REVEGETATION GUIDELINES HANDBOOK

FOR

CASPER, WYOMING

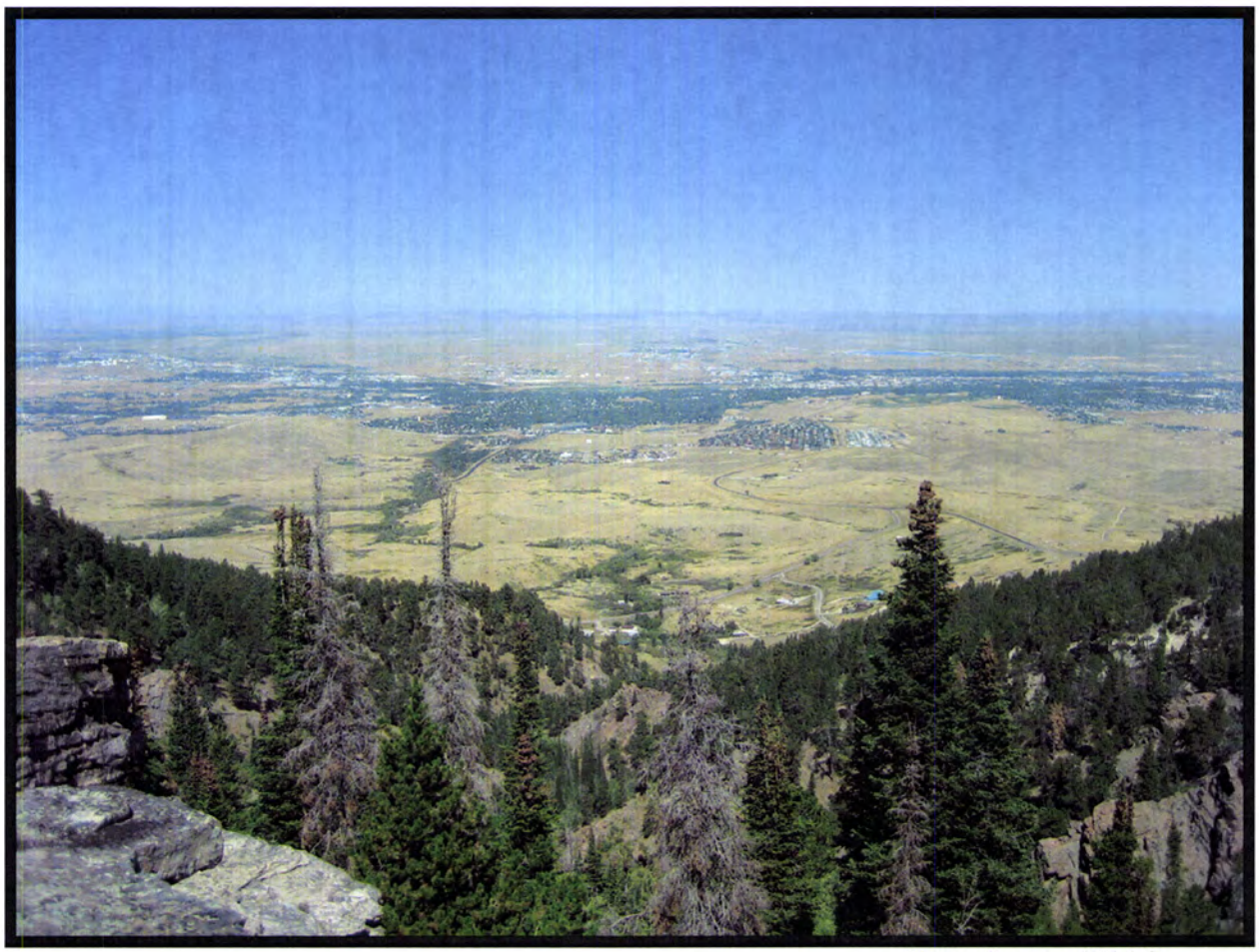

Photo: Casper and Vicinity

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REVEGETATION GUIDELINES HANDBOOK FOR CASPER, WYOMING

INTRODUCTION

The City of Casper retained the services of Rocky Mountain Reclamation for the development of Revegetation Guidelines for disturbed lands in and around Casper, Wyoming (Map 1 – Casper and Surrounding Communities). Rocky Mountain Reclamation developed revegetation guidelines based on ecological range sites and soil types.

This Revegetation Handbook was developed as a guideline for assisting the City of Casper personnel and local Project Owners in determining the best revegetation practices and materials to utilize for specific sites in the City of Casper development areas. The handbook was also written for use by Project Owners in providing satisfactory long term re-establishment of native, perennial, long term vegetation during subdivision development operations and following completion of these developments.

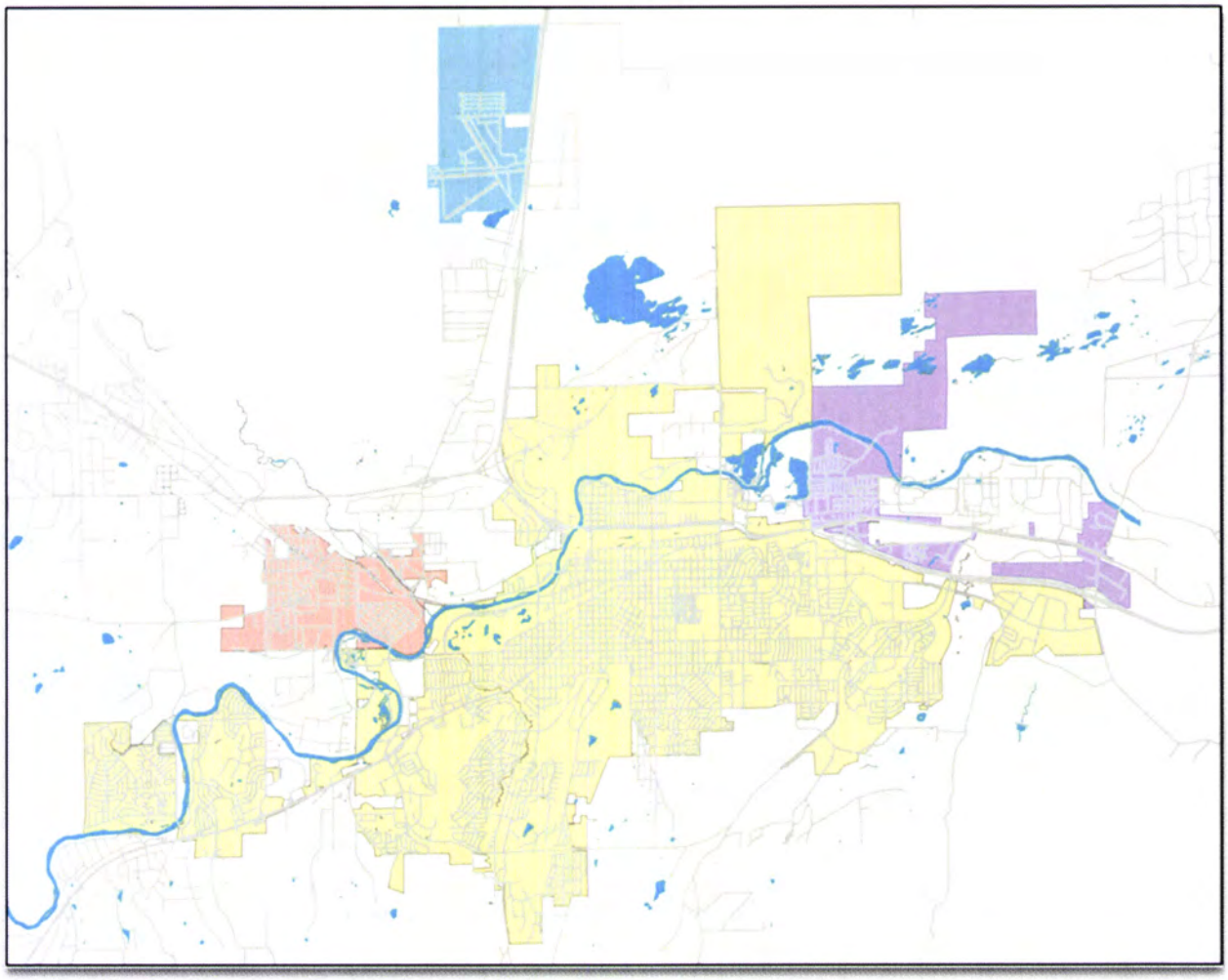
The guidelines in this handbook will assist in reestablishing natural vegetation cover and density over the long term and will assist with improving visual aesthetics while stabilizing soils and disturbed areas in the short term. The geographical range of this handbook is primarily for Casper, Wyoming and the surrounding area.

Background: The City of Casper is undergoing significant community growth and residential and commercial subdivisions are being developed all around the city and surrounding area. Once initial development is underway, Project Owners are required to satisfactorily control dust and minimize degradation of the off-site environment including adjacent private property, public facilities, and native lands.

Because the City of Casper does not require subdividers to hire professional reclamation companies to complete revegetation work, a need exists for providing City of Casper personnel, subdivision owners, and contractors a resource for determining best revegetation practices on a site specific basis. This handbook has been developed to meet this need.

Overview: This guideline is designed to assist in making correct decisions concerning revegetation of disturbed sites around the Casper, Wyoming area. The steps to take to determine the best revegetation solution are detailed below. The steps will lead to selecting the most appropriate revegetation plan or plans for the site. Once these plans are determined, then the revegetation work needs to be completed, preferably by an experienced professional company in the revegetation industry. Utilizing and properly installing the best suited revegetation and erosion control materials is essential to the success of each project. Follow up monitoring is then needed to determine if the established vegetation meets the requirements of the City of Casper. All of these topics are discussed in the following pages.

Map 1 – City of Casper and Surrounding Communities – 2009.



CHOOSING THE REVEGETATION PLAN

Utilize the following procedure to select the most appropriate Revegetation Plan:

(1) Determine the location of the disturbed area – three methods:
   a. Utilize available surveys of the land.
   b. Obtain GPS readings for the disturbed areas.
   c. Utilize available USGS quad maps or other mapping of the area.
(2) Determine the soil types for the disturbed area – three methods:
   a. NRCS Web Soil Survey – www.websoilsurvey.nrcs.usda.gov.
   b. NRCS published Soil Survey for Natrona County (contact the local or state NRCS office in Casper).
   c. Soils evaluation by soils or range professional.
(3) Determine if Special Conditions exist (refer to the Special Soil Conditions section).
(4) Determine the Revegetation Plan(s) to be used for the project.
   a. Find the soil type and texture information in Table 1 (Revegetation Plans based on Soil Types for Disturbed Areas in and around Casper, Wyoming) that most closely describes the area in question.
   b. Select the Revegetation Plan indicated for your soils type and texture.

More than one Revegetation Plan may be required for each site to be revegetated. If the site has only one soil type and no special soil conditions, then only one Revegetation Plan will need to be utilized. If the site has several soil types and/or special soil conditions, then more than one Revegetation Plan will be required.

Table 1 - Revegetation Plans based on Soil Types for Disturbed Areas in and around Casper, Wyoming.

REVEGETATION PLAN	SOIL TYPES / TEXTURES
BOTTOMLAND	Subirrigated meadows
CLAY	Clay, Silty Clay, Stony Silty Clay, Clay loam, Silty Clay Loam
SALINE / SODIC	Any soil texture with high saline or sodic conditions
LOAM	Silty Loam, Cobbly Silt Loam, Silt, Loam, Clay Loam
GRAVELLY/SHALLOW	Gravelly Loam, Gravelly Sandy Loam, Stony Loam, Stony Sandy Loam
SANDY	Loamy Fine Sand, Loamy Sand, Gravelly Loamy Fine Sand
BLOW SAND	Find Sand, Sand, Coarse Sand

SOIL SUITABILITY CRITERIA

Determining soil suitability is important if the project site soils are not easily characterized and if it is not easy to determine the appropriate Reclamation Plan.

Table 2 lists the soil suitability standards for sampling parameters of concern. If any parameters are outside the suitable soil limits, then the Project Owner is required to mitigate the soil to suitable conditions. Mitigation plans shall be submitted to the City of Casper for approval prior to implementation.

Because chemical constituents in different soil types have varying effects on native vegetation establishment, the list of suitable and unsuitable soil values and ranges in Table 2 are not absolute. The Project Owner may request a site specific exception in writing; however, the burden of proof for the exception shall be placed on the Project Owner.

Table 2 – Soil Suitability Criteria.

PARAMETER	SUITABLE SOILS			UNSUITABLE SOIL
	Good	Fair	Poor	
pH	6.0 - 8.4	5.5 - 6.0, 8.4 - 8.8	5.0 - 5.5, 8.8 - 9.0	< 5.0, > 9.0
EC (Conductivity) mmhos/cm	0 - 4	4 - 8	8 - 16 (>8 difficult to revegetate)	> 16
SAR	< 6	6 - 10	10 - 15	> 15
ESP (%)	0 - 10	10 - 15		> 15
Saturation Percentage	25 - 80	25 - 80	< 25 or > 80	
Texture	sl, l, sil, scl, vfsl, fsl	cl, sicl, sc, ls, lfs	c, sic, s	
Calcium carbonate (%)	0-15%	15-30%	> 30%	> 30%
Optional, as Needed:				
Acid-Base Potential	> -5 tons $CaCO_3$ equiv./1000 tons			< -5 tons
Selenium (mg/Kg)	< 2.0 ppm			> 2.0 ppm
Boron	< 5.0 ppm			> 5.0 ppm
Lead	< 10 ppm			> 10 ppm
Molybdenum	< 1.0 ppm			> 1.0 ppm
Arsenic	< 2.0 ppm			> 2.0 ppm

Summary information for Soil Suitability Testing Parameters, Reporting Units of Measure, and Testing Method Sources:

pH – pH is a measure of the hydrogen ion activity and indicates the solubility of salts in the soil. Values greater than 8.5 may indicate a sodium problem. Values less than 7.0 may indicate a lack of earth carbonates (calcium and magnesium carbonate). Reported as Hydrogen ion activity at saturation (paste). USDA Handbook 60, method (21a).

EC – Electrical conductivity of the saturated paste (EC) is used as a measure of salinity. EC greater than 4 dS/m has been shown to have an effect on growth of vegetation types such as blue grama (USDA 1954). Electrical Conductivity is reported as mmhos / cm at 25° C, USDA Handbook 60, method 3a, 4b.

SAR – Sodium adsorption ratio (SAR) is a measure of the concentration of soluble sodium, calcium, and magnesium in the soil. SAR is utilized as an indicator of sodic conditions. Sodium Adsorption Ratio is reported as SAR calculated from soluble Ca, MG, and Na concentrations. USDA Handbook 60.

ESP – Exchangeable sodium percentage (ESP) is a measure of the exchangeable sodium as a percentage of total exchangeable salts. ESP is an indicator of sodic concentrations in the soil. Values greater than 15 (12 in clay soils) indicate sodic conditions.

Saturation Percentage – The percentage of water to soil volume at the point which pores in a soil sample are completely filled with water without excess is the saturation percentage. The saturation percentage is influenced by the chemical and physical properties of the soil. Values less than 25 may indicate very coarse textured soils with limited water holding capacities. Values greater than 80 may be associated with high concentrations of tight clays and adsorbed sodium. Saturation Percentage is reported as a percent. USDA Handbook 60, method (27a & b).

Texture – The measurement of the proportion of mineral particles of different sizes that are found in the same sample of soil (sand, silt, clay). Reported as % clay (cl), silt (si), sand (s), and very fine sand (vfs). For agronomic use, reported as clay, silt, loam, sands, cobble, gravel, and similar gradations of particle size. ASA Mono. No 9, Pt.I, method 43-5. Texture classifications include: Good category: sandy loam (sl), loam (l), silty loam (sil), sandy clay loam (scl), very fine sandy loam (vfsl), fine sandy loam (fsl), Fair category: clay loam (cl), silty clay loam (sicl), sandy clay (sc), loamy sand (ls), loamy fine sand (lfs), Poor category: clay (c), silty clay (sc), sand (s).

Calcium Carbonate ($CaCO_3$) – Calcium carbonate is the hardened form of the primary component of caliche. Reported as a Percent. USDA Handbook 60, method (23b).

Provide the following as needed. If problems from the following are not expected based on existing soils data, NRCS information, previous revegetation successes, or other observations, then testing for Acid-Base Potential, Selenium, Boron, Lead, Molybdenum, and Arsenic are not necessary. These can be problematic in Wyoming soils and should be the first to be tested should revegetation success be unsatisfactory for reasons other than common factors such as drought, wind, erosion, damage from human disturbance, and saline or sodic conditions.

Acid-Base Potential – Record as Acid potential in meq H+/100 g. Neutralization potential and acid-base potential in +/- tons $CaCO_3$ equivalent/1000 tons of soil (Smith, R.M. et al. 1974. pg 48-51).

Selenium – The amount of Selenium available for plant uptake measured in ppm using extraction by ASA Mono. No. 9, Pt. 2, method 80-3, pg. 1122; analysis by the DAN-Flourometric method (Levesque & Vendett, 1971) or the Gaseous Hydride Method (US EPA 1979) and atomic absorption spectrophotometry. Analysis for selenium is recommended if primary selenium indicator plant species are present (Rosenfeld and Beath, 1964).

Boron – The amount of Boron available in the soil measured in ppm. Probably unlikely to be a problem in Natrona county. Extraction by ASA Mono. No. 9, Pt. 2, method 75-4, pg. 1062. Analysis by the curcumin method (Standard Methods, 1976).

Lead – Amount of lead in the soil measured in ppm. Use DTPA Extraction (Follett & Lindsay, 1971). Analysis by atomic absorption spectrophotometry.

Molybdenum – Amount of available Molybdenum in the soil measured in ppm to a detectable limit of 0.1.

Arsenic – Amount of Arsenic in the soil measured in ppm. Use appropriate testing procedure depending on soil pH.

SPECIAL SOIL CONDITIONS

Several types of site conditions exist in the Casper area that have caused significant problems in the recent past and include:

(1) saline and sodic sites where native soil are high in some type of salt and can be at or above suitability levels, thus severely restricting revegetation success. EC, SAR, or ESP in the unsuitable soil range (Table 2).
(2) sites with no available quality topsoil where such material was either not originally available or where topsoil was not initially saved and stockpiled during construction activities, and
(3) sites where soils are highly erosive and subject to blowing and ready movement off site onto adjacent private and public property (sandy soils, for example).

When subdivision construction and other disturbances occur on any of these or other special soil conditions, the Project Owner must take additional steps to mitigate the disturbances and assure long term revegetation success. If other special soil conditions are suspected, consult the City of Casper for guidance or enlist a soils consultant or revegetation specialist to address the situation.

The Project Owner may submit a request to revegetate with unsuitable soils. The City of Casper may require additional monitoring (up to ten years) and additional soil testing to demonstrate that a vegetation community can be sustained in the unsuitable soil. The City of Casper will also consider allowing the Project Owner the opportunity to establish test plots, utilizing different mitigation methodologies. Results from these test plots will be used to assist in future decision-making about utilizing unsuitable soils for revegetation.

SALINE AND SODIC SITES

Saline soils are caused by elevated levels of salts, resulting in an electrical conductivity of the saturated paste (EC) greater than 4 dS/m. The sodium adsorption ratio (SAR) is a measure of the concentration of soluble sodium, calcium, and magnesium in the soil. SAR is utilized as an indicator of sodic conditions. Sodic soils are caused by elevated sodium concentrations resulting in exchangeable sodium percentage (ESP) greater than 15 percent. Both saline and sodic soil conditions may inhibit native vegetation establishment.

Sites with excessive amounts of salts in the soils need to be addressed based on the amount of salt in the soil and the amount of time the Project Owner has to mitigate the situation before vegetation needs to be established. Salt concentrations in the rooting zone and for several feet below must be at levels low enough to adequately grow desirable plants. Vertical migration of salts from below the root zone is known to occur and therefore the Project Owner must address not only the top twelve inches of surface soil, but where salt levels are high, must also mitigate subsoils to at least a 24 inch depth although providing suitable soil and subsoil to at least a 48 inch depth would be preferred and would minimize long term negative impacts to vegetation development.

Determining Suitability

Saline conditions are determined by testing the saturated paste extract of soil samples for EC. Sodic conditions are determined by testing the soil pH, ESP, and the sodium adsorption ratio (SAR). A discussion of sampling techniques can be found in the Soil Sampling Plan & Procedures section. Following sampling activities, the Project Owner should provide a sampling report to the City of Casper for approval.

To determine suitability of the plant growth media or primarily the top twelve inches of surface soils and to determine the quality of the underlying soils where potential upward migration of phytotoxic salts may initiate, soil samples should be taken on frequent enough intervals to adequately provide a representative sample of existing conditions at the site. Provide at least three composite samples from the top twelve inches and three composite samples from 12 to 36 inches within the sampling area where salts are expected or known to be an issue. If the site is expected to have or is known to have several different concentration levels of salts, then sample each area separately.

Soil Sampling

Refer to the section, Soil Sampling Plans and Procedures, for details on how to sample the areas requiring soil sampling.

Suitability Criteria

To determine whether the existing surface material will provide an adequate soil for plant growth, the Project Owner should sample the soils and have the soils analyzed in a laboratory that specializes in providing testing for the following parameters. Most agricultural and soils testing laboratories can provide the necessary testing. The soil pH should be between 6.0 and 8.4 and definitely below 9.0. EC's (electrical conductivity) should be below 16.0 and are best if below 8.0. SAR's (sodium adsorption ratios) should be below 15 and are best if below 10. ESP's (exchangeable sodium percentage) should be below 15 and are best if below 10. If any of these or other soil suitability parameters are outside the suggested limits as detailed in Table 2 – Soil Suitability Criteria, then the Project Owner needs to address mitigating soil chemical properties to reduce salts or saline conditions or other phytotoxic situations and provide a satisfactory plant growth media. Often, the best approach is to remove contaminated soils from near the surface and replace with a quality plant growth media.

Mitigation

If either the plant growth media (top twelve inches) or the underlying soils to three foot in depth do not meet the suitability criteria, then these soils should be removed and properly disposed of either off site or buried below the top three foot of soils on-site. Table 2 provides a list of suitable and unsuitable soil conditions. The City of Casper may require the Project Owner to mitigate the soil if sampling results show 'poor suitable soil' or 'unsuitable soil'. To eliminate problems with off-site disposal, encapsulating the unsuitable material on-site may be the Project Owner's best option.

Mitigation measures typically fall into three categories: 1) off-site disposal, 2) on-site encapsulation, or 3) in-situ remediation. This Handbook briefly describes procedures for handling saline/sodic soils; therefore, it is recommended the Project Owner utilize other, more detailed references for selecting and planning for mitigation measures. If soils are proved to be saline or sodic, the Project Owner is required to submit a soils mitigation plan as part of the revegetation plan for City of Casper review and approval.

Off-Site Disposal

If the off-site disposal option is selected, excavation of saline/sodic soils for off-site disposal typically shall occur to a depth of three (3) feet. If subsoil conditions exist that may result in "wicking" of salts upwards, the City of Casper may require deeper excavation. Following excavation, clean soils shall be hauled in to return the site to the approximate contour of the surrounding area. The upper one foot of the clean soils shall be suitable topsoil. The clean soils shall be placed, compacted, and ripped as described in the On-site Encapsulation subsection below. Off-site disposal of saline/sodic soils shall occur at an approved location only.

On-site Encapsulation

On-site encapsulation involves the burial of saline/sodic soils at a depth of three (3) feet or greater. On-site disposal of saline/sodic soils requires City of Casper approval.

The following steps are required for on-site encapsulation:

1. City of Casper approval of a written revegetation plan.
2. Excavate an area that has been previously disturbed to bury the saline/sodic soil material beneath a minimum of two (2) feet of clean soil, leaving the site a minimum of one (1) foot below the surrounding grade. Compact all disturbed and placed soils as described in the Handling Soils section below. Compacting helps assure proper elevations and minimizes settling.
3. Rip the compacted soils to a depth of one (1) foot. Ripping helps assure keying in of the topsoil (next step) and helps maximize root penetration.
4. Place one (1) foot of suitable topsoil and blend to surrounding grade.
5. Revegetate according to the appropriate Revegetation Plan (refer to the Determining the Revegetation Plan section above).

In-situ Remediation

In-situ remediation of saline/sodic soils or other phytotoxic soils involves the physical or chemical treatment of soils in place. For saline soils, this typically involves blending the soil (see Handling Soils section), irrigating to leach out salts, or other methods. For sodic soils, a chemical amendment such as gypsum ($CaSO_4.2H_2O$) or other method may be utilized. The most effective method of in-situ remediation depends upon several site parameters including soil pH, soil texture, drainage, and groundwater elevation. In-situ remediation activities are not covered in this handbook. Enlist the assistance of a qualified soils or revegetation specialist to address in-situ remediation. Provide a plan for approval by the City of Casper prior to implementation. Revegetation of the site will not be approved by the City of Casper until suitable soil conditions have been established.

Some plant species can grow outside the recommended suitability ranges. If the Project Owner wishes to demonstrate that they can provide a long term sustained vegetation community, represented by high quality native perennial species, then the City of Casper will consider this as an alternative method of revegetation for the site, analyze the data provided, and provide a decision concerning either accepting or rejecting the Project Owner's proposal, based on facts and documentation provided by the Project Owner. The City of Casper will also consider allowing the Project Owner the opportunity to establish test plots, utilizing different potential mitigation methodologies.

The Project Owner is responsible in the long run for complete and satisfactory reclamation and revegetation of all high saline, sodic, or otherwise phytotoxic areas and therefore, the City of Casper is likely to allow a variety of methods with the stipulation that the Project Owner will maintain responsibility for the area and provide additional site mitigation as necessary until satisfactory long term vegetation is established on the site. This may mean that the City of Casper may require additional soils sampling to determine suitability. Based on past experience, the City of Casper wishes to minimize situations where sites have been revegetated and appear to be successful, but within a few years, salts migrate upward in the soils profile and create a phytotoxic environment for existing plants. Plant cover and density slowly begins to decrease to the point that what once appeared to be successful reclamation and revegetation is now unacceptable.

SITES WITH NO TOPSOIL

Sites with no topsoil can be revegetated as long as the on-site material provides an adequate plant growth media. Topsoil is often scarce in this region, like many areas throughout the western USA. If proper salvaging of topsoil was not done during the construction phase, then adequate topsoil or equivalent plant growth media shall be

provided by the Project Owner. Time and experience have proved the value of salvaging and reusing topsoil to enhance revegetation success.

When adequate topsoil is not available on a subdivision or other project, the Project Owner shall either import or "build" a plant growth media that will provide adequate conditions for seedling establishment and sustained vegetation cover and production:

(1) If the topsoil is imported, it should exhibit textural and chemical characteristics equal to or more suitable (Table 2) than on-site materials. Imported soils should be obtained from a pit or previously disturbed site, not from a location where the surface soils were removed for the sole purpose of obtaining the topsoil.

(2) If topsoil is "built", then utilize fertilizers and soil amendments as described in the Revegetation Techniques section below.

Multiple revegetation efforts may be required to adequately revegetate the site if inadequate topsoil materials are provided by the Project Owner. The degree of additional revegetation efforts depends on the success at the site. Additional revegetation includes: (1) completely redoing the revegetation procedures, (2) interseeding, or (3) spot revegetation as required by the City of Casper, including any or all of the revegetation techniques per the Revegetation Plan(s) for the site.

