Stoller-ESER-72

Sewage Wastewater Application Ecological Impact Study 2002

Amy Forman, Roger D. Blew,
Sue J. Vilord, Jackie R. Hafla

STOLLER-ESER-72

Sewage Wastewater Application Ecological Impact Study 2002

Amy D. Forman, Roger D. Blew, Sue J. Vilord, Jackie R. Hafla

S. M. Stoller Corp.

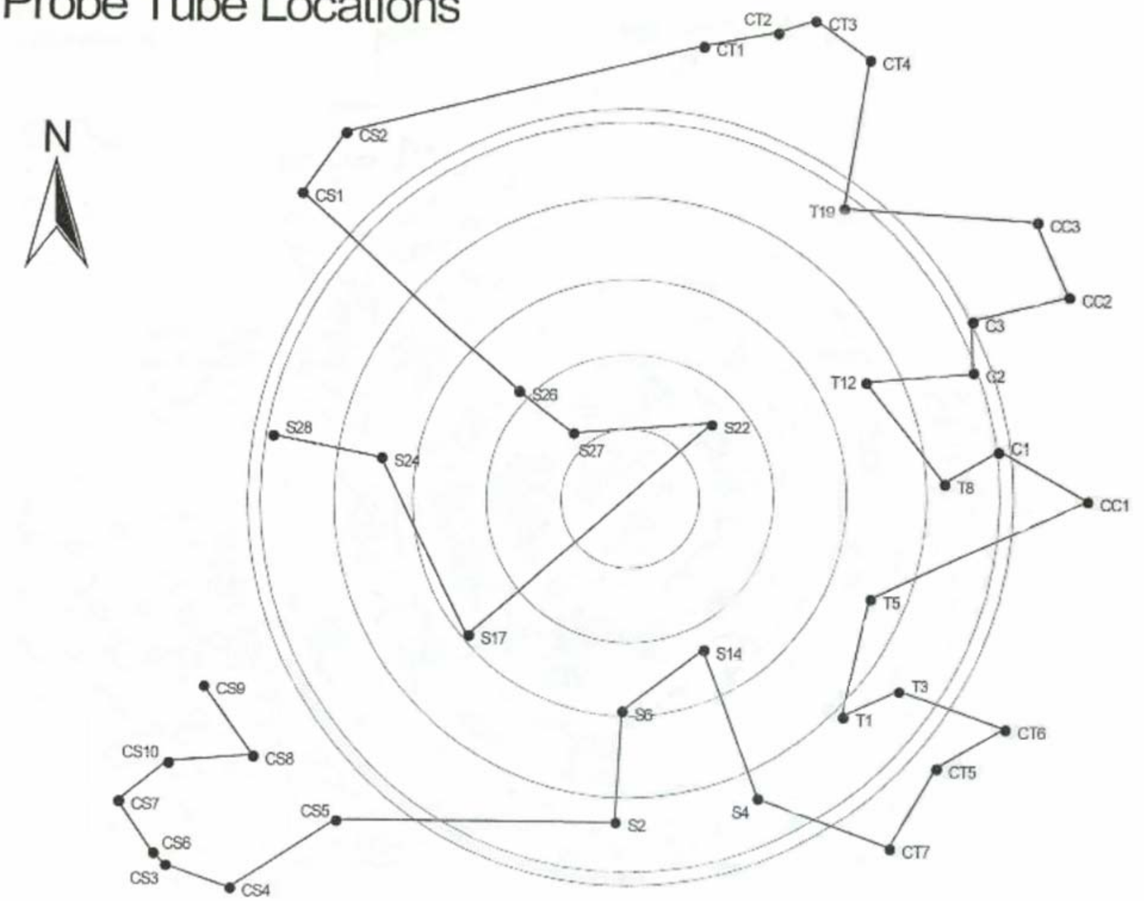
This report was prepared for the
U.S. Department of Energy Idaho Operations Office
Under Contract DE-RP07-99ID13658
By the S. M. Stoller Corporation
Environmental Surveillance, Education and Research Program
1780 First Street
Idaho Falls, ID 83401

