table F-3. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RIT PROJECT

## DTPA EXTRACTABLE METALS

| SAMPLE<br>NUMBER    | PLOT | VEG<br>TREAT-<br>MENT | DTPA<br>Al<br>(mg/<br>kg)      | DTPA<br>Fe<br>(mg/<br>kg) | DTPA<br>Ca<br>(mg/<br>kg) | DTPA<br>Mg<br>(mg/<br>kg) | DTPA<br>K<br>(mg/<br>kg) | DTPA<br>S<br>(mg/<br>kg) |
|---------------------|------|-----------------------|--------------------------------|---------------------------|---------------------------|---------------------------|--------------------------|--------------------------|
| N44( 0- 5)          | 44   | 3                     | 1.40                           | 48.16                     | 1540.00 A                 | 199.41                    | 232.16                   | 35.18                    |
| N 1( 0- 5)          | 1    | 4                     | 1.40                           | 25.31                     | 1256.34                   | 169.39                    | 139.37                   | 21.90                    |
| N30( 0- 5)          | 30   | 4                     | 1.20                           | 30.01                     | 1540.00 A                 | 313.54                    | 219.03                   | 26.62                    |
| N38( 0- 5)          | 38   | 4                     | 1.20                           | 30.41                     | 1540.00 A                 | 184.15                    | 142.93                   | 18.30                    |
| ** SOIL TREATMENT = |      |                       | 4 (Lime + Phosphorus + Manure) |                           |                           |                           |                          |                          |
| N 5( 0- 5)          | 5    | 1                     | 1.20                           | 22.27                     | 1540.00 A                 | 220.83                    | 195.61                   | 32.84                    |
| N25( 0- 5)          | 25   | 1                     | 1.20                           | 20.03                     | 1533.04                   | 320.74                    | 504.80                   | 53.06                    |
| N33( 0- 5)          | 33   | 1                     | 0.40 B                         | 24.02                     | 1540.00 A                 | 209.55                    | 323.17                   | 44.26                    |
| N10( 0- 5)          | 10   | 2                     | 0.40 B                         | 21.23                     | 1540.00 A                 | 227.81                    | 240.03                   | 35.96                    |
| N24( 0- 5)          | 24   | 2                     | 1.20                           | 29.49                     | 1359.02                   | 120.95                    | 450.22                   | 46.10                    |
| N45( 0- 5)          | 45   | 2                     | 1.40                           | 23.66                     | 1441.58                   | 328.27                    | 715.87                   | 75.64                    |
| N18( 0- 5)          | 18   | 3                     | 1.00                           | 22.24                     | 1540.00 A                 | 334.44                    | 703.77                   | 59.36                    |
| N13( 0- 5)          | 13   | 3                     | 1.80                           | 37.29                     | 1540.00 A                 | 127.40                    | 113.80                   | 18.80                    |
| N42( 0- 5)          | 42   | 3                     | 0.40 B                         | 29.88                     | 1540.00 A                 | 254.78                    | 584.12                   | 61.96                    |
| N 4( 0- 5)          | 4    | 4                     | 1.00                           | 14.12                     | 1384.16                   | 241.34                    | 412.81                   | 44.34                    |
| N31( 0- 5)          | 31   | 4                     | 0.40 B                         | 36.27                     | 1540.00 A                 | 330.14                    | 380.75                   | 43.42                    |
| N40( 0- 5)          | 40   | 4                     | 1.00                           | 38.26                     | 1540.00 A                 | 235.79                    | 757.73                   | 78.28                    |

Table F-4. Extractable metals (DTPA) in soils of the SPangler Fixation study.

SPANGLER FORAGE ESTABLISHMENT STUDY  
RIT PROJECT

## DTPA METALS

| SAMPLE<br>NUMBER                          | PLOT | VEG<br>TREAT-<br>MENT | DTPA<br>Cu<br>(mg/<br>kg) | DTPA<br>Zn<br>(mg/<br>kg) | DTPA<br>Pb<br>(mg/<br>kg) | DTPA<br>Mn<br>(mg/<br>kg) | DTPA<br>Cd<br>(mg/<br>kg) | DTPA<br>As<br>(mg/<br>kg) | DTPA<br>Ni<br>(mg/<br>kg) | DTPA<br>Hg<br>(mg/<br>kg) | DTPA<br>Cr<br>(mg/<br>kg) | DTPA<br>V<br>(mg/<br>kg) |
|-------------------------------------------|------|-----------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|
| ** SOIL TREATMENT = 1 (Control)           |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| N28( 0- 5)                                | 28   | 1                     | 74.20                     | 29.90                     | 14.05                     | 13.84                     | 0.95                      | 1.57                      | 0.43                      | 0.20 B                    | 0.13                      | 0.14                     |
| N 7( 0- 5)                                | 7    | 1                     | 97.45                     | 97.03                     | 2.06                      | 18.54                     | 1.85                      | 0.20 B                    | 0.77                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N35( 0- 5)                                | 35   | 1                     | 167.12                    | 93.18                     | 9.89                      | 28.49                     | 2.23                      | 0.20 B                    | 0.65                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N 9( 0- 5)                                | 9    | 2                     | 110.19                    | 78.86                     | 3.34                      | 22.48                     | 1.81                      | 0.35                      | 0.65                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N21( 0- 5)                                | 21   | 2                     | 52.20                     | 22.39                     | 7.16                      | 9.95                      | 0.77                      | 0.34                      | 0.38                      | 0.20 B                    | 0.08 B                    | 0.04                     |
| N48( 0- 5)                                | 48   | 2                     | 116.07                    | 45.68                     | 12.02                     | 49.44                     | 1.54                      | 0.60                      | 0.82                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N16( 0- 5)                                | 16   | 3                     | 92.13                     | 47.65                     | 8.00                      | 37.38                     | 1.76                      | 0.46                      | 0.79                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N19( 0- 5)                                | 19   | 3                     | 37.25                     | 35.59                     | 3.97                      | 14.42                     | 1.44                      | 0.48                      | 0.59                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N43( 0- 5)                                | 43   | 3                     | 103.32                    | 42.40                     | 6.51                      | 29.11                     | 1.28                      | 0.25                      | 0.68                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N 2( 0- 5)                                | 2    | 4                     | 162.30                    | 113.57                    | 4.33                      | 20.49                     | 1.99                      | 0.20                      | 0.73                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N29( 0- 5)                                | 29   | 4                     | 73.18                     | 38.99                     | 9.89                      | 18.24                     | 1.33                      | 0.81                      | 0.72                      | 0.20 B                    | 0.08 B                    | 0.06                     |
| N37( 0- 5)                                | 37   | 4                     | 98.75                     | 63.96                     | 5.81                      | 18.14                     | 1.46                      | 0.20 B                    | 0.64                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| ** SOIL TREATMENT = 2 (Lime)              |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| N 6( 0- 5)                                | 6    | 1                     | 156.74                    | 88.07                     | 4.43                      | 22.29                     | 1.79                      | 0.20 B                    | 0.62                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N26( 0- 5)                                | 26   | 1                     | 44.03                     | 30.85                     | 5.17                      | 20.30                     | 1.15                      | 0.50                      | 0.53                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N34( 0- 5)                                | 34   | 1                     | 108.73                    | 64.18                     | 7.80                      | 15.44                     | 1.52                      | 0.45                      | 0.46                      | 0.20 B                    | 0.08 B                    | 0.04                     |
| N23( 0- 5)                                | 23   | 2                     | 60.17                     | 29.05                     | 9.65                      | 22.06                     | 1.01                      | 0.79                      | 0.63                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| N12( 0- 5)                                | 12   | 2                     | 143.56                    | 102.18                    | 2.81                      | 12.71                     | 1.97                      | 0.20 B                    | 0.58                      | 0.20 B                    | 0.14                      | 0.04 B                   |
| N46( 0- 5)                                | 46   | 2                     | 106.65                    | 67.41                     | 8.46                      | 60.40                     | 2.33                      | 0.37                      | 0.53                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N15( 0- 5)                                | 15   | 3                     | 63.64                     | 41.81                     | 5.06                      | 19.09                     | 1.12                      | 0.34                      | 0.67                      | 0.20 B                    | 0.10                      | 0.04 B                   |
| N20( 0- 5)                                | 20   | 3                     | 46.08                     | 23.46                     | 7.01                      | 9.48                      | 0.84                      | 0.49                      | 0.50                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| N41( 0- 5)                                | 41   | 3                     | 82.37                     | 57.21                     | 3.89                      | 26.50                     | 1.49                      | 0.20 B                    | 0.62                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N 3( 0- 5)                                | 3    | 4                     | 78.74                     | 67.24                     | 2.90                      | 12.21                     | 1.39                      | 0.20 B                    | 0.50                      | 0.20 B                    | 0.08 B                    | 0.04                     |
| N39( 0- 5)                                | 39   | 4                     | 84.70                     | 51.90                     | 3.87                      | 14.17                     | 1.22                      | 0.24                      | 0.58                      | 0.20 B                    | 0.13                      | 0.04 B                   |
| N32( 0- 5)                                | 32   | 4                     | 69.40                     | 43.47                     | 9.49                      | 12.34                     | 1.17                      | 0.78                      | 0.50                      | 0.20 B                    | 0.15                      | 0.08                     |
| ** SOIL TREATMENT = 3 (Lime + Phosphorus) |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| N27( 0- 5)                                | 27   | 1                     | 56.47                     | 30.04                     | 8.68                      | 14.35                     | 0.98                      | 1.13                      | 0.60                      | 0.20 B                    | 0.08 B                    | 0.07                     |
| N 8( 0- 5)                                | 8    | 1                     | 110.50                    | 107.81                    | 1.40                      | 12.68                     | 1.67                      | 0.20 B                    | 0.71                      | 0.20 B                    | 0.15                      | 0.05                     |
| N36( 0- 5)                                | 36   | 1                     | 171.73                    | 81.83                     | 6.35                      | 17.21                     | 2.09                      | 0.53                      | 0.62                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| N11( 0- 5)                                | 11   | 2                     | 90.79                     | 93.07                     | 1.71                      | 17.40                     | 1.68                      | 0.20 B                    | 0.75                      | 0.20 B                    | 0.08 B                    | 0.07                     |
| N22( 0- 5)                                | 22   | 2                     | 62.01                     | 41.22                     | 6.43                      | 21.48                     | 1.33                      | 0.79                      | 0.70                      | 0.20 B                    | 0.12                      | 0.06                     |
| N47( 0- 5)                                | 47   | 2                     | 121.36                    | 58.80                     | 8.02                      | 45.82                     | 1.77                      | 0.38                      | 0.79                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N14( 0- 5)                                | 14   | 3                     | 41.70                     | 33.13                     | 2.24                      | 22.90                     | 1.33                      | 0.20 B                    | 0.69                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N17( 0- 5)                                | 17   | 3                     | 51.90                     | 25.76                     | 8.64                      | 13.12                     | 0.71                      | 1.06                      | 0.51                      | 0.20 B                    | 0.13                      | 0.08                     |

Table F-4. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RIT PROJECT

## DTPA METALS

| SAMPLE<br>NUMBER    | PLOT | VEG<br>TREAT-<br>MENT | DTPA<br>Cu<br>(mg/<br>kg)      | DTPA<br>Zn<br>(mg/<br>kg) | DTPA<br>Pb<br>(mg/<br>kg) | DTPA<br>Mn<br>(mg/<br>kg) | DTPA<br>Cd<br>(mg/<br>kg) | DTPA<br>As<br>(mg/<br>kg) | DTPA<br>Ni<br>(mg/<br>kg) | DTPA<br>Hg<br>(mg/<br>kg) | DTPA<br>Cr<br>(mg/<br>kg) | DTPA<br>V<br>(mg/<br>kg) |
|---------------------|------|-----------------------|--------------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|
| N44( 0- 5)          | 44   | 3                     | 116.20                         | 71.41                     | 8.93                      | 44.58                     | 2.34                      | 0.99                      | 0.89                      | 0.20 B                    | 0.08 B                    | 0.06                     |
| N 1( 0- 5)          | 1    | 4                     | 107.32                         | 100.04                    | 4.64                      | 16.42                     | 1.88                      | 0.77                      | 0.73                      | 0.20 B                    | 0.08 B                    | 0.09                     |
| N30( 0- 5)          | 30   | 4                     | 55.25                          | 40.34                     | 8.82                      | 12.04                     | 1.18                      | 1.15                      | 0.64                      | 0.20 B                    | 0.08 B                    | 0.12                     |
| N38( 0- 5)          | 38   | 4                     | 84.55                          | 59.77                     | 3.42                      | 18.18                     | 1.54                      | 0.29                      | 0.69                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| ** SOIL TREATMENT = |      |                       | 4 (Lime + Phosphorus + Manure) |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| N 5( 0- 5)          | 5    | 1                     | 106.96                         | 83.18                     | 3.95                      | 27.42                     | 1.86                      | 0.33                      | 0.75                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N25( 0- 5)          | 25   | 1                     | 44.02                          | 34.06                     | 6.82                      | 16.16                     | 1.13                      | 1.40                      | 0.65                      | 0.20 B                    | 0.08 B                    | 0.15                     |
| N33( 0- 5)          | 33   | 1                     | 175.36                         | 121.37                    | 4.43                      | 34.99                     | 2.77                      | 0.72                      | 0.82                      | 0.20 B                    | 0.08 B                    | 0.06                     |
| N10( 0- 5)          | 10   | 2                     | 145.28                         | 82.02                     | 3.30                      | 25.09                     | 1.62                      | 0.37                      | 0.69                      | 0.20 B                    | 0.08 B                    | 0.07                     |
| N24( 0- 5)          | 24   | 2                     | 52.46                          | 28.83                     | 5.86                      | 28.26                     | 1.13                      | 0.91                      | 0.64                      | 0.20 B                    | 0.08 B                    | 0.05                     |
| N45( 0- 5)          | 45   | 2                     | 80.98                          | 78.46                     | 5.68                      | 42.99                     | 1.99                      | 1.25                      | 0.74                      | 0.20 B                    | 0.08 B                    | 0.11                     |
| N18( 0- 5)          | 18   | 3                     | 50.52                          | 25.32                     | 9.64                      | 13.32                     | 0.88                      | 1.61                      | 0.44                      | 0.20 B                    | 0.08 B                    | 0.13                     |
| N13( 0- 5)          | 13   | 3                     | 63.89                          | 44.95                     | 4.87                      | 38.80                     | 1.74                      | 0.20                      | 0.95                      | 0.20 B                    | 0.08 B                    | 0.04 B                   |
| N42( 0- 5)          | 42   | 3                     | 98.49                          | 75.19                     | 4.16                      | 36.84                     | 1.68                      | 0.80                      | 0.76                      | 0.20 B                    | 0.08 B                    | 0.08                     |
| N 4( 0- 5)          | 4    | 4                     | 89.68                          | 91.14                     | 3.40                      | 22.65                     | 1.57                      | 0.41                      | 0.63                      | 0.20 B                    | 0.08 B                    | 0.06                     |
| N31( 0- 5)          | 31   | 4                     | 71.58                          | 41.07                     | 9.39                      | 30.96                     | 1.53                      | 0.93                      | 0.69                      | 0.20 B                    | 0.08 B                    | 0.07                     |
| N40( 0- 5)          | 40   | 4                     | 129.78                         | 61.82                     | 11.42                     | 29.42                     | 1.98                      | 2.22                      | 0.55                      | 0.20 B                    | 0.08 B                    | 0.11                     |

Table F-5. Soluble metal levels (saturation extract) in soils from the Spangler fixation study plots.

| SPANGLER FORAGE ESTABLISHMENT STUDY<br>RIT PROJECT |      |                       |                                 |                           |                           |                           |                           |                          |                          |
|----------------------------------------------------|------|-----------------------|---------------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|--------------------------|
| SOLUBLE METALS                                     |      |                       |                                 |                           |                           |                           |                           |                          |                          |
| SAMPLE<br>NUMBER                                   | PLOT | VEG<br>TREAT-<br>MENT | SATURATION<br>PERCENTAGE<br>(%) | SOL.<br>AL<br>(mg/<br>kg) | SOL.<br>Fe<br>(mg/<br>kg) | SOL.<br>Ca<br>(mg/<br>kg) | SOL.<br>Mg<br>(mg/<br>kg) | SOL.<br>K<br>(mg/<br>kg) | SOL.<br>S<br>(mg/<br>kg) |
| ** SOIL TREATMENT = 1 (Control)                    |      |                       |                                 |                           |                           |                           |                           |                          |                          |
| N28( 0- 5)                                         | 28   | 1                     | 39.0                            | 0.187                     | 0.183                     | 151.406                   | 41.666                    | 38.366                   | 23.26                    |
| N 7( 0- 5)                                         | 7    | 1                     | 30.4                            | 0.071                     | 0.091                     | 23.313                    | 5.324                     | 5.826                    | 7.79                     |
| N35( 0- 5)                                         | 35   | 1                     | 30.6                            | 0.122                     | 0.162                     | 30.367                    | 6.858                     | 9.345                    | 4.90                     |
| N21( 0- 5)                                         | 21   | 2                     | 39.2                            | 0.122                     | 0.130                     | 66.298                    | 17.431                    | 19.220                   | 8.97                     |
| N 9( 0- 5)                                         | 9    | 2                     | 35.5                            | 0.163                     | 0.141                     | 153.679                   | 44.598                    | 39.518                   | 20.44                    |
| N48( 0- 5)                                         | 48   | 2                     | 29.3                            | 0.403                     | 0.202                     | 36.446                    | 7.289                     | 12.903                   | 7.91                     |
| N19( 0- 5)                                         | 19   | 3                     | 37.1                            | 0.365                     | 0.272                     | 82.795                    | 21.871                    | 25.953                   | 10.54                    |
| N16( 0- 5)                                         | 16   | 3                     | 31.3                            | 0.438                     | 0.151                     | 33.114                    | 8.202                     | 10.925                   | 5.56                     |
| N43( 0- 5)                                         | 43   | 3                     | 29.9                            | 0.253                     | 0.202                     | 39.881                    | 6.467                     | 9.334                    | 7.66                     |
| N 2( 0- 5)                                         | 2    | 4                     | 31.8                            | 0.076                     | 0.109                     | 29.231                    | 5.474                     | 8.549                    | 3.02                     |
| N37( 0- 5)                                         | 37   | 4                     | 29.4                            | 0.056                     | 0.092                     | 23.202                    | 5.070                     | 10.433                   | 3.70                     |
| N29( 0- 5)                                         | 29   | 4                     | 34.7                            | 0.590                     | 0.193                     | 277.600 A                 | 13.607                    | 14.670                   | 7.82                     |
| ** SOIL TREATMENT = 2 (Lime)                       |      |                       |                                 |                           |                           |                           |                           |                          |                          |
| N 6( 0- 5)                                         | 6    | 1                     | 30.5                            | 0.136                     | 0.162                     | 54.581                    | 15.323                    | 10.069                   | 7.39                     |
| N26( 0- 5)                                         | 26   | 1                     | 35.8                            | 0.165                     | 0.152                     | 68.077                    | 15.686                    | 17.615                   | 5.52                     |
| N34( 0- 5)                                         | 34   | 1                     | 30.9                            | 0.169                     | 0.166                     | 156.166                   | 48.828                    | 24.646                   | 10.53                    |
| N23( 0- 5)                                         | 23   | 2                     | 34.4                            | 0.311                     | 0.257                     | 136.816                   | 41.611                    | 34.159                   | 15.00                    |
| N12( 0- 5)                                         | 12   | 2                     | 33.9                            | 0.063                     | 0.093                     | 85.881                    | 26.769                    | 14.530                   | 7.30                     |
| N46( 0- 5)                                         | 46   | 2                     | 30.7                            | 0.089                     | 0.094                     | 163.922                   | 53.988                    | 24.974                   | 16.57                    |
| N20( 0- 5)                                         | 20   | 3                     | 37.6                            | 0.067                     | 0.086                     | 110.103                   | 42.880                    | 31.939                   | 9.69                     |
| N15( 0- 5)                                         | 15   | 3                     | 30.1                            | 0.301                     | 0.174                     | 57.871                    | 14.009                    | 11.800                   | 6.02                     |
| N41( 0- 5)                                         | 41   | 3                     | 32.1                            | 0.151                     | 0.143                     | 83.010                    | 23.665                    | 27.597                   | 8.85                     |
| N 3( 0- 5)                                         | 3    | 4                     | 32.4                            | 0.100                     | 0.092                     | 152.085                   | 37.865                    | 29.188                   | 11.67                    |
| N39( 0- 5)                                         | 39   | 4                     | 33.9                            | 0.058 B                   | 0.084                     | 68.948                    | 17.875                    | 14.083                   | 5.77                     |
| N32( 0- 5)                                         | 32   | 4                     | 42.3                            | 0.423                     | 0.217                     | 110.766                   | 35.027                    | 26.509                   | 13.26                    |
| ** SOIL TREATMENT = 3 (Lime + Phosphorus)          |      |                       |                                 |                           |                           |                           |                           |                          |                          |
| N 8( 0- 5)                                         | 8    | 1                     | 31.8                            | 0.254                     | 0.125                     | 46.905                    | 12.972                    | 9.868                    | 14.18                    |
| N27( 0- 5)                                         | 27   | 1                     | 38.6                            | 0.066 B                   | 0.099                     | 122.425                   | 37.147                    | 26.959                   | 11.60                    |
| N36( 0- 5)                                         | 36   | 1                     | 30.5                            | 0.191                     | 0.163                     | 88.926                    | 21.468                    | 13.783                   | 7.90                     |
| N11( 0- 5)                                         | 11   | 2                     | 31.1                            | 0.225                     | 0.199                     | 62.059                    | 16.768                    | 10.328                   | 8.41                     |
| N22( 0- 5)                                         | 22   | 2                     | 33.3                            | 0.061                     | 0.095                     | 52.596                    | 13.863                    | 18.449                   | 7.45                     |
| N47( 0- 5)                                         | 47   | 2                     | 30.7                            | 0.068                     | 0.099                     | 77.941                    | 27.722                    | 14.834                   | 12.01                    |
| N17( 0- 5)                                         | 17   | 3                     | 31.7                            | 0.121                     | 0.115                     | 106.745                   | 28.840                    | 25.834                   | 8.34                     |
| N14( 0- 5)                                         | 14   | 3                     | 28.4                            | 0.430                     | 0.253                     | 49.668                    | 10.749                    | 7.646                    | 6.06                     |
| N44( 0- 5)                                         | 44   | 3                     | 34.2                            | 0.116                     | 0.098                     | 182.709                   | 47.417                    | 37.730                   | 21.56                    |

Table F-5. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RIT PROJECT

## SOLUBLE METALS

| SAMPLE<br>NUMBER    | PLOT | VEG<br>TREAT-<br>MENT | SATURATION<br>PERCENTAGE<br>(%) | SOL.<br>Al<br>(mg/<br>kg) | SOL.<br>Fe<br>(mg/<br>kg) | SOL.<br>Ca<br>(mg/<br>kg) | SOL.<br>Mg<br>(mg/<br>kg) | SOL.<br>K<br>(mg/<br>kg) | SOL.<br>S<br>(mg/<br>kg) |
|---------------------|------|-----------------------|---------------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|--------------------------|
| N 1( 0- 5)          | 1    | 4                     | 30.9                            | 0.053 B                   | 0.078                     | 84.686                    | 20.596                    | 14.877                   | 12.22                    |
| N30( 0- 5)          | 30   | 4                     | 39.1                            | 0.328                     | 0.279                     | 145.943                   | 41.979                    | 28.617                   | 17.59                    |
| N38( 0- 5)          | 38   | 4                     | 32.0                            | 0.071                     | 0.098                     | 45.303                    | 11.307                    | 11.757                   | 7.97                     |
| ** SOIL TREATMENT = |      | 4                     | (Lime + Phosphorus + Manure)    |                           |                           |                           |                           |                          |                          |
| N 5( 0- 5)          | 5    | 1                     | 33.8                            | 0.057 B                   | 0.092                     | 149.738                   | 37.692                    | 25.522                   | 20.41                    |
| N25( 0- 5)          | 25   | 1                     | 44.8                            | 0.896                     | 0.360                     | 358.400 A                 | 87.285                    | 111.305                  | 49.94                    |
| N33( 0- 5)          | 33   | 1                     | 32.0                            | 0.073                     | 0.088                     | 171.376                   | 46.146                    | 54.127                   | 29.48                    |
| N24( 0- 5)          | 24   | 2                     | 36.6                            | 0.256                     | 0.124                     | 202.044                   | 60.102                    | 96.534                   | 30.30                    |
| N10( 0- 5)          | 10   | 2                     | 33.1                            | 0.463                     | 0.239                     | 143.015                   | 43.862                    | 37.331                   | 23.47                    |
| N45( 0- 5)          | 45   | 2                     | 36.7                            | 0.097                     | 0.127                     | 263.117                   | 367000.00                 | 147.352                  | 50.63                    |
| N13( 0- 5)          | 13   | 3                     | 31.0                            | 0.141                     | 0.113                     | 55.538                    | 11.541                    | 9.411                    | 4.86                     |
| N18( 0- 5)          | 18   | 3                     | 41.0                            | 0.139                     | 0.202                     | 239.342                   | 410000.00                 | 184.411                  | 50.22                    |
| N42( 0- 5)          | 42   | 3                     | 36.9                            | 0.189                     | 0.160                     | 237.039                   | 68.187                    | 122.773                  | 42.32                    |
| N 4( 0- 5)          | 4    | 4                     | 34.9                            | 0.094                     | 0.119                     | 269.453                   | 72.760                    | 88.126                   | 30.78                    |
| N31( 0- 5)          | 31   | 4                     | 43.5                            | 0.189                     | 0.176                     | 206.827                   | 69.426                    | 76.961                   | 32.88                    |
| N40( 0- 5)          | 40   | 4                     | 37.3                            | 0.522                     | 0.408                     | 280.528                   | 88.464                    | 221.839                  | 63.69                    |

Table F-6. Soluble metal levels (saturation extract) in soils from the Spangler fixation study plots.