Determining Suitability

To be considered suitable topsoil, soils must meet the criteria in Table 2 – Soil Suitability Criteria. To determine suitability of the plant growth media or primarily the top twelve inches of surface soils and the quality of the underlying soils where potential upward migration of phytotoxic salts and other soil components may exist, either: (1) utilize the services of a soils or revegetation specialist to determine suitability, or (2) sample the soil on frequent enough intervals to adequately provide a representative sample of existing conditions at the site.

With the approval of the City of Casper, the Project Owner may provide a report containing the opinions of a specialist concerning the soil conditions and no soils sampling will be required. For most areas around Casper, simply determining the soil texture is all that is needed so that the proper Revegetation Plan can be selected (refer back to Determining the Revegetation Plan).

If soils sampling is selected by the Project Owner or requested by the City of Casper, then collect at least three composite samples in the top twelve inches and three composite samples from 12 to 36 inches within the sampling area where non-topsoil materials are potentially going to be used as the plant growth media. If the site has several different surface soil types and textures, then additional sampling is recommended.

Soil Sampling

Refer to the section, Soil Sampling Plans and Procedures, for details on how to sample the areas requiring soil sampling.

Suitability Criteria

To determine whether the existing surface material will provide an adequate soil for plant growth, the Project Owner should:

(1) utilize the services of the NRCS, soil scientist, or revegetation specialist, or other knowledgeable person or resource, or
(2) sample the soils and have the soils analyzed in a soils testing laboratory.
(3) In either case above, use Table 2, Soil Suitability Criteria, to determine the suitability of the non-topsoil material. When soil sampling is required, evaluate for all parameters listed in the table unless the City of Casper or soils specialist approves testing for only selected parameters. For most soils in the Casper area, not all parameters need to be evaluated (refer to notes following Table 2).

If the non-topsoil material at the surface meets the parameters for good or fair plant growth media, then fertilizers and/or soil amendments should be utilized as necessary to provide adequate nutrients for plant establishment and sustained vegetation cover. The Revegetation Techniques section (Fertilizing and Incorporating Soil Amendments subsections) provides information on materials and application rates to be utilized for non-topsoil materials.

Mitigation

The preferred method of revegetating sites is to stockpile topsoil during initial disturbance activities. When adequate quantities of suitable topsoil (plant growth media) are not available, the Project Owner then has the choice of either building a quality plant growth media from existing on-site materials or hauling topsoil to the site from an off-site borrow source. Providing quality topsoil is the preferred method and will provide the best revegetation success rate with the least amount of fertilizer and soil amendments.

Salvaging Topsoil

Project Owners shall salvage all topsoil materials prior to initiating construction efforts. Utilizing a soils professional is recommended to determine the depth of topsoil to salvage at each site. As a general rule, for which there are always exceptions, salvaging the top twelve inches of soil will often provide adequate, quality topsoil for the reclamation and revegetation phases. For best revegetation success, separate the top twelve inches of soil and stockpile the soil in two piles consisting of the top six (6) inches of soil in one pile and the lower six (6) inches of soil in another pile. These soils are then reapplied during reclamation of the site as the topsoil, reestablishing the layers in the same order, as lower and upper topsoil horizons. Acquiring the services of a soils or revegetation specialist to help delineate quality topsoil and suitable plant growth media will most likely enhance topsoil recovery efforts and help maximize the potential for successful revegetation.

Topsoil stockpiles should then be revegetated and remain on-site for the duration of the life of the operation. When possible, direct haul topsoil from one location on the project to a nearby area of the project currently under the reclamation phase.

If either the plant growth media (top twelve inches) or the underlying soils to two foot in depth, do not meet the suitability criteria, then these soils should be: (1) removed and properly disposed of either off site or buried below the top three foot of soils on-site, or (2) amended to add sufficient physical and chemical components to "build" a quality plant growth media.

If the decision is made to leave unsuitable soils on-site, then bury this material a minimum of 3.0 feet under the bottom of the plant growth media. For example, a three foot horizon of suitable soil should be placed on high saline or sodic soil and then twelve inches of quality topsoil from a quality topsoil source should be utilized to cover the

three foot subsoil horizon. If the decision is to leave unsuitable soils on-site, then add all necessary soil amendments and fertilizers to construct a quality plant growth media. Add organic material and other soil amendments as well as fertilizer per instructions in the Revegetation Techniques section.

Some plant species can grow outside the recommended suitability ranges. If the Project Owner wishes to demonstrate that they can provide long term sustained vegetation community, represented by high quality native perennial species, then the City of Casper will consider this as an alternative method of revegetation for the site, analyze the data, and provide a decision concerning either accepting or rejecting the Project Owner's proposal, based on facts and documentation provided by the Project Owner. The City of Casper may also consider allowing the Project Owner the opportunity to establish test plots, utilizing different potential mitigation methodologies.

The Project Owner is responsible in the long run for complete and satisfactory reclamation and revegetation and therefore, the City of Casper is likely to allow a variety of methods with the stipulation that the Project Owner maintain responsibility for the area and provide additional site mitigation as necessary until satisfactory long term vegetation is established on the site. This may mean that the City of Casper may require such things as additional soil sampling to determine suitability and may require continual dust suppression until satisfactory vegetation is established.

Utilizing On-Site Soils

If the Project Owner decides to utilize existing suitable surface soils, the Project Owner may need to "build" a plant growth media that will provide adequate conditions for seedling establishment and sustained vegetation cover and production. To do this, fertilizers, soil amendments, and surface mulches may be required as described in the Revegetation Techniques Section.

SOIL SAMPLING PLANS & PROCEDURES

Sampling Plan & Report

Prior to sampling soils, a plan should be developed. The City of Casper does not require pre-approval of the sampling plan, but recommends prior consultation with the City of Casper to assure concerns are adequately addressed. In many cases, sampling can be minimized or eliminated, depending on site conditions and past experience with similar soils. Following the sampling activities, a sampling report shall be submitted to the City of Casper. All sampling reports should contain the following elements:

1. Site information;
2. Site map – sketch should show sampling locations;
3. Narrative description of sampling activities;
4. Sampling parameters; and,
5. Laboratory results.

Sampling Procedures

The following procedures may be utilized as a guide in performing soil sampling. Site conditions may dictate alternative methods be performed.

1. Utilize best judgment and determine the boundaries of sampling units based on experience, NRCS or other soils maps, or other reliable methods, and by visual indications such as fluffy soils, encrusted surfaces, clay pockets, gravel bars, blowing sands, "white alkali", etc.
2. Delineate the special sampling areas on a map and identify the location of sampling points.
3. Utilize composite sampling methods: one sample from each of three different sample locations from the 0-12 inch depth and three samples from the 12-36 inch depth are recommended per sampling unit (one composite sample). One composite sample may be taken but if results are inconsistent or inconclusive, then additional sampling may be necessary and several days to several weeks may be lost in sampling and analyzing new samples.
4. Obtain additional samples to aid in defining the extent of unsuitable soils and to determine background conditions (if desired).
5. Mark sample locations on a map.
6. Composite samples as described below.
7. Submit samples to a qualified laboratory for analysis.

The composite sampling method is generally the preferred method for collecting soil samples in areas where unsuitable soil conditions are expected. Composite sampling aids in providing an average condition for an area. The following procedures may be used to obtain composite samples:

1. For each composite sample, dig a minimum of three (3) soil test pits to a depth of 36 inches or refusal (such as rock parent material).
2. From the side wall of the pit cut a vertical slice along the soil profile (an 18 inch spade shovel is recommended). A soil auger may be utilized to obtain a sample instead of a pit and shovel.
3. Segregate in 0-12 inch and 12-36 inch sections (one sample from 0-12" horizon and one sample from the 12-36" horizon per test pit times a minimum of three test pits).
4. Mix the soil sections from each test pit by soil horizon (0-12" samples in one container and the 12-36" samples in a separate container) to obtain two (2) separate composite samples. Mix each sample until the sample is homogenous (a five gallon bucket is recommended). Place approximately one gallon of each mixed sample into a sampling container and properly label the container for delivery to the soils laboratory. This procedure results in one composite sample from the 0-12" horizon and one composite sample from the 12-36" horizon.; two samples total.

5. As a general rule, repeat steps 1 through 4 a minimum of two additional times for that sampling area to provide at least three composite samples for each soil horizon; six samples total. The City of Casper may allow a less intense sampling requirement, especially if soils are expected to be suitable and no soils issues are evident.

HANDLING SOILS

Placing Soils - Compaction, Ripping & Grading

All soils placed for purposes of reclaiming a site shall utilize the following procedures. Alternate procedures may be suggested in writing by the Project Owner and may be used if approved by the City of Casper.

All soils, excluding topsoil, shall be compacted to 90% of maximum proctor density. This may require the addition of water for dry soils. Compaction shall occur in a maximum of six (6) inch lifts. Under correct soil-water content conditions, proper compaction can typically be achieved through the double-pass of heavy equipment, walk-behind vibratory compaction, or single press compaction with a heavy equipment bucket attachment.

Following compaction, the upper one (1) foot of subsoils shall be ripped. Compacting the last foot of subsoil may be eliminated upon the approval of the City of Casper if grade issues are not expected by not compacting this top 12 inches of the subsoil horizon.

Topsoil shall then be placed uncompacted on the ripped soils. The final elevation of the topsoil shall meet the grade surrounding the disturbed area. Revegetation Plans shall then be followed to stabilize and revegetate the area.

Salvaging Soils

Project Owners shall salvage all topsoil materials prior to initiating construction efforts. Utilizing a soils professional is recommended to determine the depth of topsoil to salvage at each site. As a general rule, for which there are always exceptions, salvaging the top twelve inches of soil will often provide adequate, quality topsoil for the reclamation and revegetation phases. For best revegetation success, separate the top twelve inches of soil and stockpile the soil in two piles consisting of the top six (6) inches of soil in one pile and the lower six (6) inches of soil in another pile. Label the piles for easy identification. These soils are then reapplied during reclamation of the site as the topsoil, reestablishing the layers in the same order, as lower and upper topsoil horizons.

When possible, direct haul topsoil from one location on the project to a nearby area of the project currently under the reclamation phase.

Topsoil stockpiles should be revegetated and remain on-site for the duration of the life of the construction operation at which time they will be placed as needed during reclamation and revegetation activities.

Flipping Soils

The practice of "flipping" soils places the upper soil layer beneath a lower layer via mechanical excavation and placement. Soil flipping is best suited for sites where unsuitable surface soils exist and subsurface soils are desirable below the topsoil level. Examples of sites where flipping soils may be a preferred option are: shallow wind-blown sand deposits and shallow saline/sodic soils existing above suitable soils. Sites where subsurface soils are deep sands or are highly saline or sodic are unsuitable for soil flipping.

The Project Owner shall have City of Casper approval to flip soils as part of the Revegetation Plan. The following is a typical procedure for flipping soils:

1. Unsuitable soils are excavated and stockpiled;
2. Clean soils beneath excavated unsuitable soils are removed, creating a burial pit or trench;
3. Unsuitable soils are placed in the burial pit or trench; and,
4. Clean soils are placed on top of the unsuitable soils.

Blending Soils

Blending existing soil with hauled-in soils, although not recommended, may in some cases, be an effective method of handling unsuitable soils such as saline or sodic soils. Blending soils should occur in a manner that creates a well mixed homogeneous soil. The City of Casper will require blended soils to be sampled to assure suitable soil conditions have been achieved.

Adding sandy soils to clay, or clay-loamy soils, and blending is not usually recommended. The mixture may result in one or more of several undesirable chemical or physical conditions for the soil and plant establishment may not be satisfactory. Loamy soils may be added on top of clay soils, but should be keyed-in by first ripping the clay soils and then placing the loamy soils on top.

REVEGETATION PLANS

The following Revegetation Plans were developed for revegetating sites in and around Casper, Wyoming (Map 1 and Table 3). To determine which revegetation plan is appropriate for a site, utilize the Choosing the Revegetation Plan section (near the beginning of this handbook).

The Revegetation Plans contain designs for: fertilizing, applying soil amendments, seed mixtures, preparing the seedbed, planting, mulching, and installing special soil stabilization measures. Instructions for these revegetation procedures are detailed in the Revegetation Techniques section. Therefore, once the procedures from the Revegetation Plan are determined, go to the Revegetation Techniques section for details on how to do the work, for application rates, for specific material requirements, for equipment requirements, for calibration procedures, and for potential material supplier examples.

Table 3 - Revegetation Plans, Codes, and Soil Types/Textures for the Casper, Wyoming Area.

VEGETATION PLANS	CODE	SOIL TYPES / TEXTURES
1. Bottomland	B	– Bottomland soils
2. Saline/Sodic	SAL	– Saline, Sodic soils, Clays, clay loam, loamy
3. Clay	CL	– Clay, Clay Loam, Silty Clay Loam
4. Loam	L	– Loamy soils
5. Gravelly/Shallow	GL	– Gravelly, Gravelly Loam, Loamy Sand soils
6. Sandy	S	– Sandy and Loamy Sand soils
7. Blow Sand	BS	– Blow Sand soils

Consult Tables 1 and 2 and the first three sections of this handbook for details on determining soil types /textures and selecting the best Revegetation Plan.

1. BOTTOMLAND VEGETATION PLAN (B):

Use this seed mixture on bottomland sites where some subirrigated soils may exist but salts and alkali conditions are not prevalent. Use on subirrigated sites and moist bottomland sites with heavy soil textures (clay, clay loam, silty clay, silty clay loam). River bottom sites may occasionally have this soil type, but in the Casper area, river bottom soils are often sandy or gravelly and a different Revegetation Plan would be applicable.

Revegetation Procedures to Use with the Bottomland Revegetation Plan:

I. **For flat or gently sloping areas with slopes less than 3H:1v:**
1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP with a commercial fertilizer spreader cart.
    a. If Type 1, apply at 35 lbs. N/ac.
    b. If DAP or MAP, apply at 20 lbs. N/ac.
2. **Prepare the seedbed**:
    a. Scarify
    b. Disc
3. **Drill Seed** – use a rangeland drill and apply Drill box seed to 0.5 inch depth, apply Small seed at 0.1 inch or to surface and lightly cover with drag chains or packer wheels or equal.
4. **Mulch** – Apply Grass Hay mulch at 2.0 tons/acre.
5. **Crimp** – Crimp immediately after mulching with a crimper implement. No discs allowed.
6. **Tackify** – Optional – tackify to minimize risk of mulch blowing into downwind neighbors and to hold soil and mulch in place until vegetation begins to establish.
7. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install.

II. **For areas with slopes equal to or greater than 3H:1V:**
1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP by broadcasting.
    a. If Type 1, apply at 35 lbs. N/ac.
    b. If DAP or MAP, apply at 20 lbs. N/ac.
2. **Prepare the seedbed** as necessary and as possible by Slope Chain, drag chain, raking, or similar method.
3. **Broadcast or Hydroseed** if four-wheel drive revegetation equipment pulling a rangeland drill cannot maintain traveling on the contour along the slope.
4. **Cover the seed** by Slope Chain, drag chain, raking, or similar method.
5. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.
6. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install.

III. **For areas with soil too wet to utilize revegetation equipment:**
1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP by hydroseeding or broadcasting.
    a. If Type 1, apply at 35 lbs. N/ac.
    b. If DAP or MAP, apply at 20 lbs. N/ac.
2. **Hydroseed**
3. **Cover Seed and Fertilizer:** If possible, cover the seed by Slope Chain, drag chain, raking, or similar method. If soils are too wet, then this step can be eliminated.
4. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.

5. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install. If wet most of the year, then wind fence would not be required.

For all of the above revegetation procedures, refer to the Revegetation Techniques section for details concerning proper methods, equipment, and application rates.

Wind Fence is suggested and should be installed if any reasonable potential exists for wind erosion damaging the finished revegetation work. Most projects in the Casper area will require wind fence.

Three Bottomland Seed Mixture Choices:

For Bottomland areas meeting the criteria for this Revegetation Plan, the Project Owner has three seed mixture choices. Project Owner should consult landowner for their desired type of seed mixture and consult a Revegetation Specialist for recommendations based on post disturbance land use, landowner desires, and specific site conditions.

If bottomlands do not meet the soils criteria (clay, clay loam, silty clay, silty clay loam), then utilize an alternative seed mixture from one of the Revegetation Plans included in this handbook, based on soil type and adjusted as necessary to account for moisture conditions. Consult a Revegetation Specialist for recommendations when such conditions exist.

Determine the seed mixture that best fits the project's situation and site requirements. Three choices are offered here:

1. Bottomland Seed Mixture – Native: Native species adapted to dryland to moist meadow and hayland habitats.
2. Bottomland Seed Mixture – Native and Introduced Irrigated/Subirrigated Pastureland: A combination of native and introduced species for moist sites with some irrigation and/or subirrigated conditions.
3. Bottomland Seed Mixture – Wet Meadow and Boggy Soils: Species adapted to wet conditions with frequent standing water and / or muddy soil conditions for extended periods of time.

Bottomland Seed Mixture - Native:

COMMON NAME	VARIETY	APPLICATION RATE (PLS/Acre)		SEED BOX
Grasses:				
Western wheatgrass	Rosana	5.0		Drill
Streambank wheatgrass	Sodar	3.0		Drill
Slender wheatgrass	Revenue, Pryor	3.0		Drill
Big bluegrass	Sherman	1.0		Drill
Alkali sacaton	VNS, Northern	1.0		Small
Nuttal alkali grass	Quill, VNS	0.5		Small
Redtop	VNS, Northern	1.0	Introduced*	Small
Meadow brome	Regar, Paddock	2.0	Introduced*	Small
	Subtotal	15.0		
Forbs:				
Purple prairie clover	VNS, Northern	1.0		Drill
Blue flax	Appar	1.0		Drill
Indian blanketflower	VNS, Northern	1.0		Drill
	Subtotal	3.0		
	Total PLS/acre	18.0		

Small = Small seed drill box, Drill = Standard seed drill box, Fluffy = Fluffy seed drill box
* If introduced species are not desired for the project, then eliminate this species. Increase native grasses proportionately.

Seed Mix Application Rates: These application rates are for drill seeding only. Although all areas accessible with a rangeland drill should be drill seeded, some broadcast seeding or hydroseeding may be necessary in areas which are too small, too steep, or otherwise inaccessible with standard four-wheel drive reclamation tractors and rangeland drill seeding equipment. Broadcast seeding or hydroseeding will be allowed if deemed necessary by the Project Owner based on the above limitations of standard drill seeding equipment. All broadcast seeded and hydroseeded areas should be seeded at double the seed application rate indicated in the seed mixture tables of this handbook.

If a species is not available, provide a suggested substitute to the City of Casper for approval. Utilize the advice of a revegetation expert. Increasing all other species proportionately may be acceptable. The Forb component in the seed mixture may be eliminated at the discretion of the Project Owner and City of Casper and the species in the grass component can be each increased proportionately to maintain the same total PLS/acre application rate. This will change the number of seeds per square foot, but enough seed will still be applied.

VNS, Northern – Variety Not Stated, seed should be from a northern latitude collection of this species such as Wyoming, Montana, Idaho, northern Utah, northern Colorado, Canada, etc.

Bottomland Seed Mixture - Native and Introduced Irrigated/Subirrigated Pastureland:

COMMON NAME	VARIETY	APPLICATION RATE (PLS/Acre)	SEED BOX
Grasses:			
Native:			
Western wheatgrass	Rosana	3.0	Drill
Streambank wheatgrass	Sodar	1.0	Drill
Big bluegrass	Sherman	1.0	Drill
Introduced:			
Common Timothy	Climax	1.0	Small
Orchardgrass	Paiute, Potomac	2.0	Small
Redtop	VNS, Northern	1.0	Small
Meadow bromegrass	Regar, Paddock	2.0	Drill
Smooth bromegrass	Manchar	4.0	Drill
	Subtotal	15.0	
Forbs:			
Purple prairie clover	VNS, Northern	1.0	Drill
Blue flax	Appar	1.0	Drill
Indian blanketflower	VNS, Northern	1.0	Drill
	Subtotal	3.0	
	Total PLS/acre	18.0	

Small = Small seed drill box, Drill = Standard seed drill box, Fluffy = Fluffy seed drill box

Forbs: For this pastureland mixture, the forb component may be deleted at the option of the Project Owner with approval from the City of Casper. If deleted, then increase grasses proportionately to maintain the same PLS pounds per acre (18.0 PLS lbs./acre).

Seed Mix Application Rates: These application rates are for drill seeding only. Although all areas accessible with a rangeland drill should be drill seeded, some broadcast seeding or hydroseeding may be necessary in areas which are too small, too steep, or otherwise inaccessible with standard four-wheel drive reclamation tractors and rangeland drill seeding equipment. Broadcast seeding or hydroseeding will be allowed if deemed necessary by the Project Owner based on the above limitations of standard drill seeding equipment. All broadcast seeded and hydroseeded areas should be seeded at double the seed application rate indicated in the seed mixture tables of this handbook.

If a species is not available, provide a suggested substitute to the City of Casper for approval. Utilize the advice of a revegetation expert. Increasing all other species proportionately may be acceptable. The Forb component in the seed mixture may be eliminated at the discretion of the Project Owner and City of Casper and the species in the grass component can be each increased proportionately to maintain the same total PLS/acre application rate. This will change the number of seeds per square foot, but enough seed will still be applied.

VNS, Northern – Variety Not Stated, seed should be from a northern latitude collection of this species such as Wyoming, Montana, Idaho, northern Utah, northern Colorado, Canada, etc.

Bottomland Seed Mixture - Wet Meadow and Boggy Soils:

COMMON NAME	VARIETY	APPLICATION RATE (PLS/Acre)		SEED BOX
Grasses, Sedges, and Rushes:				
Western wheatgrass	Rosana	4.0		Drill
Streambank wheatgrass	Sodar	2.0		Drill
Big bluegrass	Sherman	1.0		Drill
Alkali sacaton	VNS, Northern	1.0		Small
Nuttal alkali grass	Quill, VNS	0.5		Small
Baltic rush	VNS, Northern	0.5		Small
Water sedge	VNS, Northern	2.0		Drill
Nebraska sedge	VNS, Northern	2.0		Drill
Meadow sedge	VNS, Northern	1.5		Drill
Redtop	VNS, Northern	1.0	Introduced*	Small
Meadow brome	Regar, Paddock	2.0	Introduced*	Small
	Subtotal	15.0		
Forbs:				
Purple prairie clover	VNS, Northern	1.0		Drill
Blue flax	Appar	1.0		Drill
Indian blanketflower	VNS, Northern	1.0		Drill
	Subtotal	3.0		
	Total PLS/acre	18.0		

Small = Small seed drill box, Drill = Standard seed drill box, Fluffy = Fluffy seed drill box

* If introduced species are not desired for the project, then eliminate this species. Increase native grasses proportionately.

Seed Mix Application Rates: These application rates are for drill seeding only. Although all areas accessible with a rangeland drill should be drill seeded, some broadcast seeding or hydroseeding may be necessary in areas which are too small, too steep, or otherwise inaccessible with standard four-wheel drive reclamation tractors and rangeland drill seeding equipment. Broadcast seeding or hydroseeding will be allowed if deemed necessary by the Project Owner based on the above limitations of standard drill seeding equipment. All broadcast seeded and hydroseeded areas should be seeded at double the seed application rate indicated in the seed mixture tables of this handbook.

If a species is not available, provide a suggested substitute to the City of Casper for approval. Utilize the advice of a revegetation expert. Increasing all other species proportionately may be acceptable. The Forb component in the seed mixture may be eliminated at the discretion of the Project Owner and City of Casper and the species in the grass component can be each increased proportionately to maintain the same total PLS/acre application rate. This will change the number of seeds per square foot, but enough seed will still be applied.

VNS, Northern – Variety Not Stated, seed should be from a northern latitude collection of this species such as Wyoming, Montana, Idaho, northern Utah, northern Colorado, Canada, etc.

SALINE / SODIC REVEGETATION PLAN (SAL):

Use this seed mixture for heavy soils (clay, clay loam, silty clay, silty clay loam) where salts (saline and sodic) are evident ("alkali" showing at the surface – white, crusty, salt deposits at the soil surface, noticeable especially after a rain when the soil dries out). EC, SAR, and ESP values typically high and nearing the unsuitable soil levels (Table 2).

Revegetation Procedures to Use with the Saline / Sodic Revegetation Plan:

I. **For flat or gently sloping areas with slopes less than 3H:1V and soils with any parameters in the Poor range** (Table 2) **or ESP% of 12 or more:**

1. **Apply either Compost or Organic Soil Amendment** (Project Owner to select one or the other; Compost method generally recommended in these soil conditions).
    a. **Compost:** Apply compost and incorporate before seedbed preparation operations.
    b. **Organic Soil Amendment:** Apply organic soil amendment (Biosol, Sustane, or equal) and incorporate during seedbed preparation.
2. **Apply Humic Acid:** Apply humic acid (separately or with fertilizer) and incorporate during seedbed preparation.
3. **Fertilize:** Project Owner to select one of the following and apply with a commercial fertilizer spreader:
    a. Super phosphate (0-46-0) applied at 65 lbs. P_2O_5/acre (141.3 bulk pounds per acre) and potash (0-0-60) applied at 10 lbs. K_2O/acre
    b. DAP or MAP at 20 lbs. N/ac.
4. **Prepare the seedbed**:
    a. Scarify.
    b. Disc and / or roller harrow.
5. **Drill Seed** – use a rangeland drill and apply Drill seed to 0.5 inch depth, apply Small seed at 0.1 inch or to surface and lightly cover with drag chains or packer wheels or equal.
    a. **Apply Mycorrhiza** – Apply a minimum of 1.2 million VAM spores per acre if soils are in the Poor range (Table 2).
6. **Mulch** – Apply Grass Hay mulch at 2.0 tons/acre.
7. **Crimp** - Crimp immediately after mulching with a crimper implement. No discs allowed.
8. **Tackify** – Optional – tackify to minimize risk of mulch blowing into downwind neighbors and to hold soil and mulch in place until vegetation begins to establish.
9. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install.

II. **For flat or gently sloping areas with slopes less than 3H:1V and soils with all parameters in the Fair range or higher** (Table 2) **or ESP% less than 12:**

1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP by broadcasting.
    a. If Type 1, apply at 35 lbs. N/ac.
    b. If DAP or MAP, apply at 25 lbs. N/ac.
2. **Apply Humic Acid:** - Optional - apply humic acid (separately or with fertilizer) and incorporate during seedbed preparation.
3. **Prepare the seedbed**:
    a. Scarify.
    b. Disc or roller harrow.
4. **Drill Seed** – use a rangeland drill and apply Drill box seed to 0.5 inch depth, apply Small seed at 0.1 inch or to surface and lightly cover with drag chains or packer wheels or equal.
    a. **Apply Mycorrhiza** – Optional – recommended.
5. **Mulch** – Apply Grass Hay mulch at 2.0 tons/acre.
6. **Crimp** - Crimp immediately after mulching with a crimper implement. No discs allowed.
7. **Tackify** – Optional – tackify to minimize risk of mulch blowing into downwind neighbors and to hold soil and mulch in place until vegetation begins to establish.
8. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install.

