Cape Fear 02/03 Regional Watershed Plan

PREPARED FOR

NC Department of Environmental Quality
Division of Mitigation Services
217 West Jones Street
Raleigh, NC 27603
919.707.8976

PREPARED BY

VHB Engineering NC, P.C.
Venture 1
940 Main Campus Drive
Suite 500
Raleigh, NC 27606
919.829.0328

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Introduction

The mission of the North Carolina Division of Mitigation Services is to provide cost-effective mitigation alternatives that improve the state's water resources. As required by the federal mitigation rule, effective June 2008, the Division of Mitigation Services develops all mitigation using a watershed approach as defined in the Compensatory Planning Framework. To meet these requirements, the Division of Mitigation Services has contracted VHB to prepare a Regional Watershed Plan for portions of Cape Fear 03003002 (Haw River) and 03003003 (Deep River) watersheds.

1.1 Background

Part of the North Carolina Department of Environmental Quality (NCDEQ), the Division of Mitigation Services (DMS) is charged with providing cost-effective mitigation alternatives that improve the state's water resources while remaining responsible stewards of state resources. As part of this effort, DMS conducts watershed planning projects throughout North Carolina to prioritize and concentrate mitigation efforts to restore streams, wetlands, and forested buffers for the purpose of offsetting environmental impacts from economic development.[1]

DMS initiated a Regional Watershed Plan (RWP) for parts of two 8-digit Hydrologic Unit Codes (HUCs) within the Cape Fear Watershed: The Haw River (03030002) and the Deep River (03030003). The study area covers approximately 620 square miles and twenty-two 12-digit HUCs. The study area is further divided into catchments of an average size of approximately 0.5 square kilometers.[2] Figures 1-1 and 1-2 offer an overview of the study area boundary, its streams and major waterbodies, and the individual catchments.

According to the 2016 National Land Cover Database (NLCD), the existing land use within the proposed study area includes approximately 25% agricultural areas, 58% forested areas, and 6% developed areas, with the remainder of the study area being a combination of shrub and grasses, open water, barren, and wetland areas. This area is expected to experience further land use conversion and development due to future growth. This RWP presents an opportunity to identify a range of watershed improvements and protection strategies ahead of these potential impacts. For a more detailed discussion of the existing conditions within the study area, see Section 2 of the Task 1 Technical Report.

1.2 Purpose of the Regional Watershed Plan

DMS initiated this RWP for the study area described above to aid in planning and prioritizing mitigation. The objective of the RWP is to create a modeling strategy based on available data to evaluate the conditions of a watershed, link issues back to their underlying causes, and recommend strategies to preserve areas in good condition. Ultimately, this watershed plan will help DMS identify opportunities to mitigate sources of stressors to the three main functions of a watershed—hydrology, water quality, and habitat.

The other key objectives of the Cape Fear 02/03 RWP are as follows:

- Satisfy compensatory mitigation requirements on a programmatic level through watershed planning.
- Enhance the natural resources of North Carolina by addressing watershed needs through a process that utilizes the best available data and incorporates stakeholder input to maximize the potential watershed functional improvement.
- Prioritize watersheds where compensatory mitigation actions maximize functional improvement and promote synergy due to concentrated implementation of hydrology, water quality, and habitat projects.

[1] https://deq.nc.gov/about/divisions/mitigation-services

[2] Some catchments in the DMS dataset along the edges of the RWP boundary were removed from the study area due to a clipping issue between the study area boundary and the NHDPlusV2-dervied catchments that resulted in numerous erroneous catchments created from slivers of outside watersheds. In total, 176 edge catchments were removed from the 1480 catchments provided by DMS.

› Develop a planning approach that is forward looking, identify watersheds which are likely to develop and identify linchpin watersheds that can cause cascading effects in a region with high development potential.
› Provide feedback to improve the DMS statewide Watershed Prioritization Model through cross-validation.

1.3 Summary of Results from Task 1

During Task 1, VHB conducted a review of available data sources and a preliminary analysis of Preservation Areas, Land Use Conversion, and Focus Areas to gain a general understanding of the condition of the RWP study area ahead of development of a detailed modeling strategy.

1.3.1 Preservation Areas

Preservation Areas are catchments which exhibit intact riparian buffers, low levels of impervious cover, and a high level of forested and wetland areas beneficial to habitat and water quality. VHB analyzed the study area to identify these areas of high environmental quality that present noteworthy preservation opportunities for DMS and their partners. Table 1-1 shows the indicators used for Preservation Area analysis in Task 1.

Table 1-1 Task 1 Preservation Area Indicators

Indicator	Description of Indicator	Data Source(s)
Habitat Areas	Indicates habitat occurrence of certain species of note within a catchment.	NCNHP Habitat Data
Natural Areas	Indicates presence of areas designated of significant natural importance that are high priorities for preservation but are not already protected.	NCNHP Natural Areas Data
Water Supply Watershed	Indicates the presence of water source classified and protected as a water supply source for human use.	NCDEQ DWR Surface Water Classifications
Soil Susceptibility to Erosion	Indicates undisturbed land with a high soil erodibility factor that, if disturbed, may contribute to erosion and water quality issues.	USDA NRCS 2016 NLCD
Forested or Wetland Area	Indicates amount of forested or wetland land cover beneficial for habitat and water quality in a given catchment.	USFWS 2016 NLCD
Managed Area	Indicates the amount of land already protected by conservation easements present in the catchment. Catchments with a low Managed Area ratio were given priority due to DMS's interest in preserving areas not already protected.	NCNHP Managed Areas

Source: Multiple. See Task 1 Technical Report - Appendix A for more information.

Table 1-1 (cont.) Task 1 Preservation Area Indicators

Indicator	Description of Indicator	Data Source(s)
Impervious Cover	Indicates the percent impervious area in a catchment. Areas over 10% impervious were removed from Preservation Area consideration due to the increase in pollutant load and degradation of aquatic habitat.	2016 NLCD Impervious Cover

Source: Multiple. See Task 1 Technical Report - Appendix A for more information.

The above indicators were used to score and to identify potential Preservations Areas. In addition, VHB manually included catchments adjacent to high scoring Preservation Areas in order to improve habitat connectivity per discussions with DMS and other relevant stakeholders. A total of 390 catchments were identified as potential Preservation Areas from Task 1. It should be noted that just because a catchment was not identified as a Preservation Area by this report does not mean that there is no value to be found in applying preservation efforts in a given catchment. This effort is a large-scale prioritization of a 620 square mile study area and does not look at preservation on a granular level.

Overall, the Preservation Areas identified in Task 1 can be used to identify potential opportunities for conservation and they will be included in the final RWP publication as guidance on the best locations within the study area for DMS and their partners to search for preservation opportunities. For a more detailed discussion of the methods VHB used in the Preservation Areas analysis, including analysis of individual indicators and the manual modifications, see the Task 1 Technical Report.

1.3.2 Land Use Conversion

Development within the Cape Fear River Basin is expected to expand significantly in the coming decades. Development directly impacts water quality. habitat, and hydrology by increasing impervious cover within a watershed and decreasing forested land use ideal for habitation by multiple species. When developing a watershed plan, it is important to be aware of areas with a high probability of land use conversion so that mitigation efforts can stay ahead of impacts caused by future development. In Task 1, VHB considered many indicators that may predict where land use conversion is most likely to occur. Table 1-2 summarizes the indicators used in Task 1 for Land Use Conversion Analysis.

Table 1-2 Task 1 Land Use Conversion Indicators

Indicator	Description of Indicator	Data Source(s)
Open Space	Indicates the space available within a given catchment for development.	2016 NLCD
Road Density	Indicates density of the transportation network within a catchment from which development may spur.	NCDOT Route Arcs

Source: Multiple. See Task 1 Technical Report - Appendix A for more information.

Table 1-2 (cont.) Task 1 Land Use Conversion Indicators

Indicator	Description of Indicator	Data Source(s)
Projected Population Growth	Indicates areas of high and low projected population growth where development is most and least likely.	U.S. Census Bureau ESRI Population Growth Data
Expected Change in Development	Combines designated Megasites and other planned developments within the study area with further projected development from existing urban areas to indicate the areas with the highest likelihood of intensive development.	Greensboro Randolph Megasite Boundary CAM Megasite Boundary Moncure Megasite Boundary from Chatham County Zoning Data Chatham Park Development from Pittsboro Zoning Data SLEUTH 2070

Source: Multiple. See Task 1 Technical Report - Appendix A for more information.

The resulting score from the Land Use Conversion analysis was used as an indicator in the Task 1 Focus Area analysis.

VHB further refined the Land Use Conversion analysis during Task 3 to provide a clearer picture of future development within the study area. A detailed discussion of the additional datasets and analyses considered is contained in Section 2 of this report.

1.3.3 Focus Areas

Focus Areas are defined as one or more catchments identified as a focus for detailed assessment/modeling activities as well as the development and implementation of management strategies to address concentrated areas of key stressors or assets. In Task 1, VHB identified these Focus Areas by considering a range of datasets and indicators, which are broken down into four categories and three subcategories. The organization of the categories and subcategories are as follows:

- **Stressors**
  - Water Quality
  - Habitat
  - Hydrology
- **Ecological**
- **Social**
- **Land Use Conversion**

VHB developed a subscore for each of the three Stressor subcategories by combining their contributing indicator scores. The final Focus Area score is, therefore, a combination of the four category scores. Table 1-3 also summarizes the indicators used in Task 1 for Focus Area development.

Table 1-3 Task 1 Focus Area Indicators

Indicator	Indicator Category	Indicator Subcategory	Description of Indicator	Data Source(s)
Incremental Total Nitrogen Loading by Incremental Area	Stressor	Water Quality	Indicates the total nitrogen load from manmade sources within a catchment normalized by area that may affect water quality.	USGS SPARROW
Incremental Total Phosphorus Loading by Incremental Area	Stressor	Water Quality	Indicates the total phosphorus load from manmade sources within a catchment normalized by area that may affect water quality.	USGS SPARROW
Incremental Total Suspended Solids Loading by Incremental Area	Stressor	Water Quality	Indicates the total suspended solids load from manmade sources within a catchment normalized by area that may affect water quality.	USGS SPARROW
Impaired Streams	Stressor	Water Quality	Indicates stream impairment based on the 2018 Integrated Report and identifies stream reaches upstream of impaired streams.	NCDEQ DWR
Ratio of disturbed land within Riparian Zone	Stressor	Habitat	Indicates the portion of a riparian buffer zone that has been degraded or denuded from forested or wetland land use ideal for habitat.	USEPA Watershed Index Online (WSIO) RZ 2016 NLCD
Soil Susceptibility to Erosion	Stressor	Habitat	Indicates catchments with a high soil erodibility factor that may contribute to erosion and water quality issues.	USDA NRCS
Fish Habitat	Stressor	Habitat	Indicates fish habitat quality based on fish community assessment data.	NCDEQ DWR
Fish Biological Integrity Class	Stressor	Habitat	Indicates fish biological integrity class based on fish community assessment data.	NCDEQ DWR
Benthic Macroinvertebrate Habitat	Stressor	Habitat	Indicates benthic macroinvertebrate habitat quality based on benthic macroinvertebrate assessment data.	NCDEQ DWR
Benthic Macroinvertebrate Biological Integrity Class	Stressor	Habitat	Indicates benthic macroinvertebrate biological integrity class based on benthic macroinvertebrate assessment data.	NCDEQ DWR

Source: Multiple. See Task 1 Technical Report - Appendix A for more information.

