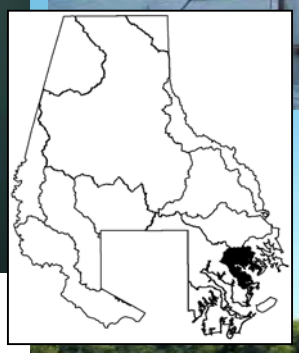
Water Quality Management Plan

for Middle River Watershed



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Submitted to:

Baltimore County Department of Environmental Protection and Resource Management

Submitted by:

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Executive Summary

INTRODUCTION

This report presents a watershed water quality management plan for the Middle River watershed located in the southeastern portion of Baltimore County. This plan presents recommendations based on the results of the Middle River Water Quality Management Plan study conducted for the Baltimore County Department of Environmental Protection and Resource Management (DEPRM). The report summarizes the work performed, findings, and recommendations for watershed protection measures in the Middle River watershed.

Middle River is located in urban and suburban portions of southeastern Baltimore County and includes Martin Airport. Figure ES-1 presents a location map of the Middle River watershed. This management plan focuses on structural and nonstructural control measures to minimize the effects of existing and future urban development and boating-related activities on water quality within tributaries of Middle River, the estuary and the Chesapeake Bay.

Background And Study Purpose

Stormwater runoff from urbanized areas carries many pollutants, including nutrients, oil and grease, heavy metals and organic pollutants such as residues from pesticides. The 1987 Clean Water Act Amendments required EPA to issue rules for permitting stormwater discharges. Under these rules, urban areas must obtain a permit and develop programs to control discharge of pollutants in stormwater to the "maximum extent practicable."

The Middle River watershed has only nine miles of stream channels. When compared with the rest of the County's watersheds, runoff from Middle River is not a significant source of impacts to the County's waterways overall or to the Chesapeake Bay, although locally significant impact could occur. Stream miles and area contained within each county watershed are as follows:

Watershed Name	Stream Miles	Area, Square Miles
Loch Raven	877	215
Lower Gunpowder	217	46
Patapsco	202	53
Little Gunpowder	154	27
Jones Falls	131	40
Gwynns Falls	112	44
Bird River	78	25
Back River	74	36
Baltimore Harbor	73	18
Middle River	9	12

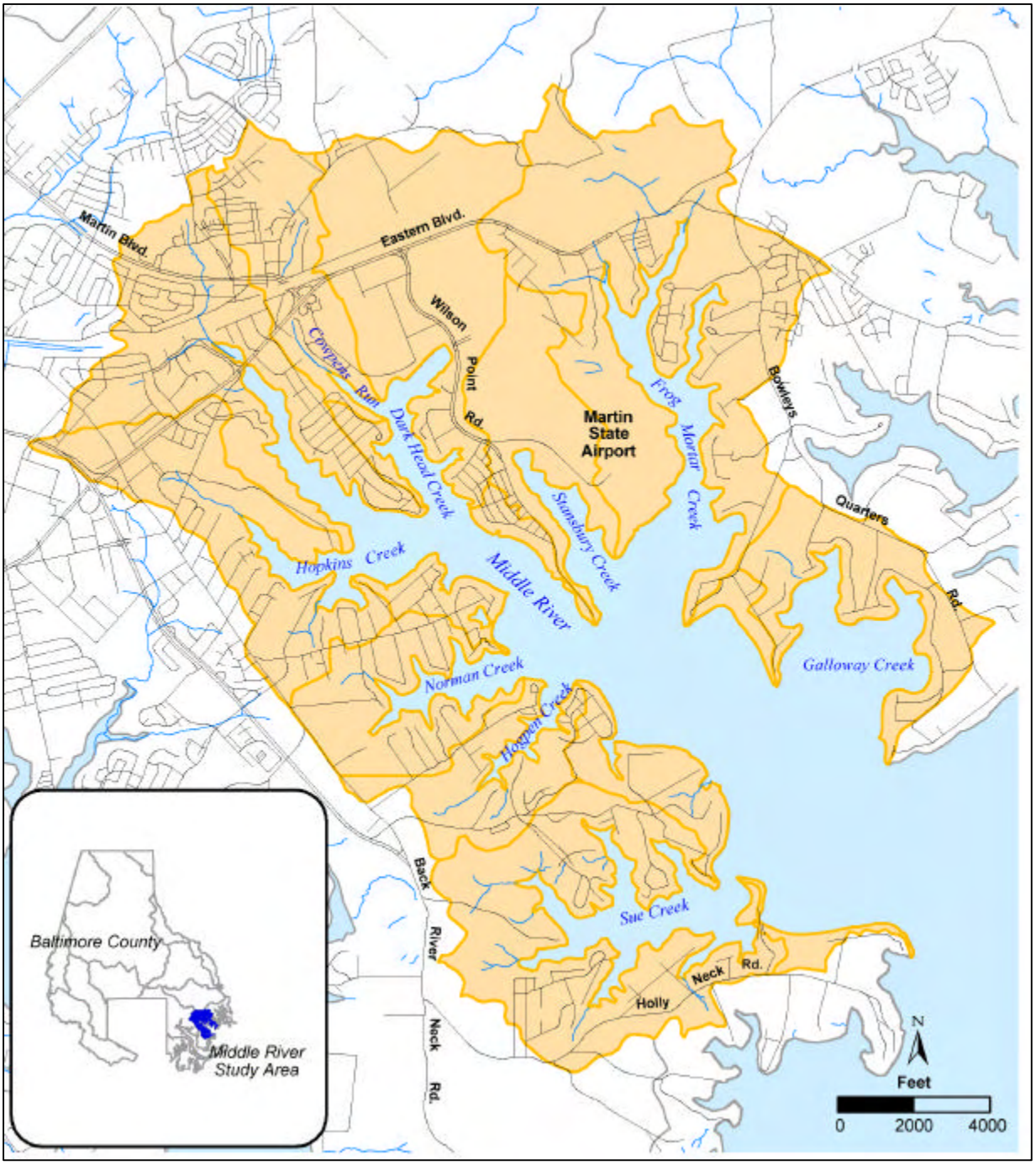

Figure ES-1. Watershed location, Middle River, Maryland

Stormwater runoff pollution is usually referred to as "nonpoint source pollution" or "nonpoint pollution" because it enters streams at thousands of different places at intermittent times during and after rainfall. Nonpoint source pollution is a threat to water quality in the Middle River watershed. Urban nonpoint pollution is directly related to the amount of imperviousness associated with each land use category within the drainage area. Impervious surfaces such as roads, airport runways, rooftops, parking lots, driveways, and marinas are major sources of nonpoint pollution. In addition, recreational boating and related facilities contribute to water quality problems and shoreline erosion in Middle River.

Stormwater Aflow@ is also a water quality concern in suburban watersheds like Middle River. Development increases the frequency and magnitude of the stormwater flows which must be conveyed by natural stream channels. As a result, stormwater runoff can degrade stream channels by causing erosion, cave-ins, and excessive sediment deposition. EPA stormwater permitting guidelines have recognized that stormwater flow may be as significant a water quality problem as stormwater pollution. In an August 1996 guidance memorandum AInterim Permitting Approach for Water Quality-Based Effluent Limitations in Stormwater Permits,@ the EPA Assistant Administrator for the Office of Water states that:

> Uses may be impacted by both water quality and water quantity. Depending on site-specific considerations, some of the water quality impacts of stormwater discharges may be more related to the physical effects (e.g., stream bank erosion, streambed scouring, extreme temperature variations, sediment smothering) than the type and amount of pollutants present in the discharge.

Increased loadings of nonpoint pollutants such as sediment, nutrients, and heavy metals resulting from the highly urbanized conditions in the watershed are also clearly a concern. Owing to the flashy nature of urban and suburban runoff, and the truncated first and second order stream system, there are relatively short hydraulic residence times in the tributary subwatersheds. Nonpoint pollution loads will therefore primarily impact downstream tidal receiving waters of Middle River and the Chesapeake Bay. During storm events, nonpoint pollution loadings are rapidly transported downstream to tidal receiving waters (typically in a few hours or less). Stormwater pollution loadings to Middle River can be managed by requiring structural best management practices (BMPs) for all new development and by pursuing a program to convert stormwater ponds into pollution control facilities and to retrofit existing development with BMPs.

Table ES-1 summarizes projected annual loadings of phosphorus, nitrogen, and metals from nonpoint sources under different land use conditions and water quality management scenarios. This table provides a watershed-wide context for evaluating water quality management measures.

Table ES-1
Summary of annual nonpoint source loadings (in pounds) to Middle River watershed for various development scenarios and new stormwater management (SWM) ponds (results based on SWMM modeling for a wet year).

	Total Nitrogen	**Total Phosphorus**	**Total Suspended Solids**	**Lead**	**Copper**	**Zinc**	**Cadmium**
Pre-development conditions	2779	485	202495	0	0	0	0
Existing conditions	32311	3245	1173913	579	209	1781	104
Existing conditions with SWM ponds	31048	3077	1109534	539	199	1682	96
% decrease with SWM ponds	4%	5%	5%	7%	4%	6%	8%
Future conditions with SWM ponds	35987	4317	1214073	721	196	1866	145
% change from existing to future with SWM ponds	10%	25%	3%	20%	-7%	5%	29%

Study Elements

The elements of the study included:

- Watershed characterization to identify and evaluate nonpoint source stormwater pollution;
- Hydrologic and water quality modeling analyses using a modified version of the United States Environmental Protection Agency's (USEPA's) Storm Water Management Model (SWMM) to assess runoff and loading characteristics of the Middle River watershed;
- Development of a 2-dimensional estuarine hydrodynamic and water quality model of the Middle River estuary, focusing on flushing rates, nutrients, and metals contamination;
- Determination of management measures for the reduction of nonpoint source pollution;
- Determination of management measures for water dependent uses in the estuarine system; and,
- Preparation of a watershed restoration framework for the County's Capital Improvement Program.

Watershed Characteristics

The Middle River Watershed covers a 12 square mile area and includes Martin Airport. At present, about 67 percent of the overall Middle River watershed consists of residential, commercial or industrial development (Figure ES-2, Table ES-2). This percentage is expected to increase to 92 percent under future land used conditions (complete build-out to levels allowed by 1995 Baltimore County zoning regulations – Figure ES-3, Table ES-3). The watershed is about 38 percent impervious at present; based on 1995 zoning, the percent of development in the watershed will increase to 49 percent imperviousness in the future. The composite percent directly connected impervious area (DCIA) is 30 percent for existing land use conditions, and is expected to increase to 38 percent under the future land use scenario (Table ES-4).