Table of Contents

List of Figures

List of Tables

Probe Tube Locations



Sewage Wastewater Application Ecological Impact Study 2002

Amy D. Forman, Roger D. Blew, Sue J. Vilord, Jackie R. Hafla

In 1996 an ecological impacts research study at the wastewater application area was begun. The primary objective of the research study was to determine the ecological benefits or hazards of applying wastewater on native vegetation in semiarid regions. Specific objectives were developed to determine the potential for impacts on rangeland quality, resident wildlife populations, soil water balance, and the potential for trace metal contamination of the environment. To address these objectives, the study would measure plant community characteristics, soil moisture, wildlife use, and plant and soil chemistry inside the application area and compare them to similar measurements made immediately outside the application area.

The present vegetation inside the application circle includes at least three distinct community types:

- Sagebrush steppe
- Crested wheatgrass planting
- Transitional zone between sagebrush steppe and crested wheatgrass.

Sampling locations were assigned such that each of these community types was adequately represented. Plant species composition and cover were determined at 20 plots inside and 20 plots outside the application circle. Each plot consisted of five point frames along a 10 m transect. At the same locations, access tubes for neutron moisture probes were installed. In 2002, soil moisture measurements were collected throughout the soil profile at each access tube on a weekly basis from April 1 through October 28. Transects were also established for small mammal trapping both inside and outside the application area to determine species composition and abundance. The trapping transects are generally the same location as those used for the vegetation and soil moisture measurements. Small mammal trapping was not done in 2002. A transect for the breeding bird survey was also established at the application area.

Vegetation

Total plant cover during the 2002 growing season was similar in both irrigated and control crested wheatgrass plots with an average of 12.0% and 11.1% absolute cover, respectively (Table 1). All plant cover in the irrigated crested wheatgrass plots resulted from crested wheatgrass (*Agropyron cristatum*). In the control crested wheatgrass plots, 10.0% of the total plant cover resulted from crested wheatgrass, and 1.1% of the cover resulted from native forbs (Table 1). Native forbs present in the control crested wheatgrass plots included spreading groundsmoke (*Gayophytum diffusum*) and goosefoot (*Chenopodium* spp.). The average amount of litter present in both the irrigated and control crested wheatgrass plots was similar at approximately 70%; bare ground averaged roughly 16% in both treatments. Mean species richness of the control crested wheatgrass plots (2.0) was twice that of the irrigated crested wheatgrass plots (1.0) due to the presence of native forbs in the control crested wheatgrass plots.

Table 1. Percent cover of vegetation in irrigated and control plots for each community type within and surrounding the wastewater application area.

	Grass Cover	Shrub Cover	Forb Cover	Total Cover
Control Crested	10.0	0.0	1.1	11.1
Irrigated Crested	12.0	0.0	0.0	12.0
Control Transition	6.8	4.0	0.0	10.8
Irrigated Transition	10.1	3.5	0.0	13.6
Control Sagebrush	3.2	22.8	2.9	28.9
Irrigated Sagebrush	2.9	16.0	1.9	20.8

Within the transition zone vegetation plots, total plant cover was slightly higher on the irrigated plots, but not significantly different from the control plots. In both irrigated and control plots, grasses comprised the majority of total plant cover. As with total cover, mean grass cover was slightly higher on the irrigated plots than the control plots (Table 1). All grass cover in both treatments resulted from crested wheatgrass. Average shrub cover was similar between the control and irrigated plots (Table 1). Average big sagebrush (*Artemisia tridentata*) cover was similar across both treatments within the transition zone vegetation. Green rabbitbrush (*Chrysothamnus viscidiflorus*) cover in the control transition plots was double that of irrigated transition plots; however, green rabbitbrush cover was relatively low across both treatments (Table 2). Within the irrigated transition plots, all shrub cover resulted from big sagebrush and green rabbitbrush. In addition to big sagebrush and green rabbitbrush, winterfat (*Krascheninnikovia lanata*) contributed slightly to shrub cover on the control transition plots. Both the irrigated and control transition plots had no measured forb cover. Mean dead shrub cover was slightly higher in the irrigated transition plots (6.9%), that of the control transition plots (4.1%); conversely, bare ground was higher in the control treatment than the irrigated treatment with 22.2% and 15.1% cover, respectively. Litter cover was the same in both treatments, averaging 63.0% cover. Mean species richness was 2.1 on control transition plots, and 1.7 on irrigated transition plots.

