

Soils and Drainage of the Bucknell Natural Area

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The soils in the Bucknell natural area may be divided into three groups, on the basis of how well water drains through them. The sloping fields below the parking area are underlain by well-drained upland soil weathered from the shales and limestones beneath it. The soils of the flat, wooded area are weakly developed in recently deposited floodplain silt and clay. This bottomland may be divided loosely into two soils -- moderately well-drained soils on slight ridges or near streams, and oxygen-poor soils of boggy areas within the elongate hollows in the floodplain.

Upland Soils

The soil of the northern half of the natural area -- the section not included in the 1981 color map -- is a cherty silt-loam ochric undult. Mapped as the Elliber series by the USDA, it has weathered out of the underlying Old Port and Onondaga limestones and shales. The Old Port limestone yields hard, angular, pale, low density shards of weathered chert which resemble fine-grain sandstone (or refractory brick, according to the local farmers who call it "firestone"). As the soils are winnowed by erosion, this fire-

stone collects as a lag on slopes and in drainage channels. The Elliber is a productive soil, although the abrasive chert dulls plows rapidly, and the fields can be quite steep in places.

These soils have lost at least four inches of their tops to erosion since farming began here less than two hundred years ago. For example, the soil in the fence row to the west of the property still has about four inches of brown A-horizon which is absent in fields, while the soils in the fields tend to have a surface layer of firestone chips which were left behind as the soil washed away. Further evidence of significant export of soil from the slopes is a wedge of firestone and light-colored silt which laps over the darker silts and stream gravels of the floodplain at its northern margin, suggesting active transport by slope-wash and soil creep. Trenches across the slope, which one finds just below the parking lot, may be relict erosion-control devices, although they are connected to drainage ditches down the slope.

Parallel drainage has developed in the recently eroded upper slopes, as rivulets extend themselves headward. In its pristine condition, the upper parts of this land would have carried virtually no surface flow, since all but the largest storms would provide water at a slower rate than can be absorbed by wooded, porous silt-loam. The stream flow entering the natural area from the north and northeast comes ultimately out of the Keyser limestone beneath the ridge across the road from the natural area. Limestones, which contain solution caverns, readily absorb water, and transport it in unpredictable directions.

Bottom-land Soils

The lowland soil of the natural area is mapped as the Holly clay-loam. It is a Fluvent (and an Aquent and a Saprist in small patches) made from the alluvium provided by the extensive region of Silurian and Devonian shale and limestones which lie further up Chillisquaue Creek. ^P There is ample evidence that the surface which supports the wooded part of the natural area is very recent, and in fact, that much of it post-dates European settlement. It is common to find European artifacts, like milled lumber, buried beneath as much as eight feet of alluvium in central Pennsylvanian stream valleys like that of Chillisquaue Creek. No buried artifacts have been found at the natural area, but a widespread layer of well-preserved woody organic material - perhaps slash from logging operations - ^{is} present about eight feet below the current surface. (The easiest way to see this is to auger about three feet down into the little clay ledge at the edge of Chillisquaue Creek where the access trail reaches it.) Chillisquaue Creek is currently cutting into its alluvial plain, suggesting that the supply of sediment is less now than during the early historic period.

The surface of the floodplain of Chillisquaue Creek shows only slight relief -- typically thirty inches difference between the highest and the lowest areas, except in natural and artificial stream channels. Many of the low areas are regularly scoured by a positive-feedback process of the concentration of flood-water flow into swales, thus maintaining or enlarging those swales. It appears that there are slight rises on the sides of the swales away from the stream --

perhaps very short-distance transport of silt excavated from the swales -- but most of the surfaces away from swales is flat to within ten inches over most of the floodplains. Subtle though they are, the swales are the dominant topographic features of the floodplain, and they are clearly aligned to the flow of the floodwaters which, because of the natural area's position on a meander of Chillisquaque Creek, enter roughly normal to the eastern boundary but tend to curve left-ward toward the creek.

The significant differences between the bottom-land soils of the natural area are controlled by the surface and subsurface movement of water, and that movement, in turn, is controlled by subtle features of the alluvial fill in the valley. Although the entire floodplain is inundated every year-or-so, the "typical" July-to-December shape of the water table (i.e., the top surface of the zone of saturated rock and soil and thus the level to which an augered hole will eventually fill) is a gradual slope from a few inches or a foot below the surface at the base of the slope down from the road, to the low-water level of Chillisquaque Creek right at its bank. The entire floodplain drains over the summer, so that in the spring there is a steep slope in the water table near the creek, but it flattens out across the floodplain by fall.

