Total Maximum Daily Load of Temperature in the Coldwater Streams of the Gwynns Falls Watershed, Baltimore County, Maryland

PUBLIC COMMENT REVIEW DRAFT

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LIST OF ABBREVIATIONS

BES	Baltimore Ecosystem Study
BIBI	Benthic Index of Biotic Integrity
BMP	Best Management Practices
BRF	Bay Restoration Fund
BTWG	Brook Trout Workgroup
CBP P6	Chesapeake Bay Program Phase 6.0
CFR	Code of Federal Regulation
cfs	Cubic feet per second
CO_2	Carbon Dioxide
COMAR	Code of Maryland Regulation
CREP	Conservation Reserve Enhancement Program
CWA	Clean Water Act
DNR	Maryland Department of Natural Resources
EJ	Environmental Justice
EQIP	Environmental Quality Incentives Program
ESD	Environmental Site Design
FAP	Financial Assurance Plans
FCA	Forest Conservation Act
FCP	Forest Conservation Plan
FDC	Flow Duration Curve
FIBI	Fish Index of Biotic Integrity
FSD	Forest Stand Delineation
GGRA	Greenhouse Gas Emissions Reduction Act
GHG	Greenhouse Gas
GIS	Geographic Information System
GJ/d	Gigajoules per day
IBI	Index of Biotic Integrity
J/d	Joules per day
LA	Load Allocation
MACS	Maryland Agricultural Cost Share Program
MAL	Minimum Allowable IBI Limit
MBSS	Maryland Biological Stream Survey
MCC	Maryland Commission on Climate Change
MCDOT	Montgomery County Department of Transportation
MD	Maryland
MD 8-Digit	Maryland 8-digit Watershed
MDE	Maryland Department of the Environment
MDP	Maryland Department of Planning
MGD	Millions of Gallons per Day
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
mT	Metric Ton
NFWF	National Fish and Wildlife Foundation
NLDAS	North American Land Data Assimilation System
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
PS	Point Source
SDM	Stormwater Design Manual
SHA	State Highway Administration
SRI	Solar Reflectance Index
SWAT	Soil and Water Assessment Tool

TAMU	Texas A&M University
TIC	Trout in the Classroom
TMDL	Total Maximum Daily Load
UCIII	Use Class III
USDA	United States Department of Agriculture
USEPA	Environmental Protection Agency
USGS	United States Geological Survey
WLA	Waste Load Allocation
WQA	Water Quality Analysis
WQLS	Water Quality Limited Segment
WQS	Water Quality Standard

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list impaired waters, known as water quality limited segments (WQLSs). These WQLSs are waters with levels of one or more pollutants that exceed water quality criteria or which are not meeting designated uses. For each WQLS, the State is required to either establish a Total Maximum Daily Load (TMDL) of the specified pollutant that the waterbody can receive without violating water quality standards, or demonstrate that water quality standards are being met (Code of Federal Regulation 2018a). This document, upon approval by the USEPA, establishes a TMDL for temperature as a pollutant in the portions of the Gwynns Falls watershed classified as Use Class III, cold water fishery (*COMAR 2018d*).

TMDLs are established to determine the pollutant load reductions needed to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include activities such as swimming, drinking water supply, protection of aquatic life, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

Water temperature exerts a major influence on biological activity, growth and reproductive behaviors, and water temperature is influenced by anthropogenic activities such as the discharge of process waters used in industrial operations or the removal of trees in a watershed as a result of the development of land. Temperature is an important factor in maintaining the aquatic life assemblage of a particular river, stream, creek or lake. Fish, insects, zooplankton, phytoplankton, and other aquatic species all have a preferred temperature range. As temperatures get too far above or below this preferred range, the number of individuals of the species decreases until finally there are none (United States Geological Survey 2018). In Maryland, Use Class III waters are those considered appropriate for coldwater assemblages, including brook, brown, and rainbow trout. Coldwater streams may also support temperature-sensitive species of stoneflies, such as *Tallaperla* and *Sweltsa*.

Temperature is also important because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperatures. Waters with higher temperatures can dissolve more minerals and other chemicals and can potentially lead to higher levels of conductivity. High levels of conductivity have adverse impacts on aquatic life--such as causing fish kills. It is the opposite when considering a gas, such as oxygen, dissolved in the water. Warm water holds less dissolved oxygen than cool water, and, depending upon the temperature, may not contain enough dissolved oxygen for the survival of different species of aquatic life (USGS 2018).

Water temperature is influenced by numerous natural variables, including solar radiation, air temperature, ground temperature, precipitation, surface water inflows, and groundwater exchanges (as cited in Constantz 1998). Water temperature is also influenced by anthropogenic factors such as point source discharges and removal of riparian shading associated with land development. Infiltration of water can also impact stream temperature --actions to decrease stormwater runoff and allow for more infiltration of stormwater into aquifers improves aquifer recharge, which in turn yields higher baseflows, leading to lower stream temperatures. Riparian shading typically exerts a positive influence on the thermal regime of a stream and can improve the health of aquatic life. Riparian corridors can, in addition to blocking direct sunlight, produce microclimates that maintain cooler local stream and air temperatures.

Another significant variable impacting water temperature is climate change. Climate change has a direct effect on water temperatures – as air temperature increases, so does water temperature. Climate change can also impact precipitation, flooding, and erosion. While Maryland is a national leader in taking actions to address climate change, MDE recognizes that climate change is a global issue and that some changes in water temperature associated with climate change may be beyond MDE's ability alone to address. This means that MDE will have to reassess this TMDL over time as it learns more about the role that climate change is playing, specifically, with regard to water temperatures in Maryland waters. The TMDL and its allocations may need to be revisited in the event that actions taken in Maryland to address elevated water temperatures may not be sufficient in light of climate change impacts to restore temperature-related water quality.

Climate change may also have an impact on the setting of water quality standards – including criteria, designated use classes, and use attainability. As climate change progresses, MDE recognizes that temperature criteria may need to be evaluated based on adaptation of trout to higher temperatures. Alternatively, it is possible that water temperature increases associated with climate change may result in the extirpation of trout in a particular location and that localized actions will not be sufficient to achieve required cool temperatures to support a coldwater fishery use designation. In such cases, climate change may result in the need to change the designated use in the event that the use is not attainable through MDE-mandated actions. Water quality standards are reviewed regularly via the Triennial Review process to determine if they are still achievable/applicable. Consideration of the evolving impacts of climate change on the attainability of WQS will/can be considered during this review. More information on this program can be found at https://mde.maryland.gov/programs/Water/TMDL/WaterQualityStandards/Pages/index.aspx

The temperature water quality criteria for Use Class III is:

> *The maximum temperature outside the mixing zone determined in accordance with Regulation .05 of this chapter or COMAR 26.08.03.03—.05 may not exceed 68°F (20°C) or the ambient temperature of the surface waters, whichever is greater.*

A methodology for assessing temperature impairment has been established by the Maryland Department of the Environment (MDE), and was updated in 2019. The Maryland Biological Stream Survey's (MBSS) temperature monitoring program was chosen as the data source for the assessment. The temperature listing methodology is based on analysis of the 90th percentile of temperature data during the critical period (June 1 through August 31) (MDE 2019).

Based on the assessment methodology, three coldwater segments in the Gwynns Falls watershed were listed for temperature impairment on the 2014 Integrated Report (MDE 2014). In order to determine the extent of impairment in the entire Use Class III portion of the watershed, MDE conducted temperature monitoring at 15 stations in the Gwynns Falls in summer (June 1 – Aug 31) 2016 and at 8 stations in summer 2017.

Temperatures observed at all of the 2016/2017 stations were found to not meet temperature criteria and, therefore, this TMDL will address the entire Use Class III portion of the watershed. The three segments that have already been listed will be incorporated into a single impairment listing covering the entire Red Run sub-basin. An additional listing will be added for the Upper Gwynns Falls sub-basin.

For this TMDL, the Soil and Water Assessment Tool (SWAT) model was used to model thermal loads in the Gwynns Falls watershed. SWAT is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds. It is a watershed hydrological transport model with the following components: weather, surface runoff, return flow, percolation, evapotranspiration, transmission losses, pond and reservoir storage, crop growth and irrigation, groundwater flow, reach routing, nutrient and pesticide loading, and water transfer. In 2012, Ficklin et al. developed a stream temperature model within SWAT that reflects the combined influence of meteorological (air temperature) and hydrological conditions (streamflow, snowmelt, groundwater, surface runoff, and lateral soil flow) on water temperature within a watershed (TAMU 2018).

Calculations of Required Thermal Loads under the TMDL

All TMDLs need to be presented as a sum of waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources generated within the assessment unit, accounting for natural background, tributary and adjacent segment loads. Furthermore, all TMDLs must include a margin of safety (MOS) to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2018a). The TMDL for temperature for the Gwynns Falls watershed adopts the implicit approach for establishing its MOS by using conservative assumptions in the model setup.

Thermal loads are calculated for nonpoint (NPS) and point source (PS) loads. Point source loads can be subdivided into two categories, wastewater and stormwater. There are no NPDES wastewater permits in the coldwater stream portions of the Gwynns Falls watershed, impacted by the TMDL. The impact of the Temperature TMDL on existing regulated stormwater entities includes NPDES MS4 permits for county and SHA. Further, existing state and federal programs will support the regulated community in complying with the temperature requirement

The baseline and TMDL thermal loads are presented in Tables ES-1 and ES-2. Loads are expressed in gigajoules per day (GJ/d) based on the daily energy discharged from the outlets of the coldwater stream networks during the period from June 1 to August 31.

Table ES-1: Red Run Sub-Watershed Baseline and TMDL Loads

Baseline Load, GJ/d	TMDL, GJ/d	Reduction (%)
399	348	13

Table ES-2: Upper Gwynns Falls Sub-Watershed Baseline and TMDL Loads

Baseline Load, GJ/d	TMDL, GJ/d	Reduction (%)
493	396	20

The TMDL allocations are presented in Tables ES-3 and ES-4.

Table ES-3: Red Run Sub-Watershed Temperature TMDL Allocations

TMDL	=	Nonpoint Source LA_{RR}	+	NPDES Stormwater WLA_{RR}	+	Wastewater WLA_{RR}
348	=	305	+	43	+	0

Table ES-4: Upper Gwynns Falls Sub-Watershed Temperature TMDL Allocations

TMDL	=	Nonpoint Source LA_{UGF}	+	NPDES Stormwater WLA_{UGF}	+	Wastewater WLA_{UGF}
396	=	335	+	61	+	0

Reasonable Assurance

Section 303(d) of the CWA and current USEPA regulations require reasonable assurance that the temperature TMDL can and will be implemented (CFR 2018a). There are several programs in the State of Maryland (MD) that can be used to reduce or provide protection against increasing stream temperatures.

MDE has issued Phase I Municipal Separate Storm Sewer System (MS4) permits to Baltimore County and the State Highway Administration (SHA), which require compliance with all TMDLs. A TMDL implementation plan, showing deployment of stormwater controls and other practices to mitigate thermal discharges, for all TMDL WLAs is required within one year of EPA's approval of the TMDL. Within the Maryland Stormwater Design Manual (SDM), the State has specific design requirements and objectives for stormwater management practices in Use Class III watersheds. This ensures that new stormwater controls will not have any inadvertent, deleterious impacts on stream temperature.

There are a variety of state and federal grant programs that can be accessed by watershed managers and farmers for financial assistance with TMDL implementation. Maryland's Bay Restoration Fund (BRF), the Chesapeake and Atlantic Coastal Bays Trust Fund, the National Fish and Wildlife Foundation's (NFWF) Chesapeake Bay Stewardship Fund, the Chesapeake Bay Trust and the 319 Nonpoint Source Grant Program can provide funding for the design and construction of practices to improve water quality, and could be used to fund projects that reduce water temperature. The Conservation Reserve Enhancement Program (CREP) and the Maryland Agricultural Cost Share Water Quality Cost-Share Program (MACS) provide state and federal funding for agricultural practices, such as riparian buffers, which can reduce stream temperature.

Maryland also has several laws and programs in place to protect existing resources. The Maryland Forest Conservation Act (FCA) of 1991 requires local governments with planning and zoning authority to establish and implement local forest conservation programs. Forests can lower stream temperature by shading and providing better infiltration than other land use types. Maryland's High Quality Waters (Tier II) – Federal regulations require states to maintain the condition of high quality (i.e. Tier II) waters that have water quality that is better than the minimum standard necessary to meet designated uses. There is one Tier II stream segment in the coldwater Gwynns Falls watershed. The Maryland Climate Change Commission has resulted in Maryland setting some of the strongest greenhouse gas reduction targets in the nation. Reduction in greenhouse gasses will help slow the rate of increase in air temperatures, thereby helping to meet water quality standards for stream temperature.

Finally, there are multiple co-benefits to implementing the temperature TMDL. These co-benefits can support communities becoming resilient to a changing climate. Actions to address temperature issues, such as restoration of riparian buffers, will also help the State meet its 2010 Bay TMDL goals for sediment and nutrients. The goals of the temperature TMDL are also included in the 2014 Chesapeake Bay agreement Vital Habitat Goal to restore, enhance and protect land and water habitats to support fish and wildlife. BMPs that support achieving the temperature TMDL also mitigate flooding, particularly in vulnerable communities. Actions to address temperature impairments in Use Class III waters will also have positive impacts on water quality in downstream areas. For example, upstream restoration promotes positive impacts on sedimentation, hydrologic alteration, and loss of biological habitat.

Given the levels of implementation described in this TMDL, the long time horizon for tree canopy establishment, the challenges of implementing stormwater retrofits that promote infiltration and filtration in high density urban watersheds, and the increasing stresses from climate change, achieving the resource management goals for temperature may be challenging using currently available technologies. To address this high level of uncertainty in the context of the MS4 permit, it is recommended that the permittee adopt an explicit, adaptive management approach for implementation.

