Restoring Freshwater Wetlands in the South Slough National Estuarine Research Reserve:

Links between water table elevation, soils, and plant communities in restored, altered, and undisturbed wetlands

Upper valley of Wasson Creek, March 2004. Photo by L. Brophy.

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Introduction

Project Goals

This study investigated soil characteristics, hydrology and plant communities at three freshwater wetland sites within the South Slough National Estuarine Research Reserve (South Slough NERR), in Coos Bay, OR. The study was designed to address key questions about the effects of anthropogenic disturbances on wetland hydrology and soil characteristics; the recovery of marsh soils and wetland hydrology after restoration actions; and the relationships between wetland hydrology, soils, and wetland plant communities. Project data were collected at one undisturbed freshwater wetland site and two disturbed freshwater wetland sites – one recently restored and one not yet restored – all within the South Slough NERR.

Products

Products from this project include:

1. This report;
2. Excel workbook "AWT_analyses_FINAL_30dec05.xls" containing raw data and analyses of soils, hydrology, and plant communities.

Background

Significant investments have been made by government and private organizations in recent years to improve the conservation and restoration of wetland habitats in the Pacific Northwest and the U.S. in general. Compensatory wetland mitigation has been mandated by state and federal law for over 20 years to replace wetlands lost to development. However, the success rate for wetland restoration, mitigation projects in particular, has been less than stellar. According to the National Research Council (2001), the national wetland mitigation goal of "no net loss" is not being met. Part of the blame for this situation lies in the relatively immature status of restoration science, and sparse knowledge of the relationships between wetland functions and underlying physical and biological processes in wetlands. Long-term improvements in wetland restoration, compensatory mitigation, and conservation will depend on increased understanding of these functions and relationships (Zedler and Lindig-Cisneros 2000; Simenstad et al. 1991).

Multiple physical processes in wetlands directly affect each other and combine to affect wetland biological processes and functions, which in turn affect physical processes in a constant feedback loop. Wetland hydrology (floodwater storage, in particular), is partly controlled by wetland soil characteristics including infiltration rate and subsurface storage potential (pore space). Infiltration rate and subsurface storage potential are strongly influenced by soil texture, bulk density, organic matter content, and soil saturation. The nutrient processing function of wetlands (part of wetlands' water quality function) is controlled in part by soil pH, the depth to the seasonally high water table, soil saturation, and water infiltration and storage (Adamus 2001). Wetland vegetation alters the physical environment by contributing organic matter to the soil, loosening soils by root growth and facilitating sediment accumulation, influencing soil texture, bulk density, and organic matter content. Thus, the ecosystem is a "dynamic interlocking equilibrium" composed of its biological and physical components (Daubenmire 1968).

Because biological and physical factors interact to provide wetland functions, both biological and physical characteristics need to be measured to determine wetland condition. The most effective way of evaluating the ecological condition of a wetland is to measure the condition of its biological community and the chemical and physical characteristics of the site and its surrounding landscape (U.S. EPA 2002). This study measured key physical and biological attributes of wetland sites at the South Slough NERR with the goal of evaluating human impacts and restoration progress.

Study sites

This project collected data from three freshwater wetland sites within the South Slough Reserve (Figure 1). All three are tributaries to the lower, tidal section of Winchester Creek at South Slough, but the study wetlands are nontidal. Site characteristics are summarized in Table 1.

Table 1. Site characteristics

Site	Impacted?	Restored?
Anderson Creek	Yes – ditched and grazed from early 1900s through 1970s	Yes – ditch filled and channel restored in 2002; planted with native wetland species; large wood placed in channel
Wasson Creek	Yes – ditched and grazed from early 1900s through 1970s	No
Tom's Creek	No – undisturbed	n/a

Hypotheses

This study attempted to confirm or reject the following three hypotheses:

Hypothesis I: Human manipulation of the Wasson Creek site altered the site's soil and water table characteristics.
Null hypothesis I: Human manipulation of the Wasson Creek site had no impact on the site's soils and water table characteristics.

Hypothesis II: Restoration at Anderson Creek is re-establishing the physical soil and water table characteristics that support wetland functions.

Null hypothesis II: Restoration at Anderson Creek is not re-establishing the physical soil and water table characteristics that support wetland functions.

Hypothesis III: There are significant relationships between soil characteristics, hydrology and plant community composition at the study sites.
Null Hypothesis III: There are no significant relationships found between soil characteristics, hydrology and plant community composition at the study sites.

We expected our single year of data collection to confirm or reject Hypothesis I, the water table portion of Hypothesis II, and Hypothesis III. We did not expect the disturbed soils at the Anderson Creek site to have fully recovered to match undisturbed soil conditions within two years (the site was restored in fall 2002), but we hoped that a single year's soils data would provide a baseline for determining the trajectory of soil development at the site and provide guidance for future sampling and study. We also expected our data to indicate whether relationships existed between soil characteristics, hydrologic regime (water table level or hydroperiod), and plant community composition. Finally, we hoped to determine the utility of the project methods for predicting plant community composition based on physical attributes in a marsh (soil characteristics and hydrologic regime).

Summary of results

Results are presented in detail in the **Results** section. Briefly, they included the following:

HYDROLOGY

- All plots at Tom's Creek (reference site) had a very high water table (within 4" of the soil surface) during the entire observation period.
- Two-thirds of sample plots at both impacted sites (Anderson and Wasson Creeks) had high water tables (within 12" of the soil surface) that lasted more than 1.5 continuous months during the observation period (March – September).
- One third of sample plots at both Anderson and Wasson Creeks had high water tables lasting only about 2 continuous weeks during the observation period.
- At Wasson Creek, shallow water table duration was strongly and inversely correlated to distance from the main ditch.
- At Anderson Creek, shallow water table duration related mainly to pre-restoration conditions.

SOILS

- Soils at Tom's Creek showed large volumes of recent sediment deposition in the upper transect. This area was a beaver pond until the beaver dam failed recently.
- Tom's Creek had large amounts of buried wood and aboveground large woody debris.

- Percent organic matter and total Kjeldahl nitrogen were higher at Tom's Creek compared to Wasson and Anderson Creeks, and higher at Wasson than at Anderson Creek.
- Percent organic matter and total Kjeldahl nitrogen in soil were higher at plots with long duration of shallow water tables, compared to plots with shorter duration.
- Soil texture was coarsest (generally sandy loam) at Tom's Creek, intermediate (loam to sandy loam) at Anderson Creek, and finest (loam to clay loam) at Wasson Creek.

VEGETATION

- Plant community composition (expressed as percent cover of wetland indicator plant species) was closely related to duration of high water tables, with wetter plots having higher cover of obligate and facultative wetland species.
- Plant community composition varied significantly between impacted sites and control, with impacted sites having lower cover of obligate and facultative-wetland species, and lower cover of native species.
- Percent cover of wetland indicator plant species did not differ significantly between the restored site (Anderson Creek) and the unrestored site (Wasson Creek).
- At Wasson Creek, percent cover of wetland indicator plant species was significantly and positively correlated to duration of shallow water tables.
- Cover of reed canarygrass at Wasson Creek did not correlate with either water table levels or soil characteristics.
- Grass-leaf rush (*Juncus marginatus*), a species which is considered a non-native invasive in the Willamette Valley but a rare native species in California, was identified at Tom's Creek. Further investigation is recommended.
- Pacific reedgrass fen, a rare native plant community, was found at Tom's Creek.

Methods

Experimental design

This study incorporated two powerful environmental research methods: BACI (before-after-control-impact) design, and reference-restoration site pairs. Both BACI and reference-restoration comparisons are recommended for analysis of ecological disturbances and human impacts to the environment.

Reference-restoration site pairs are a requirement for effective analysis of restoration success. Any study that looks at human impacts to the environment requires a "control" or baseline with which to compare impacted sites (Simenstad et al. 1991). Since human activities usually affect an entire site, and since restoration is generally applied to an entire site, it is usually not possible to have an unimpacted or unrestored control within the restoration site. Therefore, undisturbed reference sites are needed to determine the effects of both the original impacts and the restoration actions. In addition, multiple-year monitoring of both restoration and reference sites can help separate the effects of restoration from larger-scale, non-restoration related variables.

In this study, Tom's Creek served as a reference site (control) for both Wasson Creek and Anderson Creek.

BACI design is a method for testing for impact of human actions (Underwood 1991; Rybczyk 2002). In BACI design, environmental impacts are analyzed by taking multiple measurements both before and after the impact, in both a control and impact (or treatment) site. The data are analyzed using a BACI statistical analysis within an ANOVA framework.

Strictly speaking, a full BACI design was not possible at the study sites because of existing conditions and the timing of this study. Creek channelization at both Anderson and Wasson Creeks was implemented decades ago, and stream restoration at Anderson had already been implemented in 2002. Therefore, we did not have the opportunity to evaluate conditions before either of these impacts. However, the sites did provide a potential space-time substitution in which Tom's Creek serves as a pre-channelization control for Wasson Creek, and Wasson Creek serves as a pre-restoration control for Anderson Creek. As with any controls (i.e. reference sites), our ability to gain meaningful results from site comparisons depends on the appropriateness of the controls; see **Discussion** below for more details.

Sampling design

Sampling units for soils and plant communities were 6m diameter circular plots; water tables were monitored at the center of each plot. By embedding soil, hydrology and vegetation sampling within each plot, we hoped to maximize our opportunity to observe relationships between water table elevations, soil characteristics, and plant communities.

A total of 43 plots were sampled: 16 at Anderson Creek, 18 at Wasson Creek, and 9 at Tom's Creek. Plots were placed using a stratified random sampling technique. Each site was characterized by two environmental gradients that could potentially affect plant communities and physical attributes: 1) a longitudinal elevation gradient from upstream to downstream, and 2) a cross-sectional hydrologic/elevation gradient from the stream channel across the valley to the hillslope base. In the field, the second gradient appeared to be generally bidirectional, with lower, wetter areas found both near the channel and near the hillslope base, where nonchannelized hillslope drainage and seepage enters the valley. Secondary channels and swales increased the complexity on the valley bottom to the point where it seemed likely that distance from channel would not be a major factor in plant community development.

Color infrared aerial photos taken in May 2003 were reviewed to locate major plant communities. Three to five transects were placed perpendicular to the stream channel at each site, with the transects spread across the longitudinal elevation gradient. Thus, each transect could serve as a blocking factor for the longitudinal elevation gradient. A second stratification was applied to the cross-sectional gradient, with 6m diameter plots (sampling units) located randomly within major plant communities crossed by the transects. Soils, hydrology, and vegetation were sampled within 6m diameter circular plots placed along the transects. Transect and plot locations are shown in Figures 2, 3 and 4.

At Anderson Creek, plots were placed along existing vegetation transects that were established in 1999 and have been sampled approximately annually. This plot placement allows comparison of this study's vegetation sampling results with those from the annual monitoring. The comparison is discussed in the vegetation monitoring report (Brophy 2005).

Field methods

Hydrology. The elevation of the water table was determined by using shallow observation wells as described in Sprecher (2000). The wells were constructed from PVC pipe ("tube") and were 48″ in length. Perforations extended from about 6″ below the soil surface to the bottom of the tube, in order to provide integrated water table data throughout and just below the rooting zone. An unperforated riser extended about 12″ above the soil surface; the riser was capped loosely to prevent air pressure effects on water table measurements. Sand was filled in around each tube, and tubes were wrapped with landscape cloth to prevent clogging of the perforations. The top of each tube was surrounded by a layer of bentonite clay to prevent surface water from entering the tube. During tube installation, no evidence was seen of perched water tables, conductive layers, or other soil profile discontinuities that would require use of piezometers, so simple observation wells were adequate to the task.

Water table elevations were recorded during late March through early September, the period where site-to-site differences in water table elevations become most visible and are most likely to correlate strongly with plant community composition. Water tables were not monitored during the wettest months of the year (November through February). Water table elevation in each tube was measured once a week during late March through June 2004, and every 2 weeks during July, August and early September. Both the water level in the tube and the riser height were recorded for each tube at each visit, and water table elevation relative to the soil surface was calculated in the office.

Vegetation. Each 6m-diameter circular plot was divided into four quadrants centered on cardinal directions (compass bearings N, S, E, and W). Percent cover for every plant species present was determined by visual observation within each quadrant. The four quadrant cover values were averaged for each species to obtain percent cover for the entire plot. Data were entered into a spreadsheet for species with more than 5% cover.

Soils. Soils were sampled from the upper rooting zone (0-18″ depth) using a 3/4″ diameter soil probe (for mineral soils) or a Russian peat corer (for organic soils). At least 10 and generally 20 subsamples were bulked within each 6m plot, and the bulked sample was mixed well before analysis. Soils were analyzed at the Oregon State University Central Analytical Laboratory. Analyses included percent organic matter (by loss on ignition), total phosphorus and total Kjeldahl nitrogen (by Alpkem RFA 300 auto-analyzer), and texture (by hydrometer method).

Elevations and distance from channel. The soil surface elevation at each hydrology monitoring tube was measured by a separate SSNERR contractor during 2004. Elevation was determined using total station survey equipment and was reported as feet NAVD. Distance from the main channel (i.e. the main ditch, at Anderson and Wasson) was measured for each hydrology monitoring tube.

Analytical methods

HYDROLOGY

Water table measurements were consolidated into a single electronic spreadsheet, and water table elevations were charted by location and date. Analysis followed methods established for delineation of wetlands by the U.S. Army Corps of Engineers (1987). In the Army Corps method, wetland hydrology is generally defined as soil saturation or a water table within 12″ of the soil surface, which remains for a continuous period lasting at least 12.5% of the growing season. On the Oregon coast, the growing season is considered to extend year-round, so 12.5% of the growing season is about 18 days.

