8. Physical Stream Type Classification

Classifying streams by physical (non-biological) characteristics allows researchers to examine and categorize streams by the habitat type and the variety of biological assemblages that the stream can support. An examination of stream habitat types and their distribution across the region should help to inform and advance aquatic conservation work in the study area. In the past, conservation work has largely been limited to a focus on rare and endangered species. An approach such as this can often exclude more common species and habitats, leaving out integral parts of ecosystems. A so-called "coarse-filter" approach, such as this Physical Stream Type classification, focuses on habitat variability and encompasses all organisms that depend on certain habitat types (Higgins et al. 2005). The intention of this approach is to protect the network of habitats found in entire aquatic systems. It is not a surrogate for targeted rare species conservation.

For our physical stream classification we chose to use landscape variables that influence in-stream biological habitat (a "bottom-up" approach to habitat classification; Higgins et al. 2005) and were also readily available in GIS data for most of the study area: geology type, watershed size, and stream gradient (Table 8-1). These three types of data were linked to individual stream reaches using GIS. The data were divided into categories based on the effect of the variable on aquatic biota (Table 8-2); while this habitat classification is based solely on physical criteria, it was our objective that the habitat types developed be biologically meaningful.

Table 8-1. Data that were associated with stream reaches to create the Physical Stream Type Classification. Table adapted from Higgins et al. (2005).

Abiotic Attribute	Rationale for Inclusion
Geology	Geology classes can capture the influence of rock types on many stream attributes: water source (ground or surface), temperature, chemistry, substrate, stream geomorphology, and hydrological regime
Stream Gradient	Correlated with flow velocity, substrate material, channel morphology and stream habitat types (pools, riffles, runs, etc.)
Stream Size	Measured in drainage area: correlated with channel morphology, habitat types, habitat stability and flow volume.

Bear Creek, in Butler Co., PA, is an example of Physical Stream Type '123', or a sandstone geology, moderate gradient, mid-reach stream.

Geology

Geology classes were based on work done by The Nature Conservancy (TNC; Anderson and Olivero 2003). TNC's research combined factors that influence water chemistry and hydrologic regime into categories based on bedrock geology types. In order to create a similar classification based on watershed geology, we decided that six geology classes adequately reflected chemical and hydrological variables for Pennsylvania (Table 8-2). We assigned these geology classes to the geology information from Pennsylvania's bordering states (see *References* section of this chapter) in order to create seamless geological classes across the study area. Unfortunately, we were unable to obtain digital geological information for Maryland.

To perform the joining of geological data to stream reaches, the geology type that was most dominant in the upstream watershed was associated with each stream reach. Using dominant upstream geology accounts for the cumulative effects of upstream geology on water chemistry and substrate material at a location, rather than localized effects of underlying geology at a single stream reach.

Stream Gradient

Stream gradient was calculated as a measure of change in elevation from the start to end of an individual stream reach. Stream segments were defined by RF3 (Reach File, Version 3.0) stream reaches, published by the U.S. Environmental Protection Agency (Dewald and Olsen 1994).

Three gradient categories were used that reflect patterns in biological assemblages as well as patterns in the stream gradient dataset (Table 8-2), and were based on work done by The Nature Conservancy (Anderson and Olivero 2003). These classes reflect a slightly skewed distribution in gradient types, as there are many low-gradient valley streams and a lower number of high-gradient ridge-top streams in the study area. These classes also reflect patterns in biological communities. For example, some communities found in low-gradient streams showed a general affinity to gradients less than 0.5%. Alternatively, some high-gradient communities were commonly found in streams with gradients over 2.0%.

Watershed Size

Watershed area was calculated for each RF3 stream reach by summing the land area that contributes to the basin of each stream reach (Anderson and Olivero 2003). We delineated four categories of watershed size that reflect patterns in biological assemblages as well as patterns in the watershed size dataset (Table 8-2).

Table 8-2. The three variables used to determine Physical Stream Type and the categories within them. See text for further explanation of variables and data sources.