1.0 INTRODUCTION

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current levels of one or more pollutants are above water quality criteria. For each WQLS, the State is required to either establish a TMDL for the pollutant (this is the amount of the pollutant that the waterbody can receive without violating water quality standards) or demonstrate that water quality standards are being met (CFR 2018a) through alternative approaches.

TMDLs are established to determine the pollutant load reductions needed to achieve and maintain water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use (and the antidegradation policy applicable to the water). Designated uses include activities such as swimming, drinking water supply, protection of aquatic life, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. Criteria may differ among waters with different designated uses.

Water temperature exerts a major influence on biological activity and growth. Temperature governs the kinds of organisms that can live in rivers and lakes. Fish, insects, zooplankton, phytoplankton, and other aquatic species all have a preferred temperature range. As temperatures get too far above or below this preferred range, the number of individuals of the species decreases until finally there are none (United States Geological Survey 2018). In Maryland, Use Class III waters are those considered appropriate for coldwater assemblages, including brook, brown, and rainbow trout. Coldwater streams may also support temperature-sensitive species of stoneflies, such as *Tallaperla* and *Sweltsa*.

Temperature is also important because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperatures. Water with higher temperatures can dissolve more minerals and other chemicals present in the watershed and can potentially lead to higher conductivity. It is the opposite when considering a gas, such as oxygen, dissolved in the water. Warm water holds less dissolved oxygen than cool water, and may not contain enough dissolved oxygen for the survival of different species of aquatic life (USGS 2018).

Water temperature is influenced by numerous natural variables, including solar radiation, air temperature, ground temperature, precipitation, surface water inflows, and groundwater exchanges (as cited in Constantz 1998). Infiltration can also impact stream temperature by decreasing stormwater runoff and by getting water into aquifers and away from exposure to the sun. Having sufficiently recharged aquifers will yield higher baseflows, leading to lower stream temperatures. Riparian shading typically exerts a positive influence on the thermal regime of a stream and can improve the state of aquatic ecology, depending on site conditions. Riparian corridors can, in addition to blocking direct sunlight, produce microclimates that maintain cooler local stream and air temperatures.

Another significant variable impacting water temperature is climate change. Climate change has a direct effect – as air temperature increases, so does water temperature. Climate change can also impact precipitation, flooding and erosion and aquifer recharge rates. MDE recognizes that climate change is a global issue and some impacts are beyond the control of Maryland and its constituents. Because increasing water temperatures, drought, extreme rain events, and the co-occurrence of such events, can exacerbate thermal impairments, MDE commits to reassess this TMDL as better science related to climate change becomes available. The TMDL and its allocations may be revisited as appropriate to protect water quality.

Climate change may also have an impact on the setting of water quality standards – including criteria, designated use classes, and use attainability. As climate change progresses, MDE recognizes that temperature criteria may change based on adaptation of trout to higher temperatures. Alternatively, it is possible that water temperature increases associated with climate change may result in the extirpation of trout in a particular location and that localized actions will not be sufficient to achieve required cool temperatures to support a coldwater fishery use designation. In such cases, climate change may result in the need to change the designated use in the event that the use is not attainable through MDE-mandated actions. Water quality standards are reviewed regularly via the Triennial Review process to determine if they are still achievable/applicable. Consideration of the evolving impacts of climate change on the attainability of WQS will/can be considered during this review. More information on this program can be found at
https://mde.maryland.gov/programs/Water/TMDL/WaterQualityStandards/Pages/index.aspx

There are multiple co-benefits to implementing the temperature TMDL, which could include addressing water quality issues such as sedimentation, hydrologic alteration, and loss of biological habitat. Furthermore, temperature restoration can support communities becoming more resilient to a changing climate. While temperature implementation will take place in Use Class III waters, the restoration will improve the water quality downstream.

In 2014, the Maryland Department of the Environment (MDE) identified three streams in the Gwynns Falls watershed as not meeting the water quality standard for temperature. A public data solicitation for temperature was conducted by MDE in November 2016, and all readily available data have been considered in the development of the TMDL.

This document, upon approval by the USEPA, establishes a TMDL for temperature in the portions of the Gwynns Falls watershed classified as Use Class III (COMAR 2018d).

The objective of these TMDLs is to ensure that water temperature is at a level that supports the Use Class III – Nontidal Coldwater designation in the Gwynns Falls watershed, meaning that it is "suitable for the growth and propagation of self-sustaining trout populations" (COMAR 2018b).

The temperature water quality standard for Use Class III is:

> *The maximum temperature outside the mixing zone determined in accordance with Regulation .05 of this chapter or COMAR 26.08.03.03—.05 may not exceed 68°F (20°C) or the ambient temperature of the surface waters, whichever is greater.*

Ambient temperature is defined in Code of Maryland Regulations (COMAR) as the water temperature measured in areas of the stream representative of typical or average conditions, that is not impacted by a point source discharge. Water quality standards are reviewed regularly via the Triennial Review process. More information on this program can be found at https://mde.maryland.gov/programs/Water/TMDL/WaterQualityStandards/Pages/index.aspx

2.0 SETTING AND WATER QUALITY DESCRIPTION

2.1 General Setting

2.1.1 Location

The Gwynns Falls watershed is located in the Patapsco River sub-basin of the Chesapeake Bay watershed within Baltimore County and Baltimore City, Maryland. It covers approximately 65 square miles and contains approximately 133 stream miles. The Gwynns Falls mainstem is a free flowing stream that originates in Reisterstown, Maryland and flows 25 miles in a southeasterly direction until it empties into the tidal Patapsco River in Baltimore City. The watershed is highly urbanized, beginning in the suburbs of Reisterstown and Owings Mills, crossing through Baltimore City neighborhoods, and finally flowing through Carroll-Camden Industrial Area before discharging into the Middle Branch of the Patapsco River.

The coldwater streams of the watershed lie in the northernmost portion of the Gwynns Falls watershed which are completely in Baltimore County. The subwatershed encompasses approximately 25% of the total watershed area (See Figure 1). There are two separate Use Class III stream networks – those that drain from the west to Red Run and those that drain from the north to the Upper Gwynns Falls. The two subwatersheds are divided by Interstate 795. The Red Run subwatershed includes the suburban town of Owings Mills as well Soldier's Delight Natural Environmental Area. The Upper Gwynns Falls subwatershed includes the suburban towns of Reisterstown and Glyndon.

The total drainage area of the coldwater portion of the Gwynns Falls is approximately 10,300 acres, not including water/wetlands. Approximately 50 acres of the watershed area is covered by water. The total population is approximately 67,000 (US Census Bureau 2010).

There is one "high quality," or Tier II, stream segment (BIBI and FIBI aquatic life assessment scores > 4 [scale 1-5]) located within the coldwater portion of the Gwynns Falls watershed. The stream segment is on Red Run, between the confluences of the stream's 1st and 3rd unnamed tributaries. Tier II segments require the implementation of Maryland's anti-degradation policy (COMAR 2018a; MDE 2017). Additional information on Maryland's High Quality Waters (Tier II) can be found in the Assurance of Implementation section of this TMDL.

Both the University of Maryland School of Public Health and the EPA have screening tools developed to identify areas in Maryland with populations that are underserved, underrepresented and/or overly burdened with pollution impacts. Both tools should be used in combination to provide the most robust evaluation of pollution impacts. The area within the coldwater portion of the Gwynns Falls watershed is not recognized within these screening tools as being overburdened by pollutants. However, due to its proximity to Baltimore City, restoring these waters in the Gwynns Falls watershed offers an important opportunity to improve water quality in an area that is in proximity to communities that do meet EJ criteria; improving water quality and recreational opportunities in these nearby communities can benefit people who live in underserved communities as well.

2.1.2 Geology/Soils

The coldwater portion of the Gwynns Falls watershed is located in the Piedmont Physiographic Provinces in Baltimore County. The Piedmont Province is characterized by gentle to steep rolling topography, low hills and ridges. Surficial geology is characterized by crystalline rocks of volcanic and sedimentary origin consisting primarily of schist and gneiss. These formations are resistant to short-term erosion, and often determine the limits of stream banks and streambeds. These crystalline formations decrease in elevation from northwest to southwest within the Piedmont Province and eventually extend beneath the younger sediments of the Coastal Plain (MGS 2012).

The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) classifies soils into 4 hydrologic soil groups: Group A soils have high infiltration rates and are typically deep well drained/excessively drained sands or gravels; Group B soils have moderate infiltration rates and consist of soils that are moderately deep to deep and moderately well to well drained soils, with moderately fine/coarse textures; Group C soils have slow infiltration rates with a layer that impedes downward water movement, and they primarily have moderately fine-to-fine textures; Group D soils have very slow infiltration rates consisting of clay soils with a permanently high water table that are often shallow over nearly impervious material. The Use Class III portion of the Gwynns Falls watershed is comprised primarily of Group B soils (50%), Group C soils (21%), and Group D soils (23%), with a small portion of the watershed consisting of Group A soils (7%) (USDA 2006).

Soil groups affect infiltration rates, which impact stream temperature by altering the fractions of rainfall transported to the stream as surface runoff. Increased surface runoff has a warming effect on stream temperature. Infiltration gets water into aquifers and away from exposure to the sun, reducing warming, with solar radiation being one of the main heat inputs to streams. Increased groundwater recharge from infiltration supplies more baseflow, which provides a more stable stream temperature (USEPA 2018).

2.1.3 Groundwater

Surface water and groundwater were once regarded as distinct resources that could be used and managed independently. The shortcomings of this practice became obvious where sustained depletions of one resource negatively impacted the other. Scientists now recognize that groundwater and surface water are intimately coupled in many places, constituting a single system that must be understood and managed together. Exchanges between surface and groundwater include water volume, solutes, and heat (as cited in USGS 2004).

Protecting stream habitat requires an adequate understanding of groundwater movement near streams. Stream temperatures are influenced by exchanges between streams and nearby groundwater. Heat provides a natural tracer of groundwater movement that is readily tracked by measuring temperature (USGS 2004).

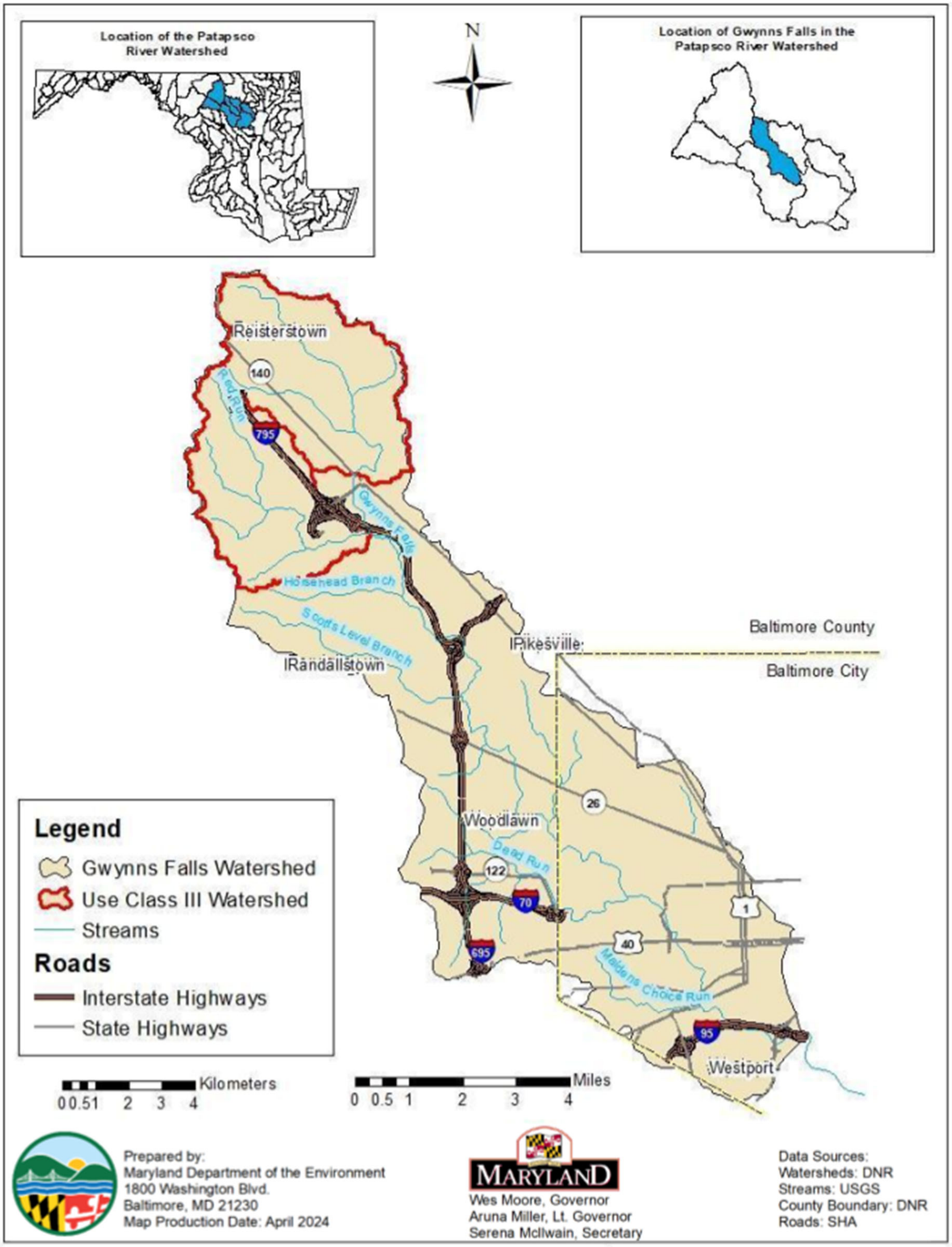

Figure 1: Location Map of the Gwynns Falls Watershed in Baltimore City and Baltimore County, Maryland

2.1.4 Land-use Distribution

The overall land-use distribution of the Use Class III portion of the Gwynns Falls watershed consists primarily of urban land (39%) and natural land (47%). A detailed summary of the land-use areas of each sub-watershed are presented in Tables 1 and 2, and a land-use map is provided in Figure 2. The land use distribution is based on land use/land cover data from the 2013 Chesapeake Conservancy High Resolution Land Cover Classification (Chesapeake Conservancy 2018).

