Appendix G. Applications of the NPSP Index

Using the NPSP Index with Historical Monitoring Data

Applying the NPSP Index with historical monitoring data makes use of the index at a single point, the monitoring point, which defines the drainage area contributing to that point on the stream. No modeling is required to apply the index in this mode, only a historical data set, and the TABINDX2 program, which calculates monthly indexes from tabular data, identical to the MAPINDX2 program incorporated in AGNPS File Builder. MAPINDX2 calculates spatially-distributed monthly indexes from map layers of runoff and loads.

For this application, the historical data from Bull Run for the period 1977-1986 was used to illustrate monthly and annual trends in the index. This time period was chosen since it corresponded both with the record of storms modeled previously and the runoff record from the USGS surface runoff gauge at the same site, which was discontinued after 1986. The USGS gauge was maintained solely for recording flow with an automatic data recorder and was serviced weekly. OWML base flow samples were reportedly taken on a weekly basis, except in winter when a bi-weekly schedule was followed. The USGS data was considered more reliable because of its more rigorous schedule with respect to flow data and its focus on a single parameter, and was used to judge when the OWML flow data was in error. A month-by-month comparison of the 2 sets of runoff data was made by calculating monthly differences in runoff. The OWML record was considered in error whenever a monthly difference of 50 mm occurred, or whenever a monthly difference of 20 mm occurred together with monthly OWML runoff greater than twice the amount of the USGS monthly runoff. The two months noted previously with suspect nutrient concentrations were also excluded. This resulted in a comparison of 111 of the 120 months over the 10-year period. Median-based statistics on the monthly NPSP index are illustrated in Figure 6-1, with annual statistics in Figure 6-2. All of the index values for this watershed are less than, or just slightly more than 3 on a scale of 10, indicating good to excellent water quality in this watershed, as one might expect for a highly protected watershed. Considerable variation is evident within each month, with median values generally quite low with the exception of the month of May, which has the highest median value, as well as one of the highest monthly inter-quartile ranges. Of note in Figure 6-2 is the distribution of indexes in 1978, which shows that half or more of the months had the lowest possible index rating, while one of the months showed one of the highest index values over the 10-year period.

To supplement the data in Figures 6-1 and 6-2, monthly median values were also calculated on monthly loads of TN and SS in kg/ha, and monthly runoff volumes in cm. These are shown for monthly and annual median values in Figures 6-3 and 6-4, respectively. While all four measures show the same trends on an annual basis, they mask the monthly variation which pops out in Figure 6-3, especially in the month of May. This is one of the strengths of the index, that of emphasizing inter-monthly variation.