Water Quality Analysis

Baseflow monitoring data collected by DEPRM under the Baltimore County National Pollutant Discharge Elimination System (NPDES) stormwater program were supplemented by regional and national studies on urban runoff to develop nonpoint pollutant loading factors for each land use category in the watershed (Table ES-5). Coupled with watershed-specific information on rainfall/runoff relationships, and point source dischargers, these data were used to develop a water quality model of the Middle River watershed. The model selected to evaluate the

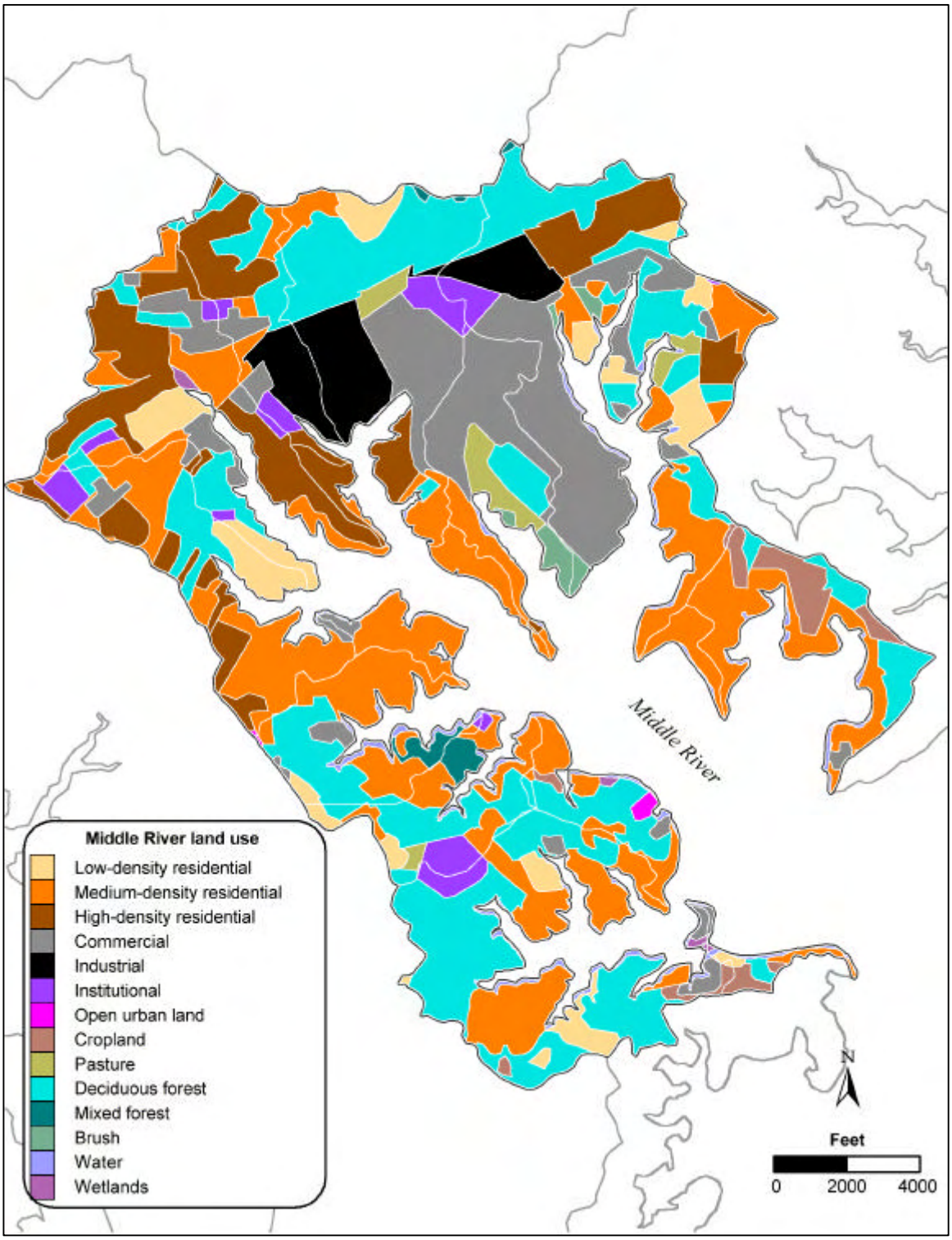

Figure ES-2. Existing (1997) land use in the Middle River watershed

Table ES-2
Existing (1997) land use in the Middle River watershed

Land use	Acres	Percent
Low-Density Residential	319	5.4%
Medium-Density Residential	1,568	26.6%
High-Density Residential	722	12.3%
Commercial	873	14.8%
Industrial	297	5.0%
Institutional	176	3.0%
Open Urban Land	9	0.2%
Cropland	115	2.0%
Pasture	94	1.6%
Deciduous Forest	1,518	25.8%
Mixed Forest	45	0.8%
Brush	44	0.7%
Water	97	1.6%
Wetlands	11	0.2%

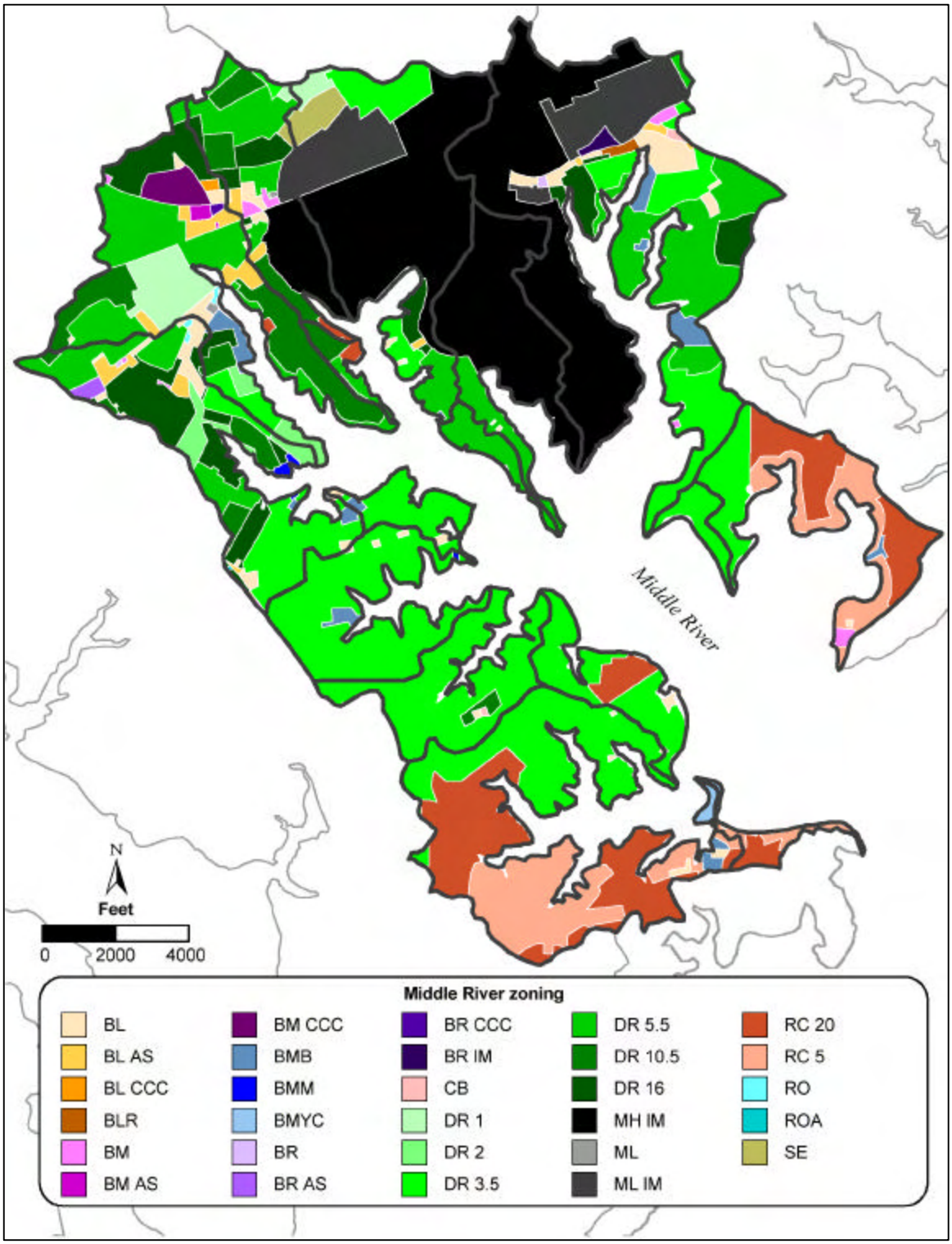

Figure ES-3. 1995 Baltimore County zoning in the Middle River watershed

Table ES-3
1995 Baltimore County zoning classes for the Middle River watershed

Code	Zoning Class	Acres	Percent
RO	Residential Office	3	0.1%
ROA	Residential Office (Class A)	0	0.0%
SE	Service Employment	35	0.6%
BL	Business Local	126	2.1%
BL AS	Business Local - Automotive Service	67	1.1%
BL CCC	Business Local - Commercial, Community Core	3	0.1%
BLR	Business Light Restricted	6	0.1%
BM	Business Major	21	0.4%
BM AS	Business Major - Automotive Service	5	0.1%
BM CCC	Business Major - Commercial, Community Core	34	0.6%
BMB	Business Maritime Boatyard	74	1.3%
BMM	Business Maritime Marina	7	0.1%
BMYC	Business Maritime Yacht Club	11	0.2%
BR	Business Roadside	3	0.0%
BR AS	Business Roadside - Automotive Service	8	0.1%
BR CCC	Business Roadside - Commercial, Community Core	2	0.0%
BR IM	Business Roadside - Industrial, Major	8	0.1%
CB	Community Business	4	0.1%
RC 5	Rural Residential	326	5.5%
DR 1	Density Residential 1 units / acre	95	1.6%
DR 2	Density Residential 2 units / acre	60	1.0%
DR 3.5	Density Residential 3.5 units / acre	1,552	26.4%
DR 5.5	Density Residential 5.5 units / acre	769	13.1%
DR 10.5	Density Residential 10.5 units / acre	275	4.7%
DR 16	Density Residential 16 units / acre	323	5.5%
MH IM	Manufacturing Heavy - Industrial, Major	1,273	21.6%
ML	Manufacturing Light	3	0.0%
ML IM	Manufacturing Light - Industrial, Major	249	4.2%
RC 20	Resource Conservation - Critical Area	458	7.8%

