Re-vegetation of Brine Damaged Soil: A Soil Rebuilding Approach.

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Abstract

Soils damaged by brine spills are difficult to bring back to a healthy vegetated state. Initial damage often causes death of plants and degradation of the soil structure followed by erosion. An historic brine spill from a remote oil and gas lease in Southwestern Louisiana was remediated by a combination of physical, chemical and biological methods.

The remediation at this site was carried out in three phases. Phase I was a screening phase in which chemical amendments (commercially purchased calcium nitrate, gypsum- calcium sulfate) and organic material (composted manure, and rice hulls) were tilled into the soil. Five plant species (plus a natural re-vegetation option) were used to evaluate the most effective method for re-vegetating the damaged soil. Irrigation was not designed into the test since many locations are too remote to adequately import water, and therefore any strategy based on water import may not always be practical. *Spartina patens* planted from a local nursery proved to be the most salt tolerant of the species tested. During the first year of the trial Western Louisiana was under drought conditions. Initial survival rates of only 20% were observed. However, plants that survived the first six weeks of planting, maintained 100% survivability over the next three years. Organic matter and chemical amendments improved the survivability of plants on the site above the untreated control conditions

Phase II was carried out with a local commercial planter to work out logistics of re-vegetation with *S. patens,* hay, and chemical amendments. All methods proved similarly effective at this site.

Phase III, the full-scale remediation, was a combination of the technical lessons learned in earlier phases and documentation of the cost of the final remediation. Hay bales were spread on the soil surface followed by planting *S. patens* in three-inch pots on five foot centers. Initial survival of the plants was greater than 60%. The results from this site indicate that significant progress has been made to re-vegetate the contaminated soil in the most cost effective manner possible. Secondary growth began filling in around the *S. patens* planted. Electrical conductivity of the soils in the rhizosphere around the *S. patens* was one-third of that of the open salt damaged soil between plants

INTRODUCTION

Oil and gas production activities require handling produced water along with crude oil and petroleum products. Produced waters can be found with a broad range of salinities from nearly-freshwater to brines with salt concentrations greater than that of seawater. In the course of handling and transferring brines spills and leaks may occur resulting in localized environmental impact. The most obvious impact of surface brine spills is the loss of vegetation. This is accompanied by increased soil erosion as the salt damaged soil is not able to sustain itself against rain and wind.

Characteristics of Healthy Soil

Healthy soil has a top layer of dead leaves, grass, sticks, or pine needles in the early process of decaying. Next is a layer called the *A* horizon, a dark colored nutrient rich, soil layer containing humic materials and other organic breakdown products. The lower *B* and *C* Horizons are layers with less organic material having characteristics closer to the source stone as the depth is increased. The organic material along with clay particles are held together by the divalent cations calcium and magnesium.

Characteristics of Damaged Soil

When soils are damaged by salt the thatch layer erodes. Calcium and magnesium in the clay particles are replaced with sodium which in turn stimulates clay dispersion (enhancing erosion). The humic materials in the soil either break down or erode away. Re-vegetation can help rebuild the damaged soil structure.

Mechanisms for Revegetating Damaged Soil

Brine spill sites that occur along the Gulf Coast may slowly restore themselves and become re-vegetated with time. This can take decades. Erosion may seriously damage the landscape and the topography of the soil before natural recovery can occur.

Physical and chemical amendments are available that restore the soil productivity. However, they are often more costly than the price of the land. Those methods are designed to accomplish the following:

- remove salt,
- restore the ion balance of the soil,
- incorporate organic material into the soi,l and
- revegetate the soil.

This manuscript describes a relatively cost effective method to restore a salt or brine impacted soil by using halophyllic (salt-loving) plants to re-vegetate the soil and stimulate the natural recovery process. In this case, the plant is *Spartina patens*, (Marsh hay cordgrass or wiregrass), a plant native to salt marshes, which is adapted to survival at high salt concentrations and occasional dry conditions.

A phased approach was used to evaluate plants and planting techniques before the implementation of the full scale revegetation effort.

