Appendix 3

Outstanding Resource Value Report: Geology

Eightmile River Watershed Management Plan

Eightmile River Watershed Outstanding Resource Value: **Geology**

06/17/05 (authored by former state geologist Ralph Lewis)

Introduction

The landscapes and drainage patterns that typify most of New England, including Connecticut, developed over the last 500 million years of our earth's history. The crushing and folding of warm pliable bedrock as mountain ranges formed and New England was assembled, the fracturing of cooler rock as the Atlantic Ocean formed, hundreds of millions of years of stream erosion and the effects of at least two glaciations created a north-south "grain" to the land.

This "grain" is evident to anyone who has driven around Connecticut. Throughout most of the state, driving east-west is difficult (resembling driving across the ridges of a corrugated roof) but driving North-south usually entails going up valleys and is much easier (e.g. Plainfield to Danbury vs. New Haven to Hartford). Owing to the shape of the land, early commerce was east-west on Long Island Sound and north-south up the river valleys. The influence of Connecticut's geology can still be seen in development patterns throughout the state. There are still very few east-west highways that cross the entire state.

The shape of the land also determines how water flows. It is no accident that a drop of water landing in CT will almost always end up in Long Island Sound. Streams generally follow the pattern of the north-south bedrock fabric and tend to flow from north to south across the state.

In the southeast corner of CT, a slight variation in the history of the bedrock produced east-west trending bedrock ridges which are cut by north–south fractures. While the Eightmile River follows the general pattern of southward flow, it does so in a distinctive way, across a landscape and geology that is unique to southeastern CT

Plate Tectonics (Building Mountains and Creating Oceans)

The earth is composed of bedrock segments called plates. There are two types, plates composed of continental type rocks and plates composed of oceanic type rocks. The theory of plate tectonics holds that these plates move over time (at about the rate that your fingernail grows). When plates move they interact with neighboring plates in three ways. They come together (collide), they move apart (rift), or they "sideswipe" each other as is happening along the San Andreas fault in California.

Continental plates can grow larger (accrete) over time as masses of continental rock that share a common geologic history (terranes) collided and stay joined (sutured) together. New England was assembled from west to east in a series of three such collisions.
The two types of plate interactions that are most important to the geology of Connecticut involve collisions and rifting. During plate collisions, the edges of the "colliding" plates get rumpled up and mountains form (e.g. India example, continent to continent collision, California ocean to continent collision). The rocks involved are heated by the compression of the collision and their depth in the earth. They become pliable and tend to fold.

The heat also commonly modifies their character and they are changed (metamorphosed) from what they were to some type of metamorphic rock (typically gneisses and schists in Connecticut). The character of rock that they become is in part determined by what type they were before they were heated. In southeastern Connecticut, the schists and gneisses were formed from heated and crushed sediments that once lay deep in the Iapetos Ocean and small continents and island arcs (similar to today's Japan) that collided with North America as the Iapetos Ocean closed (see cartoons for discussion below). The resistance of these rocks to weathering can vary depending on their origin and history.

When plates move apart, tension is involved. There is generally less heat so the rocks are more brittle and they tend to break or fracture under tension. Fractured rock is commonly more susceptible to erosion than solid rock so valleys often form along fracture zones. Rifting is termed "successful" when a new ocean forms between the plates that are moving apart.

Geologic History: Building and Shaping Connecticut

The Collision Phase: 480-250 Million Years Ago

Connecticut (and New England) was built from west to east over the course of three mountain-building events each of which involved a "collision" and the addition of new rock to the eastern margin of North America. These successive collisions were part of the sequence of events associated with the closing of the Iapetos Ocean (The Ocean that predated the Atlantic) and the assembly of the Super Continent of Pangaea.

- **480-440 Million Years Ago**-The Taconic Island Arc collides with the North American Plate. Western third of Connecticut is assembled and Taconic Mountains form. A portion of the ocean bottom sediment from the Iapetos Ocean is incorporated in this process, turned to rock and made part of western Connecticut.
- **440-350 Million Years Ago-**The Taconic Mountains are eroded away,

and the Nashoba Island Arc and a small continent called Avalonia collide with the North American Plate. The Acadian mountains form and the rocks of eastern Connecticut (including more of the metamorphosed ocean bottom sediments of the Iapetos Ocean) are joined to the North American Plate.

