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**STAND-BASED STUDY SITE SELECTION FOR SAMPLING BIOLOGICAL
DIVERSITY IN HEMLOCK AND NON-HEMLOCK FORESTS AT DELAWARE
WATER GAP NATIONAL RECREATION AREA**

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Biological diversity (biodiversity) associated with eastern hemlock (*Tsuga canadensis*) and non-hemlock forests will be sampled beginning 1997 within established forest stands at Delaware Water Gap National Recreation Area (DEWA). Boundaries of forest stands at DEWA were defined by vegetation cover type maps provided by resource managers at the Park. Cover type maps are based upon aerial, color infrared photographs of the entire Park (Myers and Irish 1981). No estimate of accuracy for vegetation cover type maps was available for stands at DEWA.

Potential hemlock stands and non-hemlock forest stands were selected based on a sampling design methodology proposed by USGS Biological Resource Division (BRD) researchers at the Leetown Science Center in cooperation with other participants in the hemlock project (Smith et al. 1996, Appendix A). Potential study stands at DEWA were ground-truthed to check the appropriateness of using the proposed BRD methodology to stratify stands based on topographic type (Smith et al. 1996, Appendix A).

Hemlock stands were clustered into 3 topographic types (termed clusters 1, 2, and 3) based on their landscape attributes, as detailed in the sampling design methodology (Smith et al. 1996, Appendix A). Hemlock stands in each cluster type were then paired with non-hemlock forest stands using multivariate analyses of landscape attributes. For aquatic sampling, the 3 clusters were further stratified using the presence of first-, second-,

and third- order streams located within the stands. For terrestrial sampling, only cluster-1 and cluster-2 stands were stratified in this manner. Furthermore, for terrestrial sampling, Penn State researchers chose cluster-3 stands that did not contain streams. Therefore, only cluster-1 and cluster-2 hemlock stands and paired, non-hemlock stands can be sampled for both aquatic and terrestrial communities.

Prior to ground-truthing potential stands to include in the hemlock project, stand maps were examined by researchers from the Leetown Science Center, Penn State, and DEWA. This initial inspection of stand maps excluded several stands from the study before field checks were employed. Based upon visual inspection of stand maps, stands were excluded for the following reasons (Appendix B):

1. Park resource managers indicated that the stand was severely affected by human development and use (e.g., stand was surrounded by private inholdings, paved road traverses stand, etc.)
2. Stand was < 5 ha in size. Potential study stands should be ≥ 5 ha in size to minimize potential edge effects (Orwig and Abrams 1993).
3. Stand was located within the jurisdictional Park boundary *but* outside the existent Park boundary.
4. Stand was heavily influenced by beaver activity.
5. Non-hemlock stands were excluded from terrestrial sampling if located adjacent to hemlock stands.
6. Non-hemlock stands were excluded from aquatic sampling if located downstream from a hemlock stand (e.g., stream contained in non-hemlock stand drained a hemlock stand).

Remaining hemlock stands and non-hemlock pairs were field checked during 3 separate visits to DEWA: 14-15 November 1996, 19 November 1996, and 25-29 January 1997 (Appendices C-G). Carolyn Mahan, Project Associate at Penn State and DEWA personnel (Rich Evans, Jeff Shreiner, or Beth Johnson) field checked stands at each visit. Other researchers also visited forest stands; including researchers from the Leetown Science Center (Dave Lemarie, Craig Snyder, John Young), National Biological Service Aquatic Research and Development Laboratory (Robert Ross, Randy Bennett), Penn State (Rich Yahner, K. C. Kim, Marc Abrams), and National Park Service (John Karish).

In addition to the aforementioned criteria, the following were used during field visits to determine if a stand should be included in the hemlock project:

1. Stand had to be fairly accessible (to facilitate the transportation of sampling equipment to the stand); all stands included as potential study stands required a ≤ 30 -minute walk to reach.
2. Non-hemlock forest stands could not have hemlock as a component in the canopy or be located adjacent to or downstream from hemlock stands.
3. Hemlock stands should be comprised of at least 50% hemlock in the canopy (based upon qualitative inspection of stand).
4. Stands should be located away (> 100 m) from human disturbances such as paved roads, tree plantations, agriculture, human habitation.
5. Aquatic sites should have a minimum of 40 stream widths within the stand. For example, if a stream is 1-m wide, 40 meters of stream must lie within the stand (Ross et al 1996).

