# Land Use and Impervious Cover in the Paradise Creek Watershed: An Initial Assessment

***Report To:***

***Paradise Creek Watershed Assessment and Protection Plan***

**Date: February 14, 2003**

**Submitted by:**


James Sheehan Jr.
PO Box 441
Analomink, PA 18320
(570) 422-3719
jf_sheehan@hotmail.com

## Introduction

Land uses within the Paradise Creek Watershed, particularly those that create impervious surfaces such as asphalt, compacted earth, and rooftops are being increasingly monitored as concern over the integrity of this watershed grows. There is growing evidence that when impervious cover comprises more than 10% of a watershed, water quality and quantity begin to be affected[1]. Aside from an increase in imperviousness, land use such as residential development also causes fragmentation and destruction of habitats[2]. To assist in the Paradise Creek Watershed Assessment and Protection Plan, an estimate of impervious cover and an analysis of land use within this watershed are needed. Several types of data exist that allow land use classification and direct estimates of the amount of impervious cover including ground surveys, aerial photography, and satellite remote sensing; usually in conjunction with a Geographic Information System (GIS)[3]. This analysis attempts to quantify impervious cover and land use in this watershed using GIS to apply an existing land use classification based on aerial photography.

The Collaborative Environmental Monitoring and Assessment Program (CEMRI)[4] recently sponsored low-level aerial photography of the Delaware River Basin (including the Paradise Creek Watershed) to quantify land use, impervious cover and forest fragmentation. CEMRI provided their impervious estimation results and land use classification to the Pennsylvania Spatial Data Access (PASDA) website (http://www.pasda.psu.edu; Access Data, New Data Additions, September 2002) as a free GIS dataset available for download. A key advantage to this dataset is that the goal of the project was to overcome the limitations of existing satellite imagery and aerial photography complicated by the extensive forest canopy of this region. (see Appendix I).

## Methods

The CEMRI land classification is a vector-based dataset, a commonly used image format in GIS that is comprised of contiguous geometric shapes (polygons), each containing information on such parameters as area and land use (Figure 1).

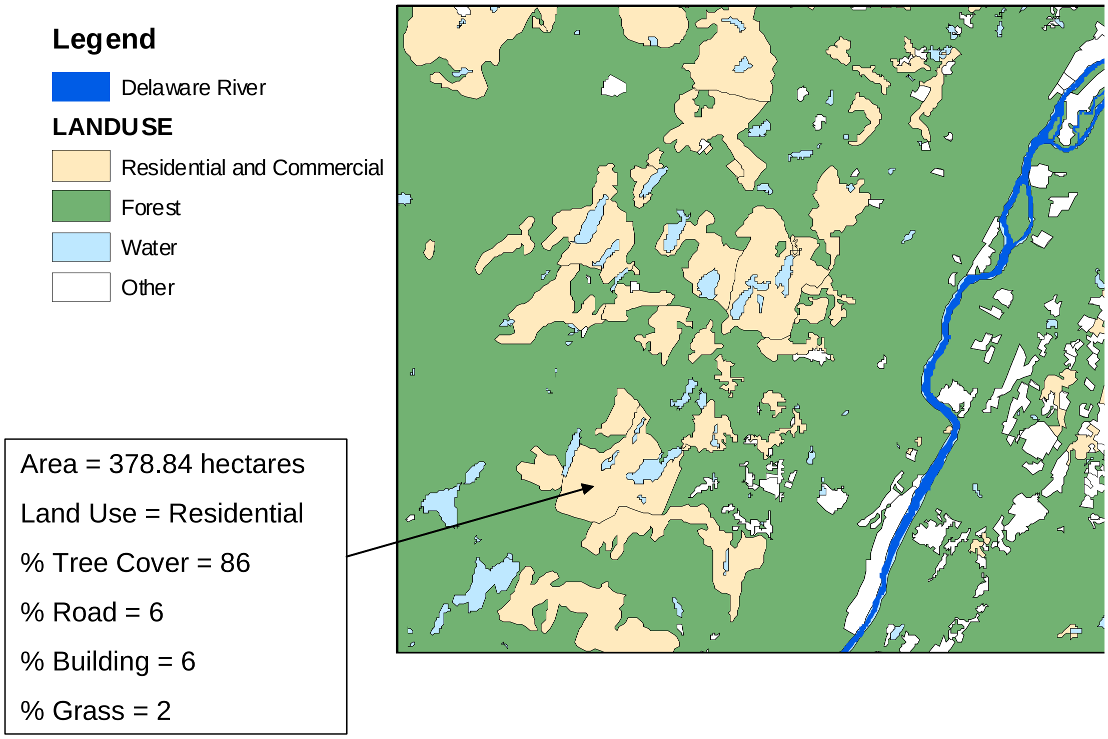



Figure 1. Portion Of CEMRI Land Use Polygons for the Delaware River Basin

Using a GIS, this image was clipped to the entire Paradise Creek Watershed and proposed management units within the watershed (Figure 2.).

