Microplastic Source Tracking: Preliminary Investigation Data Report Potomac River, Maryland

PREPARED FOR

U.S. Environmental Protection Agency

PREPARED BY

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ACRONYMS/ABBREVIATIONS

BRF	Biological Research Facility
DI	Deionized water
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
GFF	Glass Fiber Filter
GPS	Global Positioning System
ICPRB	Interstate Commission of the Potomac River Basin
MAG	Microplastic Analysis Grade
NLCD	National Land Cover Database
ORD	EPA Office of Research and Development
PPAT	Chesapeake Bay Program Plastic Pollution Action Team
QAPP	Quality assurance project plan
R3	U.S. EPA Region 3
STAC	Chesapeake Bay Scientific and Technical Advisory Committee
TOL	Task Order Leader
USGS	United States Geological Survey

1. Introduction

Plastic pollution is a pervasive and ubiquitous problem in the aquatic landscape that can impact the environment and economy. The Chesapeake Bay Program (CBP) Scientific and Technical Advisory Committee (STAC) hosted a workshop with representation from U.S. EPA Region 3 (R3) and U.S. EPA Office of Research & Development (ORD) staff in 2019 to assess the state of the science and emerging concerns of microplastics pollution on the health of the Chesapeake Bay and its watershed. The workshop concluded that microplastics pose a potentially serious risk to the success of restoration efforts. As a result, the CBP formed the Plastic Pollution Action Team (PPAT) to respond to technical questions surrounding microplastic distributions.

The PPAT oversaw the development of a conceptual ecological risk assessment (ERA) evaluating microplastic risks on juvenile striped bass. Insufficient data was available to identify the types of plastics and their sources in the Chesapeake Bay watershed. To better identify potential risks microplastics may be having on valuable and vulnerable resources in the Chesapeake Bay and its watershed, specific data on the size, shape, composition, and conveyances are needed. As a preliminary investigation to determine likely sources for microplastics related to land use, this project collected surface water samples (microplastic loadings) conveyed by several land use types including agriculture, wastewater, stormwater, urban, suburban, and wetlands/natural in the tidal Potomac River Watershed along a gradient from tidal headwaters toward the confluence with the Bay at two time series (baseflow and stormflow). Sample sites are shown in Figure 1.

2. Methods

2.1 Site Selection

Site selection criteria were implemented using geospatial analysis tools in ArcGIS Pro to explore land use/cover and stream catchment data layers. The Interstate Commission of the Potomac River Basin (ICPRB) provides free web-based GIS layers designating HUC 8, HUC 10, and HUC 12 catchment areas within the Potomac River Watershed. By combining catchment area layers with a raster file projecting 2019 land cover data from the National Land Cover Database (NLCD), the percentage of respective land use types within stream catchments were determined. Sample sites within catchments were chosen based on four dominant land uses and two point source types as follows.

Land use Types:

1. Urban
    a. Greater than 40% developed lands as defined by NLCD
2. Suburban
    a. 15%-40% developed as defined by NLCD
3. Wetlands/Natural
    a. Assumption is that no catchment will be dominated (>50%) by wetlands;
    b. This Land use was redefined as “Natural” which was defined by Tetra Tech as >70% forest/wetland with developed area <5%;
    c. Site selection prioritized catchments with as much wetland cover as practical

4. Agricultural
    a. Agricultural lands are defined by “hay/pasture” and “cultivated crops” in the 2019 NLCD definitions. Tetra Tech combined these land uses under an “agricultural” land use category defined as >70% agricultural, <5% developed

Point Source Types:

5. Stormwater Outfalls
    a. Not a designated land use/land cover type;
    b. Tetra Tech sampled stormwater outfalls at baseflow and stormflow conditions
6. Wastewater Outfalls
    a. Not a designated land use/land cover type;
    b. Tetra Tech sampled wastewater effluent (or outfall) under baseflow and stormflow conditions

Given that this was a preliminary study with limited resources, a total of 36 potential sampling sites were identified using the criteria above. Desktop reconnaissance (using satellite imagery) and field reconnaissance were performed to confirm the final 18 sampling sites (Figure 1). Each of the four land use and two point source types were designated with 3 sampling sites each, with alternate sites should they be necessary to identify 18 sample sites to collect at base and storm flows (totaling 36 sampling events). Potential sampling sites that could not accommodate a boat or where outfalls were not easily located (e.g., due to plant overgrowth) were eliminated.

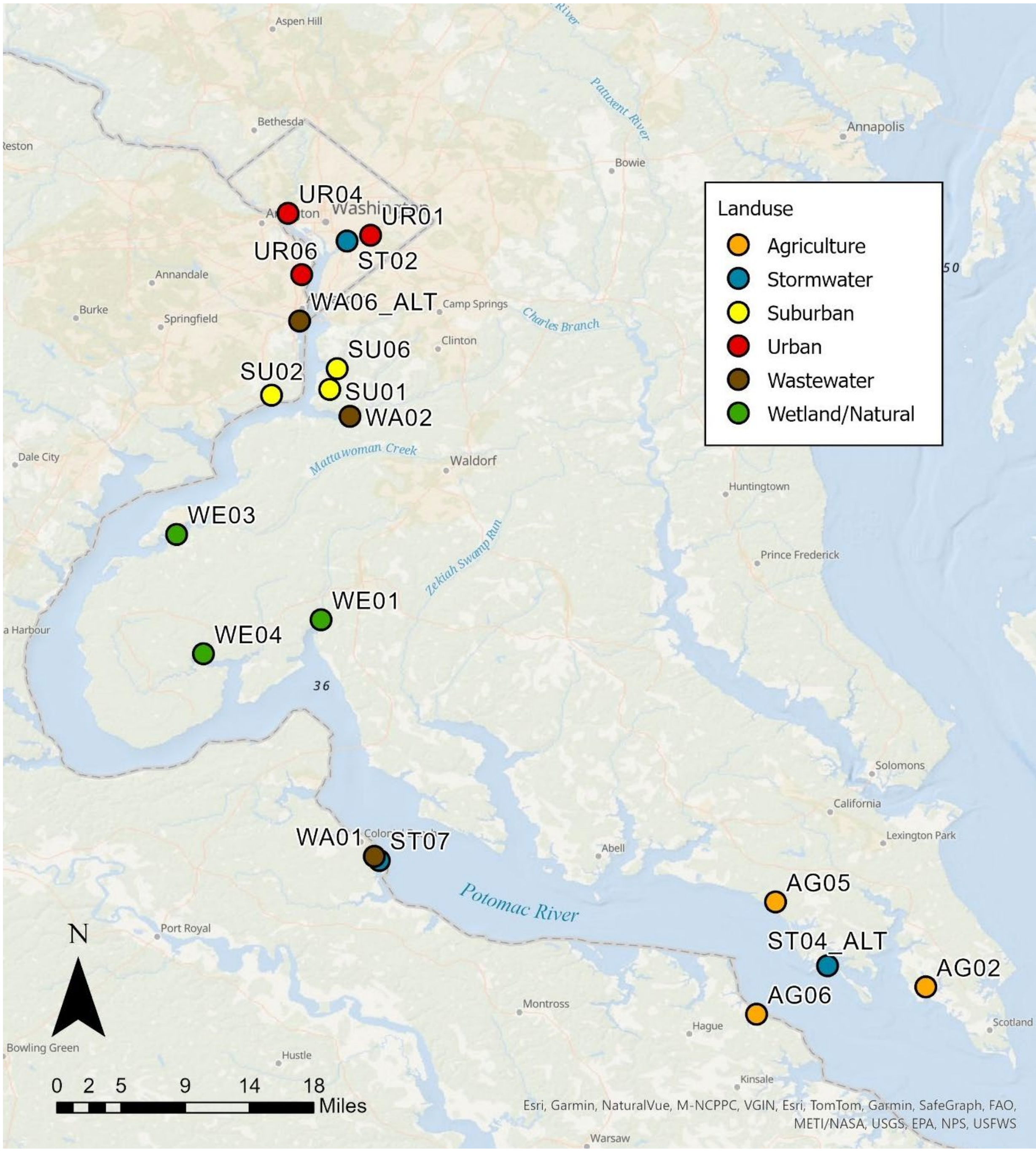

Figure 1. Microplastic sampling sites by land use (Site Name Key: UR – Urban, SU – Suburban, AG – Agriculture, WE – Wetland/Natural, WA – Wastewater, ST – Stormwater).

2.2 Field Sampling

Microplastic contamination limiting protocols were enforced before and during field sampling. Prior to sampling, each sample jar (glass, 1-L mason jar) was rinsed three times with DI water and immediately capped to minimize microplastic contamination. During sampling events, care was taken to reduce exposure of the samples to plastic sources including only opening sample jars for rinsing or collecting samples and lining the plastic-coated sample jar lids with aluminum foil. Cotton clothes were worn during field sampling when feasible. Field blanks, using deionized [DI] water, were collected during each sampling event; they were processed in the laboratory using the same methods applied to field samples to determine if method analytes or other interferences were introduced into the samples during collection and shipment.

This sampling technique (1L bulk sampling) was chosen for several reasons. The aim of this study was to determine microplastic sources related to land use so getting as close as possible to the land water interface was prioritized, as well as a more localized sampling technique (Miller et al., 2024). Trawl/towing methods aggregate particles from larger areas (Miller et al., 2024), increasing the probability that captured particles came from other parts of the river, less influenced by land use. Bulk sampling collects a greater diversity of particle sizes (Barrows et al., 2017, Hung et al., 2020) and has been used and recommended in other studies (Hung et al., 2020, Prata et al., 2020, Scircle et al., 2020). Finally, resources and time were limited so this simpler and more cost-effective method was chosen so as many stations as possible could be sampled.

Field sampling was conducted between May 2024 and September 2024 during 8 separate sampling events. Surface water samples were collected at all 18 sites during separate baseflow conditions and stormflow conditions for a total of 36 samples. Baseflow was defined as <2cm precipitation in the 24 hours prior to sampling and stormflow was defined as >2cm of precipitation in the 24 hours prior to sampling. Duplicate surface water samples were collected at 2 different sites – 1 during baseflow conditions and 1 during stormflow conditions for a total of 2 duplicate samples. Field blanks (using jars filled with DI water) were also collected during each sampling event (8) – the jar was opened to the air and remained open through the collection of the surface water samples at each site visited during a sampling event.

Upon arrival at each sampling site, field scientists used a handheld GPS unit to record the site's coordinates, took photos using an electronic tablet for a visual record of the sampling sites, and deployed a multiprobe into the water to record water temperature and salinity. The Site ID, treatment type (e.g., baseflow, stormflow), time, and date were written directly on the sample jar lid before sampling. This information was also recorded in a field notebook. To conduct surface water sampling, the scientists removed the lid of one sample jar and dipped it into the water from the side of the boat three times to rinse it *in situ* with seawater. Once rinsed, the jar was lowered into the water (to a 40-50 cm depth from relative surface) to collect the sample, brought back into the boat, and immediately capped with an aluminum foil lined jar lid (Figure 2). The sample jar was then wrapped with packing paper, to protect it during transport, and placed into a cooler filled with ice for transport back to the biological research facility (BRF) for extraction. Typical plastic packaging material (e.g., bubble wrap) was avoided to reduce potential contamination.