| SPANGLER FORAGE ESTABLISHMENT STUDY<br>RIT PROJECT |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
|----------------------------------------------------|------|-----------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|
| SOLUBLE METALS                                     |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| SAMPLE<br>NUMBER                                   | PLOT | VEG<br>TREAT-<br>MENT | SOL.<br>Cu<br>(mg/<br>kg) | SOL.<br>Zn<br>(mg/<br>kg) | SOL.<br>Pb<br>(mg/<br>kg) | SOL.<br>Mn<br>(mg/<br>kg) | SOL.<br>Cd<br>(mg/<br>kg) | SOL.<br>As<br>(mg/<br>kg) | SOL.<br>Ni<br>(mg/<br>kg) | SOL.<br>Hg<br>(mg/<br>kg) | SOL.<br>Cr<br>(mg/<br>kg) | SOL.<br>V<br>(mg/<br>kg) |
| ** SOIL TREATMENT = 1 (Control)                    |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| N28( 0- 5)                                         | 28   | 1                     | 0.195 B                   | 0.016                     | 0.027 B                   | 0.149                     | 0.039 B                   | 0.166                     | 0.027 B                   | 0.039 B                   | 0.016 B                   | 0.008                    |
| N 7( 0- 5)                                         | 7    | 1                     | 0.152 B                   | 0.809                     | 0.021 B                   | 0.293                     | 0.030 B                   | 0.030 B                   | 0.021 B                   | 0.030 B                   | 0.012 B                   | 0.006                    |
| N35( 0- 5)                                         | 35   | 1                     | 0.475                     | 2.375                     | 0.021 B                   | 0.921                     | 0.031 B                   | 0.031 B                   | 0.021 B                   | 0.031 B                   | 0.012 B                   | 0.006                    |
| N21( 0- 5)                                         | 21   | 2                     | 0.196 B                   | 0.033                     | 0.027 B                   | 0.052                     | 0.039 B                   | 0.066                     | 0.027 B                   | 0.039 B                   | 0.016 B                   | 0.008                    |
| N 9( 0- 5)                                         | 9    | 2                     | 0.299                     | 0.453                     | 0.025 B                   | 0.926                     | 0.035 B                   | 0.036                     | 0.025 B                   | 0.035 B                   | 0.014 B                   | 0.007                    |
| N48( 0- 5)                                         | 48   | 2                     | 0.349                     | 1.374                     | 0.021 B                   | 1.898                     | 0.033                     | 0.056                     | 0.024                     | 0.029 B                   | 0.012 B                   | 0.006                    |
| N19( 0- 5)                                         | 19   | 3                     | 0.185 B                   | 0.193                     | 0.026 B                   | 0.146                     | 0.037 B                   | 0.053                     | 0.027                     | 0.037 B                   | 0.015 B                   | 0.007                    |
| N16( 0- 5)                                         | 16   | 3                     | 0.176                     | 1.142                     | 0.022 B                   | 1.356                     | 0.031 B                   | 0.046                     | 0.022 B                   | 0.031 B                   | 0.020                     | 0.006                    |
| N43( 0- 5)                                         | 43   | 3                     | 0.460                     | 3.458                     | 0.021 B                   | 1.861                     | 0.042                     | 0.037                     | 0.021                     | 0.030 B                   | 0.012 B                   | 0.006                    |
| N 2( 0- 5)                                         | 2    | 4                     | 0.183                     | 1.765                     | 0.022 B                   | 0.480                     | 0.032 B                   | 0.032 B                   | 0.022 B                   | 0.032 B                   | 0.013 B                   | 0.006                    |
| N37( 0- 5)                                         | 37   | 4                     | 0.147 B                   | 0.805                     | 0.021 B                   | 0.267                     | 0.029 B                   | 0.029 B                   | 0.021 B                   | 0.029 B                   | 0.012 B                   | 0.006                    |
| N29( 0- 5)                                         | 29   | 4                     | 0.174 B                   | 0.429                     | 0.024 B                   | 0.405                     | 0.035 B                   | 0.123                     | 0.024 B                   | 0.035 B                   | 0.022                     | 0.007                    |
| ** SOIL TREATMENT = 2 (Lime)                       |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| N 6( 0- 5)                                         | 6    | 1                     | 0.152 B                   | 0.862                     | 0.021 B                   | 0.578                     | 0.030 B                   | 0.030 B                   | 0.021 B                   | 0.030 B                   | 0.012 B                   | 0.006                    |
| N26( 0- 5)                                         | 26   | 1                     | 0.179 B                   | 1.161                     | 0.025 B                   | 1.132                     | 0.036 B                   | 0.039                     | 0.025 B                   | 0.036 B                   | 0.014 B                   | 0.007                    |
| N34( 0- 5)                                         | 34   | 1                     | 0.159                     | 0.357                     | 0.023                     | 0.585                     | 0.031 B                   | 0.031 B                   | 0.022 B                   | 0.031 B                   | 0.012 B                   | 0.006                    |
| N23( 0- 5)                                         | 23   | 2                     | 0.172 B                   | 0.070                     | 0.024 B                   | 0.517                     | 0.034 B                   | 0.088                     | 0.024 B                   | 0.034 B                   | 0.014 B                   | 0.007                    |
| N12( 0- 5)                                         | 12   | 2                     | 0.169 B                   | 0.658                     | 0.024 B                   | 0.302                     | 0.034 B                   | 0.034 B                   | 0.024 B                   | 0.034 B                   | 0.014 B                   | 0.007                    |
| N46( 0- 5)                                         | 46   | 2                     | 0.153 B                   | 1.301                     | 0.021 B                   | 4.574                     | 0.037                     | 0.031 B                   | 0.021 B                   | 0.031 B                   | 0.012 B                   | 0.006                    |
| N20( 0- 5)                                         | 20   | 3                     | 0.188 B                   | 0.011                     | 0.026 B                   | 0.046                     | 0.038 B                   | 0.047                     | 0.026 B                   | 0.038 B                   | 0.015 B                   | 0.008                    |
| N15( 0- 5)                                         | 15   | 3                     | 0.150 B                   | 0.464                     | 0.021 B                   | 0.461                     | 0.030 B                   | 0.030 B                   | 0.021 B                   | 0.030 B                   | 0.012 B                   | 0.006                    |
| N41( 0- 5)                                         | 41   | 3                     | 0.161 B                   | 0.620                     | 0.022 B                   | 0.953                     | 0.032 B                   | 0.032 B                   | 0.022 B                   | 0.032 B                   | 0.013 B                   | 0.006                    |
| N 3( 0- 5)                                         | 3    | 4                     | 0.162 B                   | 0.165                     | 0.023 B                   | 0.281                     | 0.032 B                   | 0.032 B                   | 0.023 B                   | 0.032 B                   | 0.013 B                   | 0.006                    |
| N39( 0- 5)                                         | 39   | 4                     | 0.169 B                   | 0.549                     | 0.024 B                   | 0.388                     | 0.034 B                   | 0.034 B                   | 0.024 B                   | 0.034 B                   | 0.014 B                   | 0.007                    |
| N32( 0- 5)                                         | 32   | 4                     | 0.211 B                   | 0.049                     | 0.030 B                   | 0.107                     | 0.042 B                   | 0.092                     | 0.030 B                   | 0.042 B                   | 0.017 B                   | 0.008                    |
| ** SOIL TREATMENT = 3 (Lime + Phosphorus)          |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| N 8( 0- 5)                                         | 8    | 1                     | 0.159 B                   | 0.422                     | 0.022 B                   | 0.168                     | 0.032 B                   | 0.032 B                   | 0.022 B                   | 0.032 B                   | 0.013 B                   | 0.006                    |
| N27( 0- 5)                                         | 27   | 1                     | 0.193 B                   | 0.057                     | 0.027 B                   | 0.196                     | 0.039 B                   | 0.145                     | 0.027 B                   | 0.039 B                   | 0.015 B                   | 0.008                    |
| N36( 0- 5)                                         | 36   | 1                     | 0.322                     | 2.548                     | 0.021 B                   | 1.196                     | 0.030 B                   | 0.082                     | 0.027                     | 0.030 B                   | 0.012 B                   | 0.006                    |
| N11( 0- 5)                                         | 11   | 2                     | 0.155 B                   | 0.442                     | 0.022 B                   | 0.280                     | 0.031 B                   | 0.031 B                   | 0.022 B                   | 0.031 B                   | 0.012 B                   | 0.006                    |
| N22( 0- 5)                                         | 22   | 2                     | 0.166 B                   | 0.366                     | 0.023 B                   | 0.470                     | 0.033 B                   | 0.084                     | 0.023 B                   | 0.033 B                   | 0.013 B                   | 0.007                    |
| N47( 0- 5)                                         | 47   | 2                     | 0.153 B                   | 1.098                     | 0.021 B                   | 1.933                     | 0.031 B                   | 0.031 B                   | 0.021 B                   | 0.031 B                   | 0.012 B                   | 0.006                    |
| N17( 0- 5)                                         | 17   | 3                     | 0.159 B                   | 0.069                     | 0.022 B                   | 0.222                     | 0.032 B                   | 0.072                     | 0.022 B                   | 0.032 B                   | 0.013 B                   | 0.006                    |
| N14( 0- 5)                                         | 14   | 3                     | 0.142 B                   | 0.382                     | 0.020 B                   | 0.883                     | 0.028 B                   | 0.029                     | 0.020 B                   | 0.028 B                   | 0.011 B                   | 0.006                    |
| N44( 0- 5)                                         | 44   | 3                     | 0.303                     | 2.583                     | 0.024 B                   | 4.035                     | 0.059                     | 0.134                     | 0.047                     | 0.034 B                   | 0.014 B                   | 0.007                    |

Table F-6. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RIT PROJECT

| SAMPLE<br>NUMBER                                   | PLOT | VEG<br>TREAT-<br>MENT | SOL.<br>Cu<br>(mg/<br>kg) | SOL.<br>Zn<br>(mg/<br>kg) | SOL.<br>Pb<br>(mg/<br>kg) | SOL.<br>Mn<br>(mg/<br>kg) | SOL.<br>Cd<br>(mg/<br>kg) | SOL.<br>As<br>(mg/<br>kg) | SOL.<br>Ni<br>(mg/<br>kg) | SOL.<br>Hg<br>(mg/<br>kg) | SOL.<br>Cr<br>(mg/<br>kg) | SOL.<br>V<br>(mg/<br>kg) |
|----------------------------------------------------|------|-----------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|--------------------------|
| N 1( 0- 5)                                         | 1    | 4                     | 0.154 B                   | 1.532                     | 0.022 B                   | 0.636                     | 0.031 B                   | 0.083                     | 0.023                     | 0.031 B                   | 0.012 B                   | 0.006                    |
| N30( 0- 5)                                         | 30   | 4                     | 0.196 B                   | 0.074                     | 0.027 B                   | 0.186                     | 0.039 B                   | 0.185                     | 0.027 B                   | 0.039 B                   | 0.016 B                   | 0.008                    |
| N38( 0- 5)                                         | 38   | 4                     | 0.160 B                   | 0.720                     | 0.022 B                   | 0.406                     | 0.032 B                   | 0.038                     | 0.022 B                   | 0.032 B                   | 0.013 B                   | 0.006                    |
| ** SOIL TREATMENT = 4 (Lime + Phosphorus + Manure) |      |                       |                           |                           |                           |                           |                           |                           |                           |                           |                           |                          |
| N 5( 0- 5)                                         | 5    | 1                     | 0.223                     | 1.121                     | 0.024 B                   | 1.463                     | 0.034 B                   | 0.034 B                   | 0.026                     | 0.034 B                   | 0.014 B                   | 0.007                    |
| N25( 0- 5)                                         | 25   | 1                     | 0.414                     | 0.088                     | 0.031 B                   | 0.495                     | 0.045 B                   | 0.399                     | 0.031 B                   | 0.045 B                   | 0.030                     | 0.010                    |
| N33( 0- 5)                                         | 33   | 1                     | 0.379                     | 0.916                     | 0.022 B                   | 1.708                     | 0.032 B                   | 0.087                     | 0.023                     | 0.032 B                   | 0.013 B                   | 0.006                    |
| N24( 0- 5)                                         | 24   | 2                     | 0.307                     | 0.156                     | 0.026 B                   | 1.201                     | 0.037 B                   | 0.087                     | 0.026 B                   | 0.037 B                   | 0.015 B                   | 0.007                    |
| N10( 0- 5)                                         | 10   | 2                     | 0.258                     | 0.277                     | 0.023 B                   | 0.741                     | 0.033 B                   | 0.055                     | 0.023 B                   | 0.033 B                   | 0.013 B                   | 0.007                    |
| N45( 0- 5)                                         | 45   | 2                     | 0.464                     | 0.113                     | 0.026 B                   | 1.763                     | 0.037 B                   | 0.153                     | 0.026 B                   | 0.037 B                   | 0.015 B                   | 0.007                    |
| N13( 0- 5)                                         | 13   | 3                     | 0.155 B                   | 1.412                     | 0.022 B                   | 1.663                     | 0.033                     | 0.031 B                   | 0.026                     | 0.031 B                   | 0.012 B                   | 0.006                    |
| N18( 0- 5)                                         | 18   | 3                     | 0.494                     | 0.048                     | 0.029 B                   | 0.344                     | 0.041 B                   | 0.372                     | 0.029 B                   | 0.041 B                   | 0.016 B                   | 0.008                    |
| N42( 0- 5)                                         | 42   | 3                     | 0.462                     | 0.222                     | 0.026 B                   | 1.719                     | 0.037 B                   | 0.100                     | 0.026 B                   | 0.037 B                   | 0.015 B                   | 0.007                    |
| N 4( 0- 5)                                         | 4    | 4                     | 0.326                     | 0.559                     | 0.024 B                   | 1.448                     | 0.035 B                   | 0.056                     | 0.024 B                   | 0.035 B                   | 0.014 B                   | 0.007                    |
| N31( 0- 5)                                         | 31   | 4                     | 0.272                     | 0.095                     | 0.030 B                   | 0.625                     | 0.044 B                   | 0.116                     | 0.030 B                   | 0.044 B                   | 0.017 B                   | 0.009                    |
| N40( 0- 5)                                         | 40   | 4                     | 0.816                     | 0.210                     | 0.026 B                   | 1.479                     | 0.037 B                   | 0.391                     | 0.026 B                   | 0.037 B                   | 0.015 B                   | 0.007                    |

Table F-7. Plant tissue metal levels of forage from the Spangler Fixation study plots.

| SPANGLER FORAGE ESTABLISHMENT STUDY<br>RIT PROJECT |      |                        |                            |                            |                            |                            |                           |                           |
|----------------------------------------------------|------|------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|---------------------------|
| PLANT TISSUE LEVELS                                |      |                        |                            |                            |                            |                            |                           |                           |
| SAMPLE<br>NUMBER                                   | PLOT | SOIL<br>TREAT-<br>MENT | PLANT<br>Al<br>(mg/<br>kg) | PLANT<br>Fe<br>(mg/<br>kg) | PLANT<br>Ca<br>(mg/<br>kg) | PLANT<br>Mg<br>(mg/<br>kg) | PLANT<br>K<br>(mg/<br>kg) | PLANT<br>S<br>(mg/<br>kg) |
| ** VEGETATION TREATMENT = 1                        |      |                        |                            |                            |                            |                            |                           |                           |
| * SPECIES = Basin wildrye                          |      |                        |                            |                            |                            |                            |                           |                           |
| NP 7B                                              | 7    | 1                      | 189.100                    | 195.200                    | 4363.700                   | 1511.000                   | 22666.900                 | 2217.500                  |
| NP28B                                              | 3    | 1                      | 74.450                     | 2158.450                   | 4025.350                   | 1572.000                   | 27991.950                 | 1788.000                  |
| NP35B                                              | 35   | 1                      | 158.750                    | 164.100                    | 4113.300                   | 1375.000                   | 20723.700                 | 2202.000                  |
| NP26B                                              | 26   | 2                      | 153.700                    | 165.400                    | 4208.700                   | 1613.000                   | 28616.800                 | 2195.500                  |
| NP 6B                                              | 6    | 2                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                     | 0.000                     |
| NP34B                                              | 34   | 2                      | 156.850                    | 3373.450                   | 4929.900                   | 1673.000                   | 23122.850                 | 1945.500                  |
| NP 8B                                              | 8    | 3                      | 129.000                    | 145.600                    | 3640.600                   | 1388.000                   | 22922.550                 | 2022.500                  |
| NP27B                                              | 27   | 3                      | 181.850                    | 202.000                    | 4621.150                   | 1719.000                   | 25725.600                 | 2252.500                  |
| NP36B                                              | 36   | 3                      | 163.900                    | 176.700                    | 4660.500                   | 1490.500                   | 25229.350                 | 1987.500                  |
| NP25B                                              | 25   | 4                      | 224.400                    | 236.900                    | 5406.550                   | 1692.500                   | 30436.250                 | 2045.000                  |
| NP 5B                                              | 5    | 4                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                     | 0.000                     |
| NP33B                                              | 33   | 4                      | 150.000                    | 160.150                    | 4578.700                   | 1666.500                   | 24285.600                 | 2016.000                  |
| * SPECIES = Streambank wheatgrass                  |      |                        |                            |                            |                            |                            |                           |                           |
| NP28S                                              | 28   | 1                      | 163.200                    | 158.200                    | 4409.900                   | 1611.500                   | 24064.550                 | 1895.000                  |
| NP 7S                                              | 7    | 1                      | 229.000                    | 217.350                    | 5962.350                   | 1528.000                   | 19164.900                 | 1874.500                  |
| NP35S                                              | 35   | 1                      | 197.350                    | 201.650                    | 5985.300                   | 1431.500                   | 18820.750                 | 2201.000                  |
| NP 6S                                              | 6    | 2                      | 347.050                    | 311.650                    | 7309.200                   | 1863.000                   | 17965.700                 | 1788.000                  |
| NP26S                                              | 26   | 2                      | 183.300                    | 185.250                    | 4943.300                   | 1451.500                   | 21230.550                 | 1870.000                  |
| NP34S                                              | 34   | 2                      | 220.300                    | 3262.050                   | 4952.800                   | 1456.500                   | 16238.450                 | 1625.500                  |
| NP 8S                                              | 8    | 3                      | 294.700                    | 282.100                    | 6036.950                   | 1867.500                   | 21183.200                 | 2162.000                  |
| NP27S                                              | 27   | 3                      | 160.000                    | 169.850                    | 4869.000                   | 1706.000                   | 22932.450                 | 1936.000                  |
| NP36S                                              | 36   | 3                      | 252.850                    | 3395.800                   | 6550.700                   | 2175.000                   | 20595.700                 | 2343.000                  |
| NP 5S                                              | 5    | 4                      | 217.800                    | 218.250                    | 7546.400                   | 2102.000                   | 21471.100                 | 1986.500                  |
| NP25S                                              | 25   | 4                      | 190.550                    | 1826.700                   | 5578.800                   | 1683.000                   | 27364.650                 | 2011.000                  |
| NP33S                                              | 33   | 4                      | 106.350                    | 101.100                    | 4481.600                   | 1524.500                   | 19737.700                 | 1721.000                  |
| ** VEGETATION TREATMENT = 2                        |      |                        |                            |                            |                            |                            |                           |                           |
| * SPECIES = Pubescent wheatgrass                   |      |                        |                            |                            |                            |                            |                           |                           |
| NP 9P                                              | 9    | 1                      | 347.450                    | 298.700                    | 6007.950                   | 2229.500                   | 28466.000                 | 2404.500                  |
| NP21P                                              | 21   | 1                      | 228.950                    | 3396.500                   | 3780.050                   | 1816.500                   | 30968.800                 | 2667.500                  |
| NP48                                               | 48   | 1                      | 118.650                    | 122.500                    | 5706.150                   | 1840.500                   | 26620.100                 | 2007.000                  |
| NP23P                                              | 23   | 2                      | 444.000                    | 2288.000                   | 4678.500                   | 2019.000                   | 30790.800                 | 2325.500                  |
| NP12P                                              | 12   | 2                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                     | 0.000                     |
| NP46P                                              | 46   | 2                      | 342.300                    | 307.400                    | 7325.000                   | 2927.500                   | 29577.800                 | 2763.500                  |
| NP22P                                              | 22   | 3                      | 319.650                    | 362.250                    | 3897.450                   | 1917.500                   | 33751.750                 | 2683.000                  |

Table F-7. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RIT PROJECT

PLANT TISSUE LEVELS

| SAMPLE<br>NUMBER | PLOT | SOIL<br>TREAT-<br>MENT | PLANT<br>Al<br>(mg/<br>kg) | PLANT<br>Fe<br>(mg/<br>kg) | PLANT<br>Ca<br>(mg/<br>kg) | PLANT<br>Mg<br>(mg/<br>kg) | PLANT<br>K<br>(mg/<br>kg) | PLANT<br>S<br>(mg/<br>kg) |
|------------------|------|------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|---------------------------|
| NP11P            | 11   | 3                      | 612.950                    | 640.050                    | 6028.150                   | 2733.000                   | 28086.450                 | 3312.500                  |
| NP47P            | 47   | 3                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                     | 0.000                     |
| NP24P            | 24   | 4                      | 173.950                    | 559.850                    | 4650.600                   | 2627.000                   | 41146.000                 | 2687.500                  |
| NP10P            | 10   | 4                      | 222.350                    | 2306.350                   | 5273.800                   | 2248.500                   | 34356.300                 | 2579.500                  |
| NP45P            | 45   | 4                      | 152.500                    | 165.150                    | 3720.250                   | 1506.000                   | 28988.600                 | 2092.000                  |

\*\* VEGETATION TREATMENT = 3

\* SPECIES = Western wheatgrass

|       |    |   |         |          |          |          |           |          |
|-------|----|---|---------|----------|----------|----------|-----------|----------|
| NP19W | 19 | 1 | 107.350 | 115.750  | 4554.700 | 1513.500 | 25489.450 | 2093.500 |
| NP16W | 16 | 1 | 0.000   | 0.000    | 0.000    | 0.000    | 0.000     | 0.000    |
| NP43W | 43 | 1 | 220.900 | 4476.000 | 7456.350 | 2000.000 | 20181.250 | 2028.000 |
| NP15W | 15 | 2 | 251.050 | 229.350  | 7532.100 | 1870.000 | 20714.850 | 2561.500 |
| NP20W | 20 | 2 | 168.600 | 178.900  | 7281.900 | 2773.500 | 29036.600 | 2465.000 |
| NP41W | 41 | 2 | 118.900 | 1237.700 | 6223.700 | 1885.000 | 27075.300 | 2021.500 |
| NP14W | 14 | 3 | 249.150 | 244.150  | 7444.600 | 2083.000 | 22016.050 | 2018.000 |
| NP17W | 17 | 3 | 119.550 | 131.400  | 5139.950 | 1424.000 | 23412.400 | 1938.500 |
| NP44W | 44 | 3 | 183.750 | 173.600  | 8697.900 | 2578.000 | 21512.800 | 2308.000 |
| NP18W | 18 | 4 | 228.750 | 1609.250 | 6171.550 | 2971.500 | 38046.350 | 2916.000 |
| NP13W | 13 | 4 | 145.600 | 144.600  | 6084.650 | 1943.500 | 23536.500 | 2063.000 |
| NP42W | 42 | 4 | 160.950 | 1123.050 | 8559.500 | 2579.500 | 28336.850 | 2366.500 |

\*\* VEGETATION TREATMENT = 4

\* SPECIES = Smooth Brome

|        |    |   |         |          |          |          |           |          |
|--------|----|---|---------|----------|----------|----------|-----------|----------|
| NP 2Br | 2  | 1 | 168.800 | 183.700  | 7243.600 | 1949.500 | 28250.250 | 3104.000 |
| NP29Br | 29 | 1 | 131.450 | 142.300  | 5482.100 | 1846.000 | 28248.250 | 2318.500 |
| NP37Br | 37 | 1 | 172.900 | 901.350  | 6404.200 | 2075.000 | 29020.800 | 3122.500 |
| NP32Br | 32 | 2 | 147.500 | 153.050  | 4768.950 | 2032.000 | 28333.000 | 2512.000 |
| NP 3Br | 3  | 2 | 148.650 | 160.600  | 6510.150 | 2238.500 | 28040.400 | 2435.500 |
| NP39Br | 39 | 2 | 151.500 | 4680.250 | 6824.150 | 2445.500 | 26194.750 | 2384.500 |
| NP30Br | 30 | 3 | 595.950 | 616.800  | 5060.650 | 2287.500 | 31291.700 | 2304.500 |
| NP 1Br | 1  | 3 | 185.650 | 182.200  | 6012.700 | 1855.500 | 22426.500 | 2455.000 |
| NP38Br | 38 | 3 | 237.350 | 1290.150 | 6668.550 | 2219.500 | 28792.000 | 2847.000 |
| NP31Br | 31 | 4 | 128.500 | 148.100  | 5563.000 | 2138.000 | 30902.900 | 2157.500 |
| NP 4Br | 4  | 4 | 109.050 | 113.150  | 6091.150 | 2535.000 | 29100.750 | 2636.000 |
| NP40Br | 40 | 4 | 169.100 | 173.450  | 7202.900 | 2891.500 | 34333.300 | 3179.500 |

Table F-7. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RIT PROJECT

## PLANT TISSUE LEVELS

| SAMPLE<br>NUMBER                  | PLOT | SOIL<br>TREAT-<br>MENT | PLANT<br>Al<br>(mg/<br>kg) | PLANT<br>Fe<br>(mg/<br>kg) | PLANT<br>Ca<br>(mg/<br>kg) | PLANT<br>Mg<br>(mg/<br>kg) | PLANT<br>K<br>(mg/<br>kg) | PLANT<br>S<br>(mg/<br>kg) |
|-----------------------------------|------|------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|---------------------------|
| * SPECIES = Yellow Sweetclover    |      |                        |                            |                            |                            |                            |                           |                           |
| NP 2CL                            | 2    | 1                      | 224.600                    | 211.650                    | 42196.750                  | 8384.500                   | 14163.600                 | 3228.000                  |
| NP29CL                            | 29   | 1                      | 110.050                    | 118.900                    | 16999.900                  | 4289.500                   | 18512.200                 | 2820.500                  |
| NP37CL                            | 37   | 1                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                     | 0.000                     |
| NP 3CL                            | 3    | 2                      | 139.250                    | 155.300                    | 25989.850                  | 6483.500                   | 14364.200                 | 2668.000                  |
| NP32CL                            | 32   | 2                      | 130.800                    | 151.250                    | 16113.350                  | 4444.500                   | 20892.750                 | 2664.500                  |
| NP39CL                            | 39   | 2                      | 132.800                    | 142.050                    | 13164.700                  | 3800.000                   | 18940.100                 | 1930.000                  |
| NP 1CL                            | 1    | 3                      | 231.000                    | 219.150                    | 23268.600                  | 5257.000                   | 11907.050                 | 2748.000                  |
| NP30CL                            | 30   | 3                      | 123.550                    | 780.500                    | 14292.600                  | 3642.000                   | 22426.850                 | 2623.500                  |
| NP38CL                            | 38   | 3                      | 126.050                    | 136.200                    | 24062.450                  | 5599.500                   | 12370.100                 | 2837.000                  |
| NP 4CL                            | 4    | 4                      | 65.700                     | 83.800                     | 19125.800                  | 4738.000                   | 20150.150                 | 2455.500                  |
| NP31CL                            | 31   | 4                      | 179.700                    | 193.000                    | 14434.800                  | 3600.500                   | 21370.600                 | 2394.000                  |
| NP40CL                            | 40   | 4                      | 104.750                    | 130.150                    | 26015.450                  | 5342.500                   | 17898.050                 | 3336.000                  |
| * SPECIES = Thickspike Wheatgrass |      |                        |                            |                            |                            |                            |                           |                           |
| NP29T                             | 29   | 1                      | 113.900                    | 275.400                    | 4843.750                   | 1397.000                   | 21517.150                 | 1830.500                  |
| NP 2T                             | 2    | 1                      | 219.950                    | 236.650                    | 5386.100                   | 1328.500                   | 19721.750                 | 1996.000                  |
| NP37T                             | 37   | 1                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                     | 0.000                     |
| NP32T                             | 32   | 2                      | 169.400                    | 155.700                    | 4388.650                   | 1797.500                   | 21360.900                 | 1783.500                  |
| NP 3T                             | 3    | 2                      | 141.650                    | 139.850                    | 5083.400                   | 1539.500                   | 19922.700                 | 1728.500                  |
| NP39T                             | 39   | 2                      | 229.600                    | 223.050                    | 6314.350                   | 1589.000                   | 19217.800                 | 1789.000                  |
| NP30T                             | 30   | 3                      | 134.600                    | 5334.150                   | 4685.650                   | 1805.000                   | 23615.600                 | 1796.000                  |
| NP 1T                             | 1    | 3                      | 300.850                    | 268.250                    | 6148.750                   | 1540.500                   | 18578.650                 | 1897.000                  |
| NP38T                             | 38   | 3                      | 207.350                    | 181.750                    | 5649.250                   | 1704.000                   | 18451.750                 | 1750.500                  |
| NP31T                             | 31   | 4                      | 106.100                    | 112.550                    | 4849.000                   | 1583.500                   | 22415.900                 | 1763.500                  |
| NP 4T                             | 4    | 4                      | 224.300                    | 246.800                    | 10452.750                  | 2521.500                   | 24022.200                 | 2395.000                  |
| NP40T                             | 40   | 4                      | 157.000                    | 194.800                    | 6725.500                   | 1962.000                   | 22642.400                 | 1936.500                  |

Table F-8. Plant tissue metal levels in forage from the Spangler fixation study plots.