III. **For areas with slopes equal to or greater than 3H:1V ** and soils with any parameters in the Poor range** (Table 2) **or ESP% of 12 or more:**

1. **Apply either Compost or Organic Soil Amendment** (Project Owner to select one or the other).
    a. **Compost:** Apply compost and incorporate before seedbed preparation operations.
    b. **Organic Soil Amendment:** Apply organic soil amendment (Biosol, Sustane, or equal) and incorporate during seedbed preparation.
2. **Apply Humic Acid:** Apply humic acid (separately or with fertilizer) and incorporate during seedbed preparation.
3. **Fertilize:** Project Owner to select one of the following and apply by broadcasting or hydroseeding:
    a. Super phosphate (0-46-0) applied at 65 lbs. $P_2 0_5$/acre (141.3 bulk pounds per acre) and potash (0-0-60) applied at 10 lbs. $K_2 0$/acre
    b. DAP or MAP at 25 lbs. N/ac.
4. **Prepare the seedbed** to the extent reasonably possible. Soils should be in a mellow condition for seeding.
    a. Use slope chain, drags, dozer tracking, etc. as needed.
5. **Broadcast or Hydroseed** if four-wheel drive revegetation equipment pulling a rangeland drill cannot maintain the contour along the slope.
    a. **Apply Mycorrhiza** – Apply a minimum of 1.2 million VAM spores per acre if soils are in the Poor range (Table 2).
6. **Cover the seed** by Slope Chain, drag chain, raking, or similar method.
7. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.
8. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install.

IV. **For areas with slopes equal to or greater than 3H:1V and soils with all parameters in the Fair range or higher** (Table 2) **or ESP% less than 12:**

1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP by broadcasting.
    a. If Type 1, apply at 35 lbs. N/ac
    b. If DAP or MAP, apply at 25 lbs. N/ac.
2. **Apply Humic Acid:** - Optional - apply humic acid (separately or with fertilizer) and incorporate during seedbed preparation.
3. **Prepare the seedbed** to the extent reasonably possible. Soils should be in a mellow condition for seeding.
    a. Use slope chain, drags, dozer tracking, etc. as needed.
4. **Broadcast or Hydroseed** if four-wheel drive revegetation equipment pulling a rangeland drill cannot maintain traveling on the contour along the slope.
    a. **Apply Mycorrhiza** – Optional – recommended.
5. **Cover the seed** by Slope Chain, drag chain, raking, or similar method.
6. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.
7. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install.

V. **For areas with soils too wet to utilize revegetation equipment and with any parameters in the Poor range** (Table 2) **or ESP% of 12 or more:**

1. **Apply Organic Soil Amendment:** Apply organic soil amendment and incorporate if possible.
2. **Fertilize:** Apply DAP or MAP at 25 lbs. N/ac. by broadcasting or hydroseeder.
3. **Apply Humic Acid:** Apply humic acid and incorporate during seedbed preparation to the extent possible.
4. **Broadcast or Hydroseed** if four-wheel drive revegetation equipment cannot access the areas (too wet).
    a. **Apply Mycorrhiza** – Apply 1.2 million VAM spores per acre if soils are in the Poor range (Table 2).

5. **Cover Seed and Soil Amendments:** If possible, cover the seed, fertilizer, and organic soil amendment, humic acid, and mycorrhiza by Slope Chain, drag chain, raking, or similar method. If soils are too wet, then this step can be eliminated.
6. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.
7. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install. If wet most of the year, then wind fence would not be required.

VI. **For areas with soils too wet to utilize revegetation equipment and with all parameters in the Fair range or higher** (Table 2) **or ESP% less than 12:**

1. **Apply Organic Soil Amendment: -** Optional - apply organic soil amendment and incorporate if possible.
2. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP by broadcasting.
    a. If Type 1, apply at 35 lbs. N/ac
    b. If DAP or MAP, apply at 25 lbs. N/ac.
3. **Apply Humic Acid: -** Optional - apply humic acid (separately or with fertilizer) and incorporate during seedbed preparation.
4. **Broadcast or Hydroseed** if four-wheel drive revegetation equipment cannot access the areas (too wet).
    a. **Apply Mycorrhiza** – Optional – recommended.
5. **Cover Seed and Fertilizer:** If possible, cover the seed and fertilizer, and mycorrhiza (optional) by Slope Chain, drag chain, raking, or similar method. If soils are too wet, then this step can be eliminated.
6. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.
7. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install. If wet most of the year, then wind fence would not be required.

For all of the above revegetation procedures, refer to the Revegetation Techniques section for details concerning proper methods, equipment, and application rates.

Soils in the Good range (Table 2) will not fall in this Revegetation Plan.

If the Project Owner or his representative can provide information to show that applying compost or organic soil amendment and fertilizer would put too much Nitrogen or other compounds in the soil, the City of Casper will allow alteration of fertilizer requirements.

Drill seed and Small seed are bagged separately and put in separate drill boxes in the rangeland drill.

** Steep slopes can be difficult to apply organic soil amendments, compost, humic acid, and fertilizer and then incorporate this material. Allow for extra equipment and time to apply and incorporate to the extent possible. Situations will occur where proper application and incorporation or too difficult and the City will allow alternatives presented by the Project Owner.

Wind Fence is suggested and should be installed if any reasonable potential exists for wind erosion damaging the finished revegetation work. Most projects in the Casper area will require wind fence.

Saline / Sodic Seed Mixture:

COMMON NAME	VARIETY	APPLICATION RATE (PLS/Acre)	SEED BOX
Grasses:			
Western wheatgrass	Rosana	5.0	Drill
Streambank wheatgrass	Sodar	3.0	Drill
Slender wheatgrass	Revenue, Pryor	3.0	Drill
Inland saltgrass	VNS, Northern	2.0	Drill
Alkali sacaton	VNS, Northern	1.0	Small
Nuttal alkali grass	Quill, VNS	0.5	Small
Alkali grass	Fults	0.5	Small
	Subtotal	15.0	
Forbs:			
Purple prairie clover	VNS, Northern	1.0	Drill
Western coneflower *	VNS, Northern	1.0	Drill
	Subtotal	2.0	
	Total PLS/acre	17.0	

Small = Small seed drill box, Drill = Standard seed drill box, Fluffy = Fluffy seed drill box

* If not available, substitute Blackeyed susan

Seed Mix Application Rates: These application rates are for drill seeding only. Although all areas accessible with a rangeland drill should be drill seeded, some broadcast seeding or hydroseeding may be necessary in areas which are too small, too steep, or otherwise inaccessible with standard four-wheel drive reclamation tractors and rangeland drill seeding equipment. Broadcast seeding or hydroseeding will be allowed if deemed necessary by the Project Owner based on the above limitations of standard drill seeding equipment. All broadcast seeded and hydroseeded areas should be seeded at double the seed application rate indicated in the seed mixture tables of this handbook.

If a species is not available, provide a suggested substitute to the City of Casper for approval. Utilize the advice of a revegetation expert. Alternatively, increasing all other species within the life form (Grass life form, Forb life form, Shrub life form) proportionately may be acceptable.

The Forb component in the seed mixture may be eliminated at the discretion of the Project Owner and City of Casper and the species in the grass component can be each increased proportionately to maintain the same total PLS pounds/ acre application rate. This will change the number of seeds per square foot, but enough seed will still be applied.

VNS, Northern – Variety Not Stated, seed should be from a northern latitude collection of this species such as Wyoming, Montana, Idaho, northern Utah, northern Colorado, Canada, etc.

CLAY REVEGETATION PLAN (CL):

Use this seed mixture in heavy soils including clay, clay loam, silty clay loam, overflow loam soil types. Upland areas or dry lowland areas.

Revegetation Procedures to Use with the Clay Revegetation Plan:

I. **For flat or gently sloping areas with slopes less than 3H:1V:**

1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP with a commercial fertilizer spreader cart.
    a. If Type 1, apply at 35 lbs. N/ac.
    b. If DAP or MAP, apply at 20 lbs. N/ac.
2. **Apply Organic Soil Amendment or Compost (optional, but recommended) -** Choose one of the following:
    a. Apply organic soil amendment (Biosol, Sustane, or equal) and incorporate during seedbed preparation.
    b. Apply compost and incorporate before seedbed preparation operations.
3. **Apply Humic Acid:** Apply humic acid (separately or with fertilizer) and incorporate during seedbed preparation.
4. **Prepare the seedbed**:
    a. Scarify.
    b. Disc.
5. **Drill Seed** – use a rangeland drill and apply Drill box seed to 0.5 inch depth, apply Small seed at 0.1 inch or to surface and lightly cover with drag chains or packer wheels or equal.
    a. **Mycorrhiza –** Apply a minimum of 1.2 million VAM spores per acre.
6. **Mulch** – Apply Grass Hay mulch at 2.0 tons/acre.
7. **Crimp** - Crimp immediately after mulching with a crimper implement. No discs allowed.
8. **Tackify** – Optional – tackify to minimize risk of mulch blowing into downwind neighbors and to hold soil and mulch in place until vegetation begins to establish.
9. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install.

II. **For areas with slopes equal to or greater than 3H:1V:**

1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP by hydroseeder or broadcasting.
    a. If Type 1, apply at 35 lbs. N/ac.
    b. If DAP or MAP, apply at 20 lbs. N/ac.
2. **Apply Organic Soil Amendment or Compost (optional, but recommended) -** Choose one of the following:
    a. Apply Biosol or Sustane or equal soil amendment and incorporate to the extent possible during seedbed preparation.
    b. Apply compost and incorporate before / during seedbed preparation operations.
3. **Apply Humic Acid:** Apply humic acid (separately or with fertilizer) and incorporate during seedbed preparation
4. **Prepare the seedbed** as necessary. Use slope chain, chain drags, dozer tracking, etc. as needed.
5. **Broadcast or Hydroseed** if four-wheel drive revegetation equipment pulling a rangeland drill cannot maintain traveling on the contour along the slope.
    a. **Mycorrhiza –** Apply a minimum of 1.2 million VAM spores per acre.
6. **Cover the seed** by Slope Chain, drag chain, raking, or similar method.
7. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.

8. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install.

III. **For areas with soil too wet to utilize revegetation equipment:**

1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP by hydroseeder or broadcasting.
    a. If Type 1, apply at 35 lbs. N/ac.
    b. If DAP or MAP, apply at 20 lbs. N/ac.
2. **Apply Organic Soil Amendment or Compost (optional, but recommended)** - Choose one of the following:
    a. Apply Biosol or Sustane or equal soil amendment and incorporate to the extent possible during seedbed preparation.
    b. Apply compost and incorporate before / during seedbed preparation operations.
3. **Apply Humic Acid:** Apply humic acid (separately or with fertilizer) and incorporate during seedbed preparation
4. **Hydroseed or Broadcast Seed** only if drill seeding is not practical.
    a. **Mycorrhiza** - Apply a minimum of 1.2 million VAM spores per acre.
5. **Cover Seed and Fertilizer** if possible by Slope Chain, drag chain, raking, or similar method. Will possibly be too wet to rake or drag to cover the seed and soil amendments, but best results can be expected when the seed is covered or otherwise pressed into the soil.
6. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.
7. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install. If continually wet, then wind fence would not be required.

For all of the above revegetation procedures, refer to the Revegetation Techniques section for details concerning proper methods, equipment, and application rates.

The Project Owner may use soil sample results to determine fertilizer application rates or may use the above generic application rates.

Wind Fence is suggested and should be installed if any reasonable potential exists for wind erosion damaging the finished revegetation work. Most projects in the Casper area will require wind fence.

Clay Seed Mixture:

COMMON NAME	VARIETY	APPLICATION RATE (PLS/Acre)	SEED BOX
Grasses:			
Western wheatgrass	Rosana	5.0	Drill
Streambank wheatgrass	Sodar	3.0	Drill
Slender wheatgrass	Revenue, Pryor	3.0	Drill
Blue grama	Bad River	2.0	Fluffy, Drill
Green needlegrass	Lodorm	1.5	Drill
Alkali sacaton	VNS, Northern	1.0	Small
Alkali grass	Fults	0.5	Small
Bottlebrush squirreltail	VNS, Northern	0.5	Drill
	Subtotal	16.5	
Forbs:			
Purple prairie clover	VNS, Northern	1.0	Drill
Blue flax	Appar	1.0	Drill
Indian blanketflower	VNS, Northern	1.0	Drill
	Subtotal	3.0	
	Total PLS/acre	19.5	

Small = Small seed drill box, Drill = Standard seed drill box, Fluffy = Fluffy seed drill box. When two seed boxes are named, Project Owner may select either or both boxes. If both, split seed for that species between the two boxes 50% to each.

Seed Mix Application Rates: These application rates are for drill seeding only. Although all areas accessible with a rangeland drill should be drill seeded, some broadcast seeding or hydroseeding may be necessary in areas which are too small, too steep, or otherwise inaccessible with standard four-wheel drive reclamation tractors and rangeland drill seeding equipment. Broadcast seeding or hydroseeding will be allowed if deemed necessary by the Project Owner based on the above limitations of standard drill seeding equipment. All broadcast seeded and hydroseeded areas should be seeded at double the seed application rate indicated in the seed mixture tables of this handbook.

If a species is not available, provide a suggested substitute to the City of Casper for approval. Utilize the advice of a revegetation expert. Alternatively, increasing all other species within the life form (Grass life form, Forb life form, Shrub life form) proportionately may be acceptable.

VNS, Northern – Variety Not Stated, seed should be from a northern latitude collection of this species such as Wyoming, Montana, Idaho, northern Utah, northern Colorado, Canada, etc.

LOAM REVEGETATION PLAN (L):

Use this seed mixture on loamy soil types such as loams, silty loams, sandy loams.

Revegetation Procedures to Use with the Loam Revegetation Plan:

I. **For flat or gently sloping areas with slopes less than 3H:1V:**
1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP with a commercial fertilizer spreader cart.
    a. If Type 1, apply at 35 lbs. N/ac.
    b. If DAP or MAP, apply at 20 lbs. N/ac.
2. **Prepare the seedbed**:
    a. Scarify.
    b. Disc.
3. **Drill Seed** – use rangeland drill and apply Drill box seed to 0.5 inch depth, apply Small seed to surface and lightly cover with drag chains or packer wheels or equal.
4. **Mulch** – Grass Hay mulch applied at 2.0 tons/acre.
5. **Crimp** - Crimp immediately after mulching with a crimper implement. No discs allowed.
6. **Tackify** – Optional – tackify to minimize risk of mulch blowing into downwind neighbors and to hold soil and mulch in place until vegetation begins to establish.
7. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install.

II. **For areas with slopes equal to or greater than 3H:1V:**
1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP by broadcasting.
    a. If Type 1, apply at 35 lbs. N/ac.
    b. If DAP or MAP, apply at 20 lbs. N/ac.
2. **Prepare the seedbed** as necessary
3. **Broadcast or Hydroseed** if four-wheel drive revegetation equipment pulling a rangeland drill cannot maintain traveling on the contour along the slope.
4. **Cover the seed** by Slope Chain, drag chain, raking, or similar method.
5. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.
6. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install.

III. **For areas with soil too wet to utilize revegetation equipment:**
1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP by hydroseeding or broadcast seeding..
    a. If Type 1, apply at 35 lbs. N/ac.
    b. If DAP or MAP, apply at 20 lbs. N/ac.
2. **Hydroseed or Broadcast Seed.**
3. **Cover Seed and Fertilizer** if possible. Will probably be too wet to rake or drag in but best results can be expected when the seed is covered or otherwise pressed into the soil.
4. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.
5. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install.

For all of the above revegetation procedures, refer to the Revegetation Techniques section for details concerning proper methods, equipment, and application rates.
The Project Owner may use soil sample results to determine fertilizer application rates or may use the above generic application rates.
Wind Fence is suggested and should be installed if any reasonable potential exists for wind erosion damaging the finished revegetation work. Most projects in the Casper area will require wind fence.

Loam Seed Mixture:

COMMON NAME	VARIETY	APPLICATION RATE (PLS/Acre)	SEED BOX
Grasses:			
Western wheatgrass	Rosana	5.0	Drill
Streambank wheatgrass	Sodar	3.0	Drill
Thickspike wheatgrass	Critana	2.5	Drill
Slender wheatgrass	Revenue, Pryor	2.0	Drill
Green needlegrass	Lodorm	1.5	Drill
Blue grama	Bad River	1.0	Fluffy, Drill
	Subtotal	15.0	
Forbs:			
Blue flax	Appar	1.0	Drill
Indian blanketflower	VNS, Northern	1.0	Drill
	Subtotal	2.0	
	Total PLS/acre	17.0	

Small = Small seed drill box, Drill = Standard seed drill box, Fluffy = Fluffy seed drill box

Seed Mix Application Rates: These application rates are for drill seeding only. Although all areas accessible with a rangeland drill should be drill seeded, some broadcast seeding or hydroseeding may be necessary in areas which are too small, too steep, or otherwise inaccessible with standard four-wheel drive reclamation tractors and rangeland drill seeding equipment. Broadcast seeding or hydroseeding will be allowed if deemed necessary by the Project Owner based on the above limitations of standard drill seeding equipment. All broadcast seeded and hydroseeded areas should be seeded at double the seed application rate indicated in the seed mixture tables of this handbook.

If a species is not available, provide a suggested substitute to the City of Casper for approval. Utilize the advice of a revegetation expert. Alternatively, increasing all other species within the life form (Grass life form, Forb life form, Shrub life form) proportionately may be acceptable.

VNS, Northern – Variety Not Stated, seed should be from a northern latitude collection of this species such as Wyoming, Montana, Idaho, northern Utah, northern Colorado, Canada, etc.

GRAVELLY / SHALLOW REVEGETATION PLAN (GL):

Use this seed mixture for course, gravelly soils with a large percent of large soil fragments and for ridges and sites with very shallow soils (minimal available topsoil).

Revegetation Procedures to Use with the Gravelly / Shallow Revegetation Plan:

I. **For flat or gently sloping areas with slopes less than 3H:1V:**

1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP with a commercial fertilizer spreader cart.
    a. If Type 1, apply at 35 lbs. N/ac.
    b. If DAP or MAP, apply at 20 lbs. N/ac.
2. **Prepare the seedbed**:
    a. Scarify.
    b. Disc.
3. **Drill Seed** – use rangeland drill and apply Drill box seed to 0.5 inch depth, apply small seed to surface and lightly cover with drag chains or packer wheels or equal.
4. **Mulch** – Grass Hay mulch applied at 2.0 tons/acre.
5. **Crimp** - Crimp immediately after mulching with a crimper implement. No discs allowed.
6. **Tackify** – Optional – tackify to minimize risk of mulch blowing into downwind neighbors and to hold soil and mulch in place until vegetation begins to establish.
7. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install.

II. **For areas with slopes equal to or greater than 3H:1V:**

1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP by broadcasting.
    a. If Type 1, apply at 35 lbs. N/ac.
    b. If DAP or MAP, apply at 20 lbs. N/ac.
2. **Prepare the seedbed** as necessary.
3. **Broadcast or Hydroseed** if four-wheel drive revegetation equipment pulling a rangeland drill cannot maintain traveling on the contour along the slope.
4. **Cover the seed** by Slope Chain, drag chain, raking, or similar method.
5. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.
6. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install.

III. **For areas with soil too wet to utilize revegetation equipment:**

1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP by hydroseeding.
    a. If Type 1, apply at 35 lbs. N/ac.
    b. If DAP or MAP, apply at 20 lbs. N/ac.
2. **Hydroseed or Broadcast Seed.**
3. **Cover Seed and Fertilizer** if possible. Will probably be too wet to rake or drag in but best results can be expected when the seed is covered or otherwise pressed into the soil.
4. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.
5. **Install Wind Fence** – Optional - Install wind fence perpendicular to the prevailing wind for the area. May be determined necessary by City of Casper and Project Owner will need to install.

For all of the above revegetation procedures, refer to the Revegetation Techniques section for details concerning proper methods, equipment, and application rates. The Project Owner may use soil sample results to determine fertilizer application rates or may use the above generic application rates. Wind Fence is suggested and should be installed if any reasonable potential exists for wind erosion damaging the finished revegetation work. Most projects in the Casper area will require wind fence.

Gravelly / Shallow Seed Mixture:

COMMON NAME	VARIETY	APPLICATION RATE (PLS/Acre)	SEED BOX
Grasses:			
Western wheatgrass	Rosana	3.0	Drill
Bluebunch wheatgrass	Secar	3.0	Drill
Thickspike wheatgrass	Critana	3.0	Drill
Streambank wheatgrass	Sodar	2.0	Drill
Indian ricegrass	Rimrock, Nezpar	1.0	Drill
Little bluestem	Camper	1.0	Fluffy
Sideoats grama	Vaughn, El Reno	1.0	Fluffy
Blue grama	Bad River	0.5	Fluffy, Drill
	Subtotal	14.5	
Forbs:			
Blue flax	Appar	1.0	Drill
Purple prairie clover	VNS, Northern	0.5	Drill
Wild lupine	VNS, Northern	0.5	Drill
Prairie coneflower	VNS, Northern	0.5	Drill
	Subtotal	2.5	
	Total PLS/acre	17.0	

Small = Small seed drill box, Drill = Standard seed drill box, Fluffy = Fluffy seed drill box

Seed Mix Application Rates: These application rates are for drill seeding only. Although all areas accessible with a rangeland drill should be drill seeded, some broadcast seeding or hydroseeding may be necessary in areas which are too small, too steep, or otherwise inaccessible with standard four-wheel drive reclamation tractors and rangeland drill seeding equipment. Broadcast seeding or hydroseeding will be allowed if deemed necessary by the Project Owner based on the above limitations of standard drill seeding equipment. All broadcast seeded and hydroseeded areas should be seeded at double the seed application rate indicated in the seed mixture tables of this handbook.

If a species is not available, provide a suggested substitute to the City of Casper for approval. Utilize the advice of a revegetation expert. Alternatively, increasing all other species within the life form (Grass life form, Forb life form, Shrub life form) proportionately may be acceptable.

VNS, Northern – Variety Not Stated, seed should be from a northern latitude collection of this species such as Wyoming, Montana, Idaho, northern Utah, northern Colorado, Canada, etc.

SANDY REVEGETATION PLAN (S):

Use this seed mixture in fine sands, loamy sands, and silty sands with flat to predominantly undulating slopes.

Revegetation Procedures to Use with the Sandy Revegetation Plan Mixture:

I. **Preferred Sequence: For flat or gently sloping areas with slopes less than 3H:1V:**
1. **Soil Amendments:** Apply composted manure or similar at the rate of 30.0 air dry tons/acre.
2. **Fertilize:** Apply Super phosphate and potassium with a commercial fertilizer spreader cart.***
    a. Apply Super phosphate (0-46-0) at 60 lbs. $P_2 0_5$/ac.
    b. Apply Potash (potassium; (0-0-60)) at 20 lbs. $K_2 0$/ac.
3. **Prepare the seedbed and mix soil amendments**:
    a. Scarify.
    b. Disc (see Revegetation Techniques for details: multiple discing passes may be necessary to properly mix soil amendments).
4. **Drill Seed** – use rangeland drill and apply Drill box seed to 0.5 inch depth, apply small seed to surface and lightly cover with drag chains or packer wheels or equal.
5. **Mulch** – Grass Hay mulch applied at 2.0 tons/acre.
6. **Crimp** - Crimp immediately after mulching with a crimper implement. No discs allowed.
7. **Tackify** – Optional – tackify to minimize risk of mulch blowing into downwind neighbors and to hold soil and mulch in place until vegetation begins to establish.
8. **Install Wind Fence** – Install wind fence perpendicular to the prevailing wind for the area.

II. **Alternative Sequence*: For flat or gently sloping areas with slopes less than 3H:1v:**
1. **Fertilize:** Apply Type 1 fertilizer or DAP or MAP with a commercial fertilizer spreader cart.
    a. If Type 1, apply at 35 lbs. N/ac.
    b. If DAP or MAP, apply at 20 lbs. N/ac.
2. **Prepare the seedbed**:
    a. Scarify.
    b. Disc.
3. **Drill Seed** – use rangeland drill and apply Drill box seed to 0.5 inch depth, apply small seed to surface and lightly cover with drag chains or packer wheels or equal.
4. **Mulch** – Grass Hay mulch applied at 2.0 tons/acre.
5. **Crimp** - Crimp immediately after mulching with a crimper implement. No discs allowed.
6. **Tackify** – Optional – tackify to minimize risk of mulch blowing into downwind neighbors and to hold soil and mulch in place until vegetation begins to establish.
7. **Install Wind Fence** – Install wind fence perpendicular to the prevailing wind for the area.

III. **For areas with slopes equal to or greater than 3H:1V:**
1. **Soil Amendments:** Apply composted manure or similar at the rate of 30.0 air dry tons/acre. **
2. **Fertilize:** Apply super phosphate and potassium (0-0-60) by hydroseeder or broadcasting.***
3. **Prepare the seedbed and mix soil amendments and fertilizer** thoroughly.
4. **Broadcast or Hydroseed** if four-wheel drive revegetation equipment pulling a rangeland drill cannot maintain traveling on the contour along the slope.
5. **Cover the Seed** by Slope Chain, drag chain, raking, or similar method.
6. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.
7. **Install Wind Fence** – Install wind fence perpendicular to the prevailing wind for the area.

IV. **For areas with soil too wet to utilize revegetation equipment:**
1. **Soil Amendments:** Apply Biosol or Sustane or equal at 1,200 bulk pounds per acre by hydroseeder or broadcasting.
2. **Fertilize:** Apply super phosphate and potassium (0-0-60) by hydroseeder or broadcasting.***
3. **Hydroseed or Broadcast Seed.**
4. **Cover Seed, Fertilizer, and Soil Amendments** if possible. Will probably be too wet to rake or drag in but best results can be expected when the seed is covered or otherwise pressed into the soil.
5. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.
6. **Install Wind Fence** – Install wind fence perpendicular to the prevailing wind for the area.

* Alternative Sequence requires the approval of the City of Casper.

** A reduced application rate may be necessary if the compost cannot be thoroughly mixed into the soil because of accessibility on the steep slope. Reduce rate to not less than 18 air dry tons/acre or substitute Biosol or Sustane at 1,800 lbs./acre and utilize a Slope Chain, drag chain, rake, or similar method when covering the seed and fertilizer.

*** If superphosphate or potassium (0-0-60) are not readily available, then substitute MAP or DAP at 20 lbs. N/acre or slow release Type I at 35 lbs. N/acre. If high available Nitrogen sources are suspected or utilized in the compost, then apply fertilizer with no nitrogen source.

For all of the above revegetation procedures, refer to the Revegetation Techniques section for details concerning proper methods, equipment, and application rates.

The Project Owner may use soil sample results to determine fertilizer application rates or may use the above generic application rates.

Sandy Seed Mixture:

COMMON NAME	VARIETY	APPLICATION RATE (PLS/Acre)	SEED BOX
Grasses:			
Prairie sandreed	Goshen	4.0	Drill
Thickspike wheatgrass	Critana	3.0	Drill
Western wheatgrass	Rosana	2.5	Drill
Indian ricegrass	Rimrock, Nezpar	2.0	Drill
Needleandthread *	VNS, Northern	1.0	Fluffy
Sand bluestem	Woodward	1.0	Fluffy
Little bluestem	VNS, Northern	1.0	Fluffy
Sand dropseed	VNS, Northern	1.0	Small
Blue grama	Bad River	0.5	Fluffy, Drill
	Subtotal	16.0	
Forbs:			
Blue flax	Appar	1.0	Drill
White evening primrose **	VNS, Northern	0.5	Drill
Firecracker penstemon	VNS, Northern	0.5	Drill
Wild lupine	VNS, Northern	0.5	Drill
	Subtotal	2.5	
	Total PLS/acre	18.5	

Small = Small seed drill box, Drill = Standard seed drill box, Fluffy = Fluffy seed drill box

* **Note**: needleandthread is a very desirable species for this soil type, but is expensive and also not highly desirable where the public can get the seeds in their shoes and clothes during early and midsummer. Also, not highly desirable for livestock during this same period. If not acceptable to the landowner, replace the needleandthread with sand bluestem or increase Indian ricegrass. Consult a Revegetation Specialist for recommendations.
** Substitute western yarrow if white evening primrose is unavailable or expensive.