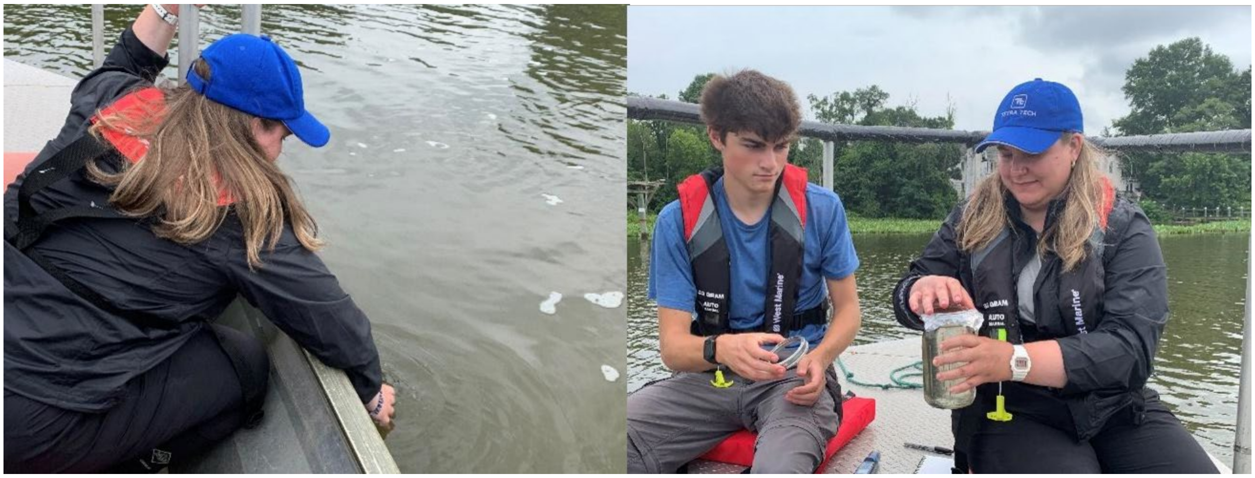

Figure 2. Sample collection and field processing.

2.3 Laboratory Methods

Prior to performing any laboratory analysis, several microplastic contamination limiting protocols were enforced. A small, isolated room was designated for processing. The room was cordoned off with a cotton sheet. Clothing worn by laboratory scientists was limited to cotton material when possible and cotton laboratory coats were worn over the clothing. Both the cotton laboratory coats, and the cotton sheet were dyed with a chartreuse dye for easy identification should they contaminate the samples during processing.

Processing began with digestion via chemical oxidation of any tissue and organic material within the surface water samples. Each sample was poured through a 100-micrometer metal sieve into the laboratory sink to capture any particles on the sieve, allowing the sample water to pass through. The sieve was carefully back rinsed with a 10% Potassium hydroxide solution into the original sample jar. The sample jar was then covered with a glass petri dish and was placed under a fume hood at room temperature for at least 48 hours to allow for off-gassing. After digestion, the sample was poured through the 100-micrometer metal sieve again to capture the remaining material. The remaining material was rinsed from the sieve into the original sample jar using Microplastic Analysis Grade (MAG) (deionized water filtered through a pore-size of 0.45 micrometers used to reduce sample contamination).

The samples were then vacuum filtered onto a Glass Fiber Filter (GFF) and all remaining particles were visually identified under a microscope at 120x magnification for length, character, and color (Figure 3). Particles ranged in length from 154 µm to 11.53 mm with an average length in the longest direction of 1.483 ± 1.466 mm. Every individual particle was placed onto a glass microscope slide that had been affixed with double-sided tape. Particles were labeled, and the microscope slides were batch shipped in small tin boxes to the U.S. EPA Office of Research and Development Atlantic Coastal Environmental Sciences Division in Narragansett, Rhode Island for polymer identification by Raman analysis.

Particles were analyzed using a Renishaw inVia Qontor Raman Microscope. Spectra were acquired under 100x magnification using a 785 nm laser for one 10 s accumulation. Spectra were processed to remove fluorescence background, perform baseline subtraction, noise filtration, and cosmic ray removal using the WiRE software (v5.4) prior to database matching against several spectral libraries, including Hawaii

Pacific University Center for Marine Debris Research Polymer Kit Reference Library 1.0, the Spectral Library of Plastic Particles (SLoPP) Spectral Library of Plastic Particles – Environmental (SLoPP-E), and OpenSpecy. Database matches above 70% were automatically accepted and matches 50-70% were individually considered, accounting for background matrix interference, fluorescence intensity, and low signal quality.

Figure 3. Visual analysis and extraction of microplastic particles.

3. Data

This section includes summary statistics and counts for polymers (plus cellulosic particles) found at each land use type (by sampling site) for both baseflow and stormflow events. Microplastic loadings are expressed as the number of particles found per liter of river water. Comments and interpretations follow each summary plot.

3.1 Particles by Flow Type

At almost all sampling sites, regardless of land use, baseflow concentrations of microplastics were greater than stormflow conditions (p=0.009) (Figures 4-9 show differences in concentrations by flow within each land use type). A Shapiro-Wilk test was used to determine normality and a Levene's test was used to examine the homogeneity of variance. The data were not normal, but the variance was homogeneous, therefore the non-parametric Mann-Whitney U test (Wilcoxon test) was used to compare the significance between the microplastics L^{-1} in baseflow vs. stormflow.

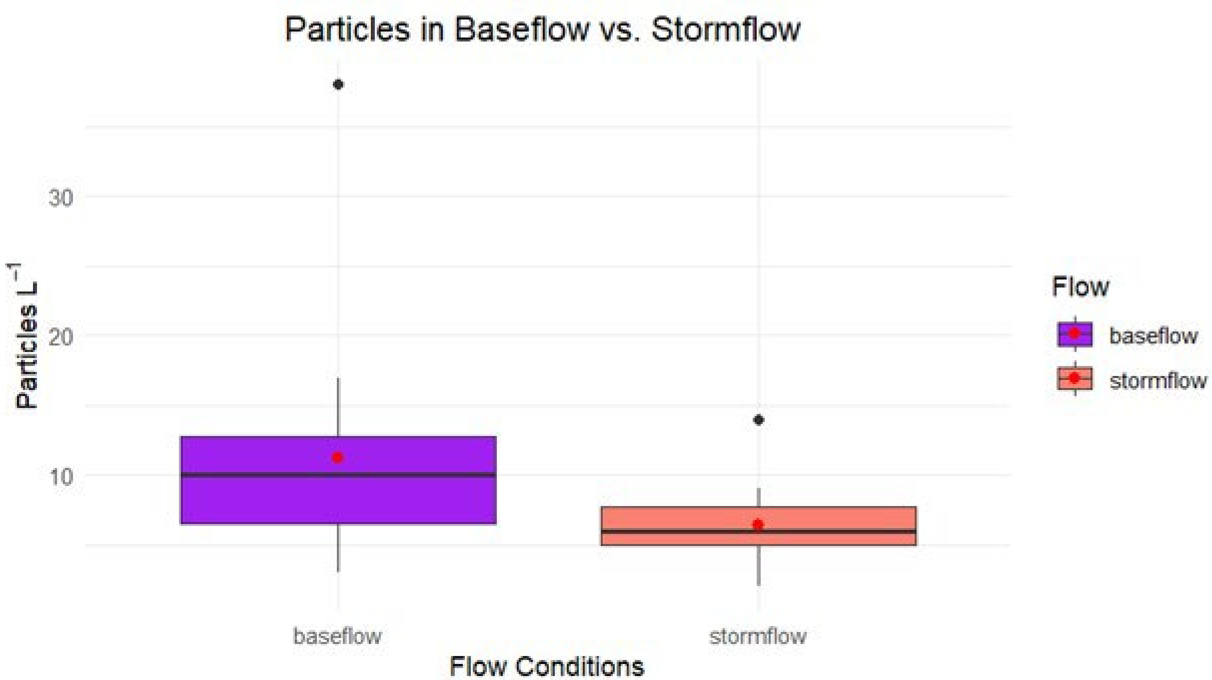

Figure 4. Box-whisker plot of the concentration of particles at baseflow (<2cm precipitation in 24 hours prior to sampling) compared to stormflow (>2cm precipitation in 24 hours prior to sampling) for all land use types combined. The concentration of particles between flow conditions is significantly different (p = 0.009) using a Mann-Whitney U test. The boxes represent the interquartile range (25-75%), the central horizontal lines are the medians, the vertical lines are the range, black dots are outliers, and red dots represent the means.

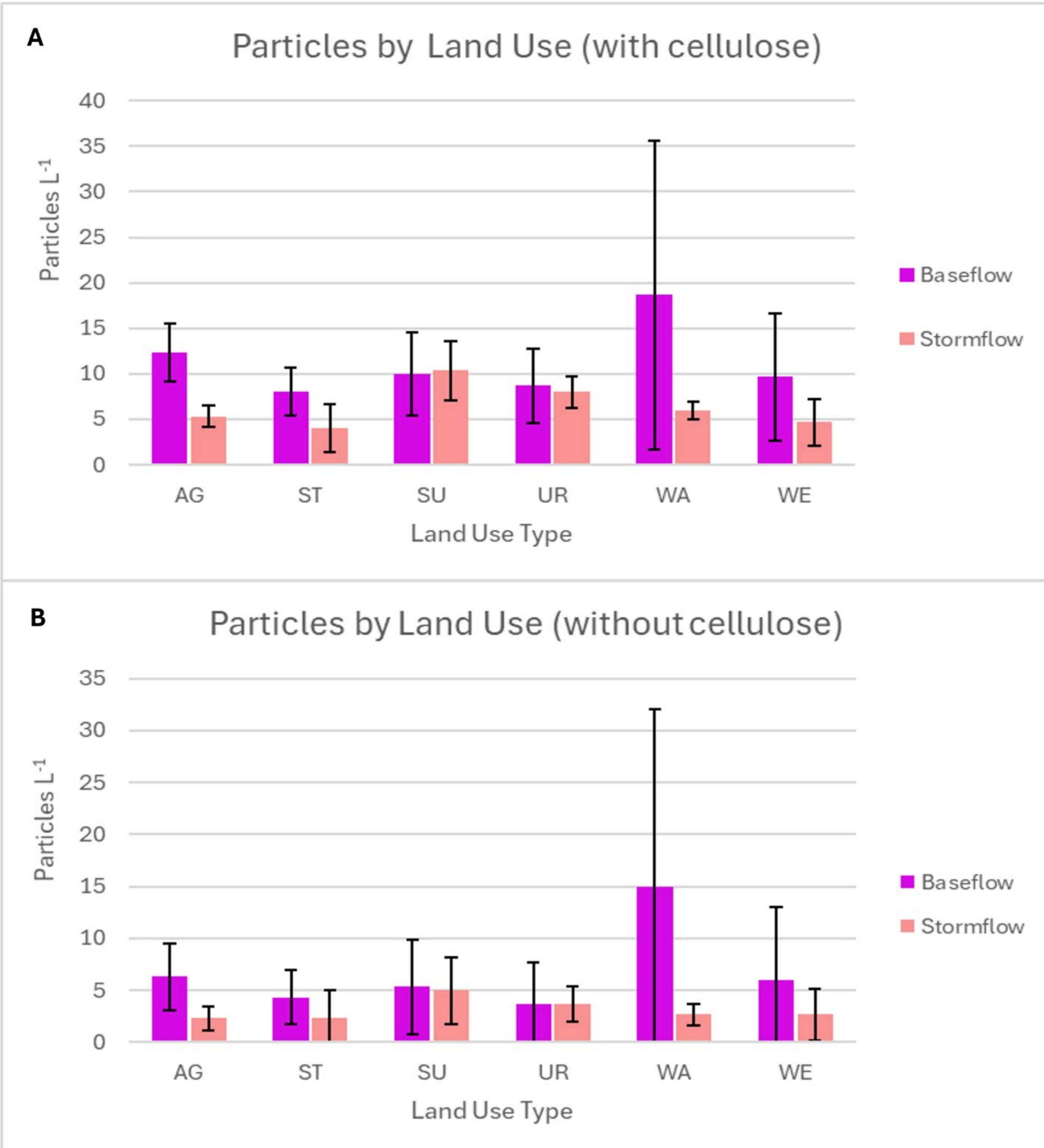

Figure 5. Mean particle concentration by land use, with cellulose (A) and without cellulose (B). Cellulose includes cotton, Tencel, viscose, and rayon. Error bars are standard deviation.