Table ES-4
Amount of impervious area and directly connected impervious area (DCIA)
in Middle River subwatersheds, based on current (1997)
and future (1995 zoning) land use

Subwatershed	AREA	Imperviousness (%)		DCIA (%)	
	Acres	Current	Future	Current	Future
Hopkins Creek	509	36%	50%	25%	37%
Norman Creek	317	27%	37%	19%	22%
Dark Head Creek-A	712	43%	71%	36%	60%
Dark Head Creek-B	38	48%	42%	43%	29%
Middle River-A	662	46%	50%	35%	37%
Middle River-B	171	21%	30%	15%	18%
Middle River-C	45	29%	14%	25%	11%
Middle River-D	88	42%	40%	28%	25%
Middle River-E	50	36%	35%	21%	20%
Middle River-F	44	38%	35%	23%	20%
Stansbury Creek	346	53%	74%	46%	63%
Frog Mortar Creek-A	11	39%	35%	25%	20%
Frog Mortar Creek-B	39	37%	35%	24%	20%
Frog Mortar Creek-C	92	30%	49%	21%	35%
Frog Mortar Creek-D	56	24%	36%	17%	21%
Frog Mortar Creek-E	193	28%	40%	21%	25%
Frog Mortar Creek-F	296	42%	71%	34%	60%
Frog Mortar Creek-G	298	50%	78%	42%	67%
Frog Mortar Creek-H	218	87%	80%	77%	70%
Galloway Creek	344	24%	16%	16%	11%
Cowpens Run	336	51%	60%	42%	47%
Sue Creek-A	9	94%	87%	87%	77%
Sue Creek-B	748	19%	19%	13%	12%
Hogpen Creek	266	20%	36%	13%	21%
TOTAL	5887	38%	49%	30%	38%

Table ES-5
Calibrated maximum pollutant accumulation values for each land use and pollutant (lbs/acre)

Land Use Category	BOD	COD	TSS	TP	DP	TN	Pb	Cu	Zn	Cd
Agricultural	0.860	3.968	4.022	0.025	0.005	0.177	0.0	0.0	0.0	0.0
Forest	0.878	4.065	4.343	0.010	0.002	0.060	0.0	0.0	0.0	0.0
Urban Open	0.924	4.279	4.578	0.011	0.002	0.062	0.0033	0.0013	0.0058	0.0000
Low Density Residential	1.486	4.639	5.011	0.043	0.009	0.493	0.0026	0.0028	0.0070	0.0005
Medium Density Residential	1.783	5.747	6.603	0.031	0.006	0.300	0.0021	0.0021	0.0090	0.0005
High Density Residential	2.106	6.597	12.056	0.048	0.010	0.369	0.0050	0.0021	0.0210	0.0007
Commercial	3.930	29.676	42.297	0.065	0.013	0.926	0.0247	0.0069	0.0751	0.0042
Industrial	2.425	16.449	22.105	0.079	0.016	0.460	0.0181	0.0015	0.0344	0.0038
Institutional	1.783	5.747	6.603	0.031	0.006	0.300	0.0021	0.0021	0.0090	0.0005
Water/Wetlands	0.394	1.338	0.706	0.011	0.007	0.133	0.0051	0.0053	0.0107	0.0001

watershed was the USEPA Stormwater Management Model (SWMM). SWMM is the primary planning tool used by the county to estimate nonpoint loads and to predict downstream benefits of structural Best Management Practices (BMPs) such as Stormwater Management (SWM) ponds. SWMM was applied to existing and future land use scenarios and management strategies to assess the relative benefits for protecting water quality.

An estuary model of Middle River was developed, consisting of two major components: a hydrodynamic model and a water quality model. In general, the hydrodynamic model computes the circulation of water due to tides, density variation, wind, and freshwater flow. An important feature of the hydrodynamic model is the computation of transport and mixing processes within the tidal cycle. The water quality model represents the physical, chemical, and biological processes that occur in the water and is directly coupled with the hydrodynamic model. In addition, the water quality model can calculate the effect of point and nonpoint source inputs on water quality parameters, such as metals, solids, and nutrient levels.

The coupled hydrodynamic and water quality models were developed to assess the impact of nonpoint source inputs and BMPs in Middle River. Specifically, the models were developed to address the complex circulation and mixing issues associated with an estuarine system and also to evaluate the impact of NPS inputs of nutrients, solids, and metals. In addition, the models were also used to assess the flushing characteristics of particular creeks or arms of the Middle River Estuary.

Watershed Management Strategies

Management strategies for water quality protection alternatives include "structural" and "nonstructural" BMPs. The Middle River watershed is currently 67 percent built-out and much of the existing development predates stormwater management regulations. Therefore, there are only limited opportunities for watershed water quality management.

Effective nonstructural BMPs include controlling land use through local zoning and subdivision regulations that can reduce the pollution generated from future development by controlling the amount and location of impervious surfaces and other pollution generating sources. Nonstructural BMPs include density restrictions, locational restrictions, prohibition or restriction of highly impervious land uses, land acquisition, buffer zones and operations programs. Operations programs are an important component of controlling nonpoint source pollution; these include the illicit connections program, storm drain inlet cleaning (VACON), street sweeping, storm water management facility maintenance, derelict boat removal, and public participation and education. Within Middle River Watershed, there is a total of about 458 acres of Resource Conservation (RC-20) zoning to control impervious surfaces and stormwater runoff within Sue Creek and Galloway Creek near the mouth of the Middle River estuary. The Baltimore County forest buffer zone requirements and forest conservation ordinance are additional nonstructural controls that could be used to provide additional protection in the watershed.

In the Middle River Watershed, implementation of structural BMPs is one feasible approach to achieve water quality control because of the high levels of existing and future imperviousness.

Structural BMPs are constructed downstream from urbanized areas and are typically designed to control the volume and discharge rate of runoff and to reduce the amount of pollutants discharged. Detention basins were identified as the most practical and cost effective BMP. This watershed includes part of the County=s recent Eastern Revitalization area under the Community Conservation initiative. As redevelopment occurs, there will be opportunities for encouraging bioretention and other infiltration practices. All structural BMPs require a capital investment for construction. In addition, a long-term commitment of funding and other resources is necessary for proper operation and maintenance to sustain effective performance of structural controls.

Evaluation Of Watershed Management Scenarios

Stormwater Management Model (SWMM) results show the greatest pollutant loadings in the upper end of the Middle River watershed, resulting from the greater level of development in that area now and development expected to continue into the future (Figure ES-4). Greatest loadings are estimated to occur from the Stansbury Creek and Frog Mortar Creek H subwatersheds, owing to the greater amounts of impervious surface and commercial and industrial land uses in those areas. Relatively high nutrient, sediment, and metal loadings also occur from the Frog Mortar Creek F and G subwatersheds, as well as from Dark Head Creek, Cowpens Run, Middle River mainstem, and Hopkins Creek subwatersheds. Somewhat lower loadings occur from Frog Mortar Creek A through E, Galloway Creek, and Norman Creek subwatersheds. Lowest loadings occur from Hogpen Creek and Sue Creek subwatersheds since they are less developed, except for marina areas near the lower end of Sue Creek which produce higher loadings.

Loadings projections with stormwater management (SWM) pond retrofits in the subwatersheds of Frog Mortar Creek and Cowpens Run showed a reduction in loadings between 13 and 22 percent in the former and between 11 and 32 percent in the latter, depending on constituent (Table ES-6). Loadings from the entire watershed are reduced by up to 8 percent with these SWM ponds. Projections for full development as currently zoned indicate up to a 34 percent increase in loadings throughout the watershed, including those with proposed SWM ponds. However, these ponds are projected to remove 17 to 31 percent of loadings in the Frog Mortar Creek subwatershed and 16 to 40 percent of loadings in Cowpens Run subwatershed.

Figure ES-5 illustrates the effectiveness of the watershed management projects in reducing future nonpoint loadings of total nitrogen (total-N). This pollutant is illustrated because it is of concern for protecting water quality in the Chesapeake Bay. Compared with present land use conditions, the annual pollution loading reductions projected for the proposed BMP projects are as follows: annual phosphorus loadings are reduced by 5 percent, nitrogen loadings by 4 percent, TSS loadings by 5 percent, and metals loadings by 4 percent to 8 percent.

Nonpoint source loadings from the SWMM model were used in the water quality model projection analyses to show the impact within the Middle River estuary (Figure ES-6). The improvement in water quality conditions with SWM pond retrofits was localized to Frog Mortar Creek (<15 percent) with negligible improvements elsewhere in the system (Figure

