Establishment of Wetland Plants by Direct Seeding: A Comparison of Methods

2004-2005

Preliminary Report (January 21, 2005)

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Introduction

Establishment of wetland plants by direct seeding methods is desirable for many reasons. Revegetating with greenhouse plugs is both time consuming and expensive. Considerable time is required in preparing seeds for greenhouse plantings, maintaining greenhouse seedlings and planting the plugs at field locations. In contrast, it would be very convenient to simply disc or press in or broadcast seed into a wetland restoration site. However; sources agree that direct seeding is unpredictable and ineffective for many wetland restoration projects.

Many of the commonly utilized perennial wetland plant species spread primarily through vegetative reproduction and thus allocate less energy and effort into seed production. While proliferation of rhizomes is desirable in wetland revegetation for soil stabilization, these plants typically have low seed production and poor viability making seeding a less effective means of establishment (Steed & DeWald, 2003; Van der Valk, 1999). For these reasons seeding is considered less successful than transplanting live materials (Allen and Klimas, 1986; Kadlec & Wentz 1979; Van der Valk, 1999). See Table 1 for a comparison of wetland revegetation costs and potential success.

Most wetland plant species must meet three requirements in order for seed to germinate: adequate heat, water and light (Hoag, 2000). Meeting the light requirement means that planted seeds should not be drilled or broadcast and chained, because the seeds will be covered blocking the necessary light. A study conducted at the Aberdeen PMC greenhouse involving four common wetland species showed a mean decrease in germination of over 40% when seeds were covered by soil (data not shown).

Broadcast seeding onto the soil surface has, as yet, proven mostly unsuccessful, because most of the commonly utilized wetland species have seeds which float or are light enough to be easily displaced by water or wind. Runoff or flooding events, which are common in wetland areas, carry seeds and deposit them at the water's edge in a narrow zone instead of being uniformly spread across the surface. Dunne et al (1998) report that in high-energy environments or erodible sites, fall sowings are particularly susceptible to displacement by wind or water energies. According to Allen and Klimas (1986), "If the revegetation site will be subjected to fluctuating water levels or wave action soon after planting, seeding is probably not the best plant establishment alternative because the seeds are likely to wash out. Seeding in these cases should be done only to augment transplanting.'

Table 1. Comparison of revegetation method costs and effectiveness.

Revegetation method	Plant Material Cost	Plant Installation Cost	Shipping and Handling Cost	Notes	Relative Success
Passive	None	None	None		Ineffective
Broadcast seeding	Low	Low	Low-Medium	Seed cost dependent on species mix; seed quantities and varieties sometimes limited; handling time can be costly due to seed pretreatment.	Ineffective
Salvaged marsh surface	None	Low-High	Low-High	Installation and shipping cost largely dependent on distance between donor and restoration sites.	Ineffective
GP* bare root plants	Medium	Medium-High	High	Installation cost varies according to site conditions; shipping costs vary by distance and region.	Effective
GP container plants	Medium	Medium-High	Medium	Installation cost varies according to site conditions; shipping costs vary by distance and region.	Effective
Wild-collected transplants	None-Low	Medium-High	Low-High	Installation cost varies widely according to site conditions; shipping and handling cost dependent on distance between donor and restoration sites.	Effective
Vegetated mats	High	Low	High	Shipping costs vary by distance and region but inherently high due to bulkiness.	Effective

*GP=Greenhouse propagated (Adapted from Klausmann and Hook, 2001).

Private sector nurseries agree that direct seeding is ineffective for areas where water levels cannot be sufficiently controlled. Ernst Conservation Seed (2004) states in their catalog, "it is not practical to seed any wetland where the water is more than 2 inches deep or where flooding is likely to occur." Milner (2003) reports similarly, "seeding opportunities are very limited in wetlands that rely chiefly on surface runoff because periodic flooding prevents seed incorporation…The dependence on a seed mix to provide vegetative cover should decrease as water levels and duration of flooding increase."

Direct seeding is more feasible where water levels can be controlled. The soil must be kept sufficiently wet to provide enough moisture for seed germination without the danger of the seed washing away. The soil must also not be allowed to dry out, or terrestrial species could become established and out compete desired wetland species (Hammer, 1992). Even with adequate water control, seeds can still be washed away or buried in silt with uncontrolled flooding.

Figure 1. Submerseed™ particles incorporated with alkali bulrush.

