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# REGIONAL COST ESTIMATES FOR RECLAMATION PRACTICES ON ARID AND SEMIARID LANDS

February 2002

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# ABSTRACT

The U.S. Army uses the Integrated Training Area Management program for managing training land. One of the major objectives of the Integrated Training Area Management program has been to develop a method for estimating training land carrying capacity in a sustainable manner. The Army Training and Testing Area Carrying Capacity methodology measures training load in terms of Maneuver Impact Miles. One Maneuver Impact Mile is the equivalent impact of an M1A2 tank traveling one mile while participating in an armor battalion field training exercise. The Army Training and Testing Area Carrying Capacity methodology is also designed to predict land maintenance costs in terms of dollars per Maneuver Impact Mile. The overall cost factor is calculated using the historical cost of land maintenance practices and the effectiveness of controlling erosion. Because land maintenance costs and effectiveness are influenced by the characteristics of the land, Army Training and Testing Area Carrying Capacity cost factors must be developed for each ecological region of the country. Costs for land maintenance activities are presented here for the semiarid and arid regions of the United States. Five ecoregions are recognized, and average values for reclamation activities are presented. Because there are many variables that can influence costs, ranges for reclamation activities are also presented. Costs are broken down into six major categories: seedbed preparation, fertilization, seeding, planting, mulching, and supplemental erosion control. Costs for most land reclamation practices and materials varied widely within and between ecological provinces. Although regional cost patterns were evident for some practices, the patterns were not consistent between practices. For the purpose of estimating land reclamation costs for the Army Training and Testing Area Carrying Capacity methodology, it may be desirable to use the "Combined Average" of all provinces found in the last row of each table to estimate costs for arid lands in general.

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# ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ATM .......................... ATTACC Training Model
ATTACC ................... Army Training and Testing Area Carrying Capacity
°C ............................. degrees Celsius
DoD .......................... U.S. Department of Defense
DOE .......................... U.S. Department of Energy
ES ............................. Erosion Status
°F .............................. degrees Fahrenheit
ft ............................... feet
gal. ............................ gallon
in. .............................. inches
*l* ................................ liters
lm .............................. linear meter
m .............................. meters
MIM ........................... Maneuver Impact Mile
$m^3$ ............................. cubic meters
mm ............................ millimeters
$ ............................... cost

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# REGIONAL COST ESTIMATES FOR RECLAMATION PRACTICES ON ARID AND SEMIARID LANDS

## 1.0 INTRODUCTION

The U.S. Army uses the Integrated Training Area Management program for managing training land. One of the major objectives of the Integrated Training Area Management program has been to develop a method for estimating training land carrying capacity and then to incorporate this concept into training land management decisions. Training land carrying capacity is generally defined as the amount of training that a given parcel of land can accommodate in a sustainable manner. The Army Training and Testing Area Carrying Capacity (ATTACC) methodology is used to estimate carrying capacity by relating training load, land condition, and land maintenance practices.

The ATTACC methodology measures training load in terms of Maneuver Impact Miles, or MIMs. One MIM is the equivalent impact of an M1A2 tank traveling one mile while participating in an armor battalion field training exercise. The impacts of all mission activities are converted to MIMs using data from the ATTACC Training Model (ATM) in combination with Training Impact Factors. The ATM includes prescribed tactical vehicle mileage by vehicle, unit, and event and is derived from the Battalion Level Training Model and Programs of Instruction. Training Impact Factors are multipliers that express the relative severity of impact of events and vehicles and are derived largely using subject matter experts and tactical vehicle characteristics. Using MIMs allows the impact of all mission activities to be aggregated and expressed as a single training load. MIM values for a given mission activity remain constant across the Army, regardless of location.

Land condition is measured by the ATTACC methodology in terms of the Erosion Status, which is the ratio of predicted erosion rates to tolerable erosion rates. Erosion Status values greater than 1.0 indicate that more soil is being lost than can be replaced naturally, and values less than 1.0 indicate that there is not a net soil loss. Erosion rates are estimated using the Revised Universal Soil Loss Equation, a scientifically accepted method utilizing percent vegetative cover, climate, soil type, topography, and conservation practices. The effects of training load and land maintenance practices on erosion rates are captured in the Revised Universal Soil Loss Equation by adjusting values of the percent vegetative cover, slope length and steepness, and conservation practice factor accordingly.