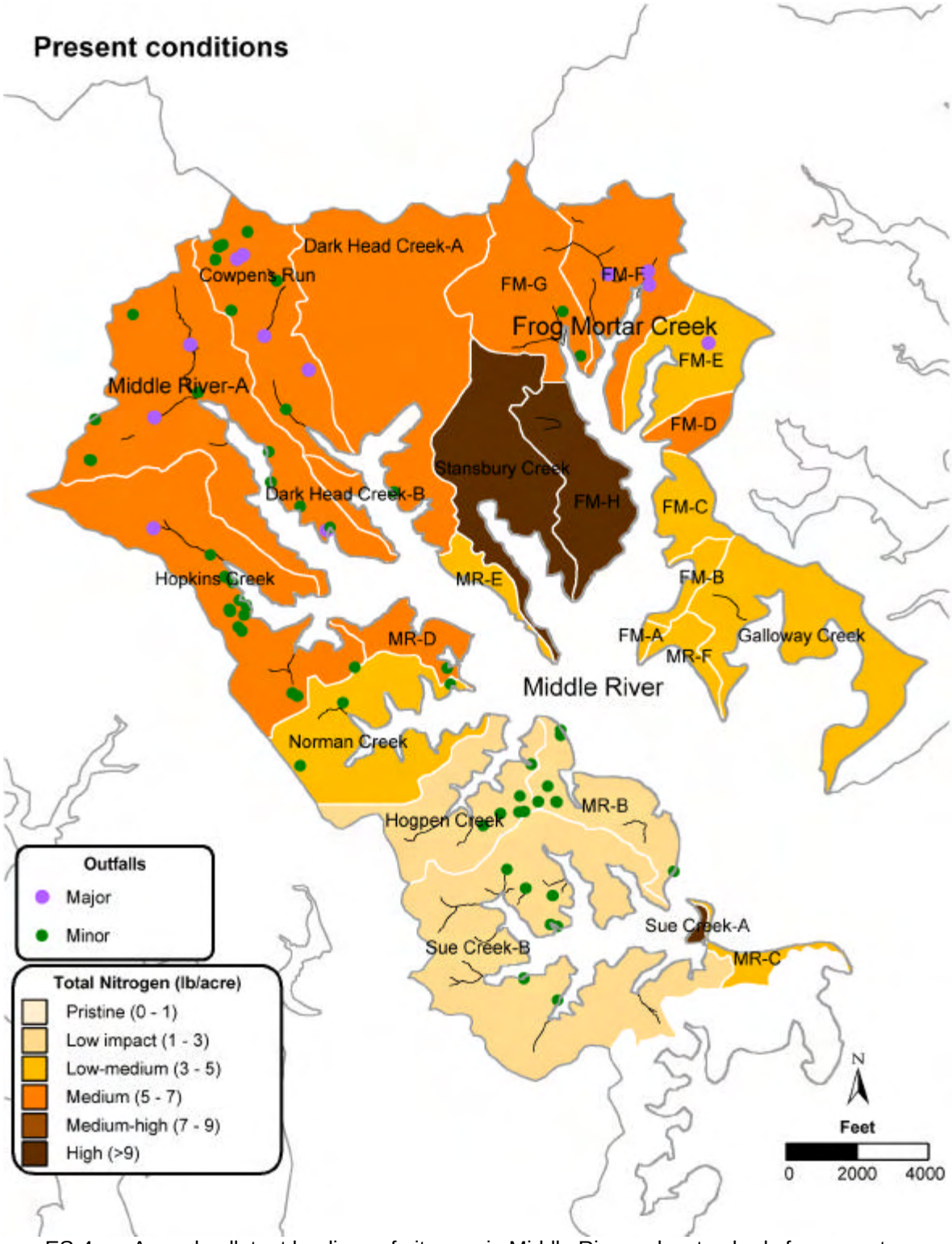

Figure ES-4. Annual pollutant loadings of nitrogen in Middle River subwatersheds for a worst-case (wet year) scenario, for existing land use

Table ES-6
Summary of pollutant changes in Middle River watershed under present and future land-use scenarios, assuming a worst-case (wet year) condition.

Percent removal of pollutants by SWM pond retrofits									
	POLLUTANT								
Present scenario	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Chemical Oxygen Demand	Total Suspended Solids	Lead	Copper	Zinc	Cadmium
Frog Mortar Creek	13%	19%	21%	16%	16%	20%	15%	16%	22%
Cowpens Run	19%	19%	32%	19%	22%	14%	30%	22%	11%
Future scenario									
Frog Mortar Creek	17%	20%	26%	24%	25%	29%	21%	26%	31%
Cowpens Run	23%	19%	34%	21%	23%	17%	40%	25%	16%
Total percent removal of pollutants by SWM pond retrofits for the present scenario									
Middle River (entire)	4%	5%	6%	5%	5%	7%	4%	6%	8%
Total percent removal of pollutants in the future scenario, compared with present conditions, with retrofits									
Middle River (entire)	14%	29%	12%	10%	9%	25%	-2%	10%	34%

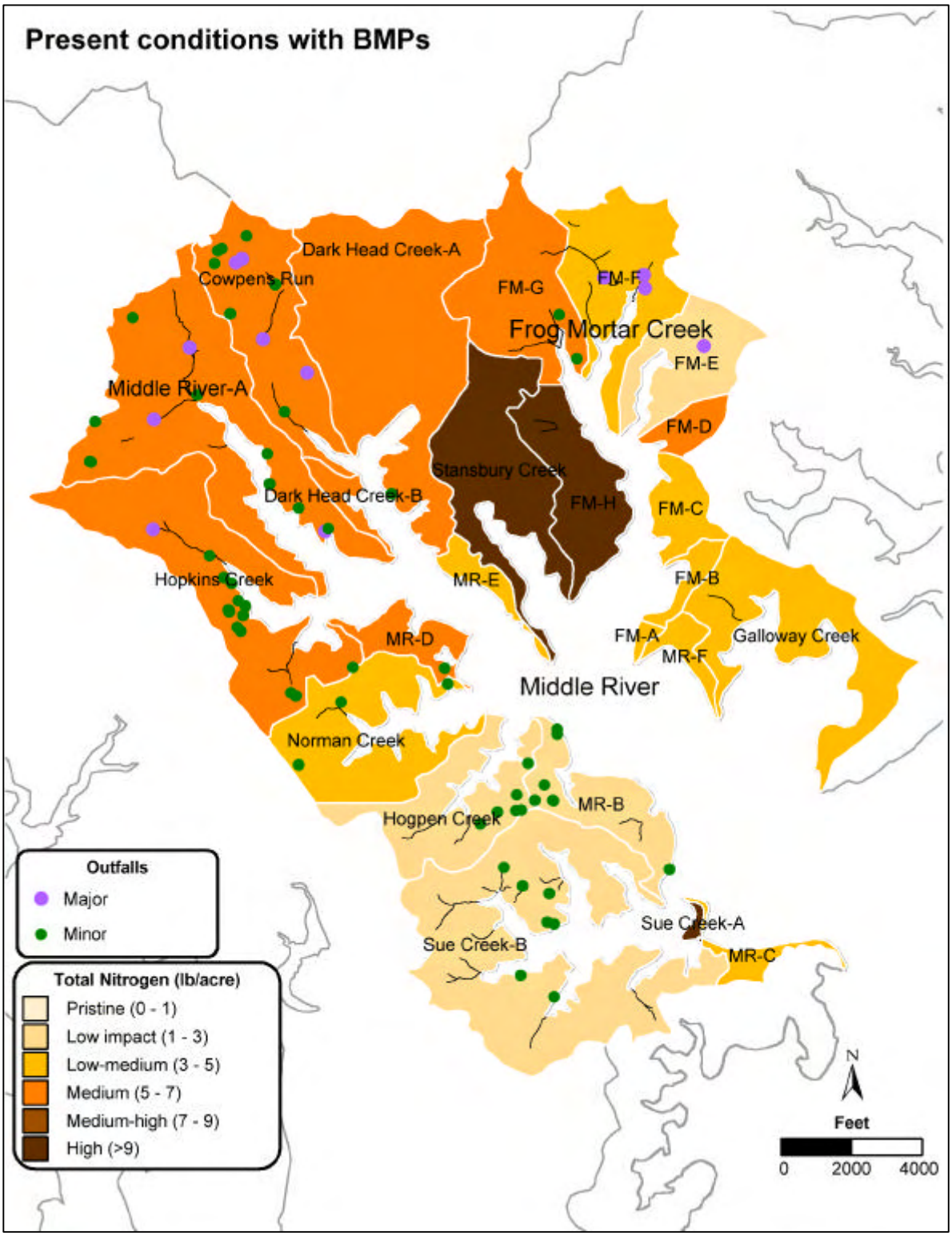

Figure ES-5. Annual pollutant loadings nitrogen in Middle River subwatersheds for a worst-case (wet year) scenario, for existing land use with SWM retrofits

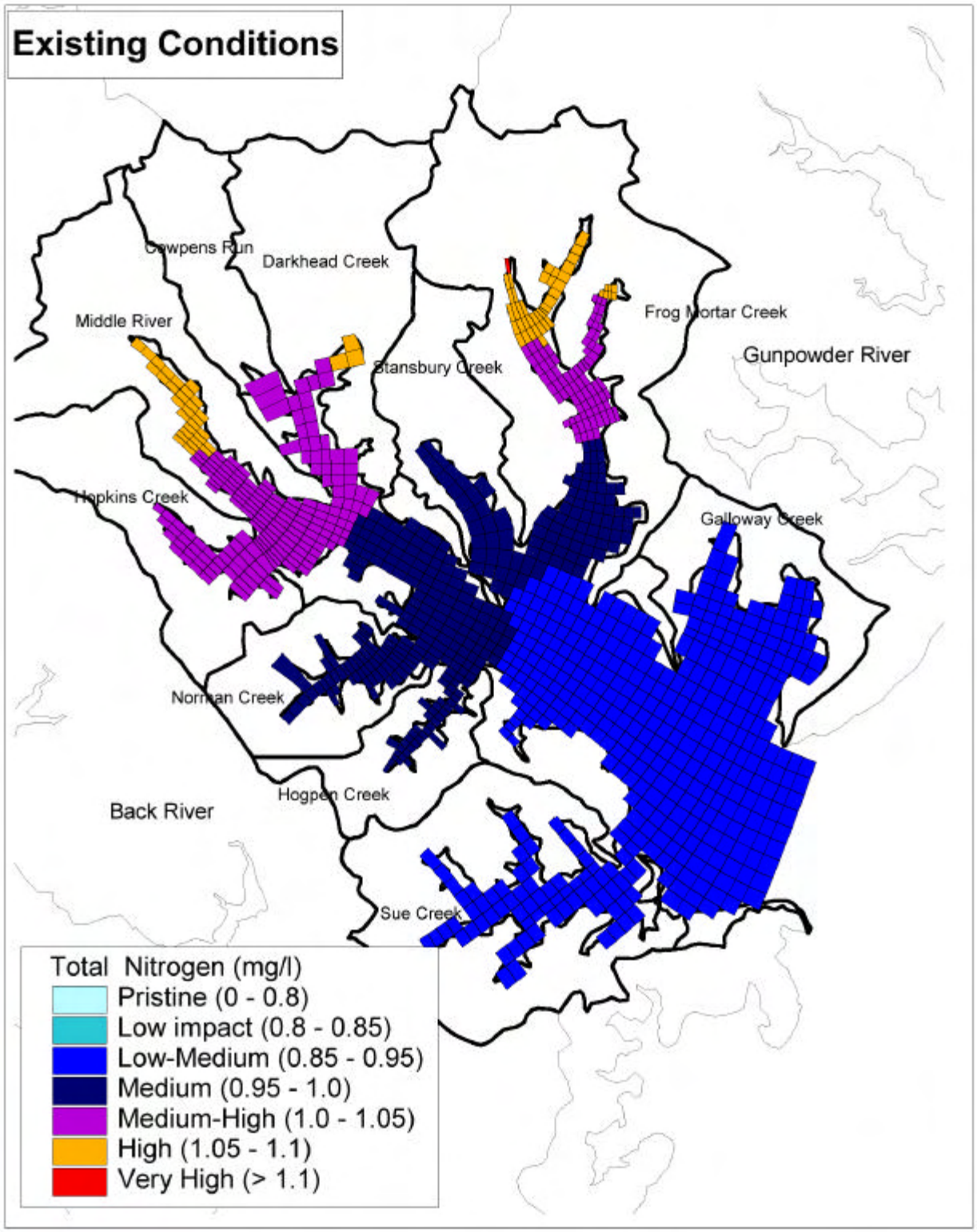

Figure ES-6. Average water column concentrations of total nitrogen in Middle River for a worst-case (wet year) scenario, for existing land use

ES-7). Water quality concentrations increased in the fully-developed condition even with new SWM ponds in Frog Mortar Creek and Cowpens Run (Figure ES-8). Increases in water quality concentrations of less than 5 percent occurred in the sub-watersheds of Galloway Run, Sue Creek, Middle River C and F, and Frog Mortar Creek B through H. Increases between 5 and 25 percent occurred in upstream areas especially within Hogpen Creek, Norman Creek, Hopkins Creek, Middle River A, B, D, and E, Cowpens Run, Dark Head Creek A and B, Stansbury Creek and Frog Mortar Creek A.