After field visits to DEWA, 15 hemlock stands and paired, non-hemlock stands were selected by the BRD researchers at the Leetown Science Center for aquatic sampling (Appendix H). A subset of these cluster-1 and cluster-2 pairs selected by BRD researchers were then chosen by Penn State researchers as potential stands for terrestrial sampling (Tables 1, 2 and 3). In addition, six cluster-3 hemlock stands and paired, non-hemlock stands (without streams) were selected as potential stands for terrestrial sampling at DEWA (Table 4).

REFERENCES:

- Myers, W. L. and R. R. Irish. 1981. Vegetation survey of Delaware Water Gap National Recreation Area. Final Report, USDI National Park Service, Mid-Atlantic Region.
- Orwig, D. A. and M. D. Abrams. 1993. Land-use history (1720-1992), composition, and dynamics of oak-pine forests within the Piedmont and Coastal Plain of northern Virginia. *Can. J. For. Res.* 24:116-125.
- Ross, R., C. Snyder, D. A. Smith, and J. A. Young. 1996. Study plan for Aquatic Biodiversity in Eastern Hemlock Forests. National Biological Service - Leetown Science Center Aquatic Ecology Laboratory, Leetown, WV.
- Smith, D. A., C. Snyder, and J. A. Young. 1996. Sampling design methodology - hemlock biodiversity research program. Draft report, Aquatic Ecology Laboratory, Biological Resources Division, USGS, Leetown, West Virginia.

Table 1. Cluster 1 hemlock stands and paired, non-hemlock stands for use as potential terrestrial sampling sites for hemlock biodiversity research project at DEWA. All stands contain first order streams.*

Hemlock Stand**	Paired, Non-Hemlock Stand** (Name)	Stream Order
1509	243 (White Brook)	1
1368	2035 (Upper Van Campen's)	1
2371? (Van Campen's Bench)	595/676 (Camp Kittatiny)	1

*Detailed description of stands presented in Appendices C-G.

**Stand numbers correspond to numbers on stand maps of DEWA prepared by John Young, Leetown Science Center, 1996.

Table 2. Cluster 2 hemlock stands and paired, non-hemlock stands for use as potential terrestrial sampling sites for hemlock biodiversity research project at DEWA. All stands contain first order streams.*

Hemlock Stand** (Name, if available)	Paired, Non-Hemlock Stand**(Name)
1449 (Broadhead Heller's)	1202 (Salt Dome)
485 (Dry Brook)	1020 (Double Pond)
365	1784 (Upstream of beaver pond)
633 (Adam's)	142 (Shimmer's)
1191(Scenic Gorge-PEEC)	1327 (below PEEC)

*Detailed description of stands presented in Appendices C-G.

**Stand numbers correspond to numbers on stand maps of DEWA prepared by John Young, Leetown Science Center, 1996.

Table 3. Cluster 2 hemlock stands and paired, non-hemlock stands for use as potential terrestrial sampling sites for hemlock biodiversity research project at DEWA. All stands contain second order streams.*

Hemlock Stand** (Name)	Paired, Non-Hemlock Stand**
2107 (Evans' Van Campen Site)	2204
2589 (Coppermine)	2346***

*Detailed description of stands presented in Appendices C-G.

**Stand numbers correspond to numbers on stand maps of DEWA prepared by John Young, Leetown Science Center, 1996.

***This stand has not been located on stand maps of DEWA

Table 4. Cluster 3 hemlock stands and paired, non-hemlock stands for use as potential terrestrial sampling sites for hemlock biodiversity research project at DEWA. No stands contain streams.*

Hemlock Stand**	Paired, Non-Hemlock Stand**
581	2391
2572	1332
1654	1841
1954	1724
1742	2016
2652	1665
1702	2729

*Detailed description of stands presented in Appendices C-G.

**Stand numbers correspond to numbers on stand maps of DEWA prepared by John Young, Leetown Science Center, 1996.

Appendix A

Sampling Design Methodology for Hemlock and Non-hemlock Forest Stands at Delaware Water

Gap National Recreation Area

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Sampling Design Methodology

Hemlock Biodiversity Research Program

This document describes the construction of a sampling design for use in Delaware Water Gap National Recreation Area and Shenandoah National Park to determine the importance of Eastern hemlock (*Tsuga canadensis*) in structuring aquatic and terrestrial communities. The goal of this effort was to stratify field samples using landscape attributes so that large-scale influences on biota could be accounted for and effectively removed from consideration when making comparisons between different forest types. The procedure for laying out sample stands, after several iterations, consisted of the following steps:

1) Landscape attributes were generated park-wide from digital representations of topography. Using a 1:24,000 digital elevation model (based on USGS topography), park-wide layers were generated depicting:

- elevation
- slope (percent)
- aspect (as "northness index"), a continuous scaled variable ($\cos(\text{aspect})$) such that north = 1 and south = -1.
- solar radiance, a relative incident light variable calculated from sun angle and position at the equinox.
- terrain shape or topographic position index, calculated using a method proposed by McNab (1989), a continuous variable depicting slope convexity and concavity - this variable determines whether the local environment is a ravine, ridge, side slope, or bottom.
- stand size (sq. meters), and perimeter
- occurrence of 1st, 2nd and 3rd order streams.