New technologies are being developed attempting to answer many of the problems faced in seeding wetlands. Tackifiers are available to glue seed to the soil. Greenhouse studies conducted by the authors indicate that a tackifier/seed slurry holds seeds well to the soil, even after multiple flooding events and does not inhibit germination (data not shown). Another product, Submerseed™ (SS) from Aquablok Industries, involves binding seed with clay or clay-sized material and organic polymers to a dense aggregate core (see Figure 1). These aggregates are reported to absorb water and be heavy enough to sink and hold to the soil (Krauss, 2004). Our preliminary test results showed excellent germination rates and no known seed loss due to washout (see Figure 2). This coupled with ease of planting and handling is very encouraging. The purpose of this study is to evaluate and compare direct seeding methods of wetland plant species in order to determine which (if any) method provides greater establishment success and is more cost effective.

Figure 2. SS particle with Baltic rush seedlings (six days after planting).

Materials and Methods

Six species were chosen to represent the most commonly utilized wetland species involved in wetland creation and restoration projects in the Intermountain West: Nebraska sedge (*Carex nebrascensis*), Creeping spikerush (*Eleocharis palustris*), Baltic rush (*Juncus balticus*), Hardstem bulrush (*Scirpus acutus*), Alkali bulrush (*S. maritimus*) and Common threesquare (*S. pungens*). In the late summer of 2004, 34 seed collections were made using a seed stripper (Prairie Habitats Ltd., Canada) from wetlands throughout the Intermountain West. One collection from each species was chosen for use in this experiment based on the quantity and quality of seed collected (See Appendix 1 for an overall summary of collections. See Table 2 for detailed seed collection data of utilized collections). Due to poor stands and low seed production in 2004, the authors were unable to obtain sufficient amounts of Nebraska sedge for testing. We therefore employed seed collected from the Aberdeen PMC wetland ponds in 2000. All harvested materials were allowed to dry and were then thrashed and cleaned at the Aberdeen PMC small seed lot cleaning facility. Appendix 2 shows machine techniques and calibrations used to clean each species.

Table 2. Seed information of utilized collections

Species	Common name	Collection #	Location	Collection date	Dirt wt (lb)	Clean wt. (lb)	% Purity	% Viability
Carex nebrascensis	Nebraska sedge	*	ID PMC wetland ponds	2000	*	*	98.62	88
Eleocharis palustris	Creeping spikerush	djt 3290	American Falls Res., ID	9/1/04	4.54	1.04	99.38	93
Juncus balticus	Baltic rush	djt 3242	Sterling WMA, ID	8/20/04	6.50	0.74	98.9	90
Scirpus acutus	Hardstem bulrush	djt 3236	Hagerman WMA, ID	8/23/04	1.72	1.02	99.68	85
Scripus maritimus	Alkali bulrush	djt 3275	Railroad Valley WMA, NV	8/28/04	12.00	7.60	99.56	94
Scripus pungens	Common three-square	djt 3223	American Falls Res., ID	8/16/04	7.00	4.24	99.07	89

*Information not available.

Trial one:

Trial one will be a greenhouse study with tightly controlled conditions designed to evaluate seed displacement caused by a single flooding event. Trial one contains four treatments: (1) Submerseed™, (2) tackifier, (3) surface pressed, (4) drilled and pressed. Twelve 22” X 16” potting trays with holes in the bottoms will be filled with standard greenhouse soil medium consisting of soil, vermiculite and sand in a 1:1:1 ratio. Trays will be placed in a 4’ X 8’ simulated wetland tank. Each species will occupy two trays. Trays will be marked with ten rows making a total of 20 rows per species. Rows are ten inches long; each row will be considered as one plot. Experimental design will be completely randomized with five replications. All seeds in Trial one will be pre-stratified in a 30 day cold soak with sphagnum moss following Hoag and Sellers (1995). Rows will be ¼” deep on 2 ¼” centers. Trial one will begin after seed stratification and SS incorporation is completed.

Treatments one, three and four will be hand seeded with 20 seeds/row. Tackifier will be applied as a tackifier/seed slurry. Tackifier slurry for treatment two will be made from Turbo Tack High Performance Tackifier, Turbo Technologies, INC, at a rate of 0.05g tackifier/125 ml H_20. The well agitated suspension will either be poured into the rows from a beaker or using a medicine eye dropper.

The 4’ X 8’ simulated greenhouse pond will be slowly filled and allowed to flow over the rims of the trays. Seed not held in place will be displaced by the water from the rows and deposited in a new location. It is foreseen that displaced seeds may relocate to other rows; however, seeds should disperse randomly and not affect the final analysis. Water will then be drained from the 4 X 8 pond until the water level is below the soil surface. Soil in the trays will remain saturated for best possible germination results.