Following the Corps definition, sample plots were placed into one of two hydrologic groups:

Long-duration wetland group: Plots that had a water table within 12″ of the soil surface for more than 18 consecutive days during the observation period. In fact, the duration was at least 44 days for all of these plots, so the 18-day break point does separate two well-defined groups.

Short-duration wetland group: Plots that had a water table within 12″ of the soil surface for less than 18 days during the observation period. In fact, the duration was 15 days or less for these plots.

It is important to note that in this study, a shallow water table lasting less than 18 days does not necessarily indicate upland status, because our observations excluded the wettest portion of the year (November through February). Hydrologic monitoring through the winter months would improve understanding of these sites (see **Recommendations** below).

If two consecutive weekly observations both showed a water table within 12″ of the soil surface, the shallow water table condition was assumed to have persisted between those observations.

SOILS

Data from the Oregon State University's Central Analytical Laboratory were incorporated into this project's analytical spreadsheets. Percent organic matter and soil texture were analyzed jointly to determine whether each sample plot had an organic soil or a mineral soil. Generally, sandy soils with more than about 21% organic matter (12% organic C) and clay soils with more than about 31% OM (18% organic C) are considered organic soils (Soil Survey Staff 1992). Organic soils are also known as *histosols*.

VEGETATION

Plant species were classified as native or non-native according to data provided at the USDA Plants website (http://plants.usda.gov). An exception was made for reed canarygrass, which is considered an undesirable invasive in Oregon wetlands. Reed canarygrass is probably native to the Pacific Northwest, but the invasive types may be a non-native genotype (Antieau 1993). For analytical purposes, reed canarygrass was grouped with non-natives.

Wetland indicator status designations for plant species have been established by the U.S. Fish and Wildlife Service (Reed 1993, 1988). Wetland indicator status was used to group plant species into three groups: Obligate (OBL), obligate to facultative-wetland (OBL to FACW), and facultative to facultative-upland (FAC to FACU).

Plant communities were determined by comparing percent cover data from the sample plots to community descriptions found in the Oregon Natural Heritage Information Center's 2005 plant community list (Kagan et al. 2005). Additional plant communities were defined as necessary based on plot data and site reconnaissance during field work.

STATISTICAL METHODS

All statistical analyses were conducted in Microsoft Excel® 2002 SP3. Means comparisons were the most appropriate statistical test for the majority of questions posed by this study. T-tests were used to compare soil, hydrology and plant community characteristics among the three sites. T-tests were also used to compare soil and plant community characteristics between sample areas with longer-duration shallow water tables and those with shorter-duration. T-tests are considered robust in analysis of data characterized by non-normal distributions, heterogeneity of variance, and unequal sample sizes (Green 1979), data characteristics that are likely to occur in environmental studies.

One additional method, linear regression, was used to explore the relationship between pairs of numeric variables that appeared to be likely to be correlated, such as duration of shallow water tables, elevation, distance from channel, and percent cover of wetland plants. A caveat is that such relationships are often nonlinear, so transformation may be necessary for further analysis (see **Recommendations: Additional analyses of this study's results** below).

T-tests and regression analyses were used to evaluate significance of differences between means, and relationships between numeric data, respectively. Neither statistical method evaluates causal relationships.

Results and discussion

Hydrology

Water table elevations are charted in Figures 6 through 8 (by site) and Figure 12 (by plant community).

At Anderson Creek, 11 out of 16 (69%) of the sample plots fell into the long-duration wetland group (see **Analytical methods: Hydrology** above), with shallow water tables lasting at least 44 consecutive days during the observation period (Figure 6). For all plots at Anderson Creek, average shallow water table duration was 71 days (Table A2, Appendix 1). At Wasson Creek, twelve out of 18 (67%) of the sample plots fell into the long-duration wetland group (Figure 7). The average shallow water table duration was 98 days (Table A2, Appendix 1). More detail is provided below.

The most striking result of this study was the very stable high water table at Tom's Creek (Figure 8). At all points sampled, the water table never dropped more than 4" below the soil surface during the entire observation period, which included the driest part of the summer. Thus, 100% of sample plots had shallow water tables for the entire observation period (166 days; Table A1, Appendix 1). Beaver have built multiple small dams within the study area, including a major dam with ponding a few hundred feet above Transect 1 visible in 2003 aerial photographs (Figure 4). Transect 1 itself was located in an area that had been a beaver pond recently, but the pond drained when the beaver dam failed (Craig Cornu, personal communication). The many beaver dams and ponds at Tom's Creek may contribute to the stability of wetland conditions here, by damping fluctuations in stream flow and releasing water gradually during the dry summer months. Beaver dams and ponds were abundant in coastal Oregon streams before European settlement, so this site, with its stable, year-round wetland hydrology, provides an appropriate control for the impacted sites.

Water table elevations at Anderson Creek (Figure 6) were much more variable than at Tom's Creek, and individual plots showed somewhat more variability than most plots at Wasson Creek. Anderson Creek sample plots were characterized primarily by seasonal wetland hydrology – that is, most plots started out wet in March and April, and dried gradually during July and August. This hydrologic pattern differs from the hydrology at the reference site (Tom's Creek), but presence of seasonal wetland hydrology may indicate an appropriate "restoration trajectory" towards re-establishment of reference conditions. Future monitoring is recommended to determine whether the trajectory continues (see **Recommendations** below).

Only one plot at Anderson Creek had hydrology similar to that at the reference site: Plot 4, the southernmost plot of Transect 2. At this plot, the water table remained within 6" of the soil surface throughout the summer. This plot was located in a dense stand of slough sedge that had been undisturbed throughout the restoration process.

At many Anderson Creek sample plots, there were large fluctuations in water table elevation during March through May, so the progression from higher water tables to lower ones in late summer was not a smooth curve. Sample points along Transect 1 (adjacent to the south fork of the upper stream channel) showed especially high variability. The water table depth at Transect 1 may have varied in response to the nearby stream water level fluctuations. Comparison of these results to stream gauge and rainfall data is recommended (see **Recommendations** below).

Wasson Creek sample plots (Figure 7) divided up into three prominent groups: Areas that stayed quite wet throughout the summer, areas that started out dry even in March and stayed dry throughout the summer, and an intermediate group. Individual sample plots generally showed less fluctuation in water level across the observation period, compared to Anderson Creek. The dry group(6 sample plots: WCT2P1, WCT3P2, WCT3P3, WCT4P3, WCT4P4, and WCT5P3), included the sample plots on slightly elevated ground near the main ditch (see **Hydrology *vs.* elevation and distance from channel** below). The wet group (8 sample plots: WCT1P1, WCT1P2, WCT2P3, WCT3P1, WCT4P1, WCT5P2, WCT6P1, WCT6P2), retained water tables within 12" of the soil surface throughout the summer. The 4 intermediate plots (WCT2P2, WCT4P2, WCT5P1, and WCT6P3) showed more variability and some seasonal wetland characteristics.

Although this study included only a single year's data and therefore can not determine site trajectory, SSNERR staff report that beaver activity at Wasson Creek has definitely created wetter conditions over the past decades (Craig Cornu, personal communication). However, duration of high water tables did not appear related to locations of beaver dams, as mapped by Marshall (2004). This was probably due in part to the fact that plots were placed within emergent plant communities, rather than in the areas of standing water located just upslope of beaver dams. However, within the context of overall beaver activity, microtopography and the presence of both longitudinal and cross-sectional gradients still strongly affect water table depths at this site. The single transect located in an area Marshall defined as having "low beaver activity," Transect 6, showed some of the longest-duration shallow water tables sampled. Transect 6 is also the transect located lowest in the valley, so the site's longitudinal gradient undoubtedly contributes to wet conditions at this transect. All sample points on this transect had water tables within 12" of the soil surface at each of the 18 observation dates, with the exception of two dates at a single point (T6P3 on July 12 and 28). All of the driest sample points at Wasson Creek were within Marshall's high beaver activity zone. Thus, although the site as a whole is noticeably wetter due to beaver activity, differences among plots appear to be determined by longitudinal gradient, microtopography and cross-sectional gradient (distance from channel). These relationships are discussed below.

HYDROLOGY *VS.* ELEVATION AND DISTANCE FROM CHANNEL

Elevations at the highest sample plots were about 30 ft NAVD (upper transects on Anderson and Wasson Creeks), and about 8 ft NAVD at the lowest transects at Tom's Creek. Transects were located perpendicular to the longitudinal elevation gradient, so the elevation range within each transect was much smaller. These "internal elevation ranges" are of interest in determining the dynamics of surface water hydrology at the sites. At Tom's Creek, transects had internal elevation ranges of 2-3 inches. At Anderson Creek, T1 had a 5-inch internal elevation range, and T2-T4 had elevation ranges of 12 to 15 inches. At Wasson Creek (Figure 9), transect elevation ranges varied from 1 to 15 inches, with T3 and T4 having the greatest range (10 and 15 inches respectively).

For Anderson and Wasson Creeks, regressions were performed on the duration of shallow water tables *versus* relative elevation within each transect, duration of shallow water tables *versus* distance from the channel, and relative elevation *versus* distance from channel. (For Tom's Creek, no such regressions were performed, because there was no variability in duration of shallow water tables, and very little variability in elevation.) Relative elevation was calculated as the increase in elevation above the lowest point on the transect.

At Anderson Creek and Tom's Creek, plot elevation showed no significant relationship to distance from the channel. Tom's Creek was relatively flat, and topographic variation at Anderson was not directly correlated to channel position. At Wasson Creek, plots located farther from the channel showed significantly lower elevations relative to other plots in the same transect (R^2=0.25, p=0.04), and plots at a lower elevation had significantly longer shallow water table duration (R^2=0.56, p=0.0004). However, typical differences in soil surface elevation were not great enough to account for observed differences in water table elevation. For most plots, soil surface elevation differences were 6 to 12 inches (Figure 9), but water tables at the drier plots were about 20" lower compared to the wetter plots. This suggested that distance from channel, rather than absolute elevation, might be causing the observed water table differences.

At Anderson Creek, duration of shallow water tables showed no significant relationship to distance from channel. However, at Wasson Creek, duration of shallow water tables was significantly longer for those plots farthest from the channel (Figure 10; R^2=0.41, p=0.004). This significant correlation between distance from channel and duration of shallow water tables suggests that plots near the ditch are dewatered (drained). In addition, hillslope seepage may contribute to shallow water tables at sample points further from the ditch.

Soils

Major soil differences were observed between the unimpacted reference site (Tom's Creek) and the impacted sites. Soils at Anderson and Wasson Creeks had significantly lower percent organic matter (% OM), lower total Kjeldahl N, and higher pH compared to control soils at Tom's Creek (Table A1, Appendix 1). The difference in % OM was large; over half the plots at Tom's Creek had soils that qualified as organic soils (histosols), but none of the soils sampled at Anderson or Wasson Creek were organic.

Soil sampling at Tom's Creek showed large volumes of buried wood. It was often difficult to find a location where the sample equipment (a Russian peat borer) could be inserted to the appropriate depth. Much of the buried wood probably comes from trees falling into the narrow valley from the nearby hillslopes, or from debris flows. Some may originate from periods when beaver dams failed and the water table dropped for long enough for trees to become established. Later rebuilding of dams could then have drowned the established trees, resulting in additional wood deposition. The year-round high water tables at Tom's

Creek may slow the decay of the buried wood, since soils remain anaerobic. The buried wood, high productivity of herbaceous plants, and slow breakdown of plant material undoubtedly contribute to the high % OM observed at the site.

The soils at Transect 1 at Tom's Creek (the uppermost transect) were characterized by large amounts of exposed sediment. The area in which the transect is located was reportedly a beaver pond until recently, when the dam downstream failed, exposing the accumulated sediment from the bed of the pond (C. Cornu, personal communication). The dominant vegetation at this transect consisted of new, small-stature growth of the rapidly colonizing, rhizomatous species *Juncus marginatus* (see **Rare species and invasive species** below). Beaver activity at Tom's Creek appears to be extensive and is probably a major controlling factor in the physical structure of the valley. The 2003 aerial (Figure 4) shows a beaver dam and pond a few hundred feet upstream of Transect 1. Most likely, dam building and dam failure -- with accompanying flooding and sediment movement -- have been repeated events in the valley over many centuries.

Differences between the restored and unrestored sites were smaller than between impacted and unimpacted sites. The restored site (Anderson Creek) had significantly lower percent organic matter and total Kjeldahl N (Table A2, Appendix 1) compared to the unrestored site (Wasson Creek). In other words, the unrestored site was more similar to the unimpacted control than the restored site. This result is probably due to two factors: First, at Anderson Creek, the top 15-25 cm of soil were removed during site grading and used for ditch fill (Craig Cornu, personal communication). This upper soil layer probably had higher % OM and N levels than the deeper layers exposed by the grading. Soil disturbance during grading may also have increased breakdown of organic matter and subsequent mobilization of nutrients. Second, Wasson Creek is strongly affected by beaver activity, (see **The Big Questions** below), and beaver are a "keystone species" known for their strong influence on site physical characteristics.

Total Kjeldahl N was closely correlated to total P at Anderson and Wasson Creeks ($R^2=0.53$, $p<0.01$), but not at Tom's Creek (Figure 11). Total Kjeldahl N was closely correlated with % OM at Anderson and Wasson (R2=0.35, $p<0.01$) and at Tom's Creek (R2=0.51, $p<0.05$). Kjeldahl N includes N found in undecomposed organic matter, which could explain this correlation.

Soil characteristics were also compared between the two hydrologic groups. Plots with long-duration shallow water tables had significantly higher percent organic matter and total Kjeldahl N compared to short-duration plots. Soil pH was slightly lower in the wetter group, but the difference was significant only at $p = 0.10$. The observed differences in soil characteristics are probably due in part to non-hydrologic site conditions such as soil compaction, grazing, and pasture improvement.