SPANGLER FORAGE ESTABLISHMENT STUDY  
RIT PROJECT

## PLANT TISSUE METALS

| SAMPLE<br>NUMBER                  | PLOT | SOIL<br>TREAT-<br>MENT | PLANT<br>Cu<br>(mg/<br>kg) | PLANT<br>Zn<br>(mg/<br>kg) | PLANT<br>Pb<br>(mg/<br>kg) | PLANT<br>Mn<br>(mg/<br>kg) | PLANT<br>Cd<br>(mg/<br>kg) | PLANT<br>As<br>(mg/<br>kg) | PLANT<br>Ni<br>(mg/<br>kg) | PLANT<br>Hg<br>(mg/<br>kg) | PLANT<br>Cr<br>(mg/<br>kg) | PLANT<br>V<br>(mg/<br>kg) |
|-----------------------------------|------|------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|
| ** VEGETATION TREATMENT = 1       |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| * SPECIES = Basin wildrye         |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| NP 7B                             | 7    | 1                      | 14.150                     | 316.900                    | 3.000 B                    | 65.100                     | 1.800                      | 5.000 B                    | 1.500 B                    | 516.000                    | 1.500 B                    | 5.000 B                   |
| NP28B                             | 3    | 1                      | 9.350                      | 65.100                     | 3.000 B                    | 78.700                     | 0.800                      | 5.000 B                    | 1.500 B                    | 387.000                    | 1.500 B                    | 5.000 B                   |
| NP35B                             | 35   | 1                      | 9.650                      | 110.400                    | 3.000 B                    | 48.850                     | 1.050                      | 5.000 B                    | 1.500 B                    | 494.500                    | 1.500 B                    | 5.000 B                   |
| NP26B                             | 26   | 2                      | 10.050                     | 83.950                     | 3.450                      | 71.400                     | 1.250                      | 5.000 B                    | 1.500 B                    | 390.000                    | 1.500 B                    | 5.000 B                   |
| NP 6B                             | 6    | 2                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000 B                    | 0.000                      | 0.000                      | 0.000                      | 0.000                     |
| NP34B                             | 34   | 2                      | 12.150                     | 159.400                    | 3.650                      | 89.750                     | 1.650                      | 5.000 B                    | 1.500 B                    | 296.000                    | 4.200                      | 5.000 B                   |
| NP 8B                             | 8    | 3                      | 9.300                      | 160.950                    | 3.000 B                    | 59.800                     | 1.400                      | 5.000 B                    | 1.500 B                    | 568.500                    | 1.500 B                    | 5.000 B                   |
| NP27B                             | 27   | 3                      | 10.850                     | 82.700                     | 3.000 B                    | 93.700                     | 1.500                      | 5.000 B                    | 1.500 B                    | 194.500                    | 1.500 B                    | 5.000 B                   |
| NP36B                             | 36   | 3                      | 11.700                     | 164.400                    | 3.650                      | 80.250                     | 2.050                      | 5.000 B                    | 1.500 B                    | 410.500                    | 1.500 B                    | 5.000 B                   |
| NP25B                             | 25   | 4                      | 12.600                     | 101.750                    | 3.000 B                    | 93.650                     | 3.100                      | 5.000 B                    | 1.500 B                    | 493.000                    | 1.500 B                    | 5.000 B                   |
| NP 5B                             | 5    | 4                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000 B                    | 0.000                      | 0.000                      | 0.000                      | 0.000                     |
| NP33B                             | 33   | 4                      | 14.500                     | 275.150                    | 3.000 B                    | 20.950                     | 3.650                      | 5.000 B                    | 1.500 B                    | 321.000                    | 1.500 B                    | 5.000 B                   |
| * SPECIES = Streambank wheatgrass |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| NP28S                             | 28   | 1                      | 9.400                      | 48.600                     | 3.000 B                    | 76.700                     | 1.200                      | 5.000 B                    | 1.500 B                    | 213.500                    | 1.500 B                    | 5.000 B                   |
| NP 7S                             | 7    | 1                      | 12.400                     | 245.000                    | 3.000 B                    | 269.300                    | 2.100                      | 5.000 B                    | 1.500 B                    | 423.000                    | 1.500 B                    | 5.000 B                   |
| NP35S                             | 35   | 1                      | 13.650                     | 153.350                    | 3.000 B                    | 54.550                     | 1.600                      | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| NP 6S                             | 6    | 2                      | 16.600                     | 241.500                    | 3.000 B                    | 96.350                     | 1.800                      | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| NP26S                             | 26   | 2                      | 8.950                      | 62.200                     | 3.000 B                    | 73.750                     | 1.100                      | 5.000 B                    | 1.500 B                    | 155.000                    | 1.500 B                    | 5.000 B                   |
| NP34S                             | 34   | 2                      | 16.700                     | 181.800                    | 3.550                      | 87.550                     | 1.950                      | 5.000 B                    | 1.900                      | 5.000 B                    | 4.350                      | 5.000 B                   |
| NP 8S                             | 8    | 3                      | 16.150                     | 242.700                    | 3.000 B                    | 98.350                     | 2.350                      | 5.000 B                    | 1.500 B                    | 528.000                    | 1.500 B                    | 5.000 B                   |
| NP27S                             | 27   | 3                      | 10.600                     | 57.000                     | 3.000 B                    | 80.550                     | 1.600                      | 5.000 B                    | 1.500 B                    | 530.000                    | 1.500 B                    | 5.000 B                   |
| NP36S                             | 36   | 3                      | 23.600                     | 238.400                    | 3.000 B                    | 128.300                    | 2.500                      | 5.000 B                    | 2.300                      | 66.500                     | 3.600                      | 5.000 B                   |
| NP 5S                             | 5    | 4                      | 15.900                     | 370.150                    | 3.000 B                    | 153.300                    | 6.300                      | 5.000 B                    | 1.500 B                    | 534.000                    | 1.500 B                    | 5.000 B                   |
| NP25S                             | 25   | 4                      | 11.550                     | 87.350                     | 3.000 B                    | 90.350                     | 2.050                      | 5.000 B                    | 1.500 B                    | 677.000                    | 1.600                      | 5.000 B                   |
| NP33S                             | 33   | 4                      | 10.350                     | 155.450                    | 3.000 B                    | 183.400                    | 2.000                      | 5.000 B                    | 1.500 B                    | 502.500                    | 1.500 B                    | 5.000 B                   |
| ** VEGETATION TREATMENT = 2       |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| * SPECIES = Pubescent wheatgrass  |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| NP 9P                             | 9    | 1                      | 21.100                     | 139.350                    | 3.000 B                    | 127.400                    | 2.600                      | 5.000 B                    | 1.500 B                    | 78.000                     | 1.500 B                    | 5.000 B                   |
| NP21P                             | 21   | 1                      | 9.100                      | 97.700                     | 3.000 B                    | 97.850                     | 0.700                      | 5.000 B                    | 1.500 B                    | 496.000                    | 1.950                      | 5.000 B                   |
| NP48P                             | 48   | 1                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000 B                    | 0.000                      | 0.000                      | 0.000                      | 0.000                     |
| NP23P                             | 23   | 2                      | 12.400                     | 72.750                     | 3.000 B                    | 1137.550                   | 1.350                      | 5.000 B                    | 1.600                      | 152.500                    | 2.000                      | 5.000 B                   |
| NP12P                             | 12   | 2                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000 B                    | 0.000                      | 0.000                      | 0.000                      | 0.000                     |
| NP46P                             | 46   | 2                      | 24.800                     | 179.950                    | 3.000 B                    | 924.350                    | 4.150                      | 5.000 B                    | 1.500 B                    | 268.000                    | 1.500 B                    | 5.000 B                   |
| NP22P                             | 22   | 3                      | 10.950                     | 57.200                     | 3.000 B                    | 103.000                    | 1.150                      | 5.000 B                    | 1.500 B                    | 595.500                    | 1.500 B                    | 5.000 B                   |

Table F-8. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RIT PROJECT

PLANT TISSUE METALS

| SAMPLE<br>NUMBER               | PLOT | SOIL<br>TREAT-<br>MENT | PLANT<br>Cu<br>(mg/<br>kg) | PLANT<br>Zn<br>(mg/<br>kg) | PLANT<br>Pb<br>(mg/<br>kg) | PLANT<br>Mn<br>(mg/<br>kg) | PLANT<br>Cd<br>(mg/<br>kg) | PLANT<br>As<br>(mg/<br>kg) | PLANT<br>Ni<br>(mg/<br>kg) | PLANT<br>Hg<br>(mg/<br>kg) | PLANT<br>Cr<br>(mg/<br>kg) | PLANT<br>V<br>(mg/<br>kg) |
|--------------------------------|------|------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|
| NP11P                          | 11   | 3                      | 26.350                     | 216.150                    | 3.000 B                    | 158.300                    | 2.800                      | 5.000 B                    | 1.500 B                    | 591.000                    | 1.500 B                    | 5.000 B                   |
| NP47P                          | 47   | 3                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000 B                    | 0.000                      | 0.000                      | 0.000                      | 0.000                     |
| NP24P                          | 24   | 4                      | 11.700                     | 61.650                     | 3.000 B                    | 156.200                    | 2.000                      | 5.000 B                    | 1.500 B                    | 356.000                    | 1.500 B                    | 5.000 B                   |
| NP10P                          | 10   | 4                      | 14.500                     | 130.450                    | 3.000 B                    | 142.850                    | 2.450                      | 5.000 B                    | 1.500 B                    | 477.000                    | 1.650                      | 5.000 B                   |
| NP45P                          | 45   | 4                      | 10.200                     | 66.500                     | 3.000 B                    | 105.300                    | 1.850                      | 5.000 B                    | 1.500 B                    | 454.500                    | 1.500 B                    | 5.000 B                   |
| ** VEGETATION TREATMENT = 3    |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| * SPECIES = Western wheatgrass |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| NP19W                          | 19   | 1                      | 8.000                      | 93.850                     | 3.000 B                    | 84.800                     | 1.300                      | 5.000 B                    | 1.500 B                    | 449.500                    | 1.500 B                    | 5.000 B                   |
| NP16W                          | 16   | 1                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000 B                    | 0.000                      | 0.000                      | 0.000                      | 0.000                     |
| NP43W                          | 43   | 1                      | 15.100                     | 250.050                    | 3.000 B                    | 174.800                    | 3.550                      | 5.000 B                    | 2.650                      | 486.500                    | 4.200                      | 5.000 B                   |
| NP15W                          | 15   | 2                      | 13.850                     | 232.100                    | 3.650                      | 94.350                     | 2.700                      | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| NP20W                          | 20   | 2                      | 9.350                      | 98.050                     | 3.000 B                    | 144.400                    | 2.750                      | 5.000 B                    | 1.500 B                    | 649.500                    | 1.500 B                    | 5.000 B                   |
| NP41W                          | 41   | 2                      | 8.450                      | 167.100                    | 3.000 B                    | 132.400                    | 1.650                      | 5.000 B                    | 1.500 B                    | 552.500                    | 1.500 B                    | 5.000 B                   |
| NP14W                          | 14   | 3                      | 10.700                     | 108.300                    | 3.000 B                    | 152.150                    | 2.700                      | 5.000 B                    | 1.500 B                    | 341.000                    | 1.500 B                    | 5.000 B                   |
| NP17W                          | 17   | 3                      | 7.800                      | 78.900                     | 3.000 B                    | 81.300                     | 1.050                      | 5.000 B                    | 1.500 B                    | 545.000                    | 1.500 B                    | 5.000 B                   |
| NP44W                          | 44   | 3                      | 14.000                     | 149.550                    | 3.000 B                    | 795.350                    | 3.200                      | 5.000 B                    | 1.500 B                    | 251.500                    | 1.500 B                    | 5.000 B                   |
| NP18W                          | 18   | 4                      | 16.250                     | 147.300                    | 3.000 B                    | 195.350                    | 2.550                      | 5.000 B                    | 1.500 B                    | 367.500                    | 1.500 B                    | 5.000 B                   |
| NP13W                          | 13   | 4                      | 9.000                      | 96.650                     | 3.000 B                    | 146.800                    | 2.150                      | 5.000 B                    | 1.500 B                    | 34.000                     | 1.500 B                    | 5.000 B                   |
| NP42W                          | 42   | 4                      | 12.450                     | 149.600                    | 3.000 B                    | 183.350                    | 2.600                      | 5.000 B                    | 1.500 B                    | 16.500                     | 1.500 B                    | 5.000 B                   |
| ** VEGETATION TREATMENT = 4    |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| * SPECIES = Smooth Brome       |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| NP 2Br                         | 2    | 1                      | 17.800                     | 292.350                    | 3.000 B                    | 106.100                    | 2.150                      | 5.000 B                    | 1.500 B                    | 219.000                    | 1.500 B                    | 5.000 B                   |
| NP29Br                         | 29   | 1                      | 13.750                     | 97.950                     | 3.000 B                    | 124.000                    | 2.150                      | 5.000 B                    | 1.500 B                    | 428.500                    | 1.500 B                    | 5.000 B                   |
| NP37Br                         | 37   | 1                      | 15.550                     | 227.350                    | 3.000 B                    | 107.300                    | 2.650                      | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.800                      | 5.000 B                   |
| NP32Br                         | 32   | 2                      | 11.450                     | 57.150                     | 3.000 B                    | 410.300                    | 1.150                      | 5.000 B                    | 1.500 B                    | 21.500                     | 1.500 B                    | 5.000 B                   |
| NP 3Br                         | 3    | 2                      | 17.600                     | 216.450                    | 3.000 B                    | 117.850                    | 2.100                      | 5.000 B                    | 1.500 B                    | 612.000                    | 1.500 B                    | 5.000 B                   |
| NP39Br                         | 39   | 2                      | 15.200                     | 205.850                    | 3.000 B                    | 166.600                    | 1.900                      | 5.000 B                    | 1.500 B                    | 466.000                    | 3.600                      | 5.000 B                   |
| NP30Br                         | 30   | 3                      | 26.150                     | 71.250                     | 3.000 B                    | 106.900                    | 1.200                      | 5.000 B                    | 1.500 B                    | 194.500                    | 1.500 B                    | 5.000 B                   |
| NP 1Br                         | 1    | 3                      | 17.400                     | 148.250                    | 3.000 B                    | 95.200                     | 1.050                      | 5.000 B                    | 1.500 B                    | 685.500                    | 1.500 B                    | 5.000 B                   |
| NP38Br                         | 38   | 3                      | 29.900                     | 172.850                    | 3.000 B                    | 123.700                    | 2.000                      | 5.000 B                    | 1.500 B                    | 340.000                    | 1.800                      | 5.000 B                   |
| NP31Br                         | 31   | 4                      | 12.550                     | 53.050                     | 3.100                      | 113.550                    | 1.300                      | 5.000 B                    | 1.500 B                    | 359.500                    | 1.500 B                    | 5.000 B                   |
| NP 4Br                         | 4    | 4                      | 18.950                     | 144.250                    | 3.000 B                    | 304.050                    | 2.100                      | 5.000 B                    | 1.650                      | 701.000                    | 1.500 B                    | 5.000 B                   |
| NP40Br                         | 40   | 4                      | 18.100                     | 84.950                     | 3.200                      | 163.600                    | 1.650                      | 5.000 B                    | 1.500 B                    | 601.000                    | 1.500 B                    | 5.000 B                   |

Table F-8. (Continued).

SPANGLER FORAGE ESTABLISHMENT STUDY  
RIT PROJECT

## PLANT TISSUE METALS

| SAMPLE<br>NUMBER                  | PLOT | SOIL<br>TREAT-<br>MENT | PLANT<br>Cu<br>(mg/<br>kg) | PLANT<br>Zn<br>(mg/<br>kg) | PLANT<br>Pb<br>(mg/<br>kg) | PLANT<br>Mn<br>(mg/<br>kg) | PLANT<br>Cd<br>(mg/<br>kg) | PLANT<br>As<br>(mg/<br>kg) | PLANT<br>Ni<br>(mg/<br>kg) | PLANT<br>Hg<br>(mg/<br>kg) | PLANT<br>Cr<br>(mg/<br>kg) | PLANT<br>V<br>(mg/<br>kg) |
|-----------------------------------|------|------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|
| * SPECIES = Yellow sweetclover    |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| NP 2CL                            | 2    | 1                      | 20.850                     | 194.700                    | 3.000 B                    | 126.400                    | 2.150                      | 5.000 B                    | 1.500 B                    | 275.500                    | 1.500 B                    | 5.000 B                   |
| NP29CL                            | 29   | 1                      | 7.950                      | 39.900                     | 3.000 B                    | 166.450                    | 1.000                      | 5.000 B                    | 1.500 B                    | 457.000                    | 1.500 B                    | 5.000 B                   |
| NP37CL                            | 37   | 1                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000 B                    | 0.000                      | 0.000                      | 0.000                      | 0.000                     |
| NP 3CL                            | 3    | 2                      | 9.850                      | 68.450                     | 3.000 B                    | 86.250                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 433.500                    | 1.500 B                    | 5.000 B                   |
| NP32CL                            | 32   | 2                      | 8.750                      | 39.050                     | 3.000 B                    | 47.350                     | 0.650 B                    | 5.000 B                    | 1.500 B                    | 364.000                    | 1.500 B                    | 5.000 B                   |
| NP39CL                            | 39   | 2                      | 8.500                      | 56.650                     | 3.000 B                    | 236.850                    | 1.200                      | 5.000 B                    | 1.500 B                    | 5.000 B                    | 1.500 B                    | 5.000 B                   |
| NP 1CL                            | 1    | 3                      | 10.650                     | 89.400                     | 3.000 B                    | 86.600                     | 0.750                      | 5.000 B                    | 1.500 B                    | 481.500                    | 1.500 B                    | 5.000 B                   |
| NP30CL                            | 30   | 3                      | 10.350                     | 47.750                     | 3.000 B                    | 77.650                     | 0.750                      | 5.000 B                    | 1.950                      | 514.000                    | 1.500 B                    | 5.000 B                   |
| NP38CL                            | 38   | 3                      | 14.950                     | 49.900                     | 3.000 B                    | 81.300                     | 0.650 B                    | 5.000 B                    | 1.650                      | 382.500                    | 1.500 B                    | 5.000 B                   |
| NP 4CL                            | 4    | 4                      | 7.300                      | 75.850                     | 3.000 B                    | 101.600                    | 1.300                      | 5.000 B                    | 1.500 B                    | 152.500                    | 1.500 B                    | 5.000 B                   |
| NP31CL                            | 31   | 4                      | 9.950                      | 40.950                     | 3.000 B                    | 92.000                     | 1.550                      | 5.000 B                    | 1.500 B                    | 414.500                    | 1.500 B                    | 5.000 B                   |
| NP40CL                            | 40   | 4                      | 7.150                      | 52.800                     | 3.000 B                    | 98.100                     | 1.200                      | 5.000 B                    | 1.500 B                    | 363.500                    | 1.500 B                    | 5.000 B                   |
| * SPECIES = Thickspike wheatgrass |      |                        |                            |                            |                            |                            |                            |                            |                            |                            |                            |                           |
| NP29T                             | 29   | 1                      | 8.700                      | 77.600                     | 3.000 B                    | 70.550                     | 1.350                      | 5.000 B                    | 1.500 B                    | 390.500                    | 1.500 B                    | 5.000 B                   |
| NP 2T                             | 2    | 1                      | 13.100                     | 285.600                    | 3.000 B                    | 64.400                     | 1.550                      | 5.000 B                    | 1.500 B                    | 602.000                    | 1.500 B                    | 5.000 B                   |
| NP37T                             | 37   | 1                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000                      | 0.000 B                    | 0.000                      | 0.000                      | 0.000                      | 0.000                     |
| NP32T                             | 32   | 2                      | 9.100                      | 55.950                     | 3.000 B                    | 61.950                     | 0.950                      | 5.000 B                    | 1.500 B                    | 139.500                    | 1.500 B                    | 5.000 B                   |
| NP 3T                             | 3    | 2                      | 11.050                     | 138.550                    | 3.050                      | 73.950                     | 1.350                      | 5.000 B                    | 1.500 B                    | 331.000                    | 1.500 B                    | 5.000 B                   |
| NP39T                             | 39   | 2                      | 11.400                     | 164.400                    | 4.650                      | 88.450                     | 2.000                      | 5.000 B                    | 1.500 B                    | 469.500                    | 1.500 B                    | 5.000 B                   |
| NP30T                             | 30   | 3                      | 11.200                     | 106.450                    | 3.000 B                    | 96.100                     | 0.750                      | 5.000 B                    | 1.950                      | 456.500                    | 3.450                      | 5.000 B                   |
| NP 1T                             | 1    | 3                      | 14.900                     | 185.100                    | 3.000 B                    | 74.550                     | 1.300                      | 5.000 B                    | 1.500 B                    | 96.500                     | 1.500 B                    | 5.000 B                   |
| NP38T                             | 38   | 3                      | 10.050                     | 129.500                    | 3.000 B                    | 91.500                     | 1.950                      | 5.000 B                    | 1.500 B                    | 381.000                    | 1.500 B                    | 5.000 B                   |
| NP31T                             | 31   | 4                      | 7.700                      | 62.050                     | 3.000 B                    | 94.550                     | 2.000                      | 5.000 B                    | 1.500 B                    | 502.500                    | 1.500 B                    | 5.000 B                   |
| NP 4T                             | 4    | 4                      | 11.000                     | 114.100                    | 3.000 B                    | 101.150                    | 1.100                      | 5.000 B                    | 1.500 B                    | 645.500                    | 1.500 B                    | 5.000 B                   |
| NP40T                             | 40   | 4                      | 14.000                     | 136.400                    | 3.000 B                    | 107.150                    | 2.350                      | 5.000 B                    | 1.500 B                    | 441.000                    | 1.750                      | 5.000 B                   |

## APPENDIX G

### MICROTOX

Raw data from analyzer

G.1 Raw data readings from 12 samples listed by plot number from the Spangler Fixation study plots.

PLOT: N1

| TIME/<br>MIN. | B   |     | 1/50 |     | 1/20 |     | 1/10 |     | 1/5 |     |
|---------------|-----|-----|------|-----|------|-----|------|-----|-----|-----|
|               | b   | c   | b    | c   | b    | c   | b    | c   | b   | c   |
| - SOIL        | 154 | 167 | 157  | 162 | 148  | 169 | 153  | 154 | 150 | 174 |
| + SOIL        |     |     |      |     |      |     |      |     |     |     |
| 5             | 100 | 113 | 91   | 102 | 72   | 84  | 62   | 65  | 40  | 47  |
| 10            | 88  | 102 | 82   | 92  | 66   | 77  | 59   | 61  | 39  | 45  |
| 15            | 81  | 95  | 74   | 85  | 60   | 70  | 54   | 54  | 36  | 40  |
| 20            | 75  | 89  | 68   | 77  | 54   | 62  | 47   | 48  | 31  | 34  |
| 25            | 72  | 84  | 64   | 74  | 50   | 57  | 44   | 44  | 27  | 31  |
| 30            | 67  | 80  | 60   | 69  | 45   | 51  | 38   | 38  | 23  | 26  |

PLOT: N2

| TIME/<br>MIN. | B   |     | 1/50 |     | 1/20 |     | 1/10 |     | 1/5 |    |
|---------------|-----|-----|------|-----|------|-----|------|-----|-----|----|
|               | b   | c   | b    | c   | b    | c   | b    | c   | b   | c  |
| - SOIL        | 82  | 63  | 68   | 73  | 72   | 70  | 68   | 69  | 68  | 67 |
| + SOIL        |     |     |      |     |      |     |      |     |     |    |
| 5             | 70  | 53  | 42   | 45  | 31   | 31  | 22   | 23  | 10  | 10 |
| 10            | 668 | 509 | 369  | 396 | 259  | 258 | 190  | 191 | 86  | 87 |
| 15            | 639 | 493 | 327  | 359 | 217  | 212 | 157  | 160 | 73  | 74 |
| 20            | 617 | 480 | 291  | 315 | 176  | 173 | 122  | 125 | 62  | 63 |
| 25            | 599 | 469 | 258  | 284 | 145  | 145 | 105  | 102 | 54  | 54 |
| 30            | 580 | 458 | 231  | 252 | 122  | 120 | 84   | 85  | 47  | 47 |

PLOT: N3

| TIME/<br>MIN. | B   |     | 1/50 |     | 1/20 |     | 1/10 |     | 1/5 |     |
|---------------|-----|-----|------|-----|------|-----|------|-----|-----|-----|
|               | b   | c   | b    | c   | b    | c   | b    | c   | b   | c   |
| - SOIL        | 392 | 382 | 380  | 400 | 370  | 380 | 423  | 381 | 399 | 412 |
| + SOIL        |     |     |      |     |      |     |      |     |     |     |
| 5             | 310 | 309 | 288  | 312 | 262  | 275 | 270  | 248 | 172 | 179 |
| 10            | 288 | 288 | 273  | 297 | 251  | 259 | 254  | 233 | 165 | 171 |
| 15            | 272 | 278 | 265  | 283 | 240  | 245 | 243  | 222 | 157 | 157 |
| 20            | 260 | 263 | 255  | 271 | 225  | 234 | 229  | 211 | 148 | 146 |
| 25            | 254 | 254 | 243  | 260 | 213  | 224 | 216  | 201 | 138 | 138 |
| 30            | 246 | 244 | 234  | 250 | 204  | 213 | 208  | 190 | 127 | 130 |

PLOT: N4

| TIME/<br>MIN. | B   |     | 1/50 |     | 1/20 |     | 1/10 |     | 1/5 |     |
|---------------|-----|-----|------|-----|------|-----|------|-----|-----|-----|
|               | b   | c   | b    | c   | b    | c   | b    | c   | b   | c   |
| - SOIL        | 508 | 454 | 536  | 590 | 570  | 543 | 575  | 570 | 528 | 492 |
| + SOIL        |     |     |      |     |      |     |      |     |     |     |
| 5             | 380 | 275 | 198  | 240 | 286  | 274 | 386  | 374 | 390 | 361 |
| 10            | 350 | 255 | 184  | 238 | 272  | 262 | 357  | 354 | 368 | 339 |
| 15            | 331 | 243 | 178  | 223 | 258  | 250 | 340  | 335 | 350 | 322 |
| 20            | 312 | 234 | 164  | 211 | 250  | 235 | 323  | 318 | 332 | 310 |
| 25            | 300 | 227 | 152  | 200 | 232  | 224 | 304  | 301 | 318 | 297 |
| 30            | 290 | 220 | 143  | 188 | 217  | 210 | 286  | 291 | 303 | 282 |

PLOT: N29

| TIME/<br>MIN. | B   |    | 1/50 |    | 1/20 |    | 1/10 |    | 1/5 |    |
|---------------|-----|----|------|----|------|----|------|----|-----|----|
|               | b   | c  | b    | c  | b    | c  | b    | c  | b   | c  |
| - SOIL        | 104 | 92 | 93   | 92 | 96   | 95 | 97   | 95 | 106 | 91 |
| + SOIL        |     |    |      |    |      |    |      |    |     |    |
| 5             | 91  | 80 | 66   | 69 | 60   | 60 | 37   | 37 | 29  | 24 |
| 10            | 83  | 73 | 60   | 63 | 55   | 56 | 36   | 36 | 29  | 24 |
| 15            | 78  | 71 | 57   | 61 | 53   | 54 | 34   | 35 | 28  | 23 |
| 20            | 74  | 67 | 55   | 58 | 51   | 51 | 32   | 32 | 26  | 22 |
| 25            | 72  | 64 | 53   | 56 | 49   | 50 | 30   | 30 | 24  | 20 |
| 30            | 69  | 62 | 51   | 54 | 47   | 48 | 28   | 28 | 22  | 18 |

PLOT: N30

| TIME/<br>MIN. | B   |   | 1/500 |   | 1/100 |   | 1/10 |   | 1/5 |   |
|---------------|-----|---|-------|---|-------|---|------|---|-----|---|
|               | b   | c | b     | c | b     | c | b    | c | b   | c |
| - SOIL        | 227 |   | 236   |   | 229   |   | 239  |   | 235 |   |
| + SOIL        |     |   |       |   |       |   |      |   |     |   |
| 5             | 144 |   | 152   |   | 155   |   | 98   |   | 141 |   |
| 10            | 122 |   | 131   |   | 135   |   | 87   |   | 125 |   |
| 15            | 106 |   | 118   |   | 123   |   | 78   |   | 115 |   |
| 20            | 96  |   | 106   |   | 109   |   | 69   |   | 103 |   |
| 25            | 87  |   | 99    |   | 98    |   | 63   |   | 96  |   |
| 30            | 80  |   | 91    |   | 89    |   | 58   |   | 88  |   |