The ATTACC methodology is designed to predict land maintenance costs in terms of dollars per MIM. The overall cost factor is calculated using the historical cost of land maintenance practices and the effectiveness of the various practices in influencing elements of the Revised Universal Soil Loss Equation calculation. Because land maintenance costs and effectiveness are influenced by the characteristics of the land, ATTACC cost factors must be developed for each ecological region of the country.

The U.S. Department of Defense (DoD) Strategic Environmental Research and Development Program has funded a research project entitled “Diagnostic Tools and Reclamation Technologies for Mitigating Impacts of DoD/DOE Activities in Arid Areas.” As part of that project, an effort was made to quantify the costs of various land reclamation practices in the arid regions of the continental United States. This report summarizes those findings.

## 2.0 METHODOLOGY

### 2.1 Regions

For the purposes of this report, the arid and semiarid regions of the Western United States have been divided into ecosystem provinces based on similarities in climate, soils, and vegetation (http://www.fs.fed.us/land/ecosysmgmt/ecoreg1_home.html). These include the Intermountain Semidesert Province, Intermountain Desert Province, American Desert Province, Colorado Plateau Semidesert Province, and Chihuahuan Desert Province (Figure 1).

The **Intermountain Semidesert Province** consists of the Columbia and Snake River Plateaus and the Wyoming Basin. Average annual precipitation ranges from 130 mm (5 in.) in parts of the Wyoming Basin to 510 mm (20 in.) on the eastern part of the plateaus. Precipitation is fairly evenly distributed throughout the year except during the summer months when there is little rain. Average annual temperature ranges from 4–11°C (40–52°F). The primary vegetation type, sometimes called sagebrush steppe, is made up of sagebrush or shadscale mixed with short grasses. Occasional alkaline flats support alkali-tolerant greasewood. This province has extensive alluvial deposits in the floodplains of streams and in the fans at the foot of mountains.