METHODS

Site

The site used in this study was a historical crude oil producing field in Southwest Louisiana. Leakage from brine tanks led to salt contamination of surrounding soil and the loss of vegetation in an area of about two acres. The surrounding habitat is upland forest predominantly vegetated with Loblolly Pine. Initially, no vegetation was found on the site, with the exception of two Salt Cedar trees approximately three m in height.

General Approach to Revegetating Soils

The evaluation for using salt tolerant plants as a means of improving the quality of salt damaged soil was performed in three phases. The first phase evaluated standard soil amendments and native salt tolerant plants for their ability to improve plant survival performance on the soils. Phase II optimized the most effective combination of soil amendments and plants found in Phase I. Phase III was the full implementation of the revegetation based on the information generated from the previous phases.

Phase I – Pilot Scale Test Plots

An initial assessment of the site was made in November of 1998. Electrical conductivity (EC) data was collected to determine the degree of impact at the beginning of the evaluation. Six, 20 ft X 20ft plots were created for the first phase of salt remediation evaluation. The soil modifications used in the evaluation were:

- Addition of calcium ions,
- Addition of organic material, and
- Tilling.

Survival of salt tolerant plants was the criteria used to measure success of the amendments. A nearby pond was used for the initial watering of plants immediately after planting. No other watering was used in this pilot study.

Soils were analyzed by EC at the start of soil amendments and throughout the pilot test. The soil treatment matrix is presented in Table 1.

Amendments were spread evenly over the surface of the test plots. All of the tracts were then tilled to approximately inches with a standard garden sized rototiller to incorporate amendments into the soil. For 110 days the soils were alone to allow the organic material and calcium to become incorporated into the soil. Plants were then transplanted into the six test plots to screen for the survival in the treated soils. The following plants were used in each plot

- *Spartina alterniflora* - 12 to 15 plants as multi-stem clusters from a local nursery on two foot centers
- *Spartina patens* - eight or nine 3 inch diameter pots per plot, purchased from a local nursery on three foot centers
- Six 3 inch diameter plugs pulled from the edge of the barren area and field identified as Dwarf Spikerush (*Eleocharis parvula*)
- Seeds of Bermuda grass purchased locally at a lawn and garden supplier
- Untreated plot to determine any natural revegetation stimulated by tilling only

Plots were posted with stakes and silt fencing was placed through the center of the plots to minimize erosion during the test.

The six test plots were scored after 38 days to evaluate the survivability of the plants in the test plot. The number of live plants, and dead plants were counted. A plant containing any green during this initial monitoring was considered a live plant. For a plant to be counted as dead, no visible green was observed on the plant. Survival was monitored as in Phase I

Phase II Optimize Scale-up

After assessing the Phase I results, it was decided that hay could be used instead of rice hulls for logistical reasons. The hay bales were easier to handle and were still easy to spread. Specialized bulk rice hull hauling trucks were ill-equipped for some lease roads and were not used. A short test was performed to determine if soils could be treated with less aggressive means. A second set of 20 ft X 20 ft parcels was planted and instead of adding rice hulls and tilling, the plants were immediately planted with *S. patens*, the most successful of the phase 1 plants. Bitter Panicum (*Panicum amarum*) was also planted as an alternative plants species known to be capable of resisting salt and drought conditions.

Phase III Full Implementation

The full implementation was performed over the remaining 2 acre section based on the Phase II results. Organic material was reintroduced to the soil in the form of hay. Two hundred bales were spread around the 2 acres of brine impacted soil. This layer of spread hay effectivesly replaced the original *A* horizon layer which had been lost to erosion over the years. The surface application of hay seemed to minimize the generation of a salt crust on the soil surface. The hay was left in place for approximately 75 days before planting. During that time the hay began to decompose and organic material began leaching into the salt damaged soil. Longer pretreatment may be need if there is no rain and the hay does not show signs of decomposing.