2) Landscape attributes occurring within each hemlock and non-hemlock forest stand were tabulated. Z-scores were used to standardize the landscape variables to mean zero and unit variance. GIS overlay methods were used to compute summary statistics of landscape variables within each stand.

3) Hemlock stands were clustered into 3 basic types based on their landscape attributes.

Multi variate clustering on Z-score means for hemlock stands was used to group stands into similar topographic types. Stands were initially clustered into between 3-10 types. We decided to use 3 cluster types because class types were easily interpretable and accurately depicted the major differences in hemlock stands. Clustering stands into more than 4 types provided no additional information about topographic variation and created uninterpretable classes.

4) Only those stands containing streams were selected for further analysis. Both hemlock and non-hemlock stands were analyzed to determine the length of 1st, 2nd, and 3rd order streams within the stand using GIS overlay techniques. Those stands with some stream length occurring in the stand were selected for further analysis. This reduced the population of hemlock stands from 141 to 55 and non-hemlock forest stands from 2145 to 322.

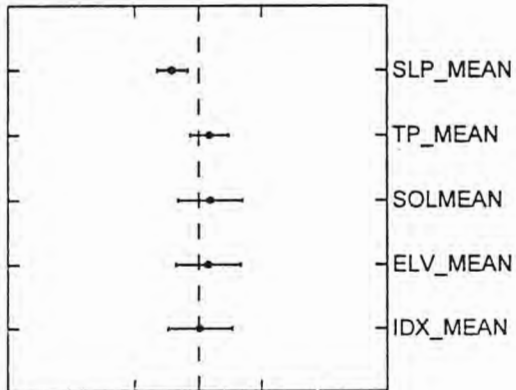
5) The remaining hemlock stands were matched to non-hemlock forest stands by calculating a multi-variate distance using landscape variables. An attempt was made to match hemlock stands to non-hemlock forest stands in order to find stands with similar physiographic environments, but different forest composition. A function was constructed in Splus ("match pair()", D. Smith) that computed a multi-variate distance between hemlock and non-hemlock forest stands based on landscape variables. Through experimentation, four landscape variables were chosen to conduct matching between stands: elevation, slope, solar radiance, and topographic position. These variables accounted for most of the topographic variation. Matching was constrained within hemlock stand types and within stream order groupings. Multi-variate distances were ranked and the top 5 (sometimes 10) "closest" non-forest stands were used to select replicates for each hemlock stand. Preliminary sample sites (hemlock stands, and three non-hemlock forest stands) were selected based on forest composition, multi-variate distance, length of stream reaches, and to a lesser extent, area.

6) Stands were mapped to facilitate field checks. Since accuracy of this method is highly dependent on GIS data layers, field checks will be used to facilitate accuracy assessment of cluster types, and matched stand pairs. A stand ID is given to each hemlock and non-hemlock forest stand based on the polygon ID of the GIS coverage. (Note: this polygon number will not be the same as the park's DEWA_VEG layer). Tables listing the matched hemlock and non-hemlock stands can be used along with the printed maps to locate sample sites. All proposed sites should be visited to check the appropriateness of using this methodology to stratify stands based on topographic type.

Sampling methods developed by David Smith, Craig Snyder, and John Young, Aquatic Ecology Laboratory, Biological Resources Division, USGS, Leetown, West Virginia.