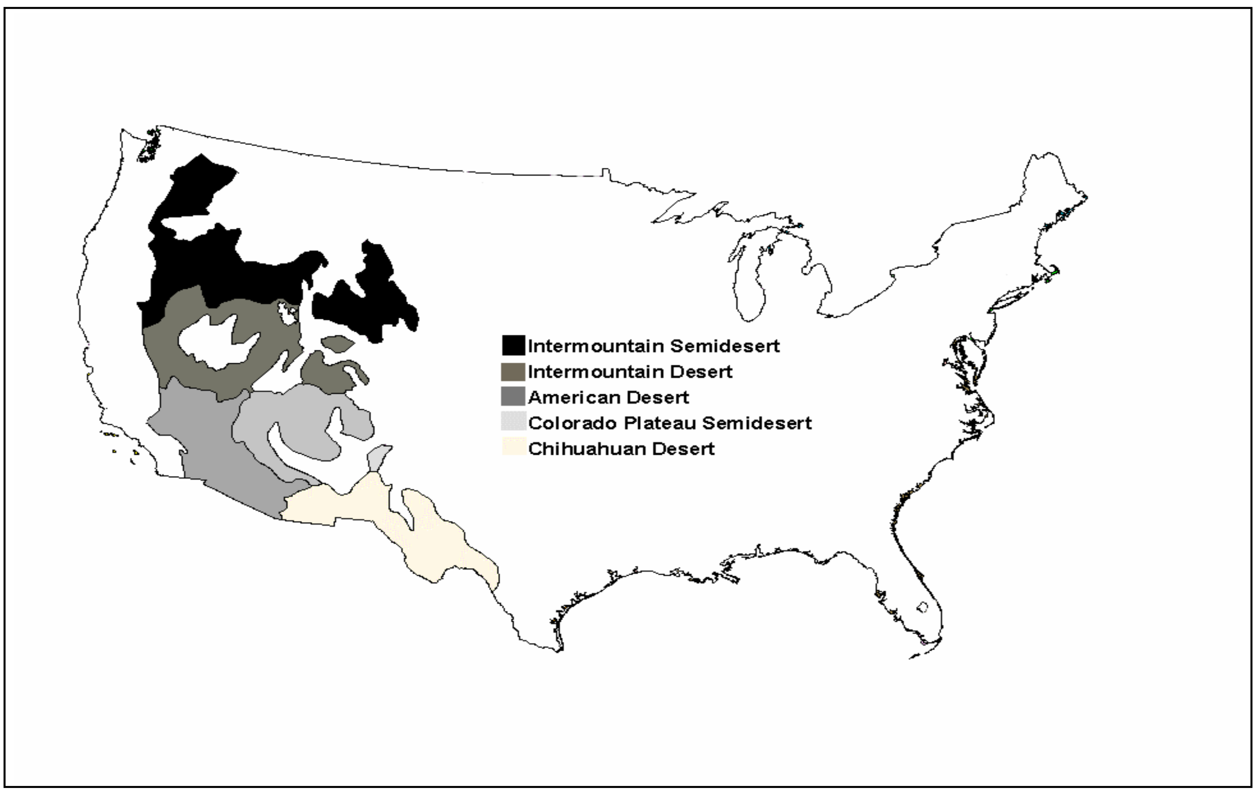


**Figure 1.** ***The arid and semiarid regions of the Western United States.***

Dry lakebeds are numerous, and there are extensive eolian deposits, including both dune sand and loess. Aridisols dominate all basin and lowland areas of the plateaus; Mollisols are found at higher elevations. Soils in the Wyoming Basin are alkaline Aridisols, often containing a layer enriched with lime and/or gypsum, which may develop into a caliche hardpan.

The **Intermountain Desert Province** covers the physiographic region called the Great Basin and the northern Colorado Plateau in Utah. Summers in this province are hot, and winters are only moderately cold. Annual precipitation averages only 130−490 mm (5−20 in.), often falling as winter snow. Almost no rain falls during the summer months except in the mountains. Average annual temperature ranges from 4−13°C (40−55°F). Much of this province is made up of basins with interior drainage; only a small part of the province drains to the sea. The lower parts of many basins have heavy accumulations of alkaline and saline salts. Streams are rare and few are permanent. Sagebrush dominates at lower elevations. Above the sagebrush belt lays a woodland zone dominated by pinyon pine and juniper. Aridisols dominate all basin and lowland areas. Salt flats and playas without soils are extensive in the lower parts of basins with interior drainage.

The **American Desert Province** includes the Mojave and Sonoran Deserts. Its topography is characterized by extensive plains, most gently undulating, from which isolated low mountains and buttes rise abruptly. Elevations range from 85 m (280 ft) below sea level to 1,200 m (4,000 ft) in valleys and basins, with some mountain ranges reaching as high as 3,400 m (11,000 ft). Summers are long and hot. The average annual temperature is 15−24°C (60−75°F). Though winters are moderate, the entire province is subject to occasional frosts. Winter rains are widespread and usually gentle, but in summer they are usually thunderstorms. In the Mojave Desert of southeastern California, there are virtually no summer rains. Average annual precipitation is 50–250 mm (2−10 in.) in the valleys but may reach 610 mm (25 in) on mountain slopes. Vegetation is usually very sparse with bare ground between individual plants. Cacti and thorny shrubs are conspicuous, but many thornless shrubs and herbs are also present. The most widely distributed plant is the creosote bush, which covers extensive areas in nearly pure stands. Cholla, mesquite, paloverde, ocotillo, saguaro, and bitterbrush are common in the Sonoran Desert; various saltbush species are common in the Mojave Desert. The Joshua tree is prominent along the northern edge of the province. Juniper and pinyon pine also occur in the north. Interior basins characterized by ephemeral shallow playa lakes are a conspicuous feature of the Mojave Desert. Entisols occur on the older alluvial fans and terraces and in the better-drained basins. Aridisols dominate throughout the rest of the province.

The **Colorado Plateau Semidesert Province** is characterized by deeply dissected plateaus in northern Arizona and New Mexico and in southeastern Utah. Elevations of the plateaus range from 1,500−2,100 m (5,000−7,000 ft), with local relief ranging from 150 to more than 900 m (500−3,000 ft) in some of the deeper canyons. Due to the region's generally high altitude, the climate is characterized by cold winters. Summer days are usually hot, but nights are cool. Annual average temperatures are 4−13°C (40−55°F). Average annual precipitation is about 510 mm (20 in.) although some parts of the province receive less than 260 mm (10 in.). Summer rains are thunderstorms with ordinary rains arriving in winter. Thus, this province differs from the Intermountain Semidesert Province, which generally lacks summer rains. Vegetation zones are conspicuous but lack uniformity. In the lowest zone, there are arid grasslands, but the shortgrass sod seldom covers the ground completely leaving many bare areas. Xeric shrubs often grow in open stands among the grasses, and sagebrush is dominant over extensive areas. A profusion of annuals and perennials blooms during the summer rainy season. At low elevations in the south, several kinds of cacti and yucca are common. The woodland zone is the most extensive, dominated by open stands of two-needle pinyon pine and several species of juniper, often termed a pygmy forest. The montane zone extends over considerable areas on the high plateaus and mountains, but it is much smaller in area than the pinyon-juniper zone. Entisols occur along the floodplains of major streams. Aridisols cover plateau tops, older terraces, and alluvial fans.