Table 2. Percent absolute cover of shrubs within the transition and sagebrush steppe community types within and surrounding the wastewater application area.

	Sagebrush	Rabbitbrush	Other	Total
Control Transition	2.2	1.5	0.3	4.0
Irrigated Transition	2.8	0.7	0.0	3.5
Control Sagebrush	8.5	11.4	2.9	22.8
Irrigated Sagebrush	1.7	8.9	5.4	16.0

More substantial differences between irrigated and control plots occurred within the sagebrush steppe community type than between the irrigated and control plots within the crested wheatgrass and transitional community types. Total plant cover was 28.9% in the control plots and 20.8% in the irrigated plots. Although this difference wasn't statistically significant (P = 0.190), the power of the t-test was too low (0.133) to conclude that the two treatments were statistically the same. Grass cover was slightly higher in the control plots and was primarily a result of bottlebrush squirreltail (*Elymus elymoides*) cover. The dominant grass species in the irrigated plots was crested wheatgrass. Shrub cover was substantially lower in the irrigated plots than in the control plots (Table 1). Lower shrub cover in the irrigated plots is largely a consequence of very low big sagebrush cover on those plots. Mean sagebrush cover in the irrigated plots was 1.7%, compared to 8.5% sagebrush cover in the control plots (Table 2). The difference in sagebrush cover between the irrigated and control sagebrush steppe plots was not significantly different (P = 0.405). However, the data did not meet equal variance assumptions and could not be transformed so that they met those assumptions; thus, the power of the non-parametric test used was likely much lower than that of a t-test. Green rabbitbrush was the most common shrub species on both treatments; although, big sagebrush and horsebrush (*Tetradymia canescens*) were also present on both control and irrigated plots. Forb cover was slightly higher in the control plots (Table 1) and most forb cover resulted from native forbs in both the irrigated and control sagebrush steppe plots. Native forbs common to both treatments include Hood's phlox (*Phlox hoodii*) and slimleaf goosefoot (Chenopodium leptophyllum). Franklin's sandwort (*Arenaria franklinii*) and whitestem blazingstar (*Mentzelia albicaulis*) were also common on the control plots. Litter cover was slightly higher on the irrigated plots (46.6%) than on the control plots (40.0%), and bare ground and dead shrub cover were similar between both treatments. Average species richness was 4.1 on the control plots and 4.7 on the irrigated plots.

The Simplified Morisita's Similarity Index was used to determine how similar the plant communities were between the irrigated and control plots for each community type for 1996, 1997, 1998, 1999, 2000, 2001 and 2002 (Table 3). This index returns a value of 1.0 for two plant communities that are identical and a value of 0.0 for two communities that have no similar community elements. These values can be considered as a "percent similarity." Morisita's Similarity Index was calculated using relative cover because we were interested in assessing only the composition of the live plant community, rather than all measures of community structure (such as litter or bare ground) with this analysis. We evaluated community structure, including litter, bare ground, and dead shrub cover in relation to absolute vegetative cover shown above.

In 2002, Morsita's Similarity Index was quite high between the control and irrigated crested wheatgrass plots and between the control and irrigated transition plots. The Morisita's similarity index value between the irrigated and control sagebrush steppe plots was much lower. These results are consistent with those from 2001. Throughout six of the past eight years, the plant community composition between the irrigated and control plots has been the most similar in the crested wheatgrass community and the least similar in the sagebrush steppe community (Table 3).

Table 3. Morisita's Similarity Index measuring similarity of vegetation community composition between irrigated a control plots for each community type.

	Crested Wheatgrass	Transition	Sagebrush Steppe
1996	0.99	0.85	0.83
1997	0.91	0.78	0.93
1998	0.96	0.93	0.85
1999	0.94	0.89	0.61
2000	0.89	0.97	0.79
2001	>0.99	0.99	0.85
2002	0.99	0.98	0.83

In summary, results from the 2002 vegetation data analyses confirm results form previous years. Sewage wastewater application affects crested wheatgrass communities the least. Similar cover values and similar species composition, as evidenced by high Simplified Morisita's Similarity Index values, support this conclusion. Crested wheatgrass communities at the INEEL tend to occur as monocultures; thus, crested wheatgrass communities are very homogenous and unlikely to exhibit much spatial variation, even when disturbed.