Watershed protection scenarios, based on both non-structural and structural controls, were evaluated to determine a recommended watershed management plan. Several components were evaluated in developing the watershed management plan:

- Nonstructural / Source Control Programs
- Urban Retrofit Structural BMP Facilities
- New Development Structural BMP Facilities
- Shoreline Restoration Projects
- Clean Marina Initiatives

The structural BMPs (Figure ES-9) were ranked (Table ES-7) by cost and feasibility recognizing that impacts of urbanization in Middle River are severe and that restoration of this watershed will be costly. For this study, structural BMPs were only evaluated in Cowpens Run, Dark Head Creek, Stansbury Creek, Frog Mortar Creek, and Galloway Creek; Baltimore County previously completed evaluations in other areas of the watershed. The watershed restoration projects using BMPs will achieve stormwater flow control benefits. The BMP retrofits and pond conversions will achieve reductions in stormwater pollution loadings in those subwatersheds where they can be implemented. A cost-benefit analysis of proposed SWM ponds is presented in Table ES-8.

Summary and Ranking of Water Quality Problems in Middle River

Table ES-9 ranks subwatersheds by water quality problems. Twenty-two subwatersheds were ranked, with a value of one awarded to the subwatershed with lowest water quality problem and twenty-two to the highest. Since both Sue Creek and Dark Head Creek contained one large subwatershed and one much smaller one, both had their two subwatersheds combined into one. Two scenarios were ranked: existing conditions without the planned SWM pond retrofits, and future conditions with these retrofits. Both the pollutant loadings and the estuary concentrations in the Middle River watershed were ranked.

The pollutant loadings used were based on the SWMM model output for the wet year. The estuary concentrations were based on 10-day averages throughout the 180-day run for that year, resulting in some of the storm event concentrations being averaged out. This was completed for existing conditions and future conditions with stormwater retrofits. Comparable pollutants were ranked, in pounds per acre for the SWMM modeling, and in milligrams per liter for the water quality modeling results. Each pollutant was ranked separately for each scenario and concentration, and the rankings were summed, creating an overall score for each scenario.

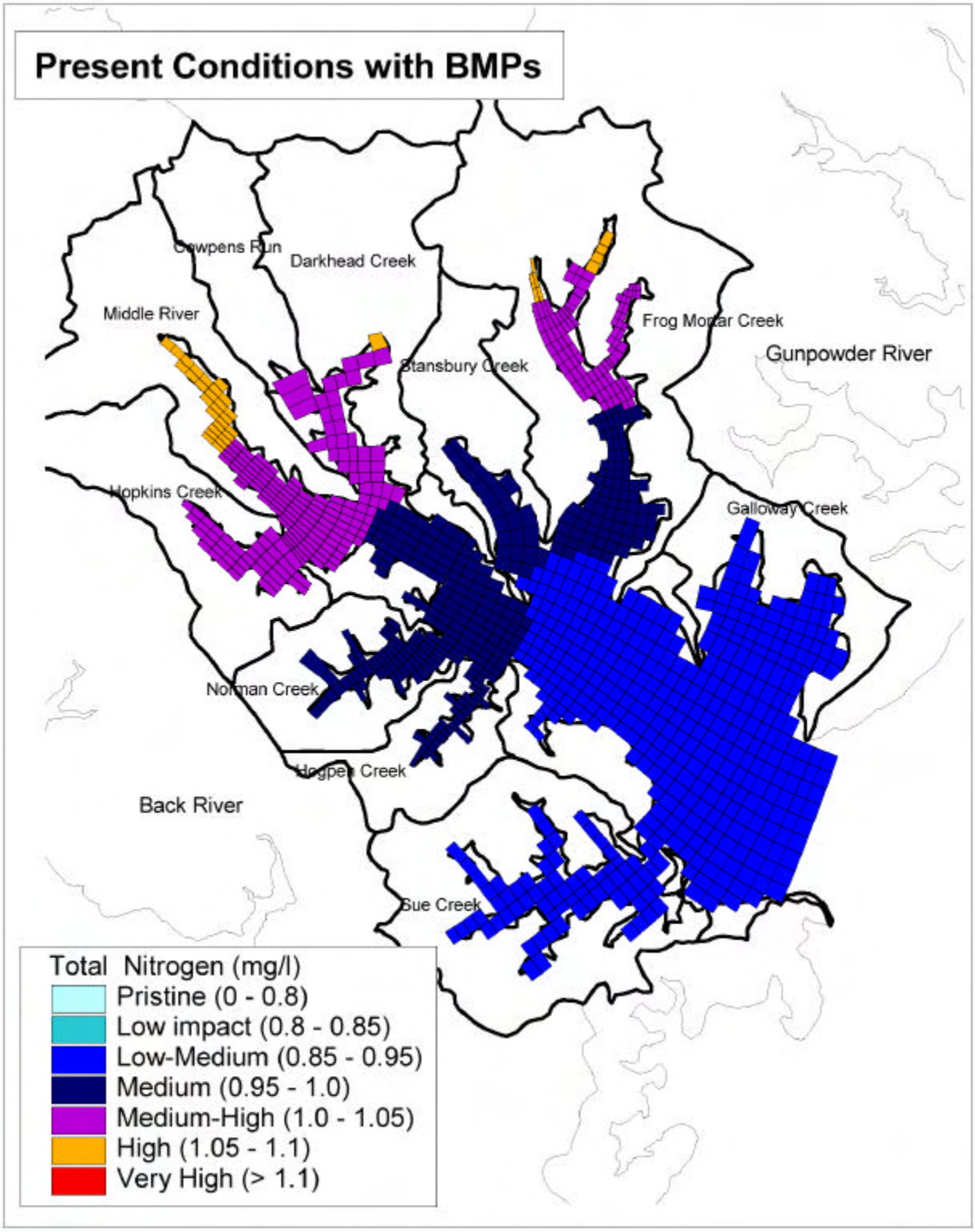

Figure ES-7. Average water column concentrations of total nitrogen in Middle River for a worst-case (wet year) scenario, for existing land use with SWM retorfits

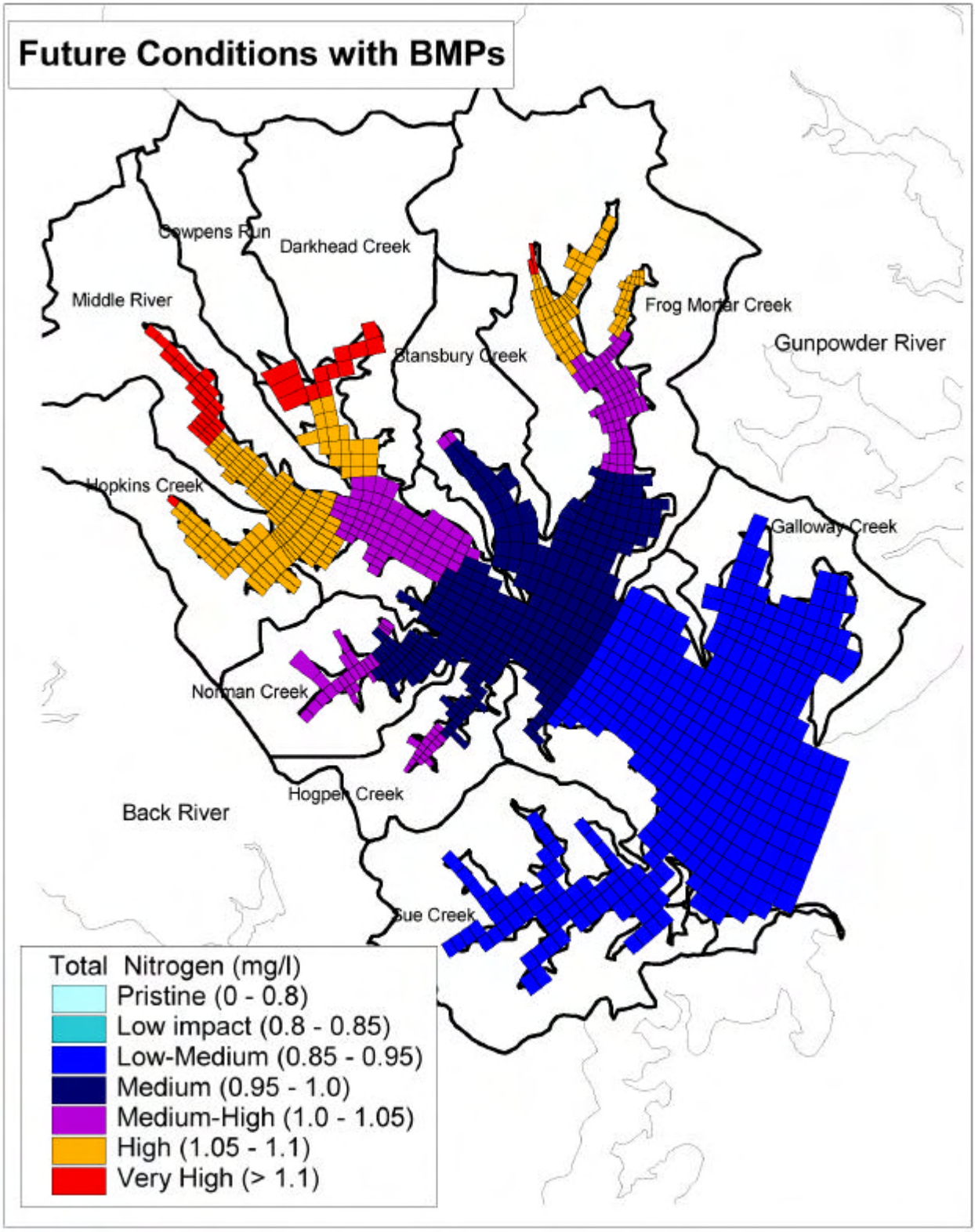

Figure ES-8. Average water column concentrations of total nitrogen in Middle River for a worst-case (wet year) scenario, for future land use with SWM retorfits