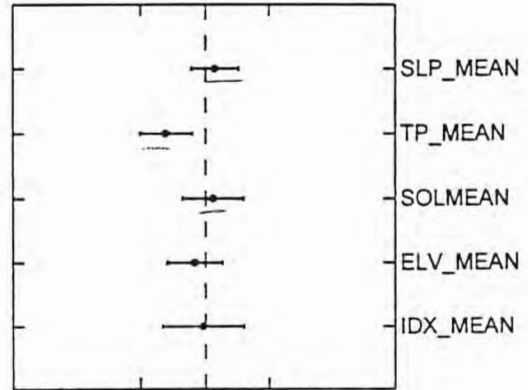
Cluster Profile Plots - DEWA

1



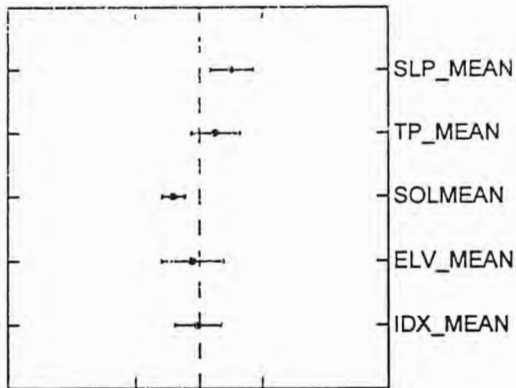
"Bench-type"

2



"Ravine-type"

3



"North-facing, midslope type"

Appendix B. Stands that were NOT field-checked but were deemed inappropriate for the hemlock project at DEWA.

Stand #	Type	Cluster	Stream Order	Size (ha)	Include/Exclude	Comments
1532	Hemlock	1 (bench)	second		Exclude	was a potential pair for stand 1335 but is too influenced by human development and use; not on original NBS list
775	Non-hemlock	1 (bench)	first	2	Exclude	too small and partially located outside the Park boundaries
1615	Non-hemlock	1 (bench)	first second	30	Exclude	severely influenced by beavers
1523	Non-hemlock	1 (bench)	first	12.2	Exclude (aquatics)	downstream of Tillman's Ravine...not a good aquatics site because too influenced by the hemlocks upstream
1901	Non-hemlock	1 (bench)	first	20	Exclude	Has many private in-holdings
1369	Non_hemlock	1 (bench)	second	24	Exclude (aquatics)	drains a hemlock stand
1406	Hemlock	2 (ravine)	second	4	Exclude	too small?
636	Non-hemlock	2 (ravine)	second	25	Exclude (aquatics)	drains a hemlock stand
2584	Non-Hemlock	2 (ravine)	second	4.4	Exclude (aquatics)	drains a hemlock stand
1935	Non-Hemlock	2(ravine)	second	8.6	Exclude (aquatics)	drains a hemlock stand
142	Non-Hemlock	2 (ravine)	second	8.5	Exclude	human development

Stand #	Type	Cluster	Stream Order	Size (ha)	Include/Exclude	Comments
1672/1649/1670	Non_hemlock	2 (ravine)	third	> 10	Exclude (aquatics)	all drain hemlock
1673	Hemlock	3 (mid-slope)	first	6.2	Exclude	human development
2109	Non_hemlock	3 (mid-slope)	first	11.1	Exclude (aquatics)	drains a hemlock stand
1272	Non-hemlock	1 (bench)	second	8.6	Exclude	partially outside Park
1497	Non-hemlock	1 (bench)	second	11.6	Exclude	outside Park
634	Non-hemlock	1 (bench)	second	13.5	Exclude (aquatics)	drains hemlock
285	Non-hemlock	1 (bench)	third	14.5	Exclude (aquatics)	drains hemlock
2287	Non-hemlock	1 (bench)	third	13.9	Exclude (aquatics)	drains hemlock
643	Non-hemlock 1 (1 (bench)		third	157	Exclude (aquatics)	drains hemlock
58	Non-hemlock	1 (bench)	third	5.2	Exclude	human influence/development
1260	Non-hemlock	2(ravine)	first	8.5	Exclude (aquatics)	drains hemlock
1858	Non-hemlock	2 (ravine)	first	2.4	Exclude (aquatics)	drains hemlock
1785	Non-hemlock	1 (bench)	first	2	Exclude	too small?

Stand #	Type	Cluster	Stream Order	Size (ha)	Include/Exclude	Comments
525	Non-hemlock	3 (mid-slope)	first	13	Exclude (aquatics)	drains hemlock
613	Non-hemlock	3 (mid-slope)	first	10.7	Exclude (aquatics)	drains hemlock

Appendix C. Stands that were field-checked on November 14, 1996 and could be included in hemlock project at DEWA.