Spartina patens was transplanted from 3 inch diameter pots on approximately five foot centers. The planting density was determined by a compromise between cost of planting, versus time to site revegetation. More aggressive planting would result in faster recovery but at a higher cost The *Spartina patens* used in the planting fulfilled the quality requirements of the project:

- The plants were a locally grown variety cultivated from a local source (within 10 miles of the site)
- Plants were grown in a nursery, not harvested from a natural wetland.
- The transplantation was performed by a reputable contractor with a history of successful projects

- Plants were previously "salt hardened" prior to planting to at least 20 ppt salt. (Plants are salt hardened by growing them in water with sequentially higher salinities. This makes the plants more tolerant to a high salt environment and improves the probability of each plant surviving following replanting on the brine site).
- Only pots containing at least 12 shoots per pot were transplanted.

The Phase III monitoring parameters for survival criteria were the same as performed in previous phases. Only plants which were without any green vegetation were considered dead. Plants removed by animals or missing for any other reason were also scored as dead.

Effect of Plants on Soil Salinity

As part of the Phase III monitoring, paired soil samples were taken from the site to determine the impact of plants on the soil salinity. One was collected within the root zone of the plant (underneath the canopy of the vegetation) while the other was collected among three neighboring plants, approximately 2-2.5 feet from the base of the plants. In the field a 1:1 suspension was made of the soil with distilled water. EC measurements were made and root zone vs interplant areas were made for the eight month and one year monitoring.

RESULTS: EVALUATION OF PLANTING SUCCESS

Phase I Pilot scale Test Plots.

Of the fifty-five *S. patens* planted, eleven survived to the first monitoring period, 38 days later. However, all the plants that survived the first 38 days, are currently alive at the site today (four years). Table 2 indicates survival of plants during the first 38 days following planting. This trend was seen throughout the project in the Phase II and III. Plants that survived the transplanting to 30-60 days, survived. Therefore, early monitoring can give a fairly accurate assessment of the success of the project.

The impact on salt was measured by determining the EC of the soils. The salt impact over time is presented in Figure 1

Based on the success of the *S. patens,* a Phase II was designed to optimize the logistics before going to the full scale planting.

Phase II Scale-up

None of the Bitter Panicum survived the Phase II plantings by the five month monitoring.

Of the 167 *S. patens* planted in the open without the hay, 18 survived five months later (11% survival. Of the 27 plants transplanted to hay-covered soil, 16 survived at five months (59% survival). The Phase II survival of *S. patens* confirmed that *S. patens which is* typically found in mid marsh throughout southern Louisiana is naturally resistant to salty soils and is a viable candidate for revegetation of a salt-impacted soil. From these data it was concluded that the most cost-effective method to revegetate the soil was to use hay with *S. patens* for the full scale revegetation.

Phase III Full Scale implementation

The first monitoring period for the Phase III was approximately 30 days after planting the *S. patens* (Table 3). As seen by the subsequent performance of the *S. patens* our monitoring criteria was conservative. The observed increase in viable plants is caused by the rejuvenation of plants that appeared to die during the initial planting but recovered and were later identified as alive in subsequent monitoring events. The site is considered an overall success, as at 18 months almost 90% of the plants are still alive. The *S.patens* survival at 18 months would be greater if not for man-made erosion (four-wheeler tracks).

While evaluating the survival of plants during the one year monitoring event, we also evaluated the impact of *S. patens* on the EC of soils (Figure 2). The electric conductivity of soils within the rhizosphere was significantly lower than the electric conductivity of soils that are not impacted by the plants. The electric conductivity of the rhizosphere soils was approximately one third of the EC of soils 3-4 feet away. Secondary growth of less salt tolerant plants has begun to fill into the areas between *S. patens*.

DISCUSSION

Spartina patens proved to be a resilient plant that could survive the heat and drought conditions found in south Louisiana in 2001. It proved to be able to survive the high saline conditions of a brine contaminated soil. We are currently very optimistic about the complete revegetation of this site. Based on the success of the revegetation to date it is likely that total coverage may be obtained in the near future. Figures 3 and 4 document the overall improvement in the soil coverage at this site. Figure 3 indicates that are no plants growing on large areas of the site. Figure four is the latest monitoring with almost full coverage in most areas.