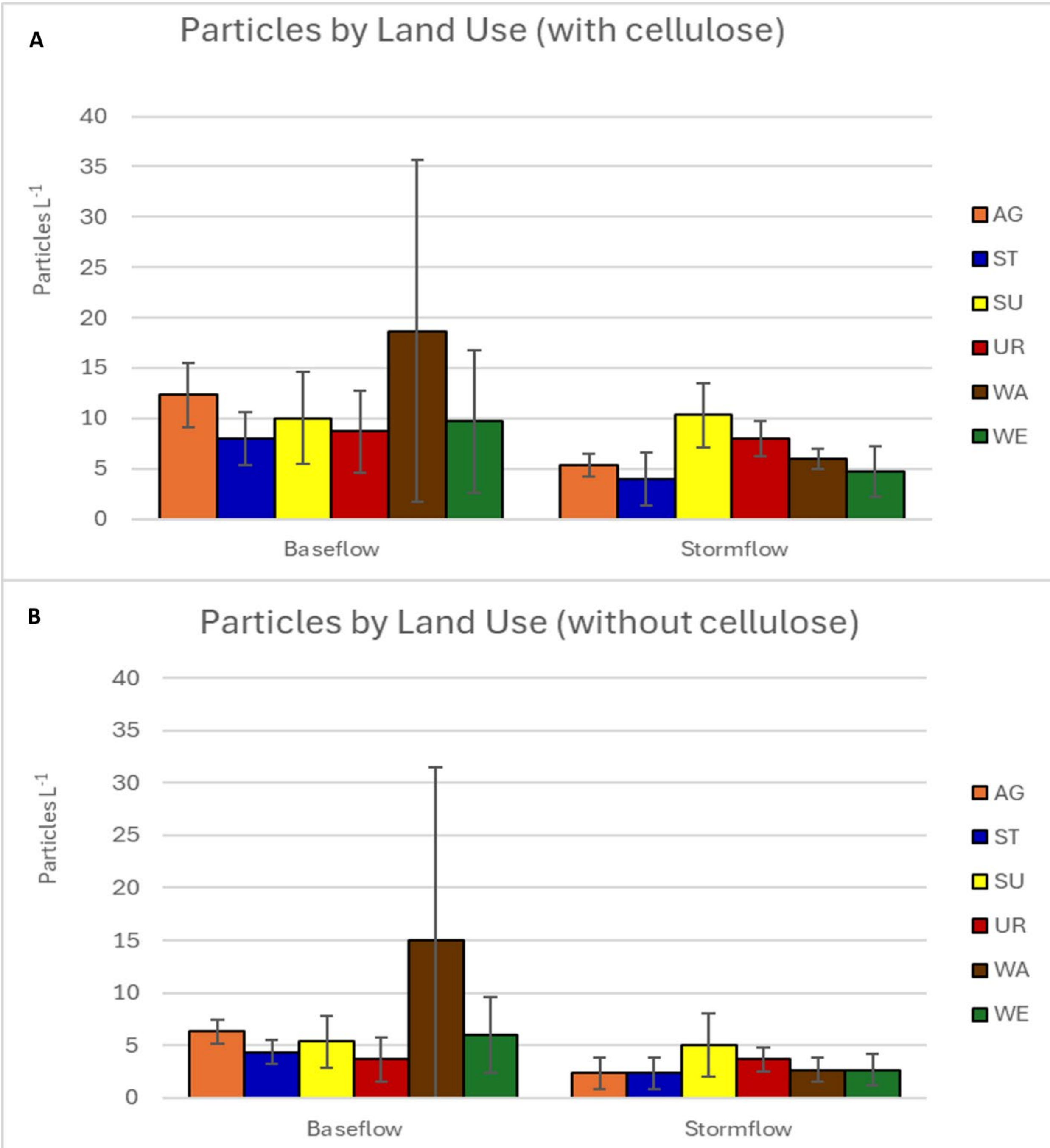

Figure 6. Mean particle concentration by land use and flow type, with cellulose (A) and without cellulose (B). This is the same data as in Figure 5 but represented in a different way. Cellulose includes cotton, Tencel, viscose, and rayon. Error bars are standard deviation.

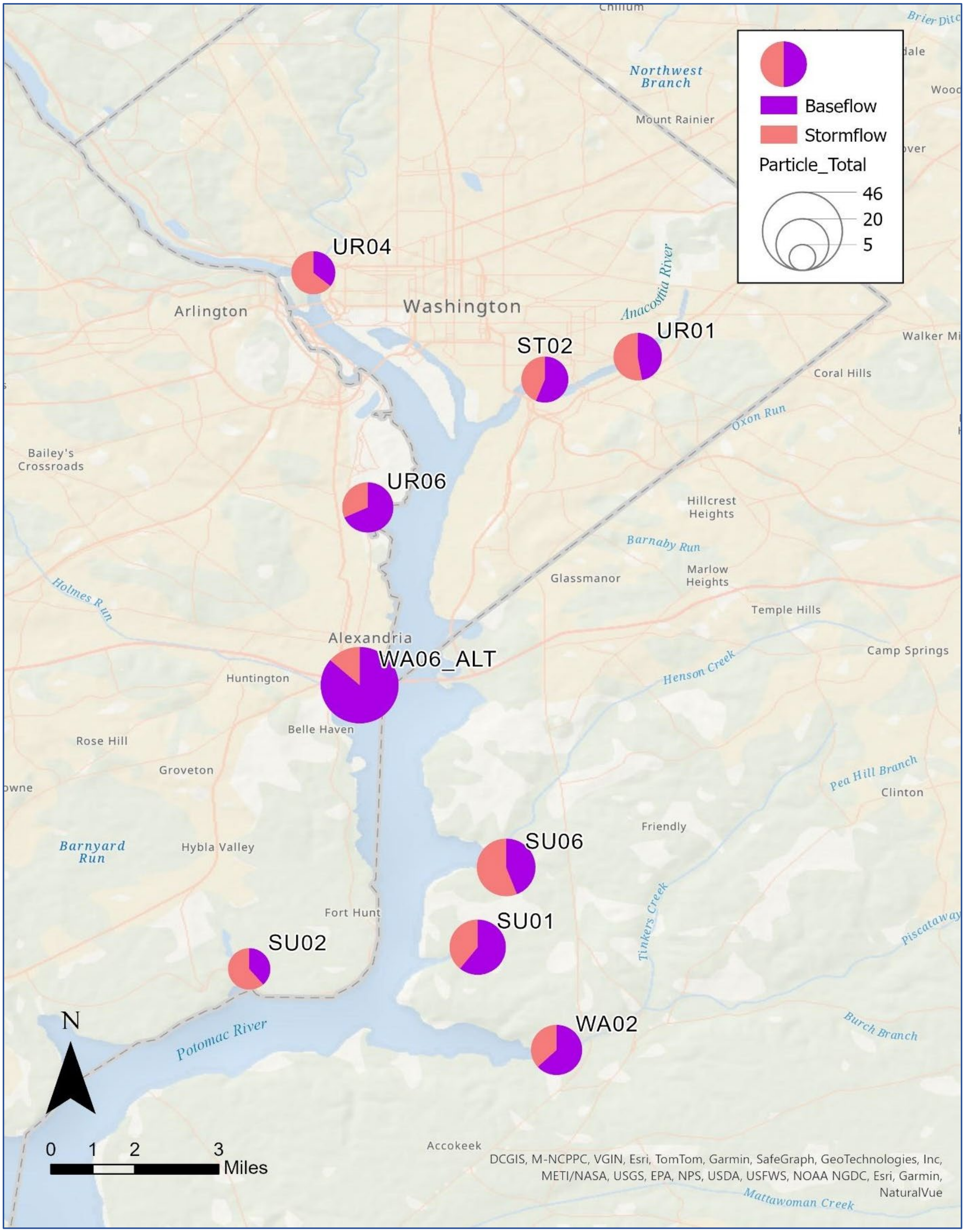

Figure 7. Upper Potomac River sites: distribution of particles by flow type and particle count by site (Site Name Key: UR – Urban, SU – Suburban, AG – Agriculture, WE – Wetland/Natural, WA – Wastewater, ST – Stomwater).

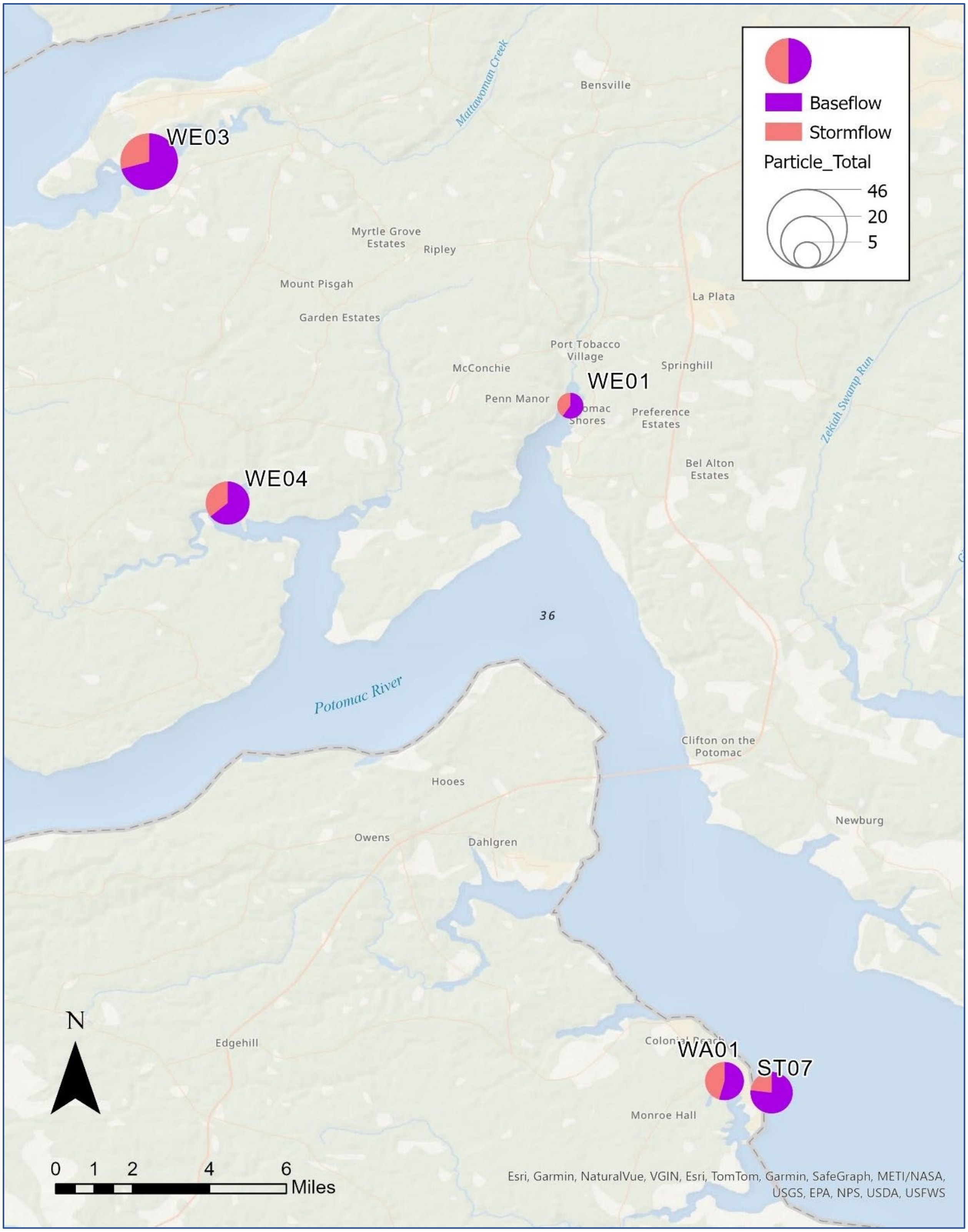

Figure 8. Middle Potomac River sites: distribution of particles by flow type and particle count by site (Site Name Key: UR – Urban, SU – Suburban, AG – Agriculture, WE – Wetland/Natural, WA – Wastewater, ST – Stormwater).

