play of history. Modern people, at the dawn of the industrial age, could go back in time to that first dawn. Through the publicized adventures of the pathfinders who pushed beyond the fringes of settlement and brought back stories of vast spaces peopled by neolithic civilizations, a partly active, partly vicarious national experience took place. But all too soon, George Catlin's vision of a trans-Mississippi preserve was sullied, the garden desecrated.

An enlightened few saw the tradegy abuilding and set aside parts of the land to allow that national experience to continue. Today, these places with varying success, depending on the human impacts they have suffered, perpetuate that national experience.

Is the Myth of Eden sustainable? Is the American character--still moved by the evocations of remnant horizons and landscapes--sustainable? Some would agrue that it is essential to maintain these things--land, myth, character. It could as well be argued that there is no rule in the future for a character so shaped. It causes unwanted stress in a world that trends toward blotting out Eden altogether.

As for me, I confess to Romantic tendencies. I want my myths. I want horizons and landscapes that nurture them. I want to be with people who want these things.

William E. Brown, Historian, Alaska Region, National Park Service; author, *Islands of Hope.*

URBAN SOILS OF WASHINGTON, D.C.

John R. Short and *James C. Patterson*

Urban soils, or highly man-influenced soils, have become more commonplace with the extensive earth moving and manipulating activities of man. Highly man-influenced soils are not limited to urban areas, but may be found wherever activities of man result in disturbance of soil profiles. Disturbance may consist merely of compaction of an existing soil by foot traffic, or may result from large scale manipulation of soil materials to create an entirely new land surface. The mode of formation of these soils, and the magnitude of impact the soils receive will surely result in soils with unique properties. It is important to understand the properties of urban soils in order to effectively manage them as a resource, whether the soils are situated in an urban or a rural setting. The study of urban soils is a new branch of soil science, so that there is much work to be accomplished to characterize these impacted soil systems. The National Capital Region has been interested in expanding the level of knowledge of these soils because of the largely urban nature of its parks.

The physical characteristics of soils in most urban environments are often unfavorable for plant growth. Use of soils for paths, trails, roadways, campgrounds, picnic areas, and recreational areas create compacted soil systems. Bulk density, which is the weight of soil material in a given volume is increased by compaction. The bulk density of an "ideal" soil is approximately 1.33 grams/cubic centimeter (g/cc), while bulk densities as high as 2.22 g/cc have been found in highly man-influenced soils. Studies have shown that soils with bulk densities of 1.67 g/cc or greater are often inhospitable environments for plants. The main result of compaction is a loss of pore space. While an "ideal" soil will contain approximately 50% pore space, evenly distributed between soil air and soil water, an impacted soil will often have 20% or less pore space. The lack of sufficient pore space usually causes plant stress. The packing of soil particles also results in increased difficulty for root penetration, contributing to the stressed conditions of plants in the urban environment. The limited root systems which develop in impacted soils are unable to take up sufficient water and nutrients to meet the needs of plants during dry periods. Storage of energy reserves in the root system also is inhibited.

Soil texture is important for support of plant growth. Soils with greater amounts of sand will tend to drain more quickly, will not retain as much water for use by plants during dry periods, and will tend to contain fewer nutrients. Clayey soils are able to retain greater amounts of nutrients and water, but the slower rate of water movement (hydraulic conductivity) in such soils may be limiting to plant growth during wet periods. A loamy soil, which is a soil with a relatively balanced distribution of sand, silt, and clay, may provide a reasonable compromise with respect to drainage and nutrient retention. However, soils of this texture are susceptible to compaction because the relatively even particle size distribution permits small particles to readily fit into voids between larger particles. Studies have shown that the highly man-influenced soils in Washington tend to be coarse textured (loamy), and susceptible to compaction.

The type and amount of coarse fragments present in the soil, such as building rubble, chunks of concrete, glass, bricks, etc., have an effect on the soils as they weather. Concrete, for example, may release lime which tends to raise the pH of the soil, or make it more alkaline.

The manipulation of material to form new land surfaces is characteristic of urban development and it results in soils with unusual properties. Materials of unlike textures, mineralogy, and other properties may be placed adjacent to or on top of each other. Often, sharp delineations between these contrasting soil materials (lithologic discontinuities) are found in these soil profiles. Water movement through the soil may become impeded at these boundaries, because water will not move from one soil texture to a different one until the first layer becomes saturated. Poorly drained soils, therefore, are of common occurrence in the urban environment.