The **Chihuahuan Desert Province** is mostly desert. The area has undulating plains with elevations near 1,200 m (4,000 ft), where somewhat isolated mountains rise 600−1,500 m (2,000−5,000 ft). Extensive dunes of silica sand cover parts of the province. In scattered areas, small beds and isolated buttes of blackish lava occur. Summers are long and hot. Winters are short but may include brief periods when temperatures fall below freezing. Average annual temperatures range from 10−18°C (50−65°F). The climate is distinctly arid; spring and early summer are extremely dry. Localized summer rains may be torrential. Average annual precipitation is in the range of 200–260 mm (8–10 in.). The northern part of the province also receives winter rains, which are more gentle and widespread. A number of shrubs, most of them thorny, are typical of the Chihuahuan Desert. They frequently grow in open stands but sometimes form low, closed thickets. Extensive arid grasslands cover most of the high plains of the province. On deep soils, honey mesquite is often the dominant plant. Yucca and cacti are also abundant. Open stands of creosote bush cover large areas especially on gravel fans. In the western and northern portions of this province, the soils are primarily Aridisols. Both Aridisols and Entisols are present in the south.

## 2.2 Cost Estimating

Within each of the defined ecological provinces, various federal and state agencies and private companies were contacted by E-mail and telephone to obtain the required information. Agencies included state departments of transportation and state offices of the Natural Resources Conservation Service and the Bureau of Land Management. Some agencies provided published documentation; most populated a simple spreadsheet. Most agencies provided recent data; others provided historical databases. Only information since 1990 was considered relevant. For databases prior to 2000, an inflation rate of 3 percent per annum was assumed and costs were adjusted accordingly.

It was hoped that labor, equipment, and material costs could be obtained and reported separately. However, few institutions record data in that fashion. More often the values represent installed costs, which include labor, equipment, and materials. Hence, in many cases it was impractical to report labor, equipment, and material costs separately.

Costs were generally reported for average-sized jobs done by experienced contractors, operators, and vendors. Most jobs have built-in mobilization costs that do not vary regardless of job size. Hence, costs per hectare are often less for large jobs and considerably higher for small jobs.

The cost of land reclamation can vary widely based on site conditions. Difficult site conditions (e.g., wet soils, steep slopes, rocky terrain, remote locations, etc.) can greatly increase the cost of most activities. Hence, costs are reported here as ranges as well as averages. Costs will be on the higher end of the spectrum for sites with difficult conditions and on the lower end for ideal conditions.

Military installations represent unique logistical opportunities that may serve to reduce or increase reclamation costs depending on local circumstances. Material costs can be reduced if on-site materials are available (e.g., riprap). Labor and equipment costs may be reduced by using military engineering personnel and machinery when available. On the other hand, costs may be increased if heavy training schedules limit access to the areas to be reclaimed. Travel costs to the remote locations of many military installations may increase overall reclamation expenditures.

## 3.0 RESULTS

### 3.1 Seedbed Preparation

Some form of mechanical seedbed preparation is often needed prior to reseeding. This can be particularly true on Army training areas where repeated passage of armored vehicles has caused significant soil compaction. Ripping, subsoiling, or chiseling (here referred to collectively as ripping) are deep-tillage operations specifically designed to break or shatter compacted soil layers that can inhibit germination, root development, and moisture infiltration. Chiseling is generally less expensive than ripping or subsoiling due to shallower depths of implement operation and reduced power requirements. Disking can be used to ameliorate shallow compaction and vesicular horizons and to remove unwanted vegetation. Disking may be accomplished with an offset disk or a tandem disk. Offset disking is generally more expensive than tandem disking but does a better job of killing and mulching existing vegetation with a single pass of the implement. Harrowing is a much less intensive seedbed preparation method used to break up superficial compaction or physical crusts. It can also be used to smooth the soil surface following ripping or disking and is often used following broadcast seeding in order to help cover the seeds and ensure seed−soil contact necessary for germination. The regional costs for the various seedbed preparation practices are listed in Table 1.