Table 1-3 (cont.) Task 1 Focus Area Indicators

Indicator	Indicator Category	Indicator Subcategory	Description of Indicator	Data Source(s)
Hydraulic Obstructions per Stream Length	Stressor	Hydrology	Indicates the extent to which a stream reach has been interrupted by pipes, culverts, and dams within the catchment.	NCDEQ DEMLR Dam Inventory NCDOT Structure Locations NCDOT Non NBIS Pipes
Stream Type	Stressor	Hydrology	Indicates whether a stream type is perennial or intermittent.	NHDPlusV2
Stream Order	Ecological	N/A	Indicates whether a stream is located upstream or downstream in the study area based on stream order.	USGS NHDPlusV2
Contains Habitat	Ecological	N/A	Indicates whether a catchment contains critical or occupied habitat of a species of concern.	NCNHP Habitat Data
Water Supply Watershed	Ecological	N/A	Indicates whether a catchment contains surface waters protected for human use or consumption.	NCDEQ DWR Surface Water Classifications
Developed Area	Social	N/A	A higher % developed area (urban) indicates less opportunity for mitigation efforts.	2016 NLCD
Agricultural Area	Social	N/A	Higher % Ag indicates more need and opportunity for mitigation.	2016 NLCD
Probability of Land Use Conversion	Land Use Conversion	N/A	A higher land use conversion percentage indicates a higher need for mitigation efforts.	Multiple; see Table 1-2

Source: Multiple. See Task 1 Technical Report - Appendix A for more information.

The indicators from the three tables above (1-1, 1-2 and 1-3) were used to compute a Preservation score, a Focus Area score, and a Land Use Conversion score for each catchment within the study area in Task 1. For the Focus Areas, a cluster analysis was performed to find groups of high scoring catchments. These clusters excluded the Preservation Areas identified in Task 1. Figure 1-3 shows the Preservation Areas and Focus Areas results. As noted in Section 1.3.1, the Preservation Areas were updated between Task 1 and Task 3 per discussion with DMS. As a result, there are minor overlaps between the Task 1 Focus Areas and the updated Preservation Areas. The Task 1 Focus Areas will be updated in Task 3 (see Section 2). The Land Use Conversion Area scores are not shown separately since they are represented in the Focus Area scores. More details on the Task 1 Focus Areas analysis can be found in the Task 1 Technical Report.

1.4 Task 3[3] Objectives/Purpose

The purpose of Task 3 is to develop and to implement a modeling strategy that builds upon the results obtained during Task 1 by performing a more granular analysis of the identified indicators and by including new indicators as needed based on the best available data. As a result of this more detailed analysis, the Focus Areas identified in Task 1 and Task 3 are different. These differences will be discussed in more detail in Section 2. Overall, the purpose of the refined Focus Areas analysis in Task 3 is to develop a more detailed picture of conditions which degrade water quality, hydrology, and/or habitat.

The results of the Task 3 modeling effort were carried forward in Task 4 into a practical analysis of the most applicable and effective mitigation strategies suited for the catchments within the identified Focus Areas. These results provide the basis for identifying the most effective mitigation strategies for addressing these watershed stressors, which is covered in subsequent sections concerning Task 4.

For more information on the mitigation opportunities and various strategies employed throughout the study area, see Section 1.5 and Section 3 of this report.

1.5 Task 4 Objectives/Purpose

The purpose of Task 4 is to identify mitigation and restoration strategy recommendations for Focus Areas refined during Task 3. The results of this analysis will aid vendors in identifying the most appropriate implementation strategies for the catchments prioritized as Focus Areas within the Cape Fear 02/03 RWP.

The recommendations in this report discuss opportunities for restoration as well as the mitigation strategies introduced above. During Tasks 1 and 3, VHB analyzed and identified Preservation Areas in addition to Focus Areas. The purpose of this exercise was to include preservation in the list of potential actions of vendors. The combination of mitigation and preservation has the potential to optimize opportunities within the study area.

For a more detailed discussion of how mitigation and preservation strategies were applied to the study area, see Section 3 of this report.

1.6 Report Layout

In this report, VHB will discuss the detailed modeling assessment performed in Task 3 and the analysis performed in Task 4 to identify mitigation and restoration strategy recommendations for the identified Focus Areas. The organization will be as follows:

[3] During Task 2 of the RWP process, VHB prepared an internal memo of recommendations for DMS to improve their modelling approach for future analysis of watershed systems. Task 2 will not be discussed in detail within this Plan.

- Section 2 will discuss the datasets, indicators, and analyses that VHB utilized to develop Water Quality, Hydrology, Habitat, and Land Use Conversion sub-models for the study area and how the sub-models combine to create a refined Focus Area score.
- Section 3 will provide background on compensatory mitigation and restoration opportunities and discuss potential strategies to be considered and how the results from Task 3 Focus Area analysis will be used to align these strategies.

2

Focus Areas Modeling Approach and Results

In this section, VHB presents the detailed modeling approach and results for the Focus Area analysis in the Cape Fear 02/03 Regional Watershed Plan study area. This modeling approach builds on the high-level Focus Areas modeling approach described in the Task 1 Report and provides a more in-depth evaluation of the indicator analysis in four critical watershed categories: water quality, habitat, hydrology, and land use conversion. Overall, the goal of the Focus Areas analysis is to identify a population of catchments where compensatory mitigation actions may serve the most benefit.

2.1 Overview

The Focus Areas modeling approach and results discussion is organized into four sub-models. The Water Quality (Section 2.2), Habitat (Section 2.3), and Hydrology (Section 2.4) sub-models use datasets that reflect existing conditions to identify catchments that may be desirable for mitigation. The Land Use Conversion (Section 2.5) sub-model complements these previous sub-models by using datasets representing predicted future conditions to identify catchments that may be desirable for mitigation. Together, these four sub-models serve to identify catchments that likely have existing watershed issues that DMS can mitigate presently or proactively target mitigation efforts.

Each sub-model contained a number of indicators that were selected based on a combination of the Task 1 indicator analyses, detailed discussions with DMS, and VHB's professional judgement. In addition, the present indicator analyses were developed with restoration strategies in mind. The goal of Task 4 is to link specific watershed stressors and restoration strategies. Note that the indicator selection and analyses were based on the best available datasets at the time of the modelling effort.

2.1.1 Key Considerations

- During the Focus Areas modeling approach development, a number of challenges were identified and discussed with DMS. VHB has documented these modeling considerations/limitations so that they may serve to assist DMS in future watershed planning efforts. This section provides a description of each of the considerations.
  Data Limitations
  - *The challenge*: The modeling efforts were limited by data availability (e.g., publicly available vs. proprietary datasets), data coverage (e.g., the spatial extent of the dataset), and data quality (e.g., the spatial resolution and analysis/release date of the dataset).
  - *VHB's approach:* In Task 3, VHB attempted to address data gaps identified in the study area by using a combination of targeted field investigations, expanded data search, regression analysis, and communication with relevant stakeholders to improve the indicator analysis. Tables in Appendix A contain the finalized list datasets used in Task 3. Datasets that were reviewed but not used in Task 3 are summarized in Table B-1 in Appendix B. In total, over 60 unique datasets were evaluated for the indicator analyses in Task 3.
- **Indicator Interconnectivity**
  - *The challenge*: One indicator may represent multiple stressors (water quality, habitat, and hydrology) at the same time (e.g., total suspended solids may be interpreted as both a water quality pollutant and as an indicator for erosive watersheds). This interconnectivity makes it challenging to assign many of the indicators into just one category or stressor.
  - *VHB's approach:* In Task 3, VHB organized the indicators into their respective sub-categories based on where that indicator may have the most direct impact on the mitigation viability. When appropriate, an indicator may be used in multiple ways as a means to support another indicator development. For example, the U.S. Geological Survey's (USGS) SPARROW[4] total suspended solids loads are used directly in the Water Quality sub-model and indirectly in the Habitat sub-model (as a part of the

[4] The Spatially Referenced Regression on Watershed Attributes (SPARROW) model is a pollutant loading model developed by the USGS. The 2014 pollutant loading results (for a model period between 1999 and 2014) from North Carolina SPARROW model was used in the Focus Areas analysis. These results were published in 2019.

Erosion indicator). In these instances, VHB is careful to make sure that the input dataset is not double counted using tailored approaches in the indicator assessment.

- **Complex Environmental Consequences**
  - *The challenge*: A number of indicators were flagged to have complex environmental consequences. For example, hydraulic barriers (e.g., stream crossings, ponds, dams, etc.) are more challenging to prioritize for mitigation because they have complex environmental consequences (both positive and negative) depending on the context and purpose that barrier is serving.
  - *VHB's approach:* Due to the complex nature of these indicators, VHB often used a simplified approach to assess and to prioritize the different hydraulic barriers based on mitigation feasibility. When appropriate, some of these indicators were evaluated under multiple sub-models. In these instances, VHB made sure to minimize overlap between the sub-models by using different approaches in the indicator analysis.
- **Local Catchment vs. Cumulative Watershed Effects**
  - *The challenge*: Certain watershed issues may only be affected by local catchment drivers whereas some may be affected by cumulative drivers (from contributing watersheds) on downstream reaches. As an example, pollutants from upstream reaches of a stream network may further degrade subsequent downstream reaches. Ideally, both the local and cumulative effects should be evaluated. However, in practice, many datasets only report results at the local catchment level.
  - *VHB's approach:* When available, VHB evaluated both the local and cumulative sources affecting an indicator in the Focus Areas analysis. For example, the USGS SPARROW datasets provided incremental (or local catchment) and cumulative (or contributing watershed) pollutant loads, and these were separated into different indicators to inform DMS of the level of pollutant impairment and where this impairment may be coming from. However, for many of the indicators, only local catchment data were available. When appropriate, VHB evaluated potential upstream mitigation opportunities by identifying catchments that were immediately upstream of the elevated downstream catchments (see e.g., Impaired Streams, Potentially Suitable Habitat, and Future Land Use Changes indicators).
- **Level of Spatial Analysis**
  - *The challenge*: Due to the large number of datasets used in the Focus Areas analysis, there was a range in the spatial resolution of the datasets. For example, for a subset of indicators, the data was available at a finer spatial resolution scale (e.g., stream reach-level) than the catchment-level.
  - *VHB's approach*: If finer resolution data was available, VHB adopted the approach to first leverage the higher spatial resolution data to compute stream reach-level indicator attributes. The stream reach-level results were then aggregated up (e.g., via a stream-length weighted adjustment) to the catchment-level in order to evaluate all the indicators at the same spatial scale. By having both the stream reach and catchment-level results, this will allow DMS to identify specific problem areas within a catchment if they desire.