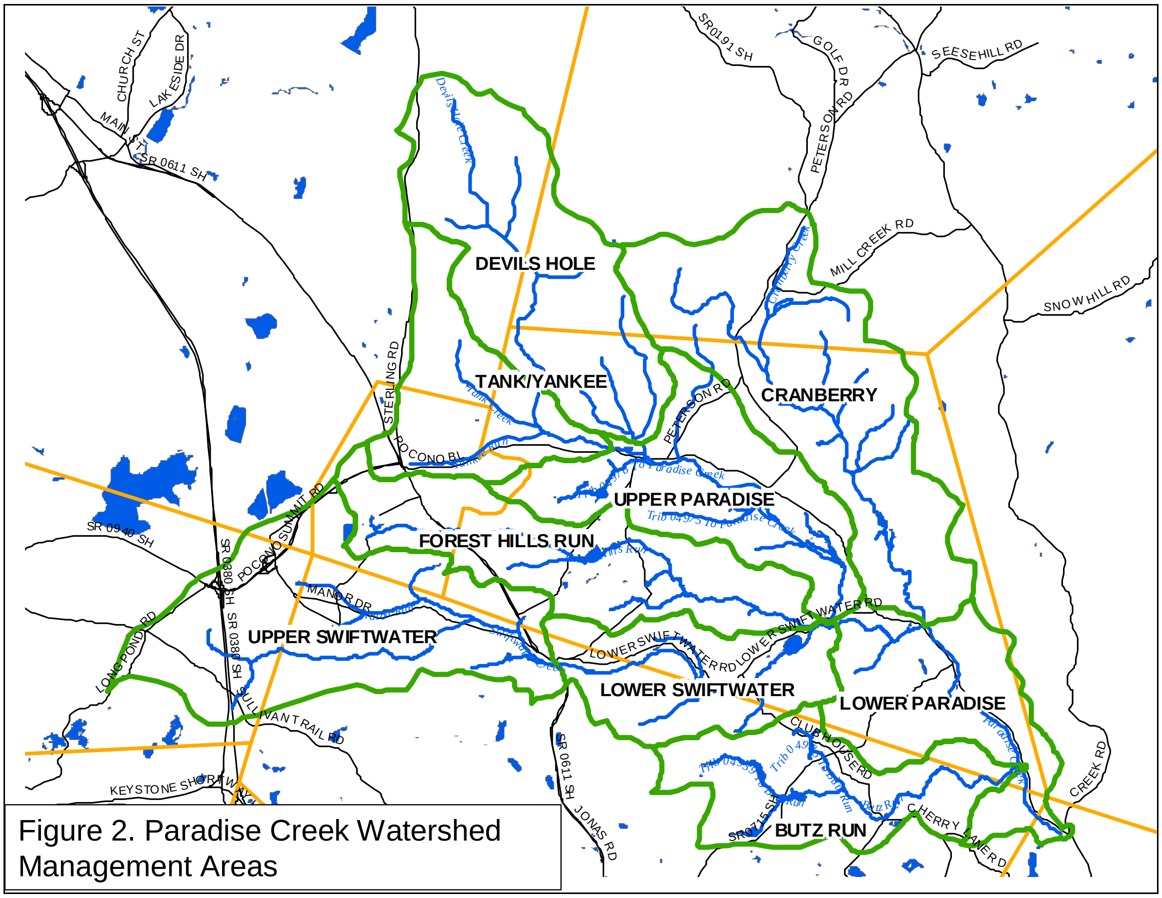



Figure 2. Paradise Creek Watershed Management Areas

The polygons within each clipped area were summarized according to the types and coverage of land use. CEMRI also estimated the percent area occupied by buildings and roads, forest, and grass cover for residential polygons. This allowed residential impervious surface area and forest cover to be calculated for each clipped area.

One problem with the CEMRI dataset needed to be overcome. Some polygons within the watershed were not classified due to occasional cloud cover obscuring the ground. These polygons were overlaid on 1999 flight file USGS digital orthophotos (available from PASDA) in the GIS, and classified according to their resemblance to CEMRI classified ones. For each of these polygons classified as residential, impervious percent cover values derived from averaging the entire CEMRI dataset were used (Table 1.). In order to determine impervious cover for other anthropogenic land use polygons (e.g. retail and industrial areas, roads) a value of 50% imperviousness was applied based on values described in the literature[1,5] and visual inspection of these polygons overlaid on the orthophotos. This value is conservative with regard to literature recommendations for some of these land uses but is considered more applicable to this analysis based on the visual assessment.

**Table 1. Land Use Polygon Codes and Values Used For Impervious Cover Estimation.**

| CEMRI [1] Polygon Code | Description | CEMRI Impervious Cover Polygon Values (%) [2] | Impervious Cover Values Used For Unclassified Polygons (%) [3] |
|---|---|---|---|
| 1101<br>1111<br>1112 | Low Density Residential | Range: 4 – 18 | CEMRI Mean: 10.597 |
| 1121<br>1122 | Medium Density Residential | Range: 4 – 18 | CEMRI Mean : 12.862 |
| 1130 | High Density Residential | Range: 8 – 35 | CEMRI Mean : 15.661 |
| 1140 | Multi-family (apartments) | -- | CEMRI Mean : 34.154 |
| 1210<br>1220 | Commercial/industrial | -- | 50 |
| 1300 | Urban open | -- | 50 |
| 1400 | Transportation | -- | 50 |
| 1500 | Powerlines | -- | -- |
| 1600 | Recreation | -- | -- |
| 2100 | Pasture | -- | -- |
| 2200 | Crop | -- | -- |
| 4000 | Forest | -- | -- |
| 5200 | Lake | -- | -- |
| 5300 | Pond | -- | -- |
| 5500 | Wetland | -- | -- |
| 7200 | Bare Soil/mining | -- | -- |

1. Collaborative Environmental Monitoring and Research Initiative (CEMRI).
2. Impervious cover was provided for each residential class polygon by CEMRI except when photo interpretation was precluded by cloud cover.
3. For Commercial/industrial, Urban open, and Transportation polygons, values were based on visual inspection of 1-meter resolution 1999 digital orthophotos from the USGS and the literature. Means derived from the entire Delaware River Basin CEMRI classification were applied to residential class polygons with no data.

# Results

Impervious cover for the Paradise Creek Watershed is estimated at 3.63% (Table 2).

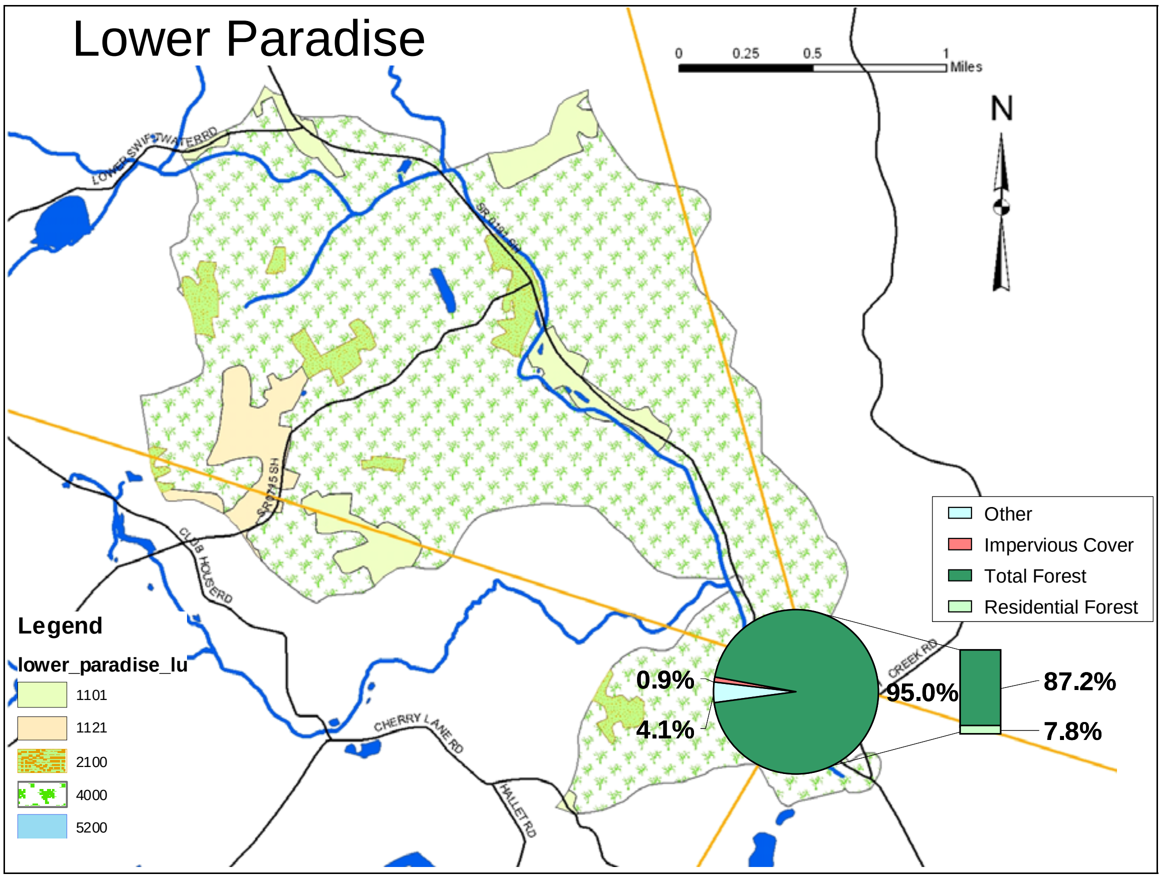
**Table 2. Summary of Results From Impervious Cover and Land Use Analysis**