Physical Variables and Categories		Description
Geology Classes		
1	Sandstone	Most common type in study area; comprised of sand-sized particles; moderate/variable stream flashiness; low conductivity, can have acidic pH
2	Shale	A fine-grained sedimentary rock, the second-most common geology type in study area; generally flashy streams; often occurs in coal regions; can have calcareous deposits, but generally has an acidic effect on streams; variable conductivity
3	Calcareous	Limestone and dolomite rock types; even small amounts of calcareous geology can have a disproportionate effect on water chemistry and biotic assemblages; flow is more stable in these streams because of porosity and fracturing; base-cation rich; relatively high pH, conductivity, alkalinity, and TDS.
4	Crystalline Silicic	Igneous or metamorphic rock containing silica ions; formed under low heat and pressure; hard rock that weathers slowly; generally has lower ion concentrations, less influence on stream chemistry than other geology types
5	Crystalline Mafic	Igneous or metamorphic rock containing calcium, sodium, iron and magnesium ions; hard rock that weathers slowly; generally has lower ion concentrations, less influence on stream chemistry than other geology types
6	Unconsolidated materials	Sands and gravels (mainly along coastal zones and larger rivers); geological characteristics derived from surrounding rocks types in the area
Stream Gradient		
1	Low Gradient	Stream slope is 0.0 - 0.5%
2	Medium Gradient	Stream slope is 0.51 – 2.0%
3	High Gradient	Stream slope is over 2.0%
Watershed Size		
1	Headwater stream	0 – 2 mi^2 (0 – 5.2 km^2)
2	Small stream	2 – 10 mi^2 (5.2 – 25.9 km^2)
3	Mid-reach stream	10 – 100 mi^2 (25.9 – 259.0 km^2)
4	Large Streams and Rivers	Over 100 mi^2 (259.0 km^2)

Size 1 watersheds represent the smallest headwater streams (0-2 mi^2 watershed area; 19,000 stream reaches). These streams hold mainly headwater macroinvertebrate communities. Size 2 watersheds (2-10 mi^2; 13,000 reaches) are still small in size, but support a greater diversity of macroinvertebrate and small-stream fish communities. Watersheds in the Size 3 category (11-100 mi^2; 12,000 reaches) represent mid-reach streams and generally maintain many types of macroinvertebrate and fish communities. Size 4 streams (100+ mi^2; 7,000 reaches) represent the larger streams and rivers of the study area. They commonly hold nearly all mussel communities and the large river fish communities.

Data Processing

The geological, gradient and watershed size data were combined for every stream reach in the study area using GIS. In order to name the physical classes developed, the numbers accompanying each variable category from Table 1 were used. For example, a sandstone-dominant ('1'), moderate gradient ('2') small stream ('2') would receive an physical classification of '122'. Once the physical stream classes were defined, the biological community groups were assigned to stream types.

Results & Discussion

The Physical Stream Type classification revealed a total of 64 stream habitat categories, with 45 classes being represented by more than 100 stream reaches in the study area. Nineteen common classes had more than 1,000 stream reaches in the study area (Table 8-3). The two most common stream types were both high-gradient headwater streams with sandstone or shale geology, respectively.

Many biological communities showed preferences towards certain physical stream types (Table 8-4). Most notable are the genus- and family-level macroinvertebrate communities that are commonly found in calcareous geology; these communities were consistently found in physical stream classes with this unique geology type. Macroinvertebrate communities indicative of either high or low stream gradients were also related to physical types that reflected these differences.

Table 8-3. Most common physical stream types in the study area.

Physical Stream Type ID	# Stream Reaches in Study Area	Physical Stream Type Name
131	11,536	Sandstone geology high gradient headwater stream
231	7,300	Shale geology high gradient headwater stream
113	4,656	Sandstone geology low gradient mid-reach stream
111	4,309	Sandstone geology low gradient headwater stream
114	4,051	Sandstone geology low gradient large stream
122	3,924	Sandstone geology moderate gradient small stream
121	3,391	Sandstone geology moderate gradient headwater stream
132	3,027	Sandstone geology high gradient small stream
123	2,895	Sandstone geology moderate gradient mid-reach stream
112	2,888	Sandstone geology low gradient small stream
221	2,626	Shale geology moderate gradient headwater stream
214	2,529	Shale geology low gradient large stream
222	2,512	Shale geology moderate gradient small stream
213	2,362	Shale geology low gradient mid-reach stream
223	1,619	Shale geology moderate gradient mid-reach stream
211	1,561	Shale geology low gradient headwater stream
212	1,450	Shale geology low gradient small stream
232	1,270	Shale geology high gradient small stream
331	1,267	Calcareous geology high gradient headwater stream

Fish communities also appeared to be differentiated among physical types. The coldwater trout stream communities were found in higher gradient smaller streams, exclusively in sandstone-dominated geology streams. The warmwater groups were in slightly larger streams with lower gradients. Lastly, the large river and impoundment groups were associated mainly with lower gradients and large streams (Size 4).