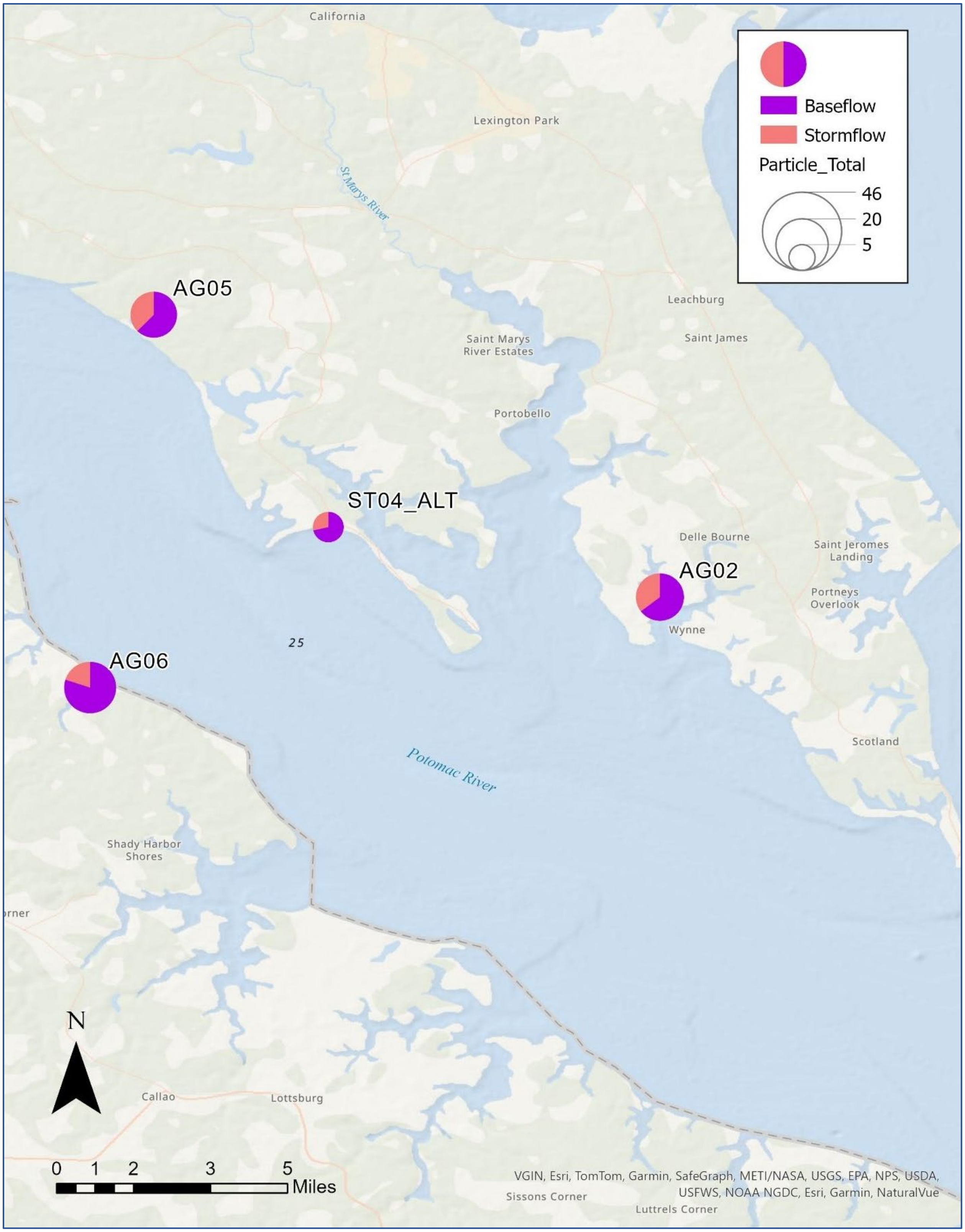

Figure 9. Lower Potomac River sites: distribution of particles by flow type and particle count by site (Site Name Key: UR – Urban, SU – Suburban, AG – Agriculture, WE – Wetland/Natural, WA – Wastewater, ST – Stomwater).

Table 1. Baseflow, stormflow, and total particle count by site.

Site	Baseflow Total	Stormflow Total	Particle Total
AG02	11	6	17
AG05	10	6	16
AG06	16	4	20
ST02	9	7	16
ST04_ALT	5	2	7
ST07	10	3	13
SU01	14	9	23
SU02	5	8	13
SU06	11	14	25
UR01	8	9	17
UR04	5	9	14
UR06	13	6	19
WA01	6	5	11
WA02	12	7	19
WA06_ALT	38	6	44
WE01	3	2	5
WE03	17	7	24
WE04	9	5	14

When comparing the number of microplastics by land use type, a Shapiro-Wilk test was used to determine normality and a Levene's test was used to examine the homogeneity of variance. The data were not normal, but the variance was homogeneous, therefore the non-parametric Kruskal-Wallis test was used. Data were compared in three different ways: 1) combined number of microplastics from both base and stormflow samples (Figure 10A), number of microplastics from baseflow samples (Figure 10B), and number of microplastics from stormflow samples (Figure 10C). There were more microplastics in suburban and urban samples during stormflow compared to other land use types but overall, there were no significant differences between land use types ($p = 0.5885$ combined, $p = 0.7248$ baseflow, $p = 0.0809$ stormflow).

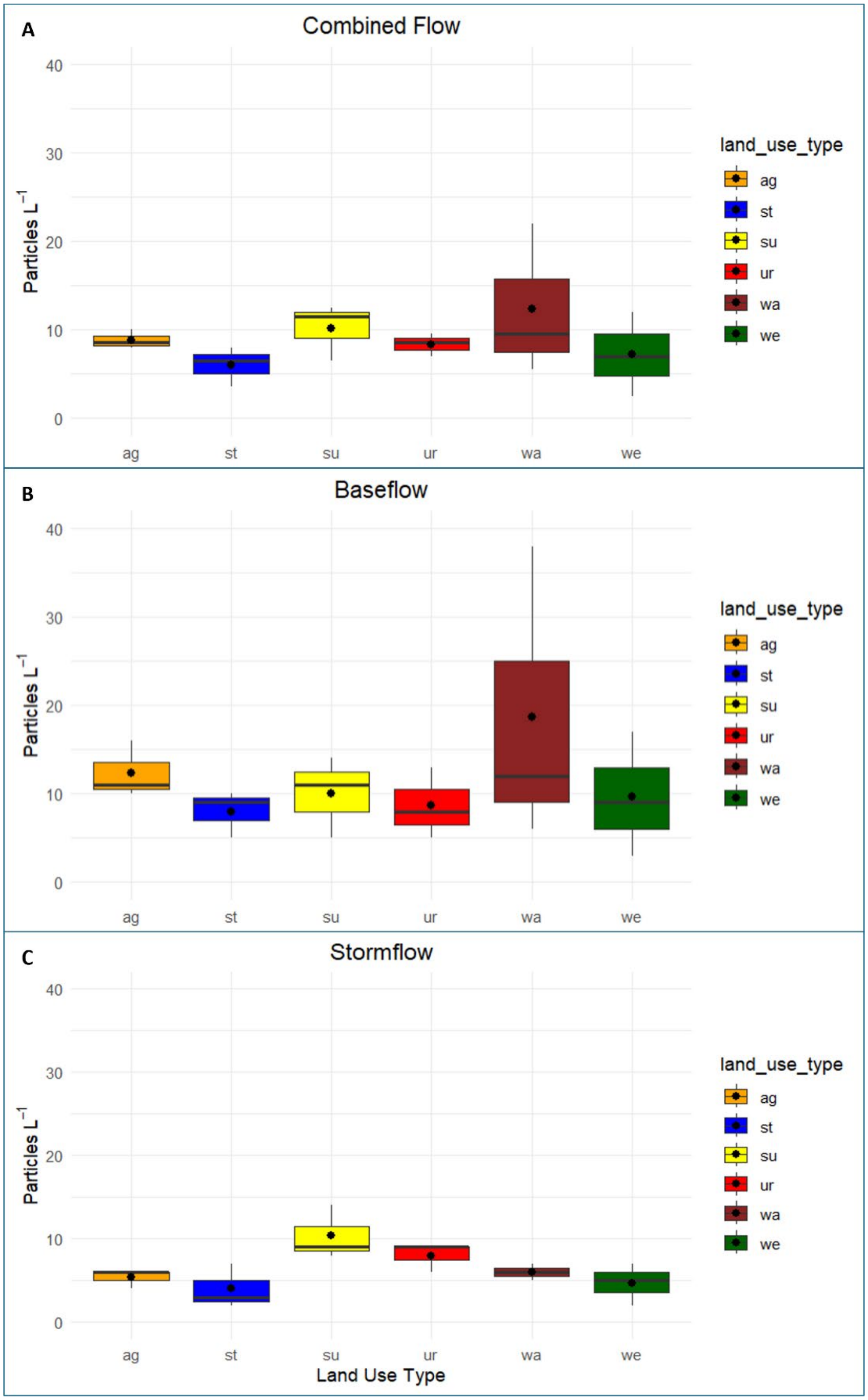

Figure 10. The concentration of microplastics by land use types for combined flow (baseflow + stormflow) (A), baseflow (B), and stormflow (C). There were no statistically significant differences between any of the sites for any flow conditions based on a non- parametric Kruskal-Wallis test (p = 0.5885, 0.7248, 0.0809 for A, B, C, respectively). The boxes represent the interquartile range (25-75%), the central horizontal lines are the medians, the vertical lines are the range, and black dots represent the means.

3.2 Particle Polymers

Cellulose (cotton, Tencel, viscose, rayon) and blue anthropogenic particles were the most abundant groups across flow conditions and all land use types except for wastewater, where polyethylene was the dominant polymer followed by cellulose and blue anthropogenic particles (Figures 11-14, Table 1). This higher number of polyethylene particles in wastewater occurred during baseflow conditions (Figure 11B). The blue anthropogenic particles are defined as particles with Raman spectra dominated by blue dye peaks, interfering with the underlying polymeric material peaks, preventing precise synthetic material identification.

When comparing the number of microplastics by polymer group across land use type, a Shapiro-Wilk test was used to determine normality and a Levene's test was used to examine the homogeneity of variance. The data were not normal, but the variance was homogeneous, therefore the non-parametric Kruskal-Wallis test was used. This was followed by Dunn's post hoc test using a Bonferroni p adjustment that showed no statistical significance between the any of the groups ($p > 0.05$ for all comparisons).