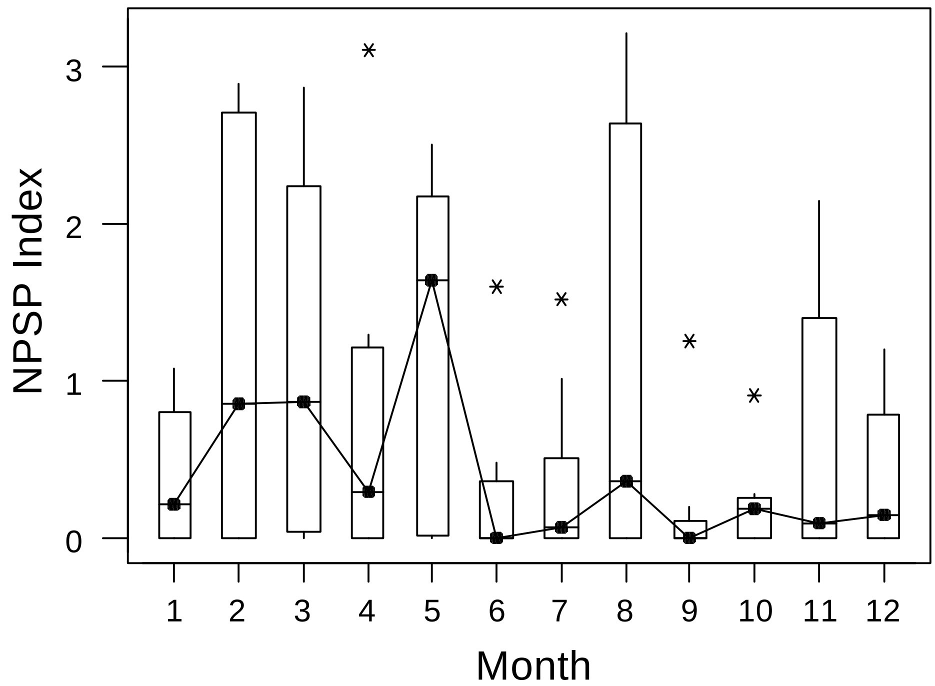

Figure G-1. Monthly Index Ranges

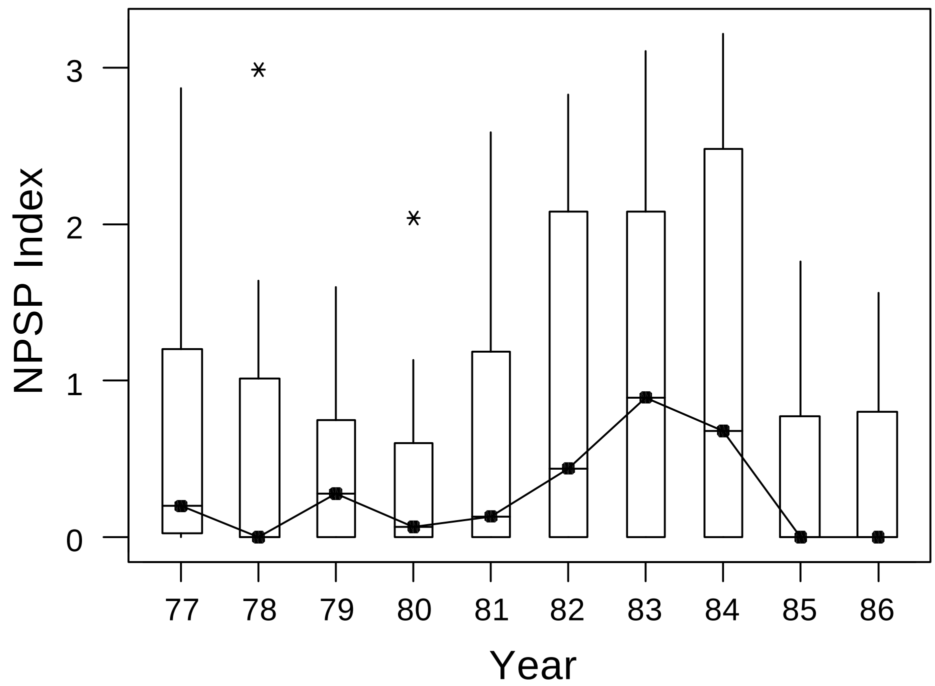

Figure G-2. Annual Index Ranges

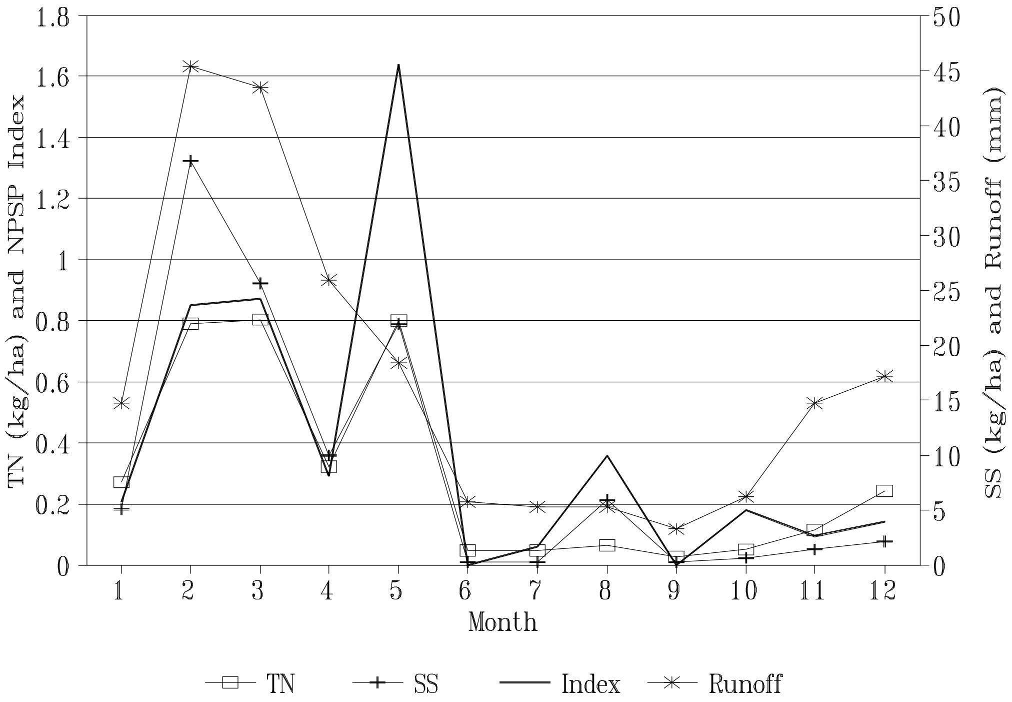

Figure G-3. Monthly Medians

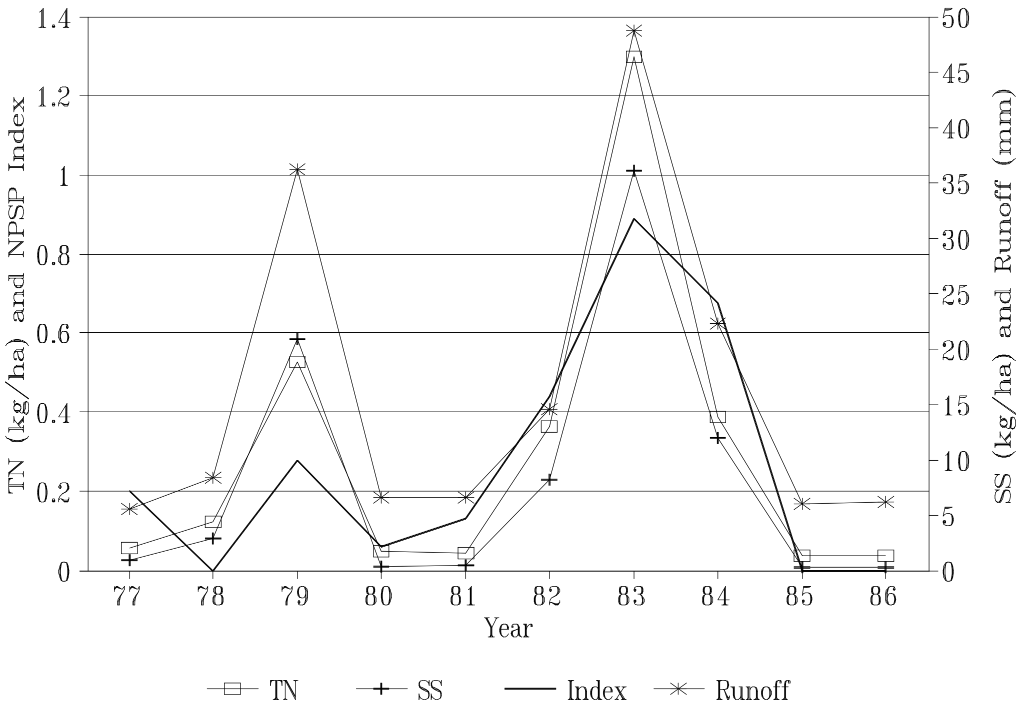

Figure G-4. Annual Medians

Using the NPSP Index for Targeting Within a Watershed

When using the index in conjunction with the AGNPS model, the index can be calculated for all stream cells in the watershed, or for any number of distinct sub-watersheds which can be defined using watershed delineation utilities such as those of Jensen and Dominigue (1988), Martz and Garbrecht (1993), or Garbrecht and Martz (1995).