PLOT: N31

| TIME/<br>MIN. | B   |     | 1/50 |     | 1/20 |     | 1/10 |     | 1/5 |     |
|---------------|-----|-----|------|-----|------|-----|------|-----|-----|-----|
|               | b   | c   | b    | c   | b    | c   | b    | c   | b   | c   |
| - SOIL        | 120 | 109 | 107  | 111 | 111  | 114 | 112  | 110 | 107 | 107 |
| + SOIL        |     |     |      |     |      |     |      |     |     |     |
| 5             | 99  | 91  | 81   | 87  | 71   | 77  | 63   | 63  | 41  | 43  |
| 10            | 91  | 84  | 76   | 83  | 65   | 71  | 61   | 61  | 42  | 44  |
| 15            | 85  | 78  | 70   | 77  | 60   | 65  | 57   | 57  | 40  | 42  |
| 20            | 81  | 74  | 67   | 73  | 57   | 62  | 54   | 54  | 39  | 40  |
| 25            | 77  | 70  | 63   | 69  | 53   | 58  | 51   | 51  | 37  | 38  |
| 30            | 74  | 67  | 61   | 66  | 51   | 56  | 49   | 49  | 36  | 37  |

PLOT: N32

| TIME/<br>MIN. | B   |     | 1/50 |     | 1/20 |     | 1/10 |     | 1/5 |     |
|---------------|-----|-----|------|-----|------|-----|------|-----|-----|-----|
|               | b   | c   | b    | c   | b    | c   | b    | c   | b   | c   |
| - SOIL        | 280 | 284 | 280  | 269 | 255  | 258 | 273  | 271 | 251 | 252 |
| + SOIL        |     |     |      |     |      |     |      |     |     |     |
| 5             | 220 | 229 | 226  | 218 | 185  | 192 | 168  | 172 | 100 | 105 |
| 10            | 207 | 220 | 214  | 208 | 174  | 183 | 159  | 163 | 95  | 98  |
| 15            | 200 | 212 | 205  | 201 | 164  | 172 | 146  | 150 | 88  | 90  |
| 20            | 197 | 209 | 197  | 192 | 155  | 164 | 139  | 143 | 82  | 85  |
| 25            | 192 | 201 | 189  | 182 | 146  | 155 | 134  | 135 | 78  | 83  |
| 30            | 185 | 197 | 178  | 173 | 140  | 146 | 127  | 130 | 74  | 77  |

## PLOT: N37

| TIME/<br>MIN. | B   |   | 1/500 |   | 1/100 |   | 1/10 |   | 1/5 |   |
|---------------|-----|---|-------|---|-------|---|------|---|-----|---|
|               | b   | c | b     | c | b     | c | b    | c | b   | c |
| - SOIL        | 662 |   | 639   |   | 612   |   | 433  |   | 597 |   |
| + SOIL        |     |   |       |   |       |   |      |   |     |   |
| 5             | 491 |   | 462   |   | 466   |   | 130  |   | 325 |   |
| 10            | 432 |   | 410   |   | 418   |   | 032  |   | 276 |   |
| 15            | 398 |   | 368   |   | 381   |   | 010  |   | 218 |   |
| 20            | 360 |   | 330   |   | 343   |   | 004  |   | 150 |   |
| 25            | 336 |   | 305   |   | 327   |   | 002  |   | 112 |   |
| 30            | 324 |   | 293   |   | 311   |   | 001  |   | 95  |   |

## PLOT: N38

| TIME/<br>MIN. | B   |     | 1/50 |     | 1/20 |     | 1/10 |     | 1/5 |     |
|---------------|-----|-----|------|-----|------|-----|------|-----|-----|-----|
|               | b   | c   | b    | c   | b    | c   | b    | c   | b   | c   |
| - SOIL        | 628 | 574 | 580  | 609 | 537  | 614 | 583  | 589 | 610 | 563 |
| + SOIL        |     |     |      |     |      |     |      |     |     |     |
| 5             | 564 | 513 | 430  | 450 | 328  | 371 | 252  | 267 | 152 | 132 |
| 10            | 535 | 493 | 389  | 418 | 293  | 337 | 239  | 243 | 141 | 119 |
| 15            | 520 | 481 | 368  | 396 | 269  | 310 | 212  | 222 | 123 | 106 |
| 20            | 505 | 475 | 349  | 375 | 248  | 283 | 190  | 197 | 107 | 92  |
| 25            | 499 | 464 | 332  | 358 | 225  | 258 | 170  | 176 | 94  | 80  |
| 30            | 490 | 459 | 320  | 345 | 207  | 239 | 151  | 156 | 82  | 71  |

PLOT: N39

| TIME/<br>MIN. | B   |     | 1/50 |     | 1/20 |     | 1/10 |     | 1/5 |     |
|---------------|-----|-----|------|-----|------|-----|------|-----|-----|-----|
|               | b   | c   | b    | c   | b    | c   | b    | c   | b   | c   |
| - SOIL        | 155 | 152 | 146  | 144 | 155  | 129 | 147  | 132 | 132 | 135 |
| + SOIL        |     |     |      |     |      |     |      |     |     |     |
| 5             | 107 | 104 | 88   | 87  | 82   | 66  | 60   | 54  | 35  | 38  |
| 10            | 98  | 97  | 82   | 82  | 77   | 63  | 57   | 51  | 33  | 36  |
| 15            | 92  | 91  | 77   | 78  | 72   | 59  | 53   | 48  | 31  | 33  |
| 20            | 86  | 86  | 74   | 73  | 68   | 56  | 50   | 44  | 27  | 30  |
| 25            | 81  | 81  | 70   | 70  | 64   | 53  | 46   | 41  | 25  | 27  |
| 30            | 77  | 77  | 68   | 68  | 61   | 50  | 43   | 38  | 22  | 24  |

PLOT: N40

| TIME/<br>MIN. | B   |   | 1/50 |   | 1/20 |   | 1/10 |   | 1/5 |   |
|---------------|-----|---|------|---|------|---|------|---|-----|---|
|               | b   | c | b    | c | b    | c | b    | c | b   | c |
| - SOIL        | 940 |   | 850  |   | 860  |   | 872  |   | 615 |   |
| + SOIL        |     |   |      |   |      |   |      |   |     |   |
| 5             | 670 |   | 265  |   | 395  |   | 530  |   | 410 |   |
| 10            | 590 |   | 255  |   | 370  |   | 480  |   | 370 |   |
| 15            | 544 |   | 246  |   | 348  |   | 447  |   | 340 |   |
| 20            | 510 |   | 238  |   | 327  |   | 417  |   | 324 |   |
| 25            | 483 |   | 227  |   | 316  |   | 393  |   | 307 |   |
| 30            | 454 |   | 216  |   | 298  |   | 370  |   | 294 |   |

G.2 Raw data from 2 absorbance correction cuvettes.

PLOT: N4

| TIME/<br>MIN. | B   | B   | 1/100 | 1/50 | 1/20 | 1/10 | 1/5 |
|---------------|-----|-----|-------|------|------|------|-----|
| - SOIL        | 968 | 250 | 254   | 254  | 260  | 970  | 960 |
| + SOIL        |     |     |       |      |      |      |     |
| 5             | 375 | 218 | 213   | 192  | 173  | 249  | 111 |
| 10            | 298 | 197 | 185   | 167  | 160  | 207  | 120 |
| 15            | 248 | 173 | 165   | 148  | 146  | 186  | 130 |
| 20            | 220 | 159 | 151   | 134  | 133  | 176  | 125 |
| 25            | 194 | 143 | 135   | 121  | 122  | 160  | 121 |
| 30            | 175 | 127 | 127   | 111  | 111  | 148  | 116 |

PLOT: N29

| TIME/<br>MIN. | B    | B    | 1/100 | 1/50 | 1/20 | 1/10 | 1/5 |
|---------------|------|------|-------|------|------|------|-----|
| - SOIL        | 1340 | 1320 | 1400  | 423  | 380  | 419  | 470 |
| + SOIL        |      |      |       |      |      |      |     |
| 5             | 740  | 343  | 300   | 302  | 254  | 262  | 269 |
| 10            | 598  | 301  | 245   | 249  | 218  | 375  | 377 |
| 15            | 532  | 267  | 210   | 221  | 198  | 365  | 369 |
| 20            | 481  | 242  | 189   | 199  | 183  | 357  | 345 |
| 25            | 428  | 222  | 176   | 189  | 176  | 337  | 313 |
| 30            | 385  | 208  | 161   | 175  | 165  | 319  | 295 |

G.3 Normalized light values expressed as % light emitted relative to control (not color-corrected).

PLOT: N1

| TIME/<br>MIN. | 1/50 |    | 1/20 |    | 1/10 |    | 1/5 |    |
|---------------|------|----|------|----|------|----|-----|----|
|               | b    | c  | b    | c  | b    | c  | b   | c  |
| + SOIL        |      |    |      |    |      |    |     |    |
| 5             | 89   | 93 | 75   | 74 | 63   | 62 | 41  | 40 |
| 10            | 91   | 93 | 78   | 75 | 68   | 65 | 46  | 42 |
| 15            | 90   | 92 | 77   | 73 | 67   | 61 | 46  | 40 |
| 20            | 89   | 89 | 75   | 69 | 63   | 58 | 43  | 37 |
| 25            | 87   | 91 | 72   | 67 | 62   | 57 | 39  | 35 |
| 30            | 89   | 88 | 63   | 70 | 51   | 57 | 31  | 35 |

PLOT: N2

| TIME/<br>MIN. | 1/50 |    | 1/20 |    | 1/10 |    | 1/5 |    |
|---------------|------|----|------|----|------|----|-----|----|
|               | b    | c  | b    | c  | b    | c  | b   | c  |
| + SOIL        |      |    |      |    |      |    |     |    |
| 5             | 73   | 73 | 50   | 53 | 38   | 39 | 17  | 18 |
| 10            | 67   | 67 | 44   | 46 | 34   | 34 | 16  | 16 |
| 15            | 62   | 63 | 39   | 39 | 30   | 30 | 14  | 14 |
| 20            | 57   | 56 | 33   | 32 | 24   | 29 | 8   | 14 |
| 25            | 52   | 52 | 28   | 28 | 21   | 20 | 11  | 11 |
| 30            | 48   | 47 | 24   | 24 | 18   | 17 | 10  | 10 |

PLOT: N3

| TIME/<br>MIN. | 1/50 |    | 1/20 |    | 1/10 |    | 1/5 |    |
|---------------|------|----|------|----|------|----|-----|----|
|               | b    | c  | b    | c  | b    | c  | b   | c  |
| -----         |      |    |      |    |      |    |     |    |
| + SOIL        |      |    |      |    |      |    |     |    |
| 5             | 96   | 97 | 90   | 90 | 81   | 80 | 54  | 54 |
| 10            | 98   | 99 | 92   | 91 | 82   | 81 | 56  | 55 |
| 15            | 100  | 98 | 94   | 89 | 83   | 80 | 57  | 53 |
| 20            | 101  | 99 | 92   | 90 | 82   | 80 | 56  | 52 |
| 25            | 99   | 98 | 89   | 89 | 79   | 79 | 53  | 53 |
| 30            | 98   | 98 | 88   | 88 | 79   | 78 | 51  | 50 |
| 80            | 87   | 90 | 80   | 81 | 68   | 69 | 41  | 39 |
| -----         |      |    |      |    |      |    |     |    |

PLOT: N4

| TIME/<br>MIN. | 1/50 |     | 1/20 |     | 1/10 |    | 1/5 |    |
|---------------|------|-----|------|-----|------|----|-----|----|
|               | b    | c   | b    | c   | b    | c  | b   | c  |
| -----         |      |     |      |     |      |    |     |    |
| + SOIL        |      |     |      |     |      |    |     |    |
| 5             | 99   | 121 | 89   | 109 | 67   | 84 | 50  | 67 |
| 10            | 99   | 121 | 90   | 110 | 69   | 86 | 50  | 72 |
| 15            | 102  | 122 | 90   | 110 | 69   | 86 | 51  | 71 |
| 20            | 102  | 122 | 91   | 109 | 71   | 84 | 50  | 69 |
| 25            | 102  | 118 | 89   | 106 | 69   | 83 | 48  | 68 |
| 30            | 100  | 118 | 87   | 106 | 67   | 80 | 47  | 66 |
| -----         |      |     |      |     |      |    |     |    |

PLOT: N29

| TIME/<br>MIN. | 1/50 |    | 1/20 |    | 1/10 |    | 1/5 |    |
|---------------|------|----|------|----|------|----|-----|----|
|               | b    | c  | b    | c  | b    | c  | b   | c  |
| + SOIL        |      |    |      |    |      |    |     |    |
| 5             | 81   | 86 | 71   | 73 | 44   | 45 | 31  | 30 |
| 10            | 81   | 86 | 72   | 74 | 46   | 48 | 34  | 30 |
| 15            | 82   | 86 | 73   | 74 | 47   | 48 | 35  | 33 |
| 20            | 83   | 87 | 74   | 74 | 46   | 46 | 34  | 33 |
| 25            | 82   | 88 | 74   | 76 | 45   | 45 | 33  | 31 |
| 30            | 83   | 87 | 74   | 75 | 43   | 44 | 31  | 29 |

PLOT: N30

| TIME/<br>MIN. | 1/500 |   | 1/100 |   | 1/10 |   | 1/5 |   |
|---------------|-------|---|-------|---|------|---|-----|---|
|               | b     | c | b     | c | b    | c | b   | c |
| + SOIL        |       |   |       |   |      |   |     |   |
| 5             | 101   |   | 107   |   | 65   |   | 95  |   |
| 10            | 101   |   | 110   |   | 68   |   | 99  |   |
| 15            | 103   |   | 115   |   | 70   |   | 105 |   |
| 20            | 106   |   | 112   |   | 68   |   | 104 |   |
| 25            | 109   |   | 112   |   | 69   |   | 107 |   |
| 30            | 109   |   | 110   |   | 69   |   | 107 |   |

PLOT: N31

| TIME/<br>MIN. | 1/50 |    | 1/20 |    | 1/10 |    | 1/5 |    |
|---------------|------|----|------|----|------|----|-----|----|
|               | b    | c  | b    | c  | b    | c  | b   | c  |
| + SOIL        |      |    |      |    |      |    |     |    |
| 5             | 92   | 94 | 77   | 81 | 68   | 69 | 46  | 48 |
| 10            | 94   | 97 | 77   | 81 | 72   | 72 | 52  | 53 |
| 15            | 92   | 97 | 76   | 80 | 72   | 72 | 53  | 55 |
| 20            | 93   | 97 | 76   | 80 | 71   | 72 | 54  | 55 |
| 25            | 92   | 97 | 74   | 80 | 71   | 72 | 54  | 55 |
| 30            | 92   | 97 | 74   | 80 | 71   | 72 | 54  | 56 |

PLOT: N32

| TIME/<br>MIN. | 1/50 |     | 1/20 |    | 1/10 |    | 1/5 |    |
|---------------|------|-----|------|----|------|----|-----|----|
|               | b    | c   | b    | c  | b    | c  | b   | c  |
| + SOIL        |      |     |      |    |      |    |     |    |
| 5             | 103  | 101 | 93   | 92 | 79   | 79 | 51  | 52 |
| 10            | 103  | 100 | 92   | 92 | 79   | 78 | 51  | 50 |
| 15            | 103  | 101 | 90   | 89 | 75   | 74 | 49  | 48 |
| 20            | 100  | 97  | 87   | 86 | 73   | 72 | 47  | 46 |
| 25            | 98   | 96  | 84   | 85 | 72   | 71 | 46  | 47 |
| 30            | 96   | 93  | 83   | 82 | 71   | 69 | 45  | 44 |

PLOT: N37

| TIME/<br>MIN. | 1/500 |   | 1/100 |   | 1/10 |   | 1/5 |   |
|---------------|-------|---|-------|---|------|---|-----|---|
|               | b     | c | b     | c | b    | c | b   | c |
| -----         |       |   |       |   |      |   |     |   |
| + SOIL        |       |   |       |   |      |   |     |   |
| 5             | 98    |   | 103   |   | 41   |   | 73  |   |
| 10            | 99    |   | 105   |   | 11   |   | 71  |   |
| 15            | 96    |   | 103   |   | 04   |   | 61  |   |
| 20            | 95    |   | 103   |   | 02   |   | 46  |   |
| 25            | 94    |   | 105   |   | 01   |   | 37  |   |
| 30            | 94    |   | 104   |   | 00   |   | 33  |   |
| -----         |       |   |       |   |      |   |     |   |

PLOT: N38

| TIME/<br>MIN. | 1/50 |    | 1/20 |    | 1/10 |    | 1/5 |    |
|---------------|------|----|------|----|------|----|-----|----|
|               | b    | c  | b    | c  | b    | c  | b   | c  |
| -----         |      |    |      |    |      |    |     |    |
| + SOIL        |      |    |      |    |      |    |     |    |
| 5             | 82   | 82 | 68   | 67 | 48   | 50 | 28  | 26 |
| 10            | 79   | 82 | 68   | 67 | 48   | 50 | 27  | 25 |
| 15            | 76   | 77 | 61   | 60 | 44   | 45 | 24  | 22 |
| 20            | 75   | 74 | 57   | 55 | 41   | 40 | 22  | 20 |
| 25            | 72   | 73 | 53   | 52 | 37   | 37 | 19  | 18 |
| 30            | 71   | 71 | 49   | 48 | 33   | 33 | 17  | 16 |
| -----         |      |    |      |    |      |    |     |    |

PLOT: N39

| TIME/<br>MIN. | 1/50 |    | 1/20 |    | 1/10 |    | 1/5 |    |
|---------------|------|----|------|----|------|----|-----|----|
|               | b    | c  | b    | c  | b    | c  | b   | c  |
| + SOIL        |      |    |      |    |      |    |     |    |
| 5             | 87   | 89 | 77   | 75 | 59   | 61 | 38  | 41 |
| 10            | 89   | 90 | 79   | 77 | 61   | 62 | 39  | 42 |
| 15            | 89   | 91 | 78   | 77 | 60   | 62 | 39  | 41 |
| 20            | 91   | 90 | 79   | 77 | 61   | 60 | 36  | 39 |
| 25            | 92   | 92 | 79   | 77 | 60   | 59 | 35  | 38 |
| 30            | 94   | 94 | 79   | 77 | 59   | 58 | 33  | 35 |

PLOT: N40

| TIME/<br>MIN. | 1/50 |   | 1/20 |   | 1/10 |   | 1/5 |   |
|---------------|------|---|------|---|------|---|-----|---|
|               | b    | c | b    | c | b    | c | b   | c |
| + SOIL        |      |   |      |   |      |   |     |   |
| 5             | 94   |   | 85   |   | 64   |   | 44  |   |
| 10            | 96   |   | 88   |   | 68   |   | 48  |   |
| 15            | 96   |   | 89   |   | 70   |   | 50  |   |
| 20            | 97   |   | 88   |   | 70   |   | 52  |   |
| 25            | 97   |   | 88   |   | 71   |   | 52  |   |
| 30            | 99   |   | 88   |   | 72   |   | 53  |   |

G.4 Transmittance (Tx) and absorbance due to color (Ac) from the absorbance color correction cuvettes.

PLOT: N4            TIME: 5 MINUTES

| DILUTION | Ac    | Tx   |
|----------|-------|------|
| -----    |       |      |
| 1/100    | .127  | .939 |
| 1/50     | .432  | .812 |
| 1/20     | .851  | .673 |
| 1/10     | 1.288 | .562 |
| 1/5      | 3.732 | .262 |
| -----    |       |      |

PLOT: N4            TIME: 10 MINUTES

| DILUTION | Ac    | Tx   |
|----------|-------|------|
| -----    |       |      |
| 1/100    | .258  | .881 |
| 1/50     | .578  | .759 |
| 1/20     | .770  | .697 |
| 1/10     | 1.106 | .605 |
| 1/5      | 2.841 | .331 |
| -----    |       |      |

PLOT: N4            TIME: 15 MINUTES

| DILUTION | Ac    | Tx   |
|----------|-------|------|
| -----    |       |      |
| 1/100    | .192  | .910 |
| 1/50     | .540  | .773 |
| 1/20     | .653  | .734 |
| 1/10     | .892  | .662 |
| 1/5      | 2.027 | .428 |
| -----    |       |      |

PLOT: N4            TIME: 20 MINUTES

| DILUTION | Ac    | Tx   |
|----------|-------|------|
| 1/100    | .225  | .895 |
| 1/50     | .578  | .759 |
| 1/20     | .692  | .722 |
| 1/10     | .692  | .722 |
| 1/5      | 1.743 | .473 |

PLOT: N4            TIME: 25 MINUTES

| DILUTION | Ac    | Tx   |
|----------|-------|------|
| 1/100    | .225  | .895 |
| 1/50     | .578  | .759 |
| 1/20     | .615  | .747 |
| 1/10     | .578  | .759 |
| 1/5      | 1.482 | .521 |

PLOT: N4            TIME: 30 MINUTES

| DILUTION | Ac    | Tx   |
|----------|-------|------|
| 1/100    | .063  | .964 |
| 1/50     | .468  | .799 |
| 1/20     | .540  | .773 |
| 1/10     | .504  | .785 |
| 1/5      | 1.288 | .562 |

PLOT: N29

TIME: 5 MINUTES

| DILUTION | Ac    | Tx   |
|----------|-------|------|
| 1/100    | .094  | .954 |
| 1/50     | .361  | .839 |
| 1/20     | 1.241 | .573 |
| 1/10     | 3.167 | .302 |
| 1/5      | 3.254 | .295 |

PLOT: N29

TIME: 10 MINUTES

| DILUTION | Ac    | Tx   |
|----------|-------|------|
| 1/100    | .292  | .867 |
| 1/50     | .540  | .773 |
| 1/20     | 1.335 | .552 |
| 1/10     | 1.383 | .542 |
| 1/5      | 1.584 | .502 |

PLOT: N29

TIME: 15 MINUTES

| DILUTION | Ac    | Tx   |
|----------|-------|------|
| 1/100    | .396  | .826 |
| 1/50     | .540  | .773 |
| 1/20     | 1.241 | .573 |
| 1/10     | 1.106 | .605 |
| 1/5      | 1.288 | .562 |

PLOT: N29      TIME: 20 MINUTES

| DILUTION | Ac    | Tx   |
|----------|-------|------|
| 1/100    | .432  | .812 |
| 1/50     | .578  | .759 |
| 1/20     | 1.196 | .583 |
| 1/10     | .892  | .662 |
| 1/5      | 1.150 | .594 |

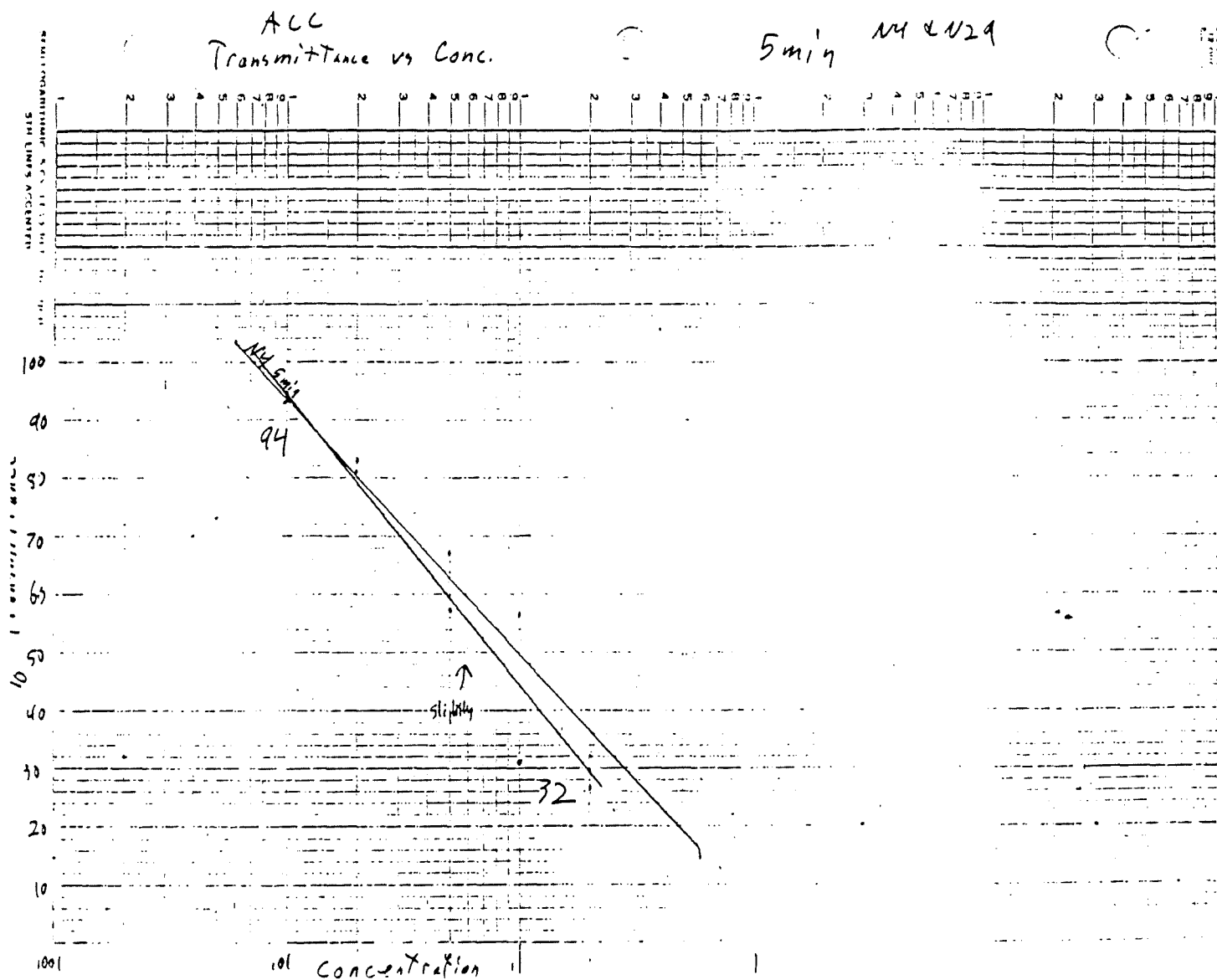
PLOT: N29      TIME: 25 MINUTES

| DILUTION | Ac    | Tx   |
|----------|-------|------|
| 1/100    | .396  | .826 |
| 1/50     | .468  | .799 |
| 1/20     | 1.062 | .616 |
| 1/10     | .692  | .722 |
| 1/5      | 1.106 | .605 |

PLOT: N29      TIME: 30 MINUTES

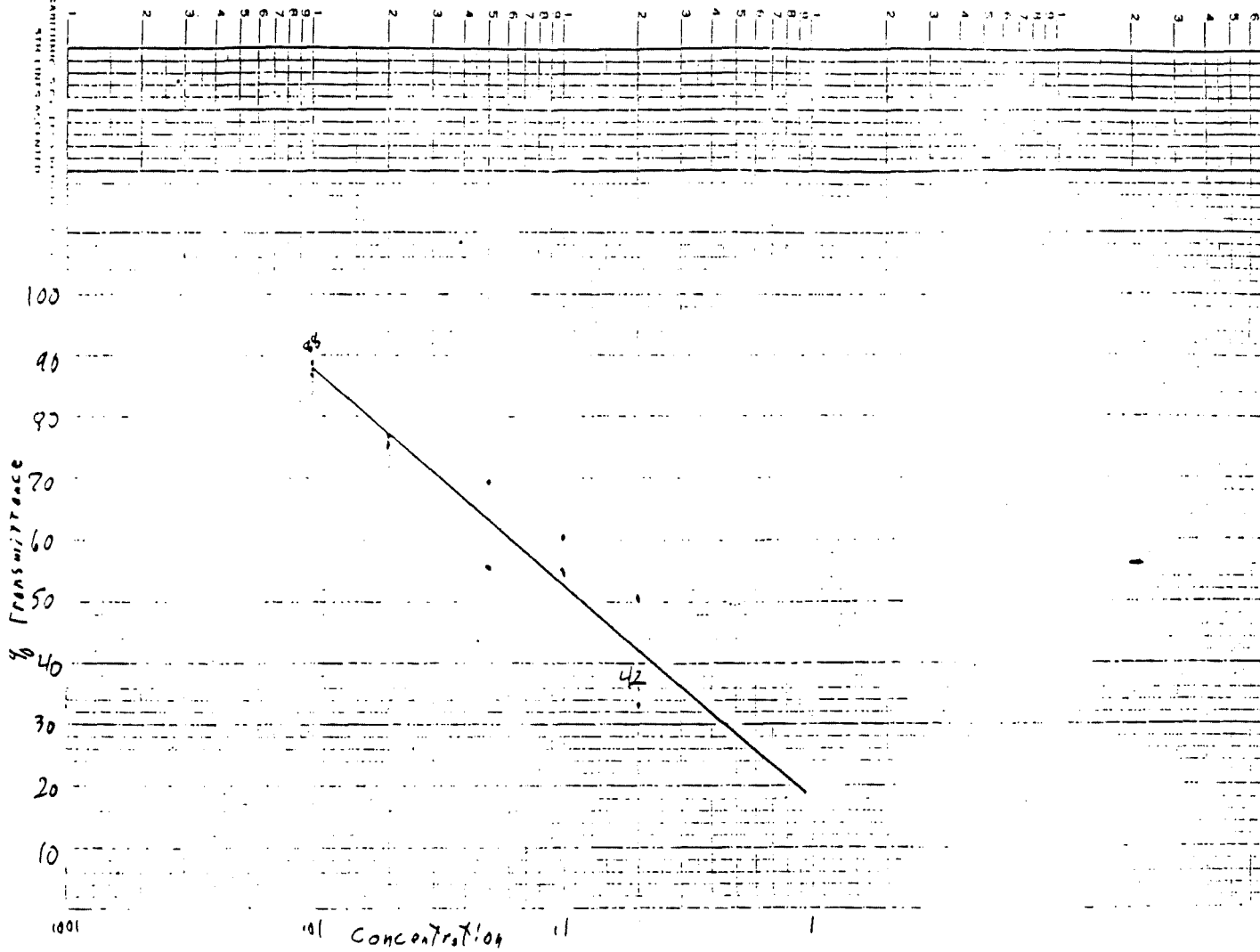
| DILUTION | Ac    | Tx   |
|----------|-------|------|
| 1/100    | .468  | .799 |
| 1/50     | .504  | .785 |
| 1/20     | 1.062 | .616 |
| 1/10     | .540  | .773 |
| 1/5      | .976  | .638 |

G.5 Graphs of % transmittance vs. concentration for each time interval. Lines are fit to points of samples N4 and N29 from the absorbance color correction cuvettes.