Stand #	Type	Cluster	Stream Order	Size (ha)	Pair Stand #	Include/Exclude	Location
1020	Non-Hemlock	2 (ravine)	first (intermittent)	17.2	Dry Brook	Include	Located across Rte 209 from Double Pond on Pa. side
1202	Non-Hemlock	2 (ravine)	first (intermittent)	> 8.6	1449 (Heller's)	Include	Located just south of salt dome on Rte 209 (PA)
1449	Hemlock	2 (ravine)	first (upstream) second? (downstream)	15.9	1202	Include	Located just North of Heller's property along "Broad-head Heller's" creek (PA)
1335	Non-Hemlock	1 (bench)	second	22.8	1368	Include	Located off Briscoe Road near P.E.E. C. (PA) along Tumbling Waters
1368	Hemlock	1 (bench)	second	38.7	1335	Include	Located just downstream of stand 1335 along Tumbling Waters
1059/1079	Hemlock	2 (ravine)	second, third	> 32.6	1614	Include	Located off of Emery Road along Hornbecks'
633/584	Hemlock	2 (ravine) misabeled as a bench	first second	4		Include as a continuation of stand 605	Upper portion of Adams' Creek (PA)
605/657	Hemlock	2 (ravine)	first second third	10.9		Include, data was collected here in previous work	Along Adams' Creek (PA)

Stand #	Description	Comments
1020	mixed hardwood; red and white oak, red maple, black birch dominate	
1202	mixed hardwood; red oak, sugar maple dominate; large sycamore	can park on pull-off across from "mile 10" marker on Rte 209
1449	eastern hemlock; some beech	found 'twice-stabbed' beetle (poss. bio. control for HWA); beech bark disease detected in stand; access of old road (blue flag marks turn-off to stand)
1335	white oak, red maple, some iron wood	blue flag off of trail from Briscoe Road marks entrance to stand
1368	eastern hemlock	may not want to pair with 1335 because on same stream; 150 m of the stream is in the true bench-type habitat
1059/1079	eastern hemlock	two large waterfalls are along the 2nd order portion of the stream above the tributary; may want to use the tributary as a first order stream; waterfalls could make aquatic sampling difficult
633/584	eastern hemlock, white pine	as mentioned, mislabeled as a cluster 1 (bench) site
605/657	eastern hemlock, white pine	should use this site because it is a site that contains very good data from previous work done in hemlock stand

Appendix D. Stands that were field-checked on November 14, 1996 but should not be included in hemlock project at DEWA.

Stand #	Type	Cluster	Stream Order	Size (ha)	Pair Stand #	Include/Exclude	Location	Description	Comments
1797	Non-hemlock	1 (bench)	first	24.9	605? this is not a cluster 1 stand	Exclude	off Broadhead Road (PA)	Hickory, ash, w. oak birch, above a hemlock ravine	too small and is influenced by human development upstream

Appendix E. Stands that were field-checked on November 19, 1996 and could be included in hemlock project at DEWA.

Stand #	Type	Cluster	Stream Order	Size (ha)	Pair Stand #	Include/Exclude	Location	Description	Comments
1509	hemlock	1 (bench)	first	not on original NBS list		Include	NJ side; N. of Butter-milk falls	about 50-60 yrs. old on one side of stream; older (75 yrs.) on other	K.C. Kim counted approx. 50 hemlock trees in a 30 X 30 m plot
2107	hemlock	2 (ravine)	second/third	not on original NBS list		Include	Van Campen's ravine	resembles a "half ravine"; one side of the stream is steep and ravine-like while other side is more flat	should be used because there is previous data from this hemlock ravine
?	hemlock	3 (mid-slope)	none	not on original NBS list because no stream present		Include	NJ side; in between stands 1653 and 1673 along road	mature hemlock mid-slope stand; seems quite extensive	no stream present; may have to use mid-slope sites without streams
1901	non-hemlock	1 (bench)	first	21	2037	Include	NJ side; near Flatbrookville	about 60 yrs. old; near road; dominated by white ash	

Appendix F. Stands that were field-checked on November 19, 1996 and should not be included in hemlock project at DEWA.

Stand #	Type	Cluster	Stream Order	Size	Pair Stand #	Include/Exclude	Location	Description	Comments
1653	hemlock	mid-slope	first	5	2826	Exclude	NJ side;	waterfall in the stand; hemlocks are about 60 yrs. old	On the ground this site really resembles a ravine site
1673	hemlock	mid-slope	first	6	2109	Exclude	Buttermilk Falls	rock-face with waterfall surrounded by hemlocks	this site would be extremely difficult to sample; also gets a lot of human use because it is near the Appalachian Trail

Appendix G. Stand number and descriptive information for all stands visited at DEWA during the week of 25 January 1997.