Two distinct types of drainage sub-areas are commonly encountered in a watershed as illustrated in Figure 6-5: *upland watersheds (A1,A2)* and *downstream extensions (C).* Upland watersheds each drain to a common point (B), the outlet, and have no channel flow entering from outside of the area. Downstream extensions receive incoming channel flow from one or more upland watersheds. Flow and loads at the outlet (D) of a downstream extension watershed includes flow and loads both from the downstream extension (C) and from the upland watersheds (A1 and A2). In order to evaluate the impact of downstream extension sub-area C, incoming total loads and flow must be subtracted from those exiting at point D, in order to isolate total loads and flow for sub-area C. Unit area loads and mean monthly concentrations for sub-area C are calculated from the total loads and flow for sub-area C along with its corresponding area. This procedure was followed for calculations of all downstream extension sub-watersheds in this illustration. USGS watershed delineation procedures were used to sub-divide the Bull Run watershed into 13 sub-watersheds, 8 of which are upland, and 5 downstream extensions, as shown in Figure 6-6. Two different storms were chosen to represent low and high runoff conditions for illustration with the NPSP index. Low flow was simulated by a 1.0" storm, which is just above the minimum TR-55

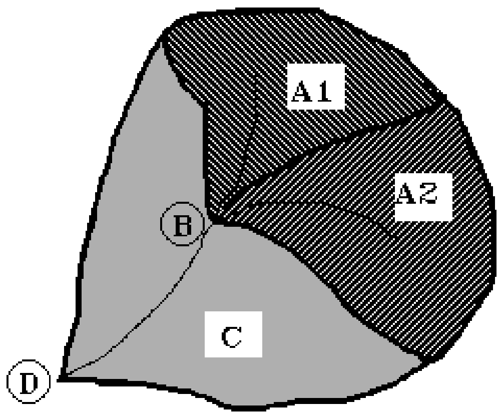

Figure G-5. Example Drainage Sub-Areas

modeling threshold for AMC=2. High flow was simulated as a TP-40 10-year design storm of 5.5", also at AMC=2. Both were simulated for June 15, 1992 conditions on the watershed. Currently, much NPS pollution targeting is performed with unit area loads of sediment, nitrogen or phosphorus, depending on the nature of the problem. In order to illustrate the use of the NPSP index for targeting with these current methods, model output by sub-watershed was ranked using total nitrogen (TN) and suspended sediment (SS) in kg/ha, to represent current targeting, and the unitless NPSP index. Figure 6-7 shows how each of the sub-watersheds ranked with each of the three ranking measures during the low flow condition, while Figure 6-8 shows rankings for the high flow condition. A watershed rank of 1 indicates high loads and indexes, while increasing rank indicates decreasing level of pollutants. Figures 6-7 and 6-8 show that all of the indicators selected the same 2 or 3 highest and the same 4 or 6 lowest ranked sub-watersheds within each flow condition. When comparing rankings by a specific pollutant, e.g.