It is important to note that a high level of Kjeldahl N does not necessarily indicate high N availability. Kjeldahl N measures total N, even the N immobilized in organic matter. Organic soils, like those at Tom's Creek, have large amounts of immobilized nitrogen. In addition, nitrogen may be less available to plants growing in saturated soils (Mitsch and Gosselink 1993).

Soil textural classes found at the study sites are shown in the data tables (Appendix 5); abbreviations are listed in Table 2 below. Soil texture was coarsest at Tom's Creek (generally sandy loam), intermediate at Anderson Creek (mostly loam and sandy loam); and finest at Wasson Creek (loam to clay loam). These soil texture differences may be due to site history and geomorphology. At Anderson Creek, surface soil was removed during site grading and ditch filling (as discussed above). The soil differences between Wasson Creek and Tom's Creek could not be determined during this study, but may relate to land use history and watershed factors like basin size, stream gradient, and beaver activity patterns.

Table 2. Soil textural classes found at study sites, and textural class abbreviations.

Texture	**Abbreviation**
Clay loam	CL
Loam	L
Loamy sand	LS
Silt loam	SiL
Sandy loam	SL

Vegetation

NATIVE VS. NON-NATIVE SPECIES

Plant species found at the three sites are listed in Appendix 2.

The unimpacted reference site had higher percent cover of native species and wetland indicator species, and lower cover of non-native and upland plant species, compared to the impacted sites (Table A1, Appendix 1). This significant difference is to be expected, since the reference site has not undergone the disturbances (stream channelization and agricultural use) that characterize Anderson and Wasson Creeks. The dominance of non-native and upland species in portions of the Anderson Creek site, and the trajectory of vegetation change there, has been documented elsewhere (Cornu 2005, Brophy 2005). Continued vegetation monitoring is recommended, because plant communities are still very dynamic at both of the impacted sites (see **Recommendations** below).

PLANT COMMUNITIES

Plot locations were chosen to be representative of major plant communities for each site. The plant communities present at each plot were classified according to Kagan et al. (2005), with additional plant communities defined as needed. Results are shown in Appendix 3, **Plant community list**.

Plant communities at the reference site (Tom's Creek) included two common coastal wetland communities (soft rush and slough sedge marsh). One very rare community (Pacific reedgrass fen) was present at Transect 2. This community has a state ranking of S1 ("critically imperiled because of extreme rarity, with 5 or fewer occurrences or very few remaining acres") and a global ranking of 3 ("either very rare and local throughout its range or found locally in a restricted range; uncommon, with 21-100 occurrences"). The *Juncus marginatus* community present at T3 is not classified by Kagan et al. (2005); this species and its status are described in **Rare species and invasive species** below.

The restoration sites had both native and non-native plant communities. The drier plots at Anderson Creek and Wasson Creek were occupied by a disturbed old pasture community dominated by non-native species (creeping buttercup, velvetgrass, giant horsetail, birdsfoot trefoil, and bentgrass). Most plots with higher water tables were occupied by native small-fruited bulrush marsh, but some of the wetter plots were occupied by native slough sedge marsh. Both the bulrush and slough sedge communities are common in Oregon coastal wetlands.

The small-fruited bulrush community was found at most of the wetter plots at Anderson Creek. Although both small-fruited bulrush and slough sedge were planted at Anderson Creek, the bulrush has established more successfully (Brophy 2005). At Wasson Creek, some plots were occupied by a reed canarygrass community, but so far, efforts to control this species at Anderson Creek appear successful.

RARE SPECIES AND INVASIVE SPECIES

A high proportion of cover at all plots on Transect 1 at Tom's Creek consisted of *Juncus marginatus* (identified by Richard Halse, Oregon State University herbarium). *J. marginatus* is an invasive non-native which is spreading rapidly in the West Eugene Wetlands of the Willamette Valley (R. Halse and B. Newhouse, personal communication). In California, *J. marginatus v. marginatus* is listed as a rare native species, but it is documented only from the Sierra Nevada foothills (Hickman 1993, Ertter 2005). The likelihood of the plants at Tom's Creek being from the Sierra Nevada population seems low. This species is being actively controlled in the West Eugene wetlands, and control should be considered at Tom's Creek. However, digging it out would cause considerable soil disturbance because the plant is widespread at the site. Soil disturbance would increase the chances of establishment of reed canarygrass, which could pose a considerably greater threat to the site's plant communities, especially the rare Pacific reedgrass fen. Therefore, at this time, control is not recommended, but further information on the status of this plant should be sought.

Reed canarygrass is an invasive species of concern; it was observed only at Wasson Creek. A subsidiary goal of this study was to determine whether reed canarygrass dominance related to hydrology or soil characteristics. Analysis of this study's data showed no such relationship. Reed canarygrass is an opportunistic species with a wide range of tolerance for soil saturation and soil physicochemical characteristics (Antieau 1993). At Wasson Creek, reed canarygrass was present at high percent cover (>40%) at all levels of wetland duration, Kjeldahl nitrogen, total P, percent organic matter, and pH (Table A5, Appendix 1). More detailed studies would be necessary to determine what controls distribution of this species at this site.

Prior to completion of restoration at Anderson Creek, reed canarygrass had been established along ditches and other disturbed areas. It has been controlled in recent years, and control efforts have apparently been successful in preventing its re-establishment. However, continued vigilance will be necessary (see **Recommendations** below).

Once established, it seems likely that reed canarygrass is best controlled by removal of existing stands; by frequent mowing and seed removal to prevent spread by seed; and by intensive efforts to establish native species that are fast-growing and provide dense cover. The best competition is probably offered by woody species that can shade out reed canarygrass, such as willow and alder, but dense establishment of other herbaceous species like slough sedge and small-fruited bulrush may also prevent reed canarygrass establishment and spread.

Remarkably, no reed canarygrass was observed at Tom's Creek. Reed canarygrass could probably grow well and spread rapidly at the site, displacing many native species. Therefore, careful management is recommended to prevent its establishment there (see **Recommendations** below).

Conclusions: Ecological linkages

The results of this study indicate that for these sites, physical site attributes and plant community attributes were closely linked. Impacted sites had lower cover of native species and of wetland indicator species compared to the reference site. Plots with long duration of shallow water tables had higher percent cover of wetland and native plant species, and their soils had higher organic matter and higher Kjeldahl N. Plots with organic soils (histosols) had a high proportion of native plant species. These relationships are shown in Appendix 1 (Tables A1 through A4) and listed in **Summary of results** above. Further discussion is found below.

Hypotheses

This study successfully confirmed Hypotheses I and III; Hypothesis II was partly confirmed.

The impacted, unrestored site (Wasson Creek) showed highly significant differences in water table elevations, soil characteristics and plant community composition, compared to the unimpacted Tom's Creek reference site (Table A3, Appendix 1). **This outcome confirms Hypothesis I**, "Human manipulation of the Wasson Creek site altered the site's soil and water table characteristics."

Most sample plots at Anderson Creek showed seasonal wetland characteristics. **These results provide partial and preliminary support for Hypothesis II**: "Restoration at Anderson Creek is re-establishing the physical soil and water table characteristics that support wetland functions." However, some portions of the Anderson Creek site remain fairly dry, with water table elevations below the expected range for riparian wetlands. Continued monitoring using this study's methods is recommended to determine the restoration trajectory at Anderson Creek (see **Recommendations** below).

As expected, soils at Anderson Creek do not yet resemble those at the reference site. Adaptive management to increase shallow water table duration will help Anderson Creek soils gradually develop greater similarity to reference site soils. Beaver activity will also contribute to this process. The high organic matter content of soils at Tom's Creek is probably the result of centuries of beaver activity, with the resulting stable high water tables and organic matter accumulation.

Plant community composition and soil characteristics differed significantly between plots with long duration of shallow water tables, and those with only short duration. **These results confirm Hypothesis III**: "There are significant relationships between soil characteristics, hydrology and plant community composition."

HYDROLOGY AND PLANT COMMUNITIES

Plots with native plant communities (dominated by obligate and facultative-wetland species) generally showed higher and more stable water tables (Figure 12). Plots occupied by the small-fruited bulrush community had hydrology that was intermediate between that of wetter native communities (slough sedge, soft rush, grass-leaf rush and Pacific reedgrass) and the drier disturbed pasture and reed canarygrass communities. At Anderson Creek, the bulrush community contains relatively high cover of disturbed pasture species; this habitat is probably dynamic and may be on a trajectory towards dominance by native species and more continuous wetland hydrology; see **"The Big Questions"** below, and Brophy (2005).

At all sites, plant community composition reflected hydrologic conditions at the sample plots. As shown by regression analysis, shallow water table duration was closely correlated to plant community composition at Wasson Creek, but at Anderson Creek the relationship was less strong. At Wasson Creek, there was a significant linear relationship between shallow water table duration and percent cover of obligate and facultative wetland plants ($R2=0.44$-0.46, $p<0.01$). At Anderson Creek, where the plant community is still quite dynamic, the relationship was significant only at $p=0.10$. No regressions could be performed for Tom's Creek, as there was no variability in shallow water table duration at that site (all plots showed shallow water tables for 166 days, the full observation period).

T-tests were used to compare the wetland indicator status of vegetation within the two hydrologic groups. When expressed in this fashion, hydrology (expressed as duration of shallow water tables) was a very good predictor of vegetation. Compared to the short-duration group, the long-duration group had significantly higher cover of obligate and facultative wetland species and native species, and significantly lower cover of facultative and facultative upland species and non-native species (Table A4, Appendix 1).

SITE HISTORY AND OTHER FACTORS

Linkages between physical and biological site characteristics do not explicitly show causality. For example, a plant community dominated by non-native, facultative-wetland species is not necessarily "caused" by low water tables. Other factors, such as site history, disturbance, succession, and watershed characteristics, play a strong role in plant community composition. These other factors limit the predictive power of the physical attributes alone.

For example, in this study, percent cover of reed canarygrass at Wasson Creek was not correlated to any physical site attribute. Past disturbance and initial establishment processes probably play a large role in distribution and density of reed canarygrass. Another example is the high cover of non-native species at Anderson Creek, even in plots with long duration of shallow water tables. This high non-native cover is due to site history. At the time of this study (3 years after restoration), Anderson Creek plant communities are still changing rapidly. In a successional situation like this one, plant community composition is affected by many factors besides hydrology and soil conditions, such as dispersal and reproductive strategies, seed bank composition, and interspecific competition. Continued monitoring is recommended as plant communities stabilize at Anderson Creek (see **Recommendations** below).

Although the three sites are well suited for exploring relationships between physical and biological site attributes, they exist in different landscape settings, so they do not provide ideal control-impact pairs. For example, Tom's Creek provides a good illustration of reference conditions at a small, low-elevation Oregon coast range stream. However, it has a narrower valley and a smaller watershed than Anderson or Wasson Creek, so the influence of the adjacent hillslopes is greater, and sediment movement, flow regimes and other basic characteristics undoubtedly differ from those that were present at Anderson and Wasson prior to impact. Wasson Creek is not an ideal unrestored control for Anderson Creek, because it has been strongly affected by beaver activity over the past 20 years. Despite these limitations, this study identified many significant differences between the sites, and points the way towards important future research and monitoring.

Recommendations

The "Big Questions"

This study documented many interesting and significant differences between the reference, restored and unrestored sites. However, a single year of field data leaves open many questions. Some of these questions, critical to restoration science at these sites and others, are discussed below.

1. Are physical and biological conditions at Anderson Creek on a trajectory towards the Tom's Creek reference conditions? For example, is hydrology progressing towards year-round high water tables, rather than seasonal wetland hydrology? Will the non-native pasture species be gradually replaced by native wetland species as wetland hydrology more closely approaches that of the reference site? This study provided a "snapshot" of conditions during a single year, but continued monitoring is needed to determine trends (see **Continuation of this study's monitoring** below).

2. Is beaver activity at Wasson Creek likely to eventually restore conditions similar to those at the Tom's Creek reference site? Hydrology, soils and plant communities at the reference site appear to be strongly affected by beaver activity. Beaver have been described as "keystone species" and "ecological engineers" that create conditions like the reference site's high, stable water tables, large amounts of buried wood, and high soil organic matter content. At Wasson Creek, beaver have been active since the 1980's (Marshall 2004), and their activity appears to be a strong determinant of site structure. Will beaver activity successfully re-create a meandering channel system on the marsh surface, replacing the incised ditch as the primary water flow path? How might 50- or 100-year flood events affect the system? For example, could such high flows cause further ditch downcutting, periodically dewatering the floodplain, or will beaver activity divert the water to the marsh surface even during major storms? How might plant communities – such as willows along the ditch or marsh surface channels -- affect floodplain processes? Does the current dominance of reed canarygrass on parts of the marsh surface affect the rate of channel development? Historic research, continuation of this study's monitoring, and additional field research (such as that conducted by Marshall, 2004) could help answer these questions. See below for specific recommendations.

3. Can Pacific reedgrass fen be re-established at Wasson or Anderson Creek? This community, found at Transect 2 at Tom's Creek, is ranked S1 ("extremely imperiled") by the Oregon Natural Heritage Program. Its restoration – even in a small area -- would be a valuable accomplishment. Restoration may be challenging, since soils and hydrology at the restoration sites are quite different from the reference area. For example, the soil in the Pacific reedgrass community at Tom's Creek is an organic sandy loam with constant, year-round saturation of the root zone. Although sandy loams are found at some locations on the restoration sites, they have lower organic content and most have seasonal wetland hydrology. However, Pacific reedgrass is also found on drier sites on the Oregon coast (Brophy, personal observation), so plantings could potentially be successful at Wasson or Anderson Creek. GPC recommends gathering seed at Tom's Creek, and planting at selected locations at Wasson and Anderson Creeks. See **Management and restoration recommendations** below for details.