The chemical properties of manipulated soils are often different from those of natural soils. The pH of soils in several cities has been shown to be higher than in associated non-impacted soils with alkaline soils being common in impacted soils. Runoff from streets has been found to increase the salt and heavy metal content in nearby soils, often to a level which may have adverse effects upon vegetation. Heavy metal content may be a concern where the soils are used for vegetable production, as in "victory gardens."

The presence of organic matter in soils is highly beneficial. A favorable environment for soil fauna, such as worms, and for microbial populations, such as mycorrhizal fungi is provided by organic matter. Nutrients become available as organic matter decays, with organic matter essentially acting as a slow release fertilizer. Organic matter tends to improve the soil structure, combining the individual soil particles into larger aggregates, or peds. This tends to improve the drainage, aeration, and water infiltration capabilities of fine-textured soils, and increases the resistance to compaction for most soils. Organic matter also increases the ability of the soil to retain nutrients, and to prevent nutrients, such as those applied as fertilizer, from leaching through the soil. The organic matter content of urban soils tends to vary with depth, and is often lower than that of natural soils throughout the entire profile.

The ability of a soil to retain nutrients is referred to as its cation exchange capacity (CEC). The CEC has been found to be similar in natural and highly man-influenced soils. The base saturation, which is a measure of the percentage of nutrients the soil can potentially hold is often much higher for urban soils than that of nearby natural soils. Higher base saturations may result from breakdown and dissolution of inclusions of concrete, mortar, or similar materials.

Urban Soils and NCR

Parkland of the National Capital Region (NCR) receives heavy visitor impact, with many soils occuring on highly manipulated landforms. The heavy visitor impact these soils receive, plus the need to maintain high quality, attractive plantings provided the incentive to intensively study the soils of the Mall.

The Mall is located on filled material between the US Capital to the East and the Washington Monument to the West (Figure 1). The soils of the Mall typify highly man-influenced soils because they were formed in fill material deposited by man in a swampy area, and have been continually impacted through pedestrian and vehicular traffic.

The objectives in studying these soils were to: (1) determine the physical and chemical properties of these soils; (2) determine the variation of these properties; (3) develop a soil map based upon obserable soil properties; (4) attempt to classify the Mall soils in a manner indicative of their highly man-influenced nature; and (5) provide information to the Park which will help meet their management objectives.

A transect sampling system was used in studying these soils to ensure representative sampling. One hundred profiles were excavated and described using accepted soil survey terminology. One hundred profiles were determined to be necessary to adequately characterize the mean of most properties. Samples were obtained from each morphological horizon for laboratory analysis, while bulk density samples were obtained only from the surface and at 30 cm (12 in).

The Soils of the Mall and Input to Management

The soils of the Mall appear to have developed in miscellaneous fill applied to a depth of about 6 m (20 ft.). Most profiles (95%) contained at least one lithologic discontinuity, where unlike soil materials were applied. These lithologic discontinuities have resulted in poorly drained soils. Poorly drained soils can often be identified by mottling in the soil matrix. Object artifacts of man, such as brick, glass, cinders, concrete, and slag, were found between 25 cm and 100 cm in 94% of the profiles. The presence of artifacts within the soil profile is significant as they illustrate that man has been instrumental in accumulation of the parent material of these soils and that the soils themselvels may have unique properties.

Further evidence of manipulation of the soil materials was shown by the presence of buried A horizons (42% of the profiles studied) and the variation of percent organic matter with depth in the profiles (Table 1). A horizons are generally considered to be surface horizons, and are characterized by accumulations of organic matter. These horizons are usually darker in color than underlying horizons, with a softer, more friable, consistence. When additional fill material was applied to the soil surface, any A horizon which may have been present at the time of filling would have been buried. That soil formation occured in this fashion on the Mall is evidenced by the presence of buried A horizons in many of the profiles.