Table 1: Land-Use Percentage Distribution for Red Run Sub-Watershed

Land Use	Area (Acres)	Percentage (%)
Mixed Open/Agriculture	831	18
Water/wetland	41	1
Urban	1,434	30
Forest	2,415	51
Total	**4,721**	**100**

Table 2: Land-Use Percentage Distribution for the Upper Gwynns Falls Sub-Watershed

Land Use	Area (Acres)	Percentage (%)
Mixed Open/Agriculture	630	11
Water/wetland	10	0
Urban	2,675	46
Forest	2,511	43
Total	**5,826**	**100**

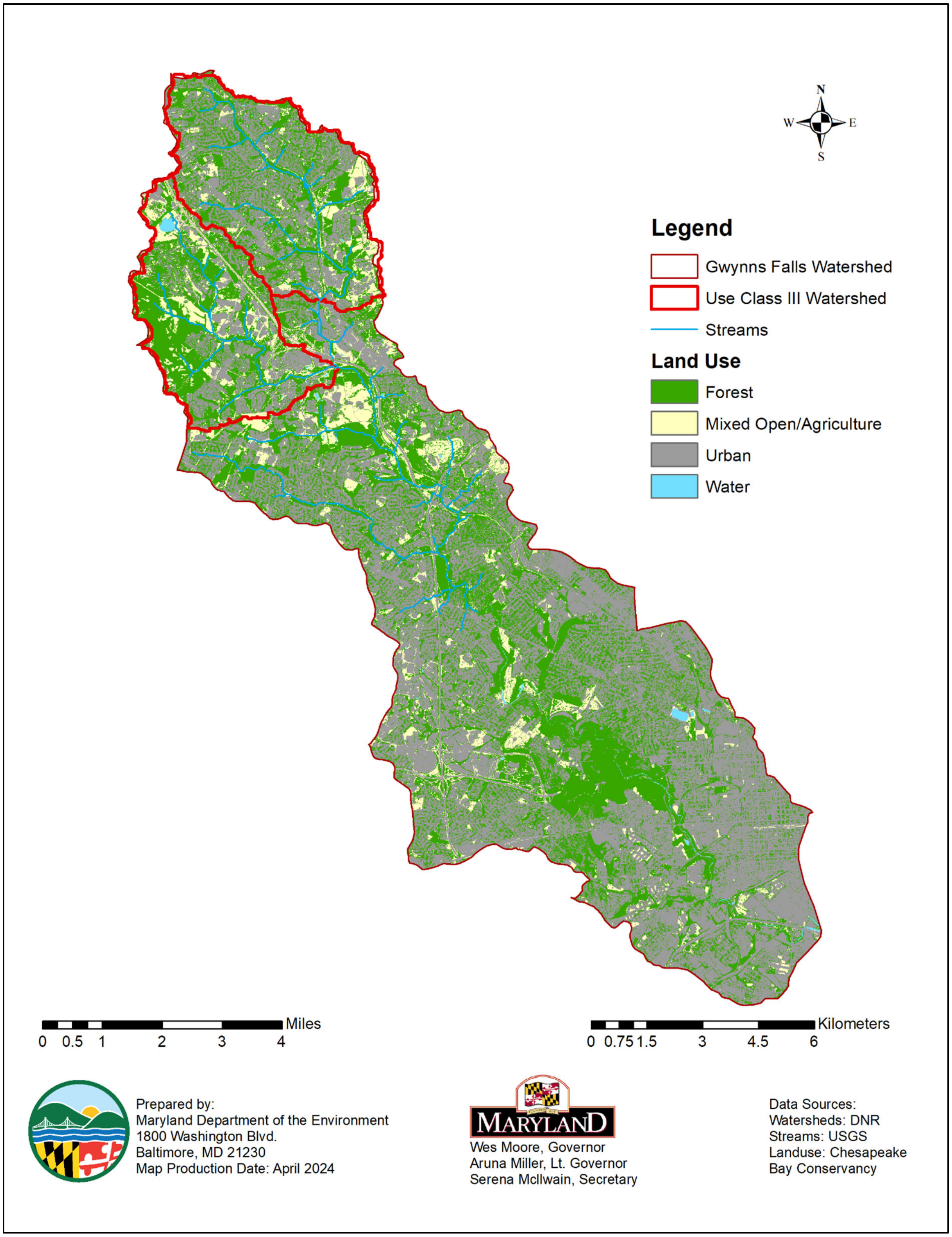

Figure 2: Land-use Distribution of the Gwynns Falls Watershed

2.2 Source Assessment

Thermal loads in a watershed are affected by both natural and anthropogenic activities. Stream temperature is influenced by numerous natural variables, including solar radiation, air temperature, ground temperature, precipitation, land use, forest cover, surface water inflows, and groundwater exchanges (as cited in Constantz 1998). The Gwynns Falls watershed total thermal load is expressed as the sum of nonpoint sources loads and National Pollutant Discharge Elimination System (NPDES) Stormwater point source loads. There are no NPDES permitted wastewater discharges in the Use Class III portion of the Gwynns Falls watershed. This section summarizes the methods used to derive loads for each of these distinct source categories.

2.2.1 Nonpoint Source Assessment

The nonpoint source thermal loads in the Gwynns Falls watershed are attributed to the natural background temperature of the water. Several natural variables that affect stream temperature are discussed below.

Air temperature

A strong linear relationship exists between air and stream temperature. In the simplest model, such as the one developed by Stefan and Preud'homme, water temperature is estimated based solely on air temperature.

$$T_{water,}°C = 5.0 + 0.75 * T_{air}$$

Using this equation, the measured water temperatures follow the air temperatures closely with some time lag. Time lags ranged from hours to days, increasing with stream depth (Stefan and Preud'Homme 1993 as cited in Neitsch et al. 2011).

Departures from this relationship do exist. For example:

- During cold weather, when water temperatures rarely reach below 0°C, in contrast to air temperatures.
- Snowmelt can keep stream temperature well below air temperature.
- Surface flow from precipitation in warm weather can result in stream temperatures that are higher than air temperatures
- Higher groundwater flow can lower temperature.

Groundwater

Groundwater and surface water are intimately coupled in many ways, including heat exchange. Groundwater maintains a relatively constant temperature over time. There is virtually no diurnal variation in groundwater temperature and only a small annual variation. Therefore, groundwater can help stabilize stream temperature. The interactions between stream temperature, streamflow, and groundwater depend on the volume of groundwater inflow. In summer, during low surface flow periods, groundwater is often a larger percentage of total stream flow and can help cool the warmer surface water. In winter, the opposite is true (as cited in Constantz 1998).

Riparian canopy

Riparian vegetation affects stream temperature in three main ways. First, riparian vegetation absorbs incoming shortwave radiation (ultraviolet and visible light) from the sun. Since less thermal energy is reaching the stream, the water temperature is reduced. Second, as part of the earth's energy balance, some of the shortwave radiation absorbed by riparian vegetation is emitted back into the atmosphere as long-wave radiation (infrared light). Some of this energy also reaches the stream, and can increase the water temperature. Third, riparian vegetation may affect the stream micro-climate (e.g., air temperature, humidity, and wind speed), which in turn affects evaporation, conduction, ground temperature, and water temperature. The amount of shading by the banks depends not only on their height but also on the elevation angle of the sun and the orientation of the sun relative to the stream channel (Rutherford et al. 1997). Riparian zone width and type of vegetation also influence the impact of the riparian canopy on water temperature.

Changing Climate

According to the Maryland Commission on Climate Change (MCCC), Maryland is one of the most vulnerable states in the nation to impacts from climate change. The four main impacts of climate change are sea level rise, increasing water temperatures, more extreme rain events, and intensifying heat waves and droughts (MCCC 2017).

Research indicates that the Chesapeake Bay region has experienced an overall increase in stream water temperature of 1.4 °C (2.52 °F) between 1960 and 2010. Stream temperatures have risen throughout the Chesapeake Bay region, with largest increases in the southern part of the region). Rice & Jastram indicates in the study these temperature increases are a combination of watershed characteristics, sources and volume of water, and anthropogenic influences (Rice & Jastram 2015). Most global climate models predict that global river temperatures will increase between 1 to 3°C by 2070 to 2100 (as cited in Dugdale et al. 2018).

Using a stochastic modeling approach, Nelson and Palmer (2007) found that stream temperature may be impacted more by urbanization than by climate change, though the two stressors reinforce each other. This study was conducted in the Piedmont region of Maryland in five small highly urbanized catchments located north of Washington, DC. However, the authors suggest that quantitative tools are needed to better assess the magnitude and direction of altered thermal regimes.

MDE is a national leader in reducing greenhouse gas emissions. MDE also recognizes that climate change is a global issue and that some impacts of climate change are beyond the control of Maryland and its constituents. Because increasing water temperatures and extreme rain events will increase stream temperatures, MDE commits to reassess this TMDL for climate change impacts in 10 years, as better science related to climate change and its impact on local water temperatures becomes available. The TMDL loads and/or the applicable WQS may be revised as appropriate.

2.2.2 Point Source Assessment

In general, there are two categories of point sources that must be considered in a TMDL, wastewater and stormwater. Both categories are regulated under the NPDES program.

Wastewater Permits

Wastewater permits include individual industrial and municipal wastewater treatment facilities, as well as general permits for process discharges from a variety of industrial sectors. Wastewater permits, in general, include specific pollutant limits. Pollutant limits are set based on protection of water quality standards. The water quality standard for Use Class III waters is 68°F (20°C).

There are no NPDES wastewater permits in the Use Class III portions of the Gwynns Falls watershed. For temperature TMDLs developed for watersheds where point source discharges are located, or for any potential new discharges, to the extent that full implementation of the TMDL would require a wastewater point source to further lower its discharge temperature through infrastructure upgrades, MDE is open to considering alternative approaches for TMDL implementation, including point sources funding other approaches for reducing water temperatures in the receiving water.

Stormwater Permits

Stormwater permits include Municipal Separate Storm Sewer System (MS4) permits, general NPDES stormwater permits, and the general permit for stormwater discharges from construction sites. Stormwater permits generally do not contain specific pollutant limits.

Urban development dramatically alters a drainage system due to changes in surface cover (i.e. impervious surface) and addition of stormwater handling systems. Increased and warmer runoff from impervious surfaces into streams can lead to a degradation of habitat for coldwater fish. Runoff temperatures from asphalt were found to be correlated to a combination of parameters: average dew point temperature during the storm, air temperature prior to the storm, and solar radiation prior to the storm. Stormwater thermal pollution has been shown to be more severe when (1) atmospheric air and dew point temperatures are higher than stream temperature, e.g. for streams that are fed by groundwater that is colder than the ambient air, (2) rainfall events are short, intense and preceded by full or partial sun, and (3) watersheds have a high percentage of impervious, particularly paved surfaces. The amount of heat added to the runoff is highly dependent on both the characteristics of the rainfall event and the weather conditions prior to the storm event (Herb et al 2008).

There are two individual and three general stormwater permits that contribute to the increase in stream temperature in the Use Class III portion of the Gwynns Falls watershed. For more detailed information regarding the Gwynns Falls watershed TMDL point source wasteload allocation (WLA), please see the technical memorandum to this document entitled *Point and Nonpoint Sources of Temperature in the Coldwater Gwynns Falls Watershed*.

2.3 Water Quality Characterization

A total of 17 water quality monitoring stations were used to characterize the Gwynns Falls watershed for the purpose of this TMDL analysis. Three Maryland Biological Stream Survey (MBSS) stations were used for the Integrated Report listings. Eight MDE stations were used to determine how much of the Use Class III watershed is impaired, in addition to the three stream segments listed on the Integrated Report. Three US Geological Survey (USGS) stations were used to calibrate hydrology. The eight MDE stations, plus three Baltimore Ecosystem Study (BES) stations were used to calibrate the temperature model. All stations are listed in Table 3 and presented in Figure 3.