Specific recommendations for management, restoration, monitoring, and further research follow.

Management and restoration recommendations

- Continue to encourage beaver colonization at Anderson Creek and existing beaver activity at Wasson Creek.
- Control reed canarygrass at Wasson Creek.

- Plant willows at Wasson Creek to provide further beaver food and construction materials, and to help shade out reed canarygrass.
- Continue to monitor for reed canarygrass at Anderson Creek and provide early control if re-establishment is observed.
- Conduct regular monitoring for reed canarygrass at Tom’s Creek; develop a control plan in advance that minimizes site disturbance.
- Practice careful boot and equipment hygiene to avoid introducing reed canarygrass to Tom’s Creek. Avoid entry to the site by large groups, and to the maximum extent possible, avoid soil disturbance.
- Gather seed of Pacific reedgrass at Tom’s Creek and plant in appropriate locations at Anderson and Wasson Creeks. Planting locations should match water table and soil characteristics as closely as possible to those at Transect 2 of Tom’s Creek. Do not dig plants of Pacific reedgrass from Tom’s Creek, due to the risk of introducing reed canarygrass into disturbed soils.

Continuation of this study’s monitoring

- Continue monitoring soils, hydrology and plant communities at all sites for several more years, using this study’s methods, to determine restoration trajectories, year-to-year variability, and trends.

Environmental data are often highly variable from year to year, even at undisturbed sites. At Tom’s and Wasson Creeks, the high level of beaver activity suggests that conditions may be quite dynamic. At Anderson Creek, site conditions are changing rapidly due to human site manipulation and beaver activity. Accurate understanding of site conditions and developmental trajectories at these sites will require more than a single year’s data (see **The big questions** above). Continued monitoring of this study’s parameters is highly recommended.

- Monitor hydrology year-round.

Monitoring hydrology during winter will complete the picture of wetland conditions at the three sites. Water table levels during winter are less important to plant growth compared to spring and summer levels, but still useful in interpreting site development. For effectiveness monitoring purposes, it is useful to know whether each plot met the regulatory definition of a wetland. The regulatory wetland definition (Environmental Laboratory 1987) uses shallow water table duration to define wetland hydrology. For a site on the Oregon coast to qualify as a wetland using this regulatory hydrology criterion, the water table (or saturated soils) must generally remain within 12” of the soil surface for at least 18 days. Some of the plots at Anderson Creek did not meet this criterion during the 166 day observation period. However, the observation period excluded the wettest months of the year, so most likely most of these “short-duration” plots were actually wetlands. The only way to determine the success of the Anderson Creek restoration in establishing wetland conditions throughout the floodplain is to monitor hydrology year-round.

- Collect GPS data for the hydrology monitoring tube locations.
- Maintain the hydrology monitoring tubes (repair broken risers and caps, pump out tubes to remove sediment).

Maintaining hydrology monitoring tubes will preserve the investment that was made in installation of this equipment.

Additional analyses of this study's results

- Conduct exploratory data analysis and ordination of plant community, soils, and hydrologic data collected in this study.

This report includes only introductory analyses of the data collected. Additional analyses, such as ordination, could help tease out the relationships between physical and biological attributes.

- Conduct nonparametric analyses, alternative analyses, or data transformations to address non-normality of data distributions and heterogeneity of variances.

Many environmental studies measure parameters displaying non-normal distributions and heterogeneous variance. The t-tests conducted in this study (two-tailed t-tests) are considered robust for use with such data (Green 1979), so the conclusions in this report are valid. However, the regressions conducted for this study do show some evidence of non-normality, particularly in shallow water table duration, for which variances were smaller at long durations. This non-normality was due to the prevalence in the dataset of "maximum duration" values (166 days) at the reference site and the wetter plots at Wasson Creek. Transformation, other data manipulations, or nonparametric statistics could be used to address this data non-normality. A log10 transformation of shallow water table duration was conducted, but it did not remove error heterogeneity, so the transformation was not described in this report.

Further monitoring and research

This project provided only preliminary data on the complex relationships between hydrology, soil characteristics, and plant communities at these three sites. This study has identified several site attributes that may be strongly correlated to wetland functions. The recommendations below list some of the studies that could further our understanding of the sites.

Elevations and hydrology

- Obtain accurate elevations for streambed and top of bank at transects, particularly at Wasson Creek (see Marshall 2004).
- Monitor stream flow levels using continuous monitoring gauges, as Marshall (2004) did at Wasson Creek.

- Conduct integrated 3D analysis/modeling of stream flows, nonchannelized flows, topography, beaver dams, and water table surfaces and compare sites. Build on Marshall's (2004) work to maximize integration with her study.
- Use stream flow and rainfall data to analyze Anderson Creek Transect 1 water table data.
- Repeat soil surface elevation measurements at sample plots; make sure that lower elevations at wetter sample points are not due to softer soil surface (survey rod sinking into mud) and/or trampling of soils near the monitoring tubes.

Soils

- Measure available nitrogen (as opposed to TKN).
- Measure bulk density. This parameter may strongly affect plant community composition, plant growth, and soil water table dynamics.
- Measure sediment deposition and erosion rates at sample locations. Place marker horizons in summer or fall, and sample after peak rainfall events, when the majority of sediment movement occurs.
- Analyze soil profiles to determine whether the elevated surface near the Wasson Creek ditch is due to sidecast from ditch maintenance (however, determination could be difficult if soils were worked for pasture improvement).
- Investigate sediment dynamics at Tom's Creek. Do deep soil cores show evidence of repeated major sediment deposition events, buried organic horizons, or other profile characteristics that could indicate site history?

Vegetation

- Confirm identification and further investigate status of *Juncus marginatus* at Tom's Creek Transect 1 (introduced invasive, or rare native species?). Genetic studies may be needed to determine whether this is an introduced east coast genotype, or part of the disjunct west coast population. Submit specimens to West Coast rush experts.
- Monitor size and reproductive status of reed canarygrass patches at Wasson Creek.

Beaver activity

- Continue to document beaver activity at Wasson Creek following methods used by Marshall (2004), and extend the beaver studies to Anderson Creek if beaver become established there.
- Conduct historical aerial photograph analysis, soil coring, and other studies to determine beaver dam spatial and temporal dynamics (distribution and timeline of dam building and dam failures) at Tom's Creek.

Additional project benefits

Education

Five students (two high school, three undergraduate) sampled soils and water table elevations for this study (Figure 5d). During this work, they gained valuable field experience and knowledge of Oregon coastal freshwater wetland systems. They directly observed the effects of a broad range of weather conditions on these ecosystems, and closely observed development of plant communities and seasonal changes in hydrology. This experience gave all of the students a deeper understanding of the ecological linkages between the biological and physical components of Oregon wetlands.

Liaison

This project emphasized liaison with other local watershed groups. Technical specifications, equipment and expertise were shared with the Coos Watershed Association (CWA). The CWA is also monitoring hydrology and plant community development at wetland and riparian restoration sites in the watershed. Matching methodologies will result in better comparability of results and improved understanding of wetland and riparian ecosystems.

Literature cited

Adamus, P.R. 2001. Guidebook for Hydrogeomorphic (HGM)-based Assessment of Oregon Wetland and Riparian Sites: Statewide Classification and Profiles. Oregon Division of State Lands, Salem, OR.

Antieau, C. J. 1993. Biology and management of reed canarygrass, and implications for ecological restoration. Washington State Department of Transportation, Seattle. Accessed December 30 2005 at http://www.sernw.org/docs/RCG.rtf

Brophy, L.S. (Green Point Consulting). 2005. Anderson Creek vegetation monitoring 2003-2005. Prepared for South Slough National Estuarine Research Reserve.

Cornu, C.E. 2005. Restoring Anderson Creek Marsh. South Slough NERR Coastal Resource Management Series. CRMS-2005-3. Coos Bay, Oregon.

Daubenmire, R. 1968. Plant Communities: A Textbook of Plant Synecology. Harper and Row, New York.

Environmental Laboratory. 1987. Corps of Engineers Wetlands Delineation Manual. Technical report Y-87-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Ertter, B. 2005. Keys to *Juncus* and *Luzula* of California (prepared for and modified during Friends of the Jepson Herbarium Weekend Workshop on Juncaceae, July, 2000). Accessed June 12, 2005 from University and Jepson Herbaria website, University of California at Berkeley, http://ucjeps.berkeley.edu/jk.html.

Green, R.H. 1979. Sampling design and statistical methods for environmental biologists. Wiley-Interscience, New York.

Hickman, J.C., ed. 1993. The Jepson Manual of Higher Plants of California. University of California Press, Berkeley, CA.

Kagan, J.A., J.A. Christy, M.P. Murray, and J.A. Titus. 2005. Classification of Native Vegetation of Oregon. Oregon Natural Heritage Program. Available at: http://oregonstate.edu/ornhic/publications.html

Marshall, S. M. 2004. Return to the Floodplain: The role of beavers (*Castor canadensis*) in restoring channel complexity at Wasson Creek. B.Sc. Thesis, Department of Environmental Science and Robert D. Clark Honors College, University of Oregon.

Mitsch, W.J., and J.G. Gosselink, 1993. Wetlands (2nd Ed.). Van Nostrand Reinhold, New York.

National Research Council. 2001. Compensating for wetland losses under the Clean Water Act. Board of Environmental Studies and Toxicology, Water Science and Technology Board, National Research Council. National Academy Press, Washington, D.C.

Reed, P. 1988. National List of Plant Species that Occur in Wetlands: Northwest Region 9. U.S. Fish and Wildlife Service, Biological Report 88 (26.9). Available on the web at http://www.nwi.fws.gov/bha/.

Reed, P. 1993. Addendum to the National List of Plant Species that Occur in Wetlands: Northwest Region 9. Available on the web at http://www.nwi.fws.gov/bha/.

Rybczyk, J.M., J.W. Day, and W.H. Conner. 2002. The impact of wastewater effluent on accretion and decomposition in a subsiding forested wetland. Wetlands 22(1): 18-32.

Simenstad, C.A., C.D. Tanner, R.M. Thom, and L.L. Conquest. 1991. Estuarine Habitat Assessment Protocol. U.S. EPA, Seattle, WA, EPA 910/9-91-037.

Soil Survey Staff. 1992. Keys to Soil Taxonomy, 5th edition. SMSS Technical Monograph No. 19. Blacksburg, VA: Pocahontas Press Inc. 556 pp.

Sprecher, S. W. 2000. Installing monitoring wells/piezometers in wetlands. *WRAP Technical Notes Collection* (ERDC TN-WRAP-00-02), U.S. Army Engineer Research and Development Center, Vicksburg, MS. Accessed June 2005 at http://el.erdc.usace.army.mil/wrap/pdf/tnwrap00-2.pdf.

Underwood, A. J. 1991. Beyond BACI: experimental designs for detecting human environmental impacts on temporal variations in natural populations. Australian Journal of Marine and Freshwater Research 42:569-87.

U.S. EPA. 2002. Wetland Monitoring and Assessment: A Technical Framework. http://www.epa.gov/owow/wetlands/facts/techfram.pdf.

Zedler, J.B., and R. Lindig-Cisneros. 2000. Functional equivalency of restored and natural salt marshes. *In* Weinstein, M.P., and D.A. Kreeger, *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer, Boston.

Appendix 1. Summary tables

Table A1. Comparison of vegetation and soil characteristics between impacted and unimpacted sites, where impact consists of stream channelization and agricultural use (grazing). Comparison disregards recent restoration at Anderson. For restored/unrestored comparison, see Table A2. **Bold type** indicates values significantly different from control at p = 0.05 (*) and p = 0.01 (**) using two-tailed t-test.

Category and site(s)	Duration of shallow water table (days)[a]	% cover OBL+ water/ mud[b]	% cover OBL to FACW +water/ mud[c]	% cover FAC to FACU[d]	% cover OBL to FACW + water/ mud, *native spp only*	% cover native spp	% cover non-native spp	soil pH	% organic matter (LOI)	Total Kjeldahl N (ppm)	Total P (ppm)
Impacted (Anderson+Wasson)	**86.5****	34.5	78.6	**22.6***	**43.9****	**44.5****	**56.4****	5.2	**9.4****	**2668.9****	584.5
Unimpacted control (Tom's Cr.)	166.0	46.9	85.3	12.4	85.3	82.3	7.1	5.1	24.1	5973.1	514.2

[a] Average continuous days with water table <=12" from soil surface (saturated rooting zone) during the 166 day observation period

[b] Average cover by obligate wetland species (OBL indicator status) and/or water or mud (saturated to surface)

[c] Average cover by obligate wetland species, facultative wetland species (FACW), and/or water or mud (saturated to surface)

[d] Average cover by facultative (FAC) and facultative upland (FACU) species

Table A2. Comparison of vegetation and soil characteristics between restored and unrestored sites (both sites impacted by stream channelization and agricultural use). **Bold type** indicates values significantly different from control at p = 0.05 (*) and p = 0.01 (**) using two-tailed t-test. Footnotes same as Table A1.

Category and site	Duration of shallow water table (days)[a]	% cover OBL+ water/ mud[b]	% cover OBL to FACW +water/ mud[c]	% cover FAC to FACU[d]	% cover OBL to FACW + water/ mud, *native spp only*	% cover native spp	% cover non-native spp	soil pH	% organic matter (LOI)	Total Kjeldahl N (ppm)	Total P (ppm)
Restored (Anderson Cr.)	71.4	30.4	73.1	25.6	45.3	46.4	52.2	5.3	**8.4***	**2465.2***	560.7
Unrestored control (Wasson Cr.)	98.1	38.2	83.4	20.0	42.8	42.8	60.1	5.2	10.3	2850.0	605.6

Table A3. Comparison of vegetation and soil characteristics between impacted, unrestored site (Wasson Creek) and unimpacted site (Tom's Creek). **Bold type** indicates values significantly different from control at p = 0.05 (*) and p = 0.01 (**) using two-tailed t-test. Footnotes same as Table A1.