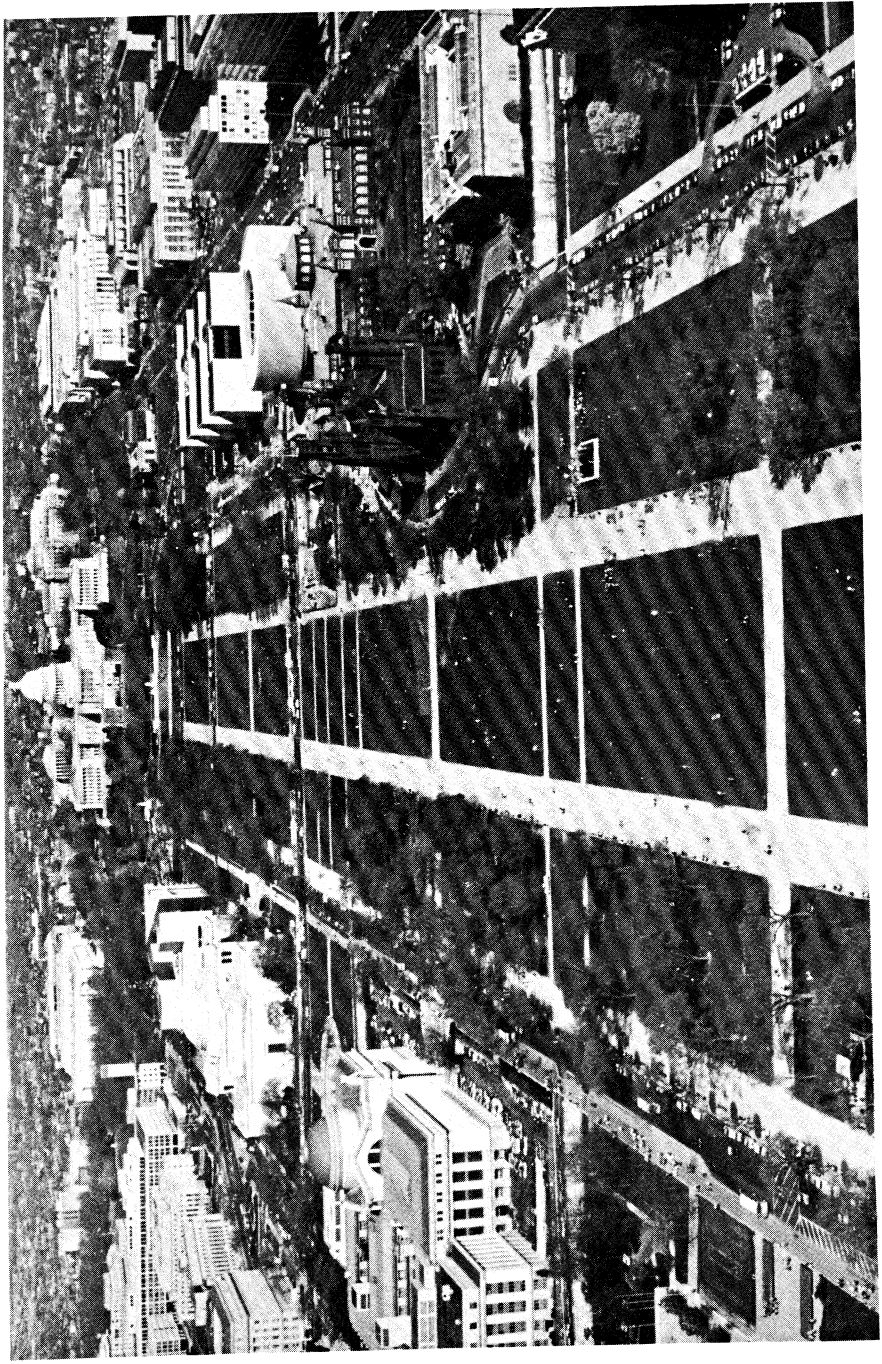

Figure 1. The Mall, as viewed from the Washington Monument. Photo by Bill Clark, National Capital Region, US National Park Service.

Table 1. Mean of Selected Chemical Properties of Mall Soils by Horizon.

Horizon (from surface)	pH	Organic Matter %	CEC meq/100g	Base Saturation %
1	6.39	1.97	11.22	88.86
2	6.52	1.08	9.51	88.19
3	6.57	0.73	8.88	117.95
4	6.64	0.50	8.24	113.87
5	6.67	0.41	8.80	94.30
6	6.59	0.66	7.51	139.36

The soils were found to be predominately coarse textured, with 99% of the soils fitting either the coarse loamy or fine loamy families of *Soil Taxonomy*. One profile was sandy in texture. Such textures are very susceptible to compaction, as discussed previously. The bulk density (Table 2) at the surface was a mean of 1.61 g/cc, and 1.74 g/cc at 30 cm. However, bulk densities up to 2.03 g/cc were found. Percent pore space was reduced from that of an "ideal" soil to mean of 36.6% at the surface and 32.8% at 30 cm. The maximum percent pore space was 50%, and was found in the surface horizon. Clearly, these soils are compacted.

The National Capital Region is following a soil management program which includes aeration of these dense, compacted soils and topdressing with organic matter such as composted sewage sludge. Restriction of visitor access in the most heavily impacted areas has been accomplished through the use of post-and-chain, with the result that some highly impacted elm trees have exhibited signs of recovery. Addition of woodchips in heavily impacted areas where turf cannot tolerate the extreme wear from visitor use has proven successful in minimizing the adverse effects of soil compaction.