The mussel communities were almost exclusively associated with physical classes indicating large streams, lower gradients and either sandstone or shale geologies. Since this physical stream classification seemed to explain differences among fish and macroinvertebrate communities, but not mussel communities, it is likely that these physical stream types do not reflect site-specific substrate variation that is important to mussel viability and distribution. However, it does appear that the classification may be effective at describing large-scale variables that influence distribution patterns of fish and macroinvertebrate assemblages. Perhaps a more detailed classification, incorporating such variables as elevation or hydrologic regime (*sensu* Higgins et al. 2005) would further elucidate relationships between stream types and resident biological communities.

Utility of Physical Stream Types

Combining the Physical Stream Type Classification with the LDS (Least-Disturbed Stream) Reaches

In conservation work, it is important to preserve stream systems that are as close to naturally functioning as possible. It is also important to protect unique stream habitats that may not be adequately represented in standard analyses (Higgins et al. 2005). By combining the Physical Stream Type Classification with the Least-Disturbed Stream (LDS) analysis (Chapter 9), the best examples of various stream habitat types can be readily identified. This will allow researchers to determine the locations where different types of stream habitats are functioning as naturally as possible. Associating the biological community information (Chapters 4-7) with LDS reaches and physical stream types will provide information as to what biological assemblages exist in these distinctive habitats.

Stream Conservation Using Physical Stream Types & LDS

Stream conservation efforts can be easily streamlined with the use of the LDS and Physical Stream Type tools. After a project area (i.e., a watershed) has been defined, the habitat types within that project area may be assessed. Knowing what stream types exist within a project area will help researchers to identify the conservation needs of the area. The best examples of stream types are easily identified by overlaying the LDS information. If there are physical stream types that are not represented by an LDS designation in the project area, knowledge of the area and streams within the area will be critical. Combining LDS and Physical Stream Type information will ensure that the best examples of each stream habitat are represented in watershed conservation work (see the Pine Creek example in “Utilities of LDS Analysis” section of Chapter 9).

Stream Restoration Using Physical Classification & LDS Reaches

The ACC tools described in this chapter should make stream restoration efforts more efficient and measurable. Target conditions for study streams (degraded streams in need of restoration action) may be established by finding an LDS stream of the same physical habitat type. The LDS stream will serve as a benchmark stream, which can be used to measure the success of restoration efforts in the study stream. This may be done through a condition analysis of the LDS stream. Gathering information from the LDS stream (water chemistry profiles, resident biological communities, etc.) will provide information about what biological and chemical qualities the study stream should exhibit if its water quality issues are remedied (see Toby Creek restoration example in “Utilities of LDS Analysis” section of Chapter 9).

References

Anderson, M.A. and A.P. Olivero. 2003. TNC Stream Macrohabitat, Lower New England Ecoregional Plan. The Nature Conservancy.

Higgins, J.V., M.T. Bryer, M.L. Khoury, and T.W. Fitzhugh. 2005. A freshwater classification approach for biodiversity conservation planning. *Conservation Biology*, 19 (2): 432-445.

Dewald, T.G. and M. V. Olsen. 1994. The EPA Reach File: A National Spatial Data Resource. SEPA, May 1994.

Reese, S.O. and Podniesinski, G. *personal communications*.

Geology Data Sources:

Delaware: www.udel.edu/dgs
New Jersey: www.state.nj.us/dep/njgs
New York: www.nysm.nysed.gov/gis
Ohio: www.dnr.state.oh.us/geosurvey
Pennsylvania: www.dcnr.state.pa.us/topogeo
Virginia: www.mme.state.va.us/dmr
West Virginia: wvgis.wvu.edu/data/data.php

Related Shapefiles

ACC_Physical_Stream_Types.shp
ACC_Geology_Classes.shp

Example Restoration Action Plan Using LDS Reaches & Physical Stream Types:

1. Select study stream; determine abiotic class type.
2. Find streams of same abiotic type, preferably in same drainage basin.
3. Identify stream of same abiotic type that is an LDS reach – this is the benchmark stream. Multiple benchmark streams may be useful, if time and funding allow.
4. Complete a condition analysis of benchmark stream – determine resident biological communities, water chemistry profile, etc; compare to LDS stream.
    a. Determine what sets the benchmark stream apart from the study stream
        i. Threats analysis – what is degrading the study stream?
5. Perform necessary restoration measures on study stream (AMD remediation, streambank fencing, etc.)
6. Measurement of restoration success:
    a. Assess new biological communities in study stream – are they like that found in the benchmark stream?
    b. Assess new water chemistry profile in study stream – is it similar to that found in the benchmark stream?