- **Prioritization for Mitigation**
    - *The challenge*: While there exist many indicators that are critical to watershed function, not all watershed impacts are appropriate for compensatory mitigation. Moreover, VHB found that prioritization for mitigation is not straightforward and may be different depending on the context of the impact.
    - *VHB's approach*: In Task 3, VHB evaluated each indicator separately in order to identify watershed conditions with potential uplift opportunities that may be appropriate or feasible for mitigation. When scoring the indicators to identify watershed conditions that potentially align with mitigation strategies, VHB prioritized the watershed need either based on its appropriateness for mitigation (e.g., typically for stressors that have impaired or degraded conditions), its potential uplift opportunities (e.g., what is the inherent watershed value of the resource in question and the added benefits if mitigation is performed), or the barriers to implementation (e.g., how a watershed feature may hinder DMS' ability to mitigate effectively).
- **Relative vs. Absolute Indicator Scoring**
    - *The challenge*: A major challenge in the indicator analyses is the development of the scoring scheme to transform a measured or computed indicator attribute to a value closely aligned with DMS' mitigation goals. For many indicators, there were very limited literature resources to guide both the shape (or response) of the scoring curve and the absolute thresholds for setting tipping points.
    - *VHB's approach:* In Task 3, VHB conducted extensive discussions internally and with DMS to develop appropriate scoring curves (e.g., positively linear, negatively linear, piecewise linear, exponential, etc.) and thresholds (e.g., absolute vs. relative) values. For indicators where literature guidance and/or professional judgement were defensible, VHB used absolute thresholds to link the indicator attribute to a score closely aligned with DMS' mitigation goals. For example, in the Erosion indicator, the sub-scoring scheme for the K factor transformation is set based on a threshold (K factor = 0.4) when soil tends to be highly erodible.[5] The benefit of the absolute scoring approach is that it is independent of the study area and can be applied to other watersheds. However, for many indicators in the study area, VHB had to use a relative scoring approach given the complexity of the indicator and the lack of literature guidance or professional knowledge. Examples of indicators that used relative scoring include the SPARROW-derived indicators in the Water Quality sub-model. Unlike the absolute scoring approach, the relative scoring approach uses the distribution of indicator values in the study area to develop relative thresholds to identify catchments that may be above or below the mean or median conditions. As such, these relative scoring schemes are designed specifically for the study area and would need to be adjusted for other watersheds.

[5] http://www.iwr.msu.edu/rusle/kfactor.htm

- **Future Research Opportunities**
  - *The challenge*: Due to the data limitations described above, there are remaining data gaps that VHB was not able to fill given the scope of work of the Cape Fear 02/03 Regional Watershed Plan. In particular, the Hydrology and Land Use Conversion sub-models may benefit from a separate modelling effort to improve the indicator analyses.
  - *VHB's approach*: While some of the identified data gaps are not addressed in the current report, VHB believes that they present opportunities for future research collaborations between DMS and their partners. For example, due to the limited stream flow monitoring stations in the study area, stream flow was not used as an indicator in the Hydrology sub-model. For future watershed evaluations, it may benefit DMS to run a separate hydrology model to obtain stream flow results at the desired spatial and temporal resolution. In addition, for the Land Use Conversion sub-model, the results may be improved if development models (e.g., USGS SLEUTH[6] and USGS FUTURES[7] models) are run with adjustments to existing and projected changes in the study area.

In summary, VHB addressed a number of challenges described above in order to refine the Focus Areas analysis and to produce model results that would be helpful to DMS' mitigation priorities. More detailed indicator considerations and lessons learned are documented in the respective sub-model sections.

2.2 Water Quality

This Water Quality sub-model section includes a brief review on the Water Quality Considerations (Section 2.2.1) that are relevant in this watershed evaluation, the specific Water Quality Indicators (Section 2.2.2) identified and analyzed for the Task 3 Focus Areas analysis, the Water Quality Sub-Model Results (Section 2.2.3), a detailed discussion on the State of Water Quality Degradation (Section 2.2.4) within the study area, and the Lessons Learned (Section 2.2.5) from this sub-model analysis.

2.2.1 Water Quality Considerations

In Task 1, the existing water quality conditions within the study area were characterized using North Carolina Division of Water Resources' (NCDWR) surface water quality classifications and the 2018 303d Integrated Report on impaired streams within the study area. In Task 3, VHB developed a more granular analysis of the potential water quality stressors that may be used to identify priority catchments for mitigation.

[6] The USGS Slope, Land Use, Exclusion, Urban, Transportation, Hillshade (SLEUTH) model (developed by University of California Santa Barbara) uses overland slope, land use, excluded zones, urban centers, transportation networks, and hillshade predictors to a generate growth model for development

[7] The USGS Future Urban-Regional Environment Simulation (FUTURES) model (developed by North Carolina State University) uses environmental, infrastructural, socioeconomic, land cover, and population predictors to generate a growth model for development.

VHB has identified three key water quality considerations in the development of the Water Quality sub-model. First, water quality impairment in a catchment may be broadly classified as overland pollutant loads (e.g., in units of mass per year) and in-stream water quality concentrations (e.g., in units of mass per volume). There is a distinction between pollutant loads and concentrations, and therefore, there is value in examining both using different datasets. Second, the source of water quality pollution is also a key factor to consider. For example, water quality pollutants may come from point versus non-point sources or from natural versus man-made sources. In terms of mitigation, it is important to note that not all pollutant sources (e.g., permitted wastewater treatment plant discharge, atmospheric pollutants, and other naturally occurring sources) and pollutant types (e.g., heavy metal and pesticides) are mitigable within DMS' capabilities. Third, elevated pollutant loads in a catchment may be attributable to local sources or to sources in the upstream contributing watersheds. When available, it is important to use this information to develop more targeted mitigation strategies if the greater contributing watershed is the driver in water quality degradation rather than the local catchment.

In the following Water Quality sub-model, VHB has taken into consideration the pollutant sources, pollutant type, and contributing watershed versus local catchment in the development and scoring of the selected water quality indicators.

2.2.2 Water Quality Indicators

The Water Quality sub-model contains five indicators, which includes: Impaired Streams, Agriculture Cumulative Contribution, Agriculture Incremental Contribution, Development Cumulative Contribution, and Development Incremental Contribution. The Impaired Streams indicator captures the water quality impairment from in-stream pollutant concentrations while the remaining indicators capture the water quality impact from source-specific overland pollutant loads. Note that all the Water Quality indicator analyses and scoring were designed with DMS' mitigation constraints in mind. For example, select pollutants (e.g., heavy metals, pesticides, points sources from wastewater treatment plants, naturally occurring sources, etc.) were excluded because they are outside of DMS' ability to mitigate.

Table 2-1 contains a high-level summary of the Water Quality sub-model indicators, the reason for selecting the indicator, and the indicator's relevance to DMS' mitigation efforts. In Appendix A, Table A-1 contains more detailed documentation on the datasets that were used in the Water Quality sub-model indicator development, the dataset processing and overall indicator methodology, and the methodology used to transform the desired indicator attribute to a score for assessing mitigation priorities. Note that all the Water Quality sub-model indicator scores are constrained to range between 0 and 1, with 1 being the most desired for mitigation.

Table 2-1 Water Quality Sub-Model Indicators

Indicator	Reason for Indicator Selection and Selected Details	Relevance to Mitigation
Impaired Streams	• Identifies catchments with impaired streams at the local catchment and at connected upstream catchments. • A stream's impaired status was derived using NCDWR's 2018 Integrated Report. • Only impaired streams with a category 4 or 5 (and excluding heavy metals and pesticides) were included to align with DMS' mitigation strategies.	Catchments containing a high Impaired Streams score means that the catchment is impaired and has a high potential for mitigation based on this indicator.
Agriculture Cumulative Contribution	• Identifies catchments with a high agricultural pollutant yield (defined as the cumulative agricultural pollutant load over cumulative area) coming from contributing watersheds. • Derived using agriculture specific sources from the USGS SPARROW Nitrogen (N), Phosphorous (P), and Total Suspended Solids (TSS) datasets.	Catchments containing a high Agricultural Cumulative Contribution score means that the catchment has a relatively high water quality impact (as compared to their cohorts) from contributing watersheds and has a high potential for mitigation based on this indicator.
Agriculture Incremental Contribution	• Identifies catchments with a high agricultural pollutant yield coming (defined as the incremental agricultural pollutant load over agricultural areas) from the local catchment. • Derived using agriculture specific sources from the USGS SPARROW N, P, and TSS datasets and the agricultural land areas were identified using the NLCD 2016 dataset.	Catchments containing a high Agricultural Incremental Contribution score means that the catchment has relatively high water quality impact (as compared to their cohorts) from the local catchment and has a high potential for mitigation based on this indicator.

Table 2-1 Water Quality Sub-Model Indicators (Cont.)

Indicator	Reason for Indicator Selection and Selected Details	Relevance to Mitigation
Development Cumulative Contribution	• Identifies catchments with a high development pollutant yield (defined as the cumulative development load over cumulative area) coming from contributing watersheds. • Derived using development specific sources from the USGS SPARROW N, P, and TSS datasets.	Catchments containing a high Development Cumulative Contribution score means that the catchment has relatively high water quality impact (as compared to their cohorts) from contributing watersheds and has a high potential for mitigation based on this indicator.
Development Incremental Contribution	• Identifies catchments with a high development pollutant yield (defined as the incremental development load over the developed areas) coming from the local catchment. • Derived using development specific sources from the USGS SPARROW N, P, and TSS datasets and the developed land areas were identified using the 2016 National Land Cover Dataset (NLCD).	Catchments containing a high Development Incremental Contribution score means that the catchment has relatively high water quality impact (as compared to their cohorts) from the local catchment and has a high potential for mitigation based on this indicator.