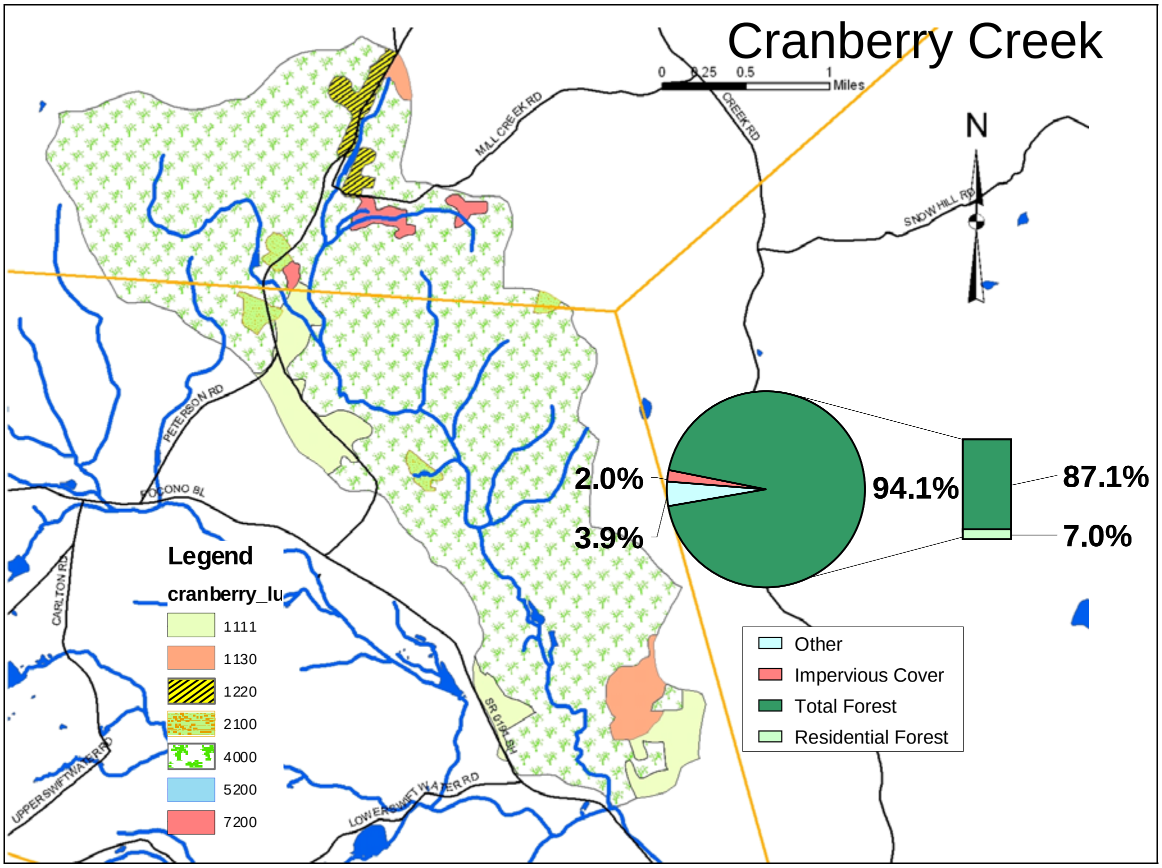
| | | Land Cover Percentages | | |
|---|---|---|---|---|
| **Watershed Management Unit** | **Area in Hectares** | **Impervious Cover** | **Other Land Use** | **Forest Cover** |
| LOWER PARADISE | 1010.97 | 0.85 | 4.14 | 95.01 |
| CRANBERRY | 1910.18 | 1.96 | 3.90 | 94.14 |
| BUTZ | 951.43 | 2.63 | 12.51 | 84.86 |
| DEVILS HOLE | 1590.97 | 2.93 | 1.85 | 95.22 |
| FOREST HILLS | 1233.65 | 3.68 | 16.21 | 80.11 |
| LOWER SWIFTWATER | 863.81 | 3.81 | 13.71 | 82.48 |
| UPPER SWIFTWATER | 1782.63 | 5.51 | 11.65 | 82.85 |
| UPPER PARADISE | 1172.80 | 5.54 | 11.48 | 82.98 |
| TANK-YANKEE | 828.30 | 6.31 | 4.22 | 89.46 |
| Calculated for Entire Watershed: | **11344.78** | **3.63%** | **8.47%** | **87.91%** |