Costs for all seedbed preparation treatments ranged widely within geographic regions (Table 1). Overall, it appears that costs in the American Desert province were highest. This province includes both the Sonoran and Mojave Deserts. The higher costs in this province are largely due to those reported for two military sites in the Mojave Desert. Costs for all three seedbed practices reported by the Natural Resources Conservation Service for a revegetation study conducted for the U.S. Navy on abandoned farmland in the Lahontan Valley, Nevada, were high. Ripping costs were 4−10 times higher at Fort Irwin, California, than for any location other than Lahontan Valley. Treatments at Lahontan Valley and Fort Irwin were experimental in nature. Because mobilization costs remain relatively constant regardless of the size of the treated acreage, the higher-per-acre costs are likely attributable to the small size of the treated areas and the remoteness of the locations. If these sites were eliminated from the data set, the

**Table 1. Regional average cost ($/hectare) for seedbed preparation activities.**

| Province | Estimate Type | Seedbed Preparation | | |
|---|---|---|---|---|
| | | Ripping | Disking | Harrowing |
| Intermountain Semidesert | Average | 54 | 42 | 37 |
| | Range | 15−183 | 15−136 | 17–92 |
| Intermountain Desert | Average | 67 | 49 | 44 |
| | Range | 15−161 | 15−124 | 12–111 |
| American Desert | Average | 213 | 106 | 126 |
| | Range | 15−741 | 15−383 | 15−366 |
| Colorado Plateau Semidesert | Average | 35 | 25 | 17 |
| | Range | 15−72 | 12−59 | 10−25 |
| Chihuahuan Desert | Average | 42 | 37 | – |
| | Range | 15−72 | 15−59 | – |
| **Combined Average** | | 124 | 64 | 57 |

average-per-acre costs are in line with the other desert ecosystem provinces. After the American Desert province, costs for all site preparation activities were highest in the Intermountain Desert, followed sequentially by the Intermountain Semidesert, Chihuahuan Desert, and Colorado Plateau Semidesert. No agency in the Chihuahuan Desert could provide cost estimates for harrowing.

### 3.2 Fertilization

Fertilization is not a common practice on rangelands in the arid West. Indeed, except where frequent and/or intense disturbance has resulted in the loss of organic matter and fine soil particles, fertilization can be counterproductive in desert ecosystems. Native perennial plants in deserts generally have low-nutrient requirements, while introduced annual plants generally have higher requirements. Hence, the addition of fertilizer may favor exotic weeds at the expense of native plants.

The number of responses from the various agencies was quite low for all provinces. Because fertilization is so rarely used, no agency in the Colorado Plateau Semidesert province was able to provide information on material costs, although they were able to estimate labor and equipment costs. Labor and equipment costs were generally low in all desert ecosystem provinces but somewhat higher in the Intermountain and American Desert provinces (Table 2). Overall, material costs were higher and more variable than labor and equipment costs. Variability in material costs is based on the type and amount of fertilizer required. These factors are, in turn, determined by existing nutrient status, soil type, organic matter content, clay mineralogy, salinity, alkalinity, site history, etc. Overall, it appears the cost of fertilization is highest in the Chihuahuan Desert followed by the American and Intermountain deserts. Costs were lowest in the Intermountain Semidesert province.

The costs included in Table 2 are for broadcast fertilization only, as this is the most common method of application for reseeding projects. When planting tublings or containerized plants, fertilizer pellets are occasionally used. Only one agency reported information on fertilizer pellets. They estimated the cost for using fertilizer pellets to be $1 per plant for materials and $0.50–2 per plant for labor. These costs should not change significantly based on region.