Seed Mix Application Rates: These application rates are for drill seeding only. Although all areas accessible with a rangeland drill should be drill seeded, some broadcast seeding or hydroseeding may be necessary in areas which are too small, too steep, or otherwise inaccessible with standard four-wheel drive reclamation tractors and rangeland drill seeding equipment. Broadcast seeding or hydroseeding will be allowed if deemed necessary by the Project Owner based on the above limitations of standard drill seeding equipment. All broadcast seeded and hydroseeded areas should be seeded at double the seed application rate indicated in the seed mixture tables of this handbook.

If a species is not available, provide a suggested substitute to the City of Casper for approval. Utilize the advice of a Revegetation Specialist. Alternatively, increasing all other species within the life form (Grass life form, Forb life form, Shrub life form) proportionately may be acceptable.

VNS, Northern – Variety Not Stated, seed should be from a northern latitude collection of this species such as Wyoming, Montana, Idaho, northern Utah, northern Colorado, Canada, etc.

BLOW SAND REVEGETATION PLAN (BS):

Use this seed mixture in blow sand and dune sand type soils where native plant species are desired. Utilize the Blow Sand – Introduced /Native Species Seed Mixture for blow sand and dune sand soils where introduced plant species are acceptable. Stabilization is critical to the success of these site conditions as is proper seedbed preparation and soil amendments.

Revegetation Procedures to Use with Blow Sand Revegetation Plan:

I. **For flat or gently sloping areas with slopes less than 3H:1V:**
1. **Soil Amendments:** Apply composted manure or similar at the rate of 30.0 air dry tons/acre.
2. **Fertilize:** Apply Super phosphate and potassium (0-0-60) with a commercial fertilizer spreader cart***.
3. **Apply Humic Acid:** Apply humic acid (separately or with fertilizer) and incorporate during seedbed preparation.
4. **Prepare the seedbed and mix soil amendments and fertilizer**:
    a. Scarify or disc to mix soil and materials.
    b. Disc (see Revegetation Techniques for details: multiple discing passes may be necessary to properly mix soil amendments).
5. **Drill Seed** – use rangeland drill and apply Drill box seed to 0.5 inch depth, apply small seed to surface and lightly cover with drag chains or packer wheels or equal.
6. **Mulch** – Grass Hay mulch applied at 2.0 tons/acre.
7. **Crimp** - Crimp immediately after mulching with a crimper implement. No discs allowed. Crimp carefully to eliminate burying the seed in soft sandy soil.
8. **Tackify** – Optional – tackify to minimize risk of mulch blowing into downwind neighbors and to hold soil and mulch in place until vegetation begins to establish.
9. **Install Wind Fence** – Install wind fence perpendicular to the prevailing wind for the area.

II. **For areas with slopes equal to or greater than 3H:1V:**
1. **Soil Amendments:** Apply composted manure or similar at the rate of 30.0 air dry tons/acre**.
2. **Fertilize:** Apply super phosphate and potassium (0-0-60) by broadcasting***.
3. **Apply Humic Acid:** Apply humic acid (separately or with fertilizer) and incorporate during seedbed preparation.
4. **Prepare the seedbed and mix soil amendments and fertilizer** thoroughly.
5. **Broadcast or Hydroseed** if four-wheel drive revegetation equipment pulling a rangeland drill cannot maintain traveling on the contour along the slope.
6. **Cover the seed** by Slope Chain, drag chain, raking, or similar method.
7. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.
8. **Install Wind Fence** – Install wind fence perpendicular to the prevailing wind for the area.

III. **For areas with soil too wet to utilize revegetation equipment:**
1. **Soil Amendments:** Apply Biosol or Sustane or equal at 1,200 bulk pounds per acre by hydroseeder or broadcasting.
2. **Fertilize:** Apply super phosphate and potassium (0-0-60) by hydroseeder or broadcasting.***
3. **Apply Humic Acid:** Apply humic acid (separately or with fertilizer) and incorporate to the extent possible during step 5 below.
4. **Hydroseed or Broadcast Seed.**

5. **Cover Seed, Fertilizer, and Soil Amendments** if possible. Will probably be too wet to rake or drag in but best results can be expected when the seed is covered or otherwise pressed into the soil.
6. **Hydromulch**: Project Owner to select one of the following. Apply a. and b. with a hydroseeder.
    a. Hydraulic mulch fiber and tackifier.
    b. Bonded Fiber Matrix or equal.
    c. Erosion Control Blanket.
7. **Install Wind Fence** – Install wind fence perpendicular to the prevailing wind for the area.

For all of the above revegetation procedures, refer to the Revegetation Techniques section for details concerning proper methods, equipment, and application rates.

** A reduced application rate may be necessary if the compost cannot be thoroughly mixed into the soil because of accessibility on the steep slope. Reduce rate to not less than 18 air dry tons/acre or substitute Biosol or Sustane or equal at 1,800 lbs./acre and utilize a Slope Chain, drag chain, rake, or similar method when covering the seed and fertilizer.

*** If superphosphate or potassium (0-0-60) are not readily available, then substitute MAP or DAP at 20 lbs. N/acre or slow release Type I at 35 lbs. N/acre. If high available Nitrogen sources are suspected in the compost, then apply fertilizer with no nitrogen source.

Blow Sand Revegetation Plan – Native Species Seed Mixture:

COMMON NAME	VARIETY	APPLICATION RATE (PLS/Acre)	SEED BOX
Grasses:			
Prairie sandreed	Goshen	6.0	Drill
Indian ricegrass	Rimrock, Nezpar	4.0	Drill
Thickspike wheatgrass	Critana	3.0	Drill
Western wheatgrass	Rosana	2.0	Drill
Sand bluestem	Woodward	2.0	Fluffy
Needleandthread *	VNS, Northern	1.5	Drill
Sand dropseed	VNS, Northern	1.0	Small
	Subtotal	19.5	
Forbs:			
Blue flax	Appar	0.5	Drill
Prairie aster	VNS, Northern	0.25	Drill
Western yarrow	VNS, Northern	0.25	Small
Fringed sagewort	VNS, Northern	0.5	Fluffy
Wild lupine	VNS, Northern	0.5	Drill
	Subtotal	2.0	
	Total PLS/acre	21.5	

Small = Small seed drill box, Drill = Standard seed drill box, Fluffy = Fluffy seed drill box

* **Note**: needleandthread is a very desirable species for this soil type, but is expensive and also not highly desirable where the public can get the seeds in their shoes and clothes during early and midsummer. Also, not highly desirable for livestock during this same period. If not acceptable to the landowner, replace the needleandthread with sand bluestem or increase Indian ricegrass.

The Forb component in the seed mixture may be eliminated at the discretion of the Project Owner and City of Casper and the species in the grass component can be each increased proportionately to maintain the same total PLS/acre application rate. This will change the number of seeds per square foot, but enough seed will still be applied.

If a species is not available, provide a suggested substitute to the City of Casper for approval. Utilize the advice of a revegetation expert.

VNS, Northern – Variety Not Stated, seed should be from a northern latitude collection of this species such as Wyoming, Montana, Idaho, northern Utah, northern Colorado, Canada, etc.

Blow Sand Revegetation Plan – Introduced/Native Species Seed Mixture:

COMMON NAME	VARIETY	APPLICATION RATE (PLS/Acre)	SEED BOX
Grasses:			
Crested wheatgrass	Fairway	5.0	Drill
Prairie sandreed	Goshen	4.0	Drill
Indian ricegrass	Rimrock, Nezpar	4.0	Drill
Smooth bromegrass	Manchar	2.0	Drill
Needleandthread *	VNS, Northern	1.5	Drill
Sand dropseed	VNS, Northern	1.0	Small
	Subtotal	17.5	
Forbs:			
Blue flax	Appar	0.5	Drill
Prairie aster	VNS, Northern	0.25	Drill
Western yarrow	VNS, Northern	0.25	Small
Fringed sagewort	VNS, Northern	0.5	Fluffy
Wild lupine	VNS, Northern	0.5	Drill
	Subtotal	2.0	
	Total PLS/acre	19.5	

Small = Small seed drill box, Drill = Standard seed drill box, Fluffy = Fluffy seed drill box

* **Note**: needleandthread is a desirable species for this soil type, but is expensive and also not highly desirable where the public can get the seeds in their shoes and clothes during early and midsummer. Also, this species is not highly desirable for livestock during this same period. If not acceptable to the landowner, replace the needleandthread with additional crested wheatgrass.

Seed Mix Application Rates: These application rates are for drill seeding only. Although all areas accessible with a rangeland drill should be drill seeded, some broadcast seeding or hydroseeding may be necessary in areas which are too small, too steep, or otherwise inaccessible with standard four-wheel drive reclamation tractors and rangeland drill seeding equipment. Broadcast seeding or hydroseeding will be allowed if deemed necessary by the Project Owner based on the above limitations of standard drill seeding equipment. All broadcast seeded and hydroseeded areas should be seeded at double the seed application rate indicated in the seed mixture tables of this handbook.

If one species is not available, provide a suggested substitute to the City of Casper for approval. Increasing all other species proportionately may be acceptable.

VNS, Northern –Variety Not Stated, seed should be from a northern latitude collection of this species such as Wyoming, Montana, Idaho, northern Utah, northern Colorado, Canada, etc.

REVEGETATION TECHNIQUES

This section of the handbook provides the Project Owner and Operators with detailed information concerning proper revegetation techniques to be used within the City of Casper jurisdiction. Alternate techniques may be suggested by the Project Owner in writing for review by the City of Casper. Materials, equipment, application rates, and other important details for proper revegetation are included below. Use this section in conjunction with the previous Revegetation Plans section. While this handbook is not a complete document of everything there is to know about each of the techniques discussed, it provides a useful guideline for satisfactorily completing the revegetation techniques needed for successful reclamation and revegetation in our community.

The Project Owner (or his Contractor) shall conduct each revegetation procedure in the proper sequence as described below and in a continuous manner. Delays in the Project Owner's operations, at his convenience, resulting in damage to the prepared surfaces or lost material, should be repaired prior to continuing revegetation operations.

The Project Owner should protect revegetated areas from damage by construction traffic or equipment. Any area damaged from these causes needs to be repaired prior to continuing revegetation operations.

Materials must be shipped with all required certifications and certificates of inspection. The Project Owner must comply with regulations applicable to seed, fertilizer, soil amendments, mulch, and all other revegetation materials.

Provide material certifications for all materials supplied. Material certifications shall include the supplier's name, address, phone number, and other contact information and a statement from the supplier, signed and dated by an authorized representative of the supplier, concerning the guaranteed analysis of the materials supplied. The statements should include details as to the material's composition and specifications and other industry standards as applicable. Include the quantity of material delivered. Original documents should be provided to the City of Casper when the materials are delivered or may be submitted prior to delivery.

Material substitutions should be avoided if possible. If the Project Owner can demonstrate to the satisfaction of the City of Casper that the specified material is not obtainable, the Project Owner may suggest a substitution to the City of Casper or their representative for their approval. All substitutions must be approved by the City of Casper.

All seed, fertilizer, soil amendments, mulches, and other revegetation materials transported, distributed, or applied within the State of Wyoming are subject to inspection and analysis. Seed and fertilizer material must be in compliance with the Wyoming Seed Law, the Federal Seed Law, and the Wyoming Fertilizer Laws.

Revegetation procedures should be completed in a continuous manner, using different combinations of the following procedures: (1) fertilizing, (2) incorporating soil amendments, (3) preparing the seedbed, (3) drill seeding, hydroseeding, or broadcast seeding, (4) mulching, hydromulching, or installing erosion control fabrics, (5) crimping mulched areas, (6) tackifying, and (7) installing erosion control materials.

FERTILIZING

Fertilizing provides additional nutrients to plants once they have germinated. Most western USA soils are deficient in one or more of the macronutrients, Nitrogen, Phosphorus, and Potassium. Native plants have adapted to these deficiencies and can often survive and thrive in a nutrient deficient edaphic environment. Fertilizing is recommended by some and not recommended by others in the field of revegetation science.

The Project Owner is requested to utilize fertilizers according to the Reclamation Plans in this handbook. It is a small incremental cost and can improve vegetation establishment and growth, assisting in reducing risk of failure. On the other hand, the Project Owner may request to eliminate fertilizer application, but is responsible for end results and obtaining satisfactory vegetation communities.

Benefits

Fertilizers can provide additional nutrients to growing plants. These nutrients can help reduce plant stress, increase plant vigor, and enhance root development and above ground biomass production.

Materials

Fertilizers are available in several formats including liquid fertilizers and prilled or granular fertilizers. Prilled fertilizer is most often available and most often used and is available from local agricultural outlets. Small quantities can even be purchased from local hardware and home improvement establishments.

Blends of nitrogen (N), phosphorus (P), and potassium (K) are most often available to the consumer. Different mixtures can be blended to meet customer needs. The most appropriate method of discussing fertilizers is to use a ratio or percentage of each of the three macro nutrients and then specifying the pounds of available material of one of the components, usually nitrogen. For example, if the soil sample data indicated a need for 30 pounds of available nitrogen per acre and 15 pounds of available phosphorus, then a standard 2:1:1 blend might be used and would be applied at 30 pounds available nitrogen per acre and would additionally supply 15 pounds per acre of available phosphorus and 15 pounds per acre of potassium.

Nitrogen sources include urea, ammonium sulfate, ammonium nitrate, and others. Slow release versions including sulfur coated urea and others are often available or can be ordered by local suppliers. Applying a slow release product increases the cost per acre but also lengthens the time the nitrogen is available to the plants.

Phosphorus sources include mono-ammonium phosphate (MAP; 11-52-0), di-ammonium phosphate (DAP; 18-46-0), super phosphate (46-0-0), and others. Using MAP or DAP also provides nitrogen or at least a portion of the nitrogen that may be needed for the project.

Potassium sources generally include a commercially available source testing at 0-0-60 or 0-0-62.

In the above examples, the fertilizers are described as a percent of each of the three standard macronutrients, Nitrogen (N), Phosphorus (P), and Potassium (K), in that order. Thus, a 20-10-10 fertilizer is 20% available Nitrogen, 10% available Phosphorus, and 10% available Potassium. Fertilizers are also reported in a ratio for the macronutrients. For example, a 2:1:1 fertilizer has a ratio of 2 parts Nitrogen (available N) to 1 part Phosphorus (available P_2O_5) to 1 part Potassium (K_20).

To determine the amount of bulk material needed to provide the pounds of available Nitrogen desired, find out the percent of Nitrogen in the blend and divide that into the pounds of Nitrogen needed per acre. For example, if 30 pounds of N are needed and the blend available from the local supplier is 20-10-10, then 30 / 0.20 is 150. This means by applying 150 bulk pounds per acre, we are applying 30 pounds of N, 15 pounds of P, and 15 pounds of K per acre.

Having the analytical laboratory or the local supplier calculate materials needed based on the results of soil tests is one approach to providing fertilizer. Estimating what is needed for a site based on historical data and past experience is another good approach. As a general rule, a revegetation contractor can apply up to 30 or 35 pounds of available nitrogen per acre on dryland sites without danger of over applying the nitrogen component in the fertilizer. Care should be taken to not apply too much fertilizer and cause "burning". If MAP or DAP are used as the primary fertilizer, then applying up to 20 or 25 pounds of nitrogen per acre is probably appropriate. The amount of phosphorus per acre could then be fairly high, ranging from 51 to 118 pounds available P_2O_5.

Procedures

The fertilizer application rate can be determined from soil sample results or can also be estimated based on past experience in the region. Often a blend of 2:1:1 (N:P:K) will provide adequate fertilizer when applied at around 35 pounds of available N per acre. Applying MAP or DAP (see below) at 20-25 pounds of N per acre may be best suited for the site being reclaimed.

The nitrogen, phosphorus, potassium fertilizer blend shall then be broadcast by equipment specifically designed for application of granular fertilizer. Fertilizer may be applied either

before or after seedbed preparation, but may not be applied at the same time as drill seeding. Applying the fertilizer before seedbed preparation is recommended and makes it possible for the fertilizer to be incorporated into the root zone of the plants. Less fertilizer is lost to the atmosphere by volatilization.

To minimize the potential for burning plants, incorporate and thoroughly mix the fertilizers prior to seeding. Do not overwork the soil though, which will make the soil more susceptible to erosion from wind and precipitation events.

For hydroseeding and hydromulching methods, fertilizer can be applied prior to seedbed preparation, after seedbed preparation, during the hydraulic seeding step, or during the hydraulic mulching operations. Applying fertilizer prior to seedbed preparation is the most preferred method. Applying fertilizer prior to seedbed preparation, after seedbed preparation, or with the hydraulic mulch is preferred to mixing the fertilizer with the seed. If mixed with the seed, mix in fertilizers last and just before spraying. If the seed and fertilizer load cannot be sprayed out within 15 minutes after adding fertilizer, then utilize another method of applying fertilizer other than adding to the seed load. Damage to the seed by the fertilizer salts is possible when applied with the seed in a water solution.

Certified weigh slips for bulk fertilizer or tags or bags with the weight indicated for each bag shall be submitted to the City of Casper personnel prior to or during application. Guaranteed analysis of the fertilizer from the manufacturer shall be provided to the City Inspector along with the materials certification paperwork.

The Project Owner shall provide the City of Casper with weigh tickets (including loaded and tare weights) for each load of bulk fertilizer delivered to the site on the same day as the load of fertilizer is delivered or shall provide bags with weights indicated on the bags. A count of the bags used along with one example bag with appropriate tag information may be all that is necessary, depending on the desires of the City Inspector.

Application Rates:

Furnish the fertilizer blend as indicated in the Revegetation Plan and uniformly apply and incorporate fertilizer into the cover soil. Different application rates are suggested for different soils and different combinations of revegetation techniques and can best be determined from sampling the surface plant growth media prior to seeding, if time allows. Otherwise, use an application rate suggested in this Handbook. A number of fertilizers and fertilizer blends are common in the western states and include, among others: (1) 2:1:1 blend (Type 1), (2) di-ammonium phosphate (18-46-0), known as DAP, (3) mono-ammonium phosphate (11-52-0), known as MAP, (4) urea (56-0-0), and (5) ammonium sulfate (21-0-0).

Applying Fertilizer when no Manure is Used:

When applying fertilizer for disturbed areas when no soil sample data is available and no other soil amendments or fertilizers are used, choose between one of the following two blends: (1) Type 1 fertilizer blend (2:1:1) applied at 35 pounds available nitrogen per acre, or (2) MAP

(mono-ammonium phosphate; 11:52:0) or DAP (di-ammonium phosphate; 18:46:0) applied at 20 pounds available nitrogen per acre except as noted in the Revegetation Plans and 25 pounds available nitrogen per acre is recommended. Whenever MAP or DAP are recommended, also include potash (0-0-60) added and applied at 10 pounds K_20/acre (16.7 bulk pounds per acre) when readily available from the supplier (recommended but not required).

Applying Fertilizer when Manure is Used:

When applying fertilizer for disturbed areas when no soil sample data is available and soil amendments or compost are used, uniformly apply and incorporate fertilizer into the cover soil at a rate of Super phosphate (0-46-0) applied at 65 lbs. P_20_5/acre (141.3 bulk pounds per acre) and potash (0-0-60) applied at 10 lbs. K_20/acre (16.7 bulk lbs. per acre). Incorporate into the soil to a depth of approximately 6 - 8 inches.

If superphosphate and/or potash are not available when needed, then substitute MAP or DAP at 20-25 pounds available Nitrogen per acre. Note that this may provide too high of a level of available Nitrogen so caution is suggested. A slow release nitrogen source may be substituted. Consult a Revegetation Specialist for recommendations in such situations.

Calibration:

Calibrating fertilizer can be done using a number of different methods. Very technical and detailed methods can be used and might be recommended for the inexperienced. In other instances where experienced operators are used, proper calibration can be simple, easy, and accurate.

Calibrating Bulk Prilled Fertilizer:

Calibrating is usually fairly simple. The table on the spreader indicates the gate opening height depending on the pounds bulk material required to meet the desired application rate. The weight per cubic foot of fertilizer is usually needed to set the gate to the proper opening. This information is available from the supplier. Once the opening is set, the material can be spread. Care should be taken to make adjacent passes at the proper distances between passes. Spreaders are often designed for 30, 40, 50, or 60 feet spread width. To make calibration simple, request that the local supplier set the spreader cart for proper calibration when the spreader is delivered full of material to the project site.

Another method of bulk material calibration is to determine the amount of material needed per acre, then park the spreader over a large tarp. Jack up the tires on the spreader and measure the circumference of the tires. Drape a cloth or other item over the spreader distribution mechanism to limit distance of spread to the area of the tarp. Determine the number of revolutions required to travel the distance needed to apply the material to one acre. To determine this, divide 43,560 by the spreading width. (Example: If a spreader has a 40 foot spreading width, then divide 43,560 by 40 to get a distance of linear travel of 1,089 feet.) Then, either add the amount of material needed for an acre or some fraction thereof or if the spreader already contains material for the project, simply measure "applied" material as follows.

(Example: If a fertilizer is to be applied at 200 pounds per acre and in the interest of time, 0.5 acres is used to determine calibration, then add 100 pounds to the spreader.) Rotate the tires the necessary times for the spreader to cover the distance necessary to apply material to 0.5 acres. (For this example, 1089 lineal feet for an acre or half of that for 0.5 acres or 544.5 feet. Thus, if the tire circumference is 8.0 feet, then 544.5 divided by 8.0 feet is 68.06 revolutions of the tire.) Now, collect all the "applied" material off the tarp and weigh that material to compare the actual application to the desired application rate. Determine the percentage of the actual to the specified application rate and adjust the flow meter setting accordingly. (For example, if 125 pounds were applied in the above example, then the desired application rate to the actual application rate is 100 divided by 125 = .8 or 80%. Therefore, shutting the flow meter down to approximately 80% of the original setting may be appropriate, assuming the opening is linear and the size of the material does not affect flow. Thus, if the setting was at 4.0 originally, then 80% of 4 is 3.2. The new setting on the gate to recalibrate would be approximately 3.2.

In theory the above method of calibration seems most accurate, but in reality may or may not be as accurate as the first method where the experience of the operator and the supplier is relied on to determine the approximate proper application rate, adjusted as necessary on a site by site basis. The spreader in a static position (jacked up) does not necessarily simulate conditions as they occur on the ground such as bouncing and shaking and sideways movements that affect flow as it actually occurs. In addition, this method is very time consuming and can affect progress and hinder efficient completion of the project, usually during short seeding windows or during busy schedules.

Calibrating Bagged Fertilizer:

If bags are used instead of bulk fertilizer and a spreader as discussed above, then add bags into the spreading unit to equal bulk fertilizer for 1.0 acre. Measure an area totaling 1.0 acre (43,560 square feet) and apply the fertilizer to the test area. Observe the fertilizer remaining in the spreader to determine if any adjustment is necessary. The operator can estimate pounds of fertilizer remaining in the spreader and calculate a ratio between what was spread and what should have been spread to determine the amount of change needed in the gate opening. For example, if the equivalent of one 50 pound bag of fertilizer remains in the spreader following application on a 1.0 acre test plot where the application rate is 30 pounds of nitrogen per acre and the fertilizer is a 20-10-10 blend, and if 150 pounds were added originally for calibration, but only 100 pounds were used, then the gate needs to be opened to 150% of the original setting (150/100=1.5 or 150%). If the original setting on the gate is at 2, then the operator would most likely open the gate to 3 (2 X 1.5=3).

Fertilizer bags usually are provided in 40 or 50 bulk pounds per bag. Determine the number of bags needed per acre. For example, if the application rate is 30 pounds available nitrogen per acre and the fertilizer blend is 20-10-10, then determine the amount of bulk fertilizer needed by taking the pounds of available Nitrogen needed and dividing that number by the percent of Nitrogen in the bulk fertilizer blend (a 20-10-10 blend is 20% available Nitrogen) converted to a decimal (30/0.2 is 150). Therefore, 150 bulk pounds per acre are needed per acre to provide the 30 pounds of available nitrogen per acre and the operator would apply 3 fifty pound bags per acre or 3.75 forty pound bags.

Equipment

Fertilizer is generally applied with a broadcast implement specifically designed for applying granular fertilizers. Generally, fertilizer spreader carts are utilized and are available from local suppliers such as an agricultural co-op, fertilizer supplier, or similar organization.

The Operator will most likely need a tractor with a 540 PTO so that the spreader can be pulled behind the tractor and fertilizer spread in a uniform pattern. Most spreaders apply fertilizer with a dual spinner arrangement on the back of the spreader. This spinner is powered by the tractor PTO. The fertilizer is metered to the back of the spreader and to the gate opening just above the spinners. This floor chain feeds fertilizer through the gate. The gate is opened to the correct opening height depending on the weight of the material (pounds/cubic foot) and the application rate.

INCORPORATING SOIL AMENDMENTS

Soil amendments are normally not used for revegetation of dryland areas when native, perennial species are used in the seed mixture. If adequate soils are available, soil amendments are not necessary. Soil amendments include organic materials, lime, special fertilizers, soil conditioners, mycorrhiza, and other additives to the soil that are available to enhance vegetation establishment.

A number of different soil amendments may be recommended depending on soil chemical and physical characteristics. For example, blow sand type sandy soils can be stabilized by adding organic material, surface mulching, tackifying, and installing wind/snow fence. The organic material portion is addressed in this section.

Benefits

Organic amendments potentially enhance vegetative growth, both in above ground biomass production and in root development. Plant vigor is often enhanced and plant diversity and density can be improved. Organic amendments also tend to assist in holding the soil together and giving it "body" as well as reducing soil movement by wind and water.

Materials

Organic amendments include composted manure, dairy manure (not composted), livestock manure, city organic materials from the green industry including chipped branches, leaves, grass clippings, and similar plant materials, commercially available organic soil amendments (examples include Biosol and Sustane, two organic, slow release fertilizers), commercially available bark and wood chips, and city sewage sludge.

Compost:

Composted materials minimize the risk of live weed seeds being incorporated into the soils and causing later problems and costs to eradicate noxious and nuisance weeds. Whenever possible, use composted organic materials. When composted organics are not available, then use available sources, keeping in mind that the Project Owner needs to be responsible for controlling and eliminating noxious weeds on-site as well as other detrimental weeds, which can not only be spread from the weed seed source found in the organic materials incorporated into the project soils, but who's growth and development are enhanced by the rich nutrient sources of the organic materials in the soils.

Manure and similar compost products (including city waste from the green industry) are best measured as soil amendments by the number of air dry tons of organic material applied to the cover soil. However, often the materials are sold by the cubic yard. Often the supplier will have a conversion from cubic yards to tons. Usually this will be stated in tons on an air dry basis, but the actual material available may not be in an air dry condition because of recent precipitation events. Therefore, the Project Owner will need to convert compost delivered to the project to air dry tons when buying by the cubic yard or when buying by the wet ton. The section below, Calculating Air Dry Tons, provides details procedures and options for these calculations.

Livestock Manure:

Manure should be clean, well-aged cattle, sheep, pig, chicken, turkey, or horse manure. Manure should be reasonably free of weed seed, non-organic materials, and large organic pieces. Fresh manure should not be utilized or should be no more than 20% of a blend with aged manure. Manure sources may include dairy, feedlot, corral, or similar sources and should not contain more than 5% live organic matter (growing plants). Dry, powdery manure is preferred to wet, chunky manure. Chunky manure should be disced or otherwise reduced in size to allow uniform mixing in the soil profile.

Livestock manure that has been well composted is preferred to non-composted manure. Even if it has not been through a composting process, it is still better for this type of project than fresh manure. Good sources include cattle feeding operations. Manure should be free of sticks, stones, earth, weed seed, and substances injurious or toxic to plant growth. In most cases, visible amounts of undecomposed straw or bedding material are acceptable since the objective is to add organic material to the soils.