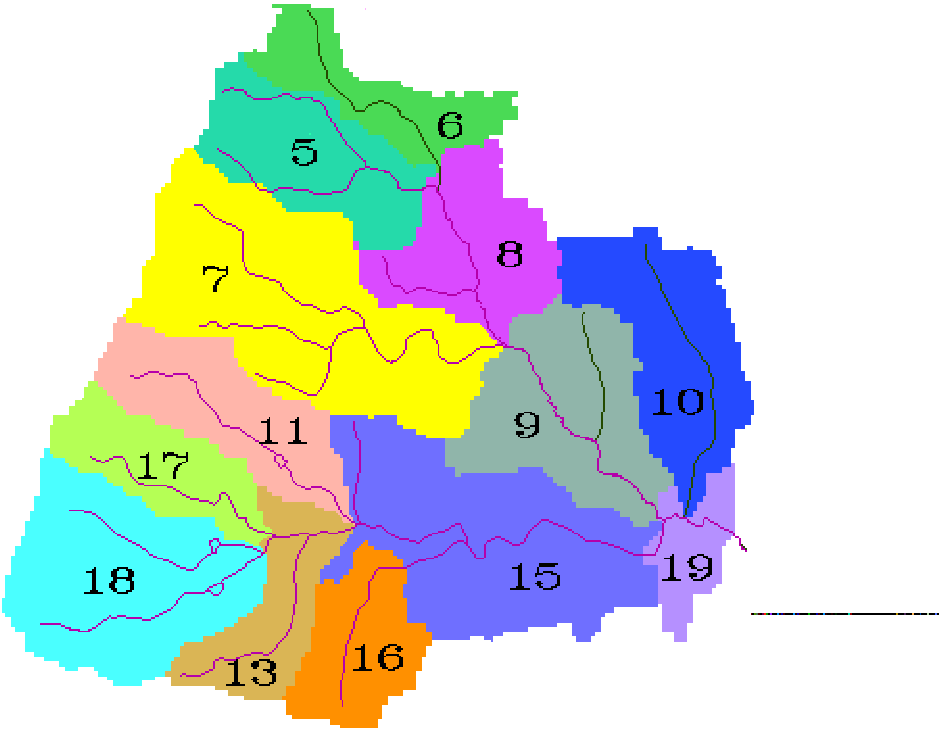

Figure G-6. Bull Run Sub-Watersheds

TN, on a unit area load basis versus ranking with the NPSP index for the same storm, the only factors that can change the relative ranking in the index are runoff and the unit area loads of the other pollutants, in this case, TP or SS. Each unit area load is translated to a sub-index value with its rating curve, but this translation does not affect the relative ranking of individual pollutants.

In order to explain the shift between relative rankings of the sub-watersheds with one of the unit area load indicators and with the index, it is necessary to look at the reasons why one or more sub-watersheds produce more or less runoff than the others. From Figures 6-7 and 6-8, sub-watershed 5 shifted 2 or more ranks upward between both TN and SS, and the index, under both flow conditions. Sub-watershed 10 also shifted 3 or more ranks downward between SS and the index rankings for both flow conditions. In sub-watershed 5, since rankings increased, we expect relative runoff to be less than from other sub-areas, while in sub-watershed 10, we would expect the opposite. From Table 6-1, we see that sub-watershed 5 is 50% forested, a land use that typically produces less runoff than agricultural or urban uses, consistent with out expectations of less runoff in this area. Sub-watershed 10, on the other hand, has the highest percentage of agricultural land of any of the sub-watersheds, a land use which typically produces greater runoff than forested and most rural residential land uses, also consistent with expectations.

When comparing the rankings between high and low flow conditions, the order of watersheds changes around considerably. Figure 6-9 illustrates the ranking changes for the NPSP index from the low to the high flow condition. Watershed 8 shows a radical change in its rank from low to high flow conditions. Tables 6-2 and 6-3 show the various load and flow components for each sub-watershed during low and high flow, respectively. Note that the magnitude of sub-watershed indexes between Tables 6-2 and 6-3 decrease for all but two of the downstream extension sub-watersheds. The index will decrease whenever pollutants decrease relative to runoff, and increase when pollutants increase relative to runoff. A sub-watershed's rank will increase from the low to the high flow condition, when its relative index increases. The expectation of why rank changes from one flow regime to another is not as straight forward as explaining why one sub-watershed ranks higher or lower with one ranking indicator than another. Runoff will increase with increasing rainfall, for sure, but whether the associated sub-watershed rank increases or decreases depends both on whether runoff increases or decreases relative to pollutants, and on whether both runoff and pollutants from one sub-watershed increase or decrease relative to the other sub-watersheds. The index integrates a large number of watershed and land use characteristics related to both flow and pollutant loading, as well as the relative sizes of the contributing sub-areas.

The application of the NPSP index to a historical data set was useful in illustrating integrated levels of NPS pollution, and its variation between months and years. In the modeling scenario above, the index, while generally in agreement with the other two indicators, accentuated sub-watersheds with suspected higher pollutant-generating land uses. In general, the index, based on the kg/ha-cm unit, assesses the mean concentrations of individual pollutants. Pollutant concentrations focus more on possible problems within a watershed, rather than loads, as with current targeting, which tend to look mainly at problems manifested downstream. For people living within the watershed, rankings with the index will more favorably target areas whose solutions benefit them, in addition to the downstream users.