Table 3: Monitoring Stations in the Gwynns Falls Watershed

Site Number	Sponsor	Site Type	Location	Latitude (decimal degrees)	Longitude (decimal degrees)
GWYN-102-S-2010	DNR	MBSS Round 3	Red Run, unnamed tributary 1	39.4062	-76.8241
GWYN-103-R-2007	DNR	MBSS Round 3	Red Run, unnamed tributary 2	39.4153	-76.8216
GWYN-204-A-2012	DNR	MBSS – special	Red Run	39.4103	-76.8008
1589197	USGS	Flow	Gwynns Falls at Delight	39.4430	-76.7833
1589290	USGS	Flow	Scotts Level	39.3615	-76.7618
1589300	USGS	Flow	Villa Nova	39.3459	-76.7332
GFGB	BES	Temperature	Gwynns Falls at Gwynnbrook Ave	39.4430	-76.7833
SCLB	BES	Temperature	Scotts Level Branch	39.3615	-76.7618
GFVN	BES	Temperature	Gwynns Falls at Villa Nova	39.3459	-76.7332
9	MDE	Temperature	High Falcon Road	39.4431	-76.8015
11	MDE	Temperature	Gwynbrook Avenue	39.4429	-76.7834
13	MDE	Temperature	Route 40/Reisterstown Rd	39.4212	-76.7813
15	MDE	Temperature	Painter Mill Road	39.4049	-76.7789
19	MDE	Temperature	Lakeside Boulevard	39.4009	-76.7992
23	MDE	Temperature	Dolfield Boulevard	39.4035	-76.8218
25	MDE	Temperature	Upper Mill Drive	39.4139	-76.8180
67	MDE	Temperature	Red Run Stream Valley Trail	39.4101	-76.8014

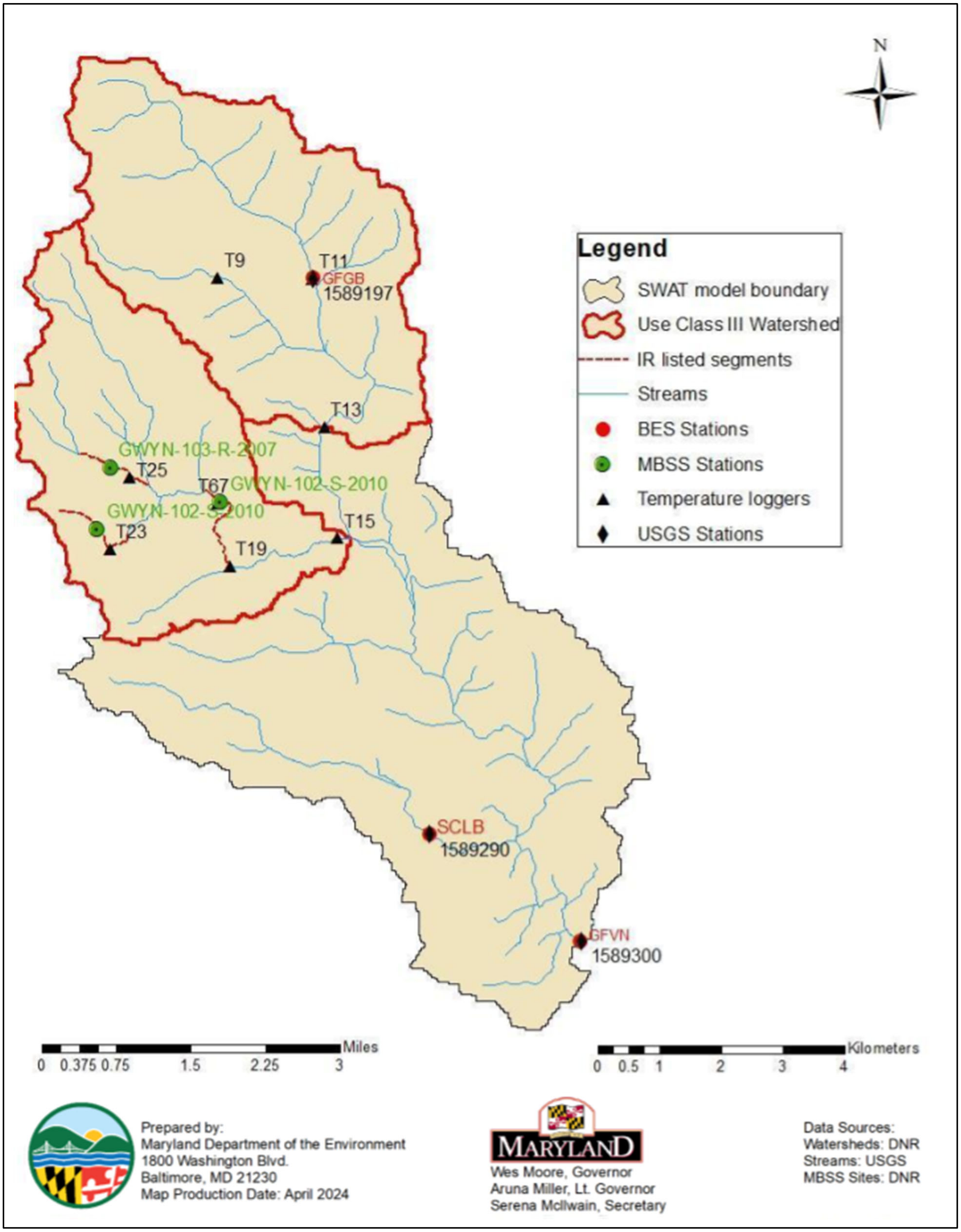

Figure 3: Monitoring Stations in the Gwynns Falls Watershed

2.4 Water Quality Impairment

A methodology for assessing temperature impairment has been established by MDE, and was updated in 2019 (Figure 4). The MBSS temperature monitoring program was chosen as the data source for the assessment. The temperature listing methodology is based on the 90^{th}-percentile and maximum observed temperatures during the critical period (June 1 through August 31) (MDE 2019).

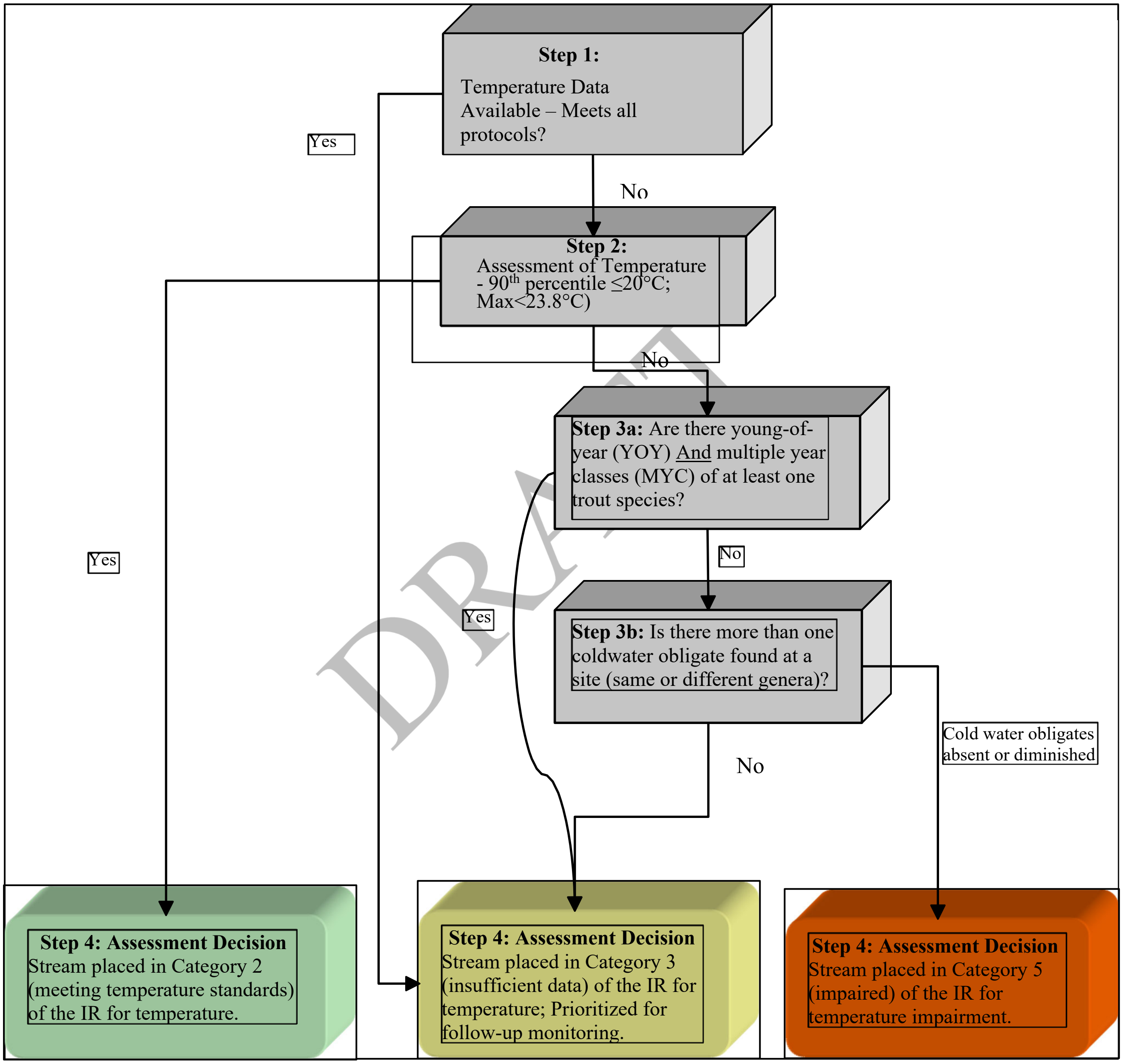

Figure 4: 2018 Temperature Assessment Methodology Decision Diagram

Based on this assessment methodology, three coldwater segments in the Gwynns Falls watershed were listed for temperature impairment on the 2014 Integrated Report (see Figure 3) (MDE 2014). The three segments are MD-021309051045-Red_Run, MD-021309051045-UTRed_Run1, and MD-021309051045-UTRed_Run2. The listings were based on MBSS data collected from 2007 to 2012. Data analysis results are presented in Table 4.

Table 4: Integrated Report Listing Data

Station	Min	Max	Mean	90th percentile
GWYN-102-S-2010	11.8	27.8	22.0	24.1
GWYN-103-R-2007	12.6	24.3	18.5	20.5
GWYN-204-A-2012	14.3	27.4	21.4	24.0
THRESHOLD	---	23.8	---	20.0

In order to determine the extent of impairment in the entire Use Class III portion of the watershed MDE conducted temperature monitoring at 15 stations in the Gwynns Falls in summer (June 1 – Aug 31) 2016 and at 8 stations in summer 2017. Water temperature was measured and recorded at 15 minute intervals. Only stations with both 2016 and 2017 data were used in this analysis. Temperatures observed at all of the 2016/2017 stations were found to be impaired based on the assessment methodology. A summary of these data is provided in Figure 5 and Tables 5 and 6. Based on these results, the temperature listings for the Gwynns Falls watershed will be revised in the next Integrated Report. Instead of the three individual stream listings, the entire extents of the two Use Class III sub-watersheds, Upper Gwynns Falls and Red Run, will be listed as impaired by temperature.

Table 5: 2016 Temperature Data at TMDL Monitoring Stations

Station	Min	Mean	Max	90th percentile
T9	16.8	20.8	23.6	22.8
T11	16.5	21.4	24.9	23.7
T13	17.4	22.3	26.2	24.9
T15	17.7	22.8	26.6	25.4
T19	17.0	22.1	26.1	24.5
T23	15.3	19.0	22.3	20.7
T25	15.3	20.3	24.2	22.7
T67	16.5	21.6	25.6	24.1
THRESHOLD	---	---	**23.8**	**20.0**

Table 6: 2017 Temperature Data at TMDL Monitoring Stations

Station	Min	Mean	Max	90th percentile
T9	16.3	20.9	23.9	22.7
T11	15.8	20.9	23.8	23.1
T13	16.5	21.8	24.8	24.0
T15	16.8	22.1	25.6	24.3
T19	16.0	21.4	24.6	23.5
T23	14.6	18.8	21.6	20.6
T25	14.6	19.9	23.0	21.8
T67	15.8	21.0	24.2	22.9
THRESHOLD	---	---	**23.8**	**20.0**

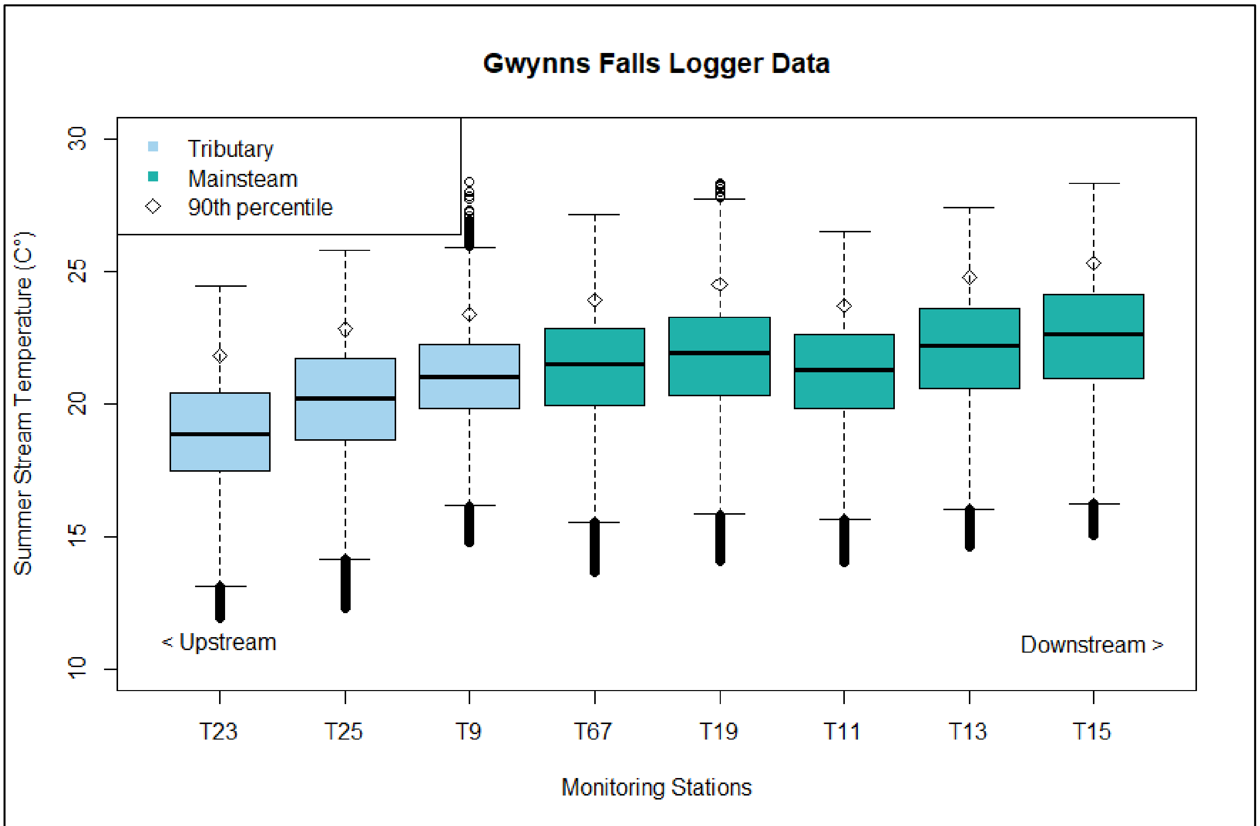

Figure 5: Box and Whisker Plots of the Gwynns Falls Logger Data Collected in 2016 and 2017

3.0 TARGETED WATER QUALITY GOAL

The objective of the temperature TMDL established herein is to reduce water temperature levels, and their detrimental, negative effects on aquatic life in the coldwater portion of the Gwynns Falls watershed to levels that support the Use Class III designation for the watershed. Use Class III waters are those considered appropriate for coldwater assemblages. Besides brook trout, two other trout species are known to grow and propagate in Maryland's streams. These are brown and rainbow trout. Coldwater streams in the State may also support temperature-sensitive species of stone flies, such as *Tallaperla* and *Sweltsa* (COMAR 2018b). A map of the Designated Use Classes in the Gwynns Falls Watershed is provided in Figure 6 (COMAR 2018d).