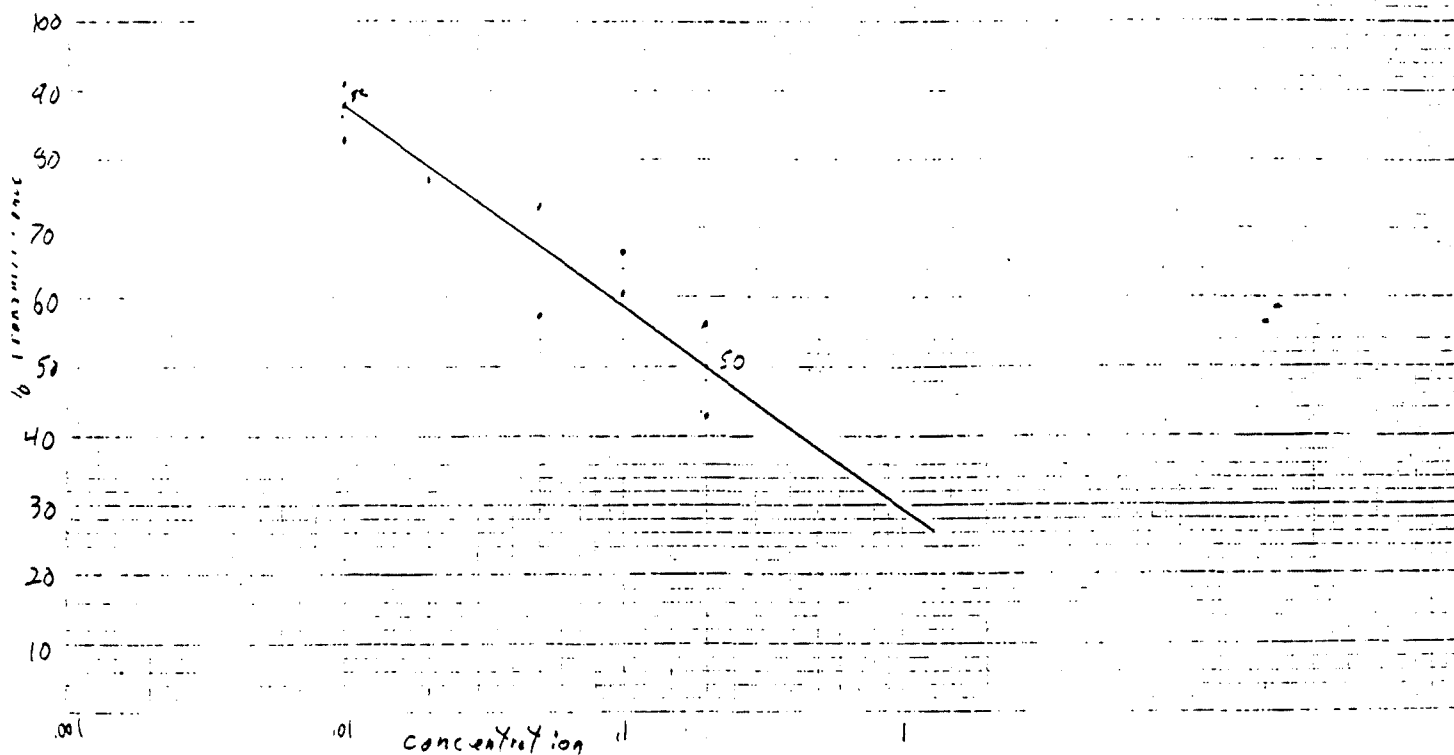
ALL  
Transmittance vs Conc.

10 min N4 + N24



ALL  
Transmittance vs Conc.

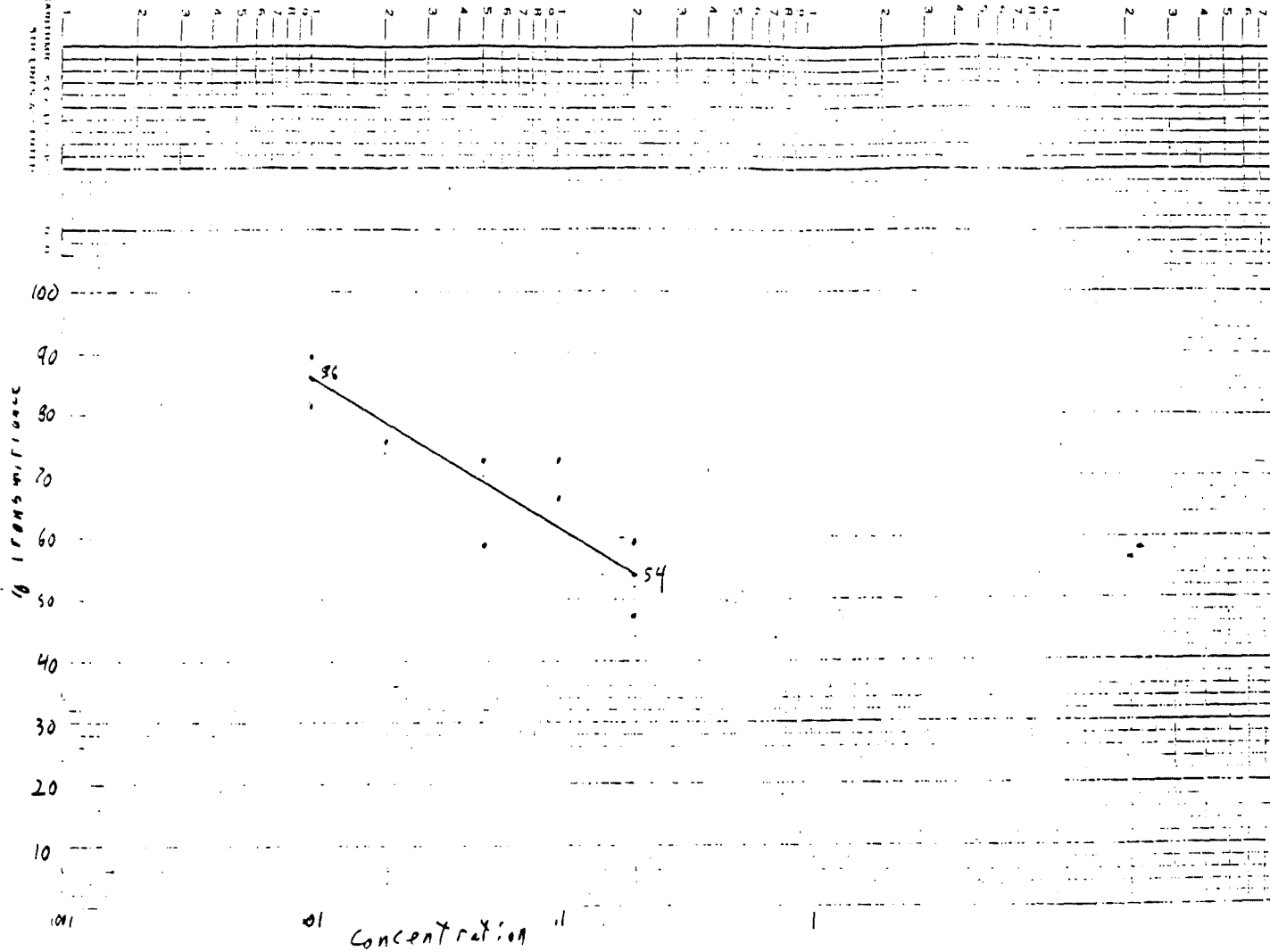
15 min N4 X N24



ALL Transmittance vs Conc.

20 min N4x N29

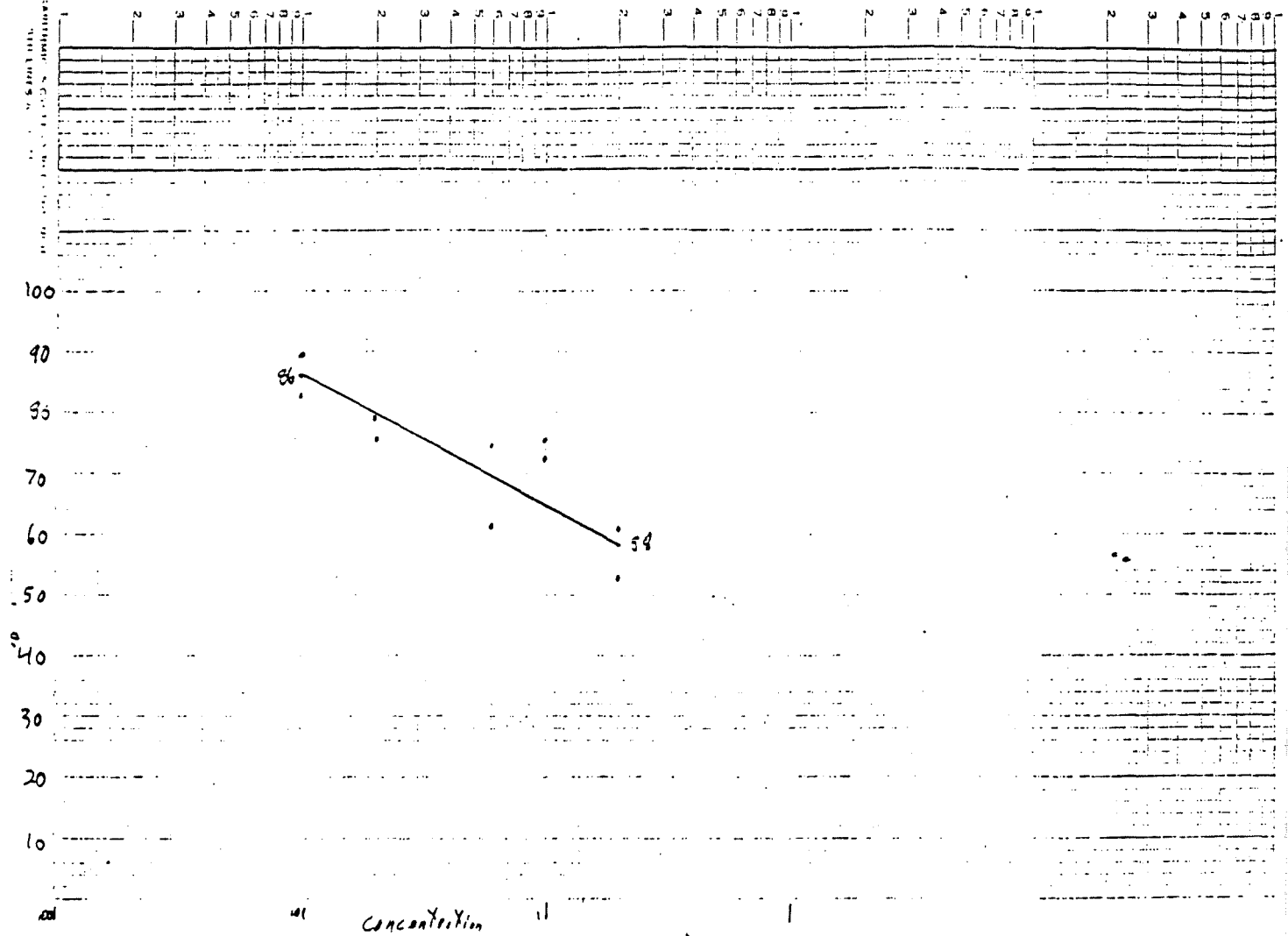
(C)

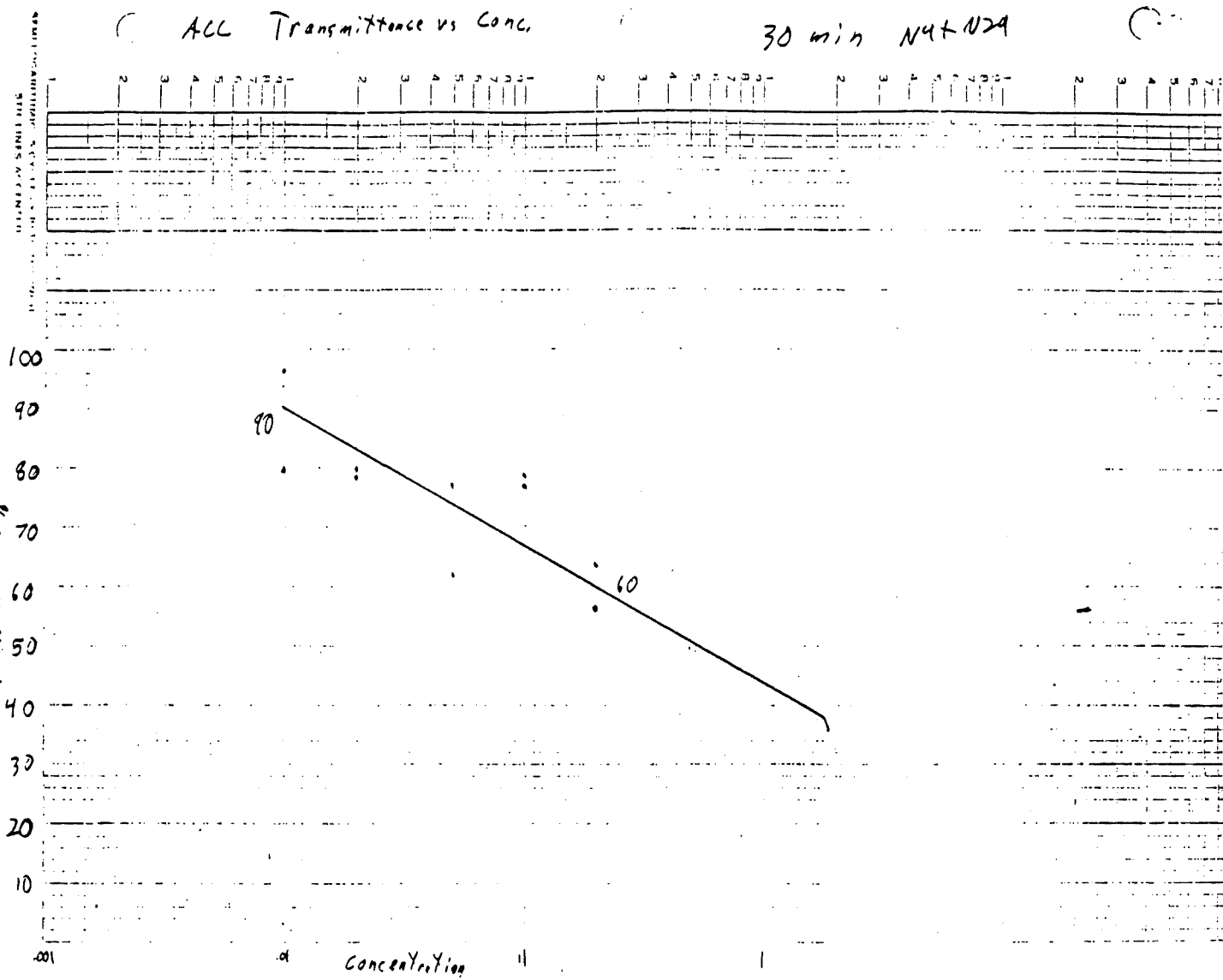


( Acc Transmittance vs Conc.

25 min N4 & N29

C





G.6 Final percent light loss due to toxicity for all 12 samples with all corrections.

PLOT: N1

| TIME/<br>MIN. | 1/50 |   | 1/20 |   | 1/10 |   | 1/5 |   |
|---------------|------|---|------|---|------|---|-----|---|
|               | b    | c | b    | c | b    | c | b   | c |
| + SOIL        |      |   |      |   |      |   |     |   |
| 5             | 3    |   | 1    |   | -2   |   | 2   |   |
| 10            | -5   |   | -3   |   | -25  |   | 17  |   |
| 15            | -3   |   | 1    |   | 6    |   | 27  |   |
| 20            | -3   |   | 5    |   | 15   |   | 34  |   |
| 25            | -3   |   | 10   |   | 16   |   | 42  |   |
| 30            | 2    |   | 18   |   | 27   |   | 51  |   |

PLOT: N2

| TIME/<br>MIN. | 1/50 |   | 1/20 |   | 1/10 |   | 1/5 |   |
|---------------|------|---|------|---|------|---|-----|---|
|               | b    | c | b    | c | b    | c | b   | c |
| + SOIL        |      |   |      |   |      |   |     |   |
| 5             | 22   |   | 31   |   | 37   |   | 63  |   |
| 10            | 24   |   | 39   |   | 47   |   | 70  |   |
| 15            | 30   |   | 48   |   | 56   |   | 76  |   |
| 20            | 34   |   | 57   |   | 60   |   | 82  |   |
| 25            | 40   |   | 14   |   | 70   |   | 83  |   |
| 30            | 47   |   | 70   |   | 76   |   | 85  |   |

PLOT: N3

| TIME/<br>MIN. | 1/50 |   | 1/20 |   | 1/10 |   | 1/5 |   |
|---------------|------|---|------|---|------|---|-----|---|
|               | b    | c | b    | c | b    | c | b   | c |
| -----         |      |   |      |   |      |   |     |   |
| + SOIL        |      |   |      |   |      |   |     |   |
| 5             | -3   |   | -20  |   | -32  |   | -15 |   |
| 10            | -12  |   | -24  |   | -27  |   | -5  |   |
| 15            | -13  |   | -19  |   | -20  |   | 7   |   |
| 20            | -16  |   | -18  |   | -17  |   | 11  |   |
| 25            | -15  |   | -16  |   | -11  |   | 17  |   |
| 30            | 2    |   | 1    |   | 7    |   | 25  |   |
| -----         |      |   |      |   |      |   |     |   |

PLOT: N4

| TIME/<br>MIN. | 1/50 |   | 1/20 |   | 1/10 |   | 1/5 |   |
|---------------|------|---|------|---|------|---|-----|---|
|               | b    | c | b    | c | b    | c | b   | c |
| -----         |      |   |      |   |      |   |     |   |
| + SOIL        |      |   |      |   |      |   |     |   |
| 5             | -17  |   | -32  |   | -24  |   | -25 |   |
| 10            | -25  |   | -35  |   | -21  |   | -15 |   |
| 15            | -27  |   | -32  |   | -14  |   | -3  |   |
| 20            | -30  |   | -32  |   | -12  |   | 2   |   |
| 25            | -28  |   | -27  |   | -7   |   | 9   |   |
| 30            | -21  |   | -19  |   | 1    |   | 16  |   |
| -----         |      |   |      |   |      |   |     |   |

PLOT: N29

| TIME/<br>MIN. | 1/50 |   | 1/20 |   | 1/10 |   | 1/5 |   |
|---------------|------|---|------|---|------|---|-----|---|
|               | b    | c | b    | c | b    | c | b   | c |
| -----         |      |   |      |   |      |   |     |   |
| + SOIL        |      |   |      |   |      |   |     |   |
| 5             | 11   |   | 4    |   | 27   |   | 35  |   |
| 10            | 5    |   | 1    |   | 27   |   | 40  |   |
| 15            | 5    |   | 3    |   | 30   |   | 42  |   |
| 20            | 1    |   | 4    |   | 33   |   | 45  |   |
| 25            | 1    |   | 3    |   | 37   |   | 50  |   |
| 30            | 6    |   | 8    |   | 41   |   | 55  |   |
| -----         |      |   |      |   |      |   |     |   |

PLOT: N30

| TIME/<br>MIN. | 1/50 |   | 1/20 |   | 1/10 |   | 1/5  |   |
|---------------|------|---|------|---|------|---|------|---|
|               | b    | c | b    | c | b    | c | b    | c |
| -----         |      |   |      |   |      |   |      |   |
| + SOIL        |      |   |      |   |      |   |      |   |
| 5             | --   |   | --   |   | -7   |   | -102 |   |
| 10            | --   |   | --   |   | -6   |   | -87  |   |
| 15            | --   |   | --   |   | -3   |   | -78  |   |
| 20            | --   |   | --   |   | -11  |   | -70  |   |
| 25            | --   |   | --   |   | -8   |   | -67  |   |
| 30            | --   |   | --   |   | 7    |   | -60  |   |
| -----         |      |   |      |   |      |   |      |   |

PLOT: N31

| TIME/<br>MIN. | 1/50 |   | 1/20 |   | 1/10 |   | 1/5 |   |
|---------------|------|---|------|---|------|---|-----|---|
|               | b    | c | b    | c | b    | c | b   | c |
| -----         |      |   |      |   |      |   |     |   |
| + SOIL        |      |   |      |   |      |   |     |   |
| 5             | 1    |   | -5   |   | -12  |   | 0   |   |
| 10            | -9   |   | -5   |   | -13  |   | 1   |   |
| 15            | -7   |   | -1   |   | -6   |   | 8   |   |
| 20            | -10  |   | -1   |   | -4   |   | 11  |   |
| 25            | -10  |   | 1    |   | -1   |   | 15  |   |
| 30            | -5   |   | 5    |   | 3    |   | 18  |   |
| -----         |      |   |      |   |      |   |     |   |

PLOT: N32

| TIME/<br>MIN. | 1/50 |   | 1/20 |   | 1/10 |   | 1/5 |   |
|---------------|------|---|------|---|------|---|-----|---|
|               | b    | c | b    | c | b    | c | b   | c |
| -----         |      |   |      |   |      |   |     |   |
| + SOIL        |      |   |      |   |      |   |     |   |
| 5             | -9   |   | -23  |   | -30  |   | -10 |   |
| 10            | -15  |   | -24  |   | -23  |   | 5   |   |
| 15            | -16  |   | -18  |   | -10  |   | 18  |   |
| 20            | -15  |   | -14  |   | -5   |   | 24  |   |
| 25            | -13  |   | -11  |   | -1   |   | 27  |   |
| 30            | -5   |   | -2   |   | 5    |   | 34  |   |
| -----         |      |   |      |   |      |   |     |   |

PLOT: N37

| TIME/<br>MIN. | 1/50 |   | 1/20 |   | 1/10 |   | 1/5 |   |
|---------------|------|---|------|---|------|---|-----|---|
|               | b    | c | b    | c | b    | c | b   | c |
| -----         |      |   |      |   |      |   |     |   |
| + SOIL        |      |   |      |   |      |   |     |   |
| 5             | --   |   | --   |   | 32   |   | -55 |   |
| 10            | --   |   | --   |   | 83   |   | -34 |   |
| 15            | --   |   | --   |   | 94   |   | -3  |   |
| 20            | --   |   | --   |   | 97   |   | 25  |   |
| 25            | --   |   | --   |   | 99   |   | 42  |   |
| 30            | --   |   | --   |   | 100  |   | 51  |   |
| -----         |      |   |      |   |      |   |     |   |

PLOT: N38

| TIME/<br>MIN. | 1/50 |   | 1/20 |   | 1/10 |   | 1/5 |   |
|---------------|------|---|------|---|------|---|-----|---|
|               | b    | c | b    | c | b    | c | b   | c |
| -----         |      |   |      |   |      |   |     |   |
| + SOIL        |      |   |      |   |      |   |     |   |
| 5             | 13   |   | 10   |   | 20   |   | 43  |   |
| 10            | 9    |   | 9    |   | 23   |   | 51  |   |
| 15            | 13   |   | 21   |   | 35   |   | 61  |   |
| 20            | 13   |   | 27   |   | 41   |   | 66  |   |
| 25            | 16   |   | 32   |   | 48   |   | 71  |   |
| 30            | 21   |   | 40   |   | 55   |   | 75  |   |
| -----         |      |   |      |   |      |   |     |   |

PLOT: N39

| TIME/<br>MIN. | 1/50 |   | 1/20 |   | 1/10 |   | 1/5 |   |
|---------------|------|---|------|---|------|---|-----|---|
|               | b    | c | b    | c | b    | c | b   | c |
| + SOIL        |      |   |      |   |      |   |     |   |
| 5             | 6    |   | 1    |   | 2    |   | 16  |   |
| 10            | -2   |   | -5   |   | 4    |   | 24  |   |
| 15            | -2   |   | -1   |   | 10   |   | 32  |   |
| 20            | -5   |   | -1   |   | 12   |   | 39  |   |
| 25            | -7   |   | -1   |   | 16   |   | 43  |   |
| 30            | -4   |   | 4    |   | 21   |   | 49  |   |

PLOT: N40

| TIME/<br>MIN. | 1/50 |   | 1/20 |   | 1/10 |   | 1/5 |   |
|---------------|------|---|------|---|------|---|-----|---|
|               | b    | c | b    | c | b    | c | b   | c |
| + SOIL        |      |   |      |   |      |   |     |   |
| 5             | 0    |   | -13  |   | -5   |   | 6   |   |
| 10            | -25  |   | -19  |   | -6   |   | 9   |   |
| 15            | -27  |   | -16  |   | -3   |   | 15  |   |
| 20            | -30  |   | -14  |   | -1   |   | 15  |   |
| 25            | -28  |   | -13  |   | 0    |   | 19  |   |
| 30            | -10  |   | -9   |   | 3    |   | 21  |   |

**APPENDIX H**  
**Quality Assurance/Quality Control**  
**Program Results**

## **APPENDIX H.1**

QA Reports for each Element

# QUALITY ASSURANCE REPORT

Project Name: Spangler Forage Establishment Study

Element: Aluminum

## ACCURACY

- 1) Using EPA ICAP 19 as a blind field standard, we are — % confident that the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data are 185.6  $\pm$  — % of the reported value.
  - 2) Using EPA ICAP 19 as a blind field standard, we are — % confident that the DTPA extractable soil data are 185.6  $\pm$  — % of the reported value.
  - 3) Using EPA ICAP 19 as a blind field standard, we are — % confident that the water soluble (saturation extract) data are 185.6  $\pm$  — % of the reported value.
  - 4) Using NBS tomato leaves as a blind field standard, we are — % confident that the  $\text{HNO}_3$  digestable plant tissue data are 29.0  $\pm$  — % of the reported value.
- \* no statistical analysis performed due to lack of replication

## PRECISION

- 1) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data lie within  $\pm$  9.36 % of the reported value.
- 2) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the DTPA extractable soil data lie within  $\pm$  46.13 % of the reported value.
- 3) Using 3 blind field replicate data pairs, we are 90 % confident that 100 % of the water soluble (saturation extract) soil data lie within  $\pm$  94.99 % of the reported value.
- 4) Using 7 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3$  digestable plant tissue data lie within  $\pm$  6.50 % of the reported value.