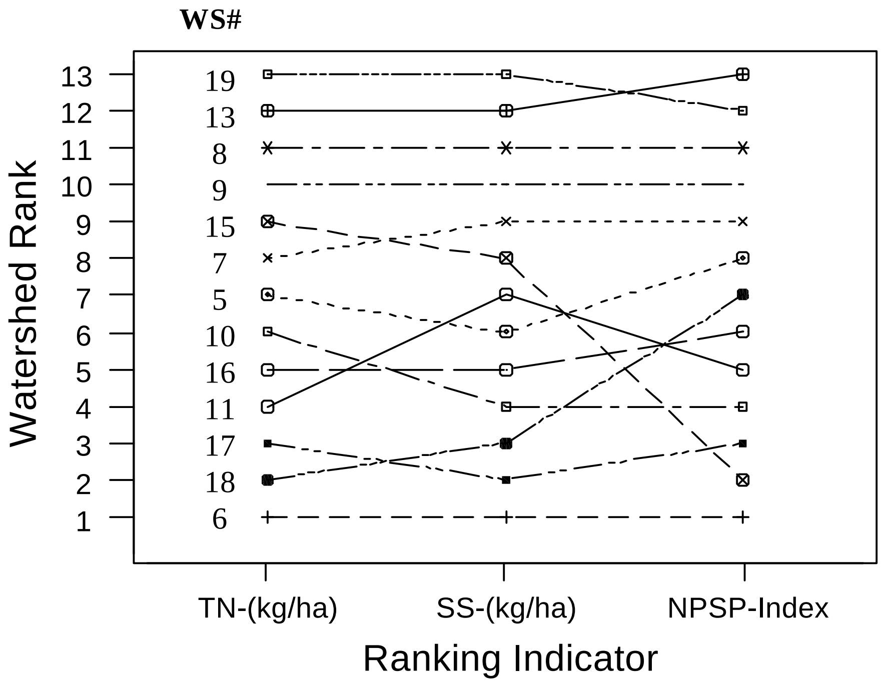

Figure G-7. Sub-Watershed Ranking with Low Flow

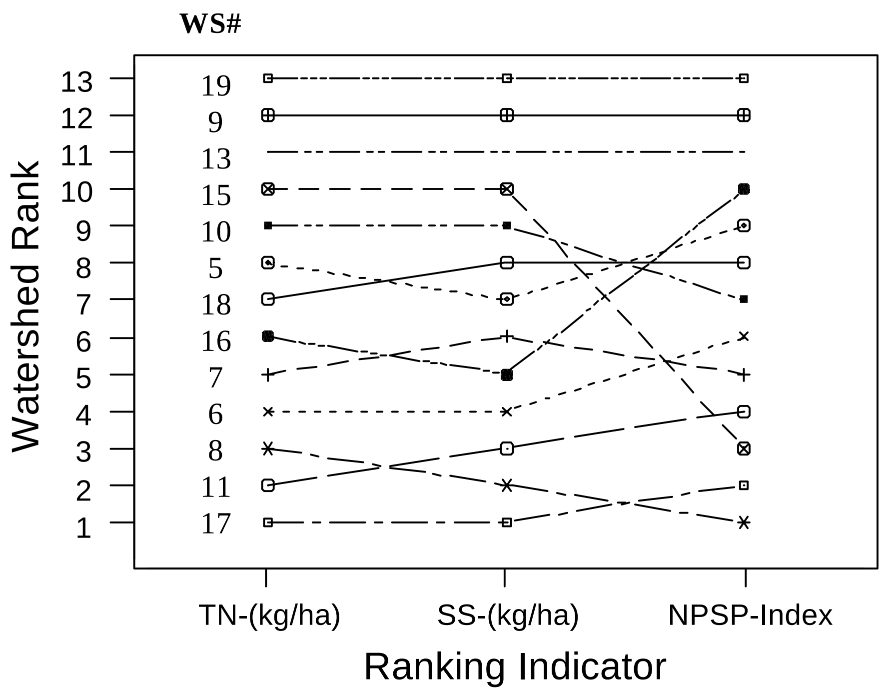

Figure G-8. Sub-Watershed Ranking with High Flow

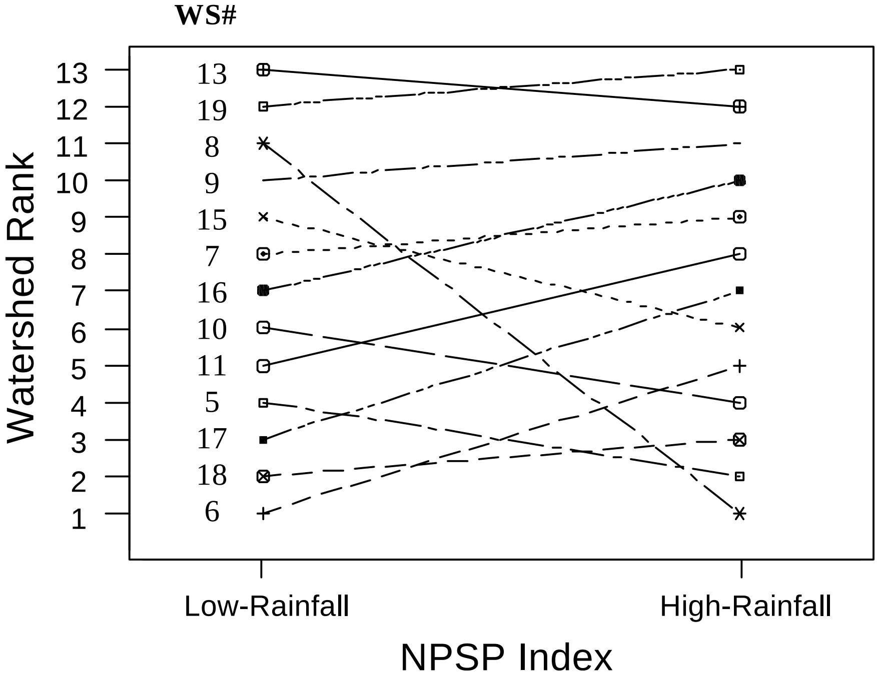

Figure G-9. NPSP Index Rank Changes with Flow Condition

Table G-1. 1992 Land Use Acreage and Percentages by Sub-Watershed

WS#	12	13	14	20	30	60	70	1300	1500	2000
5	53 5%	0 0%	0 0%	79 8%	514 50%	0 0%	9 1%	192 19%	48 5%	126 12%
6	60 9%	25 4%	12 2%	62 9%	286 41%	0 0%	0 0%	0 0%	201 29%	49 7%
7	42 2%	27 1%	93 4%	245 11%	1164 51%	0 0%	1 0%	635 28%	7 0%	83 4%
8	47 5%	15 2%	12 1%	180 19%	388 40%	0 0%	0 0%	129 13%	152 16%	48 5%
9	50 4%	3 0%	0 0%	151 12%	477 37%	0 0%	0 0%	217 17%	217 17%	190 15%
10	3 0%	52 4%	9 1%	90 7%	471 39%	0 0%	0 0%	0 0%	449 37%	148 12%
11	17 2%	50 5%	133 14%	76 8%	288 29%	3 0%	0 0%	333 34%	5 1%	78 8%