Temperature is a physical property of water that affects most biological and chemical processes that occur in water. Anthropogenic activities can alter the temperature regime of streams and rivers causing changes (sometimes permanent) in the biological community. For example, if the thermal tolerance of a fish species is exceeded in a stream reach, it can result in direct fish mortality (as cited in USGS 2018).

The eastern brook trout is an important cold-water species of North America. They are particularly sensitive to temperature change, as populations are spatially constrained to stream networks. A number of studies have found an optimal temperature for trout propagation (13-16°C), but few have investigated an upper threshold for growth. A lethal temperature of 25.3°C has been established and several studies have found no brook trout present above an average temperature of 22°C. Recent research was conducted at UMass-Amherst to more clearly understand the mechanism by which increased temperature restricts propagation of eastern brook trout and to establish an upper threshold for propagation. The hypothesis of the work was that increased temperature increases stress hormones (e.g. plasma cortisol, glucose, lactate and heat shock protein), which in turn limit growth and reproduction. Reduced growth also impacts fertility and increased vulnerability to predation. The study investigated the effect of chronic temperature exposure at 16°C, 18°C , 20°C, 22°C , 24°C. Results of the study indicated a threshold for positive growth of 23.4°C (Chadwick 2012).

An analysis of Maryland summer stream data, collected as part of the MBSS, found that streams with brook trout spent, on average, 10.7 percent of the time above 20°C. As this finding represents an average condition for brook-trout-supporting streams in the State, it is recognized that some reaches with higher temperatures will continue to have self-sustaining trout populations. These locations may have groundwater inputs, providing thermal refugia during periods of high ambient stream temperature (Hilderbrand 2009).

Based on the findings of this research, and consistent with Maryland's Assessment Methodology for temperature in Use Class III streams, this TMDL analysis adopts a 90^{th}-percentile temperature of 20°C (68°F) as the targeted water quality goal, or TMDL endpoint. This goal incorporates several conservative assumptions which comprise the implicit Margin of Safety (MOS) used in this TMDL. First, as was mentioned above, by selecting the average thermal condition where brook trout can survive, the water quality goal is below the threshold condition for self-sustaining trout populations. Second, while the Hilderbrand study focused on individual reaches, the assessment unit for this TMDL is the stream network. By looking at a specific temperature regimen across the network, this TMDL ensures that certain stream reaches, primarily in the headwaters, will have 90th-percentile temperatures below 20°C. These reaches would provide vital cold water refugia for trout during periods of elevated water temperature.

Maryland's Use Class III definition also defines it as having conditions suitable for, "other coldwater obligate species including, but not limited to the stoneflies *Tallaperla* and S*weltsa*" (MDE 2018b). Self-sustaining brook trout populations have a similar thermal regime to *tallaperla* and *sweltsa* (MDE 2019), so by creating conditions to support brook trout, this TMDL will support cold water obligate species. This ensures that under this thermal water quality goal, the cold water aquatic life designated use will be fully supported.

The CWA requires TMDLs to be protective of all the Designated Uses applicable to a particular waterbody. While the "Growth and Propagation of Trout," Designated Use is the primary focus of this report, the temperature goals established in this TMDL would also support the other Use Class III Designated Uses—particularly ensuring that the streams are both fishable and swimmable. By protecting trout populations, this TMDL ensures that the "Fishing" Designated Use is supported. For water contact recreation, according to the National Oceanic and Atmospheric Administration (NOAA), 70° to 78°F (21-26°C) is the range where most folks feel "comfortable" swimming (NOAA 2020). Therefore, the thermal reductions required by this TMDL would make waters cool for water contact recreation, but not prohibitive.

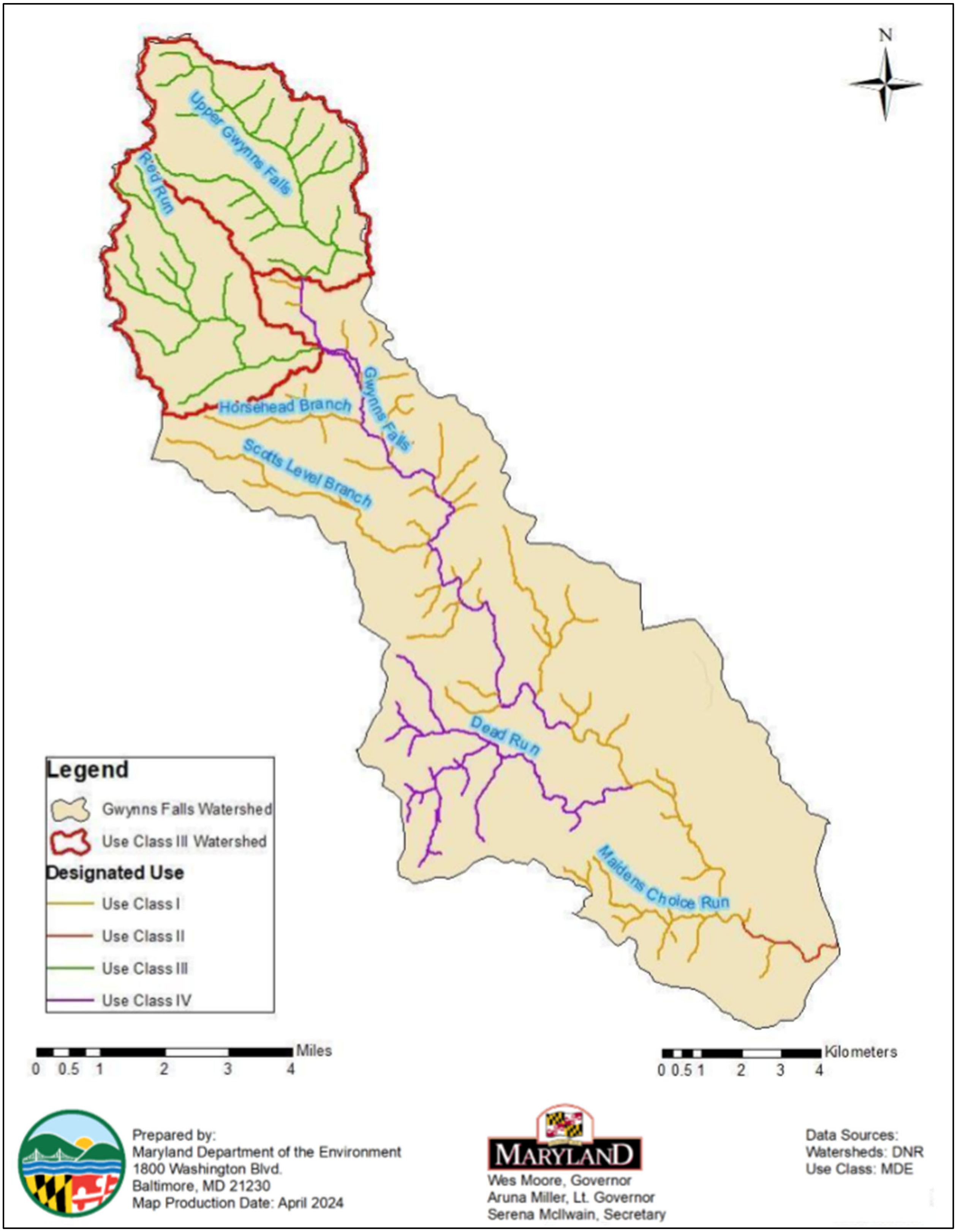

Figure 6: Designated Use Classes of the Gwynns Falls Watershed

4.0 TOTAL MAXIMUM DAILY LOADS AND SOURCE ALLOCATION

4.1 Overview

This section describes how the temperature TMDLs in the Gwynns Falls watershed were estimated, and how the corresponding allocations were established.

4.2 Analysis Framework

4.2.1 Model Selection

The Soil and Water Assessment Tool (SWAT) model was used to model thermal loads in the coldwater portion of the Gwynns Falls watershed. SWAT is a physically-based and continuous model developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in watersheds (Neitsch et al. 2011). SWAT is a public domain software-enabled model that is actively supported by the USDA Agricultural Research Service at the Blackland Research & Extension Center in Temple, Texas. It is a watershed hydrological transport model with the following components: weather, surface runoff, return flow, percolation, evapotranspiration, transmission losses, pond and reservoir storage, crop growth and irrigation, groundwater flow, reach routing, nutrient and pesticide loading, and water transfer.

In 2012, Ficklin et al. developed a stream temperature model within SWAT that reflects the combined influence of meteorological (air temperature) and hydrological conditions (streamflow, snowmelt, groundwater, rainfall, surface runoff, and lateral soil flow) on water temperature within a watershed.

The SWAT model was selected because it is able to accurately represent stream flow and temperature while providing a user friendly interface. This TMDL uses the SWAT model to simulate the conditions and management framework in which an appropriate temperature regime could be restored in coldwater streams. The ArcSWAT ArcGIS graphical interface developed by Winchell et al. (2013) was used in setting up the model. The model setup consists of delineating the watershed, dividing it into sub-basins and hydrologic response units, compiling weather data, defining default inputs, and specifying the simulation period.

The area of the Gwynns Falls watershed that was modeled is from the headwaters to USGS station #01589300 – Gwynns Falls at Villa Nova, MD. This area encompasses the entirety of the Use Class III streams plus additional Use Class I (*Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life*) and Use Class IV (*Recreational Trout Waters*) streams. The spatial extent of the model was based on the location of the primary hydrologic calibration point, USGS station 1589300. This point was chosen because it is the closest downstream flow gage for either subwatershed, yielding a calibrated model covering the entirety of the impaired systems. The model area was divided into 105 model segments. Separate analyses were completed for Upper Gwynns Falls and Red Run sub-watersheds. Upper Gwynns Falls consists of 29 model segments and Red Run consists of 27 model segments. See Figure 7 for model segmentation.

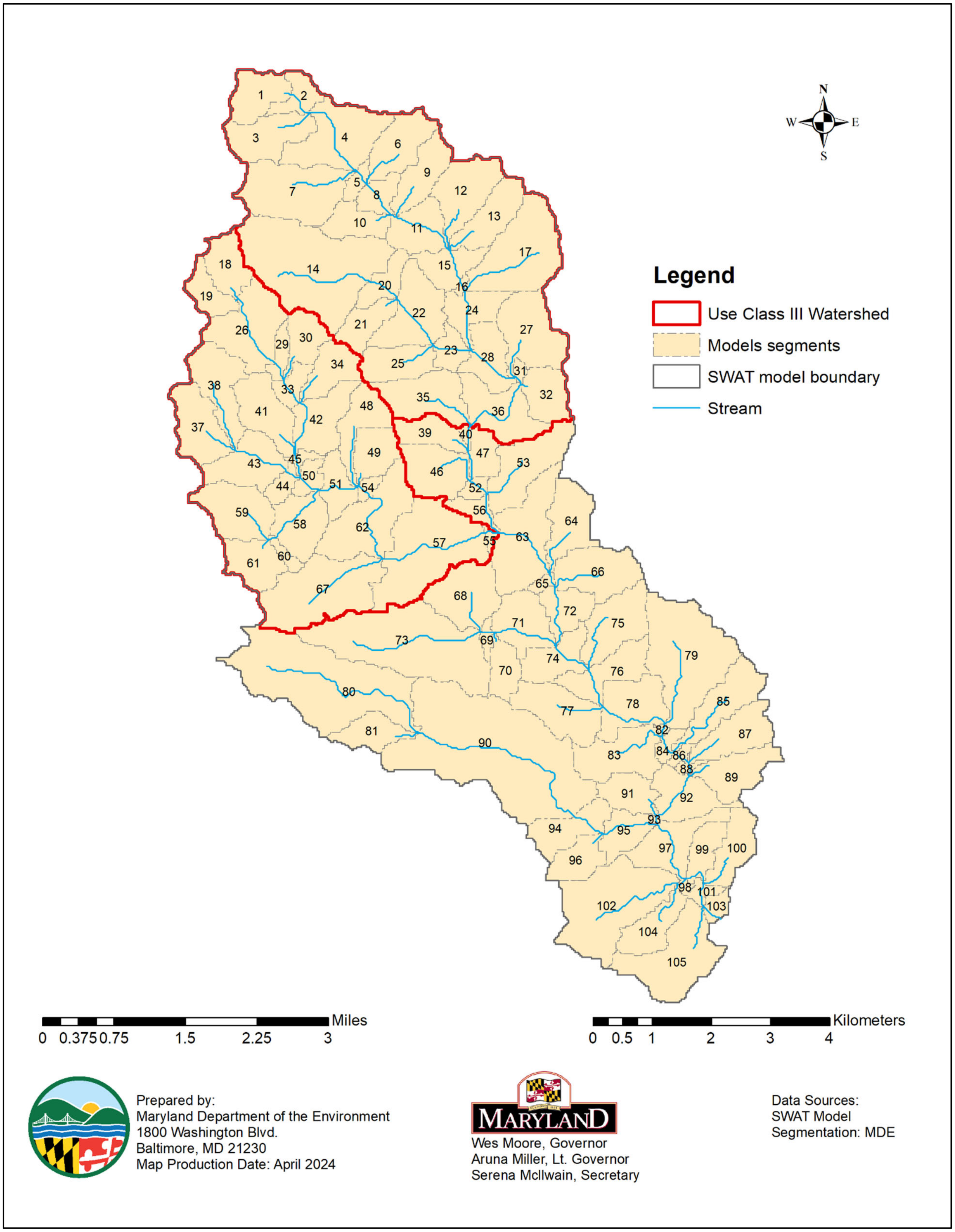

Figure 7: SWAT Model Segmentation

4.2.2 Model Development and Calibration

The model development is a three step process:

1. Model hydrology
2. Model temperature
3. Convert temperature to thermal energy

Each step is described briefly below. For a complete discussion of the model, please see Appendix A.