Because of this characteristic of the groundwater, a swale near the creek will be saturated less often, and for a shorter period of time, than will be the same size feature on the other side of the floodplain. This fact accounts in part for the presence of two large perennially boggy areas just past the tree line as one approaches the floodplain from the road, as well as the fact that

the land to the west of the natural area is cropped near the stream, but not back from it: the sloping water table is more likely to intersect the horizontal surface of the floodplain at some distance from the stream.

There is another factor, besides the regional slope of the water table, which accounts for some areas of boggy soils. A local natural "lining" of clay can be laid down within a swale -- and the resulting effects of saturation on soil structure will cause it to thicken automatically. Where the final outlet for the water is higher than the swale's surface, as in the southwestern part of the natural area, this will cause permanent or near-permanent ponds. Where the clay layer causes a saturated zone below the surface to overlie an area which freely drains, and is sometimes aeriated, a "perched" water table is created. The bog in the northwest corner of the floodplain part of the natural area has been sealed on its underside by the accumulation of fine material and organic debris. About one foot below the present surface is a ten inch layer of permanently wet and anaerobic black silt and rotten peat, but two feet below that is a layer of silt and gravel with red mottles that indicate at least episodic presence of air. Thus, the total explanation of that bog must include several factors -- the varying sloping water table mentioned above, the permanent perched water table described here, and also the natural tendency of ^{flooding} streams to be able to carry and deposit fine, impermeable material the greatest distance from their channels, and leave porous, sandy material near their banks.

Several regions of the natural area are ponded for several months at a time, but do not dry out each year. These are where our magnificent crop of mosquitoes breed in early summer when they are thickest. The best example is the swale around which the access trail bends about three hundred feet after it enters the forest. These intermittent ponds are subject to both surface and subsurface drainage. The pond just mentioned has a surface outlet which maintains its depth at a very constant 12 inches, so long as it is provided with ample surface flow. The constancy of this water level can be seen all season long by the rings of moss around the trees and logs, and by a "shore line" where the vegetation changes from the standard unpalatable sylvan under-story, to semi-aquatic plants and late-starting annuals. When, in summer, the supply of water / ^{becomes} insufficient to maintain a standing pool, the pond's level falls quickly -- in about two weeks -- until it shows only in the deepest depressions. The speed with which the pond level falls indicates a well-developed subterranean outlet from somewhere beneath it, although most of the pond is underlain by impermeable muck and clay. A possible explanation is a connection downward to the buried trace of an old stream channel, which could act as a conduit of open gravel through the layers of dense clay. Suffice it to say that the substrate drainage is intricate.

The lowland, alluvial soils of the natural area can be typified by the description of the two extremes in the continuum upon which they all lie. The extremes can be seen at the two different ends of the access trail through the woods, from the poorly drained end where it enters the woods below the parking area,

to the well-drained furthest end on the bank above the stream. The net difference in elevation between these points is about one foot, the poorly drained area actually being higher.

A soil profile in the poorly drained parts of the natural area begins either with poorly structured, buff-colored fine-grained alluvium, or with a thin layer of blackened leaves and muck and then that same pale clay-loam. A short distance below the surface one reaches the most distinctive sub-surface horizon of the natural area -- a dense, sticky, barely structured, mottled layer of a buff or an orange or a grey clay matrix, knitted with rust-colored lines and planes. This is the zone of periodic inundation, with the poor, heavy structure being the product of long saturation, but the red fibers being oxidized iron, showing that air does occasionally move down the voids left by rotting roots or the planes exposed as the mud cracks in summer. Beneath this layer, the clay becomes increasingly dense, increasingly glutinous, and increasingly blue or green. This is a glei, a soil layer which is permanently beneath the water table. The distinctive color results from the chemical reduction of the iron in the various minerals in an oxygen-less solution and the sticky and cohesive texture results from the flocculation of the clays as water removes or immobilizes the surface ions which normally keep the tiny clay particles apart. The glei layer acts as a pan, a serious barrier to all vertical movement of water. The pan underlies essentially all of the natural area at various depths, and is the effective bottom to the active soil zone. Its level follows the slope of the permanent, "typical" water table.