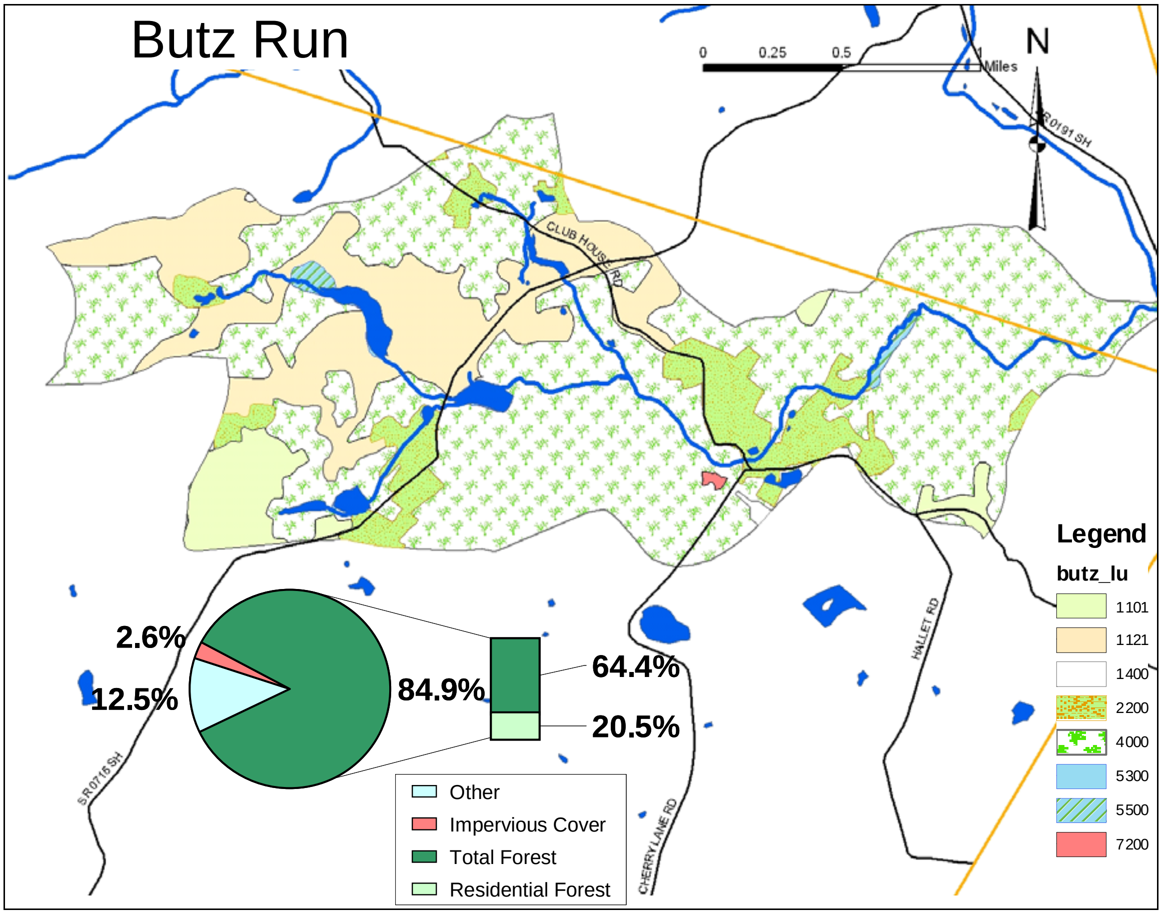
The Tank-Yankee, Upper Paradise, and Upper Swiftwater management units had the highest impervious cover values (5.51 to 6.31%) and the Lower Paradise and Cranberry management units had the lowest (< 2%). In general, the opposite trend is observed for percent forest cover, although the proportion of other land uses is more variable, resulting in the unit with the most impervious cover, Tank-Yankee (6.31%), having the fourth highest forest cover (89.46%). Forest cover is notable in that it is consistently high, with a value of more than 87% for the entire watershed, and ranging from approximately 80% to 95% for the management units.

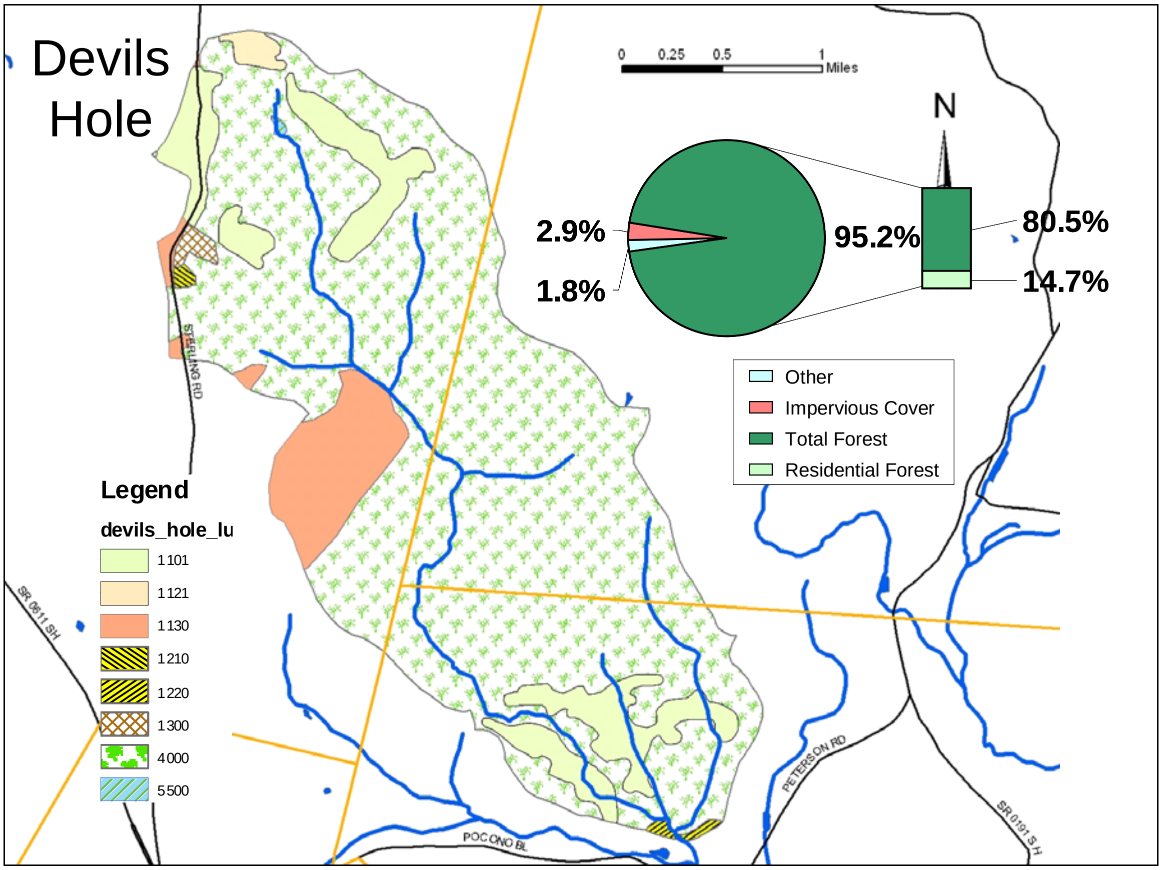
Figure 3 shows individual management unit maps summarizing the types of land uses present (see Table 1 for code descriptions) and graphically illustrating the proportion of land cover types. A detailed assessment of all land use present in these management units is beyond the scope of this research; however, some general trends are evident. Diversity and types of land use vary across management units. Forest Hills is diverse, with 12 land use categories while Lower Paradise has only four. Management units such as Devils Hole and Lower Paradise are largely contiguous forest; Butz Run and Upper Paradise have more agricultural use; and Tank-Yankee, Forest Hills, and Lower Swiftwater have the most area allocated to residential and commercial use. It is important to note that while Tank-Yankee is dominated by residential development, these areas contribute almost 25% to the overall forest cover of this unit. The distribution of land use relative to waterways is also varies. Most of the development in Tank Yankee appears to be relatively far from the nearest mainstream (Tank Creek and Yankee Run) while roads and development occur in close proximity to the mainstream in Forest Hills (Forest Hills Run). Devils Hole Creek and Cranberry Creek appear to flow through primarily contiguous forest.