- **350-200 Million Years Ago-**The Acadian Mountains erode away and Africa and South America collide with the North American Plate. The Appalachian Mountains form. The assembled rocks of New England are heated and compressed in an east-west direction so they fold along north-south alignments. By now all the rocks that represent the terranes of Connecticut have been heated and changed from what they were to a variety of schists and gneisses.
- In Southeastern Connecticut a small wrinkle in the regional pattern develops and east-west rock alignments result. The rocks of Avalonia (The Avalonian Terrane) have been pushed under the rocks of the Iapetos Ocean (Iapetos Terrane) along the east west trending Honey Hill Fault.

The Rifting Phase: 200 Million Years Ago to Present

The super continent of Pangaea covered much of the earth [Map] as the Appalachian Mountains were forming. The internal heat of the earth built up under this continental "heat blanket" and upwelling of hot magma (like thick pea soup or oatmeal boiling on the stove) began to tear the Super Continent apart. The compression of mountain building was replaced by the tension of rifting. Places where plates had come together in the collision phase (suture zones) were weakness zones that tended to fail first under tension. In Connecticut, a rift started to tear the state in half between New Haven and Hartford (today's central valley) but this rift "failed" because no oceanic rocks developed in it. Farther to the east, another rift succeeded. The rocks of the Avalonian terrane were torn apart and the Atlantic Ocean began to form.

It has taken 200 million years for the Atlantic Ocean to grow as wide as it is now. During this process part of Avalonia remained in southeastern Connecticut and part ended up in Morocco. The Atlantic Ocean is still getting larger but the earth is a fixed size so something has to "give". As the Atlantic Ocean grows the Pacific Ocean is getting smaller. The earthquake and volcanic activity around the Pacific Rim (ring of fire) are a result of the plate interactions associated with this process.

Locally we see the result of the rifting phase in the north south fractures that are common in southeastern Connecticut. These fractures occurred when the rocks of the region were relatively cool and brittle. They break across the east–west trend of the bedrock units and provided weakness zones for streams to exploit as the Appalachian Mountains were eroded down to their present configuration.

The Erosion Phase: 250 Million Years Ago to Present

The development of the modern landscape of Connecticut began as the Appalachian Mountains were still forming. As the mountains were rising, the forces of erosion (streams, ice, gravity, vegetation, etc.) were working to wear them down. Less resistant rock types and fracture/fault zones were most susceptible to these forces and stream valleys tended to form where the rock was most vulnerable. Nearly 200 million years of stream erosion preceded the glaciations that added a punctuation mark to the landscape over the past 150,000 years.

Some geologists believe that up to 30 km of rock was removed from Connecticut as the Appalachian Mountains were eroded and the pre-glacial drainage system developed. The configuration of the drainage that developed was influenced by the trend of bedrock folds, faults and fractures and by the orientation of belts of less erosion resistant rock units. Throughout most of Connecticut, the tectonic history of the rocks dictated that these influences would favor south-flowing drainage.

A very well developed south-flowing drainage system had developed in Connecticut prior to the arrival of the first known glacier about 150,000 years ago. This glacier is thought to have stripped away most of the soil and “rotten” rock that had accumulated on the bedrock over 200 million years but not much is known about it. The second of the two known glaciers began to spread over Connecticut about 26,000 years ago. It was thick enough to completely cover Mt. Washington (6,028 ft high), it covered all of CT and advanced as far south as Long Island (by about 19,000 years ago), and it persisted in northern Connecticut until about 15,500 years ago.

Glaciers flow “down hill” under the influence of gravity. In Connecticut, the last glacier flowed over around and through existing hills and valleys and its flow was influenced by the topographic features that it encountered. Hills were rounded and valleys were widened and deepened as the glacier flowed from north to south across the state. The overall effect on the bedrock surface was a slight streamlining and modification of what already existed. Bedrock “grain” preserved and in many cases enhanced.

As the last glacier melted out of Connecticut a streamlined version of the pre-glacial bedrock drainage system was uncovered and streams began to reoccupy old drainages. Southeastern Connecticut was ice free first.

Two types of glacial deposits were left behind as the ice melted. One type, till, came directly from the ice and is a combination of unsorted, boulders and fines and everything in between all mixed together. Till is unfavorable for farming, water supply, and similar endeavors. The other type, stratified drift, was deposited in or by glacial melt water and includes well sorted sand and gravel. These are compatible with development and good for water supply among other things. Till on the hills and stratified drift in the valleys influenced development of infrastructure and population distributions in Connecticut.