Trial two:
The second trial will be established at the PMC farm in six lined wetland ponds, one pond per species. Each pond measures approximately 55’ X 47’ of plantable space. Soil is a Delco silt loam with pH of 7.4 to 8.4. Plots will be eight feet of row with rows planted on three foot centers. Experimental design of Trial two will be a randomized complete block design with eight replications (see Figure 5 for pond diagram). Five treatments will be evaluated in Trial two: (1) drilled and pressed (2) seed placed on surface and pressed (3) tackifier (4) SS (5) greenhouse plugs (Table 4).

Treatments one and two will be seeded using a belt seeder equipped with a packing wheel. Treatment one will be drilled to a depth of no more than ¼”. Treatment three will be seeded as a tackifier/seed slurry as in Trial one. Slurry will be applied pouring the well agitated suspension from a pitcher. Treatment four (SS treatment) will be hand seeded. In all treatments, hardstem bulrush, alkali bulrush, common threesquare, Nebraska sedge and creeping spikerush will be seeded at a target rate of 20 PLS (pure live seeds)/foot. Baltic rush will be planted at a rate of 0.10 grams of bulk seed/ row (approximately 200 seeds/foot). Greenhouse grown plugs will be planted at a rate of one plant/foot.

Ponds will be flooded using a perforated four inch irrigation pipe laid across the edge of the pond. Water will be pumped in at a rate to approximate conditions encountered in natural settings. Water will be allowed to rise gradually until it reaches a target depth of one to two inches. Water will then be allowed to drain down naturally. Ponds will be re-flooded as necessary (when the surface soil is dry, approximately once every one to two weeks).

The original plan was to seed some treatments of this trial with non-stratified seeds in the fall and some with pre-stratified seeds in the spring, however, a large rain storm shortly before the fall planting date eliminated the possibility of a fall seeding. This trial will thus be seeded only in the spring using pre-stratified material. To compensate for the lost data, an additional small-scale trial was designed for a fall planting of non-stratified seeds (refer to support Trial two).

Support trials:
A series of smaller trials are also underway or planned at the PMC greenhouse. The first trial is being developed to determine the best water depth to plant SS pellets. Personal observations indicate that SS pellets will dissolve over time when left completely submerged in water. The trial is designed with SS pellets planted in blocks on an inclined plane with seeds above the water line, partially submerged and completely submerged.

This trial has two objectives: (1) determine the expected longevity of SS pellets at different water and saturation levels, (2) determine optimum depth for planting the six wetland species being evaluated in this study.

A second support trial was created in response to the poor weather conditions that prevented the planting of the fall treatments in the PMC wetland ponds. A 4’ X 8’ simulated wetland tank was erected outside the PMC office building in Aberdeen. The tank contained 12 greenhouse trays (two trays for each of the six species). Each species was seeded into three different treatments using non-stratified seed: (1) seed was drilled to a depth of ¼” and covered with soil; (2) seed was placed on the soil surface and pressed in and (3) SS. The trial was planted on 15 December, 2004 and will remain in place through the summer of 2005 (See Figure 3). Snow and rain will be allowed to drain out of the tank. In the late spring or early summer (when conditions and temperatures are suitable) the tank will be filled in the same manner as greenhouse Trial one and then evaluated for seed displacement and germination.