Category and site	Duration of shallow water table (days)[a]	% cover OBL+ water/ mud[b]	% cover OBL to FACW +water/ mud[c]	% cover FAC to FACU[d]	% cover OBL to FACW + water/ mud, *native spp only*	% cover native spp	% cover non-native spp	soil pH	% organic matter (LOI)	Total Kjeldahl N (ppm)	Total P (ppm)
Impacted, unrestored site (Wasson Cr.)	__98.1**__	38.2	83.4	20.0	__42.8**__	__42.8**__	__60.1**__	5.2	__10.3**__	__2850.0**__	605.6
Unimpacted control (Tom's Cr.)	166.0	46.9	85.3	12.4	85.3	82.3	7.1	5.1	24.1	5973.1	514.2

Table A4. Comparison of vegetation and soil characteristics in plots in two hydrologic groups. **Bold type** indicates significant differences at p = 0.05 (*) and p=0.01 (**) using two-tailed t-test. Footnotes same as Table A1.

Hydrology group*	Duration of shallow water table (days)[a]	% cover OBL+ water/ mud[b]	% cover OBL to FACW +water/ mud[c]	% cover FAC to FACU[d]	% cover OBL to FACW + water/ mud, *native spp only*	% cover native spp	% cover non-native spp	soil pH	% organic matter (LOI)	Total Kjeldahl N (ppm)	Total P (ppm)
>= 44 days duration	__135.8 **__	__47.1**__	__84.1**__	__16.1**__	__62.0**__	__61.5**__	__36.0**__	5.2	__13.4*__	__3557.7*__	560.2
<18 days duration	5.0	8.1	68.1	33.3	25.3	26.1	75.3	5.3	9.9	2786.5	597.5

*Plots were grouped by duration of shallow water table (continuous days with water table within 12" of soil surface during the 166 day observation period).

Table A5. Characteristics of plots with >40% cover of reed canarygrass.

Plot ID	% cover of reed canarygrass	Duration of shallow water table (days)*	pH	% organic matter (LOI)	Total Kjeldahl N (ppm)	Total P (ppm)	Soil texture
WCT5P1	100	131	5.1	9.37	2574	546	L/CL
WCT6P1	99	166	5.0	8.38	1849	458	CL
WCT2P1	95	1	5.7	9.62	2423	496	L
WCT2P2	70	115	5.5	9.91	2533	595	CL/L
WCT1P1	53	166	5.0	12.42	3341	648	SiL/L
WCT4P3	51	14	5.2	11.66	2581	609	CL
WCT4P4	43	0	5.4	10.24	2814	656	L

*Duration indicates continuous days with water table within 12” of soil surface during the 166 day observation period.

Appendix 2. Plant species list

Species present within sample plots at each site are shown below. This is not a complete species list for any of the sites.

Latin name	Species code	Common name	Anderson	Wasson	Tom's
Agrostis sp.	AGRspp	Bentgrass (generally creeping, sometimes colonial)	x	x	
Alnus rubra	ALNRUB	Red alder	x	x	x
Anthoxanthum odoratum	ANTODO	Sweet vernalgrass		x	
Athyrium filix-femina	ATHFIL	Ladyfern		x	
Blechnum spicant	BLESPI	Deer fern			x
Calamagrostis nutkaensis	CALNUT	Pacific reedgrass			x
Carex obnupta	CAROBN	Slough sedge	x	x	x
Cirsium arvense	CIRARV	Canada thistle		x	
Cirsium vulgare	CIRVUL	Bull thistle		x	
Deschampsia cespitosa	DESCES	Tufted hairgrass	x		
Epilobium ciliatum	EPICIL	Fringed willow-herb	x		
Equisetum telmateia	EQUTEL	Giant horsetail	x	x	
Festuca arundinacea (new name: Lolium arundinaceum)	FESARU	Tall fescue		x	
Galium trifidum	GALTRI	Small bedstraw			x
Gaultheria shallon	GAUSHA	Salal			x
Glyceria occidentalis	GLYOCC	Northwestern mannagrass		x	
Holcus lanatus	HOLLAN	Common velvetgrass	x	x	
Hypericum anagalloides	HYPANN	Tinker's penny			x
Juncus acuminatus	JUNACU	Tapertip rush			x
Juncus bolanderi	JUNBOL	Bolander's rush	x		
Juncus bufonius	JUNBUF	Toad rush	x		
Juncus effusus	JUNEFF	Soft rush	x		x
Juncus marginatus	JUNMAR	Grassleaf rush			x
Lonicera involucrata	LONINV	Black twinberry			x
Lotus corniculatus	LOTCOR	Birdsfoot trefoil	x	x	x
Lycopus uniflorus	LYCUNI	Northern bugleweed			x
Lysichiton americanum	LYSAME	Skunk cabbage		x	x
Myrica californica	MYRCAL	California wax myrtle			x
Oenanthe sarmentosa	OENSAR	Water parsley			x
Phalaris arundinacea	PHAARU	Reed canarygrass		x	
Picea sitchensis	PICSIT	Sitka spruce			x
Polygonum hydropiper	POLHYD	Marshpepper knotweed		x	
Ranunculus repens	RANREP	Creeping buttercup	x	x	
Rubus discolor	RUBDIS	Himalayan blackberry		x	
Rumex conglomeratus	RUMCON	Clustered dock		x	
Rumex crispus	RUMCRI	Curly dock		x	

Latin name	Species code	Common name	Anderson	Wasson	Tom's
Rumex obtusifolius	RUMOBT	Bitter dock		x	
Salix hookeriana	SALHOO	Coast willow	x		
Salix sitchensis	SALSIT	Sitka willow			x
Scirpus microcarpus	SCIMIC	Small-fruited bulrush	x	x	
Sisyrinchium californicum	SYSCAL	Golden-eyed grass			x
Trifolium repens	TRIREP	White clover	x		
Typha latifolia	TYPLAT	Broadleaf cattail			x
Vaccinium ovatum	VACOVA	Evergreen huckleberry			x

Appendix 3. Plant community list

Community name	Community dominants	USFWS wetland indicator status for dominant species	ONHP rank*	Notes	Plots representing community
Pacific reedgrass fen	*Calamagrostis nutkaensis*	FACW	G3S1	Very rare community in Oregon	TCT2P1, TCT2P2, TCT2P3
Slough sedge marsh	*Carex obnupta*	OBL	G4S4		ACT2P4, TCT3P2, TCT3P3, WCT1P2, WCT4P1
Disturbed old pasture	RANREP, HOLLAN, EQUTEL, LOTCOR, Agrostis	FAC-FACW	not on ONHP list	Non-native communities are not listed in ONHP classification	ACT1P3, ACT1P4, ACT2P1, ACT3P1, ACT4P1, ACT4P4, WCT3P2, WCT3P3, WCT4P2, WCT5P3, WCT6P3
Soft rush marsh	*Juncus effusus*	FACW	G5S5		TCT3P1
Grass-leaved rush marsh	*Juncus marginatus*	NOL	not on ONHP list	Need expert analysis of specimens to determine native (disjunct) vs. non-native status	TCT1P1, TCT1P2, TCT1P3
Reed canarygrass marsh	*Phalaris arundinacea*	FACW	not on ONHP list	Non-native communities are not listed in ONHP classification	WCT2P1, WCT4P3, WCT4P4, WCT5P1, WCT6P1
Small-fruited bulrush marsh	*Scirpus microcarpus*	OBL	G4S4		ACT1P1, ACT1P2, ACT2P2, ACT2P3, ACT3P2, ACT3P4, ACT3P3, ACT4P2, ACT4P3, WCT1P1, WCT2P2, WCT2P3, WCT3P1, WCT5P2, WCT6P2

“**Rank** is a code identifying the conservation status of the plant association. It is composed of a global rank ("G") followed by a state rank ("S").
1 = Critically imperiled because of extreme rarity, with 5 or fewer occurrences or very few remaining acres. 2 = Imperiled because of rarity, with 6-20 occurrences or few remaining acres. 3 = Either very rare and local throughout its range or found locally in a restricted range; uncommon, with 21-100 occurrences. 4 = Apparently secure, though it may be quite rare in parts of its range, especially at the periphery; many occurrences. 5 = Demonstrably secure, though it may be quite rare in parts of its range, especially at the periphery; ineradicable under present conditions.” (Kagan et al. 2005)

Appendix 4. Figures

Figure 1. Vicinity map.

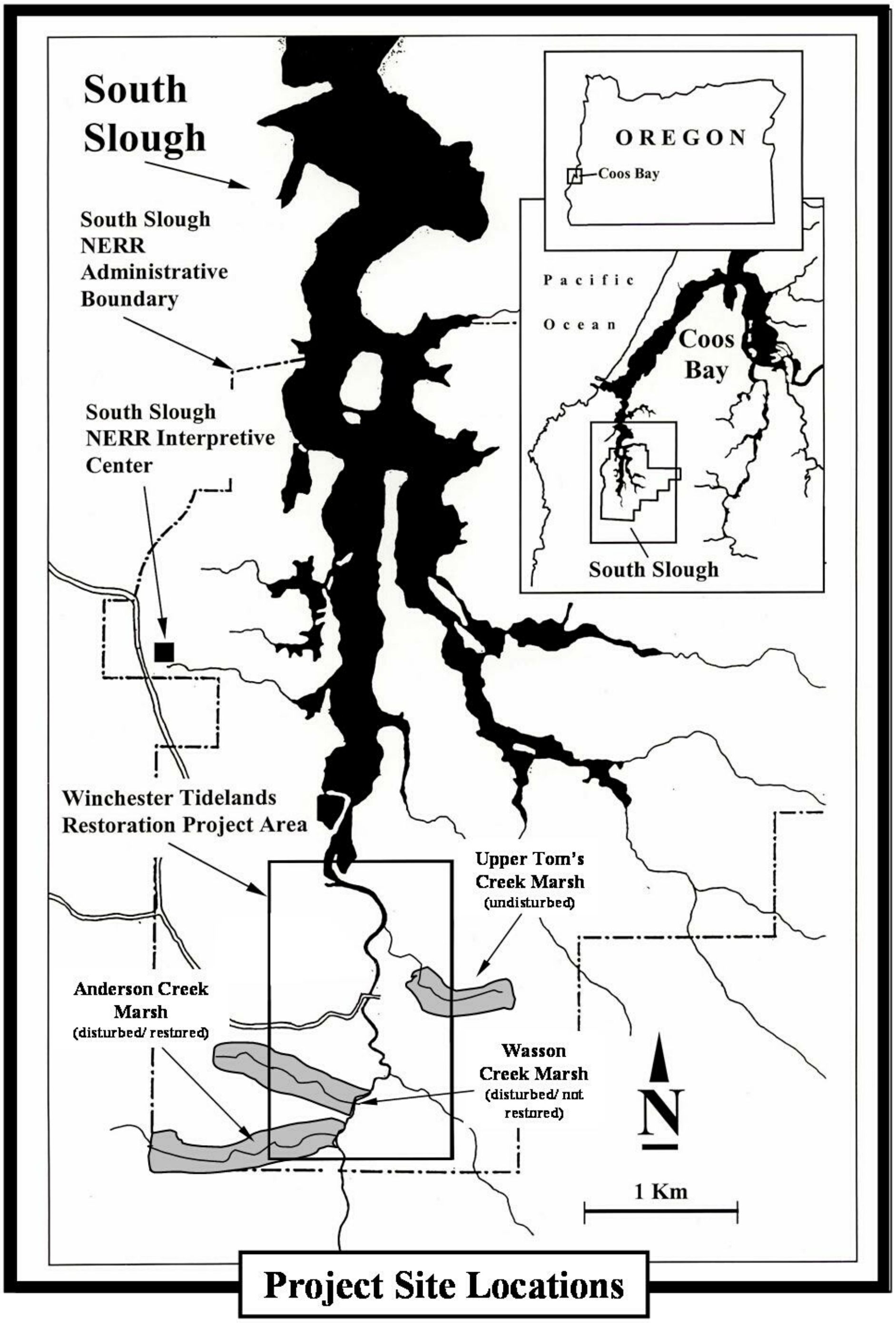


Figure 2. Annotated 2003 color infrared aerial photograph showing transect and sample plot locations (approximate) at Anderson Creek. Stream flow is from left to right; north is approximately towards top of photo. Transects are indicated by “T1,” “T2,” etc. Plots are indicated by “P1,” “P2,” etc. Background is a May 2003 color infrared aerial photo.

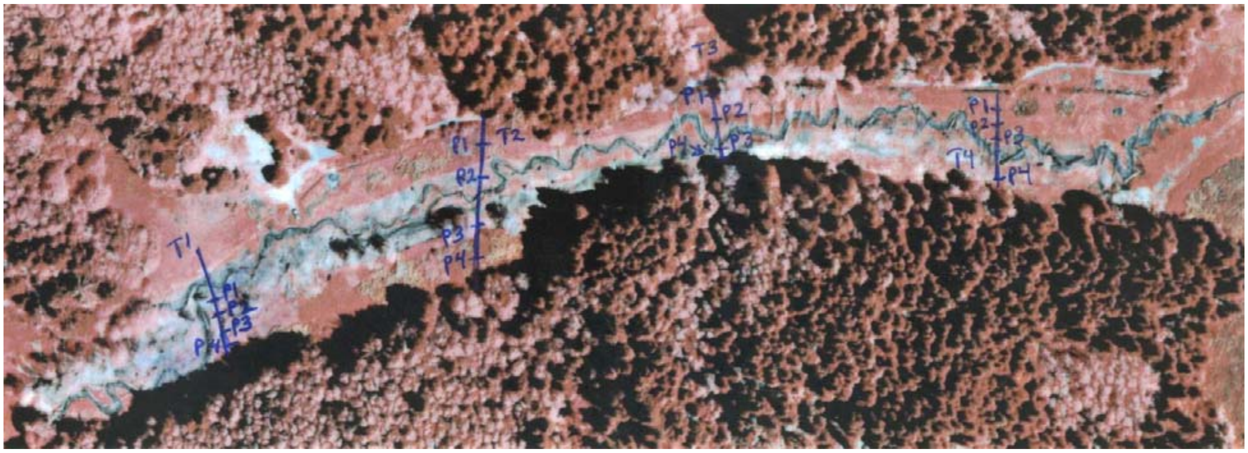


Figure 3. Annotated 2003 color infrared aerial photograph showing transect and sample plot locations (approximate) at Wasson Creek. Stream flow is from left to right; north is approximately towards top of photo. Transects are indicated by “T1,” “T2,” etc. Plots are indicated by “P1,” “P2,” etc. Letters indicate locations of notes taken during field reconnaissance. Background is a May 2003 color infrared aerial photo.