1) **Hydrology**

The first step in developing the SWAT model of the Gwynns Falls watershed was to calibrate the hydrology. Three USGS stations, shown in Figure 3, were used for the hydrology calibration: 1589197 (Gwynns Falls at Delight), 1589290 (Scotts Level, outside Use Class III area), and 1589300 (Villa Nova, outside Use Class III area). The streamflow data used for calibration was available from 1999 to 2017, from 2006 to 2017 and from 1983 to 2017, respectively.

The model was calibrated separately for base flow, surface runoff, and total stream flow. SWAT was calibrated and run at different parameter values until good agreement was obtained between observed and simulated stormflow and baseflow. See Appendix A for hydrology calibration graphs and results. In urban watersheds, like Gwynns Falls, the baseflow portion of a stream discharge usually represents a lower percentage of the total annual discharge. In forested catchments, a relatively higher baseflow percentage can be observed (Stewart, Gemmill, and Pentz 2005).

2) **Temperature**

Once the hydrology was calibrated, the temperature was simulated. Observed data used to calibrate stream temperature was from the Baltimore Ecosystem Study (2004-2008) and MDE logger data (2016 – 2017).

The stream temperature model, developed by Ficklin et al 2012, calculates stream temperature in three steps: (1) temperature and amount of local hydrological contributions (snowmelt, surface runoff, and groundwater) within the subbasin; (2) temperature and inflow volume from upstream subbasin(s); and (3) heat transfer at the air-water interface during the streamflow travel time in the subbasin.

$$T_{local} = \frac{T_{snow} * snowmelt + T_{gw} * baseflow + T_{air} * stormflow}{water\ yield} \quad \text{(Equation 1)}$$

$$T_{initial} = \frac{T_{upstream}(Q_{outlet} - water\ yield) + T_{local} * water\ yield}{Q_{outlet}} \quad \text{(Equation 2)}$$

$$T_{water} = T_{initial} + (T_{air} - T_{initial}) * K * TT \quad \text{(Equation 3)}$$

where:

T_{local} = temperature of water, °C
T_{snow} = temperature of snow, 0.1°C
Snowmelt = snowmelt contribution in subbasin
T_{gw} = temperature of groundwater, assumed constant at 12°C
Baseflow = groundwater contribution in subbasin, mm
T_{air} = average daily air temperature, °C
Stormflow = stormwater contribution in subbasin, mm
Water yield = water yield in subbasin, mm
$T_{initial}$ = temperature of local headwater streams, °C
$T_{upstream}$ = water temperature of stream entering subbasin, °C
Q_{outlet} = streamflow discharge at the outlet of subbasin, m^3/s
K = calibration conductivity parameter
TT = travel time (hour)

Equation 1 estimates the temperature at the outlet of a given model segment based on flow and temperature from snowmelt, baseflow and stormflow. Equation 2 calculates the stream temperature without the effect of air temperature based on upstream temperature, outlet flow and outlet temperature. Equation 3 calculates final stream temperature based on the difference between stream and air temperature and a calibration parameter. The calibration parameter *K* (Eq. 3) can be used to represent the effects of shading of the stream channels by riparian woody vegetation on stream temperature at reach level (Ficklin et al. 2012).

3) **Thermal energy**

Based on the hydrology and temperature simulations, thermal energy (heat) is calculated in joules per second (J/s), by the formula below.

$$H = TC_pV\rho$$

Where:

H = heat, $J\ s^{-1}$
T = water temperature, °C
C_p= specific heat, 4,184 J $(kg\ °C)^{-1}$ *
V= streamflow volume, m^3/s
ρ = water density, 998 kg/m^3

* *Water has to absorb 4,184 Joules of heat for one kg of water to increase by 1 degree Celsius.*

The heat calculation is based on the water temperature and the streamflow volume, with conversion factors for specific heat of water and water density. The loads provided in this report, expressed as gigajoules per day (GJ/d) and equivalent to one billion joules per day (J/d), are calculated based on the daily energy leaving the outlet of the system during the summer assessment period of June 1 to August 31 for the model simulation period.

4.3 Scenario Description and Results

The following analyses compare baseline conditions in the watershed, under which water quality problems exist, with potential future conditions, which project the water quality response to various simulated thermal load reductions. The analyses are grouped according to baseline conditions and future conditions associated with TMDLs.

4.3.1 Baseline Scenarios

The baseline conditions are intended to provide a point of reference from which to compare the future scenario that simulates conditions of a TMDL. The Gwynns Falls watershed baseline thermal loads are estimated using the SWAT model. The baseline model scenario was based on 2013 conditions in the watershed, using land use from the Chesapeake Bay Conservancy High Resolution Land Cover Classification. The total baseline loads for Upper Gwynns Falls and Red Run were calculated at model segments 12 and 20, respectively. These model segments represent the outlets of the Upper Gwynns Falls and Red Run sub-watersheds and capture the entire thermal load discharged from each sub-watershed. The two coldwater sub-watersheds are separated by segment 18, which is not designated as a Use Class III coldwater stream.

Within this TMDL, the total baseline loads are categorized as nonpoint and point source loads. Nonpoint source loads include natural background loads like those associated with forest as well as load increases from agricultural land use. Loads from degraded riparian canopy are also considered nonpoint source loads. Point source loads are any loads associated with an NPDES permit and can be further subdivided into two categories, wastewater and stormwater. All point source loads in this analysis are NPDES stormwater loads. There are no wastewater loads in the coldwater portions of the Gwynns Falls watershed.

Modeling thermal loads is complex. The thermal contribution of a particular land use is temporally dynamic and dependent on several interacting factors. In this analysis, there are two anthropogenic drivers of thermal loads that can be controlled at a watershed scale—those load increases that are due to a particular land use and those that are due to degraded riparian cover. In order to separate out specific thermal sources, model scenarios were run that isolated an individual land use (i.e. agriculture and forest) by replacing it with forest land. By isolating a particular land use and replacing it with forest, the thermal contribution of the particular land use can be determined. Replacing an individual land use with forest does not determine the total thermal load of the land use, but instead the controllable portion of the load. In order to separate out thermal loads that are due to degraded riparian canopy, model scenarios were also run at various percentages of riparian canopy.

Tables 7 and 8 summarize the Gwynns Falls Watershed baseline thermal loads, reported in GJ/d and presented in terms of Nonpoint Source Baseline Loads and NPDES Stormwater and Wastewater Point Source Baseline Loads.

Table 7: Red Run Sub-watershed Baseline Thermal Loads

Total Baseline Load, GJ/d	=	Nonpoint Source BL_{RR}	+	NPDES Stormwater BL_{RR}	+	Wastewater BL_{RR}
399	=	339	+	61	+	0

Table 8: Upper Gwynns Falls Sub-watershed Baseline Thermal Loads

Total Baseline Load, GJ/d	=	Nonpoint Source BL_{UGF}	+	NPDES Stormwater BL_{UGF}	+	Wastewater BL_{UGF}
493	=	375	+	118	+	0

4.3.2 TMDL Scenarios

The TMDL scenario simulates conditions under which thermal loads have been reduced to a level to meet water quality criteria. The resulting load is considered the maximum allowable load the watershed can sustain and support aquatic life.

The Gwynns Falls watershed TMDL temperature allocations were estimated using the SWAT model. The following model scenarios were run to provide an analysis of multiple watershed conditions in order to determine the TMDL allocations. Two variables are adjusted in the model scenarios in order to impact stream temperatures: percent urban retrofit and percent riparian cover. The term retrofit refers to stormwater controls applied to existing, “untreated” impervious land. To model retrofits, this TMDL assumes the use of appropriate stormwater management practices for reducing temperature, typically those described in Chapter 5 of the Maryland Stormwater Design Manual (SDM), with a rainfall target depth sufficient to achieve the hydrological goal of “woods in good condition.” Table 5.3 in the SDM describes the location-specific rainfall target depth, in inches, which is a function of both Hydrologic Soil Group and percent imperviousness of a drainage area. It can range from 1 to 2.6 inches (MDE 2009). A discussion of stormwater management practices appropriate for coldwater watersheds is found in Section 5 of this document. The term percent riparian cover indicates the percent of the 100 meter riparian buffer that has canopy cover, it does not indicate the percentage of the stream corridor length that has full cover.

The SWAT model does not have a mechanism to specifically model urban retrofit and the corresponding hydrologic benefit, so the changes in percent retrofit were modeled by changing urban land use to “woods in good condition.” Percent riparian cover is adjusted in the model using the K parameter from Equation 3. A stream is considered to be fully buffered when it has 50 meters of continuous canopy on either side. Percent riparian cover was calculated and modeled individually for Red Run and Upper Gwynns Falls. More information about the modeling exercise can be found in Appendix A.

Table 9: SWAT Model scenarios

Scenario	% retrofit beyond baseline	Red Run % riparian cover	Upper Gwynns Falls % riparian cover
Baseline	0*	79	69
Scenario 1	10	84	77
Scenario 2	30	90	85
Scenario 3	50	95	92
All forest	100	100	100

* The baseline retrofit percentage on urban lands of 6.9% for Red Run and 1.5% for Upper Gwynns Falls.

The water quality goal, a 90th-percentile temperature of 20°C, is assessed using summer temperature results from all segments in each subwatershed. Simulating the various model scenarios in Table 10 and Table 11 helps to narrow down conditions that will meet water quality standards. The simulated summer flows are required to calculate the heat load (Gj/d) and vary based on each scenario. As retrofit and riparian cover increase, the flow decreases due to increased infiltration. The TMDL scenarios were set separately for Upper Gwynns Falls and Red Run, based on percent retrofit and percent increase in riparian canopy needed to meet numeric temperature criteria for Use Class III waters in each sub-watershed.

Table 10: Red Run Baseline and SWAT Scenarios

Parameter	Baseline	Scenario 1	Scenario 2	Scenario 3	All forest
Simulated summer temperature, 90th percentile (ºC)	22.2	21.5	20.5	19.8	17.8
Simulated summer flow, cfs	2.1	2.0	2.0	1.9	1.7
Heat (Gigajoules per day)	399.3	377.7	358.1	338.3	285.5

Table 11: Upper Gwynns Falls Baseline and SWAT Scenarios

Parameter	Baseline	Scenario 1	Scenario 2	Scenario 3	All forest
Simulated summer temperature, 90th percentile (ºC)	22.3	21.8	21.2	20.4	18.1
Simulated summer flow, cfs	2.6	2.5	2.4	2.28	2.0
Heat (Gigajoules per day)	493.0	467.0	436.5	404.5	329.0

Table 12 shows the SWAT model scenario that meets water quality standards in each subwatershed. Table 13 shows the model results for each subwatershed. The TMDL values, shown as daily energy exported from the watershed outlets, are based off summer model results over a 27-year hydrologic simulation period. Long-term changes in observed air temperature and rainfall patterns may need to be addressed through future revisions to this TMDL.

Table 12: Subbasin TMDL scenarios

Subbasin	% retrofit	% riparian cover
Red Run	35	90
Upper Gwynns	55	90

Table 13: Red Run and Upper Gwynns Falls TMDL Scenario Results

Parameter	Red Run	Upper Gwynns
Simulated summer temperature, 90th percentile (ºC)	20.0	20.0
Simulated summer flow, cfs	1.98	2.25
Heat (Gigajoules per day)	348.5	396.2

For more information regarding TMDL model scenarios, please see Appendix A.

4.4 Critical Condition and Seasonality

USEPA's regulations require TMDLs to take into account seasonality and critical conditions for stream flow, loading, and water quality parameters (CFR 2018a). The intent of this requirement is to ensure that water quality of the waterbody is protected during times when it is most vulnerable.

The critical condition of the TMDL is to support the growth and propagation of self-sustaining trout populations and other coldwater obligate species. Different species of trout spawn during different times of the year. Brook trout spawning behavior is largely dictated by fluctuations in water temperature. If for some reason water temperatures rise above 55° F during the spawning season, this could have a negative effect on the success of the next generation of fish. Abrupt rises in water temperature lasting more than a couple of weeks can cause brook trout to delay the spawn. Brook trout enter their spawning season in early September which can continue for some fish through October depending on water conditions (Matachek 2020). Rainbow trout spawn earlier in their lives than most other trout species and their spawning season occurs in the late spring and early summer as water temperatures rise. Brown trout spawn in the fall, from late September to early November, and are primarily active during the daytime (Jackson 2008). Implementation activities required to achieve the TMDL allocations will not only provide temperature reductions during the summer season, but also throughout the year which will be beneficial during spawning and the overall life cycle of trout.