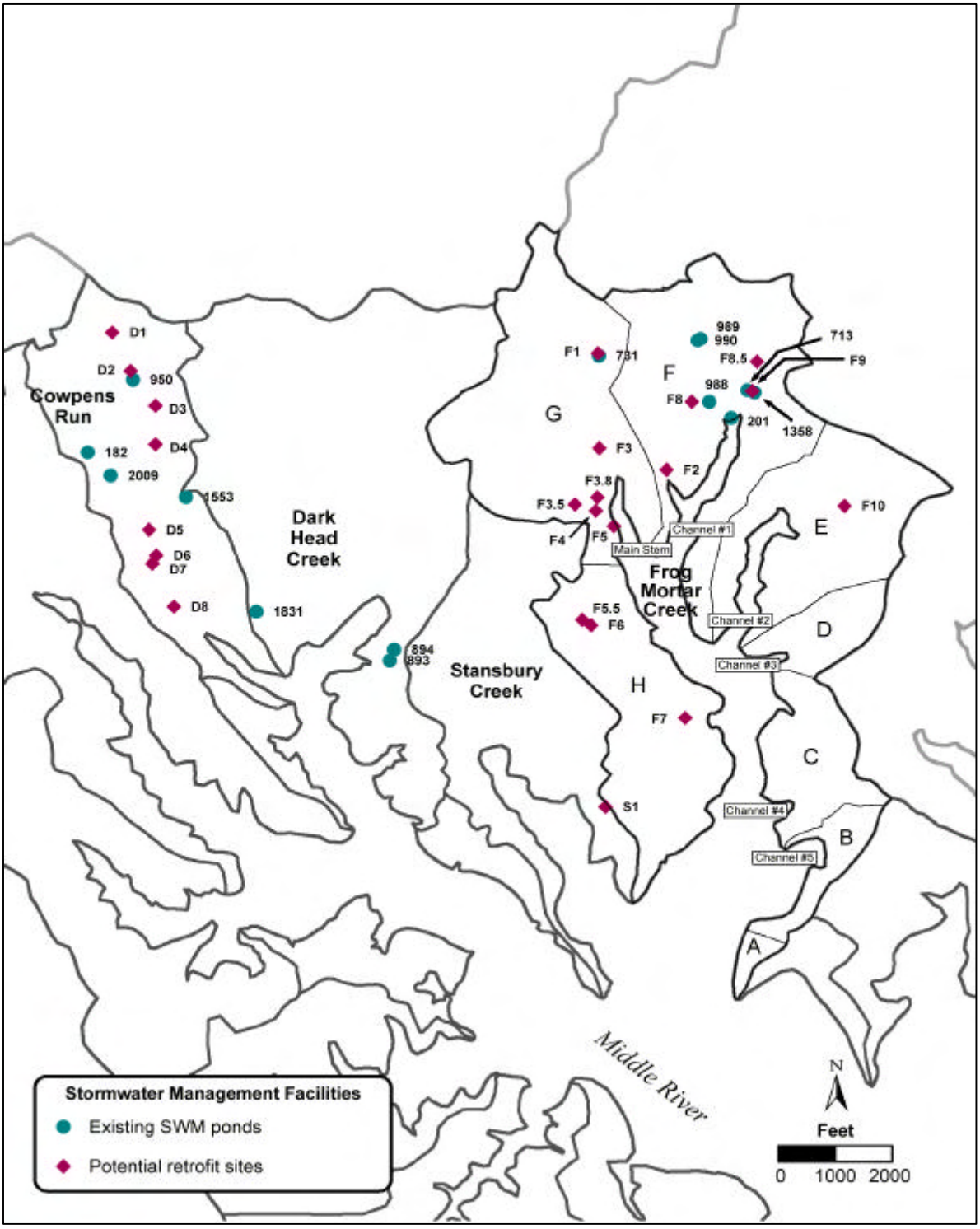

Figure ES-9. Existing stormwater management (SWM) facilities and potential retrofit sites in upper Middle River watershed

Table ES-7

Middle River BMP retrofits project evaluation summary. Sites are ranked in order of total score; subwatersheds are listed in order of decreasing pollutant loadings based on SWM modeling. Within each subwatershed, facilities are grouped by project type. The table contains the environmental, property, and community scores, the total score, and an estimate of whether the site provides high, medium, or low storage volume. Comments on constraints or opportunities are also given.

Subwatershed	Site	Project Type	Environ-mental Score	Property Score	Accept-ability	Total Score	Storage	Comments
Stansbury Creek	S1	Outfall	9	13	10	29	Low	Stream in good condition
Frog Mortar Creek	F3	New SWM	21	15	13	49	High	No environmental constraints, property req'd
Frog Mortar Creek	F7	New SWM	18	16	11	45	Med	Good site except for proximity to airport
Frog Mortar Creek	F5	New SWM	14	15	11	40	Low	Must design around existing wetland
Frog Mortar Creek	F9.5	Outfall	14	17	15	46	Med	Instream site at outfall, permits required
Frog Mortar Creek	F10	Outfall	17	15	14	46	Med	Good potential to improve water quality
Frog Mortar Creek	F6	Outfall	19	16	10	45	Low	Good site except for proximity to airport
Frog Mortar Creek	F5.5	Outfall	12	15	10	37	Med	Significant forest removal required
Frog Mortar Creek	F8	Planting	19	12	19	41	N / A	No other options for site
Frog Mortar Creek	F2	Stream	18	14	11	43	N / A	Project needed to prevent further degradation
Frog Mortar Creek	F3.8	Stream	9	10	8	27	Low	Significant forest removal required
Frog Mortar Creek	F8.5	SWM Retrofit	21	16	14	51	High	Very good retrofit site, no major constraints
Frog Mortar Creek	F9	SWM Retrofit	20	14	11	46	Low	Primarily maintenance cleanout
Frog Mortar Creek	F4	SWM Retrofit	19	15	10	44	Low	Costs and benefits both low
Frog Mortar Creek	F1	SWM Retrofit	20	12	11	43	N / A	Difficult site because of proximity to houses
Frog Mortar Creek	F3.5	SWM Retrofit	18	13	10	41	Med	Streambed recently excavated
Cowpens Run	D3	New SWM	11	15	12	38	Med	Instream pond; WQ for road drainage
Cowpens Run	D1	Outfall	20	15	14	49	Low	Convert ditch to pond
Cowpens Run	D8	Outfall	19	18	10	47	N / A	Change outfall structure to protect streambank
Cowpens Run	D5	Stream	20	14	8	42	N / A	Planting to improve habitat
Cowpens Run	D4	Stream	9	14	15	38	N / A	Project infeasible because of forest cover
Cowpens Run	D7	Stream	10	12	11	33	Med	Project infeasible because of forest cover
Cowpens Run	D2	SWM Retrofit	21	18	12	51	Med	Retrofit to protect channel downstream
Cowpens Run	D6	SWM Retrofit	12	17	11	40	Med	Source of flow not clear

Table ES-8
Cost-Benefit Analysis of proposed stormwater management (SWM) ponds

Site Designation:	D3	F3	F8.5	F9.5	F10
Drainage Area (ac)	142.83	119.65	68.38	78.44	67.57
Channel Protection Volume (ac-ft)	5.17	5.86	2.41	2.80	4.00
Water Quality Volume (ac-ft)	5.20	5.43	2.85	3.98	4.18
Total Pond Volume (ac-ft)	10.37	11.29	5.26	6.18	8.18
Pond Surface Area (sq ft)	2.59	2.82	1.31	1.54	2.05
TP Removed - Current (lb / yr)	11.4	75.6	24.6	32.4	26.9
TSS Removed - Current (lb / yr)	4,688	31,025	9,282	9,222	10,914
TP Removed - Future (lb / yr)	32.3	103.1	62.2	52.2	21.7
TSS Removed - Future (lb / yr)	14,833	42,968	25,390	44,447	8,190
Capital Cost ($)	301,445	337,853	135,499	160,837	222,796
Annualized Capital Cost ($)	19,125	21,435	8,597	10,204	14,135
Annual O&M Cost ($)	6,851	7,678	3,080	3,655	5,064
Total Annual Cost ($)	25,976	29,113	11,676	13,860	19,199
$ / lb / yr, future, TP ($)	804	282	188	266	885
$ / lb / yr. future, TSS ($)	1.75	0.68	0.46	0.31	2.34

Table ES-9

Middle River subwatersheds ranked by water quality problems. Rankings are based on annual pollutant loadings (per acre) based on SWMM modeling of existing conditions and future land-use with SWM pond retrofits, and estuarine water quality conditions near those subwatersheds during a wet year. Lower scores and ranks indicate better water quality; a higher score or rank indicates higher loadings and poorer water quality.