But the clay pan is not necessarily the bottom of the hydrologic system. As one drills beneath it, any one of a variety of sediments can be found. Sometimes one reaches light-colored or reddish, clay-free stream gravels which indicate an active subsurface conduit, and which will yield clear water up the hole. These conduits are well-isolated from the surface; when first breached, the gravel formations will hiss and bubble as gases are released -- perhaps air, perhaps methane -- which had been sealed down with the moving water. Sometimes one reaches stream gravels which are turbid, blueish and sulfurous-smelling, indicating that this layer has been stagnant and anaerobic. Sometimes one reaches layers of woody peat, which are probably from water-logged branches washed into abandoned or migrating stream channels. And often one drills through cycles of various silts and gravels, until the auger hits a rock bigger than itself, and progress stops. We have never reached bedrock beneath the alluvial plain of Chillisquaque Creek, although we have drilled ten feet deep in places.

The properties of these poorly drained soils which are relevant to plant growth are these:

1. The chronically saturated upper horizons are usually depleted of oxygen. The roots of most plants are inhibited by this condition. In its extreme state, the soil supports mainly grasses, annual herbs, and, formerly, elms. The nettles are quite sensitive to soil drainage, and indicate the sharp boundaries of the swales by their luxuriant growth on the slight ridges. Some swales currently support full-size trees, but no saplings. This

suggests that the drainage conditions may be changing, perhaps as silt seals the bottoms of swales and kills vulnerable smaller roots of seedlings. The larger roots of the full-size trees may survive inundation through the inertia of their reserves, they may aerate the soil with their heavings, or they may extend downward into better-oxygenated subsurface flows.

2. Because of the slow decomposition, and the reduced, acidic state of the soil solution, the nutrients carried to the forest floor in leaves and debris are not immediately available to the plants of subsequent generations. The fixed nitrogen which is essential for the growth of higher plants is also destroyed by anaerobic denitrifying bacteria.
3. The boggy soils are, ironically, sometimes droughty, because the clay pan of the gleied layer is a physical block to the upward movement of water during drought, and to the downward growth of roots in search of water. The pan itself has, for a clay, a low moisture capacity clay, since it is so heavily compacted.
4. The swales concentrate the flow of water toward themselves, so that leaf litter, seeds, and seedlings are often swept away at a time of flood, probably leaving some of the swales impoverished of nutrients, and also of any plants at all, in some cases. This is particularly a problem in the forest, where the immediate ground-cover is weak. Where there is sufficient sun for grasses

to grow thickly and trap sediment, the swales are net gainers, rather than net losers, of organic material. The swales seem to be sharper, deeper, narrower, and barer in the forest than in the grasslands just up- and down-stream from the wooded parts of the natural area, where the grasses encourage deposition.

At the other end of the trail, overlooking the stream, the soil profile is significantly different. At the surface is a four or five inch deep brown layer of soil with a nice, granular structure -- an incipient A horizon. Beneath this is the mottled layer, as above, but to a great depth -- over five feet, in some places. Beneath this, the pan is reached again. Beside the stream the pan is visible where it protruded from the bank near the low-water level, being somewhat more resistant to erosion than the more loosely-structured silt above it. Beneath the pan are again layers of peat and of stream gravel to at least ten feet below the floodplain.