2.2.3 Water Quality Sub-Model Results

Sub-Model Scoring Scheme

The Water Quality sub-model was scored using the five contributing indicators. For catchments with an Impaired Streams score of zero, the Water Quality score was adjusted using the other four contributing indicators only. This was necessary to avoid penalizing catchments where NCDWR has not surveyed the stream or the pollutant types were excluded if they were outside of DMS's mitigation abilities. Therefore, the Water Quality sub-model scoring schemes are as follows.

If Impaired Streams score is not 0:

$$\begin{aligned} Water\ Quality\ Score &= (Impaired\ Streams\ Score \\ &+ Agriculture\ Cumulative\ Contribution\ Score \\ &+ Agriculture\ Incremental\ Contribution\ Score \\ &+ Development\ Cumulative\ Contribution\ Score \\ &+ Development\ Incremental\ Contribution\ Score)/)/5 \end{aligned}$$

If Impaired Streams score is 0:

$$\begin{aligned}\mathit{Water\ Quality\ Score} \\ &= (\mathit{Agriculture\ Cumulative\ Contribution\ Score} \\ &+ \mathit{Agriculture\ Incremental\ Contribution\ Score} \\ &+ \mathit{Development\ Cumulative\ Contribution\ Score} \\ &+ \mathit{Development\ Incremental\ Contribution\ Score})/4\end{aligned}$$

Equal weighting was used on the contributing indicators to develop the Water Quality scores. Note that the distribution of the Impaired Stream scores is affected by the data gaps or the mitigation constraints, where approximately 500 out of 1304 catchments received a score of 0. The distribution of the Agricultural Incremental Contribution and Development Incremental Contribution scores are, in part, affected by the available agricultural and developed land areas within the local catchment. Approximately 20% of the study area contained very little or no agricultural or developed area depending on the local catchment. In comparison, the distribution of the Agricultural Cumulative Contribution and Development Cumulative Contribution scores are more evenly spread since all the contributing watershed areas are considered in these computations.

Based on the above scoring schemes, the Water Quality scores are constrained between 0 and 1, with higher scores indicating that the catchment contains higher levels of pollutant concentrations and overland pollutant loads than catchments with lower scores. These highly impacted and stressed catchments would have the highest potential for uplift to improve water quality conditions.

Sub-Model Results

Figure 2-1 shows the Water Quality sub-model results. The Water Quality scores exhibit a Gaussian distribution with a mean of 0.33 and a standard deviation of 0.12. The minimum, median, and maximum scores are 0, 0.33, and 0.72 respectively. The catchments which scored highest for Water Quality (top 2.5% with a score between 0.57 and 0.72) typically have a high degree of water quality degradation from both in-stream pollutant concentrations (via the Impaired Stream indicator) and pollutant loads from development and agricultural sources (via the SPARROW-derived indicators). Geographically, the higher scoring degrading catchments are located along the major tributaries or the main rivers in the study area (e.g., Haw River, Deep River, and Rocky River). These catchments tend to concentrate both the incremental and cumulative agricultural pollutants and NCDWR typically samples at higher stream orders for their Impaired Streams assessment. There is also a high scoring pocket around Siler City, which is likely coming from the high incremental and cumulative development loads due to urbanization.

2.2.4 State of Water Quality Degradation

Per discussions with DMS, VHB also developed a supplementary assessment of the USGS SPARROW dataset in order to better characterize the state of water quality degradation in the study area and to identify potential keystone catchments that DMS can improve and, by extension, elevate the conditions of the surrounding catchments.

As emphasized in the Key Considerations (Section 2.1.1), a major challenge with the USGS SPARROW datasets and SPARROW-derived indicators scoring (Section 2.2.2) is the lack of literature guidance on absolute thresholds for transforming the pollutant yields to a score that is reflective of the true state of water quality degradation in the study area. As a workaround, VHB developed an approach to determine pollutant loading in relatively pristine catchments to establish a baseline loading for natural conditions. The purpose of this baseline analysis is to get an understanding of how the study area's water quality loading is relative to roughly pre-development conditions. From herein, VHB will refer to this approach as the Baseline Approach.

The Baseline Approach provides a threshold for determining if a catchment has elevated pollutant loading or not and how much of the overall watershed is receiving elevated loads which lead to water quality degradation. Note that this baseline approach is meant to supplement the SPARROW-derived indicators as discussed in Section 2.2.2, and it is not meant to replace the scoring scheme in the Focus Areas analysis. VHB argues that there is value in keeping the SPARROW-derived indicators in the Focus Areas analysis in order to help identify catchments that have a relatively high pollutant load from sources that DMS can perform mitigation on. As such, the purpose of the Baseline Approach is to enhance the qualitative discussion on the state of water quality degradation in the study area.

Baseline Approach

The Baseline Approach that VHB developed include the following steps:

1. Identify 10-15 pristine[8] catchments in the study area and compute their pollutant yield using the incremental load and incremental area. This pollutant yield, unlike the SPARROW-derived indicator analyses described in Section 2.2.2, will include all the pollutant sources (e.g., agriculture, development, naturally occurring, and point sources) regardless of mitigation feasibility. The idea of this pollutant yield is to establish a baseline incremental yield (henceforth baseline yield) that is representative of natural or background water quality conditions in the study area for N, P, and TSS, respectively.
2. The computed N, P, and TSS baseline yields are compared against each catchment's incremental pollutant yields computed across the study area. A yield ratio, defined as the pollutant yield over the baseline yield, is then computed and this is used to assess the degree of deviation) of a catchment from the baseline conditions.

Using the above approach, VHB selected a total of 15 pristine catchments.[9] The mean of the respective N, P, and TSS pollutant yields from these catchments is taken as the baseline yield

[8] In the study area, VHB is defining pristine as a catchment that is heavily forested (containing greater than 80% forested area), predominantly undeveloped (less than 2% developed area), and containing predominantly headwater streams (e.g., average stream order less than 1.5). A size threshold (greater than 55 acres) was also imposed on the catchment selection in order to minimize the potential outlier effects of very small catchments.

[9] The 15 pristine catchments have the following Watershed ID: 8869812, 8870124, 8870222, 8870364, 8896040, 8896760, 8896774, 8896804, 8896978, 8897012, 8897038, 8897396, 8897878, 8898352, and 8898364.

for each pollutant type. The final baseline yields are N_b = 140 kg/(yr*km^2), P_b = 16.6 kg/(yr*km^2), and TSS_b = 3.2 Mg/(yr*km^2).

Baseline Approach Results

Figure 2-2 shows the box-and-whisker plots of all the pollutant yields in the study area with the baseline yield (dashed green line) plotted for reference. For all three pollutant types, the baseline yields are contained in the first quartile (or lower 25%) of the pollutant yields in the study area. This is consistent with the expectation that these baseline yields are representative of more pristine or natural background conditions. Note that the mean pollutant yield values (as marked by x in the figure) are much higher than the median value. This is indicative of extremely high outlier values in the study area that are inflating the mean values. The mean pollutant yields for N, P, and TSS are 591 kg/(yr*km^2), 253 kg/(yr*km^2), and 324 Mg/(yr*km^2), respectively.

The degree of deviation of each pollutant yield from the baseline yield is shown in Figure 2-3. This histogram shows the yield ratios for the three pollutant types, where a yield ratio of 1 represents that the pollutant yield and the baseline yield are exactly the same in a catchment. A yield ratio greater than 1 represents that the pollutant yield is greater than the baseline yield. The key observations of the baseline analysis are summarized below:

- **Nitrogen**: There were 613 catchments (or 47% of the total number of catchments or 56% of the total study area[10]) that showed a yield ratio greater than or equal to 2 (e.g., pollutant yield doubled the baseline yield). These higher pollutant yield catchments are generally located on the western half of the study area (especially overlapping with the Voluntary Agricultural Districts in Alamance County), with some sporadic pockets along tributaries feeding into the Rocky River and Haw River. See Figure 2-4 for more details.
- **Phosphorous:** There were 689 catchments (or 53% of the total number of catchments or 43% of the total study area) that showed a yield ratio of greater than or equal to 2. These higher pollutant yield catchments are primarily concentrated in the northwestern part of the study area (especially overlapping with the Voluntary Agricultural Districts in Alamance County). While the high nitrogen and high phosphorus yield ratio results are not identical geographically, they do have some overlaps in the western half of the study area. See Figure 2-5 for more details.
- **Total Suspended Solids:** There were 694 catchments (or 53% of the total number of catchments or 35% of the total study area) that showed a yield ratio of greater than or equal to 2. These higher pollutant yield catchments are generally located along the major transportation corridors (U.S. Route 401 and U.S. Route 501) and cities (e.g., Liberty, Siler City, and Pittsboro) in the study area. Areas with concentrated development would likely have higher impervious areas (and hence higher runoff volumes) that may result in erosion and high TSS problems in a catchment. See Figure 2-6 for more details.

[10] The total study area is 1608 square kilometers.

Overall, approximately 50% of the catchments in the study area have pollutant yields that are at least double the baseline yields for each of the three pollutant types respectively. VHB also identified 249 catchments (or 19% of the total number of catchments or 16% of the total study area) that showed at least double the baseline yields for all three pollutant types.

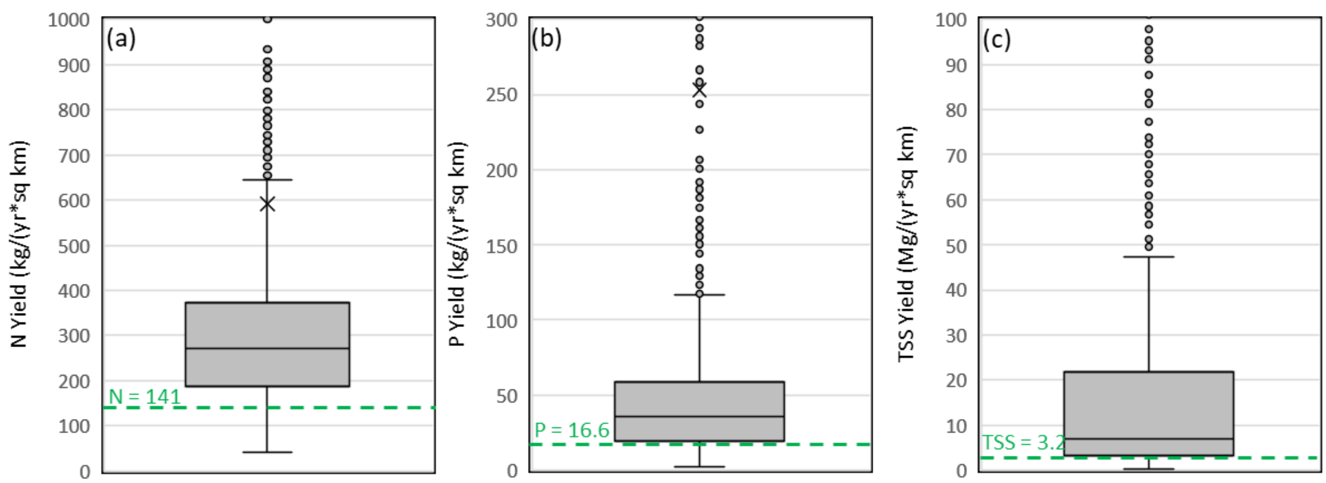

Figure 2-2. Box-and-whisker plots of USGS SPARROW incremental catchment pollutant yields for (a) N, (b) P, and (c) TSS) in the study area.