Table 2. Bulk Density and Percent Pore Space of surface Horizon and 30 cm Depths

Depth cm	Mean	n	Min	Max
		Bulk Density (g/cc)		
surface	1.61	100	1.25	1.85
30	1.74	100	1.40	2.03
		Pore Space (%)		
surface	36.6	100	2.80	50.0
30	32.8	100	21.0	45.1

The mean pH of Mall soils ranged from 6.39 in the surface horizon to 6.67 in the 5th horizon (Table 1). However, pH values for 32% of the samples obtained were 7.0 or greater. These alkaline pH values may be a result of inclusion of lime-bearing artifacts, such as concrete, compost, or mortar, within the profile. Lime should not be applied routinely to highly man-influenced soils such as these. These soils should be tested to determine the need for lime application. The value of a soil testing program is not limited to urban soils, but is applicable to any soil resource. The alkaline nature of many highly man-influenced soils may result in significant savings from limited lime applications.

The mean organic matter content tended to be low, less than 2% in the surface horizon, and decreased with depth (Table 1). Most natural soils in the Washington D.C. area contain from 3% to 5% organic matter in the surface horizon. The low organic matter content, in conjunction with the loamy textures, caused these soils to be quite susceptible to compaction. Much of the buffering capability of organic matter is lost because of the low level of organic matter present in the soils.

The cation exchange capacity (CEC) was greatest in the surface horizon (Table 1), and tended to decrease with depth. This decrease with depth is to be expected since organic matter makes a significant contribution to the CEC of a soil. Perhaps of more immediate interest in the urban environment, however, is the base saturation of these soils (Table 1). The minimum mean base saturation found was 88.2%, with values up to 139.4% being found. Values over 100% may reflect the presence of soluble salts, or ammonia fixation may have resulted in slightly low values for CEC in some horizons. Analysis indicated that calcium was the dominant cation held within the soil, possibly resulting from inclusion of lime bearing artifacts within the soil profile.

The soluble salt content for most soils of the Mall was low. Mean soluble salt content was less than 300 parts per million (ppm) in 80% of all horizons, and 80% of the surface horizons contained less than 300 ppm. However, over 1000 ppm soluble salts were found in some horizons. Soluble salt levels greater than 600 ppm can cause problems for plant growth.

Mall soils were analyzed for heavy metal content (Table 3). Lead content was 184 micrograms/gram (ug/g) in the surface horizon and decreased with depth in the profile to a low of 110 ug/g in the 4th horizon. Background levels of lead in natural soils of about 10 ug/g have been reported. Cadmium content was the lowest, ranging 0.7 ug/g at the surface to 0.3 ug/g in the 6th horizon. Background levels of cadmium found in unimpacted soils have been reported to be between 2.2 ug/g and 0.3 ug/g. Zinc, nickel, and copper contents were intermediate. The Mall soils appear to have elevated levels of heavy metals. The source of these metals may be from vehicle exhaust, from incorporation of composted sewage sludge as an organic amendment, or other sources. But this may not be a concern in this instance as these soils are not intended for crop production.

The Mall soils varied greatly in the number of samples required to estimate the mean for the properties examined. The physical properties tended to require fewer samples to estimate the mean at a given level of accuracy. Determination of mean bulk density could be accomplished with only one sample, while less than 50 samples were required to estimate the mean soil texture. The chemical properties, on the other hand, required far more samples than are usually obtained. The mean pH of the Mall could be realibly estimated with fewer than

Table 3. Mean Heavy Metal Content of Mall Soils by Horizon.

Horizon	Pb	Zn	Ni	Cd	Cu
	ug/g				
1	184	67	13	0.7	23
2	141	56	21	0.5	20
3	146	60	25	0.5	24
4	110	73	8	0.4	22
5	111	68	9	0.4	18
6	129	77	13	0.3	31

10 samples, but estimation of the mean organic matter content required nearly 500 samples. The increase in the number of samples necessary to estimate mean organic matter content is likely to be a result of inclusion of buried A horizons at depth in the profile. Estimation of cation exchange capacity could be accomplished with 41 samples or less. The most variable properties, and therefore the properties which required the most samples to estimate the mean, were the heavy metals. For example, lead required from 227 to 1965 samples, and estimation of nickel content required up to 7171 samples.