The vegetation type that represents a transitional zone between the crested wheatgrass community and the sagebrush steppe community was slightly more affected by the irrigation treatment than the crested wheatgrass community. The difference between the irrigated and control transition plots was particularly apparent in the difference in grass cover values between the two treatments. However, the Simplified Morisita's Index value returned for the transitional vegetation type indicates that the species composition between the irrigated and control plots was quite similar.

The greatest differences between the irrigated and control treatments were found in the sagebrush steppe community. Total cover values were substantially different between irrigated and control plots, largely due to very low sagebrush cover in the irrigated treatment. In addition, the Simplified Morisita's index value comparing species composition between the treatments suggests that sewage wastewater application affects sagebrush steppe communities to a greater degree than it affects the other two vegetation types studied here. Sagebrush steppe community vegetation is more likely to fluctuate in response to disturbance or changing environmental conditions because sagebrush steppe communities are much more heterogeneous, and are therefore more likely to vary in space and time. Additionally, higher species richness values for the sagebrush steppe plots suggest greater potential for niche separation, which increases the potential for vegetation composition change in response to disturbance.

Animal Species

Breeding bird surveys were conducted on the wastewater application area during June of 2002 following United States Geological Survey (USGS), Breeding Bird Survey (BBS) guidelines. A BBS route stop was established on the application area in 1997 and surveys have been conducted yearly since that time. In 2002, Western meadowlark (*Sturnella neglecta*) remained the most abundant species. Other common species included brown-headed cowbird (*Imolothrus ater*), Brewer's Sparrow (*Spizella breweri*), Brewer's blackbird (*Euphagus cyanocelphalus*), and horned lark (*Eremophila alpestris*). One species, sage sparrow (*Amphispiza belli*), which has been common in the past, was not observed during the 2002 survey. Otherwise, results from the 2002 survey were comparable to previous years and similar to that found on the Central Facilities Area BBS route.

Table 4. Species abundance and percent composition for the sewage wastewater application area during the 2002 Breeding Bird Survey.

Species	Abundance	Percentage
Western Meadowlark	14	23.3
Brown-headed Cowbird	9	15.0
Brewer's Sparrow	9	15.0
Brewer's Blackbird	8	13.3
Horned Lark	8	13.3
Sage Thrasher	6	10.0
Killdeer	3	5.0
Northern Harrier	1	1.7
Vesper Sparrow	1	1.7
Red-winged Blackbird	1	1.7
Total Individuals = 60		
Total Species = 10		

Soil Moisture

During the 2002 growing season (April through October), soil moisture dynamics were similar between irrigated and control soil profiles within the crested wheatgrass community. Figure 1 shows an example of soil moisture dynamics throughout the growing season in one control and one irrigated soil profile. Only eight sample dates, from a total of thirty, are included to facilitate interpretation, and the soil moisture profiles shown are representative of those within each treatment. Both the irrigated and control soil profiles clearly demonstrate a spring infiltration event in which the soil moisture wetting front reached approximately one meter. Water redistribution throughout the soil profile is evident through the end of April. Subsequent to this, soil moisture decreased steadily throughout the wetted profile through the summer as a result of evapotranspiration. Soils began to approach the lower limit of extraction by August in 2002.

The soil moisture profiles do not indicate an increase in soil moisture at 20cm or deeper due to wastewater application. If irrigation were to affect soil moisture, we would expect to see either small wetting fronts in the profile throughout the summer (in the case of pulses in application), or we would expect soil moisture in at least some portion of the top of the soil profile to remain elevated (in the case of relatively steady application of water). Neither of these patterns is apparent in the irrigated crested wheatgrass soil profiles. In fact, those profiles dry down throughout the summer in a manner very similar to that of the control soil profiles. Thus, most of the additional water received by a soil profile through wastewater application is evaporated or transpired before it percolates to a depth of 20cm within the soil profile. It should be noted that it is possible for a small amount of water to move downward through a soil moisture profile, without detectable changes in soil moisture content, due to unsaturated flow. Soil moisture did not change at the bottom of the soil profiles throughout the season at many of the hydroprobe access tube locations, suggesting that any flux through the bottom of the soil profiles would result form unsaturated flow.