This TMDL is specifically formulated to address temperature during the summer season when the water is warmest. The season for temperature is designated as June 1 to August 31. This period was determined based on MBSS temperature data from 2001 through 2008. Temperature was sampled monthly in each watershed for an entire calendar year. It was determined that the overwhelming majority of exceedances (> 20°C) occurred between June 1 to August 31. Historical data from the three MBSS stations in the Gwynns Falls watershed (2007 and 2011) did have several exceedances outside of the time period, two occurred on May 30 and the rest were before September 15.

4.5 TMDL Loading Caps

This section presents the TMDLs for the Red Run and Upper Gwynns Falls sub-watersheds. These loads are considered the maximum allowable thermal loads the watershed can sustain and meet water quality standards.

The Red Run Thermal Baseline Load and TMDL are presented in Table 14. The Upper Gwynns Falls Baseline Load and TMDL are presented in Table 15.

Table 14: Red Run Sub-Watershed Thermal Baseline Load and TMDL

Baseline Load, GJ/d	TMDL, GJ/d	Reduction (%)
399	348	13

Table 15: Upper Gwynns Falls Sub-Watershed Thermal Baseline Load and TMDL

Baseline Load, GJ/d	TMDL, GJ/d	Reduction (%)
493	396	20

4.6 Load Allocations Between Nonpoint and Point Sources

Per USEPA regulation, all TMDLs need to be presented as a sum of load allocations (LAs) for nonpoint source loads and waste load allocations (WLAs) for point sources generated within the assessment unit, accounting for natural background, tributary, and adjacent segment loads as well (CFR 2018a). The State reserves the right to allocate the loads among different sources in any manner that is reasonably calculated to protect aquatic life from temperature related impacts.

Load Allocation

In this watershed, forest and agriculture land use, as well as impacts from degraded riparian canopy were identified as nonpoint sources of thermal loads. Thermal loads from regulated urban lands under National Pollutant Discharge Elimination System (NPDES) permits are considered point source loads that must be included in the WLA portion of a TMDL (USEPA 2002).

In this document, the LA for the Gwynns Falls watershed is expressed as one aggregate value for all nonpoint sources. For more detailed information regarding the Gwynns Falls watershed TMDL nonpoint source LA, please see the technical memorandum to this document entitled *Point and Nonpoint Sources of Temperature in the Coldwater Gwynns Falls Watershed*.

Wasteload Allocation

Point sources included in this TMDL include all sources regulated under NPDES permits and are separated into two categories: wastewater and stormwater. A separate WLA is assigned to each category of permit.

Wastewater WLA

Wastewater permits can include individual industrial and municipal wastewater treatment facilities, as well as general permits for process discharges from a variety of industrial sectors. Wastewater permits, in general, include specific pollutant limits. Wasteload allocations for wastewater sources are calculated based on their permit limits. There are no NPDES wastewater permits in the coldwater stream portions of the watershed.

Stormwater WLA

Per USEPA requirements, "stormwater discharges that are regulated under Phase I or Phase II of the NPDES stormwater program are point sources that must be included in the WLA portion of a TMDL" (USEPA 2002). Permits can cover MS4s owned by local jurisdictions or municipalities, MS4s owned by state and federal entities, industrial facilities and construction sites.
USEPA currently recommends that WLAs for NPDES regulated stormwater discharges be expressed as different WLAs for different identifiable categories (e.g., separate WLAs for MS4 and industrial stormwater discharges). These categories should be defined as narrowly as available information allows (e.g., for municipalities, separate WLAs for each municipality and for industrial sources, separate WLAs for different types of industrial stormwater sources or dischargers). In general, states are encouraged to disaggregate the WLA to facilitate implementation. USEPA recognizes that available data and information are usually not detailed enough to determine WLAs for NPDES regulated stormwater discharges on an outfall-specific basis (USEPA 2014b).

There are two individual and three general stormwater permits that contribute to the increase in stream temperature in the Use Class III portion of the Gwynns Falls watershed. For more detailed information regarding the Gwynns Falls watershed TMDL point source WLA, please see the technical memorandum to this document entitled *Point and Nonpoint Sources of Temperature in the Coldwater Gwynns Falls Watershed.*

As stormwater assessment and/or other program monitoring efforts result in a more refined source assessment, the State reserves the right to revise the current NPDES Stormwater WLA provided the revisions are consistent with the achievement of water quality standards.

4.7 Margin of Safety

All TMDLs must include a margin of safety (MOS) to account for any lack of knowledge and uncertainty concerning the relationship between loads and water quality (CFR 2018a). The MOS shall also account for any rounding errors generated in the various calculations used in the development of this TMDL. An MOS is typically expressed either as an unallocated assimilative capacity or as conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed controls). In the TMDL calculation, the MOS can either be explicitly stated as an additional separate quantity, or implicitly stated, as in conservative assumptions. The TMDL for temperature for the Gwynns Falls watershed adopts the implicit approach for establishing its MOS by using conservative assumptions in the model setup.

One conservative component in this TMDL is that the 90th-percentile temperature is assessed in aggregate for stations across the watershed. This means that some streams in the watershed will be lower than the 20°C threshold. Generally, upstream temperatures are lower than those near the basin outlets, and the model shows that temperatures in several of the headwater subbasin streams are as low as 18°C. This means that these areas of the watershed can serve as refugia for trout during times of peak ambient temperatures. Second, a 90th-percentile temperature of 20°C represents an average condition for brook-trout-supporting streams in Maryland, meaning that there are some streams in the State above this 90th-percentile temperature that support trout populations. The selection of an average reference condition, rather than a maximum possible value for the 90th-percentile temperature, provides an additional conservative assumption to the MOS. These assumptions were discussed in greater detail in Section 3.0.

4.8 Summary of Total Maximum Daily Loads

The Red Run sub-watershed TMDL is summarized in Table 16 and the Upper Gwynns Falls Red Run sub-watershed TMDL is summarized in Table 17. Each TMDL is the sum of the LA, NPDES Stormwater WLA, Wastewater WLA, and MOS. The thermal loads are based on maximum daily conditions across the critical period (June 1 – August 31).

Table 16: Red Run Sub-watershed Temperature TMDL Allocations

TMDL	=	Nonpoint Source LA_{RR}	+	NPDES Stormwater WLA_{RR}	+	Wastewater WLA_{RR}
348	=	305	+	43	+	0

Table 17: Upper Gwynns Falls Sub-watershed Temperature TMDL Allocations

TMDL	=	Nonpoint Source LA_{UGF}	+	NPDES Stormwater WLA_{UGF}	+	Wastewater WLA_{UGF}
396	=	335	+	61	+	0

5.0 ASSURANCE OF IMPLEMENTATION

Section 303(d) of the CWA and current USEPA regulations require reasonable assurance that the temperature TMDL can and will be implemented (CFR 2018a). This section provides the basis for reasonable assurance that the temperature TMDL in the Gwynns Falls watershed will be achieved and maintained. It is anticipated that reductions in temperature will be achieved through MS4 permits, compliance with stormwater design, state and federal grants for water quality and conservation, and the programs aimed at reducing greenhouse gases, including forestry/sequestration programs and smart growth/land development regulations.

Stormwater WLA MS4 Permit Implementation Plans
Most of the reductions in this TMDL relate to runoff from developed areas and are covered by MS4 permits. MDE published the Final Determination to Issue a Stormwater Permit to Baltimore County in December 2013 and to the Maryland State Highway Administration in October 2015 (MDE 2013 and 2015). The permit states, *"By regulation at 40 CFR §122.44, BMPs and programs implemented pursuant to this permit must be consistent with applicable WLAs developed under [US]EPA approved TMDLs."*

Section IV.E. of the permit details requirements for *Restoration Plans and Total Maximum Daily Loads*. Within one year of permit issuance, the permittee is required to submit an implementation plan for each stormwater WLA approved by the USEPA prior to the effective date of the permit. For TMDLs approved after the permit, implementation plans are due within one year of the USEPA approval of the TMDL. Stormwater WLA plans should include the following: a detailed implementation schedule, the final date for meeting applicable WLAs, a detailed cost estimate for all elements of the plan, a system that evaluates and tracks implementation through monitoring or modeling to document progress toward meeting established benchmarks, deadlines, and a public participation program. Consideration for a longer implementation plan may be requested from MDE's SSDS program.

Given the levels of implementation described in this TMDL, the long time horizon for tree canopy establishment, the challenges of implementing stormwater retrofits that promote infiltration and filtration in high density urban watersheds, and the increasing stresses from climate change, achieving the resource management goals for temperature may be challenging using currently available technologies. To address this high level of uncertainty in the context of the MS4 permit, it is recommended that the permittee adopt an explicit, adaptive management approach for implementation.

Adaptive management is a structured decision-making framework that is well-suited for objectives that involve substantial uncertainty, like this one. The process includes a set of prescribed steps—planning, implementation and monitoring, and analysis and learning—that are iteratively conducted, so that lessons learned from previous successes and failures guide the implementation process. Under this approach, in the near term, the MS4 permittees would develop a plan with three key elements:

1. Goals and objectives to be achieved by a specified date
2. Monitoring plan to measure performance
3. Operational plan for implementing projects

The first element might involve, for example, setting ten-year goals of maintaining the stream temperature and preserving existing trout populations in the face of warming temperatures. Holding the line might be reasonable in the near term since many projects would take years to show any measurable temperature improvement. The monitoring component might include multiple elements, such as a plan to deploy temperature loggers, ongoing evaluation of trout populations, and tracking of forest canopy cover in the watershed. The operational plan could involve tasks such as planting a certain linear footage of riparian buffers, locating opportunities for upland thermal BMPs and identifying historic cold water seeps.

As part of this phased, adaptive management approach, the last few years of each planning window would include a period of analyzing project performance, both monitoring and operational outcomes, and learning from project successes and failures. An assessment would be conducted to see whether the phased plan resulted in progress toward the long-term resource management goal. These lessons would be incorporated into goal setting and operational planning for the subsequent phase.

In developing an adaptive planning framework, permittees should consider the resource being protected and not just the temperature endpoint of this TMDL. Under this sort of approach, projects that provide a substantial benefit to trout or cold water obligate species could be prioritized over practices with greater temperature impact. Permittees developing implementation plans should also coordinate efforts, and may want to consider developing a joint implementation plan. Regardless of the type of collaboration, it should be a priority to coordinate among stakeholders working within the watershed, including government agencies, non-profit organizations and academic institutions. At minimum, this should include using a joint fact finding process, with shared numeric and spatial data.

Additional information about developing a temperature stormwater WLA plan is described in MDE’s temperature TMDL implementation guidance document posted on MDE’s TMDL Data Center. MDE has developed an extensive Temperature TMDL Implementation guidance, which includes recommendations for data and monitoring, modeling techniques that can be used to track progress, reporting requirements to MDE, and partnerships available to assist in implementation plan development. The implementation plan guidance also provides recommendations on developing an appropriate monitoring program to be able to demonstrate progress toward meeting temperature TMDL endpoints.

Many of the practices which are described in the permittee’s stormwater WLA implementation plans may also be used by the permittee as retrofits for meeting their MS4 impervious area restoration requirements. Maryland law requires counties with a Phase I MS4 permit to develop financial assurance plans (FAPs) every two years to indicate how the impervious area restoration requirement will be achieved and paid for over the upcoming five years. These plans demonstrate that the Counties have adequate resources in place, and have done sufficient planning, for meeting their MS4 permit restoration requirements.

Stormwater Management in Coldwater Watersheds

Stormwater retrofits can address both water quality and quantity. The design objective for stormwater retrofits in coldwater streams is to maintain habitat quality by preventing stream warming, maintaining natural recharge, preventing bank and channel erosion, and preserving the natural riparian corridor. Examples of these retrofits include the reduction of impervious surfaces, modification of existing or installation of additional stormwater management practices, increased urban tree canopy, and stream restoration projects. Some BMPs can have adverse downstream impacts on coldwater streams and their use is highly restricted in coldwater streams. These include ponds and wetlands.

The Maryland Stormwater Design Manual (SDM), originally published in 2000 and revised in 2009, is the official guide for stormwater management principles, methods, and practices in Maryland. The manual contains specific requirements and objectives for stormwater management design in Use Class III watersheds. Specifically, Section 4.1 of the SDM states:

> *Cold and cool water streams have habitat qualities capable of supporting trout and other sensitive aquatic organisms. Therefore, the design objective for these streams is to maintain habitat quality by preventing stream warming, maintaining natural recharge, preventing bank and channel erosion, and preserving the natural riparian corridor. Techniques for accomplishing these objectives may include:*
>
> - *Minimizing the creation of impervious surfaces*
> - *Minimizing surface areas of permanent pools,*
> - *Preserving existing forested areas,*
> - *Bypassing existing baseflow and/or springflow, or*
> - *Providing shade-producing landscaping*

Table 4.1 in the SDM lists appropriate stormwater management practices

- ***Ponds:*** *Restricted. Offline design recommended. Maximize shading of open pool areas*
- ***Wetlands:*** *May be restricted*
- ***Infiltration:*** *OK, if site has appropriate soils*
- ***Filtering systems:*** *OK, but evaluate for stream warming*
- ***Open channels:*** *OK*

Any stormwater management retrofits specified within the Stormwater WLA plans for these temperature TMDLs will need to be designed and installed in a manner consistent with these guidelines. Beyond selecting appropriate practices, the SDM discusses design choices that can prevent stream warming. These include using paving or roofing materials with high Solar Reflectance Index (SRI) values, providing shading to paved surfaces and designing underdrains to maximize the dissipation of thermal energy (MDE 2009).

Stormwater Funding Programs

Maryland has several programs that can provide grants for implementing practices to address stormwater pollution. These include the Bay Restoration Fund (BRF), the Chesapeake and Atlantic Coastal Bays Trust Fund, and the Chesapeake Bay Trust. In addition, money is available through federally-funded programs such as the National Fish and Wildlife Foundation's (NFWF) Chesapeake Bay Stewardship Fund and the 319 Nonpoint Source Grant Program. While some of these programs focus on Chesapeake Bay restoration and are based on nutrient reductions, they may be a potential source for funding to improve water quality through nutrient and sediment reductions that might also benefit water temperature.