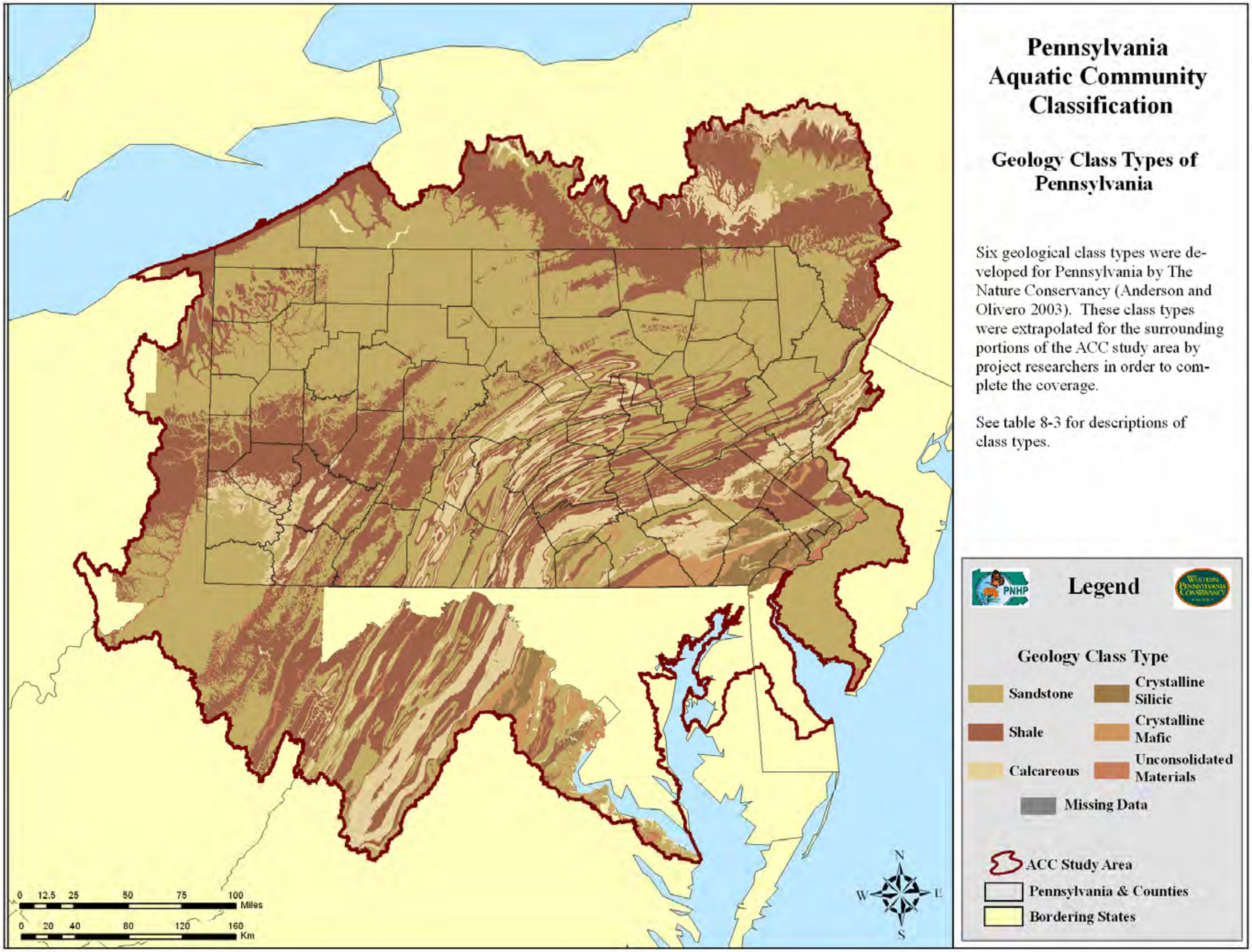
Table 8-4. Biological communities and their commonly associated physical stream types.