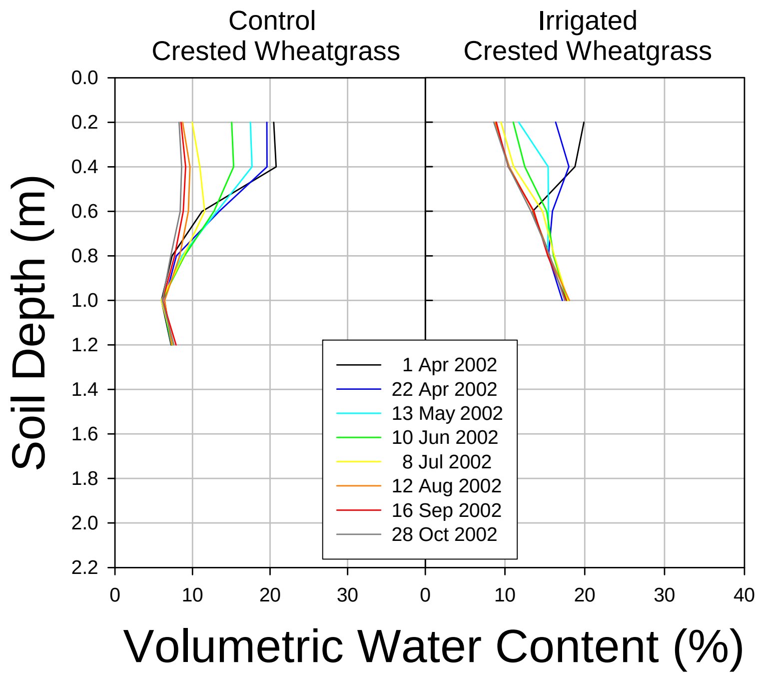


Figure 1. Soil moisture profiles for two neutron hydroprobe access tube locations in crested wheatgrass vegetation. One access tube was located in an area receiving sewage wastewater application, and the other was located in a control area.

Figure 2 depicts representative examples of soil moisture profiles for an irrigated and a control hydroprobe access tube location within the transitional vegetation type, and Figure 3 depicts comparable soil moisture profiles within the sagebrush steppe vegetation type. As with soil moisture dynamics in the crested wheatgrass vegetation type, no differences in soil moisture profiles between irrigated and control locations are apparent in either the transition or the sagebrush steppe vegetation type. In both transition and sagebrush steppe vegetation, soil moisture profiles in the irrigated locations do not indicate soil moisture increases at the top of the soil profile in response to irrigation, nor does water content at the bottom of the profiles at most access tube location change. Thus, although changes in vegetation cover and composition between irrigated and control locations vary among vegetation type (i.e. control and irrigated plots within the sagebrush steppe community are more different than control and irrigated plots within the crested wheatgrass community), no such pattern is obvious in soil moisture dynamics. In fact, soil moisture dynamics in irrigated locations do not differ substantially from those in control locations for any of the vegetation types. Therefore, the probability of water