## CONTAMINATION

Laboratory blanks were prepared to represent lab contamination introduced during the preparation or extraction of samples. Any values in excess of the instrument detection limit (IDL) indicates that significant contamination may occur in similar samples.

| Analysis Type                       | IDL (ug/l) | Number of Blanks | Number in Excess of IDL | Maximum Concentration (ug/l) |
|-------------------------------------|------------|------------------|-------------------------|------------------------------|
| $\text{HNO}_3/\text{H}_2\text{O}_2$ | .5         | 3                | 1                       | .7                           |
| DTPA                                | .17        | 3                | 3                       | 1.2                          |
| Saturation extract                  | .1         | 3                | 3                       | 1.3                          |
| $\text{HNO}_3$ Plant tissue         | .1         | 6                | 2                       | .6                           |

## QUALITY ASSURANCE REPORT

Project Name: Spangler Forage Establishment Study

Element: Arsenic

### ACCURACY

- 1) Using EPA ICAP 19 as a blind field standard, we are 2 % confident that the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data are 29.5  $\pm$  - % of the reported value.
  - 2) Using EPA ICAP 19 as a blind field standard, we are - % confident that the DTPA extractable soil data are 29.5  $\pm$  - % of the reported value.
  - 3) Using EPA ICAP 19 as a blind field standard, we are - % confident that the water soluble (saturation extract) data are 29.5  $\pm$  - % of the reported value.
  - 4) Using NBS tomato leaves as a blind field standard, we are - % confident that the  $\text{HNO}_3$  digestable plant tissue data are -  $\pm$  - % of the reported value.
- \* no statistical analysis performed due to lack of replication

### PRECISION

- 1) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data lie within  $\pm$  11.4 % of the reported value.
- 2) Using 3 blind field replicate data pairs, we are 90 % confident that 100 % of the DTPA extractable soil data lie within  $\pm$  12.1 % of the reported value.
- 3) Using 2 blind field replicate data pairs, we are 90 % confident that 100 % of the water soluble (saturation extract) soil data lie within  $\pm$  - % of the reported value.
- 4) Using 0 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3$  digestable plant tissue data lie within  $\pm$  - % of the reported value.

### CONTAMINATION

Laboratory blanks were prepared to represent lab contamination introduced during the preparation or extraction of samples. Any values in excess of the instrument detection limit (IDL) indicates that significant contamination may occur in similar samples.

| Analysis Type                       | IDL (ug/l) | Number of Blanks | Number in Excess of IDL | Maximum Concentration (ug/l) |
|-------------------------------------|------------|------------------|-------------------------|------------------------------|
| $\text{HNO}_3/\text{H}_2\text{O}_2$ | .16        | 3                | 0                       | -                            |
| DTPA                                | .10        | 3                | 0                       | -                            |
| Saturation extract                  | .10        | 3                | 0                       | -                            |
| $\text{HNO}_3$ Plant tissue         | .10        | 6                | 0                       | -                            |

# QUALITY ASSURANCE REPORT

Project Name: Spangler Forage Establishment Study

Element: Cadmium

## ACCURACY

- 1) Using EPA ICAP 19 as a blind field standard, we are — % confident that the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data are 105.9  $\pm$  — % of the reported value.
  - 2) Using EPA ICAP 19 as a blind field standard, we are — % confident that the DTPA extractable soil data are 105.9  $\pm$  — % of the reported value.
  - 3) Using EPA ICAP 19 as a blind field standard, we are — % confident that the water soluble (saturation extract) data are 105.9  $\pm$  — % of the reported value.
  - 4) Using NBS tomato leaves as a blind field standard, we are — % confident that the  $\text{HNO}_3$  digestable plant tissue data are 80.0  $\pm$  — % of the reported value.
- \* no statistical analysis performed due to lack of replication

## PRECISION

- 1) Using 1 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data lie within  $\pm$  — % of the reported value.
- 2) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the DTPA extractable soil data lie within  $\pm$  3.53 % of the reported value.
- 3) Using 0 blind field replicate data pairs, we are 90 % confident that 100 % of the water soluble (saturation extract) soil data lie within  $\pm$  — % of the reported value.
- 4) Using 3 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3$  digestable plant tissue data lie within  $\pm$  24.8 % of the reported value.

## CONTAMINATION

Laboratory blanks were prepared to represent lab contamination introduced during the preparation or extraction of samples. Any values in excess of the instrument detection limit (IDL) indicates that significant contamination may occur in similar samples.

| Analysis Type                       | IDL (ug/l) | Number of Blanks | Number in Excess of IDL | Maximum Concentration (ug/l) |
|-------------------------------------|------------|------------------|-------------------------|------------------------------|
| $\text{HNO}_3/\text{H}_2\text{O}_2$ | .02        | 3                | 0                       | —                            |
| DTPA                                | .1         | 3                | 0                       | —                            |
| Saturation extract                  | .013       | 3                | 0                       | —                            |
| $\text{HNO}_3$ Plant tissue         | .013       | 6                | 0                       | —                            |

## QUALITY ASSURANCE REPORT

Project Name: Spangler Forage Establishment Study

Element: Calcium

### ACCURACY

- 1) Using EPA ICAP 19 as a blind field standard, we are — % confident that the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data are 46  $\pm$  — % of the reported value.
  - 2) Using EPA ICAP 19 as a blind field standard, we are — % confident that the DTPA extractable soil data are 46  $\pm$  — % of the reported value.
  - 3) Using EPA ICAP 19 as a blind field standard, we are — % confident that the water soluble (saturation extract) data are 46  $\pm$  — % of the reported value.
  - 4) Using NBS tomato leaves as a blind field standard, we are — % confident that the  $\text{HNO}_3$  digestable plant tissue data are —  $\pm$  — % of the reported value.
- \* no statistical analysis performed due to lack of replication

### PRECISION

- 1) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data lie within  $\pm$  12.64 % of the reported value.
- 2) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the DTPA extractable soil data lie within  $\pm$  8.14 % of the reported value.
- 3) Using 1 blind field replicate data pairs, we are 90 % confident that 100 % of the water soluble (saturation extract) soil data lie within  $\pm$  — % of the reported value.
- 4) Using 7 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3$  digestable plant tissue data lie within  $\pm$  3.73 % of the reported value.

### CONTAMINATION

Laboratory blanks were prepared to represent lab contamination introduced during the preparation or extraction of samples. Any values in excess of the instrument detection limit (IDL) indicates that significant contamination may occur in similar samples.

| Analysis Type                       | IDL (ug/l) | Number of<br>Blanks | Number in<br>Excess of<br>IDL | Maximum<br>Concentration<br>(ug/l) |
|-------------------------------------|------------|---------------------|-------------------------------|------------------------------------|
| $\text{HNO}_3/\text{H}_2\text{O}_2$ | .50        | 3                   | 0                             | —                                  |
| DTPA                                | .50        | 3                   | 3                             | 429                                |
| Saturation extract                  | .50        | 3                   | 2                             | 5.48                               |
| $\text{HNO}_3$ Plant tissue         | .50        | 6                   | 1                             | .937                               |

## QUALITY ASSURANCE REPORT

Project Name: Spangler Forage Establishment Study

Element: Copper

### ACCURACY

- 1) Using EPA ICAP 19 as a blind field standard, we are — % confident that the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data are 104.9  $\pm$  — % of the reported value.
  - 2) Using EPA ICAP 19 as a blind field standard, we are — % confident that the DTPA extractable soil data are 104.9  $\pm$  — % of the reported value.
  - 3) Using EPA ICAP 19 as a blind field standard, we are — % confident that the water soluble (saturation extract) data are 104.9  $\pm$  — % of the reported value.
  - 4) Using NBS tomato leaves as a blind field standard, we are — % confident that the  $\text{HNO}_3$  digestable plant tissue data are 78.2  $\pm$  — % of the reported value.
- \* no statistical analysis performed due to lack of replication

### PRECISION

- 1) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data lie within  $\pm$  14.92 % of the reported value.
- 2) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the DTPA extractable soil data lie within  $\pm$  13.6 % of the reported value.
- 3) Using 2 blind field replicate data pairs, we are 90 % confident that 100 % of the water soluble (saturation extract) soil data lie within  $\pm$  — % of the reported value.
- 4) Using 7 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3$  digestable plant tissue data lie within  $\pm$  4.52 % of the reported value.

### CONTAMINATION

Laboratory blanks were prepared to represent lab contamination introduced during the preparation or extraction of samples. Any values in excess of the instrument detection limit (IDL) indicates that significant contamination may occur in similar samples.

| Analysis Type                       | IDL (ug/l) | Number of Blanks | Number in Excess of IDL | Maximum Concentration (ug/l) |
|-------------------------------------|------------|------------------|-------------------------|------------------------------|
| $\text{HNO}_3/\text{H}_2\text{O}_2$ | .5         | 3                | 0                       | —                            |
| DTPA                                | .5         | 3                | 1                       | .672                         |
| Saturation extract                  | .05        | 3                | 1                       | .406                         |
| $\text{HNO}_3$ Plant tissue         | .05        | 6                | 0                       | —                            |

## QUALITY ASSURANCE REPORT

Project Name: Spangler Forage Establishment Study

Element: Iron

### ACCURACY

- 1) Using EPA ICAP 19 as a blind field standard, we are — % confident that the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data are 120.8  $\pm$  — % of the reported value.
  - 2) Using EPA ICAP 19 as a blind field standard, we are — % confident that the DTPA extractable soil data are 120.8  $\pm$  — % of the reported value.
  - 3) Using EPA ICAP 19 as a blind field standard, we are — % confident that the water soluble (saturation extract) data are 120.8  $\pm$  — % of the reported value.
  - 4) Using NBS tomato leaves as a blind field standard, we are — % confident that the  $\text{HNO}_3$  digestable plant tissue data are 55.5  $\pm$  — % of the reported value.
- \* no statistical analysis performed due to lack of replication

### PRECISION

- 1) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data lie within  $\pm$  5.3 % of the reported value.
- 2) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the DTPA extractable soil data lie within  $\pm$  4.1 % of the reported value.
- 3) Using 3 blind field replicate data pairs, we are 90 % confident that 100 % of the water soluble (saturation extract) soil data lie within  $\pm$  47.5 % of the reported value.
- 4) Using 7 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3$  digestable plant tissue data lie within  $\pm$  15.9 % of the reported value.

### CONTAMINATION

Laboratory blanks were prepared to represent lab contamination introduced during the preparation or extraction of samples. Any values in excess of the instrument detection limit (IDL) indicates that significant contamination may occur in similar samples.

| Analysis Type                       | IDL (ug/l) | Number of Blanks | Number in Excess of IDL | Maximum Concentration (ug/l) |
|-------------------------------------|------------|------------------|-------------------------|------------------------------|
| $\text{HNO}_3/\text{H}_2\text{O}_2$ | .5         | 3                | 1                       | .514                         |
| DTPA                                | .5         | 3                | 1                       | .509                         |
| Saturation extract                  | .5         | 3                | 0                       |                              |
| $\text{HNO}_3$ Plant tissue         | .5         | 6                | 2                       | 1.5                          |

# QUALITY ASSURANCE REPORT

Project Name: Spangler Forage Establishment Study

Element: Lead

## ACCURACY

- 1) Using EPA ICAP 19 as a blind field standard, we are — % confident that the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data are 103.2  $\pm$  — % of the reported value.
  - 2) Using EPA ICAP 19 as a blind field standard, we are — % confident that the DTPA extractable soil data are 103.2  $\pm$  — % of the reported value.
  - 3) Using EPA ICAP 19 as a blind field standard, we are — % confident that the water soluble (saturation extract) data are 103.2  $\pm$  — % of the reported value.
  - 4) Using NBS tomato leaves as a blind field standard, we are — % confident that the  $\text{HNO}_3$  digestable plant tissue data are 92.8  $\pm$  — % of the reported value.
- \* no statistical analysis performed due to lack of replication

## PRECISION

- 1) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data lie within  $\pm$  9.77 % of the reported value.
- 2) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the DTPA extractable soil data lie within  $\pm$  6.10 % of the reported value.
- 3) Using — blind field replicate data pairs, we are 90 % confident that 100 % of the water soluble (saturation extract) soil data lie within  $\pm$  — % of the reported value.
- 4) Using — blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3$  digestable plant tissue data lie within  $\pm$  — % of the reported value.

## CONTAMINATION

Laboratory blanks were prepared to represent lab contamination introduced during the preparation or extraction of samples. Any values in excess of the instrument detection limit (IDL) indicates that significant contamination may occur in similar samples.

| Analysis Type      | IDL (ug/l) | Number of Blanks | Number in Excess of IDL | Maximum Concentration (ug/l) |
|--------------------|------------|------------------|-------------------------|------------------------------|
| HNO3/H2O2          | .2         | 3                | 0                       | —                            |
| DTPA               | .05        | 3                | 0                       | —                            |
| Saturation extract | .06        | 3                | 1                       | .061                         |
| HNO3 Plant tissue  | .06        | 6                | 0                       | —                            |

# QUALITY ASSURANCE REPORT

Project Name: Spangler Forage Establishment Study

Element: Magnesium

## ACCURACY

- 1) Using EPA ICAP 19 as a blind field standard, we are — % confident that the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data are 74.2  $\pm$  — % of the reported value.
  - 2) Using EPA ICAP 19 as a blind field standard, we are — % confident that the DTPA extractable soil data are 74.2  $\pm$  — % of the reported value.
  - 3) Using EPA ICAP 19 as a blind field standard, we are — % confident that the water soluble (saturation extract) data are 74.2  $\pm$  — % of the reported value.
  - 4) Using NBS tomato leaves as a blind field standard, we are — % confident that the  $\text{HNO}_3$  digestable plant tissue data are 88.6  $\pm$  — % of the reported value.
- \* no statistical analysis performed due to lack of replication

## PRECISION

- 1) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data lie within  $\pm$  5.7 % of the reported value.
- 2) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the DTPA extractable soil data lie within  $\pm$  3.9 % of the reported value.
- 3) Using 3 blind field replicate data pairs, we are 90 % confident that 100 % of the water soluble (saturation extract) soil data lie within  $\pm$  17.8 % of the reported value.
- 4) Using 7 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3$  digestable plant tissue data lie within  $\pm$  4.28 % of the reported value.

## CONTAMINATION

Laboratory blanks were prepared to represent lab contamination introduced during the preparation or extraction of samples. Any values in excess of the instrument detection limit (IDL) indicates that significant contamination may occur in similar samples.

| Analysis Type                       | IDL (ug/l) | Number of Blanks | Number in Excess of IDL | Maximum Concentration (ug/l) |
|-------------------------------------|------------|------------------|-------------------------|------------------------------|
| $\text{HNO}_3/\text{H}_2\text{O}_2$ | .10        | 3                | 2                       | 3.8                          |
| DTPA                                | .50        | 3                | 2                       | 1.876                        |
| Saturation extract                  | .50        | 3                | 1                       | .524                         |
| $\text{HNO}_3$ Plant tissue         | .50        | 6                | —                       | —                            |

# QUALITY ASSURANCE REPORT

Project Name: Spangler Forage Establishment Study

Element: Manganese

## ACCURACY

- 1) Using EPA ICAP 19 as a blind field standard, we are — % confident that the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data are 104  $\pm$  — % of the reported value.
  - 2) Using EPA ICAP 19 as a blind field standard, we are — % confident that the DTPA extractable soil data are 104  $\pm$  — % of the reported value.
  - 3) Using EPA ICAP 19 as a blind field standard, we are — % confident that the water soluble (saturation extract) data are 104  $\pm$  — % of the reported value.
  - 4) Using NBS tomato leaves as a blind field standard, we are — % confident that the  $\text{HNO}_3$  digestable plant tissue data are 79.6  $\pm$  — % of the reported value.
- \* no statistical analysis performed due to lack of replication

## PRECISION

- 1) Using 3 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data lie within  $\pm$  7.9 % of the reported value.
- 2) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the DTPA extractable soil data lie within  $\pm$  4.1 % of the reported value.
- 3) Using 3 blind field replicate data pairs, we are 90 % confident that 100 % of the water soluble (saturation extract) soil data lie within  $\pm$  15.1 % of the reported value.
- 4) Using 7 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3$  digestable plant tissue data lie within  $\pm$  6.8 % of the reported value.

## CONTAMINATION

Laboratory blanks were prepared to represent lab contamination introduced during the preparation or extraction of samples. Any values in excess of the instrument detection limit (IDL) indicates that significant contamination may occur in similar samples.

| Analysis Type                       | IDL (ug/l) | Number of Blanks | Number in Excess of IDL | Maximum Concentration (ug/l) |
|-------------------------------------|------------|------------------|-------------------------|------------------------------|
| $\text{HNO}_3/\text{H}_2\text{O}_2$ | .10        | 3                | 0                       | —                            |
| DTPA                                | .10        | 3                | 0                       | —                            |
| Saturation extract                  | .10        | 3                | 0                       | —                            |
| $\text{HNO}_3$ Plant tissue         | .10        | 6                | 0                       | —                            |

## QUALITY ASSURANCE REPORT

Project Name: Spangler Forage Establishment Study

Element: Potassium

### ACCURACY

- 1) Using EPA ICAP 19 as a blind field standard, we are — % confident that the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data are 101.8  $\pm$  — % of the reported value.
  - 2) Using EPA ICAP 19 as a blind field standard, we are — % confident that the DTPA extractable soil data are 101.8  $\pm$  — % of the reported value.
  - 3) Using EPA ICAP 19 as a blind field standard, we are — % confident that the water soluble (saturation extract) data are 101.8  $\pm$  — % of the reported value.
  - 4) Using NBS tomato leaves as a blind field standard, we are — % confident that the  $\text{HNO}_3$  digestable plant tissue data are 101.8  $\pm$  — % of the reported value.
- \* no statistical analysis performed due to lack of replication

### PRECISION

- 1) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data lie within  $\pm$  2.3 % of the reported value.
- 2) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the DTPA extractable soil data lie within  $\pm$  6.5 % of the reported value.
- 3) Using 3 blind field replicate data pairs, we are 90 % confident that 100 % of the water soluble (saturation extract) soil data lie within  $\pm$  6.2 % of the reported value.
- 4) Using 7 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3$  digestable plant tissue data lie within  $\pm$  4.2 % of the reported value.

### CONTAMINATION

Laboratory blanks were prepared to represent lab contamination introduced during the preparation or extraction of samples. Any values in excess of the instrument detection limit (IDL) indicates that significant contamination may occur in similar samples.

| Analysis Type                       | IDL (ug/l) | Number of Blanks | Number in Excess of IDL | Maximum Concentration (ug/l) |
|-------------------------------------|------------|------------------|-------------------------|------------------------------|
| $\text{HNO}_3/\text{H}_2\text{O}_2$ | .5         | 3                | 0                       | —                            |
| DTPA                                | .5         | 3                | 3                       | 2.02                         |
| Saturation extract                  | .5         | 3                | 2                       | 1.92                         |
| $\text{HNO}_3$ Plant tissue         | .5         | 6                | 2                       | 1.546                        |

## QUALITY ASSURANCE REPORT

Project Name: Spangler Forage Establishment Study

Element: Sulfur

### ACCURACY

- 1) Using EPA ICAP 19 as a blind field standard, we are — % confident that the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data are —  $\pm$  — % of the reported value.
- 2) Using EPA ICAP 19 as a blind field standard, we are — % confident that the DTPA extractable soil data are —  $\pm$  — % of the reported value.
- 3) Using EPA ICAP 19 as a blind field standard, we are — % confident that the water soluble (saturation extract) data are —  $\pm$  — % of the reported value.
- 4) Using NBS tomato leaves as a blind field standard, we are — % confident that the  $\text{HNO}_3$  digestable plant tissue data are —  $\pm$  — % of the reported value.

\* no statistical analysis performed due to lack of replication

S content not reported in ICAP 19 or NBS standards

### PRECISION

- 1) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data lie within  $\pm$  20.8 % of the reported value.
- 2) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the DTPA extractable soil data lie within  $\pm$  4.75 % of the reported value.
- 3) Using 3 blind field replicate data pairs, we are 90 % confident that 100 % of the water soluble (saturation extract) soil data lie within  $\pm$  12.6 % of the reported value.
- 4) Using 7 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3$  digestable plant tissue data lie within  $\pm$  3.96 % of the reported value.

### CONTAMINATION

Laboratory blanks were prepared to represent lab contamination introduced during the preparation or extraction of samples. Any values in excess of the instrument detection limit (IDL) indicates that significant contamination may occur in similar samples.

| Analysis Type                                   | IDL (ug/l) | Number of Blanks | Number in Excess of IDL | Maximum Concentration (ug/l) |
|-------------------------------------------------|------------|------------------|-------------------------|------------------------------|
| HNO <sub>3</sub> /H <sub>2</sub> O <sub>2</sub> | 0.5        | 3                | 0                       | —                            |
| DTPA                                            | 0.5        | 3                | 3                       | 3.12                         |
| Saturation extract                              | 0.5        | 3                | 2                       | 1.03                         |
| HNO <sub>3</sub> Plant tissue                   | 0.5        | 6                | 0                       | —                            |

## QUALITY ASSURANCE REPORT

Project Name: Spangler Forage Establishment Study

Element: Zinc

### ACCURACY

- 1) Using EPA ICAP 19 as a blind field standard, we are — % confident that the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data are 104.3  $\pm$  — % of the reported value.
  - 2) Using EPA ICAP 19 as a blind field standard, we are — % confident that the DTPA extractable soil data are 104.3  $\pm$  — % of the reported value.
  - 3) Using EPA ICAP 19 as a blind field standard, we are — % confident that the water soluble (saturation extract) data are 104.3  $\pm$  — % of the reported value.
  - 4) Using NBS tomato leaves as a blind field standard, we are — % confident that the  $\text{HNO}_3$  digestable plant tissue data are 85.4  $\pm$  — % of the reported value.
- \* no statistical analysis performed due to lack of replication

### PRECISION

- 1) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3/\text{H}_2\text{O}_2$  extractable soil data lie within  $\pm$  10.7 % of the reported value.
- 2) Using 4 blind field replicate data pairs, we are 90 % confident that 100 % of the DTPA extractable soil data lie within  $\pm$  8.14 % of the reported value.
- 3) Using 3 blind field replicate data pairs, we are 90 % confident that 100 % of the water soluble (saturation extract) soil data lie within  $\pm$  76.4 % of the reported value.
- 4) Using 7 blind field replicate data pairs, we are 90 % confident that 100 % of the  $\text{HNO}_3$  digestable plant tissue data lie within  $\pm$  3.81 % of the reported value.

### CONTAMINATION

Laboratory blanks were prepared to represent lab contamination introduced during the preparation or extraction of samples. Any values in excess of the instrument detection limit (IDL) indicates that significant contamination may occur in similar samples.

| Analysis Type                       | IDL (ug/l) | Number of Blanks | Number in Excess of IDL | Maximum Concentration (ug/l) |
|-------------------------------------|------------|------------------|-------------------------|------------------------------|
| $\text{HNO}_3/\text{H}_2\text{O}_2$ | .5         | 3                | 0                       | —                            |
| DTPA                                | .5         | 3                | 0                       | —                            |
| Saturation extract                  | .1         | 3                | 1                       | .266                         |
| $\text{HNO}_3$ Plant tissue         | .1         | 6                | 0                       | —                            |

## **APPENDIX H.2**

### **Reported Concentration of Reference Materials**

U.S. Environmental Protection Agency  
Environmental Monitoring and Support Laboratory - Cincinnati

WATER POLLUTION QUALITY CONTROL SAMPLES

ICAP Quality Control Sample

When the ampuls are diluted as per instructions, the solutions contain the following elements with concentrations expressed as mg/liter. The reference values, generated by NBS, were determined by ICAP plus at least one of the following corroborating methods; electrothermal atomization atomic absorption, laser enhanced ionization, flame atomic absorption, direct current plasma emissions, flame emission or activation analysis.

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ICAP-19

| <u>Parameter</u> | <u>Reference Value, mg/liter</u> |
|------------------|----------------------------------|
| Sb               | 0.99                             |
| As               | 1.00                             |
| Be               | 0.96                             |
| Cd               | 0.94                             |
| Ca               | 1.00                             |
| Cr               | 1.03                             |
| Cu               | 1.03                             |
| Co               | 1.00                             |
| Fe               | 1.02                             |
| Pb               | 1.01                             |
| Mg               | 1.00                             |
| Mo               | 1.06                             |
| Ni               | 1.02                             |
| Se               | 0.99                             |
| Tl               | 1.01                             |
| V                | 1.01                             |
| Zn               | 1.01                             |
| Ti               | 1.01                             |
| Mn               | 1.02                             |

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ICAP-7

| <u>Parameter</u> | <u>True Value, mg/liter</u> |
|------------------|-----------------------------|
| Ag               | 0.99                        |
| Si               | 0.05                        |
| B                | 0.99                        |
| Al               | 0.97                        |
| Ba               | 0.97                        |
| K                | 10.0                        |
| Na               | 0.86                        |

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WP1083

Table 1. Certified Values of Constituent Elements\*Major and Minor Constituents

| <u>Element</u> | <u>Content<br/>Wt. Percent</u> |
|----------------|--------------------------------|
| Potassium      | 4.46 $\pm$ 0.03                |
| Calcium        | 3.00 $\pm$ 0.03                |
| Phosphorus     | 0.34 $\pm$ 0.02                |

Trace Constituents

| <u>Element</u> | <u>Content<br/><math>\mu\text{g/g}</math></u> | <u>Element</u> | <u>Content<br/><math>\mu\text{g/g}</math></u> |
|----------------|-----------------------------------------------|----------------|-----------------------------------------------|
| Iron           | 690 $\pm$ 25                                  | Lead           | 6.3 $\pm$ 0.3                                 |
| Manganese      | 238 $\pm$ 7                                   | Chromium       | 4.5 $\pm$ 0.5                                 |
| Zinc           | 62 $\pm$ 6                                    | Arsenic        | 0.27 $\pm$ 0.05                               |
| Strontium      | 44.9 $\pm$ 0.3                                | Thorium        | 0.17 $\pm$ 0.03                               |
| Rubidium       | 16.5 $\pm$ 0.1                                | Uranium        | 0.061 $\pm$ 0.003                             |
| Copper         | 11 $\pm$ 1                                    |                |                                               |

\*Analytical values are based on the "dry-weight" of material (See Instructions for Drying).

The uncertainties of the values shown in Table 1 include allowances for inhomogeneity, method imprecision, and an estimate of possible biases of the analytical methods used.

Table 2. Non-certified Values for Constituent Elements\*

NOTE: The following values are not certified because they are not based on the results of either a reference method of known accuracy or two or more independent methods. These values are included for information only.

Major and Minor Constituents

| <u>Element</u> | <u>Content<br/>Wt. Percent</u> |
|----------------|--------------------------------|
| Nitrogen       | (5.0)                          |
| Magnesium      | (0.7)                          |
| Aluminum       | (0.12)                         |

Trace Constituents

| <u>Element</u>       | <u>Content<br/><math>\mu\text{g/g}</math></u> | <u>Element</u> | <u>Content<br/><math>\mu\text{g/g}</math></u> |
|----------------------|-----------------------------------------------|----------------|-----------------------------------------------|
| Boron                | (30)                                          | Cobalt         | (0.6)                                         |
| Bromine              | (26)                                          | Scandium       | (0.13)                                        |
| Cadmium <sup>b</sup> | (3)                                           | Mercury        | (0.1)                                         |
| Cerium               | (1.6)                                         | Thallium       | (0.05)                                        |
| Lanthanum            | (0.9)                                         | Europium       | (0.04)                                        |

\*Analytical values are based on the "dry weight" of material (See Instructions for Drying).

<sup>b</sup>Cadmium was not sufficiently homogeneous for certification.

### **APPENDIX H.3**

#### **Methods for Determining Accuracy and Precision**

### H.3 Procedures for calculating accuracy.

1. From the summarized information on the accuracy form the percent recovery of the blind field standard and the recovery of each lab spiked sample pair are calculated separately as:

$$\% \text{Recovery of BFS} = \frac{VA}{VK} \times 100; \text{ or } \% \text{Recovery of Spike} = \frac{SSR-SR}{SA} \times 100$$

where:

VA = analytical value of BFS  
VK = known (or certified) value of BFS  
SSR = spiked sample results  
SR = sample results  
SA = spike added

Perfect accuracy would be 100 percent recovery.