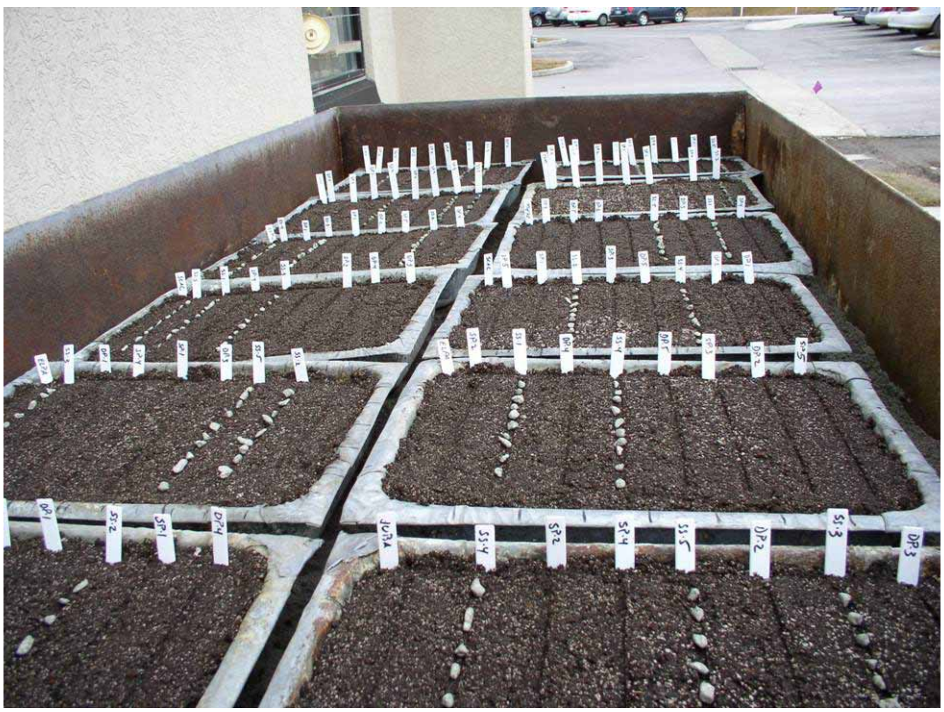


Figure 3. Outdoor trial with non-stratified seeds (white rocks are SS pellets).

Evaluations
Both trials are to be evaluated for the successful germination percentage and plant establishment percentage. Evaluations will take place after enough time has passed for most of the seeds to germinate but before vegetative recruitment occurs. In Trial one, germinated plants in each row will be totaled and divided by the known (or targeted) number of seeds in the row. In Trial two plots will be sampled to determine the mean plants per foot. Plants germinated in the soil medium but not in the row will be considered displaced and not counted.

Data will be subjected to an Analysis of Variance (ANOVA) and means will be separated with either a Tukey Test or Duncan's Multiple Range Test using the MSTAT-C Microcomputer Statistical Program (Freed et al, 1991).

Results

Early results indicate that new technologies (tackifier and SS) have great potential with regards to wetland seeding. There are however foreseen limitations in their application. Tackifier is known to degrade in sunlight. This eliminates the option of fall seeding, because the tackifier would dissolve by spring. Also, one would be forced to seed one wetland species at a time starting with species in the deeper hydrologic regimes. These would need to be allowed to establish before seeding the next zone of species and increasing water levels to allow for their establishment. Because SS pellets are not known to degrade in sunlight this would not be a problem, however, SS pellets are susceptible to frost damage. SS materials planted outdoors at the Aberdeen PMC in mid-December absorbed water during the day with above freezing temperatures. Ice wedges were subsequently created by the freezing nighttime temperatures (see Figure 4). An extended freeze-thaw cycle could potentially destroy the pellets over the winter months.

Figure 4. SS particle exhibiting ice fractures.

Cost analysis of methods

(This section will be completed after data collection and analysis)