Stand #	Type	Cluster	Stream Order	Size (ha)	Acceptable/Unacceptable	Description	Comments	Location
785	Hemlock	2	1	4.3	A	stream flow resembles order 2 stream	may be too small & affected by visitor use	adjacent to Dingman's visitor center (Pa)
2164	Non-hemlock	2	3	77.1	U	stream flow resembles order 2 stream; not a very steep ravine; runs along rte. 209		adjacent to Bushkill Outreach (Pa)
940	Non-hemlock	2	1	96.1	A	pure hardwood stand	no hemlock ravine located to pair with this stand	easy access along rte 209, north of Double Pond (Pa)
142	Non-hemlock	1	2	8.5	A	pure hardwood stand	pairs with hem. stand #633 (Adam's)	Shimmer's; located on NJ side of Park near Dingman's Ferry Bridge
2589	Hemlock	2	2	7.5	A	narrow hemlock ravine; hiking trail runs through stand	pairs with stand 2346 which is not printed on maps; pairs poorly with other non-hemlock stands	Coppermine; located on NJ side of Park below Van Campen's brook
2652	Hemlock	3	N/A	7.3	A	approx. 50-60% hemlock crown closure	pairs with non-hemlock stand 1665	located along rte 206 on NJ side of Park
2371	Hemlock	1	2	12.2	A/U	a mixed hemlock/hardwood stand; has a powerline running through the stand	R. Evans feels this is not the best bench hemlock site but could be acceptable if others are not located	located just downstream of Watergate Rec. Area along Van Campen's Brook (NJ)
2064	Hemlock	1	1	5.4	U	actually a hemlock ravine; downstream stand may be a good bench site	a lot of adelgid infestation in this stand	located along road to Crater Lake on NJ side of Park

1954	Hemlock	3	N/A	11.6	A	mixed stand of old and young hemlocks; agriculture is located across road from stand	pairs with non-hemlock stand 1724	located on NJ side of Park along Old Mine Road
1654	Hemlock	3	N/A	14.3	A	middle of stand becomes mixed with sugar maple and white oak trees; rock outcrop near top of stand	pairs with non-hemlock stand 1841	located on NJ side of Park
1702	Hemlock	3	N/A	> 5	A	portion of a continuous stand of mid-slope hemlocks	pairs with non-hemlock stand 2729	located on NJ side of Park
1742	Hemlock	3	1	19.1	A	portion of a continuous stand of mid-slope hemlock; a mini-ravine runs through the center of stand	pairs with non-hemlock stand 2016 or 368	located s. of stand 1702 on NJ side of Park
1265/1306	Non-hemlock	2	1	12	U	one side of the stream is dominated by hemlocks; resembles "half a ravine"		located on NJ side of Park
595/676	Non-hemlock	1	2	7.2	A	stand dominated by ash, tulip poplar, hophornbeam; is located near some agriculture	pairs with hemlock stand 2371	located near Camp Kittatiny on NJ side of Park
711	Non-hemlock	1	1		U	only a short reach of the first order stream is within the stand	neighboring stands 595/676 are better bench sites	located near Camp Kittatiny on NJ side of Park
643/682	Non-hemlock	2	1	15.7	U	upper portion of stand resembles a "bench"; lower portion enters into a hemlock ravine	located near road and stream may be influenced by road salt	located along Silver Lake Rd (Pa)

1191	Hemlock	2	1 and 2	21.1	A	hemlock-dominated stand that contains both first and second order streams; best to use second order portion of stream	pairs with non-hemlock stand 1327	located behind PEEC along the Scenic Gorge Trail (Pa)
1327	Non-hemlock	2	1	13.8	A	based on flow, stream resembles second not first order	pairs with stand 1191	located below PEEC along rte 209 (Pa)
1784	Non-hemlock	2	1	8.1	A	an open, "U"-shaped ravine; located above an active beaver pond	pairs with hemlock stand 365	located along rte 209 on Pa side of Park
1928/1934	Hemlock	2	1	6.2	U	mixed stand of hemlock, beech, and oak trees; most of the hemlocks are codominant trees	only a very short portion of the first order stream reach is within the hemlock stand; stand is not dominated by hemlock but is very mixed	located just off of rte 209 on Pa side of Park
1850	Non-hemlock	2	1	11.2	U/A	acceptable aquatic ravine site but it is located near a hemlock stand; may be too hemlock influenced for terrestrial sampling	no pairs located	located on Pa side of Park
2181	Hemlock	3	N/A		U	hemlock dominated forest on a very steep slope (> 100%)	too steep for any terrestrial sampling	located along Wallpack Bend on Pa side of Park
2137	Non-hemlock	3	N/A		U	dominated by red maple and oak trees; the stand contains a powerline	does not appear to be very representative of a mid-slope site	located near Bushkill on Pa side of Park
1712	Hemlock	2	2	10.7	U	mixed hemlock ravine;	upper portion of this ravine is very influence by human development	located along Toms Creek on Pa side of Park