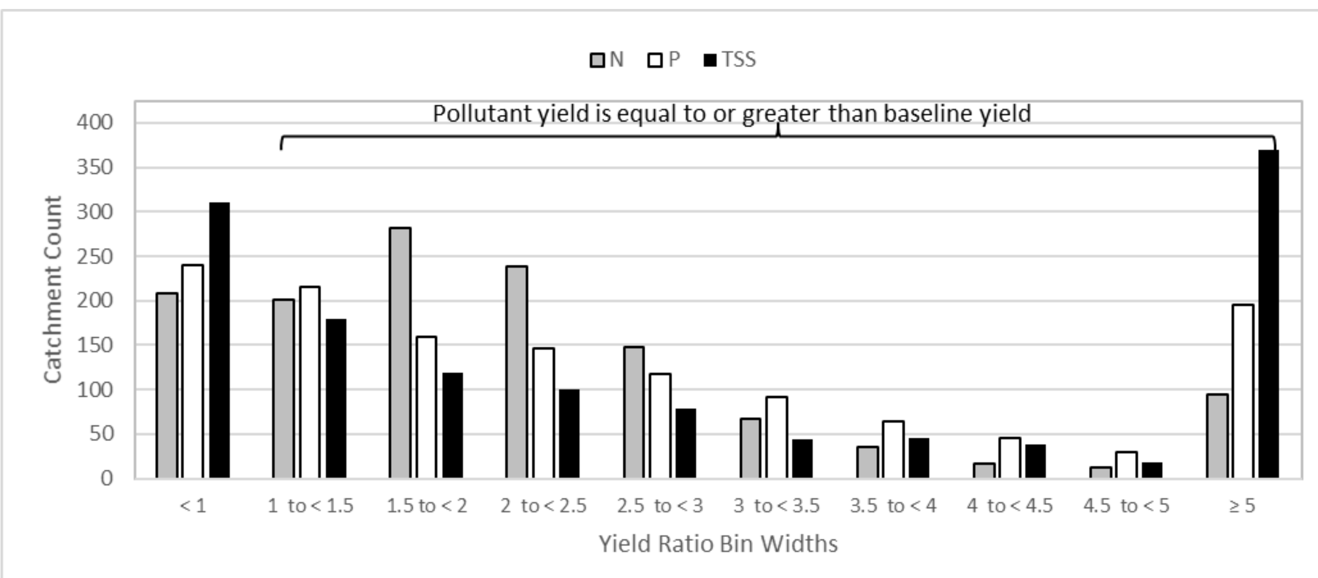

Figure 2-3. Histogram of USGS SPARROW yield ratios for N, P, and TSS in the study area.

Potential Keystone Catchments

The results from the baseline analysis and the indicator analysis of the SPARROW datasets were examined together in order to identify potential keystone catchments whose pollutant loadings are mitigable. The results from the baseline analysis alone are insufficient because a catchment may have a high yield ratio due to naturally occurring and/or point sources that

DMS may not be able to mitigate. For a more equitable comparison, only the Agriculture Incremental Contribution and Development Incremental Contribution indicator scores were used. The cumulative indicator scores (e.g., Agriculture Cumulative Contribution and Development Cumulative Contribution) were not used because the baseline analysis used incremental loads and incremental areas only.

Therefore, VHB identified two set of potential keystone catchments for targeted mitigation from agricultural and development sources. For the agriculture sources, catchments that have both elevated yield ratios (e.g., an N, P, and TSS yield ratio greater than or equal to 2) and a high Agriculture Incremental Contribution indicator score (percentile rank greater than or equal to 75%) were identified as potential keystone catchments. These two filters identified 249 and 354 catchments, respectively. The intersection of both filters resulted in the identification of 84 potential keystone catchments for mitigation aimed at reducing agricultural pollutant loads.

Similarly, for the development sources, catchments that have both elevated yield ratios (e.g., an N, P, and TSS yield ratio greater than or equal to 2) and a high Development Incremental Contribution indicator score (percentile rank greater than or equal to 75%) were identified as potential keystone catchments. These two filters identified 249 and 361 catchments, respectively. The intersection of both filters resulted in the identification of 117 potential keystone catchments for mitigation aimed at reducing development pollutant loads.

Figure 2-7 shows a map of both the agriculture and development-derived keystone catchments. Since the limiting factor in the catchment identification is the N, P, and TSS yield ratios, 42 catchments overlap between the agriculture and development-derived keystone catchments. For the development-derived keystone catchments, they are mainly located near major cities in the study area (e.g., Siler City, Liberty, and Pittsboro) and along U.S. Route 421 north of Siler City. For the agriculture-derived keystone catchments, they are mainly located on the western half of the study area (e.g., away from the existing Preservation Areas along the Haw River) and includes a concentrated cluster in the Voluntary Agricultural District in Alamance County.

2.2.5 Lessons Learned

In addition to the Key Considerations discussed in Section 2.1.1, there are specific lessons learned from the Water Quality sub-model analysis. These lessons learned are documented below:

- **Mitigation Opportunities**
  - A major consideration in the Water Quality sub-model analysis is the consideration of mitigation opportunities. Both the Impaired Streams and USGS SPARROW datasets had to be processed in order to develop indicators that are both telling of the impaired water quality conditions and that are mitigable given DMS' constraints.
- **Upstream Contributing Watersheds**
  - While the Agriculture Cumulative Contribution, Development Cumulative Contribution, and Impaired Streams indicators included considerations for the impact of upstream contributing watersheds on downstream water quality

conditions, there were limitations in these indicator analyses. For the Agriculture Cumulative Contribution and Development Cumulative Contribution indicators, only the local catchments were flagged if they had a high cumulative load over the contributing watershed area. The upstream catchments that were contributing to these high loads were not flagged as additional mitigation priorities due to the lack of guidance in the SPARROW documentation defining the upstream distance between the SPARROW contributing watershed area and the study catchment.

- For the Cape Fear 02/03 Regional Watershed Plan, this level of detail for the upstream contributing watershed indicators was deemed reasonable per discussions with DMS. However, for smaller planning efforts, DMS may want to expand on this contributing watershed analysis to refine project sites.

- **Alternative SPARROW-derived Indicators**
  - Per discussions with DMS, VHB considered recombining the SPARROW-derived incremental and cumulative indicators to develop a new metric to assess the relative contribution of water quality degradation from the local catchment versus the contributing watersheds. An Agriculture Contribution Ratio, defined as the ratio of the Agriculture Incremental Contribution over the Agriculture Cumulative Contribution, is an example of an alternative SPARROW indicator. Ultimately, VHB did not move forward with these alternative indicators for the agriculture and developed pollutant sources for two reason. First, there were concerns about overlap in the pollutant inputs since the local catchment loads are inclusive in the cumulative loads. Second, the incremental to cumulative ratio may not be a fair ratio since the normalizing area for the incremental loads is source specific (agriculture or developed areas only) and the normalizing area for the cumulative loads are non-source specific (all contributing watershed areas).
- **USGS SPARROW Scoring Challenges**
  - While literature values on in-stream pollutant concentrations exist, there were limited resources for the development of the pollutant load or yield thresholds. Developing an absolute pollutant threshold is still a major challenge because it is a very context-specific (e.g., depending on the size of the catchment, the contributing watersheds, and other concurrent environmental factors) exercise.
- **Data Gaps in Impaired Streams**
  - Gaps in the Impaired Streams indicator also presented a scoring challenge. For example, some of the catchments received a score of zero due to the lack of data, which is different from a catchment receiving a score of zero if observations exist to support it. As a result, it is important to keep track of these data gaps and not erroneously penalize catchments in their scoring.
- **Future Research Opportunities for Water Quality Models**
  - While it was not within the scope of the current analysis, it may be beneficial to take a closer look at the USGS SPARROW model and potentially update the model itself to better reflect current conditions. The USGS SPARROW datasets that VHB used in the Water Quality sub-model analysis relied on a model that was simulated for a model period between 1999 and 2014.

2.3 Habitat

The Habitat sub-model section includes a brief review on the Habitat Considerations (Section 2.3.1) that are relevant in a watershed evaluation, the Targeted Field Investigations (Section 2.3.2) conducted to address the habitat data gaps, the specific Habitat Indicators (Section 2.3.3) identified and analyzed for the Task 3 Focus Areas analysis, the Habitat Sub-Model Results (Section 2.3.4), and the Lessons Learned (Section 2.3.5) from this sub-model analysis.

2.3.1 Habitat Considerations

In Task 1, the existing habitat conditions within the study area were characterized using the North Carolina Natural Heritage Program's (NCNHP) Habitat dataset, which identified critical (for federally-listed species) and non-critical (for state-listed species) habitats that are of value for species of concern. In Task 3, VHB developed a more granular analysis of the potential habitat stressors, habitat resources, and other considerations that may make a catchment more desirable for mitigation.

VHB has identified four key habitat considerations in the development of the Habitat sub-model. First, habitat quality in a watershed is defined by both in-stream (e.g., channel stability, degree of incision, etc.) and adjacent overland habitat quality (e.g., riparian buffer areas, wetland areas, etc.). It is important to identify indicators that address both in order to develop a more comprehensive understanding of the condition of habitat quality or degradation. Second, in addition to habitat stressors, catchments may be prioritized using potential habitat resources as indicators. There is value in expanding potential wetland areas and in maintaining or improving areas adjacent to the habitats identified by NCNHP for species of concern. Third, it is important to keep in mind that some habitat issues may be more challenging for mitigation. For example, while hydraulic barriers such as dams are known features that obstruct fish migration and habitat connectivity, assessing dams for removal is not a trivial task given its complex environmental consequences. As such, some indicators may need to be simplified depending on the associated mitigation challenges and risks. Fourth, due to the complexity of habitat assessments, field investigations and verifications are typically recommended. Given the cost of field investigations, there are known data gaps in the study area that would have to be addressed through a combination of additional field work and data extrapolation.

In the following Habitat sub-model, VHB has taken into consideration both in-stream and overland habitat areas, habitat stressors, habitat resources, and mitigation opportunity in the development and scoring of the selected habitat indicators.