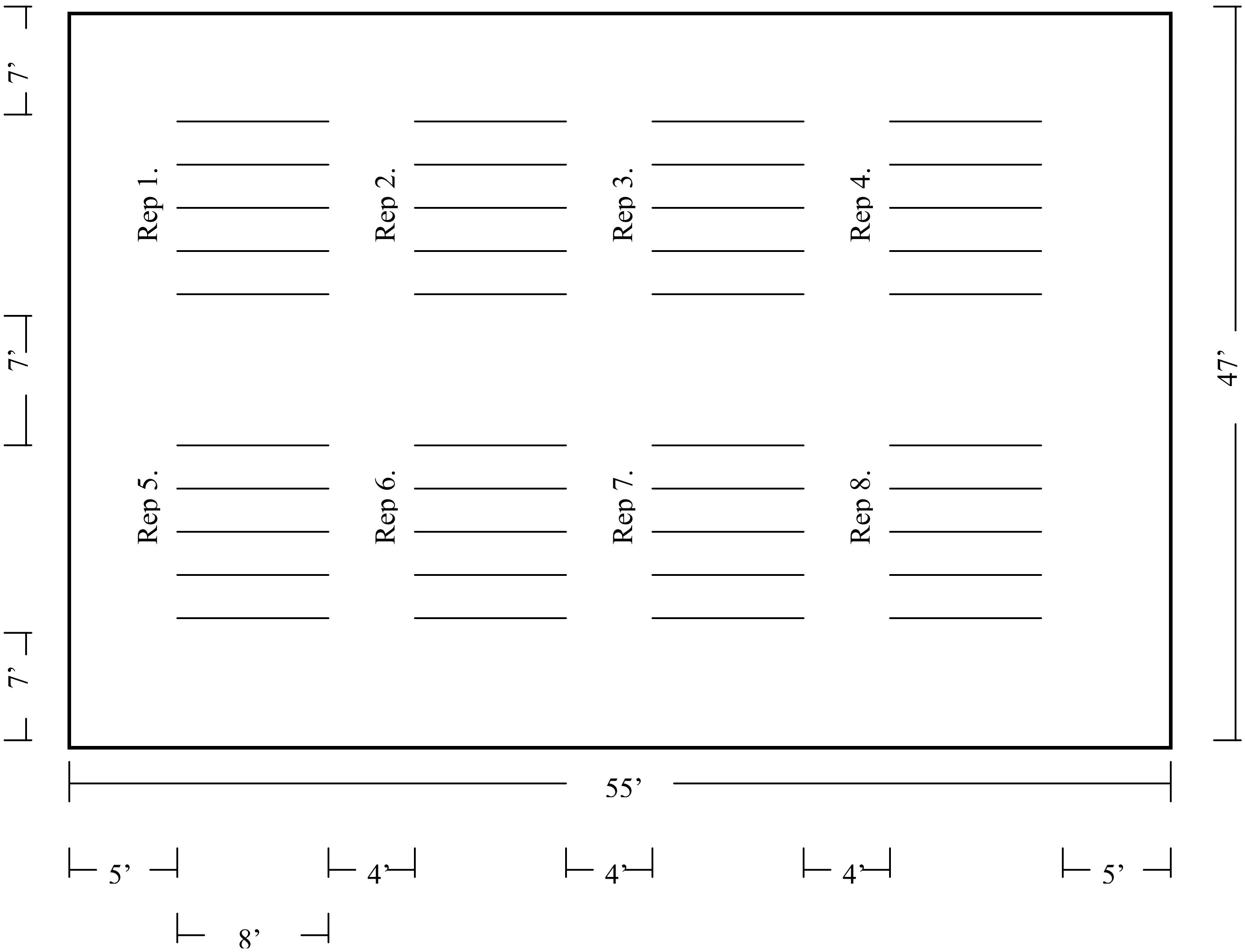
Summary/conclusions

Following data collection and analysis, a complete project summary will be written. This will include all findings and seeding protocols. Assumptions are that drilling and surface pressing of seed will be wholly ineffective. The use of greenhouse plugs is known to be an effective means of planting wetlands but is labor intensive and very costly. A tackifier has good potential, but is also limited in that it needs to be used in the spring and each species must be seeded one species at a time. SS also shows good potential. Germination rates are good with pre-stratified seed and seeding is very easy. Pellets can be broadcast easily by hand or using a fertilizer or salt-spreader (provided the holes are large enough) being hand-pushed or pulled behind an ATV. SS does require close attention to water levels, however, to allow deeper zoned species to establish before raising water levels. Seeds must be given enough time for roots to penetrate through the pellet and establish into the soil before raising the water levels, otherwise the pellet could dissolve and seedlings will be lost.

Table 3. Seeding information				
Species	Common name	Estimated seeds/lb[1]	PLS Rate[2]	Hydrologic regime[3]
Carex nebrascensis	Nebraska sedge	840K	2.3	Seasonally saturated
Eleocharis palustris	Creeping spikerush	1.4M	1.4	To 6" depth
Juncus balticus	Baltic rush	7M	0.3	Seasonally saturated
Scirpus acutus	Hardstem bulrush	500K	2.0	To 36" depth
Scripus maritimus	Alkali bulrush	150K	7.0	To 6" depth
Scirpus pungens	Common three-square	200K	5.5	To 6" depth

[1]Based on weight of 400 seeds except *Juncus balticus* which is based on 1000 seeds.
[2]PLS rates calculated using a target rate of 20-30 seeds/ft² for larger seeded species (≤ 500k seeds/lb) and 40-50 seeds/ft² for species with smaller seeds (>500,000 seeds/lb).
[3]Adapted from Ogle et al 2003.

Figure 5. Diagram of pond and experimental design for Trial two.