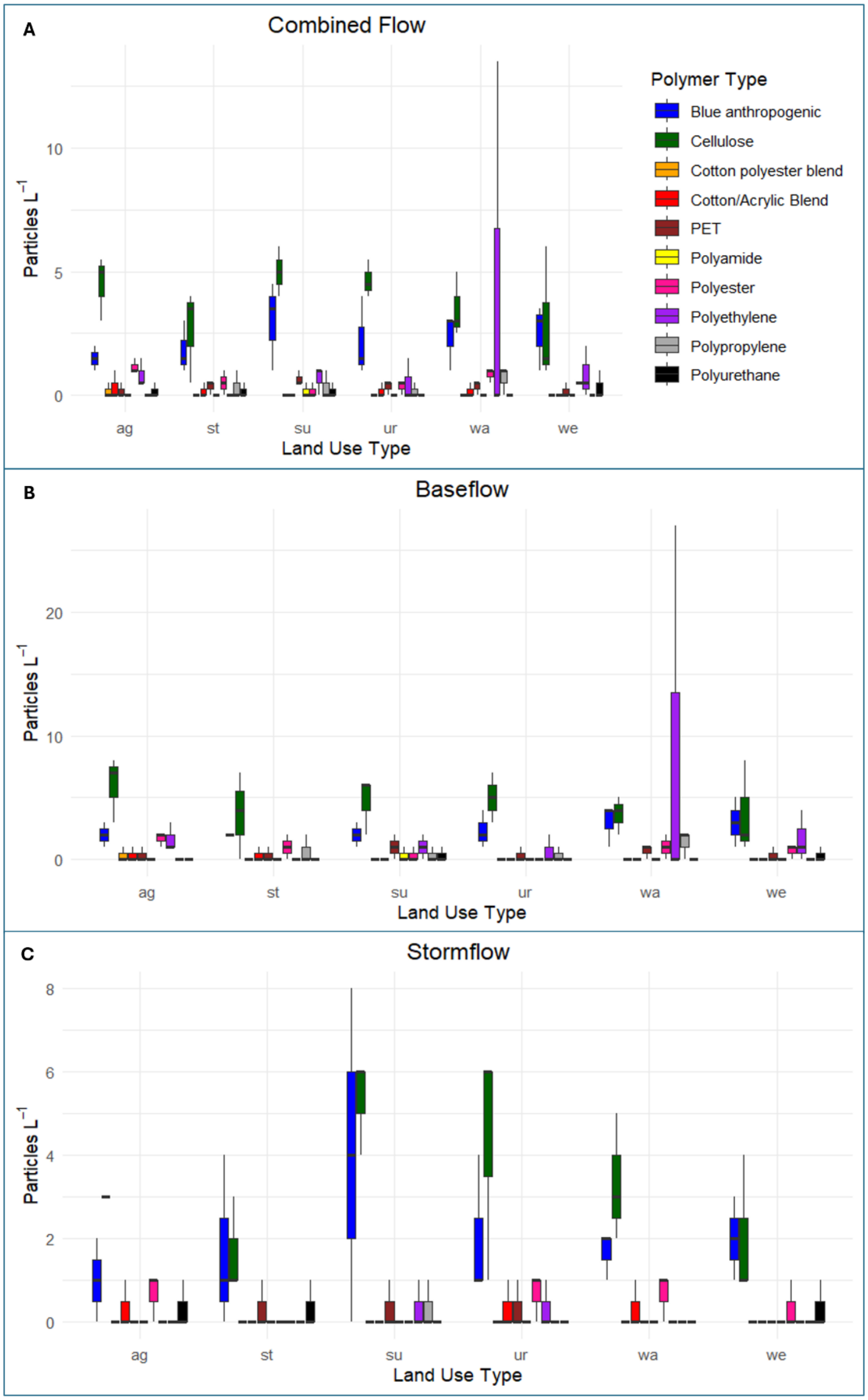

Figure 11. The concentration of particles by polymers for combined (baseflow + stormflow) flow (A), baseflow (B), and stormflow (C) separated by land use types. Cellulose (cotton, Tencel, viscose, rayon) was the largest group in all land use types followed by blue anthropogenic particles except for wastewater, where polyethylene was the dominant polymer followed by cellulose and blue anthropogenic particles. See Table 5 for further details on particle counts and polymer types. There were no statistically significant differences between groups with a non-parametric Kruskal-Wallis test followed by Dunn's post hoc test using a Bonferroni p adjustment ($p > 0.05$ for all comparisons). The boxes represent the interquartile range (25-75%), the central horizontal lines are the medians, and the vertical lines are the range.

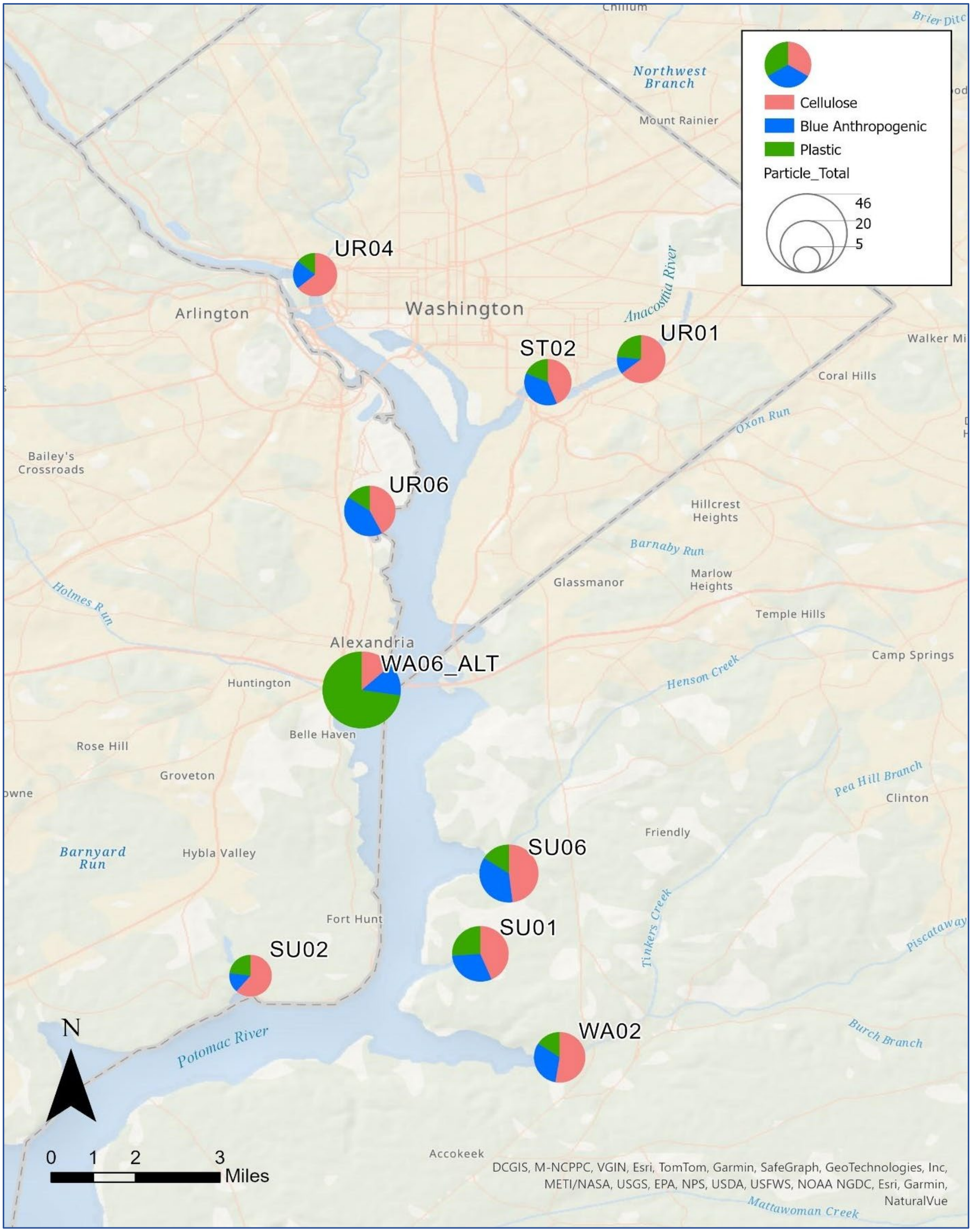

Figure 12. Upper Potomac River sites: distribution of particles by material type and particle count by site (Site Name Key: UR – Urban, SU – Suburban, AG – Agriculture, WE – Wetland/Natural, WA – Wastewater, ST – Stormwater).

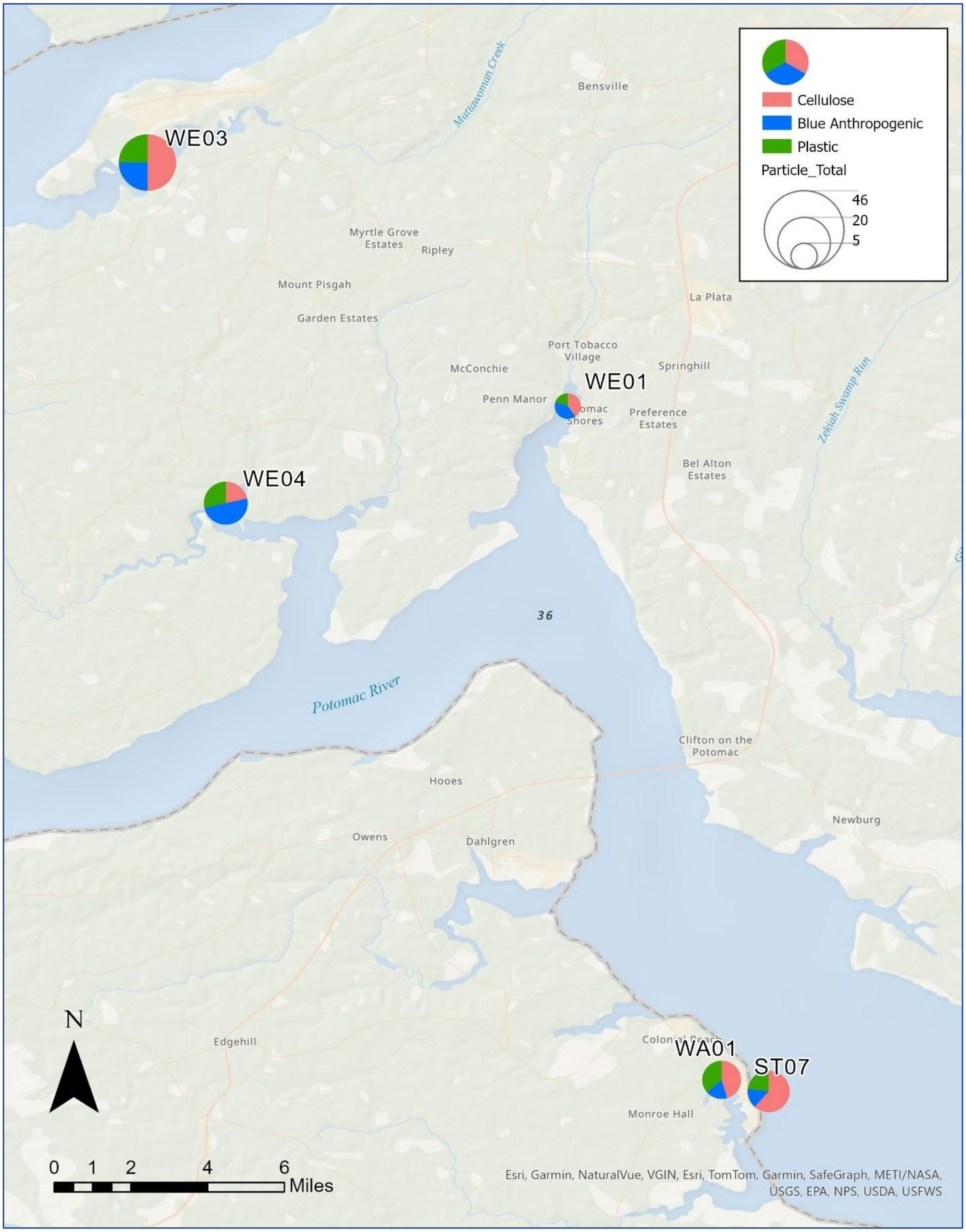

Figure 13. Middle Potomac River sites: distribution of particles by material type and particle count by site (Site Name Key: UR – Urban, SU – Suburban, AG – Agriculture, WE – Wetland/Natural, WA – Wastewater, ST – Stormwater).