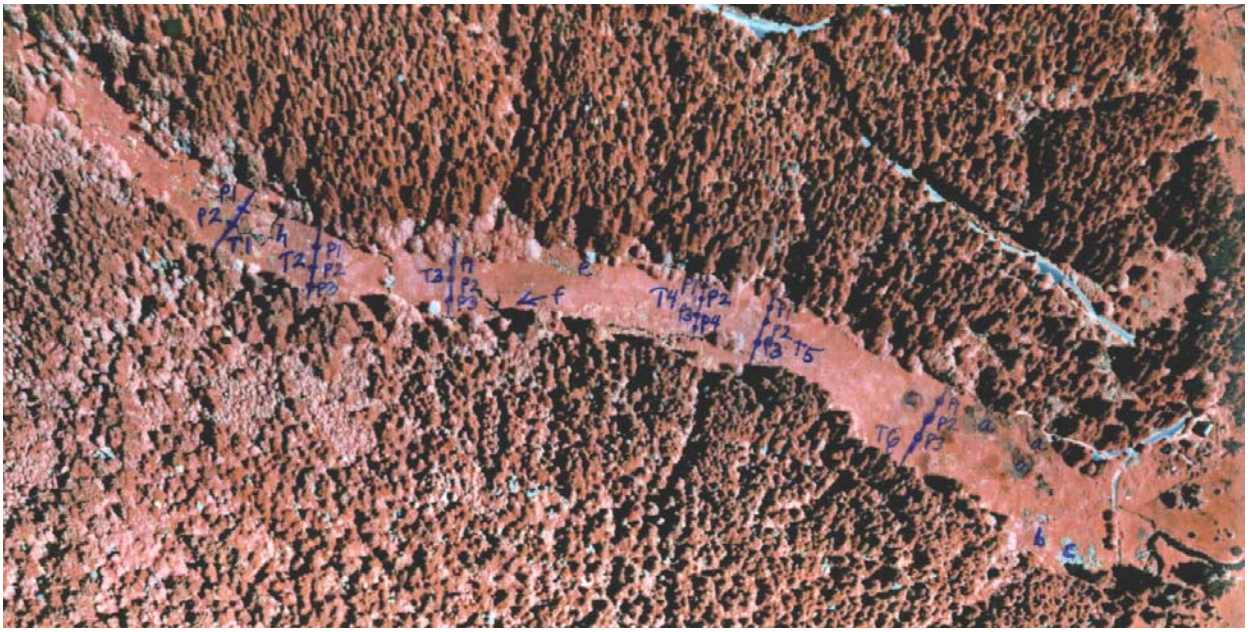


Figure 4. Annotated 2003 color infrared aerial photograph showing transect and sample plot locations (approximate) at Tom’s Creek. Stream flow is from top right to bottom left; north is approximately to left. Transects are indicated by “T1,” “T2” and “T3.” Plots are indicated by “P1,” “P2” and “P3.” Letters indicate locations of notes taken during field reconnaissance. Background is a May 2003 color infrared aerial photo.

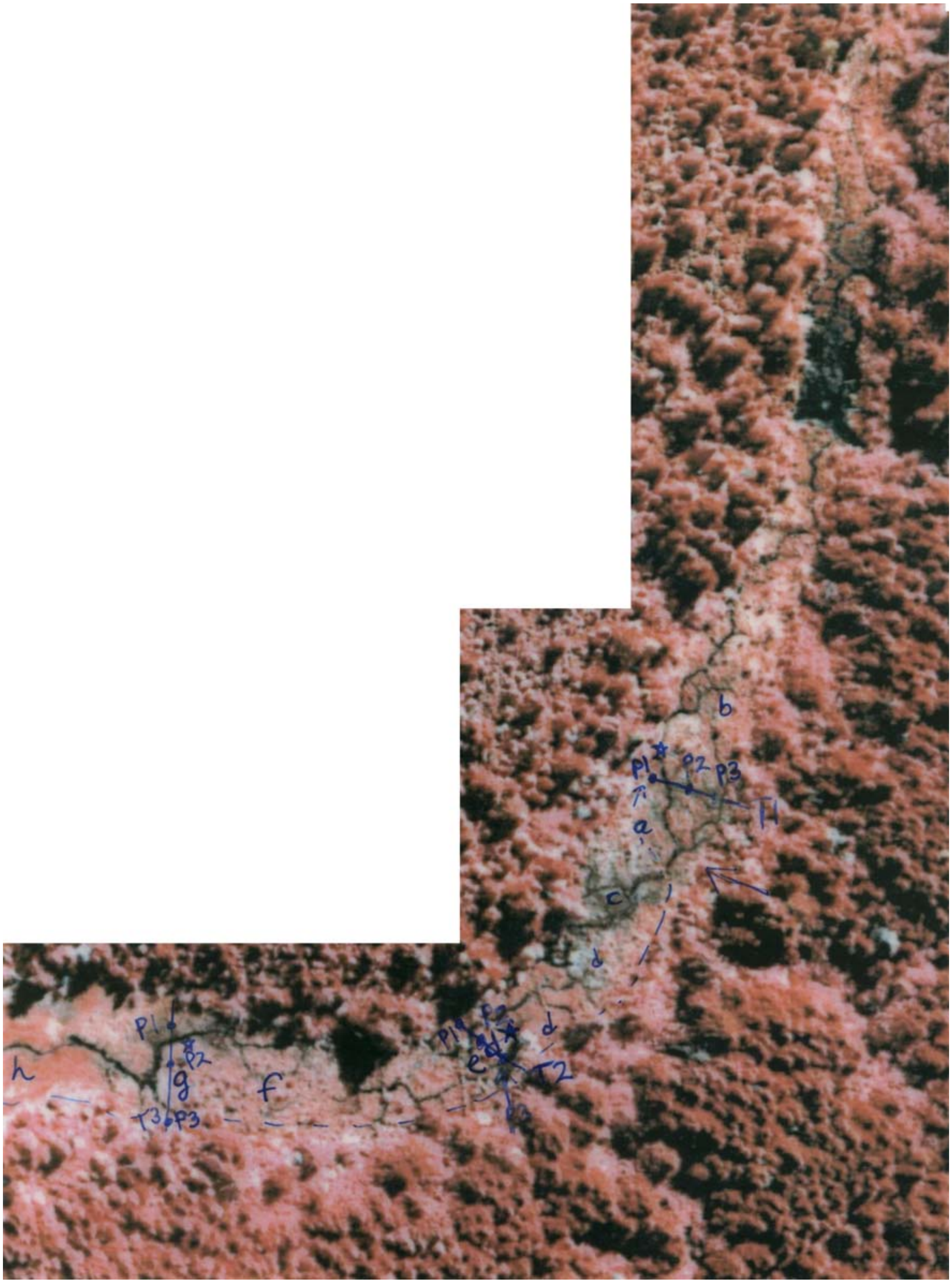


Figure 5. Study sites and field procedures.

Figure 5a. Anderson Creek, August 2004: Restored wetland site.

Figure 5b. Wasson Creek, March 2004: Altered, unrestored site (ditched and cleared old pasture).

Figure 5c. Tom's Creek, March 2004: Undisturbed reference site.

Figure 5d. Student workers Emma Johnsrude and Nathan Watkins sampling soils at Wasson Creek, August 2004.

Figure 6. Water table dynamics at Anderson Creek.

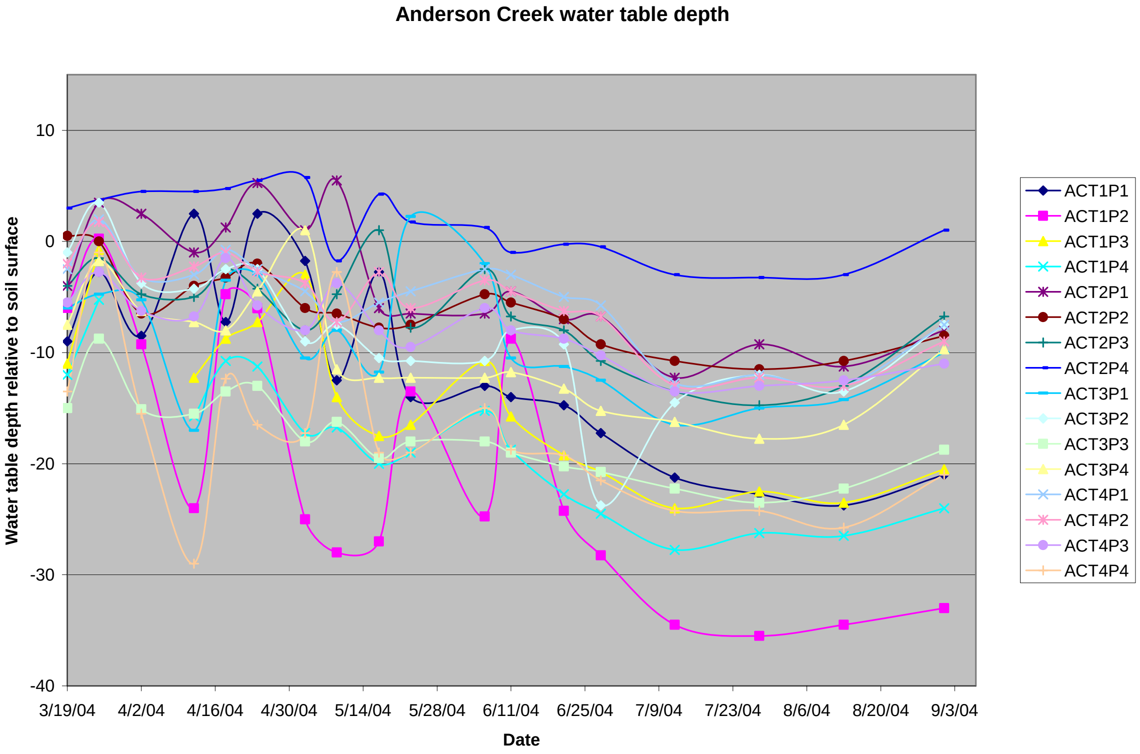


Figure 7. Water table dynamics at Wasson Creek.

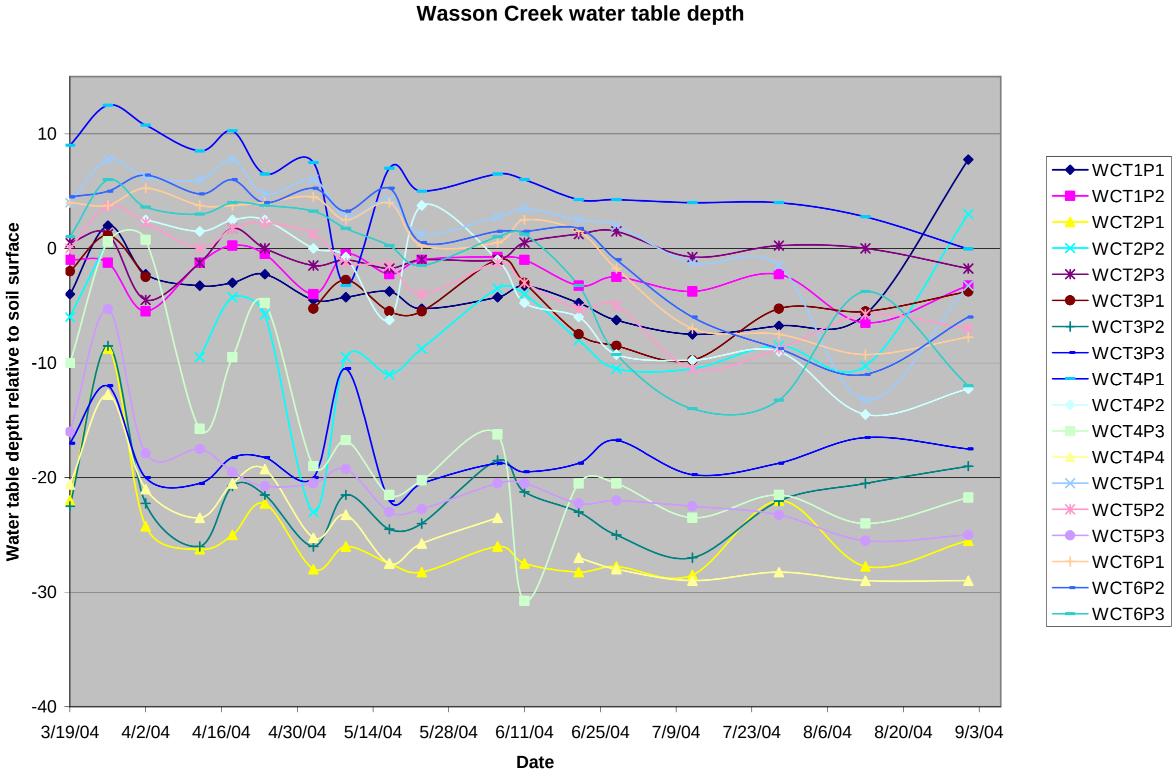


Figure 8. Water table dynamics at Tom's Creek.