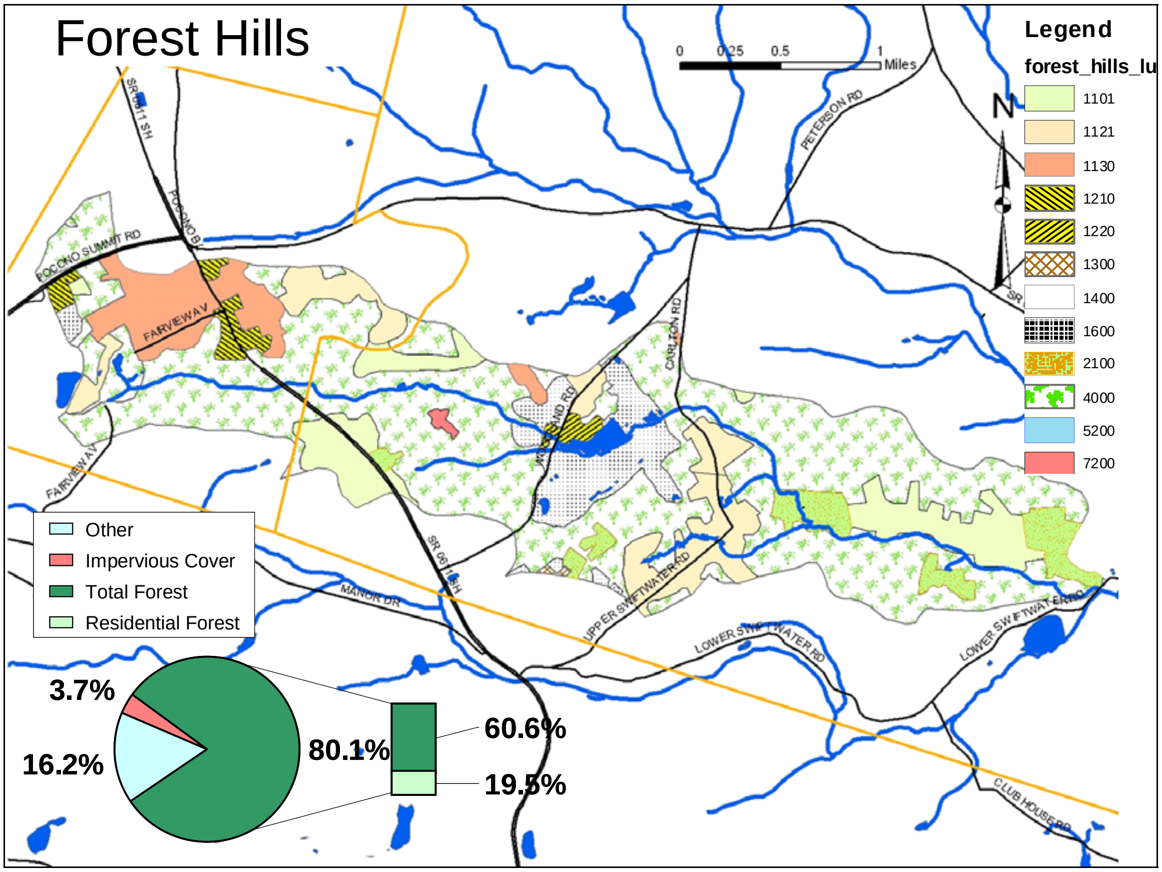
**Figure 3. Management Unit Land Cover Types (See Table 1 to interpret land use codes used in the legend).**