2.3.2 Targeted Field Investigations

In the Task 1 Report, VHB identified data gaps in the in-stream habitat scores from the NCDWR Fish Assessment and Benthic Macroinvertebrate monitoring stations in the study area. In order to address these data gaps, VHB and its sub-consultant, Three Oaks Engineering, conducted targeted field investigations to expand the coverage of the existing Fish Assessment and Benthic Macroinvertebrate habitat stations. Overall, the existing (via

NCDWR) and new (via VHB and Three Oaks) in-stream habitat scores are combined to produce the Field Habitat indicator in Task 3.

Field Site Identification

VHB developed an approach to identify potential the field sites given a number of field constraints. This approach includes the following steps:

1. **Access**: Field access was a key limiting factor in where VHB was able to sample in the study area. VHB first developed a field access map using parcel data from the respective counties in the study area and road and stream network data from North Carolina Department of Transportation (NCDOT). From the parcels data, VHB identified all the publicly accessible parcels. From the road and stream network datasets, VHB identified stream crossings where access may be gained via NCDOT's right-of-way. A final field access map was created by combining the results of the public parcels and stream crossing locations.
2. **Desired Site Features**: In addition to field access, VHB used the results from the Task 1 Focus Areas analysis to guide the prioritization of catchments for targeted field investigations. More specifically, the Task 1 Focus Area clusters and stream order 2 and 3 catchments were flagged to have a high field priority. Stream order 2 and 3 catchments were chosen in order to maximize locations where DMS are more likely to implement mitigation. A smaller number of stream order 1 and 4 catchments were included in order to develop a more representative catchment population.
3. **Exclusions:** Lastly, catchments that had existing NCDWR monitoring sites or were identified as Preservation Areas in the Task 1 analysis were excluded since they were of lower priority. In the study area, there are 44 existing NCDWR Fish Assessment and Benthic Macroinvertebrate habitat monitoring stations that reported an in-stream habitat score.

VHB identified a number of potential field sites using the above approach. Given the time and budget constraints of the field investigation, this potential list of sites was narrowed down to 83 sites spread across the study area. Figure 2-8 shows a map of the VHB and NCDWR field sites. Altogether, the combined number of field sites used for the Field Habitat indicator analysis is 127. Note that the number of unique catchments is only 114 because NCDWR had multiple sampling stations in some catchments. VHB chose to sample one representative location per catchment in order to maximize the number of catchments with data.

Field Sampling Approach

At each sampling site, VHB used the habitat sampling guidelines described in NCDWR's standard operating procedures.[11] This is to ensure that the habitat scores computed by VHB

[11] https://files.nc.gov/ncdeq/Water%20Quality/Environmental%20Sciences/BAU/NCDWRMacroinvertebrate-SOP-February%202016_final.pdf

are consistent with the existing NCDWR habitat scores. Note that the habitat scores (which range from 0 to 100) are a direct indicator of in-stream habitat quality because it is computed using characteristics such as channel modification, amount of in-stream habitat, type of bottom substrate, pool variety, riffle frequency, length and width, bank stability, light penetration, and riparian zone width. In addition to the habitat score, VHB also collected supplementary information to support the development and verification of other related indicators.

Supplemental Regression Analysis

Given the large size of the study area, some data gaps remained even after the targeted field investigations. Of the 1304 catchments in the study area, only 114 catchments had field-verified habitat scores after the targeted field investigations. In order to address the data gaps in the remaining catchments, VHB identified and used the U.S. Environmental Protection Agency's (USEPA) StreamCat Index of Catchment Integrity (ICI) dataset (available for the whole study area) to develop a regression relationship for extrapolating the habitat scores. The USEPA StreamCat ICI dataset contains a Habitat Index (CHABT) that was determined to be an appropriate proxy for estimating habitat conditions. Therefore, VHB first developed a regression relationship for the habitat score as a function of the CHABT index at co-located catchments. This regression relationship was then applied to the remaining catchments without a field-verified habitat score to develop an estimated habitat score. Altogether, the field-verified and estimated habitat scores were used as inputs for the Field Habitat indicator analysis. More details of the regression analysis can be found in Appendix A Table A-2.

2.3.3 Habitat Indicators

The Habitat sub-model contains six indicators, which includes: Buffer, Erosion, Field Habitat, Ponds, Potentially Suitable Habitat, and Potential Wetland Areas. The Buffer, Erosion, and Field Habitat indicators were evaluated to prioritize mitigation opportunities in catchments with degrading riparian buffers, overland and channel erosion, and in-stream habitat quality. Given the complexity and range of functions that ponds serve in the study area, the Ponds indicator analysis was simplified to include catchments with a low number of ponds as a screening indicator for mitigation feasibility. In other words, catchments with a high number of ponds (especially in higher stream orders) were categorized as low priority for mitigation because they present a challenge for mitigation efforts and the return on mitigation effort is likely low if ponds in series have to be mitigated together. Lastly, the Potentially Suitable Habitat and Potential Wetland Areas indicators were prioritized based on the potential positive resource values that critical habitats and potential wetland areas have on improving overall habitat quality. VHB is defining Potentially Suitable Habitat catchments as a catchment containing non-critical habitats for state-listed species of concern or catchments upstream of downstream critical and non-critical habitats.

Table 2-2 contains a high-level summary of the Habitat sub-model indicators, the reason for selecting the indicator, and the indicator's relevance to DMS' mitigation efforts. In Appendix A, Table A-2 contains more detailed documentation on the datasets that were used in the Habitat sub-model indicator development, the dataset processing and overall indicator methodology, and the scoring scheme used to transform the desired indicator attribute to a score for assessing mitigation priorities. Note that all the Habitat sub-model indicator scores are constrained to range between 0 and 1, with 1 being the most desired for mitigation.

Table 2-2 Habitat Sub-Model Indicators

Indicator	Reason for Indicator Selection and Selected Details	Relevance to Mitigation
Buffer	• Identifies catchments with likely degraded riparian buffers as a function of tree height and tree density. • Riparian buffer boundary was defined as 200 ft on either side of a stream. • Mean tree canopy height and tree density were computed using the U.S. Fish and Wildlife Services' (USFWS) LIDAR Canopy Height and the USFWS LIDAR Vegetation datasets, respectively	Catchments containing a high Buffer score means that the catchment likely contains degraded riparian buffers and has a high potential for mitigation based on this indicator.
Erosion	• Identifies catchments with a high likelihood for erosion based on high K factor values, degraded buffers, elevated TSS yields, and high existing land use change. • Erosion sub-indicators were derived using the U.S. Department of Agriculture's (USDA) K-Factor, USGS SPARROW TSS loads from erosion, Buffer indicator results, and 2001 and 2016 NLCD datasets.	Catchments containing a high Erosion score means that the catchment has a high likelihood for erosion problems and has a high potential for mitigation based on this indicator.
Field Habitat	• Identifies catchments with a low in-stream habitat quality as defined by NCDWR. • Includes 44 NCDWR Fish Assessment and Benthic Macroinvertebrate monitoring stations • VHB added 83 sampling stations in the study area and used USEPA's StreamCat habitat index to develop a regression relationship for estimating habitat quality in the study area.	Catchments containing a high Field Habitat score means that the catchment has degraded in-stream habitat and has a high potential for mitigation based on this indicator.

Table 2-2 Habitat Sub-Model Indicators (Cont.)

Indicator	Reason for Indicator Selection and Selected Details	Relevance to Mitigation
Ponds	• Identifies catchments with a low number of impoundments due to in-line pond obstructions. • Only ponds that were in-line with a stream order of 2 or higher were included. • Number of ponds and stream orders were determined using the USGS Ponds and NCDOT ATLAS Stream Orders datasets.	Catchments containing a high Ponds score means that the catchment has a low number of in-line pond obstructions and presents less of a challenge for mitigation based on this indicator.
Potentially Suitable Habitat	• Identifies catchments with potentially suitable habitats at the local catchment and at connected upstream catchments. • NCNHP Habitat was used to identify both critical habitats and non-critical habitats for aquatic species only. Additional critical habitats in the study area were verified using the USFWS Critical Habitat dataset for federally-listed species and the USFWS Expanded Cape Fear Shiner Critical Habitat. • Preservation Area Clusters from Task 1 were used to exclude any overlapping catchments with the Potentially Suitable Habitat results.	Catchments containing a high Potentially Suitable Habitat score means that the catchment contains or is upstream of habitat that has a high resource value and can improve overall habitat quality if mitigated based on this indicator.
Potential Wetland Areas	• Identifies catchments with high potential wetland areas for wetland restoration. • Total wetland areas and wetland areas on agricultural land were used to prioritize for mitigation. • Potential wetland areas derived using the USEPA Potential Wetland dataset and a number of supporting datasets to correct and update this starting layer.	Catchments containing a high Potential Wetland Areas score means that the catchment contains suitable areas for wetland restoration and can improve overall habitat quality if mitigated based on this indicator.

2.3.4 Habitat Sub-Model Results

Sub-Model Scoring Scheme

The Habitat sub-model was scored using the six contributing indicators. For catchments with a Buffer score of null, the Habitat score was adjusted using the other five contributing indicators only. This was necessary in order avoid penalizing catchments with no riparian buffers. This occurred in catchments that either had no stream segments or only contained large waterbodies, which were excluded from the Buffer indicator analysis due to potential mitigation feasibility issues. Approximately 125 catchments (out of 1304) in the study area had a null Buffer score. Therefore, the Habitat sub-model scoring schemes are as follows.

If Buffer score is not null:[12]

$$\begin{aligned} Habitat\ Score = (&Buffer\ Score + Erosion\ Score + Field\ Habitat\ Score + Ponds\ Score \\ &+ Potentially\ Suitable\ Habitat\ Score \\ &+ Potential\ Wetland\ Area\ Score)/6 \end{aligned}$$

Else if Buffer score is null:

$$\begin{aligned} Habitat\ Score = (&Erosion\ Score + Field\ Habitat\ Score + Ponds\ Score \\ &+ Potentially\ Suitable\ Habitat\ Score \\ &+ Potential\ Wetland\ Area\ Score)/5 \end{aligned}$$

Equal weighting was used on the contributing indicators to develop the Habitat scores. Note that the distribution of the contributing indicators varied. While the Field Habitat and Erosion indicators are evenly distributed, the other indicators either skew towards 0 or 1 depending on the characteristics of the study area. For example, the Buffer, Potentially Suitable Habitat, and Potential Wetland Areas indicators tend to score lower because the study area is predominantly forested (e.g., fewer degraded buffers to mitigate), is limited in the number of critical habitats and non-critical habitats to identify potentially suitable habitats, and contains only small pockets for wetland restoration, respectively. The Ponds indictor, in comparison, tends to score higher because some catchments do not contain any in-line ponds along the higher stream orders.