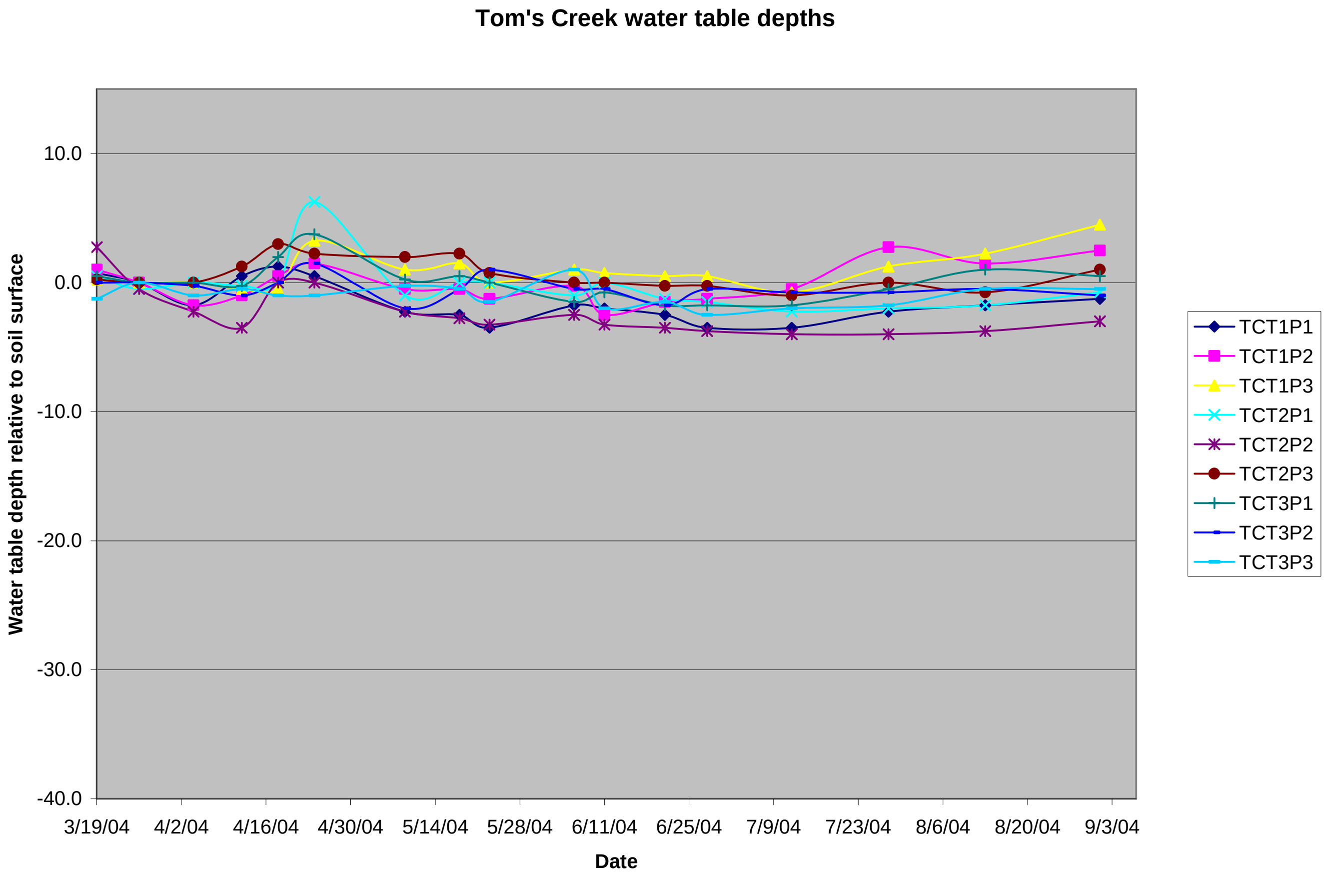


Figure 9. Elevation versus distance from main ditch, Wasson Creek transects. Sample points are shown as markers along each transect line.

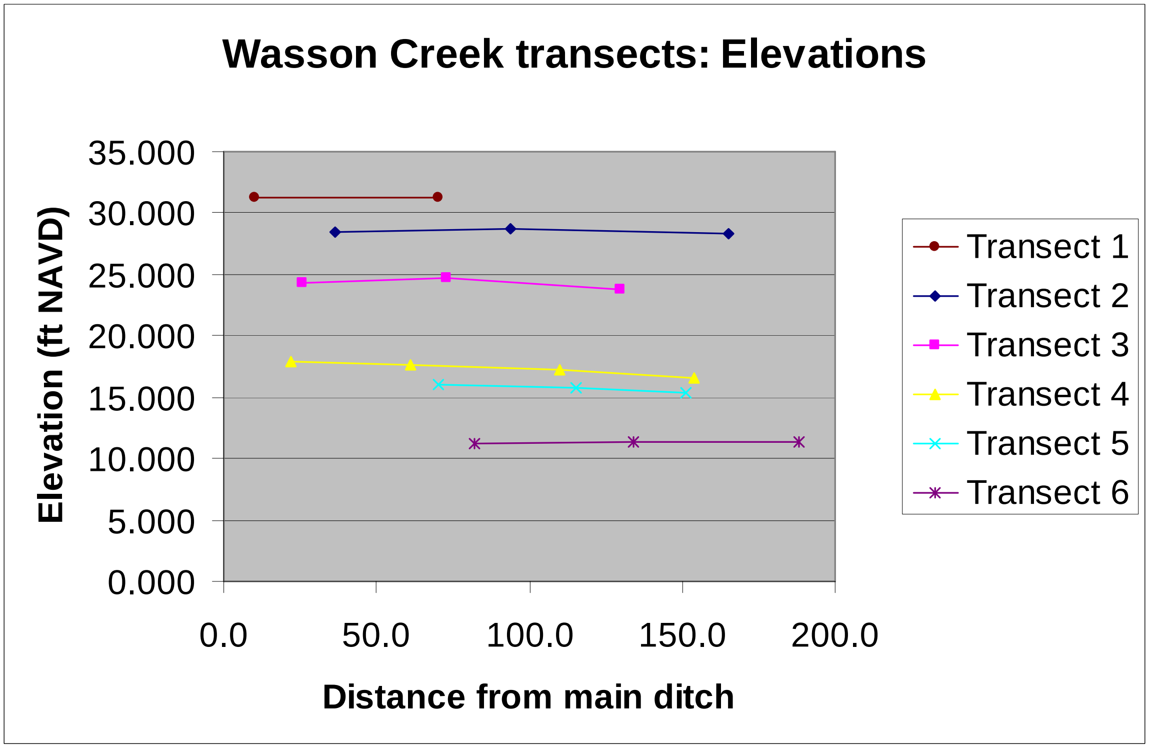


Figure 10. Duration of shallow water table (“Continuous wetland days”) *versus* distance from channel, Wasson Creek transects. Sample points are shown as markers along each transect line.

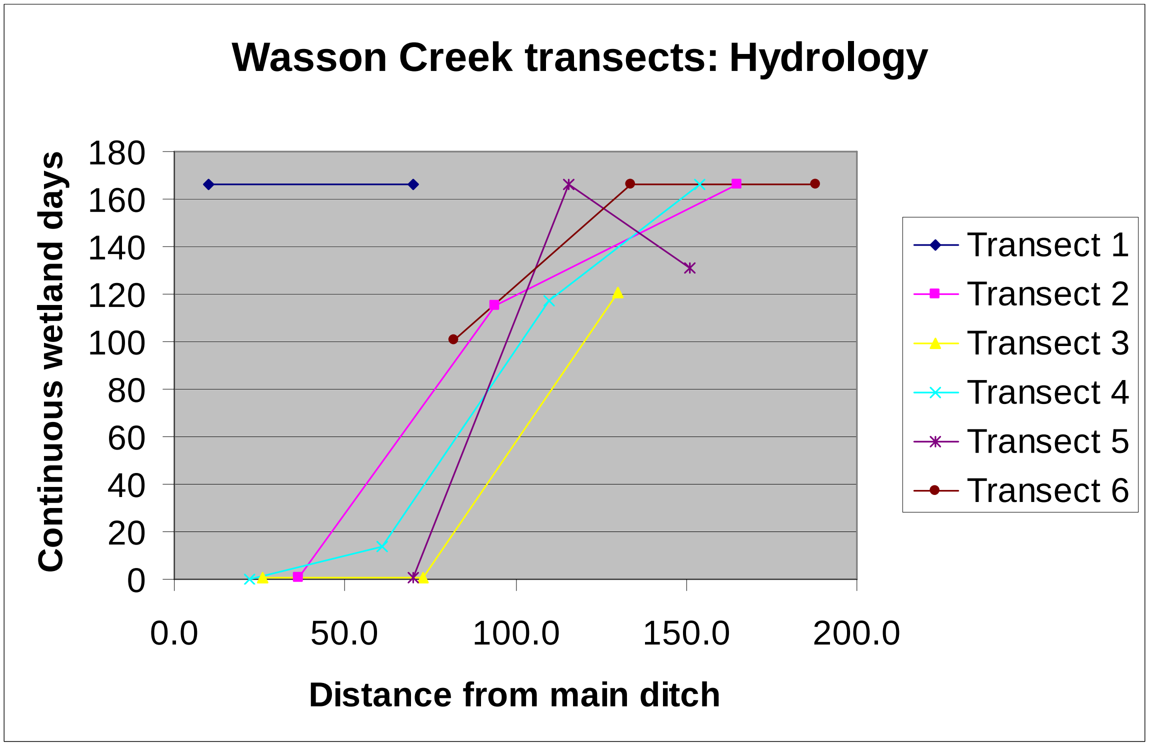


Figure 11. Soil nutrient relationships at study sites.

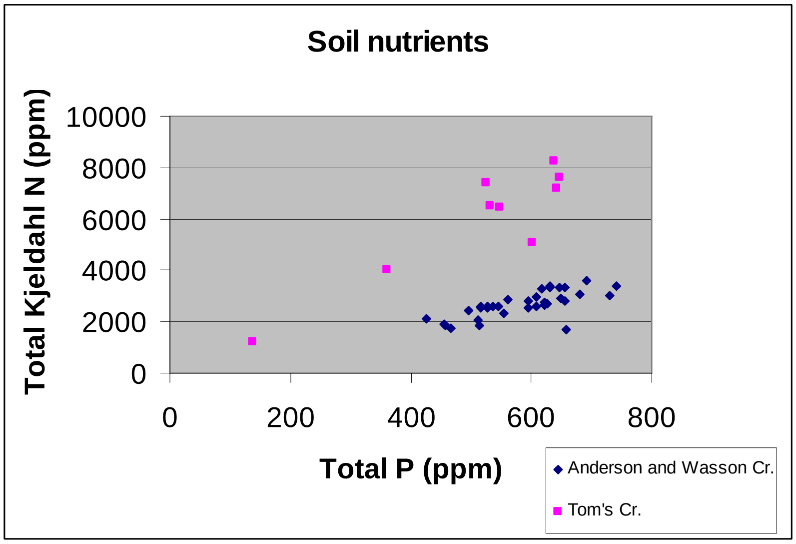
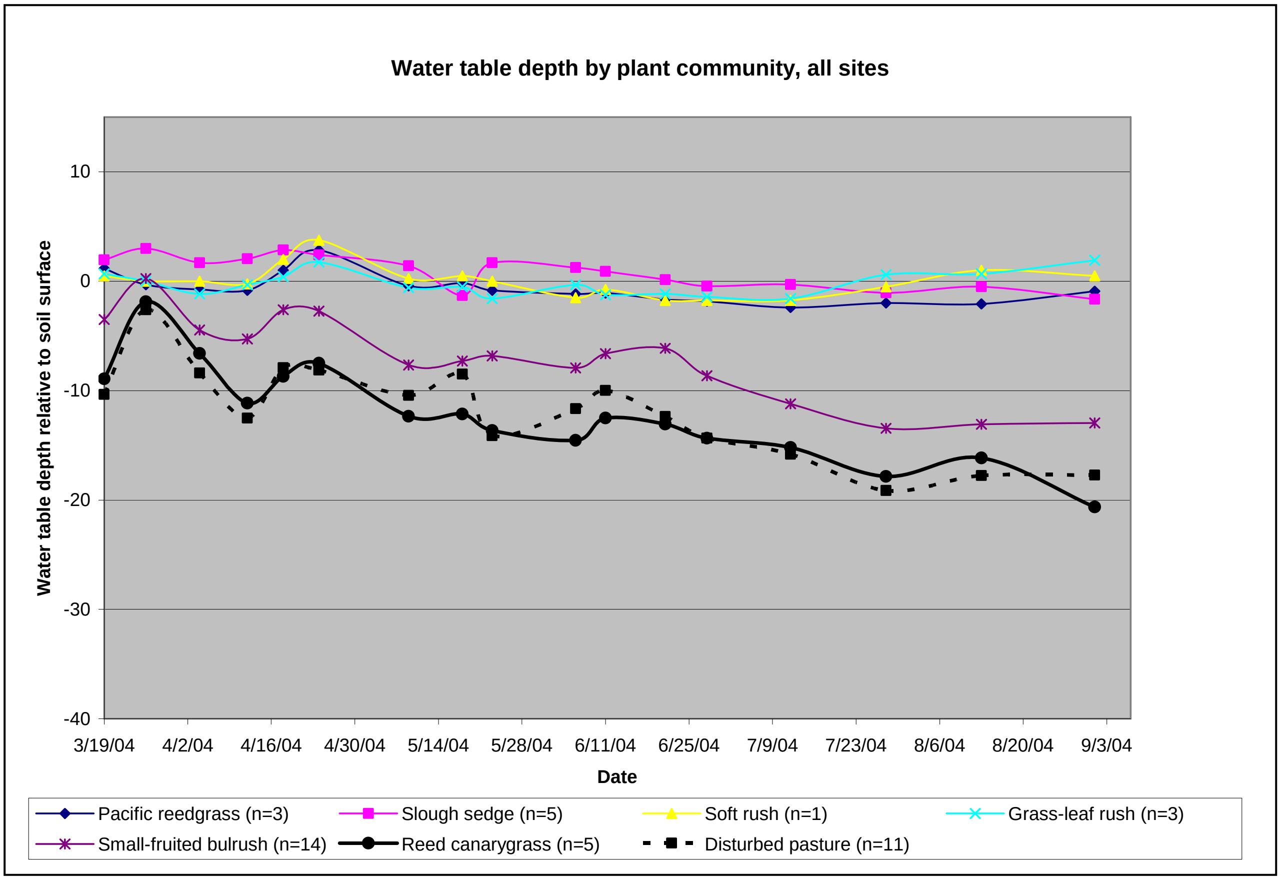