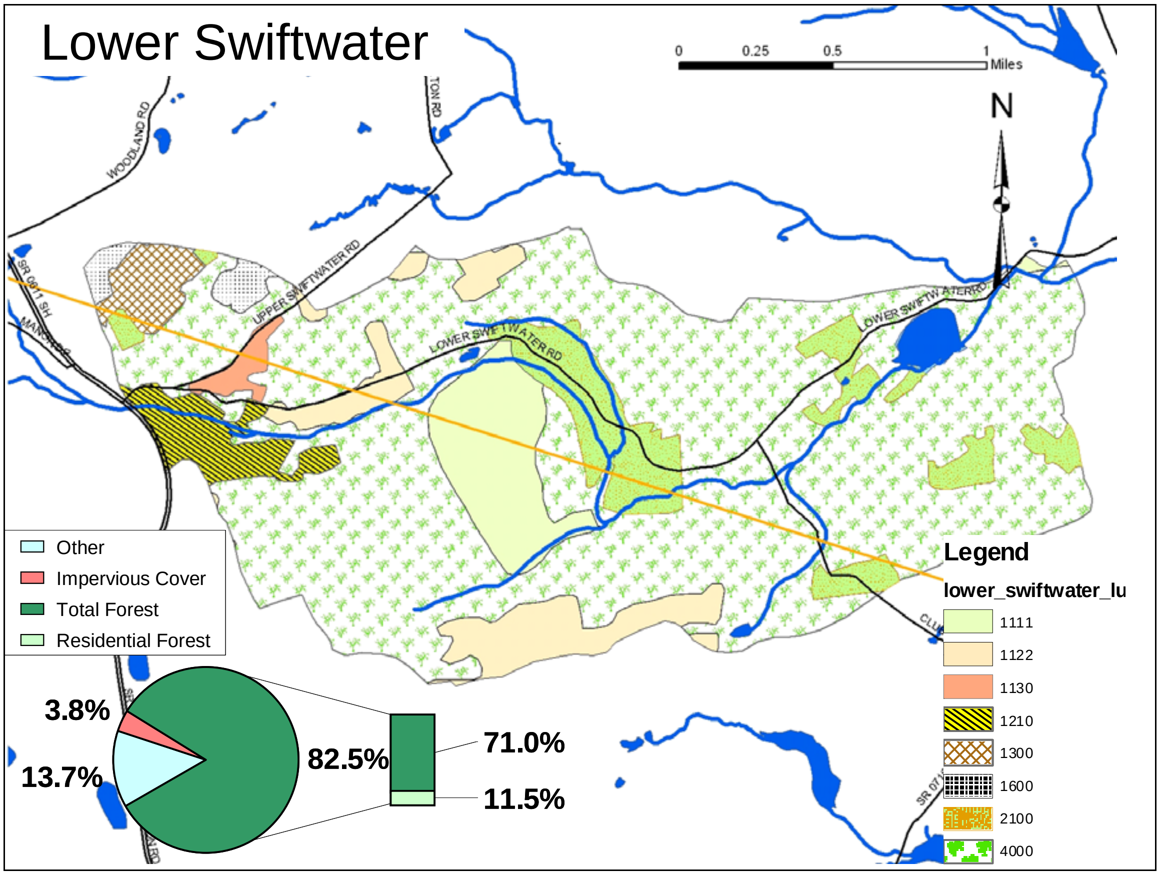


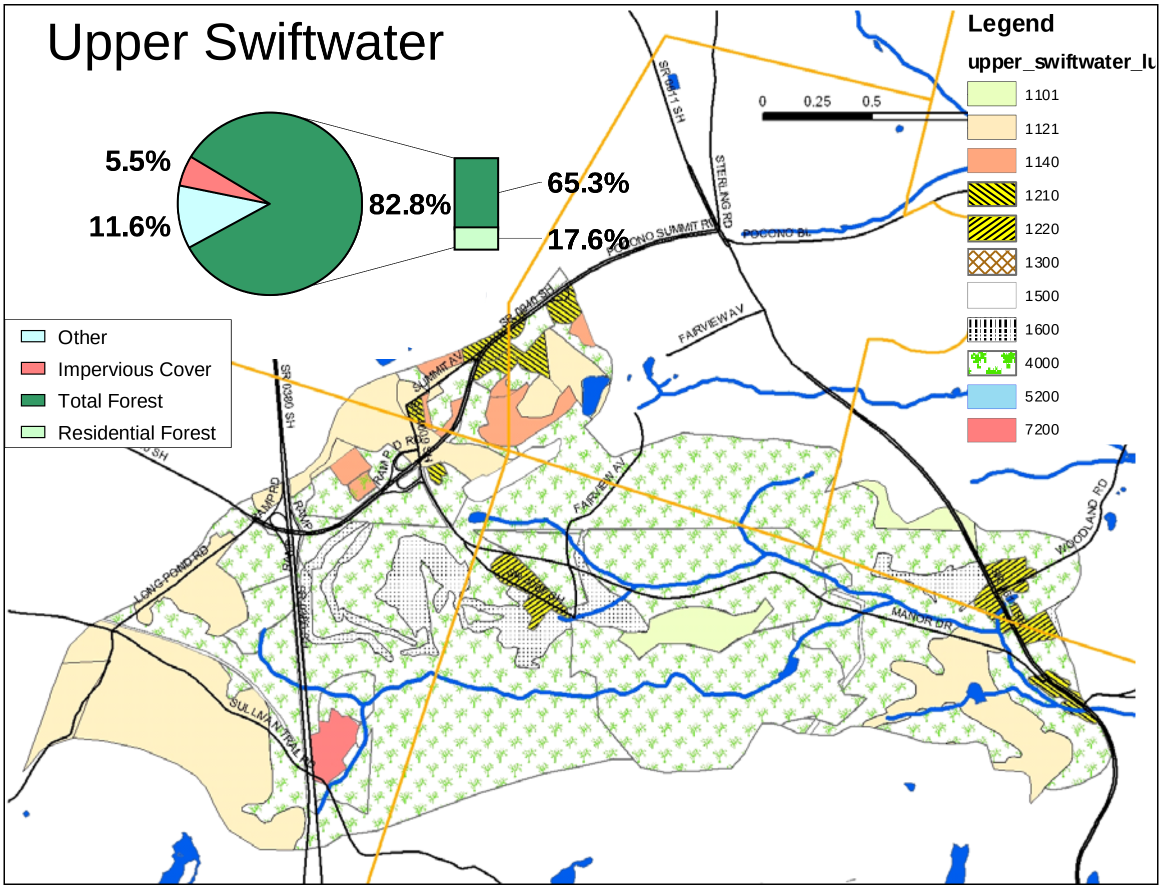

Cranberry Creek
0
0.25
0.5
1
Miles
N
MILL CREEK RD
CREEK RD
SNOW HILL RD
PETERSON RD
POCONO BL
CARLTON RD
UPPER SWIFTWATER RD
LOWER SWIFTWATER RD
Legend
cranberry_lu
1111
1130
1220
2100
4000
5200
7200
2.0%
3.9%
94.1%
87.1%
7.0%
Other
Impervious Cover
Total Forest
Residential Forest