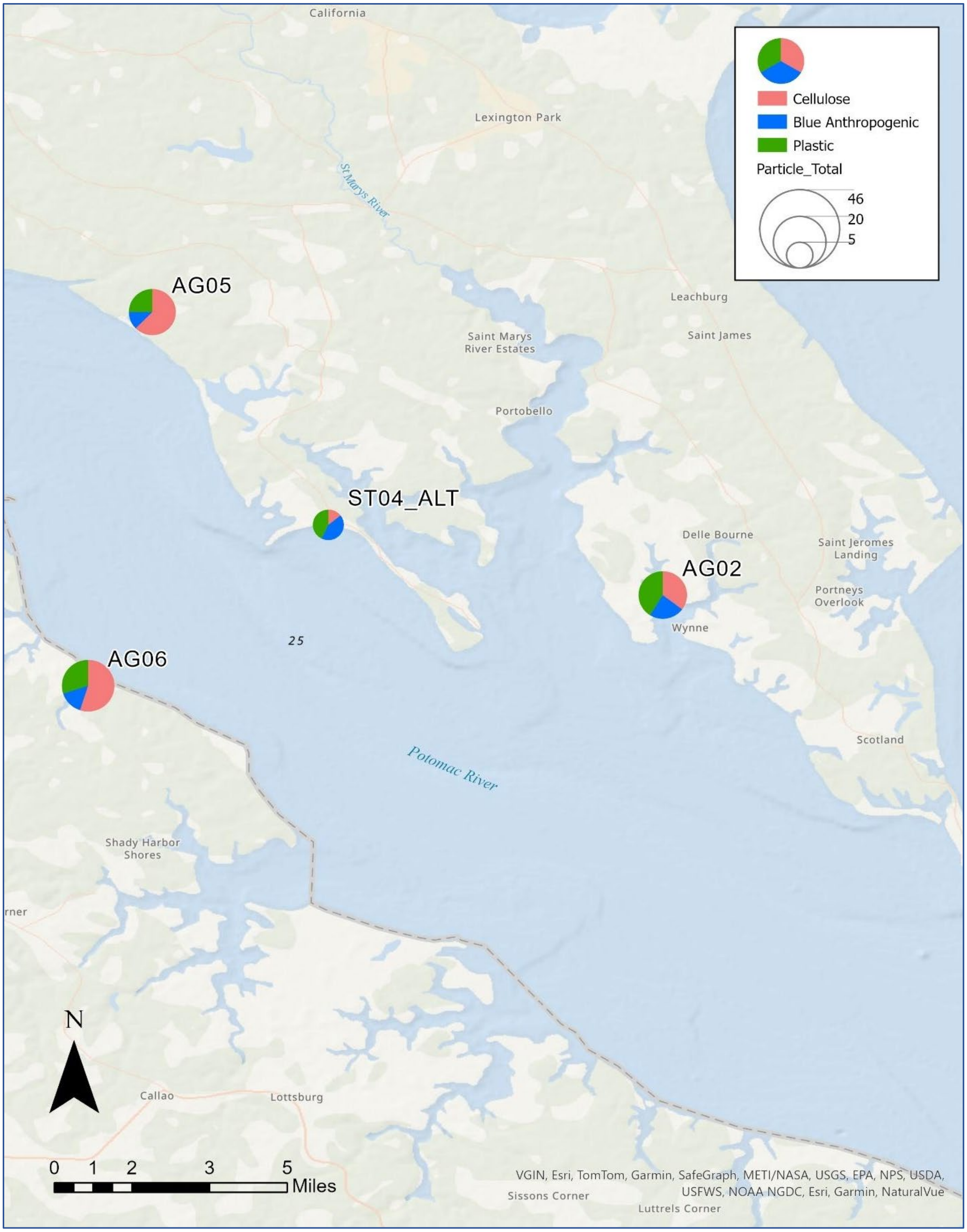

Figure 14. Lower Potomac River sites: distribution of particles by material type and particle count by site (Site Name Key: UR – Urban, SU – Suburban, AG – Agriculture, WE – Wetland/Natural, WA – Wastewater, ST – Stormwater).

Table 2. Particle material count by site.

Site	Cellulose Total	Plastic Total	Blue Anthropogenic Total
AG02	6	7	4
AG05	10	4	2
AG06	11	6	3
ST02	7	3	6
ST04_ALT	1	3	3
ST07	8	3	2
SU01	10	6	7
SU02	8	3	2
SU06	12	4	9
UR01	11	4	2
UR04	9	2	3
UR06	8	3	8
WA01	5	4	2
WA02	10	3	6
WA06_ALT	6	32	6
WE01	2	1	2
WE03	12	6	6
WE04	3	4	7

3.3 Particle Shape

Particle shape provides potential insight on the origin of individual particles from the landscape. As noted in numerous studies (Barrows et al., 2018, Miller et al., 2024, Rochman et al., 2022), fibers dominate the polymer assemblage regardless of land use type (Figures 15, 17-19, Table 3). However, there were no statistically significant differences between shapes (non-parametric Kruskal-Wallis test followed by Dunn's post hoc test and a Bonferroni p adjustment, $p > 0.05$ for all comparisons). With the fibers removed (Figure 16) it is easier to compare the remaining particle shapes. Fragments, fiber bundles, and flake with fiber are equally abundant in small numbers during baseflow conditions (Figure 16B) but there are very few of these shapes during stormflow conditions (Figure 16C).

Fibers are typically associated with fabricated textiles (e.g., clothing) based on polyesters and similar polymers (Athey and Erdle 2021). Although these particles are numerous in wastewater effluent (from inadequate filtration of gray water) (Conley et al., 2019), they are also the dominant particle type transported in air, creating widespread deposition (Dris et al., 2015, Dris et al., 2016).

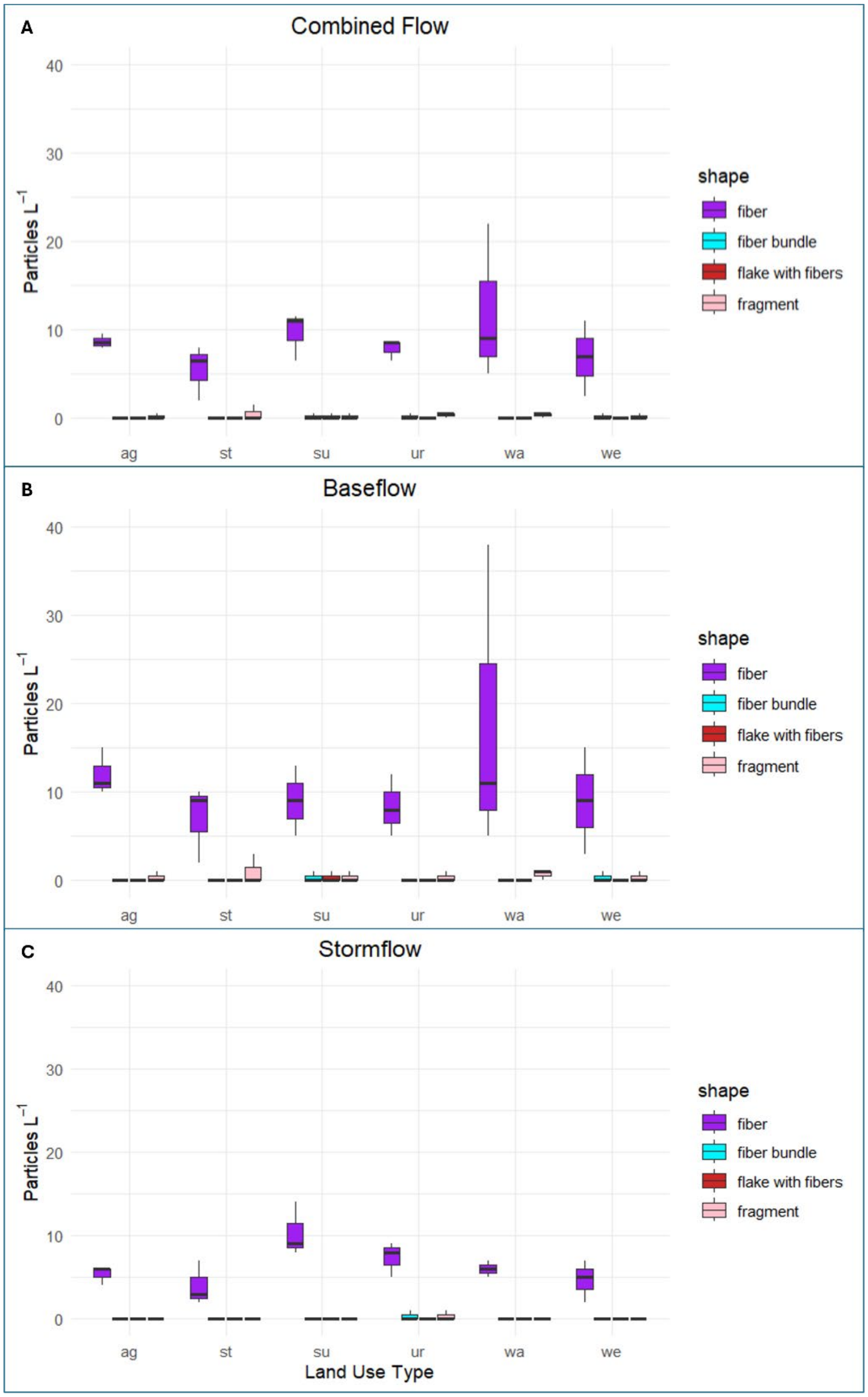

Figure 15. Concentration of particles by shape and land use at combined flow (A), baseflow (B), and stormflow (C) conditions. There were no statistically significant differences between groups with a non-parametric Kruskal-Wallis test followed by Dunn's post hoc test using a Bonferroni p adjustment ($p > 0.05$ for all comparisons). The boxes represent the interquartile range (25-75%), the central horizontal lines are the medians, and the vertical lines are the range.

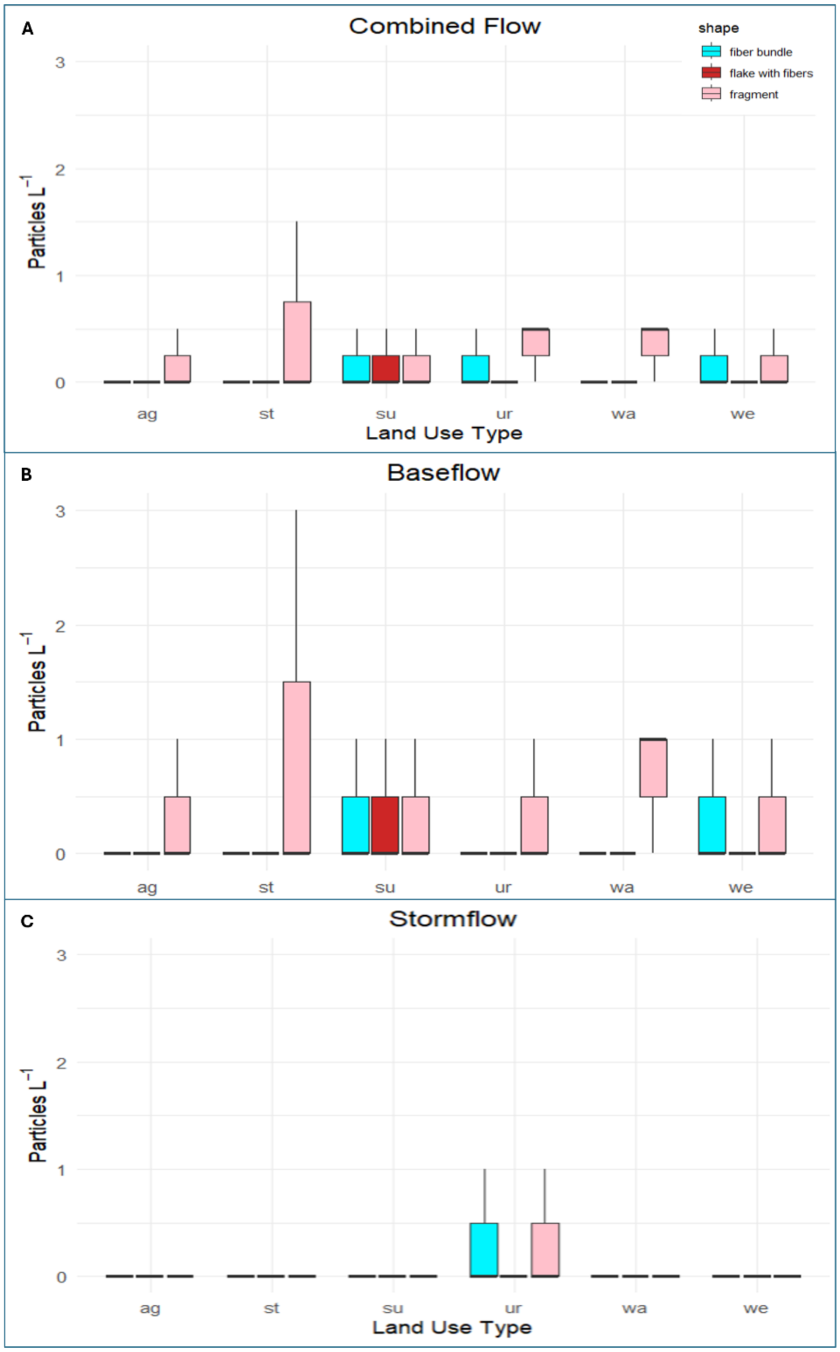

Figure 16. Concentration of particles by shape and land use type without fibers so other shapes are more visible. (A) combined flow, (B) baseflow, (C) stormflow. There were no statistically significant differences between groups with a non-parametric Kruskal- Wallis test followed by Dunn's post hoc test using a Bonferroni p adjustment ($p > 0.05$ for all comparisons). The boxes represent the interquartile range (25-75%), the central horizontal lines are the medians, and the vertical lines are the range.