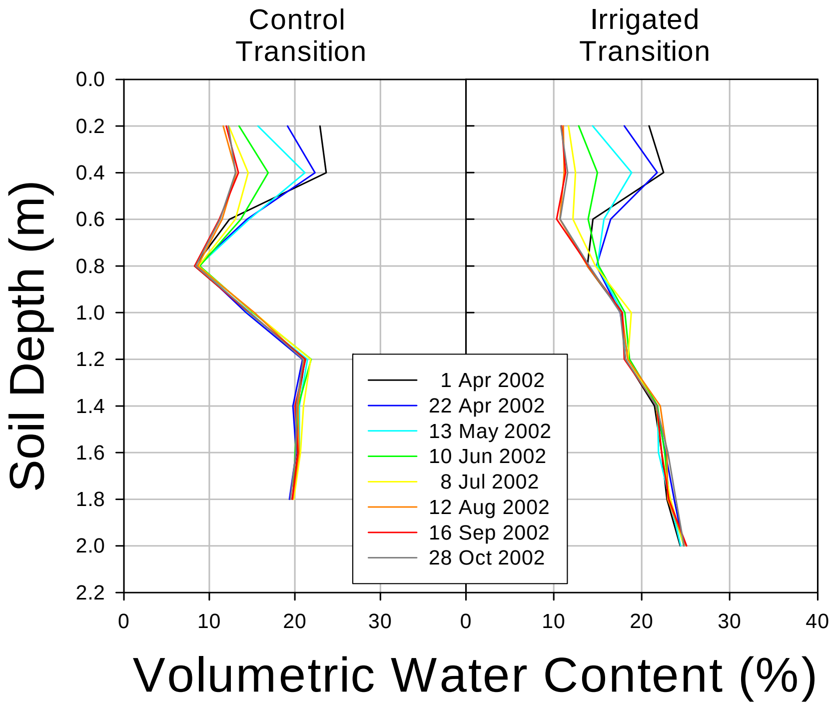


Figure 2. Soil moisture profiles for two neutron hydroprobe access tube locations in vegetation representing a transition zone between sagebrush steppe and a crested wheatgrass monoculture. One access tube was located in an area receiving sewage wastewater application, and the other was located in a control area.

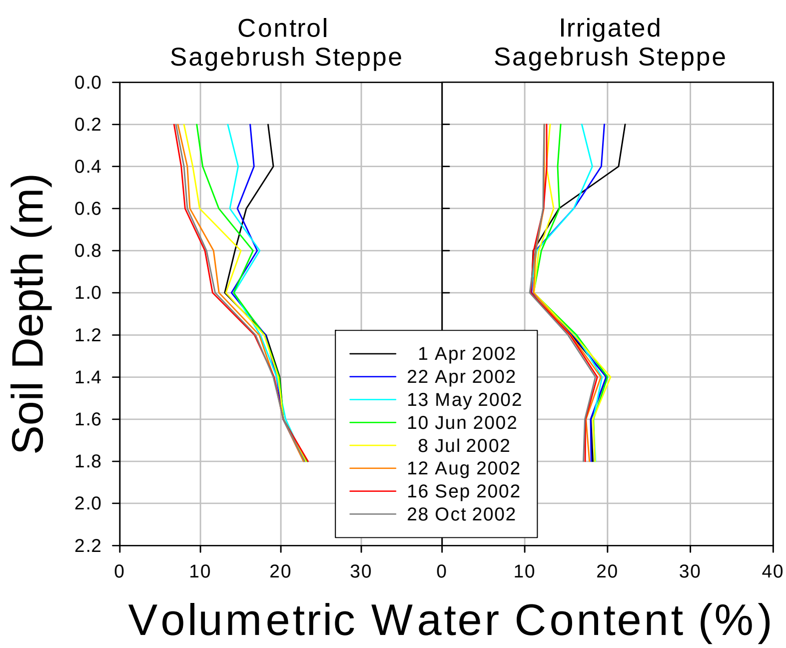


Figure 3. Soil moisture profiles for two neutron hydroprobe access tube locations in sagebrush steppe vegetation. One access tube was located in an area receiving sewage wastewater application, and the other was located in a control area.

percolating through the rooting zone and continuing to move downward was essentially the same for the wastewater application area and control locations during the 2002 growing season. Because the wetting front did not reach the bottom of the soil profile and soil moisture at the bottom of the profile remained stable throughout the growing season, water percolation below the soil profile and into the basalt was unlikely at most access tube locations regardless of irrigation treatment.