Overall, based on the above scoring schemes, the Habitat scores are constrained between 0 and 1, with higher scores indicating that the catchment is more desirable for mitigation due to a combination of overland and in-stream habitat degradation, mitigation opportunity, and potential resource values.

Sub-Model Results

Figure 2-9 shows the Habitat sub-model results. The Habitat scores exhibits a Gaussian distribution with a mean of 0.40 and a standard deviation of 0.11. The minimum, median, and maximum scores are 0, 0.39, and 0.79 respectively. The catchments which scored highest

[12] Note that the Buffer score is its standalone indicator, and it is also a sub-indicator of the Erosion indicator analysis. As such, there is some minor redundancy in this Habitat sub-model scoring scheme. VHB argues that there is a benefit in having a separate Buffer indicator for identifying potential mitigation opportunities targeting degraded riparian buffers only in Task 4.

for Habitat (top 2.4% with a score between 0.65 and 0.79) typically have degraded habitats (e.g., degraded buffers, potential erosion problems, and degraded in-stream habitat), have potential mitigable opportunities to expand valued resources (e.g., higher wetland areas and located near critical or non-critical habitats), and present less challenging mitigation obstacles (e.g., fewer in-line ponds in series along the higher stream order streams). Geographically, there does not appear to be a direct spatial correlation of the Habitat sub-model results given the high number of indicators and how they were derived using different mitigation priorities.

2.3.5 Lessons Learned

In addition to the Key Considerations discussed in Section 2.1.1, there are specific lessons learned from the Habitat sub-model analysis. The key lessons learned are documented below:

- **Data Gaps in the Index of Biological Integrity Data**
  - In the development of the Habitat sub-model, VHB considered including the NCDWR Index of Biological Integrity (IBI) dataset because the IBI scores may be used as a proxy for in-stream habitat (see Table B-1 in Appendix B). However, this dataset was excluded due to gaps in the NCDWR dataset. For example, only 43 out of the 1304 catchments contained NCDWR sampling stations that reported IBI scores. In addition, the level of effort needed to obtain additional IBI scores were outside scope of this current analysis since it involves a number of laboratory analyses. For future watershed planning efforts, DMS may consider using the NCDWR IBI dataset if the existing data coverage is deemed sufficient.
- **Erosion Indicator and Field Verification Challenges**
  - Erosion processes are fundamentally complex and a challenge to predict. As a workaround, VHB developed four predictors to estimate the likelihood for erosion problems in the Habitat sub-model analysis. In order to verify the Erosion indicator predictions, VHB compared the Erosion indicator scores against the field observed erosion conditions (a sub-score of the NCDWR habitat scores). However, agreement between the Erosion indicator scores and the field observed erosion conditions varied. Discrepancies were expected due to differences in scale between the Erosion indicator predictors and the field observations. In addition, there are potential quality concerns with the NCDWR erosion assessment, which is highly simplified.[11] As a result of these differences, VHB emphasizes that the presence of these predictors may not be sufficient to guarantee erosion depending on site-specific conditions. Therefore, when possible, VHB highly recommends field inspections in the evaluation of potential mitigation projects for addressing erosion problem specifically.
- **Potential Wetland Areas Dataset Challenges**
  - In the development of the Potential Wetland Areas indicator, VHB also considered using the USDA Hydric Soil dataset (see Table B-1 in Appendix B). The USDA Hydric Soil dataset may be useful because it identifies soil that is permanently or seasonally saturated by water.. VHB found that the hydric soil alone was not a good predictor

of existing USFWS wetland areas (from the National Wetland Inventory). Therefore, VHB did not use the hydric soil dataset in the Potential Wetland Areas indicator analysis.

- Ultimately, VHB opted to use the existing USEPA Potential Wetland Areas dataset as the starting basis for the Potential Wetland Areas indicator analysis. This dataset used soil data and a wetness index to identify soils that are poorly drained and are likely to accumulate water, two conditions that are conducive to wetlands. However, a drawback in using this existing dataset is that its data inputs are dated to the time of the analysis (in this case, the early 2010s).[13] For future watershed planning efforts, it may be beneficial for DMS to revisit this indicator analysis using more updated data inputs.

- **Ponds Indicator Simplification**
  - The Ponds indicator in the Habitat sub-model was only assessed based on feasibility considerations for mitigation projects. The environmental implications of ponds in the study area are complex and they are dependent on the context and purpose that a pond is serving. While the removal of ponds is not evaluated in the current analysis, future considerations should keep the following in mind: 1) the position of the pond in the watershed; 2) the location of the pond relative to critical habitat and species of concern; 3) the purpose that the pond is serving (e.g., serving as a Best Management Practice (BMP) or for agricultural pollutant storage); 4) potential impact on invasive species; 5) whether the pond is connected directly to a stream; and 6) whether the pond is a part of a larger series of ponds. Overall, pond removal assessment should be evaluated on a case-by-case basis due to the complex environmental consequences and mitigation challenges involved.
- **Potentially Suitable Habitat Permitting Concerns**
  - DMS and USFWS are aligned in using mitigation to improve habitat quality for species of concern. However, in-stream work in reaches containing federally-listed endangered or threatened species will require Environmental Species Act (ESA) consultation with the USFWS in order to minimize potential adverse impacts to these critical habitats. These ESA consultations may present added challenges in the permitting and approval of mitigation projects in or near critical habitats. As a result of these constraints, VHB approached the Potentially Suitable Habitat indicator by organizing the catchments into three categories: catchments containing non-critical habitats for state-listed species only, catchments containing critical habitat for federally-listed species only, and catchments upstream of non-critical and critical habitats. VHB then minimized potential permitting concerns in critical habitats by excluding overlaps between the Preservation Area Cluster results (which included all the catchments containing critical habitats) from the Task 1 and the Potentially Suitable Habitat results. Note that for certain location and type of mitigation work, DMS may still have to consult with the USFWS if the proximity of the work is close

[13] https://edg.epa.gov/metadata/catalog/search/resource/details.page?uuid=%7BD8C16461-4057-412C-994E-98C12033CB96%7D

(though not in same catchment) to critical habitats. Figure 2-10 shows the results of the Potentially Suitable Habitat analysis with the different habitat classifications.

- **Dam Removal Prioritization**
  - During the development of Habitat sub-model, VHB and DMS discussed the inclusion of a Dams indicator to identify dams that may be prioritized for removal. Similar to the Pond indicator challenges discussed above, dam removal is a highly complex process with nuanced environmental consequences. As such, VHB decided to exclude the Dams indicator from the Habitat sub-model. Instead, VHB identified a subset of dams (28 out of 76 in the study area) that may be worthy of further investigation (see Figure 2-11). These dams were identified based on guidance from USFWS to prioritize dams located along the major rivers in the study area, where the Cape Fear Shiner is known to migrate. Along with this map, VHB recommends the use of the Southeast Aquatic Resources Partnership (SARP) Prioritization Tool to assist in the prioritization of dam removal.[14]

2.4 Hydrology

The Hydrology sub-model section includes a brief review on the Hydrology Considerations (Section 2.4.1) that are relevant in a watershed evaluation, the specific Hydrology Indicators (Section 2.4.2) identified and analyzed for the Task 3 Focus Areas analysis, the Hydrology Sub-Model Results (Section 2.4.3), and the Lessons Learned (Section 2.4.4) from this sub-model analysis.

2.4.1 Hydrology Considerations

The development of the indicators for the Hydrology sub-model was the most challenging out of the four sub-models given the hydrology data gaps in the study area. While flow is a critical indicator for evaluating both the hydrologic conditions (e.g., identifying baseflow, runoff volumes, etc.) and mitigation opportunity in a catchment, VHB was not able to find a comprehensive flow dataset that would be applicable given the size of the study area. Instead, VHB approached this sub-model analysis using indirect hydrology indicators, such as potential hydrologic resources (e.g., the available floodplain area for hydrologic connectivity) and headwater improvement opportunities (e.g., headwater ponds that may be mitigable), to identify catchments that may be desirable for mitigation.

2.4.2 Hydrology Indicators

The Hydrology sub-model contains four indicators, which include: Crossings, Dams, Floodplain Area, and Ponds.[15] The Crossings and Dams indicators were prioritized to identify catchments with fewer hydraulic obstructions in order to minimize the potential mitigation challenges that may be encountered. Removal of existing stream crossings and dams are

[14] https://connectivity.sarpdata.com/

[15] Note the that Ponds indicator analysis under the Habitat and Hydrology sub-model model uses the same dataset, but the indicator methodologies are different and they do not overlap.

highly complex and are often outside of DMS' scope of work,. The Floodplain Area indicator was utilized as it represents potential hydrologic connectivity opportunities which is desirable for functional uplift. In other words, catchments with large floodplain areas (especially in tributaries with lower stream orders) were prioritized as they present better opportunity for stream restoration versus a channel with a narrowly confined floodplain. The Ponds indicator was used to identify catchments with a high number of headwater ponds for potential mitigation opportunities to improve headwater hydrology. As discussed in more detail under Lessons Learned in Section 2.4.4, VHB reviewed a number of flow datasets in order to develop a more direct Hydrology indicator. However, due to a range of data quality and data access issues, these flow datasets were not used in the Hydrology sub-model (see Table B-1 in Appendix B for more information). Therefore, VHB and DMS recognize that the current Hydrology sub-model contains indirect indicators and may be improved in future efforts if better data becomes available.

Table 2-3 contains a high-level summary of the Hydrology sub-model indicators, the reason for selecting the indicator, and the indicator's relevance to DMS' mitigation efforts. In Appendix A, Table A-3 contains more detailed documentation on the datasets that were used in the Hydrology sub-model indicator development, the dataset processing and overall indicator methodology, and the scoring scheme used to transform the desired indicator attribute to a score for assessing mitigation priorities. Note that all the Hydrology sub-model indicator scores are constrained to range between 0 and 1, with 1 being the most desired for mitigation.

Table 2-3 Hydrology Sub-Model Indicators

Indicator	Reason for Indicator Selection and Selected Details	Relevance to Mitigation
Crossings	• Identifies catchments with a low number of stream crossing obstructions.[16] • Stream crossings were identified using the NCDOT ATLAS Streams and NCDOT Route Arcs dataset.	Catchments containing a high Crossings score means that the catchment has a low number of in-line stream crossing obstructions and presents less of a challenge for mitigation based on this indicator.
Dams	• Identifies catchments with a low number of impoundments due to dams. • Dams were identified in the study area using the North Carolina Division of Energy, Mineral, and Land Resources (NCDEMLR) Dams and SARP Dams datasets.	Catchments containing a high Dams score means that the catchment has a low number of dam obstructions and presents less of a challenge for mitigation based on this indicator.
Floodplain Area	• Identifies catchments with a large amount of total floodplain area (with emphasis on the lower order streams). • Potential floodplain areas were identified within a 200 feet riparian buffer boundary using the NCDOT ATLAS Streams, NCDOT ATLAS Stream Orders, and the USGS Geomorphones datasets.	Catchments containing a high Floodplain Area score means that the catchment has a large amount of total floodplain area (especially at lower stream orders) for potential mitigation opportunity to increase hydrologic connectivity based on this indicator.
Ponds	• Identifies catchments with a high number of in-line headwater ponds • Headwater ponds were identified using the NCDOT ATLAS Stream Orders and USGS Ponds datasets.	Catchments containing a high Ponds score means that the catchment has a high number of headwater ponds for potential mitigation opportunity to improve headwater hydrology based on this indicator.