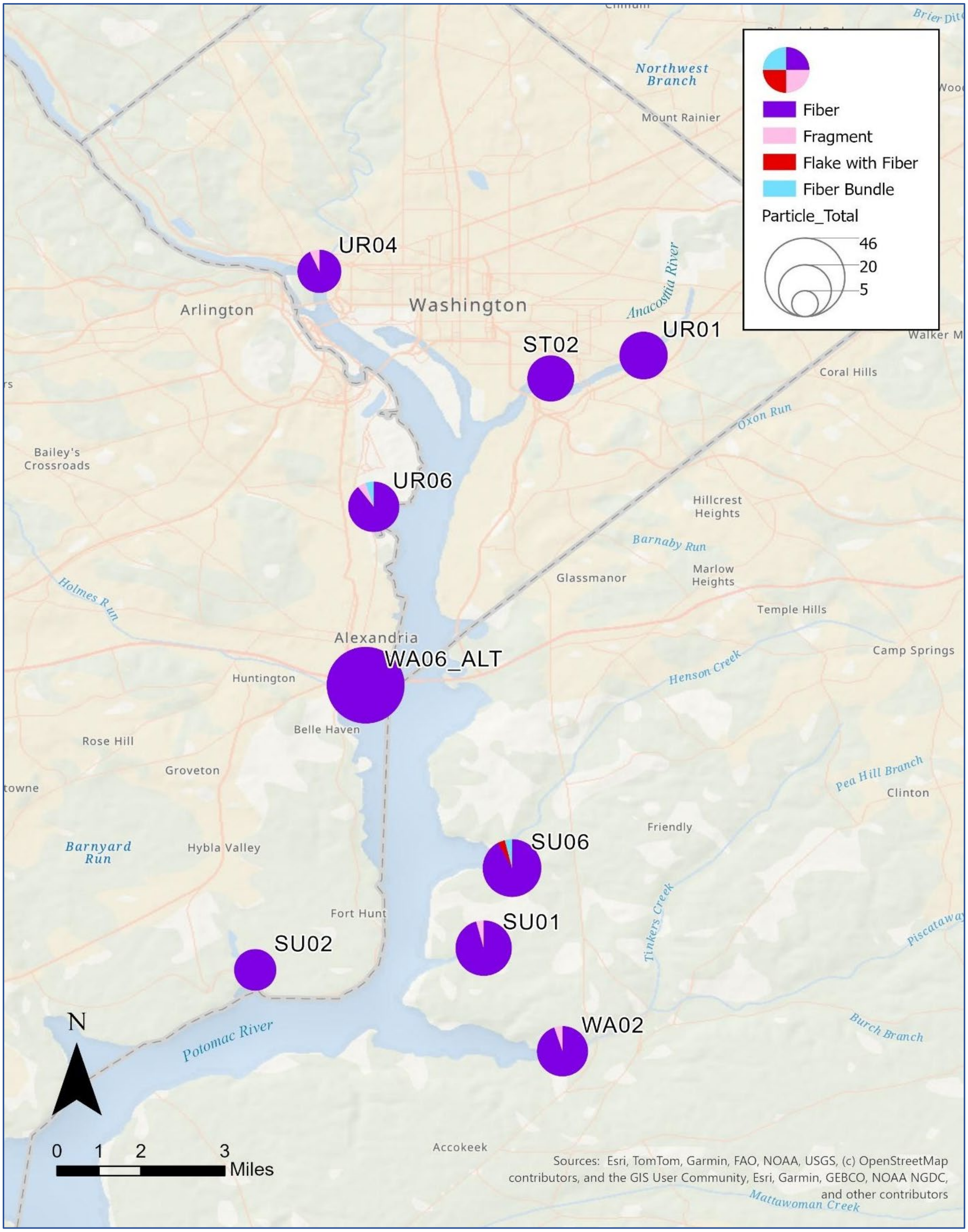

Figure 17. Upper Potomac River sites: distribution of particles by shape and particle count by site (Site Name Key: UR – Urban, SU – Suburban, AG – Agriculture, WE – Wetland/Natural, WA – Wastewater, ST – Stormwater).

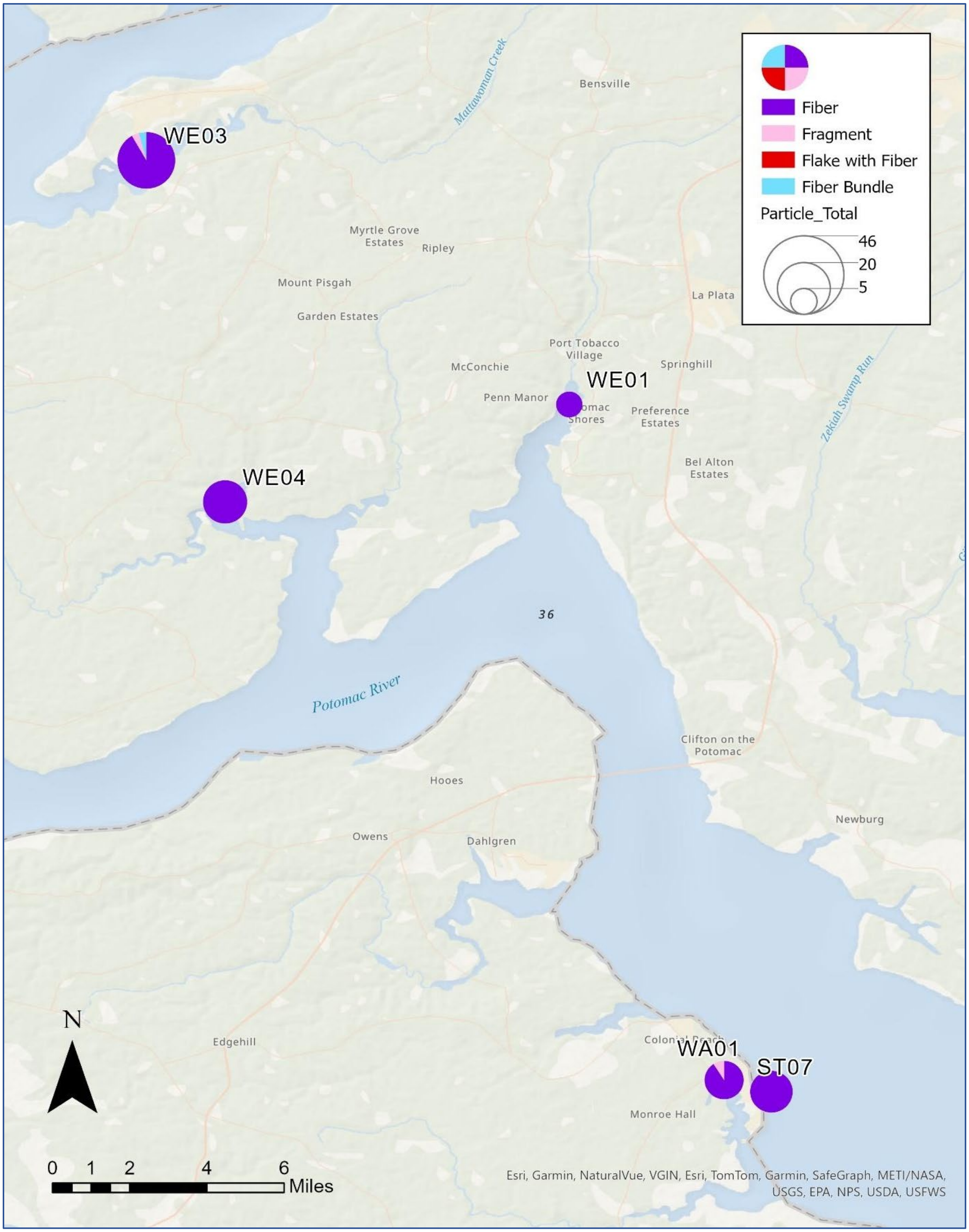

Figure 18. Middle Potomac River sites: distribution of particles by shape and particle count by site (Site Name Key: UR – Urban, SU – Suburban, AG – Agriculture, WE – Wetland/Natural, WA – Wastewater, ST – Stormwater).

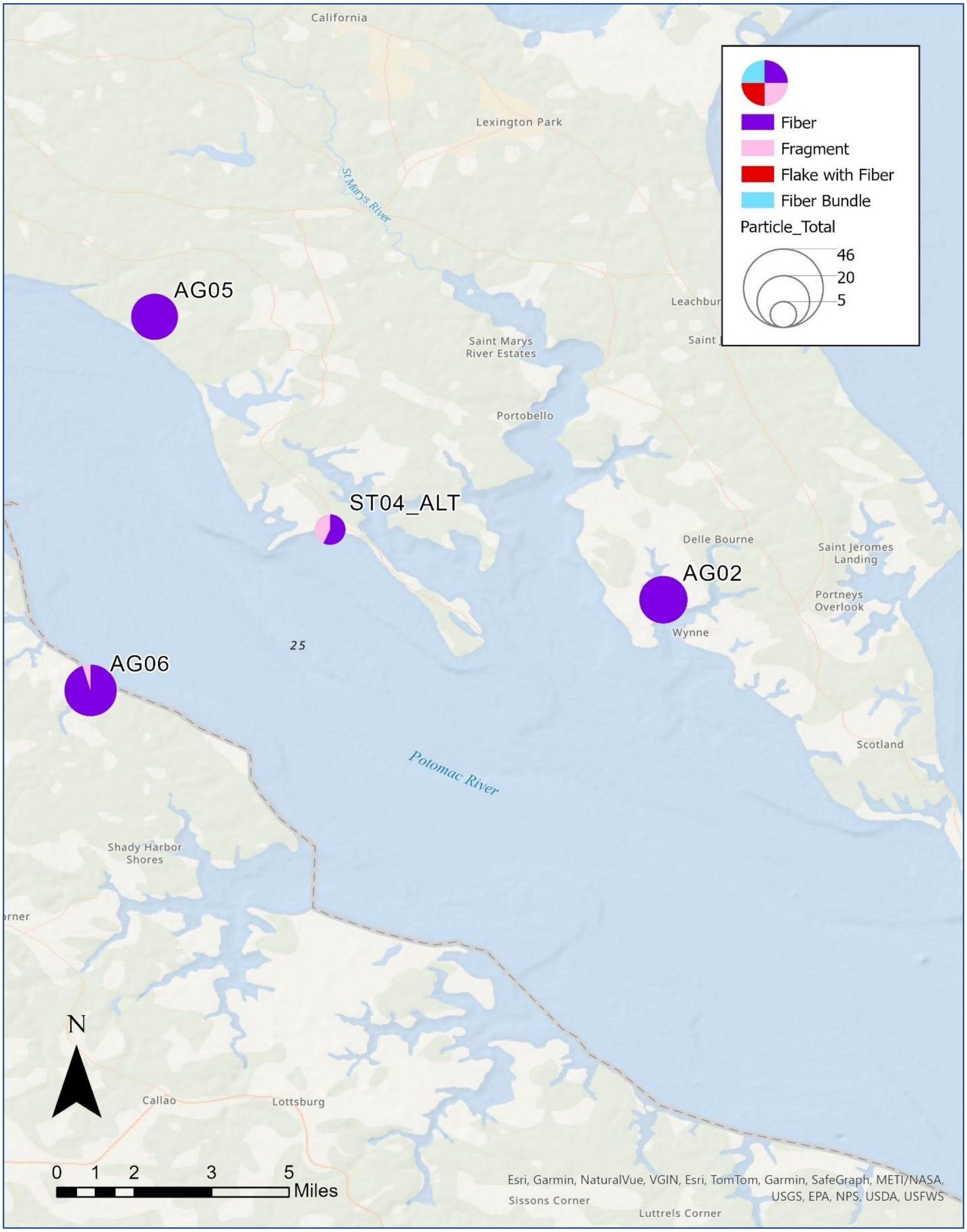

Figure 19. Lower Potomac River sites: distribution of particles by shape and particle count by site (Site Name Key: UR – Urban, SU – Suburban, AG – Agriculture, WE – Wetland/Natural, WA – Wastewater, ST – Stormwater).