243	Non-hemlock	1	1	9	A	some scattered hemlocks in the stand and is located near some old fields	sampling should be conducted S. of abandoned farm; pairs with hemlock stand #1509	located along White Brook on NJ side of Park; near Dingman's Ferry bridge
561	Non-hemlock		1	2.8	U	mixed hardwood/hemlock stand	too dominated by hemlock to be considered as a hardwood pair	located on NJ side of Park
529	Non-hemlock	2	2	8.3	A	resembles a mixed hardwood bench to some extent	no pairs identified yet	located on NJ side of Park
845/846	Non-hemlock	2	2	13.1	U	a shallow ravine; has a red pine plantation located along stream		located on NJ side of Park
1366	Non-hemlock	2	2	2	U	hemlocks are located in this ravine; in addition w. pine and a pine plantation are located along the stream		located on NJ side of Park
2075	Non-hemlock	3	N/A	12.7	A	hardwood stand located near a private residence	no hemlock pairs located	located near the mouth of the Flatbrook on NJ side of Park
1724	Non-hemlock	3	N/A	15.6	A	hardwood stand located along Old Mine Road	pairs with hemlock stand # 1954	located on NJ side of Park along Old Mine Rd
1827	Non-hemlock	3	N/A	5.2	A	hardwood stand	no hemlock pairs located	located on NJ side of Park
1862	Non-hemlock	3	N/A	6.4	A	hardwood stand located near an old field	no hemlock pairs located	access along Old Mine Rd on NJ side of Park; road to stand is gated

1665	Non-hemlock	3	N/A	57	A	hardwood stand located along Old Mine Rd	pairs with hemlock stand # 2652	located along Old Mine Rd on NJ side of Park; across the street from ag. lands
1841	Non-hemlock	3	N/A	10.8	A	hardwood stand located along Pa rte. 209	pairs with hemlock stand # 1654	located just S. of stand 1784 on rte. 209 on Pa side of Park
1883	Non-hemlock	3	N/A		A	hardwood stand	no hemlock pairs located	located off SR 2001 on the Pa side of the Park
786	Non-hemlock	2	1	1.8	U	very hemlock influenced; hemlock trees throughout the stand	stand borders on posted private property	located along Child's Rec. Area on Pa side of Park
822	Hemlock	1	1	10.6	A	resembles a hemlock ravine not a bench	no non-hemlock pairs located	located along Johnny Bee Rd on Pa side of Park
365	Hemlock	2	1	2 (larger?)	A	hemlock dominated ravine	pairs with non-hemlock stand # 1784	located on Pa side of Park
1727	Non-hemlock	3	N/A		U	very disturbed by human development		located on border of Park on the NJ side
1762	Non-hemlock	3	N/A		U	very disturbed by human development		located on border of Park on the NJ side
1789	Non-hemlock	3	N/A	27	U	access is difficult and borders a hemlock stand		located near Crater Lake on NJ side of Park
2391	Non-hemlock	3	N/A	8.9	A	mixed stand of oaks and maple; not a very steep mid-slope site	pairs with hemlock stand #581	located behind Watergate on NJ side of Park

2696	Hemlock	3	N/A	5.5	U	very steep hemlock-dominated stand; a stream runs through the stand; high human use area;		located in Worthington State Forest on NJ side along rte 206
2729	Non-hemlock	3	N/A	40	A	pure hardwood stand	pairs with hemlock stand # 1702	located in Worthington State Forest on NJ side of Park, along rte. 206
2795	Non-hemlock	3	N/A	12.9	A	pure hardwood stand	no hemlock pairs located	located in Worth. State Forest on NJ side of Park, along rte 206
581	Hemlock	3	N/A	16.4	A?	could not access during Jan. visit; Rich Evans seems to think this is an appropriate site	pairs with non-hemlock stand # 2391	located off of rte. 209 (Pa)
2016	Non-hemlock	3	N/A	8.6	A?	could not access during Jan. visit	pairs with hemlock stand # 1742	located S. of Buttermilk Falls on NJ side of Park

Appendix H

**Hemlock and Paired, Non-hemlock Forest Stands at Delaware Water Gap National Recreation Area
for use as Aquatic Sampling Sites**