Subwatershed	**Loadings in MR**				**Estuary Concentrations**				**Loads & Conc.**		**Loads & Conc.**		**Loads & Conc.**	
	Existing Conditions		**Future Scenario w/ ponds**		**Existing Conditions**		**Future Scenario w/ ponds**		**Existing Conditions**		**Future Scenario w/ ponds**		**Existing and Future**	
	Score	**Rank**	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**
Galloway Creek	31	**3**	37	**3**	28	**3**	20	**2**	59	**1**	57	**1**	116	**1**
Sue Creek-A & B	32	**4**	50	**5**	33	**4**	28	**4**	65	**2**	78	**2**	143	**2**
Middle River-F	93	**9**	90	**8**	23	**1**	22	**3**	116	**5**	112	**3**	228	**3**
Hogpen Creek	13	**1**	100	**9**	54	**9**	67	**10**	67	**3**	167	**10**	234	**4**
Middle River-C	81	**7**	110	**11**	27	**2**	18	**1**	108	**4**	128	**5**	236	**5**
Frog Mortar Creek-B	77	**6**	102	**10**	53	**8**	47	**7**	130	**7**	149	**7**	279	**6**
Frog Mortar Creek-A	112	**13**	120	**13**	34	**5**	29	**5**	146	**8**	149	**8**	295	**7**
Norman Creek	72	**5**	141	**14**	45	**7**	54	**8**	117	**6**	195	**12**	312	**8**
Middle River-E	93	**8**	74	**7**	66	**10**	80	**11**	159	**10**	154	**9**	313	**9**
Frog Mortar Creek-E	101	**12**	20	**2**	120	**17**	105	**15**	221	**14**	125	**4**	346	**10**
Middle River-B	24	**2**	60	**6**	133	**19**	139	**20**	157	**9**	199	**13**	356	**11**
Frog Mortar Creek-D	101	**11**	115	**12**	99	**14**	91	**13**	200	**12**	206	**14**	406	**12**
Middle River-A	173	**17**	177	**17**	38	**6**	38	**6**	211	**13**	215	**15**	426	**13**
Frog Mortar Creek-C	93	**10**	178	**18**	91	**13**	80	**12**	184	**11**	258	**18**	442	**14**
Frog Mortar Creek-F	174	**18**	10	**1**	146	**21**	125	**18**	320	**20**	135	**6**	455	**15**
Cowpens Run	170	**16**	40	**4**	112	**16**	139	**19**	282	**18**	179	**11**	461	**16**
Middle River-D	155	**15**	153	**15**	80	**12**	98	**14**	235	**15**	251	**17**	486	**17**
Hopkins Creek	134	**14**	165	**16**	104	**15**	121	**17**	238	**16**	286	**19**	524	**18**
Stansbury Creek	206	**21**	186	**19**	67	**11**	65	**9**	273	**17**	251	**16**	524	**19**
Dark Head Creek-A & B	176	**19**	187	**20**	127	**18**	149	**22**	303	**19**	336	**21**	639	**20**
Frog Mortar Creek-H	220	**22**	199	**21**	137	**20**	112	**16**	357	**22**	311	**20**	668	**21**
Frog Mortar Creek-G	199	**20**	216	**22**	154	**22**	144	**21**	353	**21**	360	**22**	713	**22**

These scores were then ranked, as shown in the table. The existing condition score for both pollutant loads and estuarine water quality were then summed and ranked, as were those in the future scenario. Finally, the two scores for existing and future conditions were summed and ranked, creating a final ranking for all the subwatersheds. This final ranking gives an overall picture of the severity of pollution problems for each subwatershed.

Based on the results of flushing time analyses, areas with long flushing times would be locations where water quality impacts due pollutant loading would be the greatest. Based on the "Coastal Marinas Assessment Handbook," flushing times between 2 and 4 days is satisfactory while longer flushing times may not be acceptable. Using a flushing time greater than approximately 4 to 5 days to reflect unsatisfactory conditions then Hopkins Creek, Middle River (main), Frog Mortar Creek (entire), and Frog Mortar Creek (Cove E) would be the most susceptible to pollutant loadings and water quality impacts (Figure ES-10, Table ES-10).

Recommendations of the Watershed Management Plan

Stream and subwatershed conditions in the portion of study area comprising Cowpens Run, Dark Head Creek, Frog Mortar Creek, Stansbury Creek, and Galloway Creek are typical of watersheds that were urbanized before stormwater management regulations were in place. There is evidence of stream degradation in most of the small tributaries. For example, the main stems of Frog Mortar Creek below Eastern Avenue and of Cowpens Run at a site designated D4 (see Figure ES-4) are undercutting their banks. Two existing ponds at sites in Cowpens Run (D2) and Frog Mortar Creek (F8.5) appear to be the best candidates for retrofits. Site D2 in Cowpens Run controls drainage from a townhouse development upstream and it may be possible to improve detention times for water quality. The Frog Mortar Creek site (F8.5) has sufficient area to create a wet pond or shallow marsh with a long flow path, extended detention, and sediment forebay.

New ponds at two sites (D3 and F3), and outfall improvements at three other sites (D1, F9.5 and F10), while requiring land purchase, offer good prospects for controlling excessive velocity, flow, and runoff pollution from existing development. If SWM facilities or outfall improvements could be installed at these locations, any downstream channel degradation could begin to reverse as the stream starts to regain stability. Reducing streambank erosion, combined with trapping sediment from the subwatershed, would reduce sediment loads to the tidal creeks and Middle River below the sites.

Non-structural measures should prove to be a significant aid in reducing sedimentation and pollutant loads in these subwatersheds, because much of Middle River was developed before storm water management regulations were in effect.

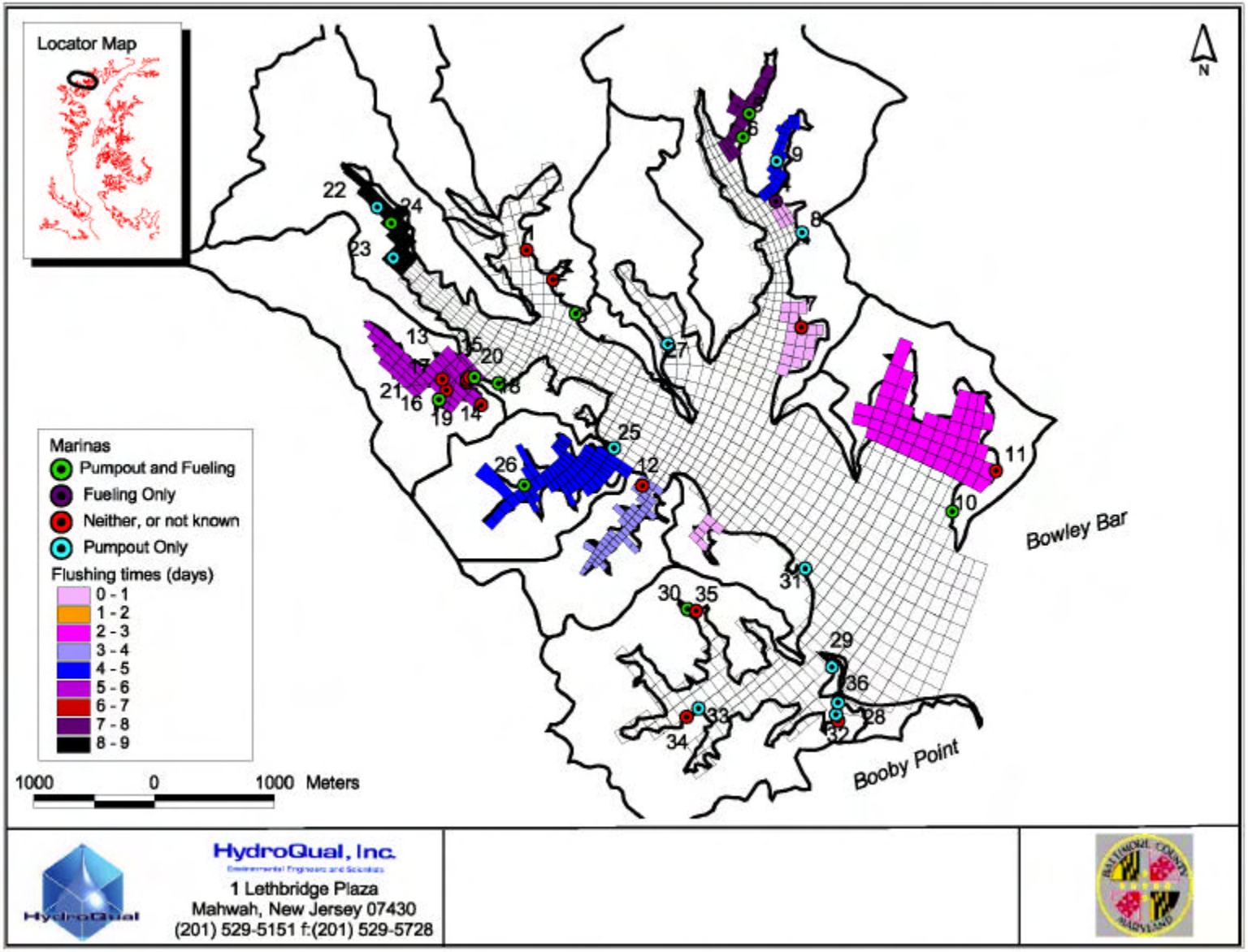

Figure ES-10. Middle River marina facilities and flushing times.

Table ES-10
Flushing time results (post-dredge)

Dye Study Area	Area Name	Post-Dredging Conditions		
		Mean Residence Time (days)	Flushing Time (days) Regression	Flushing Time (days) Model Output
#1	Greyhound Cove (MR-B)	0.62	0.68	0.61
#2	Hogpen Creek	3.6	3.9	3.3
#3	Norman Creek	4.2	4.6	3.8
#4	Hopkins Creek	6.1	6.8	3.9
#5	Middle River	8.8	9.6	7.3
#6	Galloway Creek	2.6	2.8	2.7
#7	Frog Mortar Creek – Entire	13.9	15.3	13.4
#8	Frog Mortar Creek – Cove A	0.36	0.39	0.33
#9	Frog Mortar Creek – Cove B	0.17	0.19	0.20
#10	Frog Mortar Creek – Cove C	0.17	0.19	0.19
#11	Frog Mortar Creek – Cove D	4.2	4.7	3.5
#12	Frog Mortar Creek – Cove E	8.1	8.9	6.9

The Galloway Creek subwatershed is the only one that can benefit significantly from watershed protection measures based on zoning. These measures have been established by the County and are currently in effect (Rural Residential and Resource Conservation Zoning). In the forested areas of Dark Head Creek and Frog Mortar Creek, site design techniques that cluster development and protect natural resources are recommended.

Establishing or encouraging pollution prevention plans for the industrial facilities, marinas, and agricultural areas in the watershed may considerably reduce the potential for other toxic pollutants to be delivered to Middle River. Continuing storm drain cleaning and street sweeping in selected areas will help reduce sedimentation and pollution associated with vehicle use. Increasing public education and providing more opportunities for Hazardous Household Waste disposal will help eliminate this source of toxic pollutants.

Other non-structural controls, such as erosion and sediment controls for construction activity, the "Let's Be Partners..." outreach program, illicit discharge investigations, and surveys of failing on-site sewage disposal systems appear to be effective and should be continued or extended.

Middle River has about 42 miles of shoreline, nearly 6,400 registered vessels, and 36 marinas (Figure ES-11; Table ES-11). Efforts to protect shorelines from erosion and improve tidal wetland water quality and habitat value through the use of non-structural measures should continue where appropriate. Tidal wetland enhancement can be accomplished by increasing the number of native species within the wetland. Shoreline protection proposals should be encouraged, within the context of the regional plan for the area.

Marina and other waterfront property owners should install stormwater pollution control measures. Marinas and other property owners could contribute to pollution control by measures such as monitoring and controlling upland sediment sources and other water pollutants carried to waterways as stormwater runoff. They could also aid in pollution control by minimizing structures within the shoreline buffer and by establishing vegetation in areas not used for access to the water through the buffer to provide shoreline enhancement.