Table 3. Particle shape count by site.

Site	Total Fiber	Total Fragment	Total Flake with Fibers	Total Fiber Bundle
AG02	17	0	0	0
AG05	16	0	0	0
AG06	19	1	0	0
ST02	16	0	0	0
ST04_ALT	4	3	0	0
ST07	13	0	0	0
SU01	22	1	0	0
SU02	13	0	0	0
SU06	23	0	1	1
UR01	17	0	0	0
UR04	13	1	0	0
UR06	17	1	0	1
WA01	10	1	0	0
WA02	18	1	0	0
WA06_ALT	44	0	0	0
WE01	5	0	0	0
WE03	22	1	0	1
WE04	14	0	0	0

4. Quality Control

Data review, validation, and verification provide methods for determining the usability and limitations of data and provide a standardized data quality assessment. Two replicate field samples were taken to assess variability within samples. Baseflow urban concentrations between replicates was 11 vs 12, suggesting low variability among samples. The stormflow replicate, collected at WE04 showed a higher degree of variability between sample and replicate (8 vs 4). All field forms and chain-of-custody forms entries were reviewed by the Tetra Tech Task Order Leader (TOL) for completeness and correctness. Data quality was assessed by comparing entered data to original data or by comparing results with the measurement performance criteria summarized in the quality assurance project plan (QAPP) to determine whether to accept, reject, or qualify the data. This application of data quality assurance was applied to Tetra Tech's laboratory processing of laboratory blanks and particle recovery estimates (Table 4). Data provided by the U.S. EPA ORD Atlantic Coastal Environmental Sciences Division (Raman analytical results) was subjected to their own QA/QC protocols and not reported here.

Table 4. Results from lab QC extraction and recovery of various microplastic morphologies.

Sample type	Spiked or Blank	Bead Recovery (%)	Target Bead Recovery (%)	Glitter Recovery (%)	Target Glitter Recovery (%)	Fiber Recovery (%)	Target Fiber Recovery (%)	Total Ambient Fibers Found	Target Ambient Fibers Found
QCLFB01	Spiked	93.3	≥ 70.0	90.0	≥ 70.0	53.3	≥ 50.0	NA	25% of Sample Mean
QCLFB02	Spiked	93.3		103.3		60.0		NA	
QCLFB03	Spiked	93.3		96.7		53.3		NA	
QCBK04	Blank	NA		NA		NA		4	
QCBK05	Blank	NA		NA		NA		2	
QCBK06	Blank	NA		NA		NA		5	

5. Discussion

Microplastic particles were detected in each sample of Potomac River water, regardless of land use, further confirming the ubiquity of these contaminants in the aquatic environment. Particle type (shape) was dominated by fibers, in contrast to other studies conducted in the Chesapeake Bay (Bikker et al., 2020, Yonkos et al., 2014). This is likely due to the different sampling techniques used. Bikker et al. (2020) and Yonkos et al. (2014) both used 330µm mesh net trawls which have been shown to collect a greater diversity of particle shapes but can miss smaller microfibers due to the large mesh size (Hung et al., 2020). Rochman et al. (2022) used bulk sampling with slightly larger volumes (4 and 10 L) and observed fibers in large proportions especially at their wastewater treatment site. As Table 5 suggests, the most likely source of fiber contamination is via laundry activities that create numerous particles dispersed via wastewater or atmospheric deposition.

This study suggests patterns of microplastic loadings are variable, dependent on flow (precipitation events). This difference may be an artifact of collecting bulk samples, which are limited in volume of water sampled, compared to net sampling or in-line pump filtration. Nonetheless, lower concentrations during stormflow (>2cm precipitation in 24 hours prior to sampling) events are observations that likely reflect dilution of the river system with increased precipitation.

We recognize this study was limited in sampling effort due to constrained resources. To improve resolution of land use and point source contributions We recommend improving upon this study by taking the following steps:

1. Increased replication per station to improve statistical power and ability to detect differences between stations and conditions.
2. Increased number of stations.
3. Replace bulk samples with manta (neuston) net sampling or in-line pump filtration.

Of course, the time and labor intensity of extracting and identifying microplastics makes addressing points 1 and 2 particularly challenging. However, a greater number of samples (replication and stations) will provide much greater statistical power. Conducting a power analysis and using the newly available Representative Sample Volume Predictions (RSVP) tool (Cross et al., 2025) can guide future studies expanding on this work. Including measured or nearby monitored streamflow data, such as U.S. Geological Survey (USGS) stream gauges, would be a better technique for determining flow conditions and it would provide a metric to normalize and compare the data more robustly. Additionally, changing the sampling technique from bulk sampling to a towed net or in-line pump methodology increases the volume sampled, potentially capturing samples that are more representative of the sites.

Table 5. Potential sources of particles by land use.

Material type by land use	Particle Count	Potential Sources
Biological	**7**	Biological material would be expected in the Potomac River as the watershed supports an abundance of life.
Stormwater	1	
Urban	1	
Wastewater	1	
Wetland/Natural	4	
Blue anthropogenic [1]	**80**	Given the Raman spectra were dominated by blue dye peaks and specific polymer types could not be identified, it is challenging to determine potential sources. Blue anthropogenic particles (all but two are fibers) are dominant in environmental samples (Barrows et al., 2018). Some potential sources are denim fabric, marine ropes, (Athey et al. 2020; Napper et al., 2021), and blue tarps. Although suburban sites had the most, there is no significant difference by land use, suggesting atmospheric deposition.
Agriculture	9	
Stormwater	11	
Suburban	18	
Urban	13	
Wastewater	14	
Wetland/Natural	15	
Cotton	**133**	Cotton fibers are a dominant feature of the materials collected from the water column. While they are not the focus of this assessment, their ubiquity supports the hypothesis that many fibers, cotton or polymer, are dispersed via atmospheric deposition.
Agriculture	24	
Stormwater	16	

Material type by land use	Particle Count	Potential Sources
Suburban	28	
Urban	27	
Wastewater	21	
Wetland/Natural	17	
Cotton polyester blend	**1**	One fiber of cotton-polyester blend was detected, likely from clothing or fabric of some kind. With only one particle detected, it is hard to draw conclusions on sources, considering the one particle was found in an agricultural watershed. Research has shown that biosolids, collected from wastewater treatment plants, often contain debris from laundry facilities, which could possibly explain the location of this particle (Crossman et al., 2020; Phong et al., 2024; Ramasamy et al., 2022).
Agriculture	1	
Cotton/Acrylic Blend	**5**	Cotton acrylic blends are a popular fabric for a variety of clothing and home textiles (rugs, blankets, etc.) and likely behave similarly to cotton polyester and other fibers that are released into the air during the laundry process. Again, although the number of fibers found is generally low, they are found across several land use types. As noted for cotton polyester blend, fibers captured at wastewater treatment plants may be transported to agricultural lands via biosolid application (Crossman et al., 2020; Phong et al., 2024; Ramasamy et al., 2022).
Agriculture	2	
Stormwater	1	
Urban	1	
Wastewater	1	
Lapis Lazuli	**1**	Lapis lazuli is not a synthetic material, but rather lithogenic and a naturally occurring substance. A single fragment was found in an urban site, likely due to escape from either the waste stream (litter), or from wear and tear on an item (jewelry, most likely).
Urban	1	
Polyamide	**1**	Polyamides constitute a class of polymers that are both natural (e.g., wool, silk) and synthetic (e.g., nylon). The

Material type by land use	Particle Count	Potential Sources
		single particle (fiber) is clear and is indistinguishable as to type (natural vs synthetic).
Suburban	1	
Polyester	**21**	Polyesters are a common class of polymers used in many commercial applications, particularly clothing manufacture. Both wastewater and agricultural sites had the highest concentrations, thus supporting the presumed pathway for many textile fibers: laundry to treatment plants to biosolid application on ag fields (Crossman et al., 2020; Phong et al., 2024; Ramasamy et al., 2022).
Agriculture	7	
Stormwater	3	
Suburban	1	
Urban	2	
Wastewater	5	
Wetland/Natural	3	
Polyethylene	**44**	A widely produced synthetic resin used in industrial processes and used to make common household products like shopping bags and cosmetic products. It is associated with anthropogenic activities and is commonly found in urbanized areas from industrial sources, in sewage sludge applied in agricultural settings, and in wastewater effluent (Crossman et al., 2020; Ramasamy et al., 2022). Most of the polyethylene particles found in this study were blue fibers; this corresponds to the above reference ("blue anthropogenic") as polyethylene is the primary constituent polymer found in tarps (also known as synthetic burlap).
Agriculture	5	
Suburban	4	
Urban	3	
Wastewater	27	
Wetland/Natural	5	

Material type by land use	Particle Count	Potential Sources
Polyethylene terephthalate	**12**	A common resin in the polyester category used for textiles, manufacturing, and for food and liquid containers like water bottles. Synthetic microfibers are commonly found in atmospheric samples and deposition could lead to them entering waterways with no known, local sources. Microfibers are also common in wastewater effluent due to garment and textile washing (Ramasamy et al., 2022).
Agriculture	1	
Stormwater	2	
Suburban	4	
Urban	2	
Wastewater	2	
Wetland/Natural	1	
Polypropylene	**9**	A commonly produced and resilient synthetic polymer with various applications including manufacturing (e.g., piping systems), yarns and textiles, and household products (e.g., food storage containers, rugs, waste baskets). Its prevalence in nature is associated with anthropogenic activities and it is commonly found in urbanized areas and in wastewater effluent (Contreras-Llin et al., 2024; Wang et al., 2020). Polypropylene was not found in agricultural or wetland/natural watersheds, thus supporting the conclusion it is largely a contaminant from developed lands.
Stormwater	2	
Suburban	2	
Urban	1	
Wastewater	4	
Polyurethane	**5**	Refers to a class of polymers commonly used to produce foams (e.g., footwear foam, upholstery and bedding foam, insulation, cleaning sponges, boats/surfboards). It is also used to varnish wood, in wheels (e.g., skateboards), to waterproof garments, and in textiles (e.g., spandex). Polyurethane is commonly found in wastewater effluent as fibers (Li et al., 2023). There is no pattern in distribution among

Material type by land use	Particle Count	Potential Sources
		land use types, although none were found in urban or Wastewater samples.
Agriculture	1	
Stormwater	1	
Suburban	1	
Wetland/Natural	2	
Rayon	**1**	A semi-synthetic fiber made from cellulose. Used in garment and textile production, it is commonly found in wastewater effluent, sewage sludge, and in urban stormwater runoff as a microfiber (Edo et al., 2019; Zambrano et al. 2019). Microfibers are commonly found in atmospheric samples and deposition could lead to them entering waterways across different land use types with no known local sources.
Suburban	1	
Tencel	**3**	A semi-synthetic fiber made from cellulose similar to rayon but produced differently. Used in garment and textile production, it is commonly found in wastewater effluent, sewage sludge, and in urban stormwater runoff as a microfiber (Edo et al., 2019; Zambrano et al. 2019). Microfibers are commonly found in atmospheric samples and deposition could lead to them entering waterways across different land use types with no known local sources.
Agriculture	1	
Suburban	1	
Urban	1	
Viscose	**2**	A semi-synthetic fiber made from cellulose similar to rayon but produced differently. Used in garment and textile production, it is commonly found in wastewater effluent, sewage sludge, and in urban stormwater runoff as a microfiber (Edo et al., 2019; Zambrano et al. 2019). Microfibers are commonly found in atmospheric samples and deposition could lead to them entering waterways across different land use types with no known local sources.
Agriculture	2	

Material type by land use	Particle Count	Potential Sources
Grand Total	**325**	

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