13	54 8%	27 4%	7 1%	43 6%	251 36%	0 0%	0 0%	254 36%	1 0%	64 9%
15	58 3%	57 3%	6 0%	134 7%	546 28%	0 0%	1 0%	696 35%	6 0%	467 24%
16	276 38%	16 2%	2 0%	89 12%	195 27%	0 0%	0 0%	113 16%	2 0%	36 5%
17	27 4%	39 5%	55 8%	66 9%	281 39%	0 0%	0 0%	87 12%	4 1%	153 21%
18	57 3%	286 17%	97 6%	134 8%	970 59%	4 0%	0 0%	53 3%	0 0%	35 2%
19	81 21%	7 2%	1 0%	11 3%	177 47%	0 0%	0 0%	41 11%	0 0%	60 16%
Total:	**825**	**604**	**427**	**1360**	**6008**	**7**	**11**	**2750**	**1092**	**1537**
Ave:	**63**	**46**	**33**	**105**	**462**	**1**	**1**	**212**	**84**	**118**

where Land use 12 = Rural residential
Land use 13 = Lawns
Land use 14 = Woody urban areas
Land use 20 = Unspecified agricultural
Land use 30 = Forestry
Land use 60 = Water
Land use 70 = Marsh
Land use 1300 = Agricultural land in Prince William County
Land use 1500 = Agricultural land in Loudoun County
Land use 2000 = Pasture land