Commercial Organic Soil Amendments:

Commercially available organic sources known to enhance vegetation establishment and provide a slow release nitrogen source include products such as Biosol (7-2-3) and Sustane Natural Fertilizer (8-2-4). Other similar products exist on the market today. These products can

be used on plant growth media with poor macronutrient characteristics (N, P, K) and with very low organic matter content (less than 0.5%). These materials are more expensive than agricultural fertilizers on a per acre basis because considerably more material is generally applied per acre. We suggest using these soil amendments when soils are poor (Table 2) and for small sites and highly exposed areas where rapid stabilization is desired.

Under certain site conditions (see Revegetation Plans section), Organic Soil Amendments are suggested when incorporating the preferred compost is not possible.

Bark and Wood Chips:

Bark and wood chips are available commercially and are often waste products from the lumber industry. This material provides soil stabilization and adds organic material to the surface soils. Generally, a carbon: nitrogen imbalance is possible when these materials are utilized and applying and incorporating additional nitrogen may be necessary to reduce the imbalance. The Project Owner should provide the City of Casper with documentation concerning the need for nitrogen when this material is utilized. Contact a soil scientist, Revegetation Specialist, or material supplier to determine the need for additional nitrogen when these products are used.

Limit the use of fresh bark, saw dust, and wood chips to no more than 20% of the total material. Resins and other volatile components may restrict revegetation success. Utilize materials generally more than two years old. The better materials for use as an organic soil amendment are often more than ten years old and should be used when available.

City Sewage Sludge:

City sewage sludge can be very beneficial for nearly any disturbed site where soil quality is marginal or poor. In combination with VAM, vesicular arbuscular mycorrhiza, positive results have occurred on very poor soil conditions. Proper equipment and application methods are important to the success of the VAM, but the city sewage sludge can be applied and incorporated utilizing standard agricultural and reclamation equipment.

City sewage should be tested for quality characteristics and for potentially hazardous materials, heavy metal concentrations, salt levels, and other chemical attributes that would potentially cause negative impacts to the revegetation process and the long term land use of the reclaimed and revegetated site. Standard testing parameters are available in the city sewage sludge industry and certain criteria are required before this material can be utilized for agricultural or related purposes. The city supplying this material is generally aware of these requirements and this information is available from the City of Casper for their sewage sludge. Additional testing may be necessary as required by the City of Casper if other material is utilized.

Humic Acid:

Humic acid is a principal component of humic substances, major organic constituents of soil, coal, and other areas with high organic matter. Humic acid is produced from the breakdown of organic matter and is a combination of a number of different acids. Humic acids form complexes common in the environment and are commonly used as a soil supplement in agriculture to enhance plant growth and production.

Using Humic Acid in reclamation improves the structure of soil, increases plant yields, retains moisture, makes plants stronger and more pest resistant, and encourages aeration of the roots by providing plants with nutrients. Humic Acid also contributes to the conversion of minerals from an insoluble form to a soluble form.

Humic Acid encourages the growth and development of plants through an increased extraction of macro and micronutrients. On a biochemical level, Humic Acid helps increase the permeability of cell membranes, thus increasing the uptake and effectiveness of nutrients into the plant root system.

The list of positive impacts from humic acid is long and includes:

1. improving soil tilth, workability, aeration, and water filtration;
2. increasing water holding capacity, water uptake, and nutrient uptake;
3. stimulating above ground biomass, root development, and chlorophyll production,
4. providing a stimulus for beneficial soil microorganisms,
5. making macro and micro nutrients available to plants,
6. assisting in pest and disease defense, and
7. reducing absorption of toxic materials.

Humic acid is not new to the reclamation industry or agriculture community, but has not been used as extensively in reclamation as it has in agriculture for crop production. Per acre costs have become very reasonable and material is now readily available. Humic acid, in combination with mycorrhiza and other soil amendments, can be very beneficial for revegetating poorer quality soils.

Apply humic acid in a granular product meeting the following minimum standards:

1. 6% minimum Humic Acid by analysis.
2. Other nutrients and Fulvic Acid are acceptable but not included in the calculation for percent of useable material.
3. Uniform, free flowing granular material capable of being uniformly dispensed in the implement being utilized for application.

Sources of humic acid may include Geotec, Casper, Wyoming; Granite Seed, Lehi, Utah; Riverton Agricultural Services, Riverton, Wyoming; and local farm supply stores.

Mycorrhiza:

Mycorrhiza are fungi that attach to vascular plant roots and provide a mutually beneficial relationship between the plant and the root fungus. Mycorrhiza are specialized fungi that colonize plant roots and extend far into the soil with filaments that are truly extensions of the root systems and are very effective in nutrient and water absorption, even more so than the roots themselves. More than 90 percent of plants form a symbiotic relationship with mycorrhiza.

Mycorrhizal fungi are advantageous in that they increase the root system's surface absorbing area from 100 to a 1,000 times that of the plant's own root system, significantly enhancing the plant's ability to obtain soil nutrients. In addition to the miles of filaments used to absorb available nutrients, mycorrhiza release enzymes into the soil that dissolve difficult to obtain nutrients (organic nitrogen, phosphorus, iron, and other tightly held soil macro and micro nutrients.

Undisturbed soils generally have sufficient quantities of mycorrhiza and other beneficial soil organisms. When these soils are disturbed, populations decrease significantly. Endo mycorrhizal fungi recolonize slowly and some sort of source is needed to speed up the repopulation process. Adding mycorrhizal fungi spores during revegetation can dramatically improve plant performance and speed up the revegetation process, thus reducing risks of soil erosion and degradation of on-site and off-site environments.

Procedures

The Project Owner / revegetation contractor may apply soil amendments such as compost, manure, and similar products with any equipment that will evenly spread the material on the soil surface. A loader is generally not an acceptable method of spreading these materials nor is a motor grader. Even distribution is all but impossible utilizing this equipment.

Immediately after applying the organic material, incorporate the amendments into the plant growth media. Incorporation is best done utilizing a tandem disc or rototiller (rototillers are not expected to be used, but might prove to be the best method on small areas). The best procedure generally is to scarify or rip to a 12 inch depth on no more than 18 inch centers (12 inch between rip rows recommended) and then disc to further mix the amendments. If soils are compacted or cloddy or smaller revegetation equipment is used, then additional passes to mix and incorporate the amendments will most likely be necessary.

Areas used for stockpiling soil amendments need to be cleaned up thoroughly to eliminate concentrations of the organic material, which in turn may prohibit plant germination and growth on areas with concentrations of the soil amendments.

Once the amendments are applied and mixed in the soil, the area is ready for the next steps, seedbed preparation and seeding.

Application Rates:

Application rates may vary, depending on type of soil amendment and soil physical and chemical characteristics. Heavier rates are recommended in saline clay, sandy soils, or subsoil material being used as the plant growth media.

Compost, Manures, and City Sewage Sludge:

Compost, manures, and city sewage sludge are often applied at 25-30 air dry tons of material per acre. For sandy and blow sand soils, 30 air dry tons per acre is preferred. For non-topsoil material being developed as a plant growth media, apply and incorporate 30 air dry tons per acre. Bark and wood chips are usually applied at 25 to 30 dry tons per acre along with an appropriate amount of nitrogen to balance the carbon to nitrogen ratio.

An air dry ton is a ton of manure that is as dry as it can be under normal dry weather conditions and usually has less than approximately 10 – 15% moisture. If wet manure is delivered to the project, determine the average amount of moisture and calculate the amount of air dry material actually delivered. Moisture probes are available to test materials for percent moisture. Procedures for calculating air dry tons are detailed in the next section.

Organic Soil Amendments:

Commercially available amendments such as Biosol and Sustane or equal are applied at 1,200-1,800 bulk pounds per acre. Apply at 1,800 pounds per acre unless stated differently in the Revegetation Plans or a different rate is approved on a case by case basis. The Project Owner may submit a written request for an application rate change if the Project Owner wishes to document the need for an alternative application rate.

Humic Acid:

Humic acid can be applied as a liquid or in a dry format as a granule or prill. Apply at the rate of 12.0 pounds/ acre of a 6% Humic Acid product utilizing any professional application process. Humic acid can be applied with the seed and mycorrhiza through the drill seeder or it can be applied with the fertilizer or it can be applied alone or can be added to the hydroseeding load. Calibration will be necessary to account for this added material to the seed mixture.

Mycorrhiza:

Mycorrhizae are microscopic fungi that form a symbiotic relationship with vascular plant root systems and enhance the plant's ability to survive and grow in poor plant growth media. Several companies in the western USA have developed formulations of a number of different mycorrhizal species that have been proven to be effective in enhancing plant establishment and growth.

Species specific to western USA native dryland plant species should be used for the mycorrhiza source. VAM or vesicular arbuscular mycorrhiza are produced commercially and should have a guaranteed number of live spores exceeding 400,000 per liter of material or 60,000 spores per pound or equivalent or can guarantee 1.2 million spores / acre. Live, propagating parts are not

considered in determining the application rate; only live spore counts are to be used to supply the 1.2 million spores / acre requirement.

To enhance the potential for both short term and long term revegetation success, apply a minimum of 1.2 million live spores of mycorrhiza (VAM) per acre to non-topsoil materials and areas receiving heavy rates of composted manure or other organics as detailed in the Revegetation Plans section of this handbook. Response to this technique is highest when VAM spores are placed slightly below the seed when it is placed in the soil profile. For example, if the seed is drilled to a depth of 0.5 inches, then the VAM spores need to be somewhere between 0.5 and 1.5 inches deep, immediately below the seeds. This is generally not possible with current revegetation technology so applying the mycorrhiza with the seed is an acceptable alternative.

Calculating Air Dry Tons:

Calculating air dry tons may be done in the following manner. Bulk tons delivered X conversion factor to air dry % = air dry tons. For example: 200 bulk tons delivered with test results averaging 25% moisture and assuming an air dry percentage of 15%, then 25%-15% = 10% or approximately 10% too much water in the manure that does not get counted toward the total tonnage delivered. Thus, 200 bulk tons X 0.90 (100%-10%=90% converted to a decimal) = 180 tons of air dry material delivered.

Since the City of Casper is interested in dry tonnage applied, the Project Owner needs to provide the appropriate dry tons as requested in the Revegetation Plans. At least four methods are available:

1. The Project Owner can collect samples of manure delivered to the site and have the samples tested to determine the equivalent air dry weight basis for each load. The analysis can be performed at delivery, utilizing portable moisture testing equipment.
2. The Project Owner may also test the moisture content of the material at the time the material is delivered and can pull samples and send the samples to an independent lab for analysis. Take at least one sample per truck load. This slows down the revegetation process and progress may linger several days waiting on test results. Calculations to determine air dry material delivered are the same as the first method above.
3. The Project Owner may sample the supplier's stockpiles to determine estimated moisture content before initiating trucking operations to deliver the material. This procedure minimizes the down time waiting on test results if samples are sent to a laboratory for determining moisture content.
4. The supplier may provide information that states the approximate moisture content. The City of Casper may then agree to a percent moisture average for the project. This number is likely to vary from time to time, depending on recent precipitation events. This method eliminates the need for testing and the time lost in testing and waiting for test results and is recommended when good data are available from the supplier and/or good estimations are possible by the Project Owner or his representative and those estimations are acceptable to the City of Casper.

The Project Owner will need to provide the City of Casper with weigh tickets (including loaded and tare weights) for each load of manure delivered to the site.

To simplify the above process, especially when the material is purchased by the cubic yard, the Project Owner and the City of Casper can agree on the amount of material incorporated based on volume delivered (cubic yards, for example). This simplifies the process for all concerned because only the number of loads of material times the cubic yards per load need be recorded and a calculation made to determine volume of material to be incorporated per acre. For example, if the supplier states that one cubic yard of the material weighs approximately 1,000 pounds (air dry weight), then it will take two cubic yards per air dry ton. If 30 air dry tons/acre are requested, then 30 X 2 = 60 CY of material should be incorporated per acre. If each truckload is 20 CY, then for this example, it would take three truckloads per acre (60 CY per acre divided by 20 CY per truckload = 3 loads/acre). If good volume to air dry weight information is available from the supplier, then sampling for air dry weight as described above may only be necessary following local precipitation events.

Calibration:

Calibrating soil amendments can be done using a number of different methods. Very technical and detailed methods can be used and might be recommended for the inexperienced. In other instances where experienced operators are used, proper calibration can be simple, easy, and accurate.

Calibrating Bulk Materials:

At least two calibrating methods are available as described below. The two methods discussed in this handbook can be altered to fit specific situations and operators.

If experienced operators are providing revegetation services, then the following procedure is acceptable. Bulk soil amendments can be calibrated by measuring a given area, such as 1.0 acre and then measuring the amount of soil amendment applied to that acre. Once a test area is determined, add the appropriate amount of soil amendment for that surface area. For example, if each acre requires 1,000 bulk pounds of a soil amendment, then put 1,000 pounds of the soil amendment in the spreading unit and determine a setting for the flow meter. Apply the soil amendment and when about 25% done, stop and check the spreader to determine if approximately 25% of the material has been used. If it seems close, then proceed to the halfway point and recheck. Make adjustments as necessary. If an adjustment is made, then once the first test area is completed, a new test area should be measured and the new area should receive the soil amendment at the new flow meter setting. Repeat until no adjustments are necessary.

If less experienced operators are providing revegetation services, then the following procedure is recommended. First, determine the amount of material needed per acre, then park the spreader over a large tarp. Jack up the tires on the spreader and measure the circumference of the tires. Drape a cloth or other item over the spreader distribution mechanism to limit distance of spread to the area of the tarp. Determine the number of revolutions required to travel the distance needed to apply the material to one acre. To determine this, divide 43,560 by the

spreading width. (Example: If a spreader has a 40 foot spreading width, then divide 43,560 by 40 to get a distance of linear travel of 1,089 feet.) Then, either add the amount of material needed for an acre or some fraction thereof. (Example: If a soil amendment is to be applied at 1,000 pounds per acre and in the interest of time, 0.5 acres is used to determine calibration, then add 500 pounds to the spreader.) Rotate the tires the necessary times for the spreader to cover the distance necessary to apply material to 0.5 acres. (For this example, 1089 lineal feet for an acre or half of that for 0.5 acres or 544.5 feet. Thus, if the tire circumference is 8.0 feet, then 544.5 divided by 8.0 feet is 68.06 revolutions of the tire.) Now, collect all the "applied" material off the tarp and weigh that material to compare the actual application to the desired application rate. Determine the percentage of the actual to the specified application rate and adjust the flow meter setting accordingly. (For example, if 400 pounds were applied in the above example, then the desired application rate to the actual application rate is 500 divided by 400 or 125%. Therefore, opening the flow meter to approximately 125% of the original setting may be appropriate, assuming the opening is linear and the size of the material does not affect flow. Thus, if the setting was at 4.0 originally, then 125% of 4 is 5. The new setting to recalibrate would be approximately 5.

In theory the above method of calibration seems most accurate, but in reality may or may not be as accurate as the first method where the experience of the operator and the supplier is relied on to determine the approximate proper application rate, adjusted as necessary on a site by site basis. The spreader in a static position (jacked up) does not necessarily simulate conditions as they occur on the ground such as bouncing and shaking and sideways movements that affect flow as it actually occurs. In addition, this method is very time consuming and can affect progress and hinder efficient completion of the project, usually during short seeding windows or during busy schedules.

Calibrating Bagged Materials:

If bags are used instead of bulk soil amendments and a spreader as discussed above is used to apply the material, then add bags into the spreading unit to equal the bulk soil amendment for 1.0 acre. Measure an area totaling 1.0 acre (43,560 square feet) and apply the soil amendment to the test area. If the operator is unsure of where to set the spreader metering devise, he can consult his supplier for instructions. Observe the soil amendment remaining in the spreader to determine if any adjustment is necessary. The operator can estimate (or scoop up and weigh) the pounds of soil amendment remaining in the spreader and calculate a ratio between what was spread and what should have been spread to determine the amount of change needed in the gate opening. For example, if the equivalent of two 50 pound bags of soil amendment remain in the spreader following application on a 1.0 acre test plot where the application rate is 1,000 pounds, then the gate or metering devise needs to be opened to 110% of the original setting. If the original setting on the gate is at 2, then the operator would most likely open the gate to 2.2.

Organic Soil Amendments are usually provided in 50 bulk pound bags. Determine the number of bags needed per acre. For example, if the application rate is 1,800 pounds of Organic Soil amendment (Biosol, Sustane, or equal) per acre and the bags weigh 50 pounds each, then 36 bags should be applied per acre. Utilize one of the test methods described above (Calibrating Bulk Materials).

Equipment

Apply manure and similar products with any equipment that will evenly spread the material on the soil surface. Heavy duty agricultural manure spreaders, especially those made for commercial applications, and similar organic material distribution equipment, work well for most organic amendments. A commercial prilled fertilizer spreader cart or hydroseeder work well for applying the commercially available products such as Biosol and Sustane. Loaders and motor graders are generally not an acceptable method of spreading these materials. Even distribution is difficult utilizing this equipment.

Rangeland drills, small broadcasters, and hydroseeders can be used to apply Humic Acid and Mycorrhiza. See the Revegetation Plans section for details on when to apply these amendments.

Following application, most soil amendments must be incorporated utilizing scarifiers and discs as described in the next section.

PREPARING THE SEEDBED

Proper seedbed preparation is key to successful revegetation and erosion control. Inadequate seedbed preparation will most often lead to revegetation failure or spotty results that are less than satisfactory. The Project Owner should always provide funding for adequately preparing the soils for seeding. Providing a mellow seedbed is essential. The plant growth media should be mellow or in a state somewhere between firm and loose and fluffy. The soil should be loose enough to allow water penetration and percolation, yet firm enough to hold the seed at the desired elevation in the soil profile and provide for proper contact of the seed with the mineral soil without being compacted and hard. The following seedbed preparation techniques are generally most appropriate prior to drill seeding dryland species.

Benefits

The objective is to have a mellow seedbed, allowing the seeds to be in full contact with the mineral soil to the extent possible. In addition, the soil should be prepared to a depth such that crimping can be done adequately (mellow soil for about 6 inches for best results) and so that potential hard pans or compacted layers in the first 8 or more inches are eliminated to the extent possible to assist with appropriate root development.

Procedures

The disturbed areas should be scarified to a 12 inch depth when possible, followed by discing on the contour for sloping areas and perpendicular to the prevailing wind on flat areas to a

minimum depth of 8 inches, leaving definite furrows and providing a mellow, uncompacted seedbed. Roller packing may be used instead of discing, depending on soil conditions.

Note that seedbed preparation requires both scarifying and discing (or roller packing) in most cases on slopes less than 3H:1V, although on soft soils or sandy soils, it is possible that only one operation is necessary and even possible that no seedbed preparation should be done. If the soil is already in a mellow state to a depth of 8 inches, then no seedbed preparation would be necessary. Working sandy soils too much may be detrimental and cause them to erode and blow more readily. When soil amendments are applied, incorporate thoroughly.

Equipment

Seedbed preparation equipment for revegetation includes scarifiers, discs, roller harrows, chain harrows, and similar implements that change the characteristics of the surface plant growth media into an environment appropriate for planting seeds and holding mulch and erosion control materials. Well-designed seedbed preparation implements are capable of withstanding the rigors of difficult terrain including rocky soils, uneven terrain, and steep slope gradients.

Scarifying:

To the extent possible, scarifying should be done on the contour or perpendicular to prevailing winds on flat areas. Equipment capable of penetration to a depth of 12 inches is needed and spaces between scarifier teeth should be close enough to provide for complete fracturing of the soils between rip marks. Generally, scarifier teeth on 18 inch spacing or closer will accomplish this fracturing when scarifying to a 12 inch depth although in some tight soils, several passes might be needed to adequately loosen compacted soils. On rocky soils, scarifying should be done to shallow depths of only a few inches to minimize bringing rocks to the surface.

Discing:

To the extent possible, discing should be done on the contour or perpendicular to prevailing winds on flat areas. Equipment should be able to properly disc the soil to a depth of eight inches. Heavy duty discs with 20" disc blades (coulters) generally are needed to get adequate penetration on finer textured soils. Generally disc blades should have 9 inch or closer spacing between blades although some large, construction discs have blades with twelve inches or more between blades. In this case, when the large construction disc is utilized, roller packing or tandem discing may be necessary following the heavy discing operation to properly prepare the seedbed.

Roller Packing / Roller Harrowing:

Roller Packing, like scarifying and discing, should be done on the contour or perpendicular to the prevailing winds on flat areas. Roller packers, also known as roller harrows and cultipackers, are generally found in the agricultural industry and can vary in width. A ten or twelve foot wide roller packer is recommended compared to the wider units to help assure uniform soil preparation. Utilize roller packers when soils need firmed to provide a mellow seedbed. If soils

are too soft and fluffy, seed may not remain at seeded depths and mulching and crimping activities may bury seed.

Roller packers may have either one or two rollers the full width of the implement. Generally a pull type roller packer has a front roller, chisel teeth in the center, and a back roller. Roller surface configurations vary and are long, round cylindrical sections with a diameter of 12 to 20+ inches.

Chain Harrowing:

When possible, utilize chain harrowing or a similar seedbed preparation technique prior to broadcast seeding on areas needing soil manipulation to provide an adequate seedbed but that are inaccessible with standard revegetation equipment. Chain harrows, also called English harrows, are used on steep slopes where access with a tractor to work the slopes on the contour is not possible but an ATV or four wheel drive tractor can prepare the seedbed up and down the slope. Sometimes this same implement can be used to cover seed, fertilizer, and soil amendments after broadcast applications. The operator would need to change the settings / positioning to a less aggressive configuration so the seed is not incorporated too deep into the soil profile.

Slope Chaining, Chain Dragging, and Raking:

Seed applied by broadcast seeding or by hydroseeding should be covered as soon as possible after seeding operations. Chain dragging and raking are the methods used most often on steep slopes, inaccessible to standard revegetation equipment. Slope chaining is an excellent soil manipulation procedure, but is seldom used because of the infrequent availability of this equipment.

Slope chains are difficult to obtain although a few exist in the western USA. Slope chains are comprised of a large metal disc at the base with a swivel attached to a heavy "boat anchor" chain 30 or more feet in length. Welded to the links of the chain are round rods the act to churn and loosen the soil as the unit is rolled along a steep slope from above by a tractor or other power unit. The disc at the base of the hill moves with the tractor at the top of the slope and the soil is worked and loosened for seeding. The slope chain can even be used following seeding to lightly cover the seed if the operator is careful and proceeds slowly.

Chain drags are any assortment of chains either drug along slopes by hand or attached to some sort of power equipment. Chains are often 5/16" or 3/8" diameter links and can be any length, depending on the ability of the person or power unit to pull or drag the chain.

Raking seeded slopes is a labor intensive method of covering seed, but is relatively effective. Care should be taken by the laborers to minimize dragging seed down slope or dragging seed off high spots and concentrating that seed in the low spots. Although usually not practical, raking grass seed labeled for the Drill box (see seed mixture tables in the Revegetation Plans section) should be raking into the soil while seed labeled for Small box or Fluffy box should be lightly raked into the soil.

All of these and other methods used to cover broadcast or hydroseeded seed, fertilizer, and amendments should be initiated as soon after the materials are spread as possible to minimize negative impacts from wind and water erosional forces, from damage by rodents and birds, and from injury from heat and sunlight.

SEEDING

Three types of seed application methods are generally utilized in revegetation of dryland sites in the semi-arid western USA. These methods include drill seeding, broadcast seeding, and hydroseeding.

Drill seeding is the preferred method for applying and incorporating the seed into the soil surface. Other methods of seeding should only be used when drill seeding is not possible. Steep slopes (steeper than 3H:1V), wet, boggy areas, and small, tight areas inaccessible with standard revegetation equipment will most likely dictate the need for utilizing a seeding method other than drill seeding.

Drill Seeding

For best results, drills should be rangeland style drills and should be capable of applying the seed in uniform rows with the spacing not to exceed twelve inches, although 8 inches and less is more standard and generally preferred. The drills should be capable of distributing the seed at the specified application rate consistently and uniformly. The seed mixture should be applied at the application rate indicated in the seed mixture tables with adjustments as necessary to address particular site conditions and seed availability.

Avoid drills incapable of handling small or fluffy seed. Do not use drills that plug or do not have a good method of controlling seeding depth for the different seed types.

Drill Seeder Application Rates:

Seed mixtures should be applied at the drill seed application rates in the Revegetation Plans section of this handbook. Drill seeding is the most efficient type of seeding and about half the seed is required for drill seeding compared to broadcast and hydroseeding. Application rates in the seed mixtures are designed to address more than soil type including equipment efficiency, operator error, wind, wildlife impact, and related factors that often negatively impact seed placement and survival.

Drill Calibration:

Calibrating the drill at the beginning of drill seeding operations is necessary for each seed mixture. Continual checking and adjusting the drill settings may be necessary, depending on uniformity of the mixed seed, humidity, dust and trash accumulation in the drill metering system, and variability in the roughness of the surface.

Drills can be calibrated by a number of different techniques. Drill manufacturers generally can provide new operators with their recommended method.

For experienced drill seeding equipment operators, the following method is usually acceptable. First, carefully measure a 1.00 acre test area. Read the drill acre meter, if one exists on the drill, and record the reading to the nearest tenth or one hundredth if that degree of accuracy exists or can be interpolated or estimated.

Then, clean the drill of all old seed and debris and place a small known quantity of seed evenly across the bottom of the drill boxes to an even, level height above the floor of the drill box or boxes. Mark this level on the inside of the box(es). Then add one acre of seed to the drill, utilizing the Drill box and one or more other boxes if the Fluffy box and / or Small box are being calibrated as well. The level at that time should be marked or at least noted. If the operator has used this seed mixture or a similar one in the past, then the setting should be similar, depending on seed purity and germination. The operator then begins drill seeding and checks his drill box seed level every few minutes to see if an adjustment to the flow control setting is necessary. If the seed is feeding too quickly, then the operator needs to reduce the flow by whatever method is required of the drill being used. If the seed is feeding too slowly, then the operator needs to increase the flow setting. A rule of thumb is to estimate the percent the seed is being metered either too fast or too slow and make a like adjustment to the flow setting.

Once the operator drill seeds the 1.00 acre test area, the seed level in the drill box is carefully compared to the original level as marked to determine what adjustments are necessary to accurately meter the seed. If seed still remains above the mark at the end of the one acre test, then that seed can be removed and weighed. A ratio of seed removed to the pounds of seed for one acre can be calculated and converted to a percentage. The drill flow setting can then be adjusted appropriately. For example, if, after the initial seed is place in the bottom of the drill, 15 bulk pounds are added to the Drill box and 10 bulk pounds are added to the fluffy box for one acre of seeding and the test area is seeded. The Drill box and Fluffy box seed level are checked and the seed level is above the mark in the Drill box and below the level in the Fluffy box. Remove the extra seed in the Drill box and weigh it. If, for example, 3 bulk pounds remain above the mark, then the drill under seeded by about 20% (3/15=0.20). If the flow setting is linear, then reducing the setting by about 20% may be an accurate adjustment. Seed size compared to flow opening could affect this method and experience will provide the best source for flow adjustment. For the Fluffy box, remove the balance of the seed and determine how much too much was applied. If, for this example, one pound too much was applied, then 10% too much seed was applied (1/10=0.1 or 10%). Adjust the setting for this box to reflect a 10% reduction in seed application rate, with the same precautions as mentioned above for the Drill box.