The cost per acre to revegetate with S. patens depends on the concentration of plantings as well as the cost for growing, transporting and planting the plants. A planting frequency of 6'-10' centers may be adequate for coverage in three years. Tighter spacing between plants leads to more rapid coverage and, obviously, greater cost. Depending on the distance from the nursery and the logistics of the planting, 3" pots can be purchased for around $3.50-$5.00 per pot.

REFERENCES

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Tables and Figures

Table 1 Soil amendments for each 20'X 20' plot during the phase 1 trial

	Cell1	Cell2	Cell3	Cell4	Cell5	Cell6
Soil Treatments	25% Gypsum (36 lbs) 75% Ca NO3 (102 lb, 11gal) Tilled Rice Hulls (4 ft^3)	50% Gypsum (70 lb) 50% CaNO3 (69 lb 6 gal) Tilled Rice Hulls (4 ft^3)	25% Gypsum (36 lbs) 75% Ca NO3 (11 gal) Tilled Manure (66 lbs)	50% Gypsum (70 lb) 50% $CaNO_3$ (6gal) Tilled Manure (66 lbs)	Gypsum (143) Tilled	Tilled

Table 2 Survival of plants during phase I. The march planting was one month after

Date of Monitoring	Per cent survival of *S. patens*	Comments
March 1999	100%	
One Month	21%	All other plants species used in the test plot died
Six Month	21%	
Nine Month	21%	At this point in the year only 75% normal rain has fallen
11 Month	21%	
22 Month	21%	Starting from 22 months is the drought of 2001
29 month	21%	
33 Month	21%	
39 Month	21%	

Table 3 Survival of plants during full scale operations

Date of Monitoring	Per cent survival of *S. patens*	Comments
December 2000	100%	Initial planting following three months of dispersed hay
One Month	65%	
Eight Months	89%	No corrective action plantings performed. Increased survival was by rejuvenation of plants
Twelve Months	93%	
Eighteen Months	88%	

Table 4 Costs of S. patens used in this study per planted acres

Theoretical Costs of Re-vegetating with S. patens 3" pots based on the cost of the plants			
Cost per *S. patens* planted	Distance between plants (ft)	Approximate number of plants per acre	Cost of plants per acre
$ 3.00	3	4840	$14,520.00
	4	2723	$ 8,167.50
	6	1210	$ 3,630.00
	10	436	$ 1,306.80
$ 3.50	3	4840	$16,940.00
	4	2723	$ 9,528.75
	6	1210	$ 4,235.00
	10	436	$ 1,524.60
$ 4.00	3	4840	$19,360.00
	4	2723	$10,890.00
	6	1210	$ 4,840.00
	10	436	$ 1,742.40
$ 5.00	3	4840	$24,200.00
	4	2723	$13,612.50
	6	1210	$ 6,050.00
	10	436	$ 2,178.00