Boater education could improve awareness of watershed conditions and the impacts and influences that boat handling and maintenance methods might have on ecosystem health and stability. The following Maryland DNR initiatives and educational materials should continue to be promoted to enhance water quality in Middle River as affected by boating-related activities:

- Clean Marina Initiative
- Maryland Clean Marina Guidebook
- Clean Marina Boating Tips
- Clean Boating Lesson Plan.

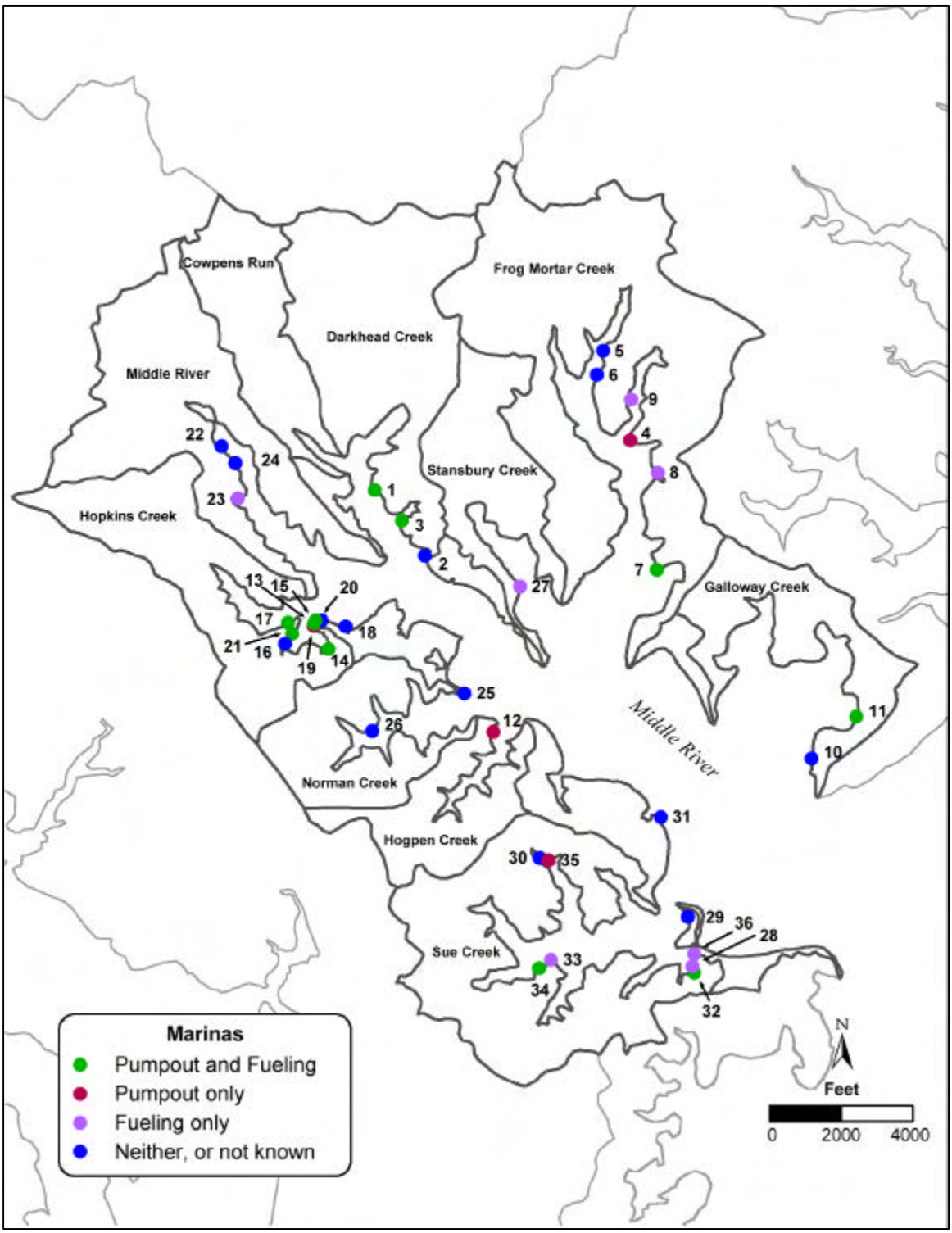

Figure ES-11. Locations of Middle River boating facilities

Table ES-11
Characteristics of Middle River boating facilities

River/Creek/ Cove Name	Boating Facility Number as in Figure ES-11 (Map)	Boating Facility Name (1994 Boating Almanac & Baltimore County DEPRM's 1997 Vessel And Mooring Survey)	Number Of Slips Water/Land/High and Dry (1994 Boating Almanac)	Number Of Slips Water/Land/High and (Baltimore County DEPRM's 1997 Vessel and Mooring Survey)	Certified Maryland Clean Marina (MDNR 2000)	Maryland Clean Marina Pledges (MDNR 2000)	Pumpout Station (1994 Boating Almanac and MDNR 2000)	Fueling Station (1994 Boating Almanac)
Chestnut Cove	1	Berg Marina	#	15	NO	NO	NO	NO
Dark Head Creek	2	Stansbury Yacht Basin (Glenmar Sailing Assoc.)	100 / 130	#	NO	NO	YES	GAS
	3	Wagus Marina	25	#	NO	NO	NO	NO
Frog Mortar Creek	4	Brigadoon Marine Facility	70 / 100	70	NO	NO	NO	GAS / DIESEL
	5	Chesapeake Yachting Center	200 / / 200	200 / 150 / 200	NO	NO	YES	GAS / DIESEL
	6	Edwards Boat Yard	110 / 100	110	NO	NO	YES	GAS
	7	Long Beach Marina	327 / 150	300	NO	NO	NO	NO
	8	Maryland Marina	360 / 375	360	NO	5 / 4 / 99	@YES	NO
	9	Tradewinds Marina	78 / 110	78	NO	NO	@YES	NO
Galloway Creek	10	Bowley's Quarters Condomarina	492	500	NO	NO	YES	GAS / DIESEL
	11	Galloway Creek Marina	163	140	NO	NO	NO	NO
Hogpen Creek	12	Crescent Yacht Club	#	#	NO	NO	NO	#
Hopkins Creek	13	Anchor Bay Ship Shore & Marina Inc.	22	25	NO	NO	NO	NO
	14	Deckelman's Boat Yard Inc.	15 / 90	15	NO	NO	NO	NO
	15	Driftwood Inn	30	20	NO	NO	NO	NO
	16	Essex Marina Boat Yard	88 / / 35	88	NO	NO	YES	GAS
	17	Hilltop Marine	33	33	NO	NO	NO	NO
	18	Markley's Boat Yard	56 / 175	53	NO	NO	*YES	@GAS
	19	Middle River Yacht Club	#	40	NO	NO	NO	#
	20	River Watch Restaurant & Marina	110	110	NO	NO	YES	GAS / DIESEL
	21	Snug Harbor Boat Yard	40	35	NO	NO	NO	NO
Middle River	22	Buedel's Marina & Boat Yard Inc.	150 / 200	160	NO	NO	YES	~NO
	23	Cutter Marine Yacht Basin	160 / 200	165	NO	NO	YES	NO
	24	Riley's Marina Sales & Service	100 / 100	97	NO	NO	YES	GAS
Norman Creek	25	Norman Creek Marina	#	24	NO	NO	@YES	#
	26	Sunset Harbor Marina (Brown's Cove Marina)	27 / 250 / 50	42	NO	1 / 29 / 99	YES	GAS
Stansbury Creek	27	Marco (Martin Co.) Hunting and Fishing Club	^40 / ^40	#	NO	NO	YES	NO

Table ES-11
(Continued)

River/Creek/ Cove Name	Boating Facility Number as in Figure 7-5 (Map)	Boating Facility Name (1994 Boating Almanac & Baltimore County DEPRM's 1997 Vessel And Mooring Survey)	Number Of Slips Water/Land/High and Dry (1994 Boating Almanac)	Number Of Slips Water/Land/High & Dry (Baltimore County DEPRM's 1997 Vessel and Mooring Survey)	Certified Maryland Clean Marina (MDNR 2000)	Maryland Clean Marina Pledges (MDNR 2000)	Pumpout Station (1994 Boating Almanac and MDNR 2000)	Fueling Station (1994 Boating Almanac)
Sue Creek	28	Anderson Brothers Boat Sales	/75/300	#	NO	NO	YES	NO
	29	Baltimore Yacht Club	#	#	YES	YES	YES	#
	30	Boating Center of Baltimore	60/150/100	#	NO	NO	YES	GAS
	31	Eastern Yacht Club	#	#	NO	NO	YES	#
	32	Holly Neck Marina	46/75	#	NO	NO	NO	NO
	33	Red Eye Yacht Club, Inc.	70	#	NO	NO	YES	NO
	34	Sue Creek Boat Yard	15	#	NO	NO	NO	NO
	35	Sue Haven Yacht Club	#	#	NO	NO	NO	#
	36	Sue Island Yacht Basin (Sun Marine Inc.)	52	#	NO	NO	YES	NO
Totals	36	MIDDLE RIVER BOATING FACILITIES	**3039/2320/685 SLIPS**	**2680/150/200 SLIPS**	**1 CERTIFIED CLEAN MARINA**	**3 CLEAN MARINA PLEDGES**	**21 FACILITIES w/PUMPOUT STATIONS**	**11 FACILITIES w/ FUELING STATIONS**

^ = Personal communication on 9/14/00 with an anonymous member (approximate # of slips)
~ = Personal communication on 9/18/00 with the marina owner
@ = 2000 – 2001 Maryland Cruising Guide
* = Mentioned only in the 1994 Boating Almanac
# = No readily available information

Other Considerations

The Middle River Water Quality Management Plan also assumes the continued strict adherence to the existing Baltimore County stormwater management regulations. These regulations require construction of structural detention pond BMPs to control stormwater discharges from all new nonresidential developments and medium and high density residential developments. Structural BMPs should be designed to maximize pollutant removal efficiencies and to achieve peak flow reductions to minimize downstream streambank erosion.

For all structural BMPs, an effective maintenance program is essential. All regional BMPs and onsite BMPs serving residential areas should be maintained with public funds. Maintenance agreements should be secured for onsite BMPs serving nonresidential development.

Other regulatory programs are also assumed to be continued and contribute to improved water quality; these programs include: sediment control, storm water management, stream buffers, forest conservation, Chesapeake Bay Critical Area, wells and onsite disposal systems regulations.