In addition to checking the seed level at the end of seeding the 1.00 acre test area, the drill meter should be reread. If it does not indicate exactly 1.0 acres, then a conversion factor must be determined. For example, if the drill meter reads 0.8 acres seeded and the entire 1.00 acre test area is drill seeded, then a conversion factor of 1.25 must be used. Divide the acres actually seeded (1.00 in this case) by the acres indicated on the drill acre meter (0.80 in this case). The result (1.00/0.80 = 1.25, in this example) is then used to determine actual acres seeded. Take the

drill acre meter reading and multiply it by the conversion factor (1.25 in this example.) Thus, if the meter reads 3.0 acres after seeding a bag of seed, for example, then the drill has actually seeded 3.75 acres (3.0 X 1.25 = 3.75). To verify the accuracy of the first calibration, measure an additional 1.0 or 2.0 acre area for rechecking the calibration of both the seed application rate and the drill acre meter accuracy.

Seeding Depth:

The depth of drilling must be maintained at the proper depths for the seed species being planted. In theory, the sandier the soil, the deeper to plant the seed and conversely, the finer the soil texture (silts and clays), the shallower the seed should be planted. In reality, because seed tends to work its way down into sandy soil during mulching and crimping operations, plant the seed in sandy soil shallow as well. Most larger seed should be planted at 0.25 to 0.5 inches in heavy textured soils and 0.5 inches or slightly more in sandy and course soils unless they are loose, then plant at less than 0.5 inches.

Some seeds (such as sand dropseed, alkali sacaton, and big sagebrush) are so small they should only be dropped on the soil surface and carefully either pressed into the soil by the packer wheels or lightly covered by small drag chains. Otherwise, for most other species, the seed should be covered by packer wheels or cover chains attached to the drill.

Plant species listed in the seed mixtures in the Revegetation Plans are categorized in the far right hand column of the seed mixture tables into Drill, Fluffy, or Small under the heading Seed Box. Seeds listed as Drill should be planted to about a 0.25 to 0.5 inch depth, depending on soil conditions, and seeds listed as Fluffy or Small should be planted at the surface or within $1/16^{th}$ inch of the soil surface to the extent possible. These seeds should then be firmed into the soil with packer wheels or slightly covered with light drag chains.

Types of Drills:

Only rangeland drills are recommended. A number of quality rangeland drills are manufactured in the USA and can be researched on the internet or priced from local dealerships. Light duty farm drills and drills in poor working condition are not acceptable and should be avoided. These drills tend to have mechanical problems which generally lead to poor seed application and placement, resulting in sub-standard seed germination and vegetation establishment. Turf grass type seeders can be utilized but may have difficulty seeding in rough and rocky terrain and may be subject to considerable damage and need for repair. Most of these types of seeders are incapable of seeding fluffy and trashy seed and should be avoided.

Rangeland drills capable of seeding a variety of seed types are best for the complex native seed mixtures utilized in dryland revegetation operations. Some rangeland drills have several seed boxes, often three. One box for small seed, one box for average, non-fluffy, non-trashy seed, and one box for fluffy, trashy, or otherwise difficult seed. All three boxes will have their

own flow metering system and can be different for one or all three of the boxes. The drill manufacturer will provide operator's instructions on how to set the drill boxes.

Broadcast Seeding

Areas requiring broadcast seeding should be seeded at double the drill seed application rate. Areas to be broadcast seeded should receive, to the extent possible, the same topsoil placement and seedbed preparation as drill seeded areas. Generally this is not entirely possible, but some type of soil surface loosening is necessary. The topsoil must be in a mellow, loosened condition, to the degree possible, prior to broadcast seeding. Immediately following broadcasting, the seed shall be covered approximately 0.25 to 0.5 inches to the extent possible by raking, dragging, chaining, or chain harrowing.

Do not broadcast an area larger than can be immediately (within 30 minutes or so, less time if it is windy and more time if it is calm with no threatening weather) raked, dragged, or chained to cover the seed. Note that it is easy to simply broadcast seed and then not go to the effort and cost to cover the seed. In so doing, the chances of survival, germination, and growth are reduced significantly. Covering the seed is highly recommended to enhance the chance of seedling establishment and satisfactory plant cover and density.

Broadcast seeding should not be done during windy conditions. Small and fluffy seed will be caught in the wind and blown away, sometimes picked up and lofted into the air for many feet or sometimes for miles.

Although hand broadcasting is acceptable as long as the person broadcasting the seed applies the seed in a uniform fashion and at the proper application rate, utilizing any one of a number of commercially available broadcasting devises is recommended. Many of these mechanical broadcasting units are not capable of handling fluffy or trashy seed and the applicator may often end up hand broadcasting anyway and just using the broadcast unit as a container for the seed.

Commercially available mechanical broadcasters that attach to ATV's and that run by an electrical motor can often times be satisfactory for tight areas and other areas inaccessible with larger four wheel drive reclamation tractors. Larger, tractor powered broadcasters are also available and can be used if conditions allow. If slopes are too steep to apply on the contour by drill seeding, then broadcasting up and down the slope or at a diagonal may be feasible. Exercise caution to minimize rutting and marks running up and down the slope. Rake out or otherwise remove as necessary to reduce the potential for rilling and gullying initiated by these marks.

Broadcast Application Rates:

Seed mixtures should be applied at double the drill seed application rates indicated in the Revegetation Plans (refer to the Revegetation Plans section of this handbook). Because the seed is not carefully placed in the soil profile to a controlled depth, considerable seed is lost to environmental impacts including wildlife (birds and rodents), sunlight (UV light, heat), wind

(blowing the seed away), rain (washing the seed away), and similar negative impacts to seed placement and survival.

Calibration:

Accurate calibration is difficult for broadcast seeding. The skills and consistency of the individual broadcasting the seed greatly influence the accuracy of the seed application rate and the even distribution of the seed on the soil surface.

A known quantity can be weighed and a given area can be measured on the ground that matches the seed being applied. The seed can then be broadcast seeded and the operator can determine if the technique used satisfactorily applies the seed at the needed application rate. Walking speed, terrain changes, slopes, wind, and similar factors will influence seed application rate and uniformity of application.

Hydraulic Seeding

Hydraulic seeding is the process of broadcast seeding using a hydraulic seeder to apply the seed and soil amendments when requested. Several commercial hydraulic seeders (commonly called hydroseeders) are available on the market and include such brand names as Finn, Bowie, and others. Searching the internet or contacting a local dealer will provide you with a number of sources.

Hydraulic seeding and mulching can be accomplished in a two, three, or four step process. At least a two-step process is necessary for hydroseeding and hydromulching dryland areas in the semi-arid West. Combining seed with mulch and applying everything in a one-step operation is highly discouraged; success will be unlikely.

Fertilizer can be applied prior to seedbed preparation, after seedbed preparation, during the hydraulic seeding step, or during the hydraulic mulching operations. Applying fertilizer prior to seedbed preparation, after seedbed preparation, or with the hydraulic mulch is preferred to mixing the fertilizer with the seed. If mixed with the seed, mix in fertilizers last and just before spraying. If the seed and fertilizer load cannot be sprayed out within 15 minutes after adding fertilizer, then utilize another method of applying fertilizer other than adding to the seed load.

Application Rates:

Seed mixtures should be applied at double the drill seed application rates in the seed mixture tables in the Revegetation Plan section. Because the seed is not carefully placed in the soil profile to a controlled depth, considerable seed is lost to environmental impacts including wildlife (birds and rodents), sunlight (UV light, heat), wind (blowing the seed away), rain (washing the seed away), and similar negative impacts to seed placement and survival.

Calibration:

Accurate calibration is difficult for hydroseeding. Like broadcast seeding, the skills and consistency of the individual operating the hydroseeder greatly influence the accuracy of the seed application rate and the even distribution of the seed on the soil surface.

A known quantity can be weighed and a given area can be measured on the ground that matches the seed being applied. The seed can then be hydroseeded and the operator can determine if the technique used satisfactorily applies the seed at the needed application rate. Some of the hydromulch material is used during the hydroseeding step to assist the operator in determining the evenness of the seed and to help estimate the application rate. Use no more than 300 pounds per acre as an indicator for evenness of distribution.

For best results, measure areas to be seeded by the broadcast seeding or hydroseeding methods. Calculate the amount of seed (and other materials) to be used on each area and apply accordingly. This can be done by dividing the disturbed area into small components and prepare a chart or plan for determining the number of seed loads and the location(s) for each load.

Preparing the Area for Seeding:

The Project Owner should first prepare the seedbed to provide an adequate soil surface for germination and growth. Slopes and conditions will vary from one slope/site to the next and some areas will require this step while others will not. Several methods exist. Dozer tracking by running a dozer up and down steep slopes and leaving the grouser tracks is often an effective method of preparing the seedbed. Hand raking or dragging a heavy chain may also loosen the slope adequately for seeding. Using a chain harrow pulled up and down the slope behind an ATV or tractor may also be appropriate. Be sure to use all safety precautions when operating ATV's and tractors on steep slopes.

The area to be revegetated is best served if it is left in a roughen condition. At the end of construction, some slopes may be compacted or the surface may be hard or crusted or rill and gully erosion may exist. On such sites and where accessible with equipment, the Project Owner should : (1) utilize a slope chain or equal to prepare the surfaces. (Utilization of a slope chain requires good access to the top of the slope with revegetation equipment.), or (2) attempt to form horizontal furrows and ridges to assist with erosion control and slope stabilization. Crawler tractor grouser cleat tracks on steep slopes often provide an adequate seedbed. An excavator or similar equipment may be able to roughen the surface and provide a loose, but mellow seedbed.

When seedbed preparation utilizing equipment as described above is required and the Project Owner is contracting out revegetation services, this work is often best paid for by the hour (payment by the acre may also be possible except conditions of the slopes are seldom known at the time of bidding and a fair price may be difficult to develop).

When areas to be hydraulically seeded and/or mulched are inaccessible with equipment, then hand preparation may be necessary. Once again, if the Project Owner is contracting out revegetation services, this work is often best paid for by the hour since many variables can affect this type of work.

Hydraulic Seeding:

Seed, water, and up to 300 pounds per acre of hydraulic mulch can be mixed and uniformly applied to the areas to be seeded. Seed should not be left in the tank with water for more than one hour. If this should happen due to equipment failure or for any other reason, then this material may need to be disposed of either off-site or applied to the slopes at the Project Owner's expense. If applied to the slopes, it should not be counted as applied seed and new seed will probably need to be applied to those slopes. If the Project Owner believes the seed has not been damaged, then the Project Owner may take the risk of continuing the covering and expensive hydromulching steps, knowing that he must provide satisfactory vegetation for this area in question.

The seed, water, and hydraulic mulch (used as a tracer to assist the operator and inspector in observing even seed distribution) shall be mixed and applied to the areas requiring revegetation. Seed should be applied at double the drill seed application rate. At least 1,000 gallons of water should be used per acre for applying the seed and hydraulic mulch. The slurry must be maintained in a homogenous mixture during application to assure even application and distribution of the seed during hydraulic seeding.

Covering the Seed:

The seed should be covered with approximately 0.25 to 0.5 inches of soil when possible. The seed may be covered by dragging, chaining, utilizing a slope chain, raking, or other appropriate mechanical means. This step may be omitted on inaccessible slopes, but the Project Owner should plan on getting less than satisfactory vegetation establishment and may then have to repair slope damage and off-site sedimentation and then reseed the area several years later.

Hydraulic Mulching:

See the Hydraulic Mulching section for details. Basically, the remaining hydraulic mulch and all fertilizer and tack Type M shall be mixed with water and uniformly applied. This application shall be accomplished as soon after seeding as possible. Applying hydraulic mulch to seeded areas during the same day is preferred and should follow within 36 hours whenever possible.

Applying Bonded Fiber Matrix Hydromulch:

See the Bonder Fiber Matrix (BFM) section for details. Apply BFM at stated application rates if this method is selected. Apply as soon as possible after seeding. Apply during the same day when possible or within 36 hours if weather conditions allow that much leeway.

Rangeland Pitting and Seeding

Rangeland pitting is a process of making small pits in the soil surface to improve water holding abilities of the soils and provide a soil surface that resists erosional forces from wind and rain events. Rangeland pitting has proven successful on many reclamation projects for many years. Over time, pitting and seeding operations have been combined into one operation. Because this method has proven successful, it is included in this handbook, but because properly designed rangeland pitting and seeding equipment is not common in the industry, it is not expected to be a prevalent method used in revegetation operations in the Casper area.

At no time between loosening the soil with the ripper teeth and completion of dribble seeding should compaction be allowed to the final surface. This includes but is not limited to travel by vehicle, tractor, implement trucks, or other equipment. No vehicles or equipment should be allowed on the completed pitted areas as traffic will destroy the integrity of the pits and will increase the potential for soil erosion and poor vegetation stand establishment.

Because of the rough surface condition remaining for potentially many years following reclamation and revegetation, rangeland pitting and seeding is not generally recommended for the City of Casper subdivision developments.

Procedures:

Rangeland Pitting requires: (1) ripping with a crawler tractor or similar to a depth of 16 to 24 inches, and (2) scarifying to a 15 to 20 inch depth. For ripping, spacing between rip lines should not exceed 28 inches and may be constructed by one or more passes (for example, for two passes, the ripper rows of the second pass should split the ripper rows of the first pass). Proper loosening and heaving of the interspaces between ripper shanks is controlled by the distance between ripper shanks, soil type and moisture content, depth of ripping, and the width of the ripper shanks. This ripping step is then followed by scarifying to a 15 to 20 inch depth with the spacing between shanks not more than 19 inches. Scarifying shall immediately precede the pitting operation.

Application Rates:

Seed mixtures should be applied at double the drill seed application rates.

Calibration:

All seeding work must be calibrated to assure proper seed application rates. Utilize methods similar to drill seeding to calibrate rangeland pitters, depending on the rangeland pitter used. Refer to the drill seed calibration section for details on calibrating the rangeland pitter.

Equipment:

If rangeland pitting and seeding is chosen by the Project Owner, then utilizing equipment specifically designed to loosen the soil, form pits as described below, and apply seed to the prepared seedbed in a single operation is recommended. The Rangeland Pitter should be specifically designed and constructed for reclamation conditions. Light duty pitters, designed for the agricultural market and farm ground type soil conditions and incapable of handling rough terrain, are not acceptable. Agricultural pitters and seeders are commercially available but for the most part are not designed for reclamation on uneven terrain and sites with rocky or non-uniform surface conditions.

The Rangeland Pitter should be equipped with ripper teeth sufficient to reach beyond the bottom of the pits and shall immediately precede the pit forming devices. Ripping to 12 to 20 inches, depending on soil conditions, is generally required to construct the pits as described below. The pits shall be approximately twelve or more inches long by approximately eight inches wide and approximately six to eight inches deep. Spacing between pit rows shall be approximately two feet (center to center between adjacent rows of pits is two feet). The pits shall be constructed so that the downward flow of water between pits in one row is entrapped by the next row of pits (i.e., staggered rows). Ripping depth and pit size may, out of necessity, be reduced in rocky soil conditions. Mutual agreement between the Project Owner/Pitting Contractor and the City of Casper is necessary prior to reducing pit sizes as significant water holding capacity and surface roughness is given up when pit sizes are reduced.

When possible, utilize a rangeland pitter that does not merely broadcast the seed, but one that is capable of dribble seeding utilizing a mechanical seeder capable of accurate metering of the seed. Seed metering should be ground driven; pitters with hydraulic, electric, or air application metering are not recommended. Broadcast seeders utilizing a fan or circular spreader are not recommended.

Compacting the soil to form pits is not acceptable; pits must be constructed by ripping and pitting. Sheep's-foot rollers and similar devices are not acceptable for pit formation.

Seed Mixtures

All seed used on this project must be purchased through a dealer licensed with the Wyoming Department of Agriculture. A number of businesses are licensed in the State of Wyoming to provide seed to the public. Contact the Wyoming Department of Agriculture for a list of licensed seed suppliers for the state or check with local feed stores. In addition, seed companies such as Granite Seed, Lehi, Utah; Wind River Seed, Manderson, Wyoming; Sharp Bros. Seed, Longmont, Colorado, Arkansas Valley Seed, Denver, Colorado; and Rocky Mountain Reclamation, Laramie, Wyoming, are examples of other licensed seed suppliers.

All seed should be furnished in sealed, undamaged containers and needs to be plainly labeled showing:

1. The commonly accepted name of the species and variety of seed.
2. Lot number.
3. The percentage of pure seed, crop seed, inert matter, weed seeds by weight, and germination and hard seed.
4. The month and year of the germination test.
5. Origin of seed.
6. The full name and address of the supplier.
7. Name and number of each kind of secondary noxious weed seeds as listed in Wyoming Seed Law. Seed shall not contain any of the primary noxious weed seeds as designated in the Wyoming Seed Law.
8. Net weight of seed in each container.
9. The words "poisonous treated" shall appear on the label of seeds treated with chemicals, which are toxic to either humans or livestock.

The Project Owner shall furnish to the City of Casper, one copy of a materials certification signed by the vendor prior to initiating seeding operations. This document shall certify that each lot of seed has been tested by a recognized State Seed Testing Laboratory or by a commercial laboratory employing a certified seed analysis technician(s). The seed must have been tested not more than nine months prior to the date of seeding on the project.

The Project Owner shall also furnish to the City of Casper, one copy of the seed analysis reports as prepared by the respective Seed Testing Laboratory. A tetrazolium viability test will be accepted in lieu of the germination portion of the sample seed analysis report as prepared by the respective testing laboratory. The City of Casper reserves the right to random sample all seed used on state lands. The table of tolerances are as follows:

Offered % Pure Live Seed (PLS)	Tolerance (In Percentage Points)
96% or over	-2
90% or over but less than 96%	-2
80% or over but less than 90%	-2
70% or over but less than 80%	-3
60% or over but less than 70%	-4
60% or less	-5

If the % PLS of the delivered seed is below the accepted tolerance and if tested by a third party laboratory, such as the Wyoming State Seed Laboratory, the independent, third party seed laboratory test results shall govern and the seed shall be corrected or rejected. The Project Owner should then increase the amount of seed to be applied to meet seed mixture recommendations so that listed PLS pounds of seed for each species are actually applied to the site.

One or more random samples may be taken by the City of Casper or their representative prior to or during seeding operations for testing and analysis by an independent seed laboratory.

The total percentage of "crop seed" shall not exceed 1% by weight. The species and varieties of seed or blends of seeds shall furnish the Pure Live Seed (PLS) at the rates as called for in the seed mixtures in the Revegetation Plans (refer to Revegetation Plans section of this handbook). Cool season grass species seed, which has less than 85 percent pure seed, shall not be used unless otherwise approved by the City of Casper. When possible, only use seed with high germination percentages, usually above 80%. Be aware though that some species inherently have low germination percentages. Check with more than one supplier to be sure quality seed is being provided to the project.

No substitution of species, variety, or origin of seed will be allowed unless evidence is submitted in writing by the Project Owner to the City of Casper showing that the specified materials are not reasonably available during the seeding period. The substitution of species, varieties, or origins shall be made only with the written approval of the City of Casper personnel prior to making a substitution.

Different plant species respond to soil types in different ways. Some plant species are adapted to a wide range of soil textures and other soil physical and chemical properties while other species are more specific to the types of soil conditions suitable for their growth and long term survival.

A number of seed mixtures within the Revegetation Plans have been developed to address the different soil types in the area. Some species are in many of the mixtures while some species are in only a few of the seed mixtures. The seed mixtures were developed to address not only the soil types and post reclamation land use, but to address soil stabilization and erosion control issues as well as seed availability and seed costs, environmental impacts to the seed prior to germination, inconsistencies in site conditions, and operator errors and imperfections. Very expensive seed was only specified when absolutely important to the final results. Some species, common to the area, are not available commercially or only rarely or occasionally available. These species were not included in the seed mixtures.

Best Times to Seed

Seeding can be accomplished nearly year round although some times of year minimize the risk of inadequate seed germination and plant development. Seeding prior to the spring rainy season is often considered the optimum time of year to seed in this area. This means seeding in the fall when soil temperatures are low enough to minimize the chance of seed germination (dormant seeding) or seeding as soon as the frost goes out of the ground in the spring and the areas are accessible with equipment. May and June are often the rainiest months of the year.

Seeding in hot, dry conditions is thought to increase risk of unsatisfactory plant establishment and in theory risks are higher although past experience has not documented this to be a high risk option. Seeding is difficult during windy seasons such as often occur in late fall and early spring. Seeding should not be done when the ground is frozen. Seeding may proceed when

there is evidence of frost, providing the seedbed can be kept in a workable condition so that the seed is planted at the correct depths and all mulching and erosion protection tasks can be correctly completed. Late summer or early fall seeding runs the risk of seed germinating in the fall just in time to be damaged by killing frosts. Although it is a risk, it seems to be a very low risk and as long as mulching or other erosion control measures are incorporated into the revegetation process, this risk should not be given much weight in the decision making process concerning time of year to seed, especially when erosion control and dust abatement issues are significant.

Seeding prior to summer and warm weather generally provides the best situations for warm season species and some shrubs while seeding at other times of the year provide better opportunities for cool season species and other shrubs. For this area, cool season species and shrubs dominate the native vegetation communities.

MULCHING

Applying a surface mulch following seeding operations has been proven to significantly reduce the risk of vegetation establishment failure and provides short term soil erosion protection and minimizes the potential for degradation of the downstream and downwind environment. Many surface mulches exist including hay, straw, hydraulic mulch fiber, bonded fiber matrix materials, erosion control blankets, organic compost, recycled lawn clippings, city waste from the green industry, and other forms of materials capable of protecting the soil surface while also providing nutrients for developing plants. Because of the proven success of hay mulch, this material is the mulch of choice and should be used whenever possible. Straw should be used as a last resort when hay is not available. Hydraulic mulch fibers, bonded fiber matrix materials, and erosion control blankets should be used for areas where hay mulching is not possible (steep slopes, wet, boggy areas, and small, tight areas for example). The other forms of mulch mentioned above have limited use as a surface mulch and are often limited in their availability and are not considered preferred materials for this handbook.

Materials

The mulch material utilized on the disturbed areas shall consist of native grass hay. Acceptable species include high quality native perennial grasses, sedges, rushes, and similar native species. Introduced pasture and meadow grasses such as common timothy, orchard grass, smooth brome, meadow brome, and similar species are not acceptable. Grass hay containing crested wheatgrass, pubescent wheatgrass, intermediate wheatgrass, tall wheatgrass, and similar dryland introduced species are also not acceptable unless similar species are being utilized in the revegetation seed mixture. All mulch shall be free of noxious weeds or other seed-bearing weeds that would be detrimental to the seeded area. Straw, wheat hay, sorghum, rice, millet, Sudan grass, or other annual species are not acceptable for mulch.

All materials used as mulch within the state are subject to the inspection and approval of the Wyoming Department of Agriculture. Mulch materials require a certificate of acceptance / certification that the mulch is free of noxious weeds for this project.

All materials used for mulch should be certified free of noxious weeds. Straw and hay are available from sources that are certified by governmental agencies as noxious weed free materials. This certification should be provided with all such materials brought on-site.

All shipments of mulch material must be accompanied by a certificate of origin stating that such shipments are free of noxious weed seeds. A noxious weed free certification from Wyoming (WDA Form 70) or another state (WDA 70 equivalent) shall be submitted to the City of Casper when the mulch is delivered to the project. Certified weigh slips indicating date, source, trucking company, gross weight, empty weight, net weight, destination, and number of bales shall be submitted to the City of Casper at the time of delivery of the mulch material.

Procedures

Mulch should be delivered to the site and carefully placed to minimize disturbance to seeded areas. The mulch machine operator should begin mulching so that mulching equipment can remain on mulched areas as much as possible. Apply mulch using any wind occurring to help distribute the mulch in an even manner. Minimize the number of passes and the amount of travel over the seeded area during mulching operations.

Application Rates:

The mulch should be uniformly spread over the designated areas. Application rates will vary depending on the material used. For grass hay, the recommended mulch, apply at the rate of 2.0 tons per acre.

For straw mulch, apply at the rate of 2.0 tons per acre. Apply at 2.0 tons per acre unless this rate puts too much material on the surface and it is difficult to crimp into the soil when a heavy duty crimper is used. Reducing the rate to 1.5 tons per acre may be possible, depending on the surface coverage, often influenced by the type of straw mulch utilized. A reduction to 1.5 tons/are is not recommended and must be approved on-site during operations by a representative with the City of Casper.

The placing of mulch shall be evenly distributed, leaving no bare areas or thick piles of mulch material.

Mulching should not proceed during windy conditions. Usually wind speeds in excess of 15 to 20 mph will make mulching with straw difficult or impossible while wind speeds of 25 to 30 mph will make mulching with hay difficult. The operator should carefully watch the mulch material and shut down operations when the mulch begins to blow and move due to the force of the wind or when the tractors drive over the mulched areas during mulching and crimping

operations and the mulch blows out from under the equipment, leaving bare areas. Before these conditions exist, operations should cease until wind speeds drop.

Calibration:

Like other revegetation techniques, calibrating the mulch is best done by measuring a given area, such as an acre or some similar sized unit and then applying a known quantity of mulch material to that area that equals the application rate. Experienced mulching machine operators become very good at visually determining the proper application rate and this should be checked daily by comparing tons of materials applied with the actual acres mulched.

Operators can also determine the amount of mulch to apply by calculating the tons of mulch needed for areas within the project. The size of these areas can be determined by measuring the individual areas or using the drill acre meter. The operator would then multiply the acres for each area times the application rate (2.0 tons/acre) to determine the tons needed per area. He would then calculate the weight per bale for the mulch delivered to the project and divide the tons needed per area by the weight of the bale (in tons). For example, if an area within the project is 1.5 acres and the application rate is 2.0 tons/acre then the total tons needed for that area is 3.0 tons (1.5 acres X 2.0 tons/acre=3.0 tons). If the bales delivered are large, round bales of grass hay mulch weighing 1,500 pounds/bale, then 4 bales would be needed (1 bale = 1,500 pounds or 0.75 tons/bale and 3.0 tons are needed for the area. Thus, 3.0 / 0.75 = 4 bales).

Equipment

Hay and straw mulch can be applied by a number of different pieces of equipment available commercially. New designs are being tested each year. Utilize a machine capable of evenly spreading mulch across the seeded area with minimal disturbance to the seedbed and carefully placed seeds. Because many types and sizes of mulch material exist, many types of mulchers are available. The key is to use a mulcher capable of even distribution of the mulch with minimal impact to the fiber length. Contact a local agricultural dealer for available models, advantages and disadvantages of each, and prices.

The mulch material should be spread with approved equipment that will not pulverize or excessively break down the original size of the individual stems of the mulch. Do not utilize mulchers that chop or otherwise reduce stem size any more than absolutely necessary. Stay away from mulchers with knives the cut, chop, or grind the mulch. Tub grinders and similar machines that chop and significantly reduce fiber length are not acceptable and will not be allowed.

CRIMPING

After the hay mulch has been spread it must be anchored in the soil by means of a crimping implement. Discs and other implements not designed specifically for crimping should not be used for crimping. Damage to the seedbed and alteration of seed placement may occur and would not be acceptable.

Procedures

Crimping operations should be done on the contour on slopes and when possible, perpendicular to the prevailing winds on flat areas. Crimping should immediately follow mulching operations (within approximately 2 hours or less if possible) to minimize the occurrence of wind blowing the mulch prior to crimping. A longer time between mulching and crimping is possible, but the Project Owner should be aware that the risk of damage to the mulch is possible if wind or other weather should disturb the work completed. Remulching may then be necessary.