2. Calculate the standard deviation of all pairs.

$$SD = \left[ \frac{(\text{Recovery}_i - \text{Recovery}_{avg.})^2}{n-1} \right]^{1/2}$$

where  $\text{recovery}_i$  is the individual recoveries,  $\text{recovery}_{avg.}$  is the average recovery, and  $n$  is the number of values.

3. To validate recovery data, the individual recoveries are compared with the average recovery value to identify individual values that lie outside the range or reasonableness. Chauvenet's criterion is used to identify individual recovery values that lie outside this range.

To use Chauvenet's criterion, the screening variable was computed for recovery values that are suspected of lying outside the range of reasonableness.

$$\text{Screening Variable} = (\text{Recovery}_i - \text{Recovery}_{avg.}) / SD$$

The calculated screening variable is then compared to the maximum allowable value (Table B-1) for the appropriate number of recovery determinations. The suspect recovery value is set aside (set aside values are called "outliers") if the calculated screening variable equals or exceeds the maximum allowable value.

If outliers are identified using Chauvenet's criterion, a new average recovery and a new standard deviation are recalculated using the remaining "good" values, and Chauvenet's criterion is reapplied. This procedure is repeated until all surviving recovery values pass Chauvenet's criterion. (Usually one application and one recalculation are enough.) The final average recovery and final standard deviation are

calculated from the "surviving" recovery values. The final average recovery value is used to eliminate any bias from the laboratory data.

4. The range of uncertainty (R) in the recovery is then calculated.

$$\pm R = \pm tSD/(n)^{1/2}$$

where:

R is the range of uncertainty expressed as a percent

t is the value of the t distribution for the selected confidence level (90 percent) and (n-1) degrees of freedom (Table B-3)

n is the number of samples

SD is the standard deviation.

The range of uncertainty, is used in conjunction with the average recovery to determine if bias adjustments are required.

5. Together, the final average recovery value for BFS and lab spike and the corresponding range of uncertainties constitute the QA statements of accuracy for a particular sampling program.
6. The completeness of accuracy data is that percentage of the total number of samples that remained after outliers are identified and set aside with Chauvenet's criterion.

Table H.1 Chauvenet's Criterion.

CHAUVENET'S CRITERION  
FOR REJECTING A SUSPECTED VALUE<sup>a</sup>

| Number of Samples<br>n | Maximum Allowable Values for<br>(Recovery <sub>i</sub> - Recovery <sub>avg</sub> ) / <del>σ</del> SD |
|------------------------|------------------------------------------------------------------------------------------------------|
| 3                      | 1.901                                                                                                |
| 4                      | 1.983                                                                                                |
| 5                      | 2.015                                                                                                |
| 6                      | 2.111                                                                                                |
| 7                      | 2.164                                                                                                |
| 8                      | 2.195                                                                                                |
| 9                      | 2.214                                                                                                |
| 10                     | 2.228                                                                                                |
| 11                     | 2.279                                                                                                |
| 12                     | 2.318                                                                                                |
| 13                     | 2.348                                                                                                |
| 14                     | 2.373                                                                                                |
| 15                     | 2.393                                                                                                |
| 16                     | 2.409                                                                                                |
| 17                     | 2.424                                                                                                |
| 18                     | 2.435                                                                                                |
| 19                     | 2.445                                                                                                |
| 20                     | 2.454                                                                                                |
| 21                     | 2.462                                                                                                |
| 22                     | 2.469                                                                                                |
| 23                     | 2.475                                                                                                |
| 24                     | 2.480                                                                                                |
| 25                     | 2.485                                                                                                |
| 26                     | 2.502                                                                                                |
| 27                     | 2.517                                                                                                |
| 28                     | 2.530                                                                                                |
| 29                     | 2.543                                                                                                |
| 30                     | 2.555                                                                                                |
| 40                     | 2.634                                                                                                |

<sup>a</sup>Based on "t" distribution rather than the traditional "normal" distribution.

<sup>b</sup>Individual Recovery = Recovery<sub>i</sub>  
Average Recovery = Recovery<sub>avg</sub>

Table H.2 Critical values of  $Q^*$  ( $P=0.05$ )

| <u>Sample size</u> | <u>Critical value</u> |
|--------------------|-----------------------|
| 4                  | 0.831                 |
| 5                  | 0.717                 |
| 6                  | 0.621                 |
| 7                  | 0.570                 |
| 8                  | 0.524                 |
| 9                  | 0.492                 |
| 10                 | 0.464                 |

\*E.P. King. 1958. J. Am. Statisti. Assoc. Vol. 48, 531.

#### H.4 Procedures for calculating precision.

1. From the summarized information on the precision form the relative percent difference (RPD) of each replicate pair (blind field replicates and laboratory duplicates) are calculated separately as:

$$RPD = \frac{|S-D|}{(S+D)/2} \times 100$$

where:

RPD = Relative Percent Difference  
S = First sample value (original)  
D = Second sample value (duplicate)

Perfect precision would result in 0% RPD.

2. Any RPD value exceeding the control limit of +20% is evaluated as an outlier using the Dixon's Q method. This method compares the difference between the suspected outlier and the value nearest to it in size with the difference between the highest and lowest values. The ratio of these differences (without regard to sign) is the Dixon's Q.

$$Q = \frac{|\text{suspect RPD value} - \text{nearest RPD value}|}{|\text{largest RPD value} - \text{smallest RPD value}|}$$

The critical values of Q for  $P=0.05$  are given in Table B-2. If the calculated value of Q exceeds the critical value the suspect RPD value is rejected, and not used in the following precision QA statement calculations.

3. Calculate the relative standard deviation (RSD) of each duplicate pair (field duplicates and lab duplicates are treated separately).

$$RSD_{\text{each pair}} = SD/\text{Mean}$$

4. Calculate the RSD for all the pairs (field duplicates and lab duplicates are treated separately).

$$RSD_{\text{overall}} = \left[ \sum_{i=1}^n \frac{RSD_{\text{each}}^2}{n-1_{\text{pairs}}} \right]^{1/2}$$

- 5.. Calculate precision as a percent.

$$\text{Precision (\%)} = \frac{t_{n-1_{\text{pairs}}} \times \text{RSD}_{\text{Overall}}}{(n-1_{\text{pairs}})^{1/2}} \times 100$$

where: t is value from the 90% probability level (Table B-3).

6. Calculate the maximum uncertainty for any individual test result as:

$$x \pm xt_{\text{SD}_{\text{Overall}}/(n-1_{\text{pairs}})^{1/2}}$$

where: x is the reported test result  
t is the value of the t distribution at the 90% probability level.

7. The completeness of precision data is that percentage of the total number of RPD values that remained after outliers are identified and set aside with Dixon's Q ratio.

Table H.3

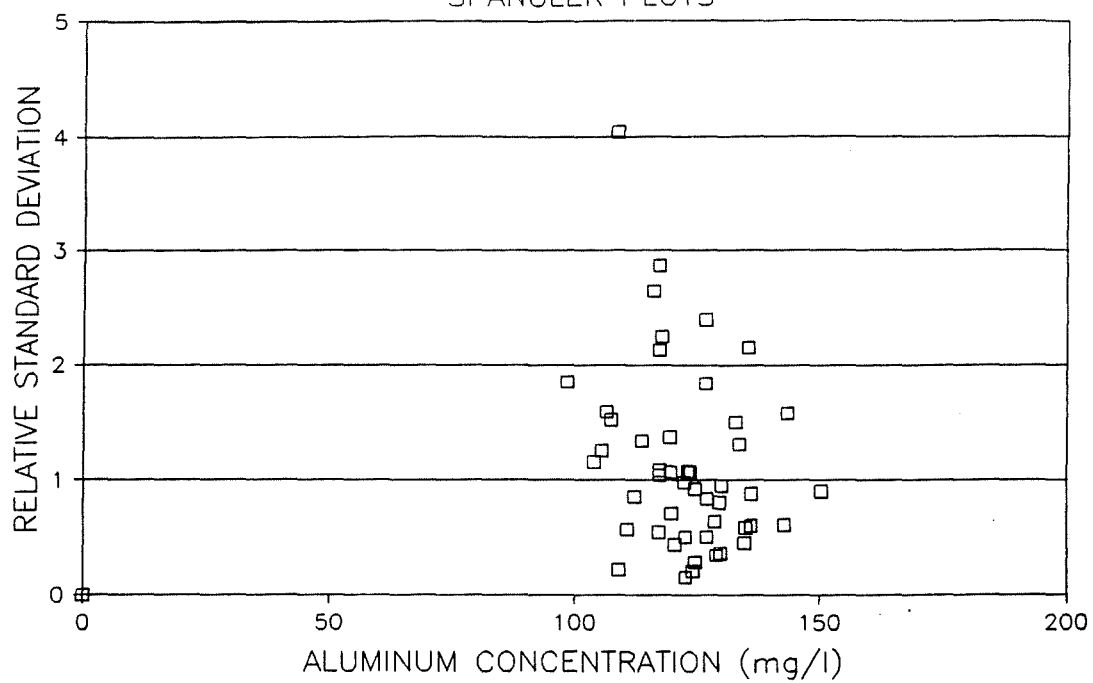
DISTRIBUTION OF  $t$ 

| Number<br>of<br>Sample | Degrees<br>of<br>Freedom | "Complementary" Probability (as percent) |       |       |       |        |        | 99     |
|------------------------|--------------------------|------------------------------------------|-------|-------|-------|--------|--------|--------|
|                        |                          | 50                                       | 70    | 80    | 90    | 95     | 98     |        |
| 2                      | 1                        | 1.000                                    | 1.963 | 3.078 | 6.314 | 12.706 | 31.821 | 63.657 |
| 3                      | 2                        | .816                                     | 1.386 | 1.886 | 2.920 | 4.303  | 6.965  | 9.925  |
| 4                      | 3                        | .765                                     | 1.250 | 1.638 | 2.353 | 3.182  | 4.541  | 5.841  |
| 5                      | 4                        | .741                                     | 1.190 | 1.533 | 2.132 | 2.776  | 3.747  | 4.604  |
| 6                      | 5                        | .727                                     | 1.156 | 1.476 | 2.015 | 2.571  | 3.365  | 4.032  |
| 7                      | 6                        | .718                                     | 1.134 | 1.440 | 1.943 | 2.447  | 3.143  | 3.707  |
| 8                      | 7                        | .711                                     | 1.119 | 1.415 | 1.895 | 2.265  | 2.998  | 3.499  |
| 9                      | 8                        | .706                                     | 1.108 | 1.397 | 1.860 | 2.306  | 2.896  | 3.355  |
| 10                     | 9                        | .703                                     | 1.100 | 1.383 | 1.833 | 2.262  | 2.821  | 3.250  |
| 11                     | 10                       | .700                                     | 1.093 | 1.372 | 1.812 | 2.228  | 2.764  | 3.169  |
| 12                     | 11                       | .697                                     | 1.088 | 1.363 | 1.796 | 2.201  | 2.718  | 3.106  |
| 13                     | 12                       | .695                                     | 1.083 | 1.356 | 1.782 | 2.179  | 2.681  | 3.055  |
| 14                     | 13                       | .694                                     | 1.079 | 1.350 | 1.771 | 2.160  | 2.650  | 3.012  |
| 15                     | 14                       | .692                                     | 1.076 | 1.345 | 1.761 | 2.145  | 2.624  | 2.977  |
| 16                     | 15                       | .691                                     | 1.074 | 1.341 | 1.753 | 2.131  | 2.602  | 2.947  |
| 17                     | 16                       | .690                                     | 1.071 | 1.337 | 1.746 | 2.120  | 2.583  | 2.921  |
| 18                     | 17                       | .689                                     | 1.069 | 1.333 | 1.740 | 2.110  | 2.567  | 2.898  |
| 19                     | 18                       | .688                                     | 1.067 | 1.330 | 1.734 | 2.101  | 2.552  | 2.878  |
| 20                     | 19                       | .688                                     | 1.066 | 1.328 | 1.729 | 2.093  | 2.539  | 2.861  |
| 21                     | 20                       | .687                                     | 1.064 | 1.325 | 1.725 | 2.086  | 2.528  | 2.845  |
| 22                     | 21                       | .686                                     | 1.063 | 1.323 | 1.721 | 2.080  | 2.518  | 2.831  |
| 23                     | 22                       | .686                                     | 1.061 | 1.321 | 1.717 | 2.074  | 2.508  | 2.819  |
| 24                     | 23                       | .685                                     | 1.060 | 1.319 | 1.714 | 2.069  | 2.500  | 2.807  |
| 25                     | 24                       | .685                                     | 1.059 | 1.318 | 1.711 | 2.064  | 2.492  | 2.797  |
| 26                     | 25                       | .684                                     | 1.058 | 1.316 | 1.708 | 2.060  | 2.485  | 2.787  |
| 27                     | 26                       | .684                                     | 1.058 | 1.315 | 1.706 | 2.056  | 2.479  | 2.779  |
| 28                     | 27                       | .684                                     | 1.057 | 1.314 | 1.703 | 2.052  | 2.473  | 2.771  |
| 29                     | 28                       | .683                                     | 1.056 | 1.313 | 1.701 | 2.048  | 2.467  | 2.763  |
| 30                     | 29                       | .683                                     | 1.055 | 1.311 | 1.699 | 2.045  | 2.462  | 2.756  |
| 31                     | 30                       | .683                                     | 1.055 | 1.310 | 1.697 | 2.042  | 2.457  | 2.750  |
| 41                     | 40                       | .681                                     | 1.050 | 1.303 | 1.684 | 2.021  | 2.432  | 2.704  |
| 61                     | 60                       | .679                                     | 1.046 | 1.296 | 1.671 | 2.000  | 2.390  | 2.660  |
| 121                    | 120                      | .677                                     | 1.041 | 1.289 | 1.658 | 1.980  | 2.358  | 2.617  |
|                        |                          | .674                                     | 1.036 | 1.282 | 1.645 | 1.960  | 2.326  | 2.576  |

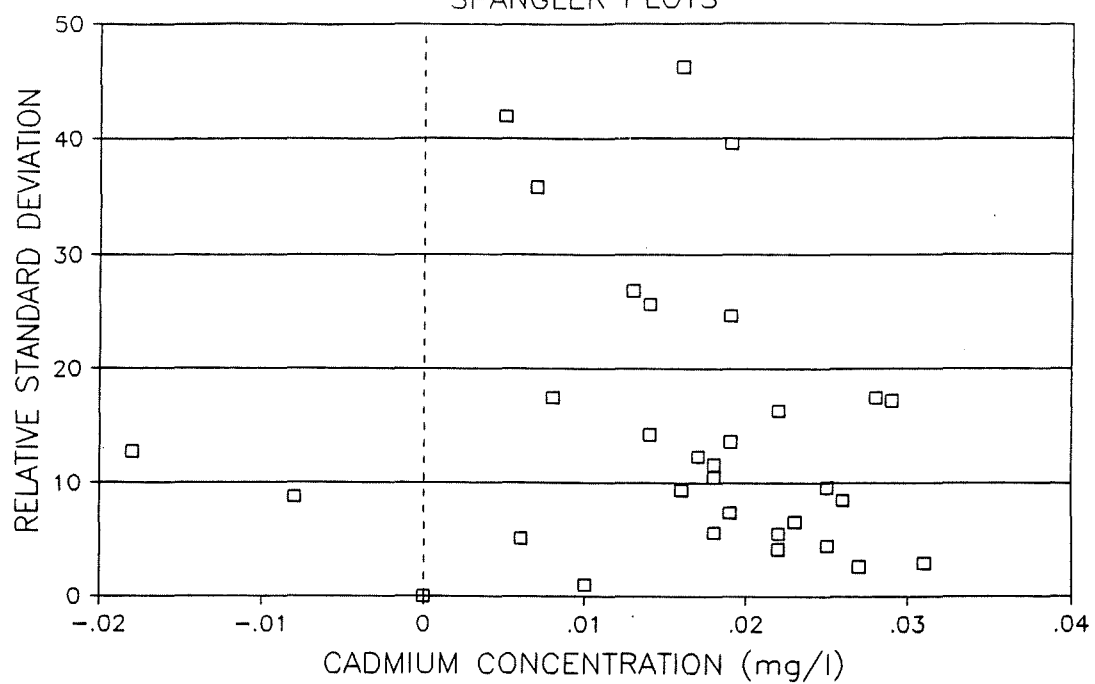
#### **APPENDIX H.4**

**Graphs Used to Determine  
Instrument Detection Limits  
for Various Elements**

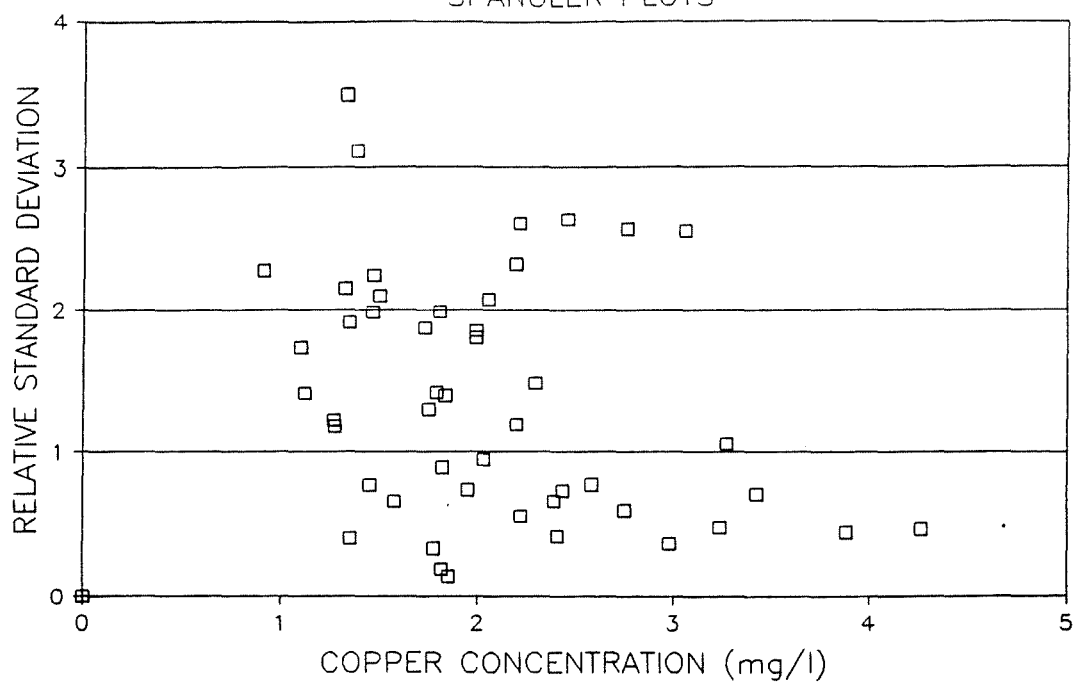
# TOTAL METALS IN SOIL SPANGLER PLOTS

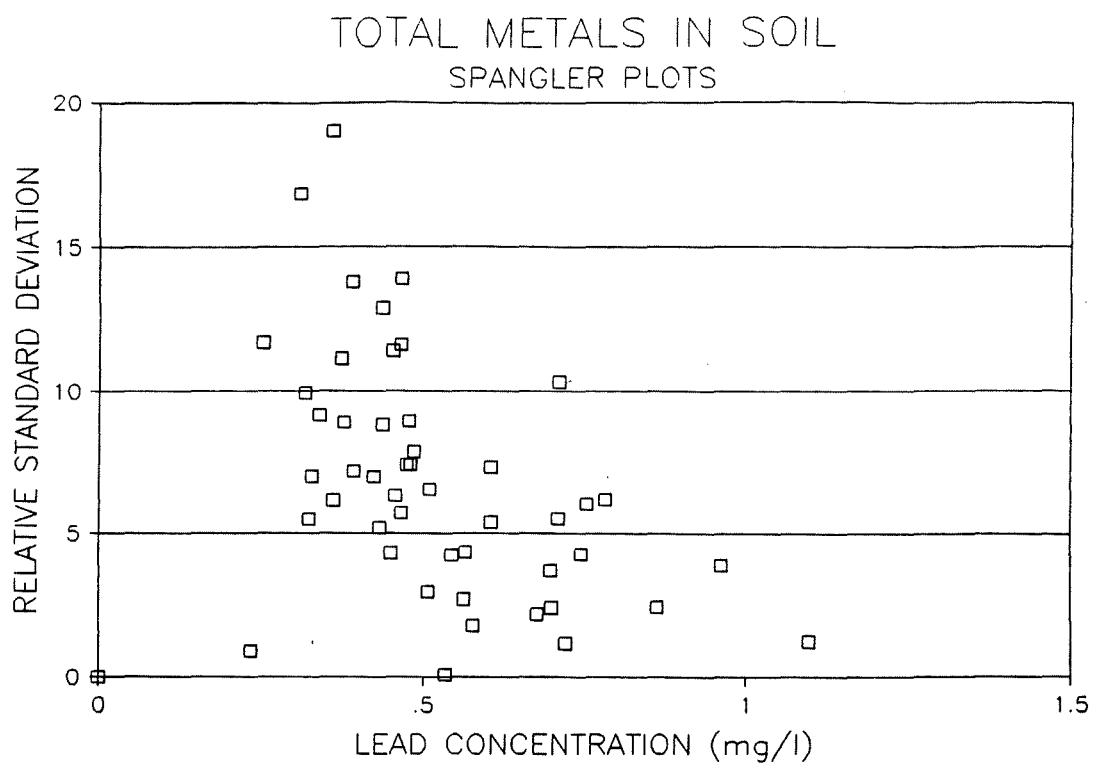


# TOTAL METALS IN SOIL SPANGLER PLOTS

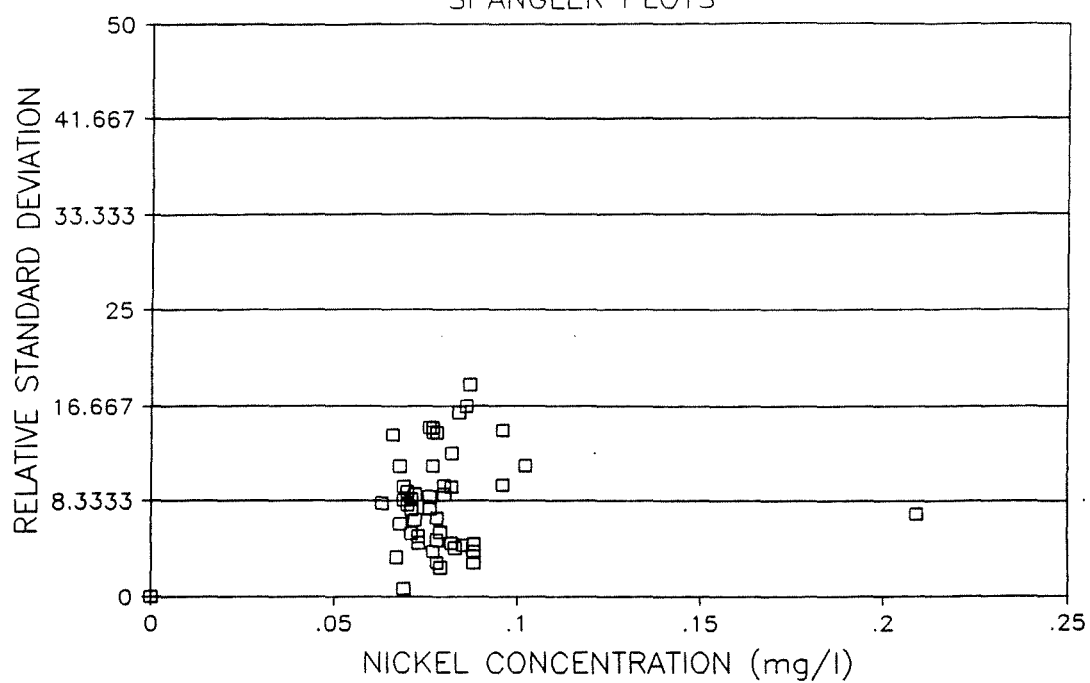


# TOTAL METALS IN SOIL SPANGLER PLOTS

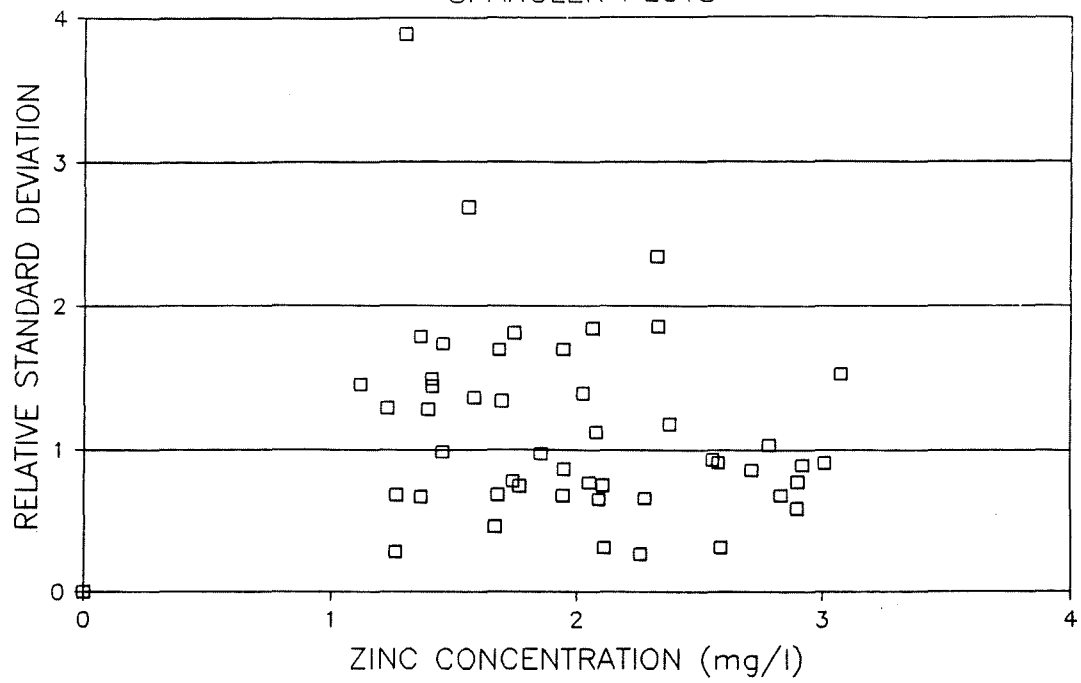




# TOTAL METALS IN SOIL SPANGLER PLOTS



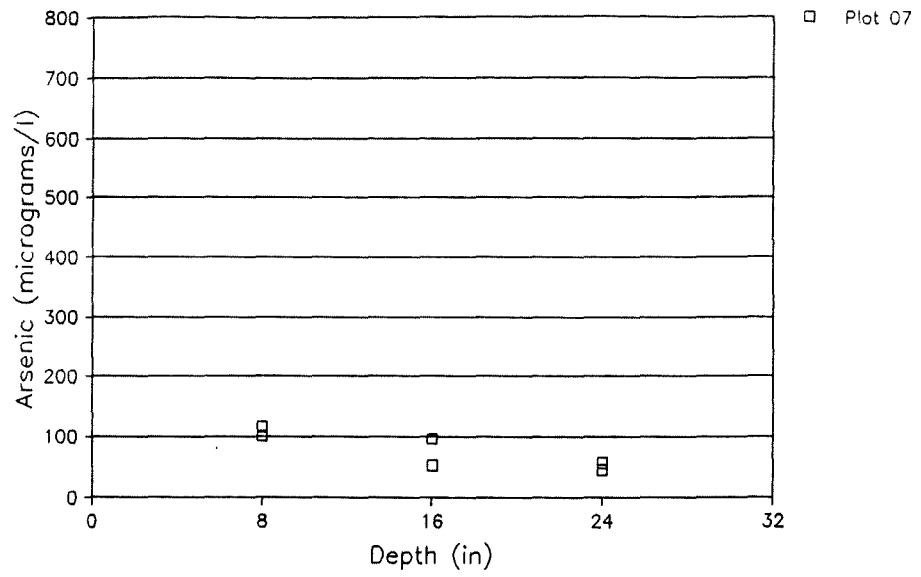
# TOTAL METALS IN SOIL SPANGLER PLOTS



## APPENDIX I

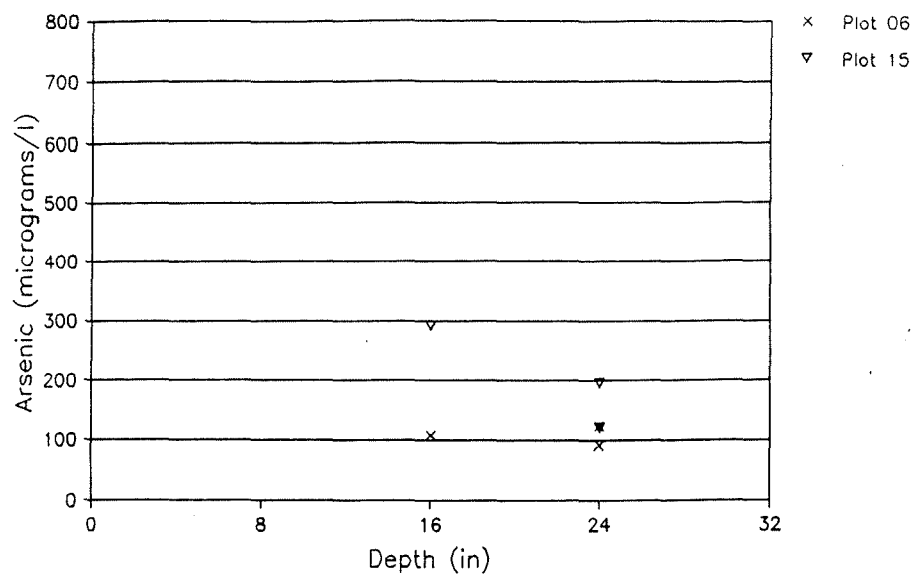
Lysimeter Data Results Obtained by the  
MBMG in 1987