**Table 2. Regional average cost ($/hectare) for broadcast fertilization.**

| Province | Estimate Type | Broadcast Fertilization | |
|---|---|---|---|
| | | Labor and Equipment | Materials |
| Intermountain Semidesert | Average | 10 | 106 |
| | Range | 5–22 | 49–185 |
| Intermountain Desert | Average | 35 | 217 |
| | Range | 10–111 | 62–371 |
| American Desert | Average | 30 | 217 |
| | Range | 17–111 | 62–371 |
| Colorado Plateau Semidesert | Average | 12 | – |
| | Range | 7–22 | – |
| Chihuahuan Desert | Average | 17 | 304 |
| | Range | 10–22 | 124–482 |
| | Combined Average | 35 | 151 |

### 3.3 Seeding

On large tracts of nonagronomic land, broadcast or drill seeding most often accomplishes reestablishment of vegetative ground cover. Broadcast seeding is a process of spreading seed onto the soil surface. Prior seedbed preparation is not always required or even desirable. Broadcasting is often the least expensive seeding alternative in terms of labor costs. This is due primarily to the fact that more ground surface can be seeded with a single pass of the seeding equipment than with drill seeding. However, because the seed is left on the soil surface, seed−soil contact may not be adequate for good germination success. Hence, it may be necessary to seed at a higher rate or to drag a second implement over the site following seeding to help cover the seed with a thin layer of soil. Drill seeding is a process of placing seeds directly in the ground. Depending on the condition of the soil surface and the nature of the seed drill, some form of seedbed preparation may be necessary. Seed distribution is generally improved by drilling. Many seed drills can be adapted to place seeds at variable depths depending on their germination requirements. Seed drills are also often equipped with press wheels or dragged chains to help cover the seeds with soil and improve seed−soil contact. Where rough or steep terrain limits the access of drilling implements, broadcasting or hydroseeding may be required. Hydroseeding is a process of spraying seed on the soil in a liquid slurry. It is much more expensive than drill seeding or broadcasting due to the cost of equipment and the cost of transporting large quantities of water.

Across all ecological provinces, broadcast seeding had the lowest labor and equipment costs (Table 3). The average cost of drill seeding was almost double the cost of broadcasting. However, these estimates do not include the potential cost of using an additional implement to cover the seed in the case of broadcast seeding or the possible added cost of seedbed preparation in the case of drill seeding. The highest average costs for broadcast and drill seeding were reported from the American Desert Province. As in the case of seedbed preparation practices, the higher-per-acre costs here were attributable to the mobilization costs for treating small acreages and the remoteness of the sites treated. Average per-acre hydroseeding costs were uniformly high and exceeded broadcasting and drilling by an order of magnitude. There are fewer contractors equipped to do hydroseeding, and many hydroseeding contractors travel throughout the West.

**Table 3. Regional average cost ($/hectare) for seeding practices.**

| Province | Estimate Type | Labor and Equipment Cost | | Seed Cost | Hydroseeding (includes labor, equipment, seed, fertilizer, mulch, and tackifier) |
|---|---|---|---|---|---|
| | | Broadcast | Drill | | |
| Intermountain Semidesert | Average | 20 | 32 | 200 | 5,444 |
| | Range | 7–37 | 10–138 | 47–618 | 3,529–14,085 |
| Intermountain Desert | Average | 35 | 59 | 531 | 5,103 |
| | Range | 10–99 | 15–161 | 148–988 | 3,529–14,085 |
| American Desert | Average | 111 | 138 | 425 | 5,103 |
| | Range | 49–148 | 25–297 | 148–988 | 3,529–11,752 |
| Colorado Plateau Semidesert | Average | 15 | 35 | 628 | 5,182 |
| | Range | 10–20 | 12–138 | 148–1142 | 3,529–14,085 |
| Chihuahuan Desert | Average | 17 | 40 | 524 | 4072 |
| | Range | 10–20 | 15–138 | 148–618 | 1,853–14,085 |
| **Combined Average** | | 36 | 49 | 353 | 5,320 |

The rate of seeding, and hence the cost of seed, was assumed to be constant regardless of the equipment used. Executive Order 13112 issued February 3, 1999, requires federal agencies to prevent the introduction of invasive species and work toward the restoration of native species. Hence, seed costs were estimated based on using only mixtures of native species despite the fact that such a strategy may increase the cost of reseeding by as much as an order of magnitude in some cases. Seed costs were lowest in the Intermountain Semidesert province. This was apparently due to the fact that agencies in that province tend to use mixtures of grasses and shrubs, while agencies in other provinces tend to add more wildflowers to their seed mixtures. Grass seed is generally less expensive overall, and shrubs are generally seeded at low rates. Seed costs tended to be marginally highest in the Colorado Plateau Semidesert, although the reason for the trend was not apparent. Seed costs can vary widely within and between years based on supply and demand; low supplies and/or high demand can greatly increase the cost of seed.