Figure 12. Water table dynamics by plant community (averaged across all study sites)



Appendix 5. Data tables

ID	Elev (ft NAVD)	Dist fr chan (ft)	Elev rel to lowest pt (in)	Transect elev range	Minimum continuous WL days	pH	%OM (LOI)	TKN (ppm)	TP (ppm)	Texture	Sum_OBL/ water/mud	SUM_OBL to FACW + water/mud	SUM_FAC to FACU	Sum_OBL to FACW+water/mud, NATIVES ONLY	Sum_Native	Sum_Exotic
ACT1P1	31.730	10.0	0.000	5.880	45	5.4	10.12	2086	511	L/CL	61	102	7	91	91	18
ACT1P2	32.020	10.0	3.480		14	5.3	7.55	2328	555	L	39	73	27	60	60	40
ACT1P3	32.030	20.0	3.600		15	5.1	10.15	2880	561	L	0	67	29	21	21	75
ACT1P4	32.220	44.0	5.880		6	5.1	11.22	3358	655	L/SiL	6	74	18	30	30	62
ACT2P1	23.340	17.0	0.000	15.720	115	5.2	9.96	2590	535	L	10	76	26	10	10	92
ACT2P2	23.390	23.0	0.600		166	5.3	2.82	2648	621	L	34	75	27	46	46	56
ACT2P3	23.680	26.0	4.080		101	5.5	6.91	1869	514	SL	35	70	25	65	75	20
ACT2P4	24.650	95.0	15.720		166	5.3	7.92	2103	426	SL	94	99	0	99	99	0
ACT3P1	18.780	105.0	5.640	12.480	64	5.1	8.80	2551	528	L	19	70	32	19	19	83
ACT3P2	18.310	75.0	0.000		94	5.4	5.88	1701	657	L	25	66	34	43	43	57
ACT3P3	19.350	16.0	12.480		1	5.4	6.84	1928	455	L	26	63	31	43	52	42
ACT3P4	19.010	35.0	8.400	13.080	51	5.0	8.72	2802	596	L	61	92	0	72	72	20
ACT4P1	13.240	100.0	0.240		101	5.4	8.70	2684	626	L	8	43	53	13	13	83
ACT4P2	13.220	59.0	0.000		101	5.4	6.33	1750	466	L	33	66	30	33	33	63
ACT4P3	13.420	21.0	2.400		101	5.4	10.14	2904	648	L	35	69	30	51	51	48
ACT4P4	14.310	29.0	13.080		1	5.2	11.64	3259	617	L	0	64	40	28	28	76
TCT1P1	10.786	17.0	0.170	-2.160	166	5.1	38.01	7409	526	LS	27	77	32	77	98	11
TCT1P2	10.606	20.0	-0.010		166	5.1	19.03	4029	360	SL	28	94	0	94	81	0
TCT1P3	10.616	56.0	0.000		166	5.1	6.54	1206	138	LS	32	87	9	87	61	9
TCT2P1	9.326	16.0	0.890	3.480	166	5.0	37.12	8255	637	SL	31	81	8	81	81	8
TCT2P2	9.536	15.0	1.100		166	5.0	12.15	7624	646	SL	39	68	20	68	74	14
TCT2P3	9.246	36.0	0.810		166	4.8	29.77	7222	642	SL	32	89	11	89	94	6
TCT3P1	8.436	20.0	-0.080	-2.760	166	5.4	23.67	6434	547	L	59	88	10	88	77	10
TCT3P2	8.516	19.0	0.000		166	5.3	18.48	5060	601	CL	94	94	16	94	110	0
TCT3P3	8.666	79.0	0.150		166	5.1	31.99	6520	531	L	80	90	6	90	65	6
WCT1P1	31.300	10.0	0.960	0.960	166	5.0	12.42	3341	648	SiL/L	44	97	0	44	44	53
WCT1P2	31.220	70.0	0.000		166	5.1	10.63	2576	515	L	101	101	0	101	101	0
WCT2P1	28.480	36.5	2.640	4.800	1	5.7	9.62	2423	496	L	0	95	0	0	0	95
WCT2P2	28.660	94.0	4.800		115	5.5	9.91	2533	595	CL/L	30	100	0	30	30	70
WCT2P3	28.260	165.0	0.000		166	5.0	12.25	3086	681	L	90	96	8	90	80	14
WCT3P1	23.810	130.0	0.000	10.440	121	5.1	11.75	3309	632	L	83	88	14	88	88	14
WCT3P2	24.680	73.0	10.440		1	5.1	10.32	3366	740	L	0	50	57	21	21	86
WCT3P3	24.360	26.0	6.600		1	5.2	10.20	2729	621	L	18	70	32	27	27	75
WCT4P1	16.630	154.0	0.000	15.000	166	5.4	12.75	2564	515	L/SL	100	100	10	100	110	0
WCT4P2	17.170	110.0	6.480		117	5.1	10.95	2995	730	L/CL	18	73	25	18	18	80
WCT4P3	17.660	61.0	12.360		14	5.2	11.66	2581	609	CL	0	81	26	14	14	93
WCT4P4	17.880	22.0	15.000		0	5.4	10.24	2814	656	L	0	66	44	23	23	87
WCT5P1	15.410	151.0	0.000	7.080	131	5.1	9.37	2574	546	L/CL	0	100	0	0	0	100
WCT5P2	15.720	115.5	3.720		166	5.1	11.66	3360	630	CL	89	89	23	89	89	23
WCT5P3	16.000	70.1	7.080		1	5.3	9.47	2984	608	L	0	46	62	11	11	97
WCT6P1	11.400	188.0	2.280	2.280	166	5.0	8.38	1849	458	CL	0	99	0	0	0	99
WCT6P2	11.390	134.0	2.160		166	5.0	12.33	3599	692	CL	98	98	0	98	98	0
WCT6P3	11.210	82.0	0.000		101	5.1	2.23	2615	527	CL	16	53	59	16	16	96

Appendix		% cover																															
		O	O	O	O	O	O	O	O	O	FW	FW	FW	FW	FW	FW	FW	FW	FW	F+	F+	F	F	F	F	F	F	F-	FU-	FU	FU	FU	
ID	Plant community	CAROBN N	GLYOCC N	HYPANN N	JUNACU N	LYCUNI N	LYSAME N	OENSAR N	SCIMIC N	TYPLAT N	CALNUT N	DESCES N	EQUTEL N	JUNEFF N	PHAARU E	RANREP E	JUNMAR N	EPICIL N	SALHOO N	BLESPI N	LONINV N	AGRspp E	ALNRUB N	HOLLAN E	LOTCOR E	PICSIT N	TRIREP E	FESARU E	CIRARV E	ANTODO E	GAUSHA N	RUBDIS E	Water/mud
ACT1P1	SCIMIC	0	0	0	0	0	0	0	61	0	0	0	6	6	0	11	0	8	10	0	0	7	0	0	0	0	0	0	0	0	0	0	0
ACT1P2	SCIMIC	0	0	0	0	0	0	0	39	0	0	0	9	0	0	13	0	0	12	0	0	8	0	19	0	0	0	0	0	0	0	0	0
ACT1P3	PASTURE	0	0	0	0	0	0	0	0	0	0	0	21	0	0	46	0	0	0	0	0	0	0	9	6	0	14	0	0	0	0	0	0
ACT1P4	PASTURE	6	0	0	0	0	0	0	0	0	0	0	24	0	0	44	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0
ACT2P1	PASTURE	10	0	0	0	0	0	0	0	0	0	0	0	0	0	66	0	0	0	0	0	0	0	26	0	0	0	0	0	0	0	0	0
ACT2P2	SCIMIC	5	0	0	0	0	0	0	29	0	0	6	0	6	0	29	0	0	0	0	0	0	0	0	14	0	13	0	0	0	0	0	0
ACT2P3	SCIMIC	0	0	0	0	0	0	0	35	0	0	0	0	30	0	5	0	0	0	0	0	0	10	6	9	0	0	0	0	0	0	0	0
ACT2P4	CAROBN	94	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACT3P1	PASTURE	8	0	0	0	0	0	0	11	0	0	0	0	0	0	51	0	0	0	0	0	0	0	8	24	0	0	0	0	0	0	0	0
ACT3P2	SCIMIC	0	0	0	0	0	0	0	25	0	0	10	0	8	0	23	0	0	0	0	0	0	0	0	34	0	0	0	0	0	0	0	0
ACT3P3	SCIMIC	0	0	0	0	0	0	0	26	0	0	0	6	11	0	20	0	0	0	0	0	0	9	11	11	0	0	0	0	0	0	0	0
ACT3P4	SCIMIC	0	0	0	0	0	0	0	61	0	0	0	0	11	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ACT4P1	PASTURE	0	0	0	0	0	0	0	8	0	0	0	0	5	0	30	0	0	0	0	0	0	0	53	0	0	0	0	0	0	0	0	0
ACT4P2	SCIMIC	0	0	0	0	0	0	0	33	0	0	0	0	0	0	33	0	0	0	0	0	0	0	5	25	0	0	0	0	0	0	0	0
ACT4P3	SCIMIC	0	0	0	0	0	0	0	35	0	0	0	0	11	0	18	0	5	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0
ACT4P4	PASTURE	0	0	0	0	0	0	0	0	0	0	0	28	0	0	36	0	0	0	0	0	0	0	21	19	0	0	0	0	0	0	0	0
TCT1P1	JUNMAR	5	0	0	8	14	0	0	0	0	0	0	0	0	0	0	50	0	0	5	0	0	16	0	11	0	0	0	0	0	0	0	0
TCT1P2	JUNMAR	0	0	6	0	0	0	0	0	9	0	0	0	0	0	0	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
TCT1P3	JUNMAR	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	55	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	26
TCT2P1	CALNUT	10	0	0	0	0	21	0	0	0	20	0	0	5	0	0	25	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0
TCT2P2	CALNUT	18	0	0	0	0	21	0	0	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	6	0	0
TCT2P3	CALNUT	19	0	0	0	0	8	0	0	5	39	0	0	0	0	0	18	0	0	0	5	0	0	0	6	0	0	0	0	0	0	0	0
TCT3P1	JUNEFF	16	0	0	18	0	0	5	0	9	0	0	0	21	0	0	8	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	11
TCT3P2	CAROBN	80	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	8	0	0	0	0	0	0	0
TCT3P3	CAROBN	45	0	0	0	0	5	0	0	5	0	0	0	10	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	25
WCT1P1	SCIMIC	5	0	0	0	0	6	0	33	0	0	0	0	0	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WCT1P2	CAROBN	80	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WCT2P1	PHAARU	0	0	0	0	0	0	0	0	0	0	0	0	0	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WCT2P2	SCIMIC	0	0	0	0	0	0	0	30	0	0	0	0	0	70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WCT2P3	SCIMIC	0	0	0	0	0	55		25	0	0	0	0	0	6	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	10
WCT3P1	SCIMIC	0	0	0	0	0	0	0	83	0	0	0	5	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0
WCT3P2	PASTURE	0	0	0	0	0	0	0	0	0	0	0	21	0	0	29	0	0	0	0	0	20	0	19	0	0	0	10	0	8	0	0	0
WCT3P3	PASTURE	0	0	0	0	0	0	0	18	0	0	0	9	0	0	43	0	0	0	0	0	19	0	8	5	0	0	0	0	0	0	0	0
WCT4P1	CAROBN	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0
WCT4P2	PASTURE	0	0	0	0	0	0	0	18	0	0	0	0	0	19	36	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0
WCT4P3	PHAARU	0	0	0	0	0	0	0	0	0	0	0	14	0	51	16	0	0	0	0	0	0	0	21	0	0	0	0	5	0	0	0	0
WCT4P4	PHAARU	0	0	0	0	0	0	0	0	0	0	0	23	0	43	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	28	0
WCT5P1	PHAARU	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WCT5P2	SCIMIC	0	0	0	0	0	0	0	89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	11	0	0	0	0	0	0	0	0
WCT5P3	PASTURE	0	0	0	0	0	0	0	0	0	0	0	11	0	0	35	0	0	0	0	0	23	0	29	10	0	0	0	0	0	0	0	0
WCT6P1	PHAARU	0	0	0	0	0	0	0	0	0	0	0	0	0	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WCT6P2	SCIMIC	0	0	0	0	0	0	0	98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WCT6P3	PASTURE	0	6	0	0	0	0	0	10	0	0	0	0	0	8	29	0	0	0	0	0	59	0	0	0	0	0	0	0	0	0	0	0