A soil map was prepared of the Mall using taxonomic criteria developed for use with highly man-influenced soils (Figure 2). Subgroups previously developed for use with highly man-influenced soils were used in conjuncion with standard soil taxonomy to classify these soils. These subgroups are the "urbic" and "spolic" subgroups. The urbic subgroups contain object artifacts within the soil profile. These artifacts were used to define the subgroup because of their effect upon soil characteristics. The spolic subgroup does not contain the artifacts within the profile, but is soil created by earth moving activities of man. These soils may be identified by topographic position, random orientation of coarse fragments, and historical records. Examination of the soil map of the Mall shows that the majority of the soils of the Mall contain artifacts of man. Soil development, while limited, has also occurred. The majority of soils on the Mall exhibit only limited profile development, and are delineated as Urbic Udorthents and Spolic Udorthents. More developed soils are delineated as Urbic Eutrochrepts, Spolic Eutrochrepts, and Urbic Dystrochrepts.

Conclusions

The characteristics of these soils have an impact upon management practices. Plant management is made more difficult by the compacted nature of these soils with the resulting reduction in pore space. The texture of these soils make them susceptible to compaction and, therefore, less able to support activities without being adversely affected. Layering of the soils during filling, with formation of lithologic discontinuities, has resulted in soils with poor drainage, moisture holding capacity, and soil aeration, in some areas. The chemical properties of the Mall soils are influenced by their highly impacted nature. Heavy metal content, though high, is not limiting the use of these soils. The great variation in some of the properties required over 7000 samples in order to estimate the mean. Clearly, it is impractical to routinely perform sampling of this magnitude! However, no matter where these soils are found, the great variability of highly man-influenced

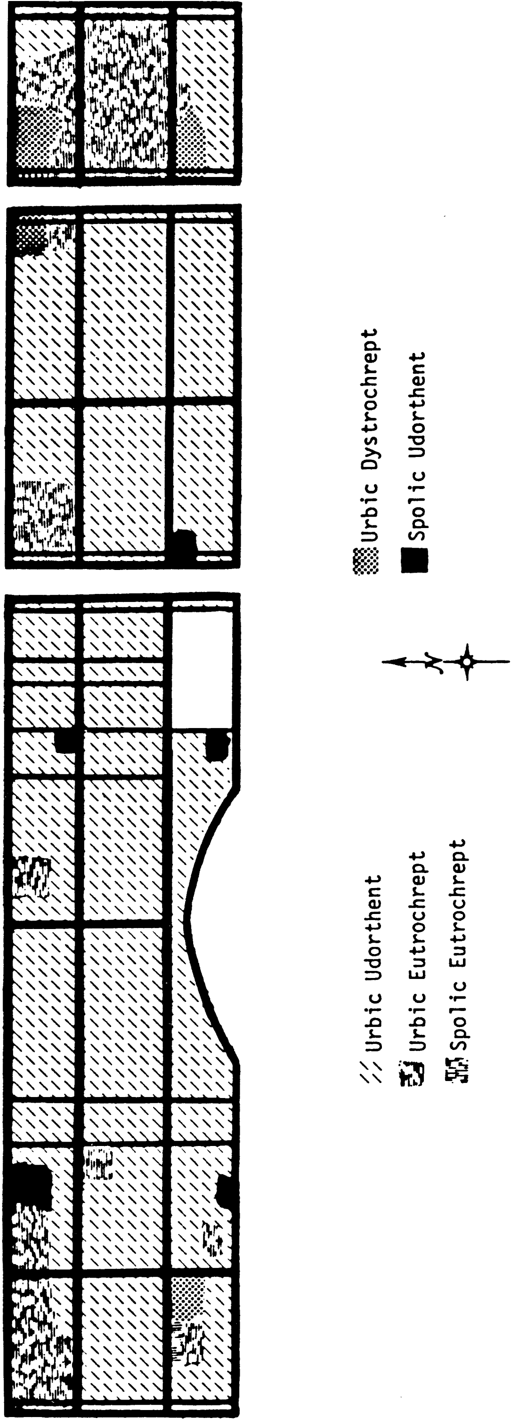

Figure 2. Detailed soil map of the Mall.

soils will require more intensive sampling than natural soils to gain the same information for effective management. This study provides an example of how gathering basic data upon a Park resource can be utilized to supply management with information needed to more effectively manage a challenging resource problem. Although the results of this study were obtained from a park in an urban area, the principles obtained are applicable to any park situation where impacted soil systems are located.

There is need for further research on the formation of crusts at the soil surface through destruction of soil aggregates. Formation of soil crusts limits the infiltration of water and gases into an already poor soil system. Orientation of soil particles in surface layers may contribute to the formation of these crusts, and research on such occurrences in impacted and nonimpacted soils should be undertaken. Evaluation of successful techniques to mitigate such impacts on highly man-influenced soils in park situations should occur. These investigations are a concern to the natural science research and management program of NCR.

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