### 3.4 Planting

Where land rehabilitation prescriptions call for trees and shrubs, it is often more cost effective to utilize live plants rather than seeds. This is due to the higher cost and lower availability of tree and shrub seeds, as well as generally low-germination and -seedling survival rates. The choice of woody plants for desert regions is limited. When available, they are most often supplied as tublings or containerized plants. Bare rootstock is used by some agencies but is comparatively rare in dry regions due to the higher risk of desiccation of the tender roots during and after the planting process. Relatively few agencies per region were able to provide cost estimates for the use of live plants. Estimates were limited to commonly available native species (estimates for unusual species can run as high as $200 per plant). Costs are reported in Table 4.

The cost of tublings was markedly less than containerized plants in all ecological provinces. Planting tubes are smaller and cost less than most other containers. Because of their small size, space requirements for growing and transporting are minimized. For containerized plants, the reported costs reflect 3.8 *l* (1 gal.) containers. The use of larger container sizes tends to increase expenses dramatically due to the higher cost of transportation and the fact that the plants in larger containers tend to be older

**Table 4. Regional average cost ($/plant) for live plants.**

| Province | Estimate Type | Tublings | | | Containerized Plants (3.8 *l*) | | |
|---|---|---|---|---|---|---|---|
| | | Labor | Material | Labor and Material | Labor | Material | Labor and Material |
| Intermountain Semidesert | Average | 2 | 1 | 3 | 9 | 15 | 11 |
| | Range | 1–3 | – | 2–4 | 6–14 | 3–30 | 3–36 |
| Intermountain Desert | Average | 2 | 2 | 11 | 10 | 14 | 17 |
| | Range | 1–3 | 1–3 | 4–24 | 7–25 | 5–29 | 6–36 |
| American Desert | Average | 2 | 2 | 4 | 10 | 8 | 10 |
| | Range | 1–3 | 1–3 | 2–6 | 2–18 | 2–11 | 2–36 |
| Colorado Plateau Semidesert | Average | 2 | 2 | 4 | 11 | 18 | 18 |
| | Range | 1–3 | 1–3 | 2–6 | 7–14 | 14–21 | 7–36 |
| Chihuahuan Desert | Average | – | – | – | 9 | 15 | 13 |
| | Range | – | – | – | 6–14 | 2–2 | 3–36 |
| **Combined Average** | | 2 | 2 | 9 | 11 | 12 | 13 |

and have required more effort to grow. Labor costs are estimated for hand planting in normal soils; where soils are hard or rocky, labor costs can be expected to increase. Some agencies procure labor and materials through separate contracts. This has a tendency to increase the overall cost when compared to contracts that procure labor and materials jointly (Table 4). This is especially true for large contractors who grow their own plants or who can take advantage of volume discounts by securing plant materials for multiple contracts simultaneously.

In some areas it is desirable to use translucent tubes to protect young seedlings from sunscald and herbivores while providing a greenhouse-like microenvironment. Such tubes for containerized plants or tublings cost an average of $2 (range $1–3) each when purchased in bulk, regardless of region. Installation of the tubes costs an average of $2 per plant (range $1–2). Although inoculation of woody plant roots with mycorrhizal fungi can significantly enhance survival and growth of many woody species, it is not widely used. Only one agency reported costs of inoculation. These averaged less than $1 per plant including labor and materials. Supplemental watering of young seedlings can also enhance survival. The practice, however, is not common. Two agencies reported the cost of supplemental watering at $16 and $28 per plant. This can be twice the cost of the plants themselves (Table 4), and likely accounts for the fact that the practice is uncommon.

### 3.5 Mulching

Germination and survival of plants in reseeded areas can be enhanced by the addition of mulch. Mulch helps conserve soil moisture and adds organic matter to the soil. Commonly used materials include straw, hay, and commercial fiber mulch. Straw and hay can be spread by hand or blown on the soil with special equipment designed for that purpose. The labor cost for applying mulch is the same for straw and hay, although the material cost can vary widely both within and between regions (Table 5). Hay is often more expensive than straw because of its alternative value as winter feed for livestock. Straw and hay are both susceptible to blowing. Hence, crimping or tackifying may be necessary to hold it in place. Most contracts that call for mulching do not separate the costs of materials and labor. Hence, Table 5 too reflects average regional costs for the entire process. The cost of mulching was highest in the American Desert province followed closely by the Chihuahuan Desert and Colorado Plateau Semidesert provinces.