Although the likelihood of flux through the bottom of the soil profile is very small at most access tube locations, the potential for water to move into the basalt below the soil profile exists at a few locations. Several pathways by which water may percolate through the soil profile are possible, but two mechanisms are particularly evident in soil moisture profiles from the 2002 growing season. Saturated flow can be especially problematic in soils, or portions of a soil profile that are comprised of very coarse materials such as sand and/or gravel. If coarse soils are overlain by finer textured soils, they may initially cause a capillary break, which forces the finer textured soils to become saturated before the wetting front can move into the coarser material. However, coarse textured soils have very low drained upper limits, and therefore, hold very little water. Thus, once water breaks through the fine textured soils, it can move quickly through coarser textured soils, making movement of water very difficult to infer by changes in volumetric water content with a neutron hydroprobe. Figure 4a. shows a soil profile in which soil moisture from 80cm to the bottom of the soil profile is very low (approximately 5%), and volumetric water content changes are not detected throughout the growing season, which is indicative of very coarse soils. Data from similar studies at the INEEL indicate that soil moisture content in gravel/cobble is typically 2-3% volumetric water content (Anderson and Forman 2002). Consequently, if moisture received during spring infiltration exceeds the storage capacity of the fine soil, water

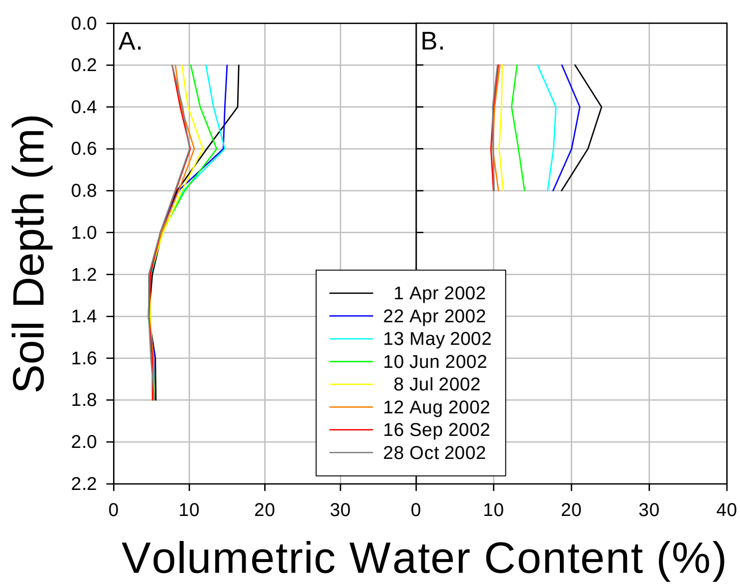


Figure 4. Soil moisture profiles for two neutron hydroprobe access tube locations at the sewage wastewater application area. These profiles depict scenarios where water movement through the soil profile and into the basalt is possible.

from the infiltration event or water remaining in the soil from the previous growing season may move quickly through the coarse soil layer and into the basalt, and it would be unlikely to detect this movement with a neutron hydroprobe, as soil moisture content in the coarse soils would not appear to change.

Saturated flow may also be a problem in very shallow fine soils. Although soil moisture content did not change at the bottom of many of the soil profiles throughout the growing season, a few very shallow profiles did exhibit changes in soil moisture at the bottom of the soil profile (Figure 4b.). These shallow profiles occurred in areas where access tubes could only be placed at shallow depths because basalt was very close to the soil surface. As with the above scenario, water could move through the soil profile and into the basalt during a spring infiltration event.

In relation to size of the application area, the relatively small number of access tubes which indicated that infiltration was likely in 2002 suggest that infiltration is probably quite limited spatially. However, depth of soil profiles, and distribution of different textured soils within the soil profiles at the sewage wastewater application area are quite variable, which makes estimating water storage capacity of those soils very difficult. Additional mechanisms for water movement associated with variations in soil texture throughout a soil profile are; unsaturated flow as mentioned above, lateral flow, and preferential flow. The potential for water movement through the soil profile due to the mechanisms discussed in this report can be better understood by; examining soil texture profiles in relation to soil moisture profiles, installing tensiometers and fluxometers to better understand water potential and water flux through profiles with variable textures, and mapping depth to basalt and associated variability on the application area.

References

Anderson, J.E., and A. D. Forman. 2002. The Protective Cap/Biobarrier Experiment: A Study of Alternative Evapotranspiration Caps for the Idaho National Engineering and Environmental Laboratory. Environmental Surveillance, Education, and Research Program report, Stoller Corporation and Idaho State University, STOLLER-ESER-46.