Crimp at less than 4.0 mph for best results. Do not turn with the crimper coulters in the ground. On soft ground and sandy soils, the operator needs to be aware that the depth of the coulters must be controlled and coulters should not be placed too deep, causing damaging disturbance to the seeded soil.

Equipment

Several manufacturers make crimpers including Finn, Bowie, and others. Dealers are situated around the USA. Crimpers can also be found on the internet. Crimpers should be heavy duty implements, capable of applying considerable down force to the ground surface in order to adequately press mulched hay or straw into the soil. Crimpers with at least 20" diameter straight coulters with a thickness of 0.25" are recommended. Some crimpers allow the user to attach weights or fill baskets with dirt or other heavy material; this procedure is recommended for fine textured soils and in conditions where it is difficult to maintain a mellow seedbed to an 8" depth.

Light weight discs and implements that disc mulch into the soil rather than crimp will not be allowed. The mulch must be pushed into the topsoil material three or more inches by straight coulters or flat discs aligned parallel to the movement of the implement. These implements should not be spaced greater than an average of 7.0 inches between coulters/discs. A number of commercially available crimpers have 8 inch spacing and can be acceptable although not preferred and not recommended.

HYDROMULCHING

Hydraulic mulching (hydromulching) is the application of hydraulic wood fiber or blends of wood fiber and paper and other materials utilizing hydraulic methods and equipment. Hydraulic mulching may or may not be used in conjunction with hydraulic seeding (hydroseeding). Areas may be broadcast or drill seeded and then hydromulched or areas may be hydroseeded and hydromulched. In addition to these two procedures, additional procedures may be required to adequately complete revegetation. These procedures include preparing the seedbed and covering the seed. Therefore, a two step, three step, or four step process may be required for revegetation utilizing hydraulic seeding and mulching. The Revegetation Plans section of this handbook lists revegetation techniques to be used in a variety of situations.

Materials

Hydraulic mulch fiber shall be high quality wood fiber material. Products produced from sawdust, 100% paper, cardboard, and other recycled materials are not acceptable.

Natural wood fiber shall have the property of dispersing readily in water and shall have no toxic effect when combined with seed or other materials. A colored dye, noninjurious to plant growth, should be used.

The wood fiber mulch shall be shipped in packages bearing the name of the manufacturer, and shall be marked to show the air dry mass based on the mass standard for wood cellulose according to the Technical Association of the Pulp and Paper Industry. Acceptable air dry mass shall include a moisture content of not more than 15% (plus or minus 3%). The Project Owner shall furnish certifications from the Manufacturer stating that the material furnished has been laboratory tested and field tested and that the materials meet the intent of these specifications.

Pure virgin wood fiber mulch manufactured utilizing a heating process to obtain fiber length and size. The mulch shall be processed with heat and pressure to soften the wood chips so that the mechanical refining process yields fibers having the shape and size suitable for hydraulic mulch application. The mulch shall form a blotter-like ground cover with moisture absorption and percolation properties. The mulch shall not inhibit penetration of seedlings through it, but shall have the ability to cover and hold seed and other materials in direct contact with the soil. This mulch shall contain no growth or germination inhibiting factors and shall remain in uniform suspension in water under agitation. The mulch shall be appropriately colored to facilitate metering. Materials equal to Conwed 100% wood fiber products and Mat Mulch 100% wood fiber products are acceptable.

Bonded Fiber Matrix (BFM) Hydromulch Fiber:

Bonded Fiber Matrix (BFM) type hydromulch materials provide additional protection when compared to typical hydromulches. BFM materials may meet or exceed the erosion protection of some erosion control blankets and in some situations, utilizing BFM material is the preferred method for slope protection. Costs are similar to or less than installing erosion control blankets.

Bonded Fiber Matrix hydromulch can be utilized instead of the normal hydromulch fiber. Use the following information and substitute BFM for hydromulch, where appropriate, except apply at 3,600 pounds per acre. Tackifiers are already included in BFM hydromulch so no additional Type M tackifier needs to be added.

The Project Owner generally will have the option to use this material as an upgrade to hydromulching when situations suggest its use. For example, the Project Owner should seriously consider using BFM material on sandy locations where hay mulching is not possible because of slope gradients, wet, boggy soil conditions, or inaccessibility with four-wheel drive revegetation equipment.

Procedures

Provide adequate quantities of hydraulic mulch material and tackifier (or BFM) as determined necessary for the project. Load the materials per the manufacturer's recommendations. Spray areas to be hydromulched, taking precaution not to spray down into the soil and disturb the soil surface and thereby cause bare areas with no seed and very little mulch.

The hydraulic mulching step should be accomplished as soon after seeding as possible. Applying hydraulic mulch (or BFM) to seeded areas during the same day is preferred and should follow within 24 - 36 hours whenever possible.

Use only hydroseeder equipment specifically designed for mixing, agitating, and applying hydraulic wood fiber mulches and tackifiers. Equipment with pumps and tanks and no agitating mechanism are not acceptable.

Application Rates:

Hydromulching (hydraulic mulching), using 2,000 to 2,300 pounds of wood cellulose fiber per acre, will be acceptable on steep slopes and areas inaccessible with standard revegetation equipment (3,600 pounds/acre for BFM).

The hydraulic mulch, tackifier, and water should be mixed and applied to the areas requiring revegetation. Hydraulic mulch should be applied at 2,000 to 2,300 pounds per acre (300 pounds during the hydroseeding operations and 2,000 pounds during the hydromulching operation). A tackifier is required to be used with hydromulch fiber in the Casper area. If drill seeding or broadcast seeding are used, then hydraulic mulch shall be applied at 2,000 per acre during hydromulching operations. Whether the seed is covered or not following hydroseeding (and 300 pounds of fiber per acre), a full 2,000 pounds per acre should be applied in this hydraulic mulching step (300 pounds/acre during hydraulic seeding and 2,000 pounds/acre during hydromulching).

Several different tackifiers are available on the market. Each has different attributes dealing with longevity and tackifying ability. Some are soluble in water and others are less soluble.

The most common tackifier currently in use is an organic compound made as a free flowing and noncorrosive powder produced from the natural plant gum of Indian wheat (*Plantago insularis*). This tackifier is often termed Type M tackifier. Type M tackifier should be applied at 250 pounds per acre. The City of Casper may allow Type M tackifier at 200 pounds/acre when site condition are mostly flat and the reason for using hydromulching is because areas are inaccessible to drill and hay mulching equipment. The slurry must be maintained in a homogenous mixture during application to assure even application and distribution of hydraulic mulch and tackifier during hydraulic mulching operations.

Many alternative tackifiers exist in the revegetation marketplace and some are equal to and possibly superior to Type M tackifier. Type M tackifier is "tried and true" in the semi-arid West while most other tackifiers are relatively new in comparison. The City of Casper is willing to entertain alternate tackifiers and invites written proposals from Project Owners documenting the pros and cons of alternate tackifiers. Generally having a supplier submit information concerning an alternate tackifier, its benefits, application rates, and documentation of success may be sufficient information for analysis by the City of Casper.

Calibration:

Measure an area equal to the size of one full load of hydromulch (BFM). This will vary, depending on the size of the hydroseeder and the type of material. Spray a full load on the measured area to determine coverage by visual comparison. Continue spraying at the same rate of coverage, continually keeping track of loads of material and measured areas completed.

Equipment

Machines used for hydromulching shall be approved types capable of continuous agitation of the slurry mixture during the seeding operation. Pump pressure shall be such as to maintain a continuous non-fluctuating spray capable of reaching the extremities of the seeding area with the pump unit located on a safe surface, either from the canon nozzle or by utilizing hoses. The sprayer shall be equipped to use the proper types of nozzles to obtain a uniform application on the various slopes at the distance to be covered.

Hydraulic equipment used for mixing and applying slurry mixtures shall have built-in agitators. These agitators shall keep the various components (water, hydraulic mulch fiber, tackifier, etc.) thoroughly mixed as a homogenous slurry. The pump pressure shall be sufficient to maintain a continuous, non-fluctuating stream of the slurry. The sprayer shall be equipped with nozzles and shall have the capability to attach and operate hose extensions. The equipment shall be sized appropriately for the project (small hydroseeders should not be allowed on large hydroseeding projects). All equipment shall be maintained and in good working order meeting all state and federal requirements.

The hydraulic mulch fiber, the Type M tackifying agent, and water shall be combined in the proportions of the various materials per the Application Rate paragraph above and allowed to mix a minimum of five minutes prior to starting the application of the slurry.

Where equipment can operate, the area to be seeded shall be prepared by disking, harrowing, or by other approved methods of loosening the surface soil to the depth specified in the Seedbed Preparation section above. On slopes too steep for equipment to operate, the area shall be prepared by hand raking to the specified depth. On sloping areas, all discing, harrowing, and raking should be directional along the contours when practical. All eroded areas shall be restored to the appropriate condition, grade, and slope prior to seeding.

Care shall be taken during the seeding operations to prevent damage to existing trees and shrubs in the seeding areas.

TACKIFYING

Tackifying is a procedure to further assure mulch and soil materials remain on-site. Tackifying significantly reduces soil erosional forces from wind and minimizes mulch, seed, and soil blowing into downwind neighbor's homes and property. Considerable advantages exist for using this technique, especially on slopes and highly sensitive areas. We recommend tackifier for all areas with a high erosion potential, where aesthetic value is critical, and where blowing mulch and soil may cause problems with downwind neighbors.

Tackifying should not be confused with adding tackifier to hydromulch during hydromulching operations. Tackifying is a completely separate procedure added to revegetation techniques and follows hay or straw mulching and crimping operations.

Materials

Several different tackifiers are available on the market. Each has different attributes dealing with longevity and tackifying ability. Some are soluble in water and others are less soluble. The most common tackifier currently in use is an organic compound made as a free flowing and noncorrosive powder produced from the natural plant gum of Indian wheat (*Plantago insularis*). This tackifier is often termed Type M tackifier. For most conditions existing in the Casper, Wyoming, Type M tackifier is suggested. Type M tackifier is "tried and true" in the semi-arid West while most other tackifiers are relatively new in comparison.

Because alternative tackifiers exist in the revegetation marketplace and some are thought to be equal to and possibly superior to Type M tackifier, the City of Casper is willing to entertain alternate tackifiers and invites written proposals from Project Owners documenting the pros and cons of alternate tackifiers. Generally having a supplier submit information concerning an

alternate tackifier, its benefits, application rates, and documentation of success may be sufficient information for analysis by the City of Casper.

Procedures

Type M tackifier should be mixed with hydraulic mulch material and applied uniformly during Tackifying operations.

The hydraulic mulch, tackifying agent, and water should be combined in the proportions of the various materials as outlined in the Application Rate paragraph below and allowed to mix approximately five minutes prior to starting the application of the slurry.

Application Rate:

For Tackifying, Type M tackifier (*Plantago insularis*) should be applied at 200 pounds per acre. In addition, 400 pounds of hydraulic mulch fiber per acre should be added and mixed with the water and tackifier. A minimum of 750 gallons of water should be used per acre to help assure even distribution of the tackifier. The slurry must be maintained in a homogenous mixture during application to assure even application and distribution of hydraulic mulch and tackifier during hydraulic mulching operations.

If another tackifier is used to replace the Type M tackifier, use at least the manufacturer's maximum application rate specified for steep slopes and severe conditions, even if the area to be tackified is not steep. Wind intensity and duration in the Casper area are expected to necessitate the need for heavy application rates to provide sufficient protection for a reasonable amount of time. At least one full year of protection is needed and two years are recommended.

Calibration:

Measure an area equal to the size of one full load of Tackifier mix. This will vary, depending on the size of the hydroseeder and the type of material. Spray a full load on the measured area to determine coverage by visual comparison. Continue spraying at the same rate of coverage, continually keeping track of loads of material and measured areas completed.

Equipment

The same machines used for Hydromulching are used for Tackifying. These machines used for tackifying shall be approved types capable of continuous agitation of the slurry mixture during the tackifying operation. Pump pressure shall be such as to maintain a continuous non-

fluctuating spray capable of reaching the extremities of the seeding area with the pump unit located on a safe surface. The sprayer shall be equipped to use the proper types of nozzles to obtain a uniform application of the tackifier on the various slopes at the distance to be covered.

Hydraulic equipment used for mixing and applying slurry mixtures shall have built-in agitators. These agitators shall keep the various components (water, hydraulic mulch fiber, tackifier, etc.) thoroughly mixed as a homogenous slurry. The pump pressure shall be sufficient to maintain a continuous, non-fluctuating stream of the slurry. The sprayer shall be equipped with nozzles and shall have the capability to attach and operate hose extensions. The equipment shall be sized appropriately for the project (small hydroseeders should not be used on large hydroseeding projects). All equipment shall be maintained and in good working order meeting all state and federal requirements.

INSTALLING EROSION CONTROL MATERIALS

Erosion control materials such as wind fences, blankets, bales, and wattles minimize the potential for damage from wind and water erosional forces and are used on sites that are more susceptible to erosion.

These materials are used primarily on special areas and for unique situations. Installation of erosion control materials can significantly increase the reclamation cost per acre. Because of the high cost, these materials are required only when the risk of revegetation failure is high or the potential for erosion is significant. For example, blow sand soils are difficult to stabilize and revegetate. Using standard revegetation methods, including hay mulching, are generally inadequate. Additional erosion control measures, such as wind fences, are often necessary to minimize impact from wind and stabilize the soils long enough for vegetation to have a chance to establish.

Installation Procedures and Materials

The following information is available to assist Project Owners in utilizing these erosion control materials should the City of Casper, a consultant, or other specialist recommend the use of one of these products. The Project Owner may propose other erosion control products to the City of Casper for approval. Technical data and documentation concerning success of the product in similar climatic and soils conditions should be submitted with the proposal.

Wind Fences:

Wind fences, commonly referred to as snow fences, are used to reduce the wind's erosional forces on highly susceptible soils (blow sands and similar soils). Wind fences block and redirect the wind along, and just above, the soil surface so that wind speeds along the ground surface are reduced significantly.

Install the wind fence perpendicular to the prevailing winds of the area. For the most part, west, west southwest, and southwest winds often prevail in the area. Determine the prevailing wind direction by visual observation or by checking local collected weather data.

Wind Fence Installation:

Construct wind fence in the following manner:

1. Install 5.5 or 6.0 feet steel T-posts in a line on 10 foot centers, perpendicular to the prevailing wind.
2. Install one length (2 strands) of 12.5 gauge smooth barbless two-strand wire along the bottom and one length (2 strands) of the same wire at a height near the top of the where the wind fence will be installed.
3. Anchor the ends of the fence with steel T-posts driven a minimum of four (4) feet into the ground. Drive these anchor posts at an approximate 45 degree angle so the top leans away from the end of the fence.
4. Attach two (2) strands of minimum 12.5 gauge wire to the anchor post and the last steel post in the fence line so that pressure by wind forces will be counteracted by the anchor post.
5. Unroll and wire the wind fence to the steel posts.
6. Use minimum 12.5 gauge wire and attach at 4 locations on the steel post.
7. Single or double wrap all wires around the steel posts before pulling tight and twisting the wire to form a binding knot. Do not over twist the wire and stretch or break the wire. Replace stretched or broken wire.
8. Optional – recommended: Install additional upwind anchor posts along the wind fence on the upwind side of the wind fence to assist in supporting the fence to minimize wind forces pushing the fence over. Install one upwind anchor every 50 feet during wind fence construction. Anchoring frequency will depend on expected wind impact but placing an upwind anchor every fifth steel T-post will generally provide significant assistance in counteracting the force of the wind.

Parallel lines of wind fences shall be placed a maximum of 70 feet on center. Wind fences shall be constructed across the entire disturbed area, perpendicular to the prevailing winds. For example, a disturbed area, 420 feet long would have a wind fence at the leading edge of the disturbance and then another line every 70 feet maintaining fences perpendicular to the wind. For a 420 foot long area, 6 lines would be installed, one along the edge of the disturbance in the direction of the prevailing wind, and 5 interior lines.

Maintenance of the wind fence will be necessary and the fence should be checked on frequent intervals (weekly during windy seasons). Repair broken attachment wires and anchor wires as necessary to maintain the wind fence in like new condition.

Wind Fence Materials:

Wind fences or small, portable, wooden, snow fences, are available commercially and are generally made by wiring wood "lathe" in a vertical, side by side configuration with small gaps between 4 feet high lathe boards. Rolls are generally 50 feet long and are a dull orange or rust color.

Wind fences shall consist of wood slats woven together with five 2-wire strands of galvanized wire and meet the following specifications:

1. Slats shall be wood measuring 3/8" thick and 1.5" wide and 48" high. Both ends shall be cut square and stained red iron oxide color.
2. The wire shall be galvanized and 13 gauge or thicker.
3. Slats shall be spaced 2.25" apart.
4. Wire shall be two (2) stands with a minimum of two (2) full twists between slats.
5. The fabric shall be tightly woven forcing the wire into the wood slats holding the slats tightly in place.
6. Rows of wire shall be 10" apart and no closer than 4" from the ends of the slats.

Steel T-posts shall be hot rolled steel formed in a "T" dimension and shall be 1 7/16" X 1 5/16" X 1/8" X 6' long and shall weigh at least 1.25 pounds per foot. The anchor plate shall be 23 square inches and the posts shall be painted. Tie wire shall be a minimum of 12.5 gauge galvanized wire.

Erosion Control Blankets:

Erosion control blankets (ECB) are also called erosion control netting and are used on steep slopes and in ditches to limit erosional impacts from wind and water. These materials offer more erosion protection than mulches but are considerably more expensive.

Erosion Control Blanket Installation:

Install erosion control blankets according to the manufacturer's recommendations. To achieve maximum blanket to soil contact, roll blankets evenly and smoothly without stretching the blankets. Lay rolls of netting in the direction of water flow with the ends overlapped at least one (1) foot with the uphill blanket on top (like shingles of a house). Install staples at this junction on two foot centers in a zig zag fashion in two rows six inches apart. In all other areas of the blanket, install a minimum of one staple per square yard of blanket. Otherwise, follow the manufacturer's recommendation for staple pattern.

As a general rule, overlap blanket edges (sides) approximately three to four inches and staple according to manufacturer's recommendation. In the Casper area winds are a major concern and the ECB should be installed so that the upwind blanket is overlapped over the top of the downwind blanket. In most cases in the Casper area, start blankets at the east end of the slope and work westward and work from northeast to southwest, from southeast to northwest, and from north to south for most areas where the prevailing wind is from the west or west southwest.

Start erosion control blanket two to three (2-3) feet past the crest of the hill when possible. Anchor the uphill terminal end of all blankets in a trench six (6) inches deep. Install staples every foot in the bottom of the trench and bury the ECB. Compact the soil over the ECB by foot, vehicle wheel, or similar. Hand seed all trenches and areas disturbed during netting installation.

Run the rolls of ECB up and down the slopes except on short slopes one or two blanket widths in which case, it is acceptable to run the blanket rolls parallel with the contour of the slopes. For dry stream beds, channels, and other water courses, run the ECB in the bottom of the channels and parallel to the direction of water flow. If the channel requires more than one blanket in width, be sure the seam is not in the lowest part of the channel but at least 12" from the bottom of the channel to the degree possible.

Anchor the netting with U-shaped wire staples, metal geotextile stake pins or triangular wooden stakes. Use 6, 8, or 9 inch long staples (11 gauge minimum) with either a 1 inch or 2 inch top (center of the U); 2 inch is preferred. If metal stake pins are used, they should be 3/16 inch diameter steel with a 1.5 inch steel washer at the end of the pin. Drive wire staples and metal pins flush with the ground surface. All anchors should be long enough to provide sufficient ground penetration to resist pullout. Longer (8inch and 9 inch staples, for example) are required for sandy or blow sand soils and are usually best for loamy soils.

Care shall be taken during installation to avoid damage to the Erosion Control Blankets as a result of the installation process. Should the Erosion Control Blankets be damaged during installation, a material patch shall be placed over the damaged area extending two feet beyond the perimeter of the damage.

Use sufficient staples so that blankets are anchored to the soil and maintain contact with the soil. Staples shall be placed down the center and staggered with the staples placed along the edges. For wider blankets, use the same staggered pattern and add rows of staples as necessary. See manufacturer's recommendations. As a general rule, for steep slopes, 1:1 to 2:1, use 2 staples per square yard. For moderate slopes, 2:1 to 3:1, install 1-2 staples per square yard (1 staple every 3'). More gentle slopes, when ECB is utilized, should have 1 staple per square yard.

Erosion Control Blanket Materials:

For normal slopes equal to or steeper than 3H:1V, install 100% coconut erosion control blanket (Type CC2), such as North American Green (NAG) CC125 and Greenfix America CF072RR, and utilize a slope staple pattern provided by the manufacturer.

Using a straw-coconut blanket, Type STC, such as North American Green (NAG) STC125 straw-coconut blankets and Greenfix America CFS072R Photodegradable Double Net Straw Coconut blankets, as described below, may be possible on slopes when 100% coconut erosion control blanket (CC2) is not available or when prior written approval has been obtained from the City of Casper. For ditch bottoms and minor drainage channels, install only the 100% coconut ditch liner erosion control blanket (CC2); i.e., no STC in ditch bottoms. STC is not a substitute for CC2 for ditches and channels where flowing water is expected.

Certifications:

A certification should be provided by the Project Owner (or his authorized Contractor) to the City of Casper stating the name of the manufacturer, product name, style number, chemical composition of the fiber, netting, thread, and all other pertinent information to fully describe the erosion control blanket. The Certification shall state that the furnished erosion control blanket

meets the performance requirements of this specification as evaluated under the Manufacturer's quality control program. The Certification shall be signed by a person having legal authority to bind the Manufacturer.

A certificate of weed free status shall be available from the manufacturer if requested. The manufacturer shall use straw that is certified weed free and meets Wyoming's straw and hay certification program (Mulch section above).

Erosion Control Blanket Type STC:

Type STC erosion control blanket is straw-coconut erosion control blanket comprised of a maximum of 70% certified weed free straw matrix and minimum of 30% coconut fibers evenly distributed over the entire are of the blanket. The straw and coconut fibers are mechanically stitched between two photodegradable, synthetic nets (top and bottom). Life expectancy is less than one year. Use on slopes, but not ditches.

Type STC should meet the following requirements to the extent possible. Not all similar materials will have all of the follow testing data available.

1. Tensile strength MD: min. 17.2 lbs./in
2. Tensile strength TD: min. 15.3 lbs./in
3. Mass: 0.7 lbs./sq. yd.
4. Thickness: +/- 0.38 inches
5. Light penetration: +/- 19% open
6. Water Absorption: +/- 425%
7. Netting: Synthetic photo-degradable
8. Top Net Opening: 0.50" X 0.50" +/- 10%
9. Bottom Net Opening: 0.50" X 0.50" +/- 10%
10. Soil Loss: 0.11 max (Min 5"/hr., min. duration: 0.75 hr. or 10 yr. storm event on 2:1 slope with sandy loam soil type.)
11. Germination Ratio: +/- 81 % of total possible ((Min 5"/hr., min. duration: 0.75 hr. or 10 yr. storm event on 2:1 slope with sandy loam soil type.)

Erosion Control Blanket Type CC2:

Coconut erosion control blanket comprised of 100% coconut fibers stitched between two photodegradable, synthetic nets (top and bottom). Coconut blankets have a life expectancy of up to 36 months. Use for slopes and ditch bottoms.

Type CC2 should meet the following requirements to the extent possible. Not all similar materials will have all of the follow testing data available.

1. Tensile strength MD: min. 22.2 lbs./in
2. Tensile strength TD: min. 19.5 lbs./in
3. Elongation: 25-30%
4. Mass: 0.7 lbs./sq. yd.
5. Thickness: +/- 0.30 inches
6. Light penetration: +/- 8% open
7. Netting: Synthetic photo-degradable

8. Top Net Opening: 0.625" - 0.75" X 0.625" - 0.75" +/- 10%
9. Bottom Net Opening: 0.625" - 0.75" X 0.625" - 0.75" +/- 10%
10. Soil Loss: 0.45 max (Min 5"/hr., min. duration: 0.75 hr. or 10 yr. storm event on 2:1 slope with sandy loam soil type.)
11. Germination Ratio: +/- 74 % of total possible ((Min 5"/hr., min. duration: 0.75 hr. or 10 yr. storm event on 2:1 slope with sandy loam soil type.)

Check Bales:

Check bales are used to assist with controlling water flow in channels. Check bales act as dams and as filters to slow water velocities and reduce off-site sedimentation.

Check Bale Installation:

Install the check bales in the following manner:

1. Mark the layout for the bales in a shallow uphill "C" shape, with the two ends of the "C" uphill and up gradient from the center of the "C".
2. Place bales in one row perpendicular to the flow of water down a ditch in the shallow uphill "C" shaped configuration previously marked.
3. Dig a four (4) inch deep trench the width of the bales.
4. Place the bale in the shallow trench and backfill against the downhill side of the bale.
5. Pound two (2) 2" X 2" X 36" long, wooden stakes per bale into the top of the bale perpendicular to the slope gradient. Space stakes a minimum of eight (8) inches from the end of the bale, attempting to evenly distribute the stakes across the top of the bale. Pound the stakes flush with the top of the bale.
6. Bales shall be loosely butted up against each other. The length of the bale row is dependent on the width of the ditch and the expected maximum flow.
7. Place the bales such that the ends of the bale row exceed the maximum flow width projected by a minimum of three (3) feet in each direction.
8. In addition, when topography allows, be sure that the elevation at the ground surface at the outside edges of the two outside bales is at least two feet higher than the top elevation of the lowest bale in the row (usually in the center of the row). This configuration allows water to pass over the center bales rather than running around the end of the bale row, thus minimizing the potential for further soil erosion.

Check Bale Materials:

Check bales or generally either small, rectangular hay bales or straw bales. They can be either string or wire tired and can be two wire (string) or three wire bales. The bales should be solid and well constructed; do not use rotting, moldy, loose, or poor quality bales. Certification that the bales are free of noxious weeds shall be provided to the City of Casper.

Wattles and Logs:

Wattles and logs are flexible linear rolls designed to reduce hydraulic energy and filter sediment laden water in channels and on slopes. Wattles act as small dams and deterrents to slow water flow on steep slopes or small drainage channels.

Wattle and Log Installation:

Install wattles and logs in the following manner:

1. Align wattles perpendicular to the water flow on slopes or small drainages.
2. Install the wattles by digging a shallow two inch trench the width of the wattle.
3. Place the wattle in the trench.
4. Backfill the downhill side of the wattle.
5. Install 1" X 2" X 24" or 2" X 2" X 24" stakes on three foot centers along the length of the wattles, being sure to have one stake within 12 inches of the end of each wattle.
6. Pound stakes flush with the top of the wattle.

Wattle and Log Materials:

Wattles can be made from straw, excelsior (wood) fiber, saw dust particles, compost, and other similar biodegradable materials and are made to conform to the soil surface, secured by staking. Wattles generally are available in diameters from 9 to 20 inches. Lengths vary, but are generally at least ten feet long and can come in long rolls, giving the installer the capability to cut the length needed for the area being treated.