Table G-2. Parameter Components for Ranking Sub-Watersheds During Low Flow

WS#	AREA	RV	AV	MV	TN	AN	MN	TP	AP	MP	SS	NX	MN-L	SS-L	NX-L
5	1021	0.050	0.136	0.185	0.22	0.03	0.25	0.112	0.002	0.113	48	5.1	4	7	5
6	695	0.060	0.136	0.196	0.38	0.13	0.51	0.191	0.019	0.209	100	6.4	1	1	1
7	2297	0.060	0.136	0.196	0.15	0.04	0.19	0.078	0.002	0.079	41	4.5	8	9	9
8	971	0.070	0.136	0.206	-0.01	0.01	0.00	-0.005	0.002	-0.003	14	1.9	11	11	11
9	1305	0.060	0.136	0.196	0.09	0.00	0.09	0.000	0.000	0.000	39	3.6	10	10	10
10	1222	0.110	0.136	0.245	0.26	0.01	0.26	0.123	0.001	0.123	72	4.9	2	3	7
11	983	0.070	0.136	0.205	0.20	0.10	0.29	0.101	0.013	0.114	52	5.1	5	5	6
13	701	0.090	0.136	0.226	-0.18	0.04	-0.14	-0.073	0.005	-0.068	-91	0.0	12	12	13
15	1971	0.040	0.136	0.176	0.10	0.03	0.13	0.046	0.002	0.048	46	6.2	9	8	2
16	729	0.060	0.136	0.196	0.17	0.12	0.28	0.078	0.008	0.085	48	4.9	7	6	8
17	712	0.060	0.136	0.196	0.19	0.13	0.32	0.101	0.013	0.114	65	5.4	6	4	4
18	1636	0.030	0.136	0.166	0.22	0.16	0.38	0.112	0.011	0.122	76	6.1	3	2	3
19	378	0.080	0.136	0.216	-1.40	0.01	-1.39	-0.540	0.001	-0.539	-398	0.0	13	13	12

Table G-3. Parameter Components for Ranking Sub-Watersheds During High Flow

WS#	AREA	RV	AV	MV	TN	AN	MN	TP	AP	MP	SS	NX	MN-H	SS-H	NX-H
5	1021	2.550	0.136	2.685	0.72	0.07	0.78	0.359	0.003	0.362	418	3.00	7	8	8
6	695	2.540	0.136	2.675	0.80	0.26	1.05	0.404	0.033	0.436	487	3.20	5	6	5
7	2297	2.750	0.136	2.885	0.83	0.13	0.96	0.415	0.010	0.424	570	3.20	4	4	6
8	971	2.920	0.136	3.056	0.99	0.07	1.06	0.482	0.007	0.489	756	5.30	3	2	1
9	1305	2.890	0.136	3.026	0.28	0.02	0.30	0.145	0.003	0.148	122	2.60	11	11	11
10	1222	3.260	0.136	3.395	0.77	0.02	0.78	0.381	0.002	0.382	495	2.90	6	5	10
11	983	2.810	0.136	2.945	1.00	0.25	1.25	0.493	0.027	0.520	667	3.50	2	3	4
13	701	2.840	0.136	2.976	0.10	0.17	0.27	0.080	0.012	0.092	-56	0.90	12	12	12
15	1971	2.540	0.136	2.676	0.40	0.09	0.49	0.195	0.008	0.203	234	3.60	10	10	3
16	729	2.740	0.136	2.875	0.70	0.18	0.88	0.348	0.011	0.359	444	3.00	8	7	9
17	712	2.760	0.136	2.895	1.24	0.24	1.48	0.617	0.020	0.636	1030	4.10	1	1	2
18	1636	2.390	0.136	2.525	0.61	0.26	0.87	0.303	0.014	0.316	390	3.00	9	9	7
19	378	3.030	0.136	3.166	-4.41	0.04	-4.37	-1.966	0.005	-1.961	-3485	0.00	13	13	13

RV = storm surface runoff, cm
AV = monthly base flow, cm
MV = RV + AV
TN = storm total nitrogen, kg/ha
AN = monthly septic system TN, kg/ha
MN = TN + AN
TP = storm total phosphorus, kg/ha
AP = monthly septic system TP, kg/ha
MP + TP + AP
SS = storm suspended sediment, kg/ha
NX = non-point source pollution index

MN-x = sub-watershed rank based on MN
SS-x = rank based on SS
NX-x = rank based on NX
where x = L indicates low flow conditions, and x = H indicates high flow conditions.