Community Name	Representative Taxa	Common Physical Stream Types
Mussels		
Delaware Basin		
Eastern Elliptio	*Elliptio complanata* , *Villosa iris*	114, 214
Alewife Floater	*Anodonta implicata*	114
Other	rare mussel species	222
Ohio - Great Lakes Basin		
Pink Heelsplitter	*Potamilus alatus*	114
Fluted Shell	*Lasmigona costata* , *Ptychobranchus fasciolaris*	114, 113
Fatmucket	*Lampsilis siliquoidea* , *Pyganodon grandis*	114, 113
Spike	*Elliptio dilatata* , *Ligumia recta*	114, 113
Susquehanna - Potomac Basin		
Lanceolate Elliptio	Lanceolate *Elliptio* complex	214, 113
Squawfoot	*Strophitus undulatus*	114, 213, 113, 313
Yellow Lampmussel	*Lampsilis cariosa*	214, 114, 223, 113
Elktoe	*Alasmidonta marginata*	214, 213, 231
Eastern elliptio	*Elliptio complanata*	214, 114, 213, 113
Eastern floater	*Pyganadon cataracta*	114, 124, 214, 322
Macroinvertebrates		
Genus-level		
High Quality Small Stream	*Epeorus* , *Oulimnius*	132, 131, 122, 123
High Quality Headwater Stream	*Amphinemura* , *Lepidostoma*	131, 132, 122, 231
High Quality Large Stream	*Drunella* , *Acentrella*	123, 122, 113, 223, 132
Sluggish Headwater Stream	*Physidae, Hirudinea*	121, 221, 122, 313, 322
Common Large Stream	*Dubiraphia, Caenis*	122, 113, 123, 213, 222
Limestone / Agricultural Stream	Isopoda, Oligochaeta	313, 231, 312, 322, 323
Small Urban Stream	*Cheumatopsyche, Stenelimis*	421, 413, 113, 131
Large Stream Generalist	Generalist Taxa	213, 221, 113, 222, 114
Forested Headwater Stream	*Alloperla* , *Tipula*	131, 122, 132
Common Small Stream	*Stenonema, Psephenus*	522, 213, 221, 113, 123
Ohio River	*Cyrnellus, Amphipoda*	114
Mixed Land Use Stream	*Hydropsyche, Nigronia*	123, 331, 221, 232
Family-level		
Low Gradient Valley Stream	Elmidae, Psephenidae	222, 122, 113, 221, 213
High Quality Mid-Sized Stream	Isonychiidae, Philopotamidae	122, 123, 222, 131, 113
Common Headwater Stream	Lepidostomatidae, Capniidae	131, 132, 231, 122
Limestone / Agricultural Stream	Amphipoda, Simuliidae	313, 322, 122, 114, 331
High Quality Small Stream	Leuctridae, Baetidae	131, 122, 132, 231, 222
Common Large Stream	Nemouridae, Ameletidae	131, 231, 122, 221, 222
High Quality Headwater Stream	Chloroperlidae, Pteronarcyidae	131, 132, 122, 123, 231
AMD Stream	Sialidae, Empididae	122, 132, 231

Table 8-4., Cont.

Community Name	Representative Taxa	Common Physical Stream Types
Fish		
Atlantic Basin		
Warmwater Community 1	central stoneroller, northern hogsucker	113, 123, 114, 213
Warmwater Community2	redbreast sunfish, rock bass	214, 213, 113, 114
Coolwater Community 1	slimy sculpin, fathead minnow	132, 123, 122
Coolwater Community 2	blacknose dace, white sucker	123, 122, 313
Coldwater Community	brook trout, brown trout	132, 123, 131, 122
River and Impoundment	walleye, yellow perch	114, 214, 113
Lower Del. River Community	white perch, channel catfish	114, 214, 213
Ohio - Great Lakes Basins		
Warmwater Community	greenside darter, northern hogsucker	114, 113, 123, 213
Coldwater Community	brook trout, mottled sculpin	122, 132, 123, 131, 113
Coolwater Community	blacknose dace, creek chub	113, 122, 123, 213, 223
Large River Community	channel catfish, sauger	114

Belted Kingfisher, Ten Mile Creek, Greene Co., PA.



Pennsylvania Aquatic Community Classification

Geology Class Types of Pennsylvania

Six geological class types were developed for Pennsylvania by The Nature Conservancy (Anderson and Olivero 2003). These class types were extrapolated for the surrounding portions of the ACC study area by project researchers in order to complete the coverage.

See table 8-3 for descriptions of class types.

Figure 8-1. Geology type classes for the ACC study area.