Straw wattles shall meet the following specifications:

1. 9 inch minimum average diameter.
2. 100% noxious weed free straw
3. Netting: Synthetic photo-degradable
4. Top Net Opening: 0.50" X 0.50" +/- 10%
5. Bottom Net Opening: 0.50" X 0.50" +/- 10%
6. Configuration: cylindrical with closed ends
7. End Closure: tied or shut with hog rings

Sediment logs or excelsior logs (excelsior wattles) shall meet the following:

1. 12 inch minimum average diameter
2. Made from curled wood excelsior (other materials may be substituted on approval from the City of Casper.)
3. 80% of the fibers longer than 6.0"
4. Netting: Synthetic photo-degradable
5. Top Net Opening: 0.50" X 0.50" +/- 10%
6. Bottom Net Opening: 0.50" X 0.50" +/- 10%
7. Configuration: cylindrical with closed ends
8. End Closure: tied or shut with hog rings

Material Sources

Erosion control blankets, sediment logs, and straw wattles are available from erosion control products suppliers such as Geotec, Inc., Casper, WY; Granite Seed Co, Lehi, UT; Bowman Construction Supply, Inc., Denver, CO; and many others in the region. Hay and straw check bales are available from local feed stores, hay brokers, and local agricultural producers. Wood stakes and wind fences are available from local hardware stores, home improvement centers, discount retailers, farm supply centers, and reclamation material suppliers such as Geotec, Granite Seed, and Bowman Construction Supply, Inc. Allow sufficient time for suppliers to order and deliver these materials.

MAINTAINING REVEGETATED AREAS

Once the disturbed areas are revegetated, maintenance of these areas is sometimes necessary. Controlling weeds and assuring proper establishment of the vegetation species planted during the revegetation phase is important for the long term.

IRRIGATING

Irrigating revegetated areas is generally not recommended for native, dryland locations and may only be recommended by the City of Casper during periods of drought conditions. Irrigation adds to the cost of the project and from data from past projects in Wyoming and other states, irrigation can even be detrimental in selecting species adapted to the higher water regime so that when irrigation is discontinued, species density decreases.

Careful irrigation can be beneficial in quickly establishing vegetation but the costs generally considerably outweigh the benefits. As a general rule, four or five years after seeding, the difference between irrigated and non-irrigated areas is insignificant and can actually favor the non-irrigated areas. The converse can also be true, depending on precipitation events, and occasionally positive results are possible from short term irrigating.

Watering with a water truck is generally not recommended. It can cause compaction and washing. Topsoil and seed can be washed away from the project, leaving spotty results during plant establishment.

If irrigating is determined to be the preferred approach for a specific project due to situations that would favor irrigating, then water conservatively and infrequently. Attempt to apply slightly more or no more water than would be received naturally. The amount of water per episode and the frequency of watering will depend on the time of year, the seed mixture, the soil type, air temperatures, and similar factors that affect the moisture regime in the soil root zone profile. As an example, watering in the late spring or summer once or twice a week at a rate of 0.5 to 0.7 inches per episode might simulate a wet spring or summer season.

In general then, watering dryland, native species is not recommended. The negatives often outweigh the positives. Artificial watering increases weed densities, cover, and heights, minimizing sunlight to the young, establishing dryland species. Washing and erosion can sometimes be a problem. Compaction often occurs. Undesirable perennial species often germinate and compete. Watering can actually reduce establishment of desirable native dryland, perennial species. On the other hand, proper watering can help with perennial plant establishment, but costs can be high and benefits generally do not outweigh the costs.

CONTROLLING WEEDS

The Project Owner is responsible for controlling and minimizing noxious and invasive weeds. A weed is a plant out of place or a plant species that interferes with the native community. An invasive weed is a plant species that is not native to the area and has a negative impact on the environment.

Mowing weeds or applying herbicides are the two most common methods of controlling weeds on newly reclaimed areas.

Mowing:

Mowing may be useful for reducing impacts to the native species from weed invasion. To minimize regrowth, weeds should be mowed late in their growing season, just prior to the weeds setting seed (soft dough stage). If mowed too late, then the weed seeds will continue to mature after mowing and may become viable seed to germinate and grow in the future.

The Project Owner should use a rotary mower, set to cut the vegetation above the bulk of the top height of the perennial grasses planted and as low as possible to remove and chop as much of the weed biomass as possible. Usually a setting of around 4 or 5 inches above the ground is appropriate. To the extent possible, do not mow the planted species in the seed mixture.

Applying Herbicides:

Local commercial herbicide applicators and the Natrona County Weed and Pest Control District office are available to assist with providing spraying and weed control services. These individuals will provide necessary chemicals and methods to eliminate or minimize weeds. Table 4 – Noxious and Invasive Weeds of Casper, Wyoming, provides some general information on weeds of concern in the area.

CONTROLLING WILDLIFE IMPACTS

The Project Owner may need to monitor wildlife movement and impacts to newly seeded areas. Hiring a consultant may be the best method to devise a plan to minimize negative impact from wildlife.

Fencing may minimize impact from wildlife. When necessary to minimize wildlife impacts to newly seeded areas, fences should be constructed to eliminate large undulate movement into the revegetated areas and therefore should be constructed of woven or mesh wire in combination with barbed wire and generally need to be six to eight feet high. Such fencing is costly and the practical need for this type of fence needs to be considered and the benefits weighed against the cost and reasons not to construct this type of fence.

Repellent sprays are available but may be cost prohibitive on a large scale. Creating diversions for the wildlife to attract them to other areas may prove successful although this method may be difficult to incorporate into the reclamation plan because of other variables out of the control of the Project Owner.

MANAGING LIVESTOCK GRAZING

To the extent possible, the Project Owner should limit livestock grazing on newly seeded areas for up to three years. Practically, this is not always possible. In such cases, the Project Owner should negotiate with the landowner or grazing right tenant to limit grazing until after the growing season where revegetation has occurred within the past three years. Grazing after the vegetation is dormant for the year will reduce negative impacts from over utilization.

FENCING

Fencing is an option available to the Project Owner to assist in enhancing the chances of revegetation success. Fencing is relatively expensive and for many small sites, the cost of fencing may be considerably higher than the cost of revegetation work.

The Project Owner should consider other options, including but not limit to, controlling public access, limiting livestock grazing pressure until after the newly seeded areas have had a chance to establish, and similar proactive approaches are recommended. The Project Owner is responsible for providing satisfactory vegetation and soil stabilization on the project and enhancing the chances for revegetation success assists greatly in meeting this responsibility.

Fencing contractors are available locally to provide fencing services. A fencing plan should be provided to the City of Casper for approval. The City of Casper will generally allow any type of fence that is not a public hazard and addresses the issues at hand.

Table 4 – Noxious and Invasive Weeds of Casper, Wyoming.

Common name	Scientific Name	Designated or Prohibited Noxious Weed
Black henbane	*Hysocyamus niger*	
Blue lettuce	*Lactuca pulchella*	
Blue mustard	*Chorispora tenella*	
Buckhorn plantain	*Plantago lanceolata*	
Canada thistle	*Cirsium arvense*	Yes
Cheatgrass	*Bromus tectorum*	
Common burdock	*Arctium minus*	Yes
Dalmation toadflax	*Linaria dalmatica*	Yes
Diffuse knapweed	*Centaurea diffusa*	Yes
Dodder	*Cuscuta* spp.	
Dyers woad	*Isatis tinctoria*	Yes
Field bindweed	*Convolvulus arvensis*	Yes
Foxtail barley (foxtail)	*Hordeum vulgare*	
Houndstongue	*Cynoglossum officinale*	Yes
Halogeton	*Halogeton glomeratus*	
Japanese brome (cheatgrass)	*Bromus japonicus*	
Jointed goatgrass	*Aegilops cylindrica*	
Kochia	*Kochia scoparia*	
Leafy spurge	*Euphorbia esula*	Yes
Musk thistle	*Carduus nutans*	Yes
Oxeye daisy	*Chrysanthemum leucanthemum* (*Leucanthemum vulgare*)	Yes
Perennial sowthistle	*Sonchus arvensis*	Yes
Perennial pepperweed	*Lepidium latifolium*	Yes
Perennial ragweed	*Ambrosia psilostachya*	
Plumeless thistle	*Carduus acanthoides*	Yes
Poverty weed	*Iva axillaris*	
Puncturevine	*Tribulus terrestris*	
Purple loosestrife	*Lythrum salicaria*	Yes
Quackgrass	*Agropyron repens* (*Elytrigia repens*)	Yes
Russian knapweed	*Centaurea repens* (*Acroptilon repens*)	Yes
Russian olive	*Eleagnus angustifolius*	Yes
Russian thistle	*Salsola kali*	
Salt cedar	*Tamarix* spp.	Yes
Scotch thistle	*Onopordum acanthium*	Yes
Skeletonleaf bursage	*Franseria discolor*	Yes
Spotted knapweed	*Centaurea masulosa*	Yes
Swainsonpea	*Swainsona salsula*	
Tansy	*Tanacetum vulgare*	
Tansymustard	*Descurainia pinnata*	
Whitetop	*Cardaria draba*	
Whitetop (hoary cress)	*Cardaria pubescens*	Yes
Wild oat	*Avena fatua*	
Yellow starthistle	*Centaurea solstitialis*	
Yellow toadflax	*Linaria dalmatica*	Yes

Weeds not currently listed as designated or prohibited noxious weeds are included in the above list because these weeds are some of the many weeds that can negatively impact revegetation success on reclamation projects in the Casper area.

Please refer to: The local office of the Wyoming Weed and Pest for more information. Also, *Weeds of the West,* Western Society of Weed Science, 5th Edition, 1996 (available through the University of Wyoming).

HANDLING PUBLIC ACCESS

Access points should be limited or blocked to allow for proper development of vegetation communities on newly seeded areas. Even a minor amount of vehicular travel, including ATV's, can do considerable damage to young, tender seedlings and new vegetation. As needed, block access points with fences, signs, boulders, deep ditches (appropriately marked), berms, and any other method to restrict and control public access to newly seeded areas. Signs may need to be posted, but should not be considered a deterrent; physical structures are generally required.

RECORDKEEPING AND MONITORING

RECORDKEEPING

During reclamation and revegetation activities, the Project Owner should provide to the City of Casper appropriate certifications for all materials used and incorporated into the project during the revegetation phase. Certifications as to the quality of the material and to the quantity of material incorporated should be included in the submittals to the City of Casper. Certifications are discussed in each material section above. The Project Owner should be ready to provide the City of Casper with certifications upon arrival at the project and prior to incorporating that material into the project.

Following revegetation, monitoring of site conditions should be initiated. Frequency and degree of effort will depend on site conditions and many variables. Monitor the site as described below.

VEGETATION MONITORING:

Revegetation typically requires three (3) years before success can be completely and finally assessed (see Three Year Rule of Thumb section below for details). Following the first growing season the revegetation area may look weedy and mostly devoid of native perennial grasses (grasses); generally, grasses exist, in varying stages of growth, hidden among the annual weeds, near the ground surface. The leaf structure of grasses emerges like hair and is hard to see by the untrained eye. As the growing season continues, more evidence of the seed mixture species can occur and sometimes drill rows and occasionally seed stocks develop.

During and at the end of the second full growing season, more grasses should be evident and drill rows should be more apparent. The grasses generally dominate over the annual weeds, although annual weeds are still common members of the new plant community. Grasses sometimes head out and reproduce during this second growing season. The untrained individual can generally see the grass this season. Normal to above normal precipitation will increase this development, but drought will significantly reduce it.

By the end of the third growing season, the Project Owner and City of Casper can generally determine the success of the revegetation project. The planted seed mixture species should dominate the surface and few weeds should exist. Plant cover and density should be at or near the desired levels.

The Project Owner should evaluate the revegetation site following each growing season for at least three years. When possible, schedule revegetation success monitoring between August

1st and October 15th. Monitoring in late June and July is also possible, depending on plant growth for the season; more wildflowers will most likely be noticeable during this time period then after these species have dried out by late summer or early fall. Monitoring documentation recommendations are specified in the Recordkeeping Section.

The following observational assessment is recommended:

1. Observe revegetation results and document success.
   a. Sample revegetated areas and compare to adjacent native areas.
   b. Provide an ocular estimation of plant cover, production, and density and document with photographs.
2. Record and photograph erosional aspects observed (gullies, rills and sheet erosion).
3. Photograph current conditions with an emphasis on problem areas where vegetation establishment is less than expected.
4. Identify, map, describe, and photograph invasive and noxious weeds and initiate immediate mitigation.
5. Observe grazing utilization and overgrazing potential.
6. Describe wildlife impacts including rodents, rabbits, and large grazing undulates (deer, antelope, etc.).

Generally, a good standard to use is to compare the reclaimed and revegetated area with adjacent native rangeland that has not been overutilized or overgrazed. This comparison can be done by utilizing quantitative sample data or by ocular estimation of plant community cover, production, and diversity. In a matter of a few hours, an experienced individual, with sufficient knowledge of plant species and erosional features, can determine the information recommended above by visual observations and a visual comparison of the revegetated area to appropriate adjacent native sites. The Project Owner may wish to hire a vegetation specialist to provide quantitative data and in some situations where potential problem areas appear to exist, may be requested to do so by the City of Casper.

Inspection Form for Revegetated Areas

Following is a sample form, Inspection Form for Revegetated Areas, for use in evaluating site conditions during field inspections. Use this form or modify as necessary to address and document reclamation, revegetation, and soil stability issues and success on the reclaimed sites.

CITY OF CASPER - INSPECTION FORM FOR REVEGETATED SITES

File Number: _____ Inspection Date: _____

Project Owner: _____ Site Name: _____

Inspector: _____ Participants: _____

Status: □ Active □ Inactive □ In Reclamation □ Abandoned

Site acreage: _____ Access Road Acreage: _____ Total Disturbed Acreage: _____

Month and Year Revegetated: _____ Revegetation Company: _____

This inspection is occurring after: (circle one) 1 2 3 4 5 6 7 full growing seasons.

Photos Attached: yes / no (number of photos: _____) Maps Attached: yes / no

DESCRIPTION	ADEQUATE? YES	NO	COMMENTS AND NOTES
Project Signs			
Topsoil Salvage			
Topsoil Protection			
Topsoil Signs			
Off-Project Land Disturbed			
Native Lands Disturbed			
Erosion			
Rilling			
Gullying			
Roads and Culverts			
Overhead Powerlines			
Impoundments			
Steep Slopes			
Sediment Control			
Dust Control			
Grading			
Through Drainage			
Drainages Protected			
Off-Site Protected			
Weeds Present*			
Oil Spills Present			
Toxic Material Present			
Other:			

NOTE: Some line items above will not necessarily apply to this project or this inspection. Indicate with N/A.

* describe noxious and invasive weeds and their location and dominance on the revegetated site below and indicate on map.

CITY OF CASPER
INSPECTION FORM FOR REVEGETATED SITES

Vegetation Established:

a. Vegetation Species Composition _____

_____

b. Dominant Species _____

c. Invader Species & Weeds: _____

d. Noxious Weeds occurring on site: _____

e. Vegetation Cover/Production/Density:

	Poor	Fair	Good	Excellent
Cover	❑	❑	❑	❑
Production	❑	❑	❑	❑
Density	❑	❑	❑	❑
Species Diversity	❑	❑	❑	❑
Plant Vigor	❑	❑	❑	❑

f. Grazing Utilization _____

Compliance Assessment: _____
_____
_____

Action Recommended / Required by Project Owner: _____
_____
_____
_____
_____
_____

- For all of above, attach additional pages and data as necessary and document all observations with photographs.

Additional Comments: _____
_____
_____
_____
_____

Inspector Signature: _____ Date: _____

Copy Sent: □ Project Owner □ City of Casper □ NRCS □ BLM □ Other (_____)

Field Notes, Diagrams, Drawings, Reminders (Use back of form and/or additional pages as needed):

THREE YEAR RULE OF THUMB FOR REVEGETATION SUCCESS:

Plant establishment often takes longer than most people expect. A Three Year Rule of Thumb commonly known throughout the reclamation industry exists for native, perennial, dryland grass establishment in the semiarid west: Following reclamation and revegetation, desirable, perennial, native, dryland plant species of the West require up to three years to establish. The three year Rule of Thumb time table is described below (in good years, development is more rapid and in drought years development is even slower).

The first year, the area looks weedy and mostly devoid of perennial grasses (they are generally there, in varying stages of growth, hidden among the annual weeds, near the ground surface). Leaf structure is like hair at first and hard to see to the untrained eye. Some seeds germinate months before others.

In the second year (second full growing season), more grass and desirable plants are noted, drill rows appear, and the perennial grasses and other planted species generally dominate over the annual weeds. However, annual weeds are still common members of the new plant community. Grasses sometimes head out and reproduce this year. The untrained individual can generally see the grass and some of the other planted species this growing season.

By the end of the third growing season, the Project Owner and City of Casper generally can determine the success of the revegetation project. If bare areas and other unsatisfactory conditions still exist, the City of Casper may request that the Project Owner determine the cause of the bare areas or other unsatisfactory conditions. Many variables exist to cause less than adequate vegetation establishment. Some of these variables include duration, timing, and quantity of precipitation events, soil temperatures, soil texture, soil chemical characteristics, nutrient availability, phytotoxic materials in the soil, heavy metals, chemical spills, utilization of non-topsoil material for the plant growth media, impact by wildlife, livestock, pets, and humans, herbicide spraying, weed and noxious weed invasion, poor soils selection and placement techniques, inappropriate revegetation equipment or workmanship, and inappropriate plant species selection in the original seed mixture.

Most native perennial species utilized in standard reclamation / revegetation work require 21 to 28 days to germinate after soil temperature and moisture conditions meet certain minimum standards for a certain length of time. It may rain sufficiently the day after seeding to initiate germination but this is rarely the case. If it does rain, the soil temperatures may be too cold or too hot to allow germination of some or most of the species and seed. Seed may lay dormant in the soil for months before conditions are right for it to germinate. Some seed must go through a winter and a scarification of the seed coat before it will germinate. Some seed of one species on one micro site may have the proper conditions to allow initiation of germination while 3 foot way, conditions are enough different to keep germination from starting for that species at that point in time. Some species have a larger 'window of opportunity' in which they will germinate; they may germinate and grow in conditions that restrict other species from germinating (annual weeds, for example, have a large range of conditions that allow for germination).

As with any Rule of Thumb, exceptions to the rule always occur. Sites revegetated just prior to the summer monsoons may witness vegetation stands at the end of the first growing season as good as most areas look after two or three years. The other extreme also exists. Areas can be

seeded and no rain or inadequate rain or other factors keep seed from germinating for an entire growing season. Sometimes the area can even be devoid of weeds. Generally, the seed is still intact and viable and is simply waiting for conditions that will allow initiation of germination. In such cases, waiting through another growing season can produce successful revegetation.

A rainstorm in the middle of the summer will not necessarily initiate germination nor will a week of cold, wet weather in early spring (or fall). During drought years, which no one can predict, vegetation establishment will be slower or non-existent. This does not mean that revegetation is a failure, it generally means that nature has slowed the process and more time is necessary to allow proper vegetation establishment. If the Project Owner implemented appropriate erosion control measures during the revegetation process, then the risk of failure will be minimized during these times.

Occasionally, seeds germinate and begin to grow and the weather pattern turns off hot and dry and many of the young, immature seedlings dry up and die. This is the exception rather than a common occurrence, but it has happened in the past on revegetation projects. Without expensive and time consuming studies by experts in plant physiology and related fields, a positive determination of failure or potential success is not generally possible. The logical and most cost effective method is to give Mother Nature some time and then re-evaluate after another growing season or two.

When weather conditions or other uncontrollable factors slow the revegetation process, the possibility of damage to the site by external forces (wind, heavy precipitation events, traffic, etc.) is increased. Mulch and weed cover help minimize the impact from these forces. The use of surface mulch is important to the success of many projects. Grass hay mulch is by far the superior mulch over straw and hydromulch in most of the West as it generally has much better holding abilities in wind and rain storms and generally has a longer life expectancy. Weeds are often beneficial the first year by protecting the soil surface and young, establishing perennial species. A heavy, tall weed cover can be detrimental and may need to be mowed for best results, but generally weed if weed cover is scattered and weeds are less than three feet tall or so, mowing and weed control are not usually necessary.

Therefore, the Project Owner or City of Casper should evaluate revegetated sites, using this Three Year Rule of Thumb. At the end of each growing season for at least three years following revegetation efforts, and between August 1st and October 15th, for example, revegetation success monitoring is recommended. The Project Owner and/or the City of Casper should tour the sites in question and observe revegetation results and photograph current conditions with an emphasis on problem areas where vegetation establishment appears to be less than expected. Remember, in the first year, do not expect significant desirable species development. During and after the second growing season, some drill rows and noticeable amounts of desirable species will most likely be present. By the end of the third growing season, a good stand of grasses and other desirable species will generally dominate the site. The best standard to use in year three and beyond is to compare the reclaimed and revegetated area with adjacent undamaged native rangeland. This comparison can be done by utilizing quantitative sample data or by ocular estimation of plant community cover, production, and diversity as described in the above section, Vegetation Monitoring.

List of Plant Species Utilized in Seed Mixtures in the Revegetation Plans

Grasses

Common Name	Variety	Scientific Name
Alkali grass	Fults	*Puccinellia distans*
Alkali sacaton	VNS, Northern	*Sporobolus airoides*
Blue grama	Bad River	*Bouteloua gracilis*
Bluebunch wheatgrass	Secar	*Pseudoroegneria spicata ssp. spicata*
Bottlebrush squirreltail	VNS, Northern	*Elymus elymoides*
Crested wheatgrass	Fairway	*Agropyron cristatum*
Green needlegrass	Lodorm	*Nasella viridula*
Indian ricegrass	Nezpar, Rimrock	*Achnatherum hymenoides*
Inland saltgrass	VNS, Northern	*Distichlis spicata*
Little bluestem	VNS, Northern, Camper	*Schizachyrium scoparium*
Needleandthread	VNS, Northern	*Hesperostipa comata ssp. comata*
Nuttal alkali grass	Quill, VNS	*Puccinellia nuttalliana*
Prairie sandreed	Goshen	*Calamovilfa longifolia*
Redtop	VNS, Northern	*Agrostis gigantea*
Sand bluestem	VNS, Northern, Woodward	*Andropogon hallii*
Sand dropseed	VNS, Northern	*Sporobolus cryptandrus*
Sideoats grama	Vaughn, El Reno	*Bouteloua curtipendula*
Slender wheatgrass	Revenue, Pryor	*Elymus trachycaulus ssp. trachycaulus*
Smooth bromegrass	Manchar	*Bromus inermis*
Streambank wheatgrass	Sodar	*Elymus lanceolatus ssp. psammophilus*
Thickspike wheatgrass	Critana	*Elymus lanceolatus ssp. lanceolatus*
Western wheatgrass	Rosana	*Pascopyrum smithii*

Forbs

Common Name	Variety	Scientific Name
Blue flax	Appar	*Linum perenne*
Blue flax	Maple Grove	*Linum lewisii*
Firecracker penstemon	VNS, Northern	*Penstemon eatonii*
Fringed sagewort	VNS, Northern	*Artemisia frigida*
Indian blanketflower	VNS, Northern	*Gaillardia aristata*
Prairie aster	VNS, Northern	*Machaeranthera tanacetifolia*
Prairie coneflower	VNS, Northern	*Ratibida columnifera*
Purple prairie clover	VNS, Northern	*Dalea purpureum var. purpureum*
Western coneflower	VNS, Northern	*Rudbeckia occidentalis*
Western yarrow	VNS, Northern	*Achillea millefolium var. occidentalis*
White evening primrose	VNS, Northern	*Oenothera pallida*
Wild lupine	VNS, Northern	*Lupinus perennis*

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APPENDIX A - QUICK GUIDE TO REVEGETATION PLANS AND REVEGETATION TECHNIQUES

REVEGETATION PLANS	BEST SUITED REVEGETATION TECHNIQUES									
	Seed Mix	Fert.	Soil Amend.	Seedbed Prep.	Seeding Method	Hay Mulch	Hydro-mulch	Tack Type M	Erosion Control Materials	Irrigation
Bottomland	B	Yes	No	Sc, Ds	Drill	Hay	Opt.	w/ Hym.	Opt.	Opt.
Saline Bottomland	CL	Yes	Yes	Sc, Ds	Drill	Hay	Opt.	w/ Hym.	Opt.	Opt.
Saline / Alkali	CL	Yes	Yes	Sc, Ds	Drill	Hay	Opt.	w/ Hym.	Opt.	Opt.
Clay	CL	Yes	Opt.	Sc, Ds	Drill	Hay	Opt.	w/ Hym.	Opt.	No
Clay Loam	CL	Yes	No	Sc, Ds	Drill	Hay	Opt.	w/ Hym.	Opt.	No
Silty Clay Loam	CL	Yes	No	Sc, Ds	Drill	Hay	Opt.	w/ Hym.	Opt.	No
Loam	L	Yes	No	Sc, Ds	Drill	Hay	Opt.	w/ Hym.	Opt.	No
Fine Sandy Loam	SL	Yes	No	Sc, Ds	Drill	Hay	Opt.	w/ Hym.	Opt.	No
Shallow Loam	CoL	Yes	No	Sc, Ds	Drill	Hay	Opt.	w/ Hym.	Opt.	No
Cobbly Loam	CoL	Yes	No	Sc, Ds	Drill	Hay	Opt.	w/ Hym.	Opt.	No
Gravelly Loam	GL	Yes	No	Sc, Ds	Drill	Hay	Opt.	w/ Hym.	Opt.	No
Gravelly	GL	Yes	No	Sc, Ds	Drill	Hay	Opt.	w/ Hym.	Opt.	No
Loamy Sand	S	Yes	Opt.	Sc, Ds	Drill	Hay	Opt.	w/ Hym.	Opt.	No
Sandy	S	Yes	Yes	Sc or RH	Drill	Hay	Opt.	w/ Hym.	W.Fence	Opt.
Very Sandy	S	Yes	Yes	Sc or RH	Drill	Hay	Opt.	w/ Hym.	W.Fence	Opt.
Blow Sands / Dune Sand	BS	Yes	Yes	Sc or RH	Drill	Hay	Opt.	w/ Hym.	W.Fence	Opt.
Non-Topsoil Surfaces:										
No Topsoil	Var.	Yes	Yes	Sc, Ds	Drill	Hay	Opt.	w/ Hym.	Opt.	Opt.
Site Phases: (Adjust Techniques above as altered below)										
Slopes > 3V:1H	Var.	Yes	Var.	Sp Ch	Bd or Hys	No	Yes	Yes	STC, CC2	No
Rocky or cobbly	Var.	Yes	Var.	Ds	Drill or Bd	Hay	Hym	Yes	Opt.	Opt.

The above chart provides only a general overview in quickly determining revegetation techniques needed for different soil and site situations. Refer to the Revegetation Plans for details, exceptions, and additional techniques necessary.

Definitions and descriptions of abbreviations:

- Seed Mix – Seed mixtures are detailed in each Revegetation Plan according to soil type.
- Opt. = Optional.
- Var. = Variable. Depends on soil type and site conditions.
- Seedbed Preparation column: Sc = Scarify, Ds = Disc, RH = Roller Harrow, Sp Ch = Slope chain or other method of loosening and preparing the seedbed including raking, dragging a chain, etc.
- Seeding Method column: Drill = Rangeland Drill
- Erosion Control Materials column: W.Fence = Wind Fence, STC = double sided straw-coconut (70%/30%) blanket, CC2 = 100% coconut ditch liner erosion control blanket.
- Seeding Method: Bd = Broadcast seeding, Hys = Hydroseeding
- Hydromulch: Hym = Hydromulch if cannot hay mulch (first option)

Once the revegetation technique or group of techniques is determined, detailed information about each technique, located in the Revegetation Techniques section of this handbook, should be consulted for details in using each suggested technique.

The City of Casper has provided this revegetation handbook to assist City of Casper personnel and Project Owners in addressing reclamation and revegetation aspects of construction projects in the Casper area. If you have used this handbook and found it useful, please let the Engineering Department know. If you have comments and ideas for changing or adding to the handbook, please advise. The City of Casper wants this handbook to be a useful field tool for all involved.

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