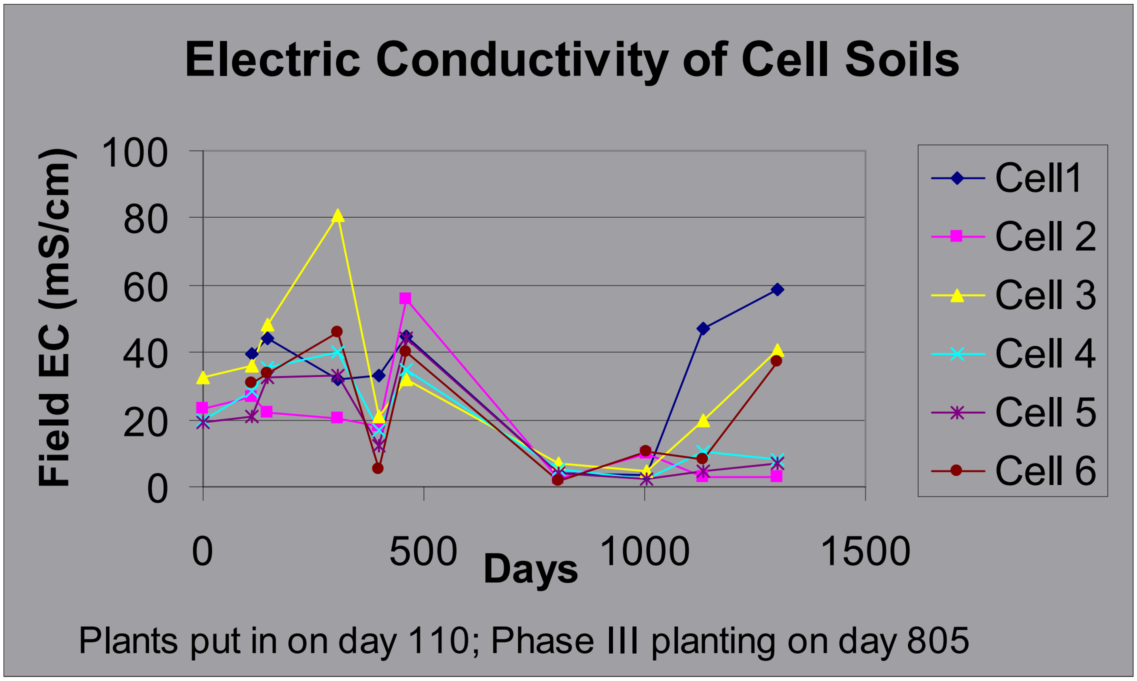

Figure 1 Electric Conductivity of soils in the Phase I planting plots throughout the study

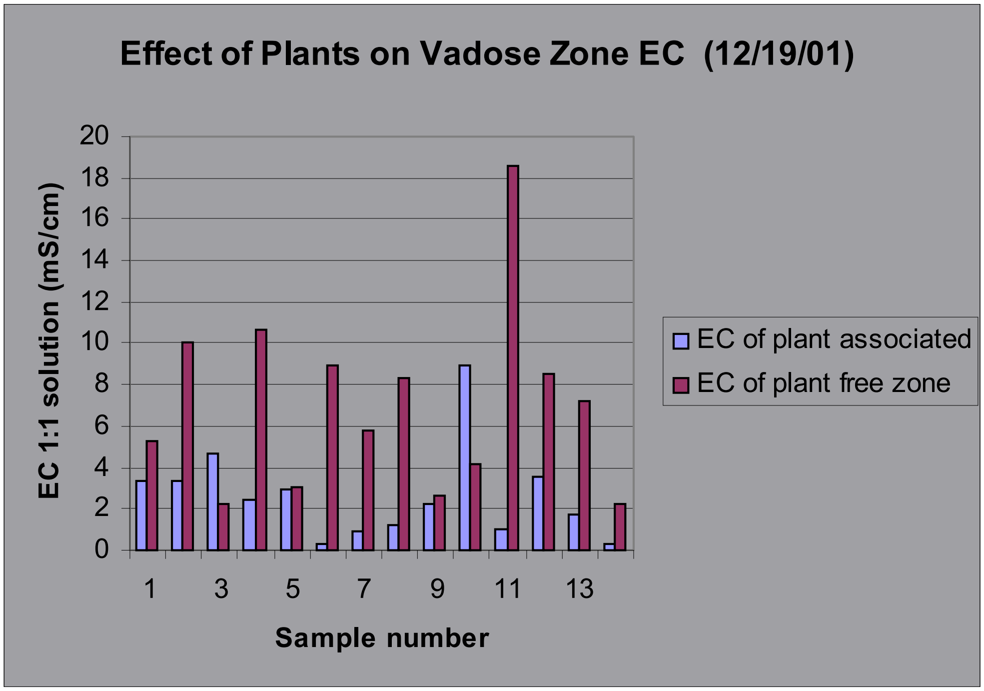

Figure 2. Effect of *S. patens* on the electric conductivity of soils immediately around plants

Figure 3 Initial condition of the site.

Figure 4 Same area of the sight Eighteen months into Phase 3