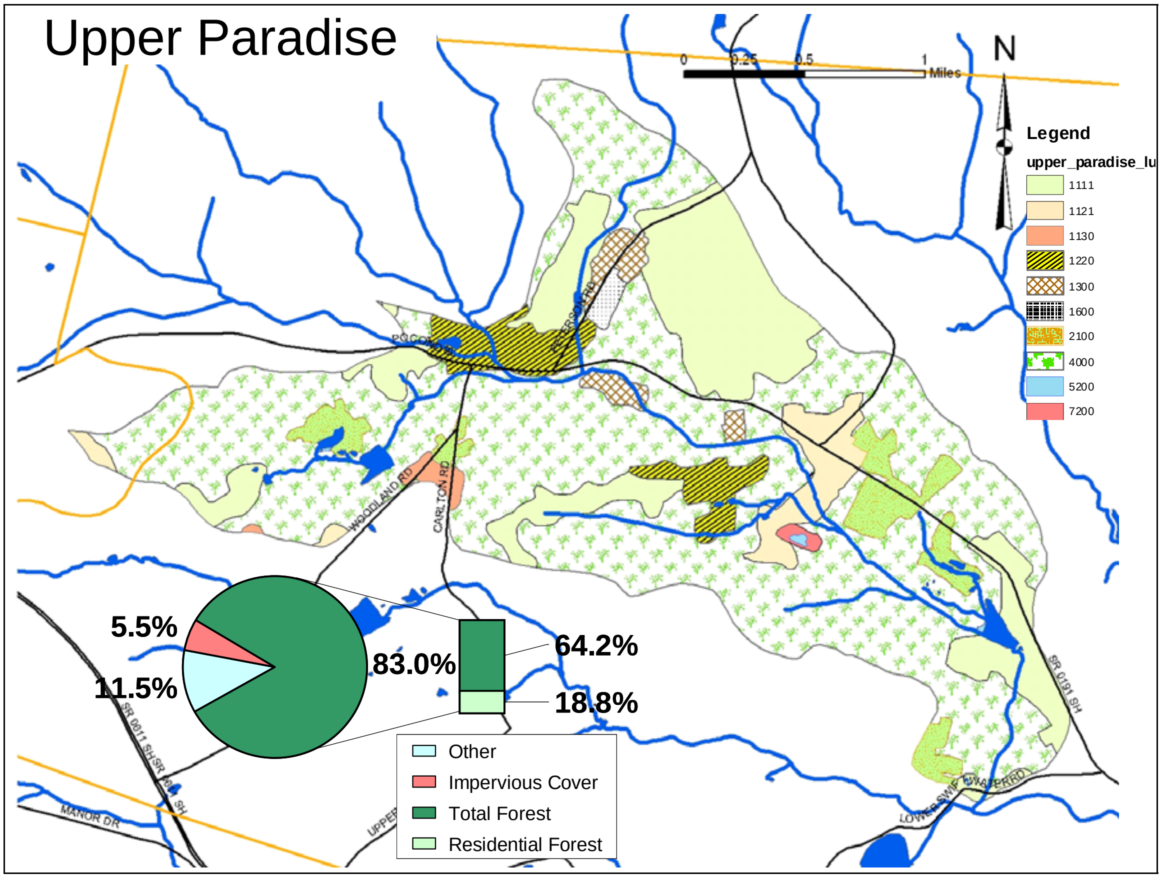

Butz Run
0
0.25
0.5
1
Miles
N
CLUB HOUSE RD
SR0191 SH
HALLET RD
CHERRY LANE RD
SR0715 SH
Legend
butz_lu
1101
1121
1400
2200
4000
5300
5500
7200
2.6%
12.5%
84.9%
64.4%
20.5%
Other
Impervious Cover
Total Forest
Residential Forest

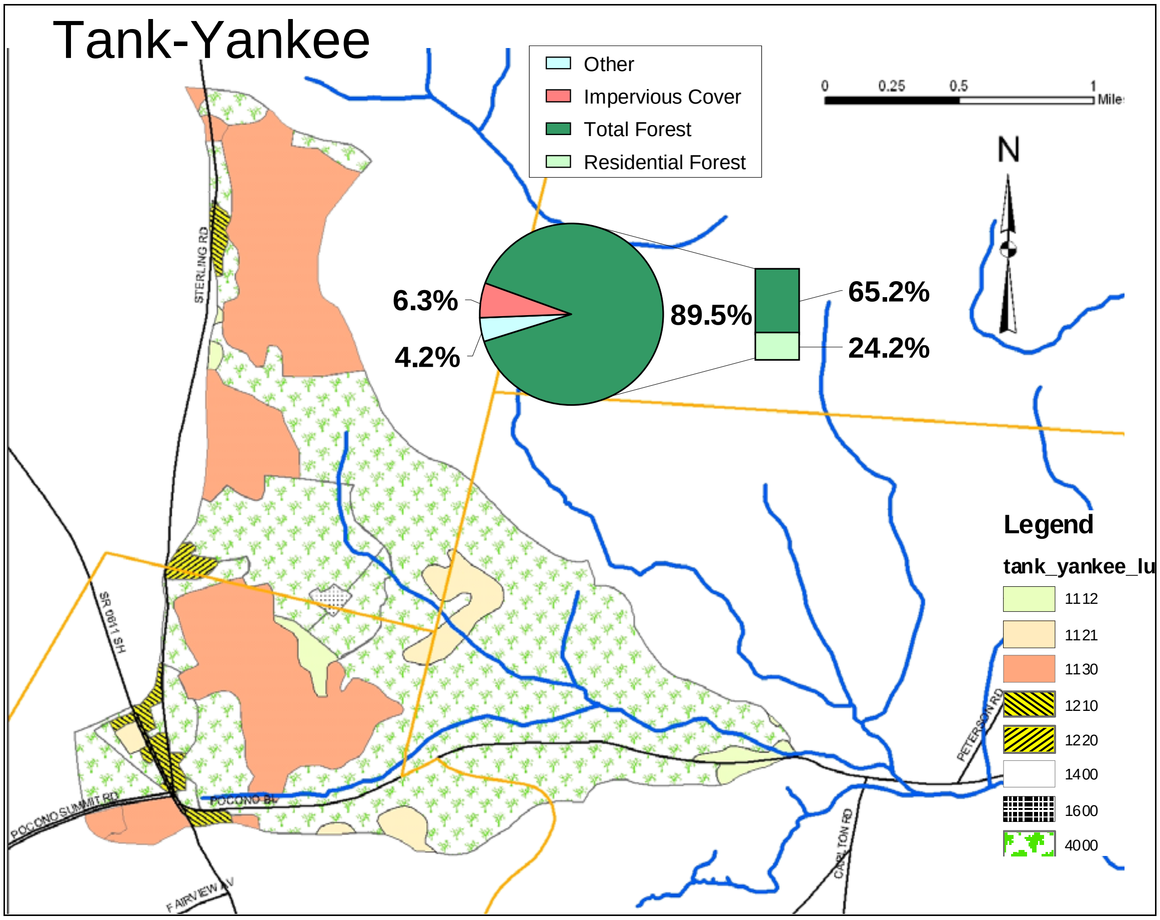

Devils Hole
0
0.25
0.5
1
Miles
N
2.9%
1.8%
95.2%
80.5%
14.7%
Other
Impervious Cover
Total Forest
Residential Forest
Legend
devils_hole_lu
1101
1121
1130
1210
1220
1300
4000
5500
STERLING RD
SR 0611 SH
POCONO BL
PETERSON RD
SR 0191 SH


Forest Hills
Legend
forest_hills_lu
1101
1121
1130
1210
1220
1300
1400
1600
2100
4000
5200
7200
0
0.25
0.5
1
Miles
N
Other
Impervious Cover
Total Forest
Residential Forest
3.7%
16.2%
80.1%
60.6%
19.5%
POCONO SUMMIT RD
FAIRVIEW AV
PETERSON RD
CARLTON RD
MANOR DR
UPPER SWIFTWATER RD
LOWER SWIFTWATER RD
CLUB HOUSE RD


Lower Swiftwater
0
0.25
0.5
1
Miles
N
WOODLAND RD
TON RD
UPPER SWIFTWATER RD
LOWER SWIFTWATER RD
Other
Impervious Cover
Total Forest
Residential Forest
3.8%
13.7%
82.5%
71.0%
11.5%
Legend
lower_swiftwater_lu
1111
1122
1130
1210
1300
1600
2100
4000


Upper Swiftwater
5.5%
11.6%
82.8%
65.3%
17.6%
Other
Impervious Cover
Total Forest
Residential Forest
Legend
upper_swiftwater_lu
1101
1121
1140
1210
1220
1300
1500
1600
4000
5200
7200
0
0.25
0.5
STERLING RD
POCONO SUMMIT RD
POCONO BL
FAIRVIEW AV
SUMMIT AV
SR 0380 SH
LONG POND RD
SULLIVAN TRAIL RD
MANOR DR
WOODLAND RD


Upper Paradise
0
0.25
0.5
1
Miles
N
Legend
upper_paradise_lu
1111
1121
1130
1220
1300
1600
2100
4000
5200
7200
WOODLAND RD
CARLTON RD
MANOR DR
5.5%
11.5%
83.0%
64.2%
18.8%
Other
Impervious Cover
Total Forest
Residential Forest




## Discussion

Impervious cover values as estimated by this analysis are considerably lower than the 10% threshold suggested for the beginning of watershed degradation. Given the primarily forested nature of this region, this is not surprising. While the accuracy of this value needs to be verified, this assessment strongly suggests that this watershed is in good ecological condition with respect to the amount of impervious surfaces present. These surfaces will increase rapidly based on current growth projections, however. Continued monitoring of impervious surface cover within this watershed is required for successful preservation of water quality and quantity because mitigation becomes increasingly difficult after degradation caused by imperviousness[1]. Several factors must also be considered beyond simply the amount of impervious cover present. The distribution of impervious surfaces, point-source discharges of pollution, the condition and extent of riparian buffers, impacts of other land use such as agriculture, and the appearance of the hemlock wooly adelgid as a major factor in the health of riparian hemlock are all potentially strong influences on the integrity of this watershed.