Chesapeake Bay Program Vital Habitats Goal

Implementation of this TMDL frequently aligns with work being done to restore the Chesapeake Bay. Specifically, one of the 10 goals of the 2014 Chesapeake Bay Agreement is the Vital Habitats Goal: *Restore, enhance and protect a network of land and water habitats to support fish and wildlife and to afford other public benefits, including water quality, recreational uses and scenic value across the watershed.* The Vital Habitats Goal has six outcomes, one of which is brook trout restoration. The main goal of the Brook Trout Workgroup (BTWG) is: *Restore and sustain naturally reproducing brook trout populations in Chesapeake Bay headwater streams, with an eight percent increase in occupied habitat by 2025.* The BTWG recognizes that, based on science, "stream water temperature remains the best predictor of brook trout occurrence" and they strongly recommend increasing riparian forest cover to at least 75% in all brook trout watersheds. The BTWG sites several recent legislative/policy actions that will be useful in achieving their goal. The America Conservation Enhancement (ACE) Act and ChesapeakeWILD component provide direction and authorization for fish habitat programs generally and increased emphasis on habitat conservation and restoration. The Surface Mining Control and Reclamation Act funds abandoned mine drainage treatment, an important restoration activity to mitigate loss of brook trout habitat. There is a bill in the Congress that would extend the collection of coal reclamation fees through 2036 and increase the minimum annual payment that some states receive from $3 million to $5 million. More information can be found at: https://www.chesapeakebay.net/what/goals/vital_habitats#brook_trout

Maryland Forest Conservation Act

The Maryland Forest Conservation Act (FCA) of 1991 requires local governments with planning and zoning authority to establish and implement local forest conservation programs, and provides for the Maryland Department of Natural Resources' administration of forest conservation requirements, in the absence of a local forest conservation program. The main purpose of the FCA is to minimize the loss of Maryland's forest resources during land development by making the identification and protection of forests and other sensitive areas an integral part of the site planning process. Of primary interest are areas adjacent to streams or wetlands, those on steep or erodible soils or those within or adjacent to large contiguous blocks of forest or wildlife corridors.

Any person making application for a subdivision, grading permit or sediment control plan on a tract of 40,000 square feet or more must submit a Forest Stand Delineation (FSD) and a Forest Conservation Plan (FCP). FSD includes the identification of existing forest cover and the environmental features of a proposed development site. It consists of an application available in Adobe Acrobat format, map and summary of specific field data collected.

The forest stand delineation and forest conservation plans implement forest conservation, reforestation, and afforestation requirements for certain land use categories and certain regulated activities established in Natural Resources Article, § 5-1601--5-1612, Annotated Code of Maryland.

Maryland House Bill 991

Maryland House Bill 991 was introduced and approved in early 2021. The purpose of HB991 is to establish the use of qualified conservation in a forest mitigation bank of all or a part of certain existing forests as a standard for meeting afforestation or reforestation requirements under the Forest Conservation Act. The bill also establishes a new policy of the State to support and encourage public and private tree planting, with the goal of planting and helping to maintain 5,000,000 sustainable native trees in Maryland by the end of 2031. To help achieve these goals, the bill alters and directs additional resources to a number of existing programs and initiatives, including by way of example, in fiscal 2023, $2.5 million must be transferred from the Wastewater Account of the Bay Restoration Fund to the Chesapeake and Atlantic Coastal Bays 2010 Trust Fund for tree plantings on public and private land, and for fiscal 2024 through 2031, the Governor must include an annual appropriation of $2.5 million in the State budget for tree plantings on public and private land. The bill also establishes a $10 million annual Urban Trees Program, administered by the Chesapeake Bay Trust, for the purpose of making grants to qualified organizations for native tree-planting projects in underserved urban areas. Additionally, the bill establishes a Commission for the Innovation and Advancement of Carbon Markets and Sustainable Tree Plantings charged with developing a plan to achieve the State's carbon mitigation goals.

Baltimore County Forest Buffer Protections

Baltimore County has laws in place to protect natural buffers around streams, wetlands, and floodplains. Within the forest buffer, these prohibit disturbance, such as tree removal, grading, creation of new impervious surfaces or structures. A 75-foot buffer is in place around all Use Class I streams and a 100-foot buffer exists around Use Class III and Use Class IV streams. The County has also established a 25-foot buffer around wetlands, floodplains, and erodible slopes. Additionally, principle buildings must be 35 feet from a buffer. The County also enforces the Critical Area law, providing a 100-foot buffer around all tidal wetlands (Baltimore County 2019).

In addition to forest buffers, the County prohibits the discharge of pollutants into streams including sewage, wastes, toxics, and high-temperature effluents.

Maryland Climate Change Commission

Climate change is the shift in worldwide weather phenomena associated with an increase in global average temperatures of both air and water temperatures. If climate change effects are not mitigated, stream temperatures will continue to rise and threaten coldwater species.

In 2007, The Maryland Commission on Climate Change (MCCC) was established by Executive Order (01.01.2007.07) and charged with developing an action plan and firm timetable for mitigation of, and adaptation to, the likely consequences and impacts of climate change in

Maryland, including strategies to reduce Maryland's greenhouse gas (GHG) emissions. As a result of the work of more than 100 stakeholders and experts, the MCCC produced a climate action plan which was the catalyst for the Greenhouse Gas Emissions Reduction Act (GGRA) of 2009. In 2014, a second Executive Order (01.01.2014.14) expanded the scope of the MCCC and its membership to include non-state government participants.

Maryland has set some of the strongest greenhouse gas reduction targets in the nation. The General Assembly passed the GGRA of 2009, which required Maryland to develop a plan to reduce greenhouse gas emissions by 25 percent from 2006 levels by 2020. Governor Larry Hogan signed the landmark GGRA of 2016, which renewed the 2009 Maryland law and also further extended the emissions goal to a 40 percent reduction from 2006 levels by 2030 (MCCC 2017). Reduction in greenhouse gasses will help slow the rate of increase in air temperatures, thereby helping to meet water quality standards for stream temperature.

This TMDL may be revisited in the future if changes to long-term air temperature and rainfall resulting from climate change prevent water quality standards from being achieved in the Red Run and Upper Gwynns Falls subwatersheds under the implementation conditions described in this document.

<u>Co-Benefits of TMDL Implementation</u>
Prioritizing riparian tree planting and management to decrease stream temperature will have significant co-benefits. Restoring the riparian canopy in the Gwynns Falls watershed could result in lower localized ambient summertime temperatures, reduced heating and cooling costs, decreased energy demand, and reduced vulnerability to the effects of heat waves on at risk populations. In addition to the public health and economic benefits, the restored riparian buffer has the potential to sequester approximately 87,000 metric tons of carbon dioxide (CO_2) for 10 years and 260,000 metric tons of CO_2 for 30 years. That's the equivalent of burning 600,000 barrels of oil. See Table 18 for variable sequestration estimates.

Table 18: Carbon Dioxide Sequestration Estimates

Riparian buffer (100 meter*) tree planting			
Duration of Maintenance	Low Sequestration Estimate (mT CO_2)	Medium Sequestration Estimate (mT CO_2)	High Sequestration Estimate (mT CO_2)
10 years	78,000	87,000	95,000
30 years	235,000	260,000	285,000

*Note: 50 meters per stream bank

MDE recognizes that the levels of implementation described in these TMDLs (see Table 12) are substantial and may take several permit cycles to achieve. A number of challenges exist which may slow the pace of implementation. The stormwater management practices that mitigate temperature represent a subset of practices described in the SDM, meaning that watershed planners will have fewer implementation options to choose from. In addition, much of this watershed is built out, and much of the land is privately owned, so that land to build stormwater facilities can be difficult to obtain. It is also important to remember that the establishment of new riparian forest buffer may take many years before trees reach mature height and provide adequate stream shading.

Fortunately, implementation of this TMDL frequently aligns with work being done to restore the Chesapeake Bay. Cost-share programs for agricultural conservation practices, like those described above, will be very important. The Vital Habitats Goal from the 2014 Chesapeake Bay Agreement sets an objective of annually restoring 900 miles of riparian forest buffers watershed-wide, with the longer-term goal of achieving 70 percent forestation of riparian areas. Work toward this goal in the Upper Gwynns Falls and Red Run sub-watersheds would also help to reach temperature TMDL goals.

Potential implementation actions should not be limited to the retrofits and riparian forest buffers described previously in this report. The Gwynns Falls watershed is described on the Category 4c List in Maryland's 2018 Integrated Report as being impaired for stream habitat alterations due to channelization. Projects that remove fortified streambanks of concrete or other hardened materials have the potential to promote lateral baseflow, which would result in lower stream temperatures. Mill dams were constructed throughout Maryland during the preceding centuries and significantly altered hydrology in many of the region's watersheds. Research has suggested that the removal of old dam structures and legacy sediment that built up behind the dams can decrease temperatures by exposing buried springs and by increasing lateral baseflow. These are just a few examples of more novel approaches to managing stream temperatures, and while none of these strategies are certain to be successful, practitioners should continue to investigate ideas beyond traditional stormwater management and stream shading.

MDE anticipates that practices installed to meet the required thermal reductions will be implemented in an iterative process that first addresses those sources with the largest impact on thermal reduction, with consideration given to ease of implementation and cost. The iterative implementation of BMPs in the watershed has several benefits: tracking of water quality improvements following BMP implementation through follow-up stream monitoring; providing a mechanism for developing public support through periodic updates on BMP implementation; and helping to ensure that the most cost-effective practices are implemented first.

Environmental Justice Funding

Environmental justice is an issue that began to get attention starting in 1990. In 1990, EPA established the first Environmental Equity Workgroup. In 1997, Maryland established the Maryland Advisory Council on Environmental Justice. The concept behind the term environmental justice (EJ) is that all people – regardless of their race, color, national origin or income – are able to enjoy equally high levels of environmental protection. In recent years, EJ has become a much more prevalent issue in the environmental community. In response, there are many funding opportunities for EJ projects available at the federal, state, and local levels. A list of resources can be found on the MDE Environmental Justice webpage:
https://mde.maryland.gov/programs/Crossmedia/EnvironmentalJustice/Pages/index.aspx
Additionally, many federal grants and funding opportunities now include EJ considerations

(BRF, Chesapeake Bay Trust Fund, State Revolving Loan Fund, EPA, Chesapeake Bay Regulatory and Accountability Program grants.

Temperature restoration can have positive impacts on EJ concerns – pollution exposure and impacts. While ideally the restoration would be within an EJ area of concern, temperature impairments do not always coincide with EJ areas. Restoration outside of EJ areas can provide benefits for nearby EJ communities. One specific program that benefits from temperature restoration is Trout in the Classroom (TIC), originally developed by Trout Unlimited and now run by MDDNR. TIC can be taught in areas of EJ concern and can also experience real world interactions if there are trout present nearby.

Maryland's High Quality Waters (Tier II)

Federal anti-degradation regulations (40CFR131.12) require states to develop and adopt a statewide anti-degradation policy that protects all Waters of the U.S. from degradation (CFR 2018b). These regulations also require states to maintain the condition of high quality (i.e. Tier II) waters that have water quality that is better than the minimum standard necessary to meet designated uses.

The Maryland anti-degradation implementation procedures are found in the Code of Maryland Regulations (COMAR) 26.08.02.04-1. This regulation explains how Maryland identifies Tier II waters, when a Tier II anti-degradation review is required for certain State permits and approvals, and how to determine current Tier II water quality status based on new data. The regulation also describes the social and economic justification procedure that would be necessary in order to permit the lowering of water quality in a Tier II water.

The purpose of the Tier II anti-degradation review is to prevent degradation to high quality waters as a result of permitted activities. The review process identifies impacts associated with any proposed regulated activity, and then identifies if there are appropriate alternatives that may avoid these impacts to Tier II waters. If impacts cannot be avoided, then the review identifies reasonable alternatives that may minimize or mitigate impacts within the Tier II watershed. More broadly, the review identifies practices that could be considered along with existing conservation, restoration, and planning activities.

Within the coldwater portion of the Gwynns Falls watershed, there is one Tier II stream in the Red Run sub-basin. Anti-degradation review would be required for activities in the watershed draining to this stream.

Future Thermal Sources

It is expected that new development or redevelopment within these watersheds will incorporate stormwater management consistent with the SDM, including environmental site design (ESD) and requirements for Use Class III watersheds. Redevelopment may result in developed areas with little-to-no stormwater treatment being rebuilt with modern stormwater controls, resulting in an improvement to water quality. Under ESD requirements, new development will be designed to maintain pre-development runoff conditions. While it is not anticipated that future stormwater sources in these watersheds will significantly impact stream temperature, the TMDL may be revisited if development patterns substantially impact local hydrology.

Future surface discharge permits issued to new municipal or industrial wastewater discharges in this watershed will have effluent requirements consistent with thermal water quality standards for Use Class III watersheds. Thus, additional wastewater discharges would not be expected to increase temperatures above water quality criteria.

Agricultural Cost Share Programs

Maryland and the federal government make a variety of grants available to farmers interested in installing conservation measures. These grants could be used to pay for practices, such as forest buffers, that would have a beneficial impact on stream temperature. These programs include the Maryland Agricultural Cost Share Water Quality Cost-Share Program (MACS), the Conservation Reserve Enhancement Program (CREP) and the Environmental Quality Incentives Program (EQIP). Maryland’s Phase III WIP commits to a substantial level of agricultural implementation by 2025, and many of the practices installed to meet WIP goals, and funded through cost-share programs, will decrease stream temperatures.

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