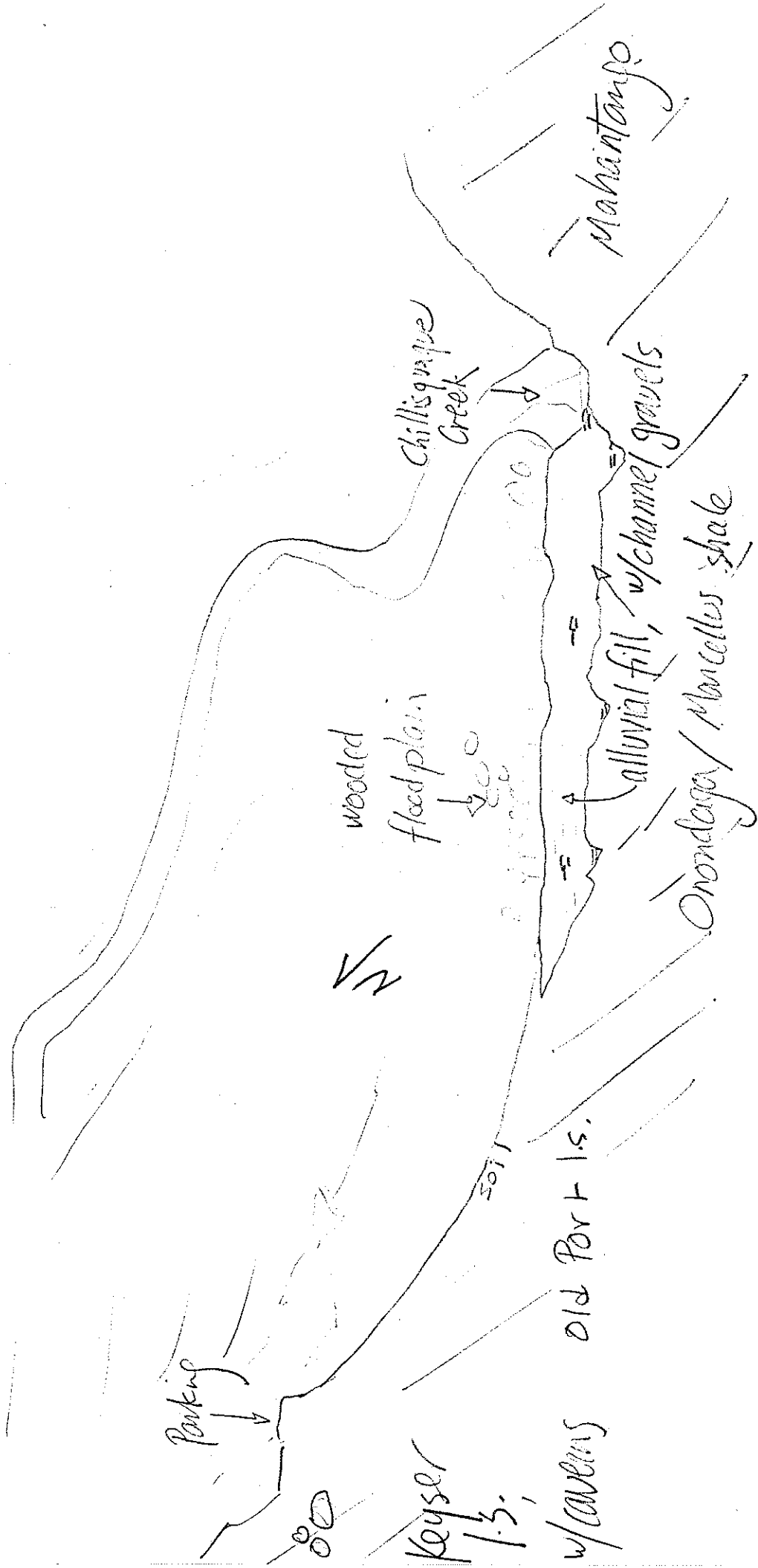
This soil is a good medium for plant growth, although it is atypical of Pennsylvania forest soils, in three ways. First, it is very deep and free of rocks. Wind-throws are rare, for example, although the absence of very ancient trees is a factor here. Second, the stream seems to sweep litter off the surface, or to concentrate it into swales and channels. This is the explanation for the natural area's regrettable impoverishment of mushroom species, and probably also for the absence of the acid-loving forest-floor plants one expects in Pennsylvania -- ferns and blueberries -- although they may also be too slow growing to compete in that vigorous under-story. In any case, the absence of a well-developed organic layer

at the surface suggests that nutrient cycling may be inefficient throughout the floodplain part of the natural area. The third difference between this soil and other forest soils around here is the lack of any horizons besides a thin O and a weak A. In particular, there has not been sufficient time for translocation of clays or oxides to form the distinctive B horizons of Pennsylvania's podzolic soil-forming regime.