This analysis only provides an initial estimate of impervious cover and assessment of land use for this watershed and needs to be validated. In addition, several data limitations beyond those caused by cloud cover exist in the CEMRI dataset, likely influencing the results. The dataset does not include all impervious surfaces and land uses within the watershed due to a minimum mapping unit of 1 acre or a width of < 120 feet. Impervious cover within contiguous forest, such as that caused by forest roads, is not measured and some misclassification of land use are apparent when polygons are viewed on orthophotos. Finally, to date impervious cover has not been determined for some land use categories (e.g. commercial and industrial) necessitating a more qualitative estimate for these areas. Despite these difficulties, the CEMRI dataset is the most detailed and recent assessment for this region. Continued technological advancement and new data sources also hold promise for the refinement of this impervious cover determination and land use classification. For instance, IKONOS satellite data may be useful in accurately detecting the amount of impervious cover present under a dense forest canopy[6]. USGS digital orthophotos are updated on an approximately 5-year schedule and Monroe County is in the process of releasing its own high-resolution aerial photography. These new techniques and data could be used to measure the validity of this initial analysis and should provide new insight for management, assessment and planning.

## Bibliography


1. Giannotti, L. and S. Prisloe. 1998. Do it yourself! Impervious surface buildout analysis. Technical Paper #4, NEMO (NonPoint Education for Municipal Officials) Project, University of Connecticut Cooperative Extension System. http://www.nemo.uconn.edu

2. Barnes, K. B., J. M. Morgan III, and M. C. Roberge. 2001. Impervious surfaces and the quality of natural and built environments. Dept. of Geography and Environmental Planning, Towson University, Baltimore, MD 21252. http://chesapeake.towson.edu/landscape/impervious/download/Impervious.pdf

3. Stocker, J. 1998. Methods for measuring and estimating impervious surface coverage. Technical Paper #3, NEMO (NonPoint Education for Municipal Officials) Project, University of Connecticut Cooperative Extension System. http://www.nemo.uconn.edu

4. http://www.fs.fed.us/ne/global/research/drb/

5. Albert, R. C. and P. V'Combe, unpublished manuscript

6. Forney W., C. Raumann, T. B. Minor, J. L. Smith, J. Vogel, and R. Vitales. 2000. Land use change and effects on water quality in the Lake Tahoe Basin, Nevada and California: Year-1 progress. USGS Open-File Report 02-014.

# Appendix 1

CEMRI Project Description
USDAForestServiceProjectDescription.txt (ftp://www.pasda.psu.edu/pub/pasda/delwatergap/)

This photography was flown in order to have recent photo coverage, at a reasonably large scale, of the tributary watersheds around the Delaware Water Gap. The imagery was photointerpreted for landuse and landcover and is being used for a study on forest fragmentation and its effects on water quality. The primary reason for choosing this particular area was the need for the Delaware Water Gap National Recreation Area (NRA), managed by the National Park Service (NPS), to monitor and try to maintain the quality of the stream water entering the park. The USGS National Water Quality Assessment (NAWQA) program and the USGS Water Resources Division (WRD) will be collecting stream sample data in the summers of 2001 and 2002. The landuse and landcover information derived from this photography will be summarized, and measures of how the forest and developed landuses are distributed in the basins with respect to the streams and sample sites will be calculated. The relationship between these different parameters of fragmentation and current water quality will be analyzed. The data will also provide baseline information for monitoring these watersheds over time.

The photography was considered necessary because the satellite-derived landuse/landcover maps in the area (e.g. NLCD?92 and PA GAP) were not picking up the numerous residential areas in this region. This gap is understandable, because of the large amounts of tree cover in these residential areas, however the project needed to have more accurate information for investigating how these parameters of fragmentation and landuse composition were related to changes in water quality. The imagery was thus acquired to get an accurate picture of the current status of forest fragmentation and landuse composition in the area.

In addition to the work on forest fragmentation and water quality, the data will also be used as a source of comparative truth about actual land use to try to improve the accuracy of TM-derived datasets in this regard. Detailed mapped photointerpretation as was used in this project is expensive and thus not suited to mapping over large areas. Thus, if we can utilize TM-derived data sources, and other existing information on potential human impact such as road densities or housing densities, to derive the relevant parameters of forest fragmentation and land use context, we will be able to map the status of forest fragmentation and land use context over larger areas. Before we can do so at the scales that are often relevant to changes in water quality, forest composition and health, and some habitats, we need to find ways to improve the ?fragmentation accuracy? of the land use datasets we are working with.
This study is being expanded this summer (2002) to include many of the basins sampled by USGS NAWQA program as part of their larger effort to study the effects of urbanization on streams in the Piedmont and Appalachaian ecoregions of the Delaware River Basin. From this broader gradient of conditions, we hope to address questions like: Which aspects of urbanization and forest fragmentation cause ecological responses? And which of these are ?manageable?? And is the effect gradual or is there a threshold beyond which change is substantial? Those parameters of urbanization and forest fragmentation that are most strongly correlated to change will be those we are interested in monitoring most accurately over the entire region over time. This effort will utilize the 1999 DOQQs now available, but will use most of the same landuse/landcover classes. This photointerpreted data will also be made available on this site when it is completed, probably by the end of 2002.

This project is part of a larger Collaborative Environmental Monitoring and Research Initiative (CEMRI) between the US Geological Survey (USGS), US Forest Service (USFS), the National Park Service (NPS), and other agencies to implement a prototype environmental monitoring strategy that will link air quality, hydrological and forestry information across the landscape of the Delaware River Basin. (for more info, see the CEMRI web site at: http://www.fs.fed.us/ne/global/research/drb/).
Contact for this project: Rachel Riemann, Research Forester/Geographer, Northeastern Research Station, USDA Forest Service, c/o USGS, 425 Jordan Road, Troy, NY, 12180, 518-285-5607, rriemann@fs.fed.us,