Cluster 1/Order 1

Hemlock			Non-hemlock		
Stand No.	Stream State	Comments	Stand No.	Stream State	Comments
1509	Unnamed trib. of Flat Brook, NJ	BIG stand	243	White Brook NJ	
2037	Unnamed trib. of Flat Brook, NJ	<i>Looks like 2nd order¹</i>	529	Unnamed NJ	Enters Del. R. nr Namanock Isl. <i>Drains some hemlock</i>
822	Dingmans Creek PA	pond source. <i>CGM could not find pond. Very ravine-like</i>	1909	Unnamed trib. of Flat Brook, NJ	Near Park cabin & group camp, Flatbrookville. "Donkeys Corners". <i>Too near hemlock for terrestrial, but OK for aquatic.</i>
			2881*	Slateford Creek PA	<i>Jeff Shriner says access is tough; 2-4 mile hike on AT. Alternate site, some urban influence. Stroudsburg Quad</i>

* - May need to be field checked.

Italicized notes are Carolyn's comments, 10 Feb 97.

¹ If 2037 is more like 2nd order, 894 may be a more comparable match.

Cluster 1/Order 2

Hemlock			Non-hemlock		
Stand No.	Stream State	Comments	Stand No.	Stream State	Comments
1368	Tumbling Waters, PA (Sunset Lake)	Just downStream State from stand 1335, near PEEC	2035	Vancampens Brook, NJ	Just upstream of 2107. Some development. <i>High visitorship; hiking and horseback.</i>
2107	Vancampens Brook, NJ	In matrix of hardwood. <i>One of Rich Evans' original study sites; he called a ravine². Stand boundary may be incorrect.</i>	1335	Tumbling Waters (Sunset Lake)	Located off Briscoe Road near PEEC. <i>No good for terrestrial. 2204 was also identified as a potential match for 2107.</i>
1532*	Toms Creek PA	<i>Rich has problems with this one. Mixed ravine with many leach fields in upper part of drainage³.</i>	894	Unnamed NJ	Near stand 845. Just below confluence of two 1st order streams.
2371	Vancampens Brook, NJ	<i>Rich prefers 2037 here, although this would be OK if necessary. Drains Watergate Rec. Area⁴. Hemlock probably only on north side.</i>	595/676	Unnamed NJ	near Kittatiny Camp. Culvers Gap quad

* - May need to be field checked.

Italicized notes are Carolyn's comments, 10 Feb 97.

² Question: Was Rich's study site in the same stand area, or just the same stream? Topo maps suggest bench in identified stand.

³ Eliminate 1532. 894 is therefore available, see Cluster 1/Order 1 comments. Intend to use other three pairs.

⁴ Response: Both 2371 and 595/676 drain camp areas. We feel this is a good match.

Cluster 2/Order 1

Hemlock			Non-hemlock		
Stand No.	Stream State	Comments	Stand No.	Stream State	Comments
1449	Broadhead-Heller's Cr.	N. of Heller's property. Trib. of Tumbling Waters.	1202	Unnamed PA	S. of salt dome on Rt. 209. Upstream of Shapnack Island
485*	Dry Brook PA		1020	Unnamed PA	Across Rt 209 from Double Pond.
365	Conashaugh PA		1784	Unnamed PA	beaver pond. Next drainage downstream of Toms.

* - May need to be field checked.

Cluster 3/Order 1

Hemlock			Non-hemlock		
Stand No.	Stream State	Comments	Stand No.	Stream State	Comments
1673	Unnamed trib. of Flat Brook, NJ		2204*	Unnamed trib. of Del. NJ	mixed hemlock similar to trib. of Toms site.
1653*	Unnamed trib. of Flat Brook, NJ		578*/561	Unnamed trib. of Del. NJ	Above road is good, below road is mixed (~10%). Enters near Namanock Isl.
1742	Unnamed trib. of Flat Brook, NJ		1614	Unnamed trib. of Flat Brook, NJ	coded as 2nd order, but has little discharge, therefore matched as 1st. May be mixed site twd top.
2843*	Caledonia Cr. PA	Stroudsburg Quad			Close to town of Delaware Water Gap.
			2868*	Unnamed trib. of Del. PA	May be mixed stand. Stroudsburg quad
			2883*	Unnamed trib. of Del. PA	Above 2868. Also mixed. Small stream. Stroudsburg quad
			2845*	Caledonia Cr. PA	Small hemlock stand splits this stand - may be able to work above. Is mixed stand. Feeds Lake Lanape

* - May need to be field checked.