Appendix 1. Seed collection summary

Collection #	Species	Date Collected	Dirt wt. (lbs)	Clean wt. (lbs)	Location	% Viability*	% Purity*
3219	JUBA	8/13/04	0.34	0.10	Little Hole, ID		
3222	SCAC	8/16/04	5.90	3.20	American Falls Res, ID		
3223	SCPU3	8/16/04	7.00	4.24	American Falls Res, ID	89	99.07
3232	CANE2	8/23/04	trace	trace	Centennial Marsh WMA, ID		
3236	SCAC	8/23/04	1.72	1.02	Hagerman WMA, ID	85	99.68
3237	ELPA3	8/25/04	1.01	0.26	McTucker Pond, ID		
3238	SCAC	8/19/04	5.70	1.62	Camas NWR, ID	47	97.52
3239	JUBA	8/19/04	1.18	0.10	Camas NWR, ID		
3240	SCPU3	8/19/04	4.50	1.02	Market Lake NWR, ID	56	99.49
3242	JUBA	8/20/04	6.50	0.74	Sterling WMA, ID	90	98.9
3243	SCMA	8/17/04	7.01	5.25	American Falls Res, ID		
3244	ELPA3	8/27/04	1.33	0.16	Ruby Valley WMA, NV	79	98.87
3252	SCAC	8/27/04	1.86	1.00	Ruby Lake NWR, NV		
3253	JUBA	8/27/04	1.40	0.04	Ruby Lake NWR, NV		
3254	CANE2	8/27/04	trace	trace	Ruby Lake NWR, NV		
3264	JUBA	8/27/04	5.96	0.40	Kirch WMA, NV		
3269	SCMA	8/27/04	0.84	0.20	Kirch WMA, NV		
3270	ELPA3	8/27/04	1.54	0.30	Kirch WMA, NV		
3271	SCPU3	8/27/04	4.22	1.14	Kirch WMA, NV	65	91.27
3272	JUBA	8/27/04	2.86	0.26	Kirch WMA-Darcy, NV	53	56.21
3274	JUBA	8/28/04	3.14	0.04	Rail Road Valley WMA, NV	74	83.8
3275	SCMA	8/28/04	12.00	7.60	Rail Road Valley WMA, NV	94	99.56
3285	SCAC	8/29/04	1.46	0.54	Stillwater NWR, NV	82	99.72
3286	SCPU3	8/30/04	0.80	0.10	Ft. Boise WMA, ID		
3287	SCAC	8/30/04	3.44	1.46	Ft. Boise WMA, ID	41	98.88
3288	SCMA	8/30/04	2.72	1.02	Ft. Boise WMA, ID	96	99.48
3289	ELPA3	8/30/04	trace	trace	CJ Strike, ID		
3290	ELPA3	9/1/04	4.54	1.04	Little Hole, ID	93	99.38
3291	ELPA3	9/3/04	5.10	0.38	Malheur NWR, OR	93	98.59
3292	SCAC	9/3/04	1.40	0.32	Malheur NWR, OR		
3299	CANE2	9/3/04	0.30	0.12	Malheur NWR, OR		
3302	SCMA	9/9/04	13.10	7.50	Bear Lake NWR, ID	94	99.29
3307	SCMA	9/10/04	1.92	1.70	Bear River MBR, UT	97	99.05
3308	SCAC	9/10/04	trace	trace	Ogden Bay WMA, UT		

* As determined by the Idaho State Seed Lab

Appendix 2. Summary of seed cleaning techniques and equipment calibrations.

Baltic Rush (*Juncus balticus*)

1. Thrashing
    - A. 3/8” screen (left several unbroken capsules; see #3)
2. Air screen cleaner
    - A. Screens
        - 1. top-5.150
        - 2. middle-3.150
        - 3. bottom-1.250
    - B. Valves
        - 1. 2.0
        - 2. 5.5
        - 3. 2.0
        - 4. closed
    - C. Settings
        - 1. blower-1.5
        - 2. sieve-2
3. Debearder
    - A. unbroken capsules from above ran through debearder and again through air-screen cleaner.
4. Gravity table
    - A. Valve-3 ½
    - B. Blower-2.1
    - C. Sieve-2.2
    - D. Pitch-1.5
    - E. Slope-1.75

Creeping spikerush (*Eleocharis palustris*), Common three-square (*Scirpus pungens*), Alkali bulrush (*S. maritimus*) and Hardstem bulrush (*S. acutus*)

1. Hammer mill
    - A. Screen-1/4”
2. Indent cleaner
    - 1. Drum-2.75
    - 2. Speed-10
3. Air screen cleaner
    - A. Screens
        - 1. top-2.10 to 2.75
        - 2. bottom-blank
    - B. Valves
        - 1. 3.8
        - 2. 5.0
        - 3. 4.75
        - 4. closed

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