The Eightmile River Drainage Basin

Several aspects of the geology of the Eightmile River watershed stand out as being regionally and locally significant. On the bedrock side, these include a rare (for New England) combination of tectonic setting, rock assemblages and fractures that controlled the development of a topography that is unique to a small part of southeastern Connecticut. The advance and retreat of the two glaciers that are known to have overridden Connecticut also left their mark on the watershed in the form of a nice sampling of most of the glacial features that would typically be found in Connecticut.

<u>Bedrock</u>:

Lundgren (1966) describes the assemblage of bedrock units that underlie the watershed of the Eightmile River as "an exceptionally varied suite of rocks that includes representatives of nearly all of the major stratigraphic and granitic units known in eastern Connecticut". This exceptional variety in rock units has its origin in the plate tectonic history of New England, which involved the closing of the Iapetos Ocean as the African and North American plates converged and ultimately collided between 480 and 250 million years ago. Eleven rock units representing the remnants of the Iapetos Ocean and rock units that were once part of western Morocco were crushed together, heated and metamorphosed to form what is now the bedrock foundation of the Eightmile watershed.

Throughout most of New England, the closing of the Iapetos Ocean resulted in a general north-south alignment of terrane boundaries and their attendant rock units. This is not the case in a small area of southeastern Connecticut, which includes the Eightmile. A small crinkle in the regional bedrock fabric produced an anomalous east-west alignment of rock units in this area. As a result, rocks from two of the major players in the New England-wide plate tectonic scenario are represented in the watershed. The east-west trending Honey Hill fault is a terrane boundary that delineates the contact of oceanic affinity Iapetos Terrane bedrock units to the north, and Avalonian Terrane (African affinity) rock units to the south.

Most of the metamorphic bedrock of Connecticut is acidic and weathers to an acidic soil. Five of the eleven metamorphic rock units underlying the Eightmile River watershed have basic (calc-silicate or marble) members that would be expected to weather to basic or "sweet" soils. The occurrence of these soils is ecologically significant in a regionally acidic setting. Calc-silicate and/or marble rock members are mapped in the vicinity of Cedar Lake and at the south end of Moulsons Pond.

Topography and Glacial Modification:

Stream erosion over the past 250 million years, and the erosive power of the two known Pleistocene glaciations have combined to sculpt the bedrock surface that forms the rolling topography so typical of most of Connecticut (and New England). Weathering of less resistant bedrock units and of similarly aligned north-south fault/fracture zones, which developed across the region as rifting formed the Atlantic Ocean, created an overall north-south grain to the landscape. The pattern of north-south ridge systems drained by south-flowing streams holds true for most of southern New England, save for the small section in and around the Eightmile watershed. The anomalous alignment of rock units in this area creates a series of east-west trending strike ridges which are cut by valleys that mirror the regional pattern of north-south fractures. The result is a rectangular or "blocky" local topography that is atypical for Connecticut and the region as a whole. The drainage pattern of the Eightmile River, and its tributaries, locally reflects the east-west bias produced by the bedrock alignments (strike ridges) and the north-south bias of the crosscutting fractures.

The pattern of glacial deposition in the watershed is typical for areas of southern New England that are underlain by metamorphic rock. Upland areas are blanketed by thin till which is punctuated by the occurrence of patches of thicker till, drumlins (at least two nice examples) and bedrock outcrops. Striations, polished surfaces, rouche moutonnee and evidence of relict glacial spillways are most often found in association with the exposed bedrock of the uplands (glacial map here?). Valleys are filled with the stratified drift deposits (sands, gravels and lake/pond deposits) that issued from the last glacier as it retreated northward. Five former ice positions are marked by ice-contact stratified drift deposits that lie in the valley between Hamburg Cove and Rte. 82. Eskers and Kettles occur in several locations but exemplary examples of these passive ice features are found in the Pleasant Valley Preserve. Open fields adjacent to Rte.156 (just north of Hamburg Cove and in the pleasant valley area) and Rte. 82 (in the North Plain area) afford a very nice example of the "eggs in basket" topography that the game of golf was invented on in Scotland. Just down the street an exaggerated man-made form of this glacial topography has been recreated for the Fox Hopyard course.