Summary: Land-Use History and Soils

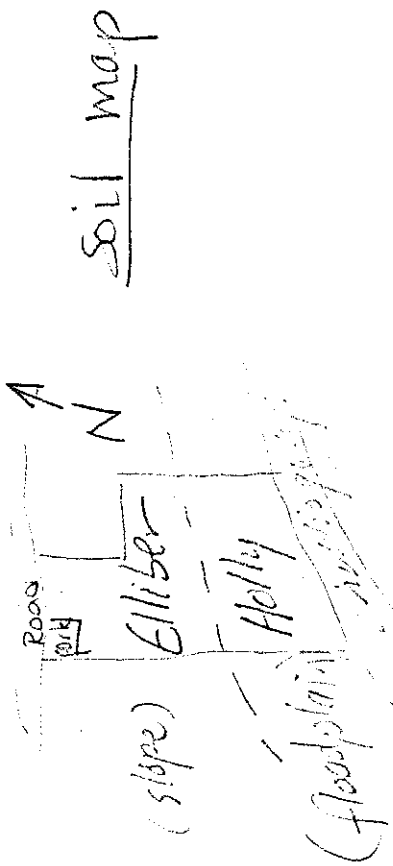
Although the soils of the natural area are not particularly "natural", they illustrate the history of agricultural land-use in Pennsylvania very neatly. Careless farming and forestry effected wholesale transport of soil in this region from steeper slopes to the channels and valleys of streams such as Chillis-
quaque Creek. Most of the eroded soil is still in the region, although off the fields. This diminished the value of both uplands and the lowlands. Typically the steep hills, such as across the legislative route from the natural area, were abandoned by re-treating agriculture just a few decades after they were cleared, and this process is continuing. The lowlands, like the wooded part of the natural area, are still productive, but too wet to plow. Either the farmer must invest in extensive drainage works -- like the tiles and the ditches in the field upstream or like the channelization of the little stream through the ponds in the natural area -- or he can use the land for hay and pasture, which need not be cultivated each year -- like in the field just downstream from the natural area, or like the patches of the natural

area are mapped as regrowth in the 1981 map had been in 1950 air photos -- or the land reverts completely to woodlot -- as much of the natural area has been for many decades. Only the middle slopes - like our goldenrod fields - can still be worked productively with modern equipment, and even there the soil has been scalped by erosion and is marked by futile ditches to halt the damage of running water.



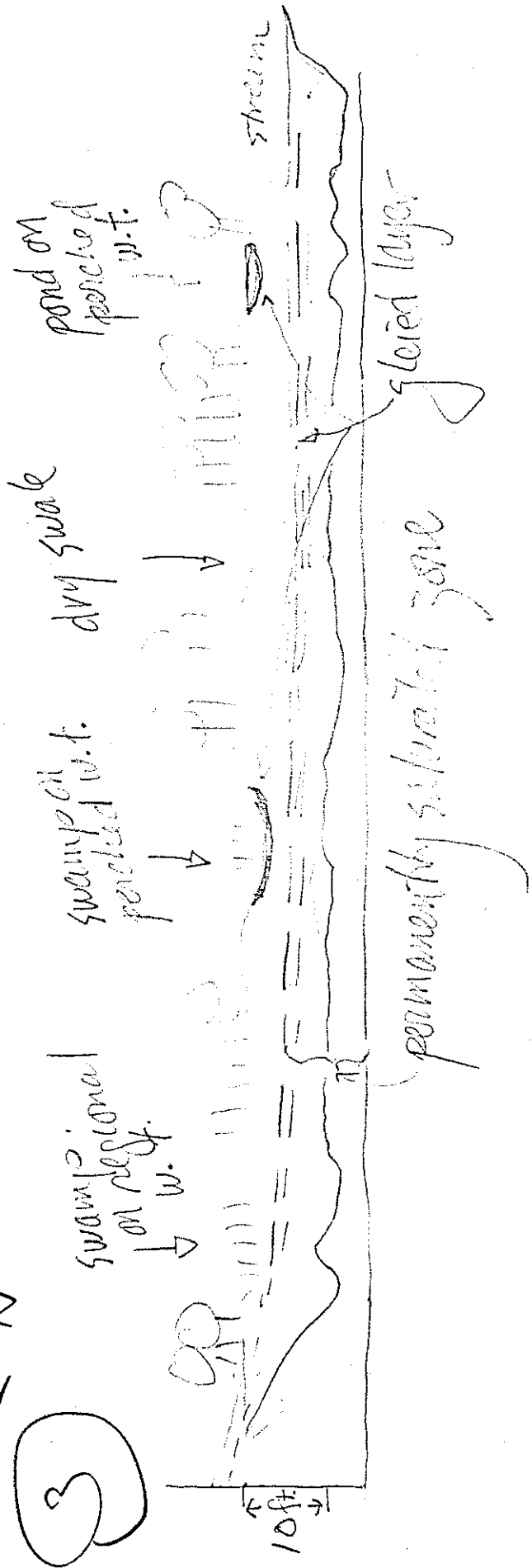
① Geology & sediment -- schematic block diagram
 (20 min. cartography)

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Hydrology of the floodplain (schematic)