**Table 5. Regional average cost ($/hectare) mulching with straw or hay.**

| Province | Estimate Type | Material, Spreading, and Crimping |
|---|---|---|
| Intermountain Semidesert | Average | 610 |
| | Range | 237–1,001 |
| Intermountain Desert | Average | 2,734 |
| | Range | 321–1,129 |
| American Desert | Average | 2,320 |
| | Range | – |
| Colorado Plateau Semidesert | Average | 2,246 |
| | Range | 793–4,942 |
| Chihuahuan Desert | Average | 1,638 |
| | Range | 793–4,942 |
| | **Combined Average** | 1,366 |

Mulching was far less expensive in the Intermountain Desert and Semidesert provinces, possibly due to the proximity of numerous farms and ranches at higher elevations within those regions where cooler temperatures and irrigation systems provide a setting more conducive to hay and straw production. Fiber mulch is generally used only in conjunction with hydromulching or hydroseeding. The combined cost of labor and materials for hydromulching is much higher than mulching with straw or hay. As labor and equipment expenses remain relatively constant for hydraulic applications regardless of the materials used, estimated costs of hydromulching alone can be approximated from Table 3 by subtracting the costs of seed and fertilizer from the cost of hydroseeding.

### 3.6 Supplemental Erosion Control

At some locations, revegetation alone may not be adequate to control soil erosion. Some form of supplemental erosion control may be necessary. Common erosion control practices include diversion trenches and riprap. Diversion trenches may be used to divert water away from areas of concentrated flow thus reducing the erosive energy of flowing water. Diversion trenches may also be used to divert water into areas where revegetation efforts are taking place in order to supplement the supply of water to the new plants. For the purposes of this report, diversion trenches are defined as shallow, linear excavations produced by a single pass of heavy equipment such as a road grader, although an experienced driver of a bulldozer or front-end loader can often accomplish a similar result. Average regional costs for the construction of diversion trenches are listed in Table 6. Costs are generally low and do not vary widely by region. There is generally as much or more variation within provinces than between them. Variability in cost per linear meter ($/lm) is attributable to mileage to and from the construction sites and to the size of the job. Riprap is commonly placed in gullies or waterways to slow the flow of water and minimize its erosive energy. Riprap is available in many different sizes depending on the expected flow of water. The size of the rock can greatly affect the cost. Most agencies do not record the costs of materials and labor separately. Hence, the values recorded in Table 6 include both labor and material. The cost of riprap varies widely both within and between provinces. On average,

**Table 6. Regional average costs for supplemental erosion control practices.**

| Province | Estimate Type | Diversion Trenches ($/lm) | Riprap Installed ($/m$^3$) |
|---|---|---|---|
| Intermountain Semidesert | Average | 3 | 27 |
| | Range | 3–6 | 13–50 |
| Intermountain Desert | Average | 6 | 40 |
| | Range | 3–6 | 20–69 |
| American Desert | Average | 6 | 48 |
| | Range | 3–12 | 26–87 |
| Colorado Plateau Semidesert | Average | 6 | 41 |
| | Range | 3–6 | 28–86 |
| Chihuahuan Desert | Average | 6 | 90 |
| | Range | 3–6 | 28–348 |
| **Combined Average** | | 6 | 53 |

costs per cubic meter ($/m$^3$) of material were much higher in the Chihuahuan Desert than in the other provinces. The higher costs there may be attributable to the long distances between sources of riprap and construction locations.

## 4.0 CONCLUSIONS

Costs for most land reclamation practices and materials covered by this report varied widely within and between ecological provinces. Although regional cost patterns were evident for some practices, the patterns were not consistent between practices. Due to the wide intra-provincial variability in costs and frequent small number of cost estimates per province (i.e., 1–13), it is impossible to conclude with any degree of certainty that differences in average costs between provinces are statistically significant. For the purpose of estimating land reclamation costs for the ATTACC methodology, it may be desirable to use the “Combined Average” of all provinces found in the last row of each table to estimate costs for arid lands in general.

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