# RIT FORAGE STUDY LYSIMETERS CONTROL PLOTS



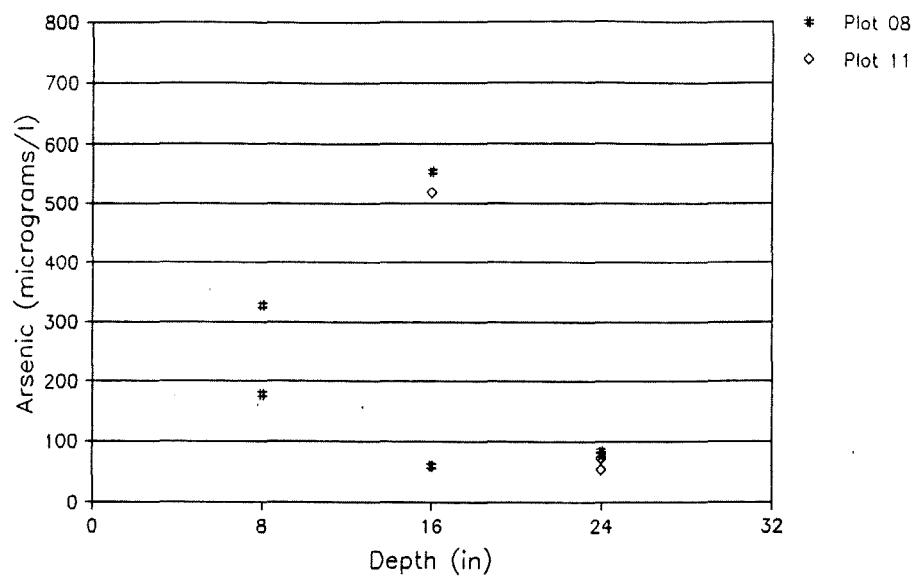
# RIT FORAGE STUDY LYSIMETERS

7 t/a LIME

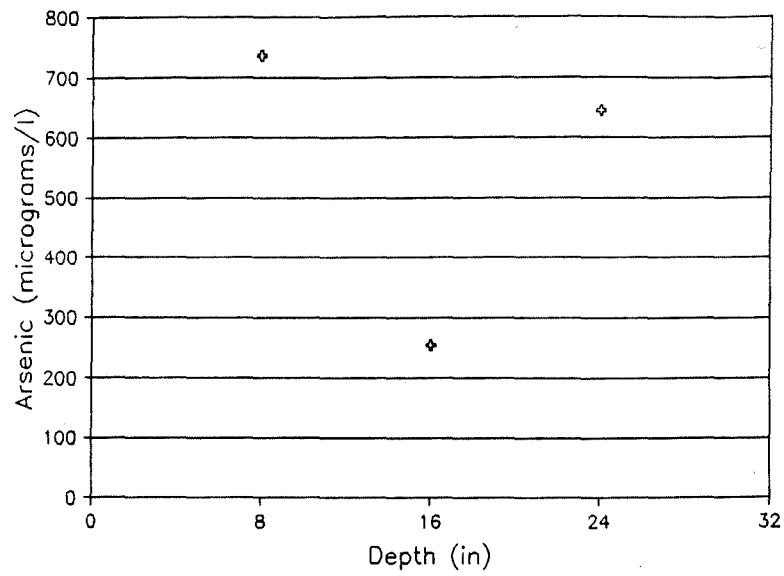


# RIT FORAGE STUDY LYSIMETERS

LIME + 750 lb/ac P205

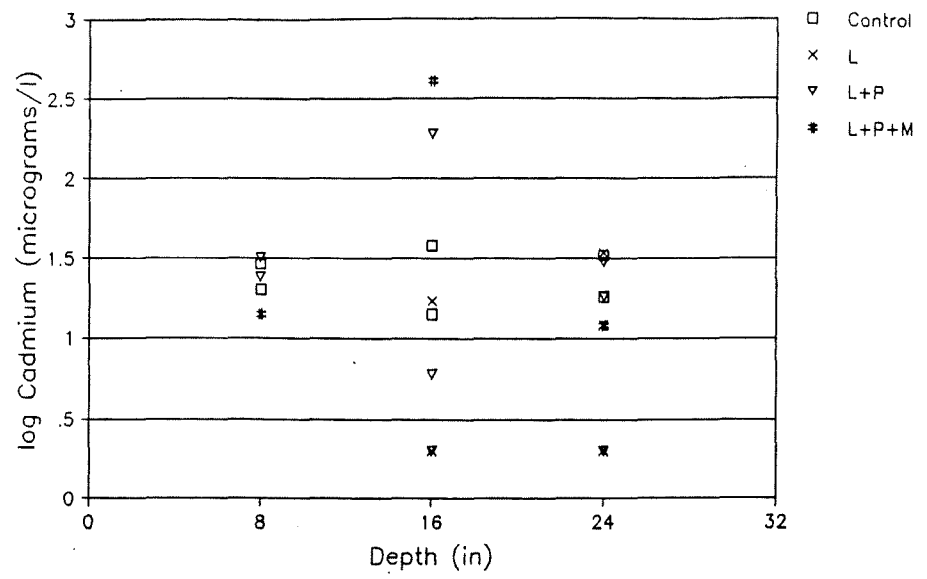


RIT FORAGE STUDY LYSIMETERS  
LIME + P + 24 t/a MANURE

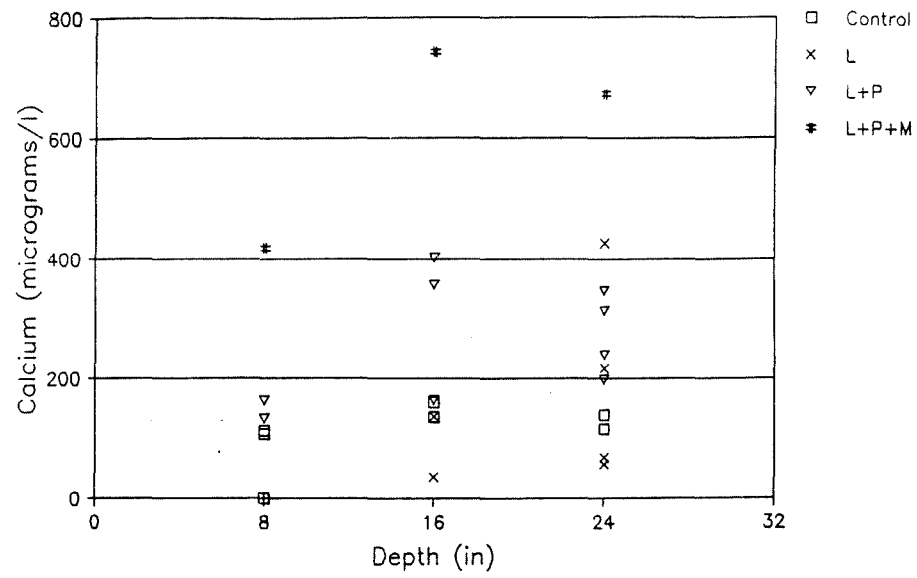


◆ Plot 05

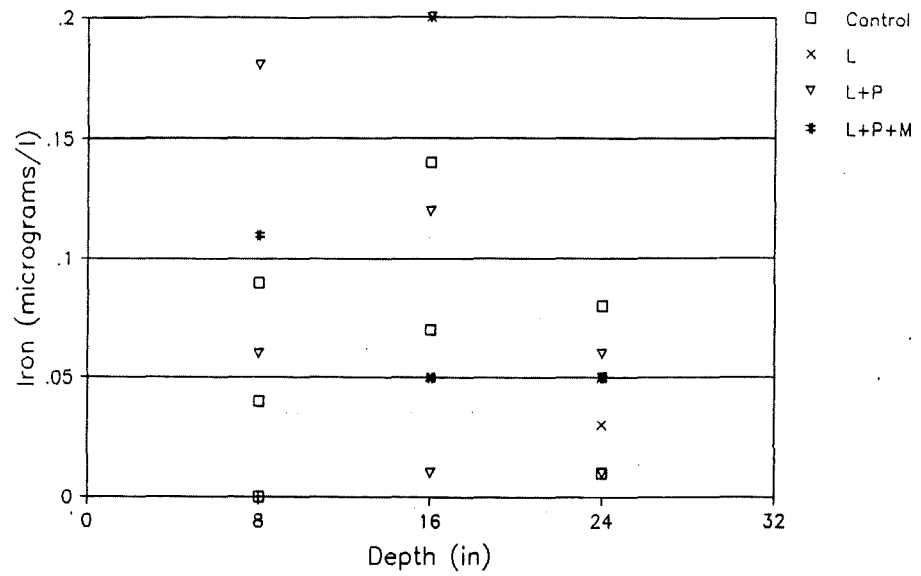
# RIT FORAGE STUDY LYSIMETERS



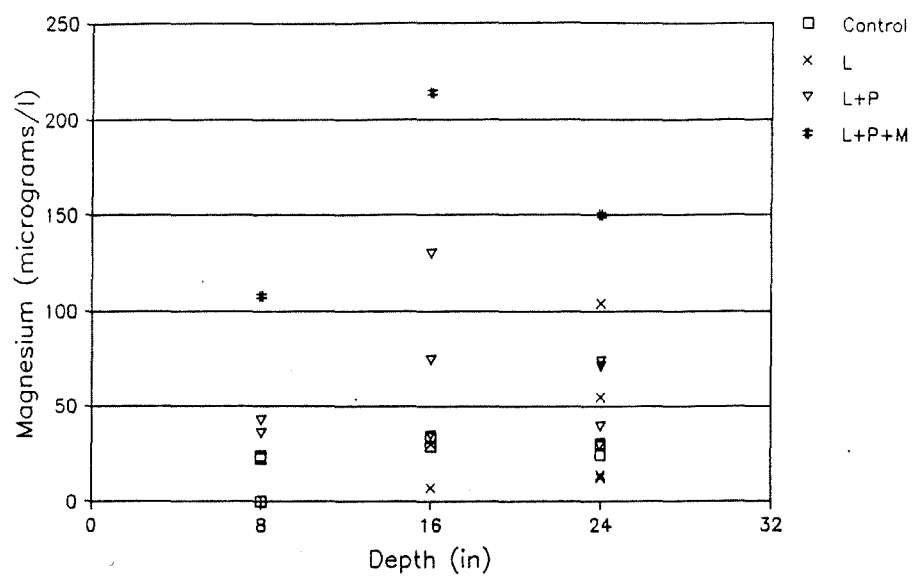
# RIT FORAGE STUDY LYSIMETERS CONTROL PLOTS



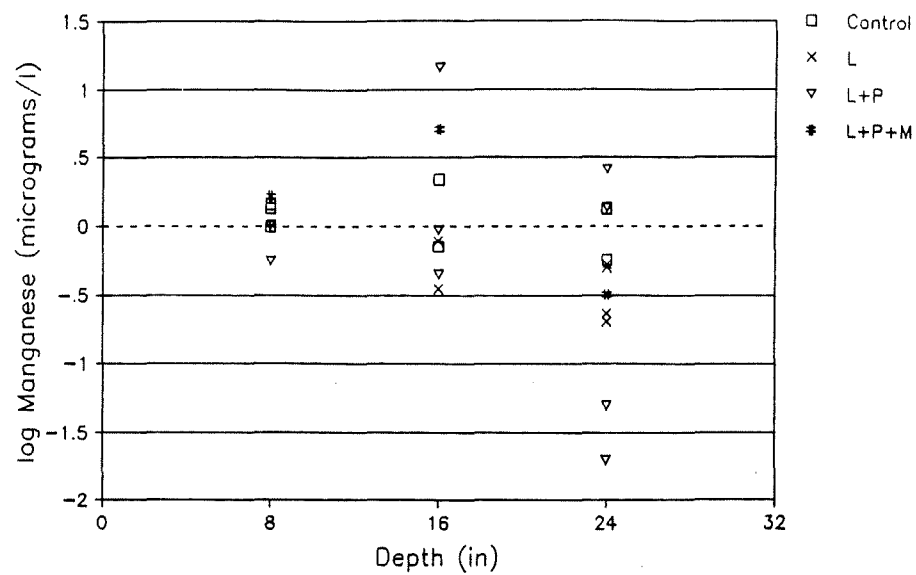
# RIT FORAGE STUDY LYSIMETERS CONTROL PLOTS



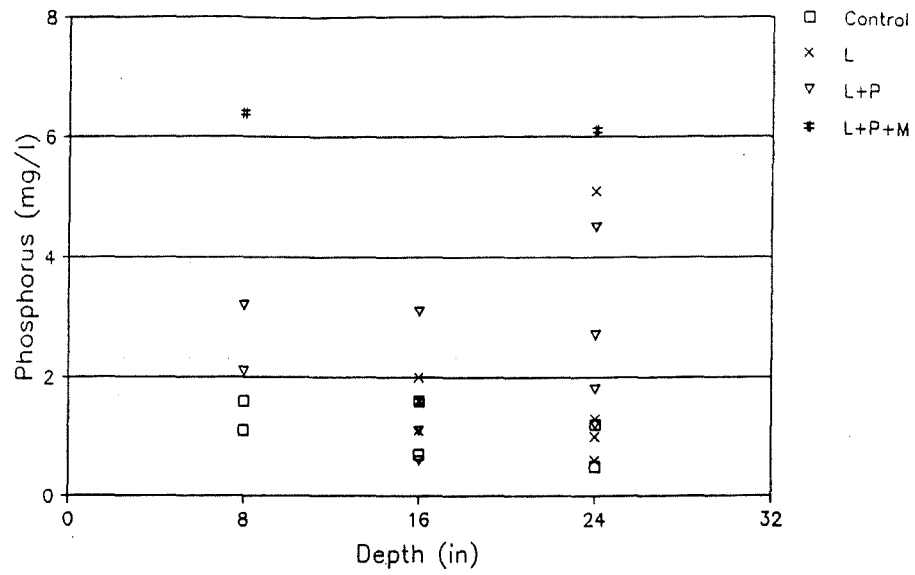
# RIT FORAGE STUDY LYSIMETERS CONTROL PLOTS



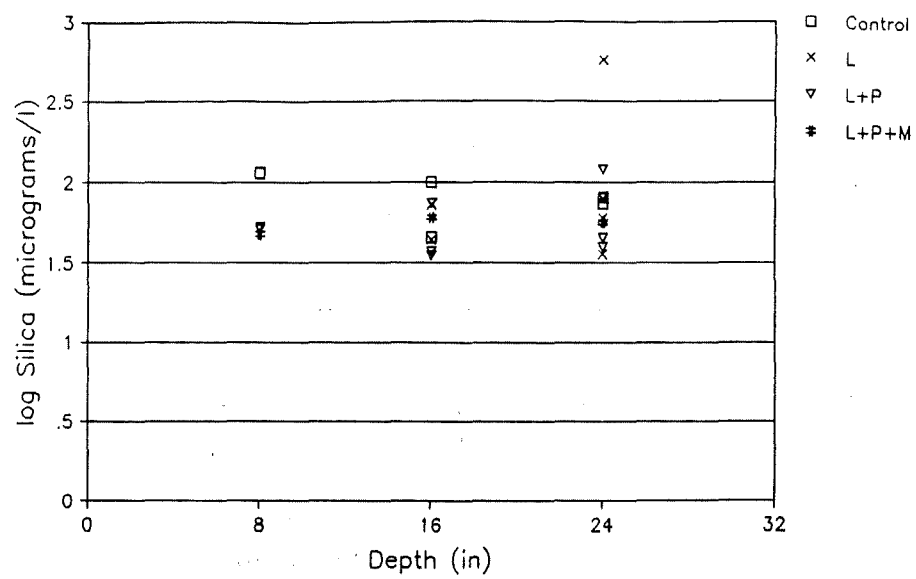
# RIT FORAGE STUDY LYSIMETERS CONTROL PLOTS



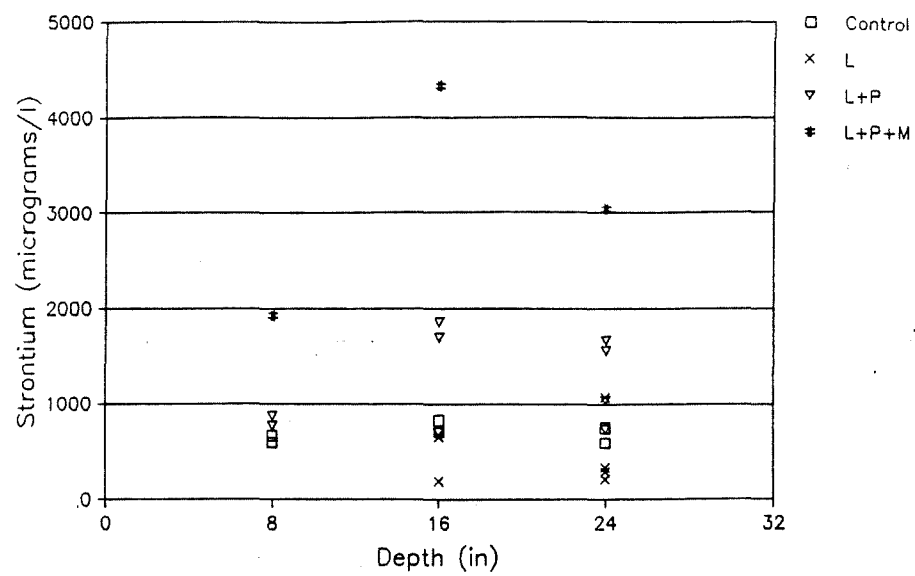
# RIT FORAGE STUDY LYSIMETERS



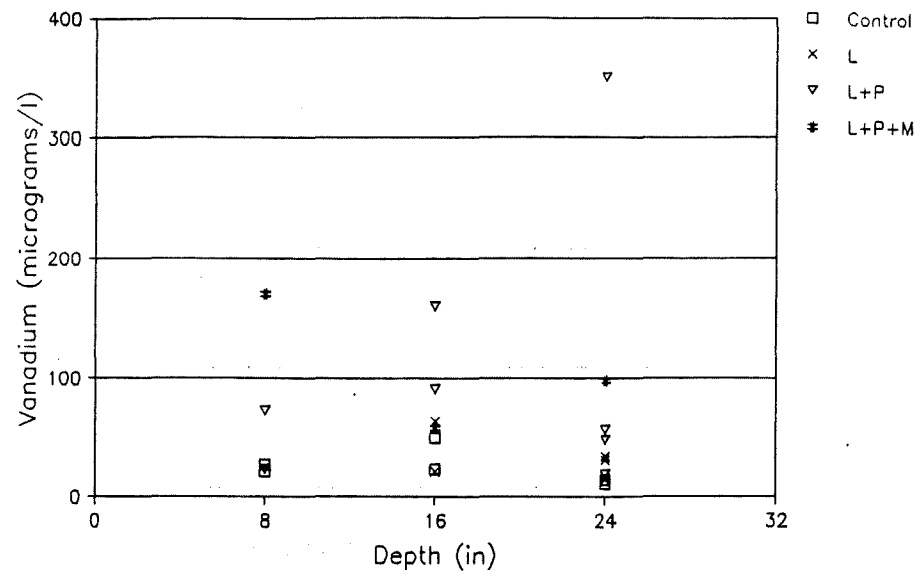
# RIT FORAGE STUDY LYSIMETERS



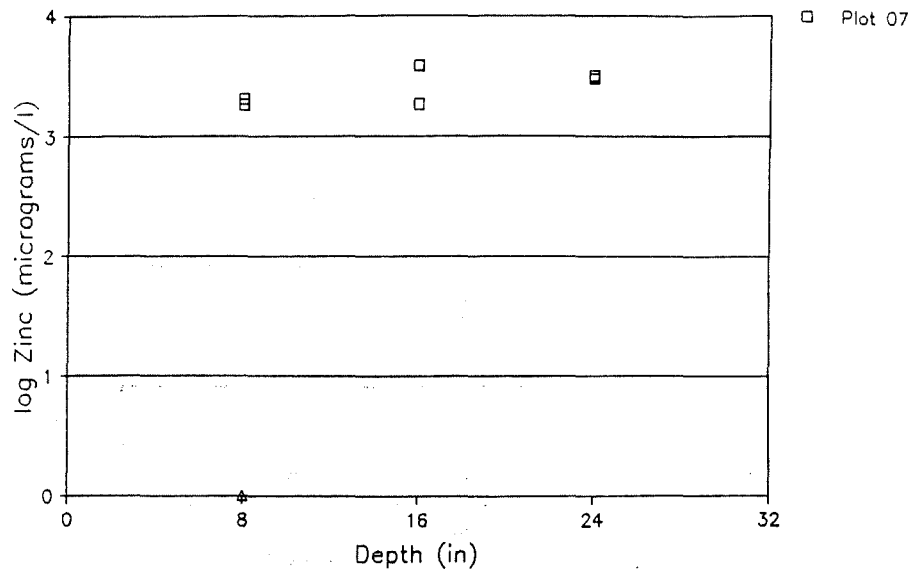
# RIT FORAGE STUDY LYSIMETERS



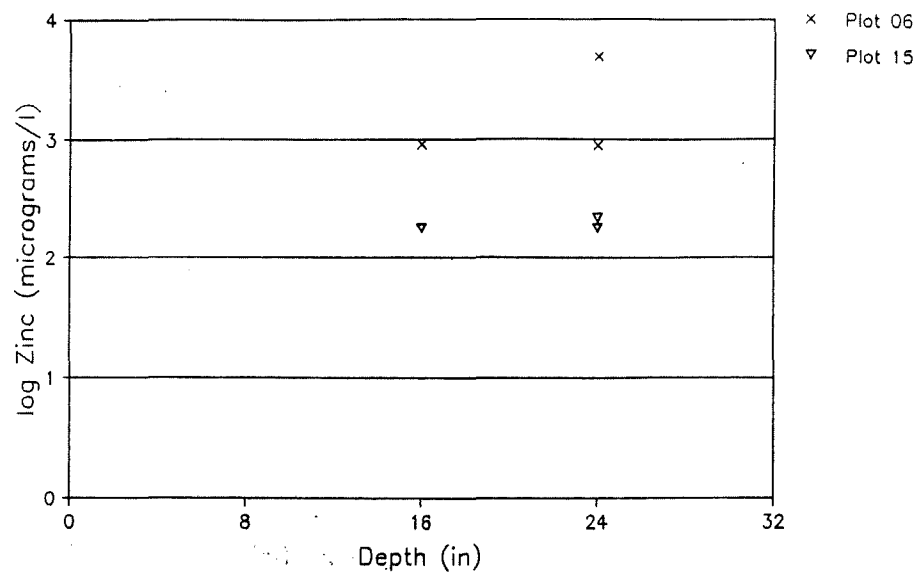
# RIT FORAGE STUDY LYSIMETERS



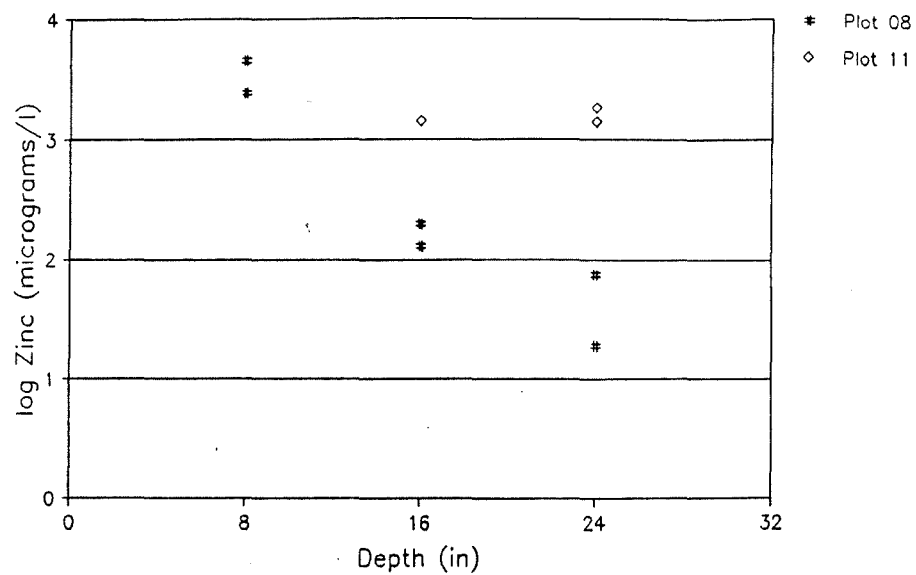
# RIT FORAGE STUDY LYSIMETERS CONTROL PLOTS



RIT FORAGE STUDY LYSIMETERS  
7 t/a LIME

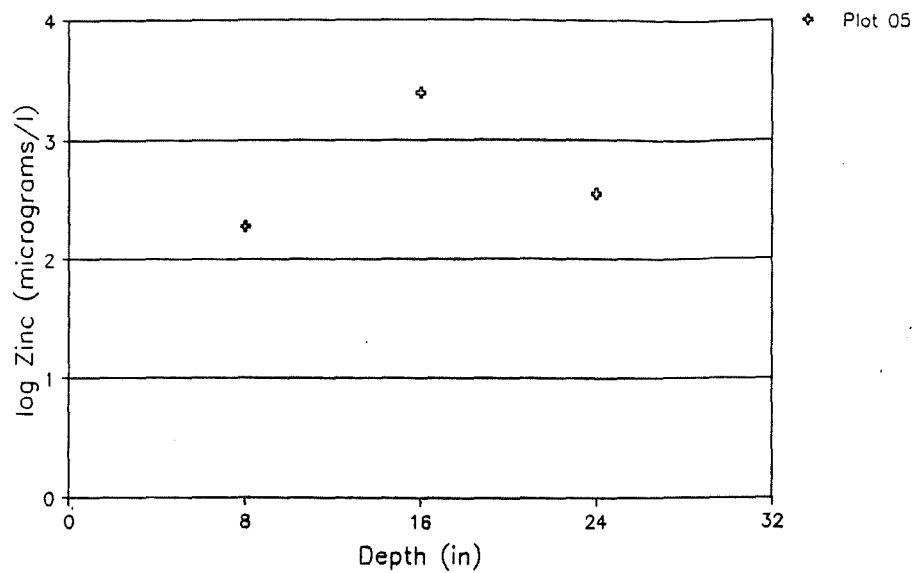


# RIT FORAGE STUDY LYSIMETERS LIME + 750 lb/ac P205



# RIT FORAGE STUDY LYSIMETERS

LIME + P + 24 t/a MANURE



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