[16] In order to make this indicator better align with how DMS evaluates crossing barriers for mitigation feasibility (see https://files.nc.gov/ncdeq/Mitigation%20Services/Contracting/Score_Sheets_Maps/16-20200205_TP01.pdf), the total number of stream crossings in a catchment was transformed to a total structure length in a catchment by assuming that each stream crossing is on average 50 feet in length (based on VHB professional judgement). A stream crossing barriers ratio can then be defined as the total stream crossing length over the total stream length in a catchment.

2.4.3 Hydrology Sub-Model Results

Sub-Model Scoring Scheme

The Hydrology sub-model was scored using the four contributing indicators. The Hydrology sub-model scoring schemes is as follows with equal weighting on the contributing indicators:

$$\begin{aligned} \mathit{Hydrology\ Score} \\ &= (\mathit{Crossings\ Score} + \mathit{Dams\ Score} + \mathit{Floodplain\ Area\ Score} \\ &+\ \mathit{Ponds\ Score})/4 \end{aligned}$$

Based on the above scoring scheme, the Hydrology scores are constrained between 0 and 1, with higher scores indicating that the catchment is more desirable for mitigation due to a combination of mitigation feasibility and potential resource values.

Sub-Model Results

Figure 2-12 shows the Hydrology sub-model results. The Hydrology scores are distributed across the range of scores (a mean of 0.50 and a standard deviation of 0.12) but there is a very pronounced concentration of scores around 0.5. The minimum, median, and maximum scores are 0, 0.50, and 0.90 respectively. The highest scoring Hydrology catchments (top 4.1% with a score between 0.71 and 0.90) typically contain little to no stream crossings or dam obstructions (via the Crossings and Dams indicator), contain a high number of headwater ponds (via the Ponds indicator), and contain a high amount of total floodplain areas along the lower stream orders (via the Floodplain Area indicator). Geographically, these high scoring catchments are spread out in the study area. They are typically concentrated away from the major river junctions and urban developments and, instead, are located in the upper reaches of the HUC-12 watersheds. This makes sense since there are typically more hydraulic barriers downstream and in urban areas.

As noted above, a large portion of the Hydrology scores are concentrated around 0.5. This may be a result of how the contributing indicators were scored or distributed. For both the Crossings and Dams indicators, their scores tend to be skew towards 1 because a large portion of the watershed had no dams (94%) or a low number of stream crossings (47%). In contrast, for both the Floodplain Area and Ponds indicator, their scores tend to skew towards the lower values due to the smaller number of lower stream orders to identify viable ponds and floodplain areas for mitigation. As a result, the overall Hydrology score tends to concentrate around 0.5 due to the different indicator behaviors.

2.4.4 Lessons Learned

In addition to the Key Considerations discussed in Section 2.1.1, there are specific lessons learned from the Hydrology sub-model analysis. The key lessons learned are documented below:

- **Hydraulic Barrier Assessment Simplification**
  - For both the Crossings and Dams indicator, these hydraulic barriers were only assessed based on feasibility considerations for mitigation projects. The direct hydraulics and hydrologic effects of these structures were not assessed due to their complex environmental consequences. For example, if there is an issue with a structure being undersized or oversized, it is often outside of DMS' capabilities to modify and/or remove these structures. More importantly, these types of mitigation projects may not result in reliable mitigation credits due to the number of challenges and risks involved.
- **Floodplain Area Indicator Challenges**
  - There were challenges in the development of the Floodplain Area indicator. Per discussions with DMS, the original intent of this indicator was to identify floodplain connectivity using the USGS Geomorphones (e.g., used to identify floodplain areas) and USGS Positive Openness (e.g., used as a proxy for the degree of stream incision) datasets. There are a number of functional advantages in connecting streams and floodplains, and these include attenuating extreme flood events by increasing storage, improving water quality through overland filtration, and expanding habitats for terrestrial and aquatic species. Therefore, the combination of the available floodplain areas and the degree of stream incision would allow DMS to more directly identify catchments where they can improve hydrologic connectivity. However, due to spatial resolution and data accuracy concerns with the USGS Positive Openness dataset, it was removed from the indicator analysis (see Table B-1 in Appendix B). These data issues were identified using the field observed bank angles and bank height ratios from the Targeted Field Investigations (see Section 2.3.2). As a result, a modified indicator was developed using the floodplain areas only. DMS may wish to revisit this indicator if better stream incision data becomes available.
- **Future Research Opportunities for Flow Models**
  - As discussed in Section 2.4.2, the Hydrology sub-model lacks an indicator directly related to flow due to data limitations in the study area. For future watershed planning efforts, it may be worth the effort to estimate flow using USGS Regression Equations or publicly available watershed model (e.g., Hydraulic Engineering Center's Hydrologic Modeling System (HEC-HMS), Generalized Watershed Loading Function (GWLF), and Hydrological Simulation Program – Fortran (HSPF) for example). In VHB's review of potential flow datasets (see Table B-1 Appendix B), a web-based flow model was also identified. The Model My Watershed website uses the GWLF model as its core hydrological engine. The advantage of Model My Watershed is that it is very user-friendly and fast for single catchment analysis. However, when a higher degree of site specification is needed and/or a large number of catchments have to be processed, then the web-based model is more challenging to customize and to automate. In addition to flow modeling, DMS may

wish to leverage tools such as the Indicators of Hydrologic Alteration[17]to develop more tailored hydrology indicators if better flow datasets become available. While it was outside of the scope of the current analysis to develop a flow model for the Cape Fear 02/03 study area, the above flow modelling options presents a potential research opportunity for DMS to fill with its collaborators.

2.5 Land Use Conversion

The Land Use Conversion sub-model section includes a brief review on the Land Use Conversion Considerations (Section 2.5.1) that are relevant in a watershed evaluation, the specific Land Use Conversion Indicators (Section 2.5.2) identified and analyzed for the Task 3 Focus Areas analysis, the Land Use Conversion Sub-Model Results (Section 2.5.3), and the Lessons Learned (Section 2.5.4) from this sub-model analysis.

2.5.1 Land Use Conversion Considerations

In Task 1, VHB proposed an approach to predict Land Use Conversion in the study area. Per additional review and subsequent discussions with DMS, VHB has developed a more detailed Land Use Conversion analysis in Task 3.

In practice, land use conversion models have used a combination of inputs to estimate future land use. These inputs may include existing terrain characteristics (e.g., slope, hillshade, etc.), existing land use, development, supporting infrastructure networks (e.g., roads, sewers, etc.), and other relevant features in a study area. In addition, these models may be corrected to exclude certain areas that are either protected by law from development or have been zoned for other purposes. The final existing conditions is then used as the seed in a growth model that iteratively predicts development in time. If available, these models often take into account future population predictions to improve the growth model. Given the complexity of these models, it is important to note the spatial resolution of modeling analysis. Many of these models are designed for regional and planning purposes only, and they may not be tailored for very site-specific scenarios depending on data availability at the time of analysis.

In the following Land Use Conversion sub-model, VHB has leveraged the model outputs of existing development models (such as the USGS SLEUTH and USGS FUTURES datasets) in predicting future development hotspots in the Cape Fear 02/03 study area by 2060. This time horizon was selected to provide a long enough window for DMS to implement mitigation projects ahead of the predicted land conversion.

2.5.2 Land Use Conversion Indicators

The Land Use Conversion sub-model contains only the Future Land Use Change indicator. The Future Land Use Change indicator was designed to identify catchments with a low total

[17] https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/IndicatorsofhydrologicAlteration/Pages/indicators-hydrologic-alt.aspx

area of existing and future development so that resources can be restored and/or preserved ahead of development. More specifically, VHB is defining a total developed area ratio as the sum of the existing developed area in 2016 and the predicted developed area by 2060 over the catchment area.

Table 2-4 contains a high-level summary of the Land Use Conversion sub-model indicator, the reason for selecting the indicator, and the indicator's relevance to DMS' mitigation efforts. In Appendix A, Table A-4 contains more detailed documentation on the datasets that were used in the Land Use Conversion sub-model indicator development, the dataset processing and overall indicator methodology, and the scoring scheme used to transform the desired indicator attribute to a score for assessing mitigation priorities. Note that the Future Land Use Change indicator score is constrained to range between 0 and 1, with 1 being the most desired for mitigation.

Table 2-4 Land Use Conversion Sub-Model Indicators

Indicator	Reason for Indicator Selection and Selected Details	Relevance to Mitigation
Future Land Use Change	• Identifies catchments at the onset of development at the local catchment and at connected upstream catchments. • Existing developed areas were identified using the 2016 NLCD dataset. • Future developed areas were identified using the 2060 USGS SLEUTH and USGS FUTURES model results.	Catchments containing a high Future Land Use Change score means that the catchment has a low total area ratio of existing and future development and presents an opportunity for mitigation efforts to get ahead of development using this indicator.

Future Land Use Change

The Future Land Use Change indicator identifies catchments at the onset of develop at the local catchment and at connected upstream catchments. Three key components fed into the Future Land Use Indicator:

1. **Projected Development:** The projected development areas by 2060 were determined using the USGS SLEUTH and USGS FUTURES model results. Both models were run in the early 2010s for a model period between 2020-2100 (in decadal increments) and 2011 and 2065 (in annual increments), respectively. As a conservative estimate of future development, any land pixel with a greater than 40% chance of development was assumed to be developed by 2060. The union of the SLEUTH and FUTURES model results formed the basis of projected development layer. Note that neither the existing SLEUTH nor FUTURES model were tailored to the Cape Fear 02/03 conditions. As such, corrections were performed on this projected development layer.

2. **Study Area Inclusions:** The second component is the Megasite areas in the study area. The projected development layer was amended to include Megasites that are proposed in the study area: the Moncure Megasite, the Chatham-Siler City Megasite, and the Greensboro-Randolph Megasite. These Megasites represent land parcels that are being actively marketed for large scale development. The inclusion of the Megasites in the projected development layer is necessary because the USGS SLEUTH and USGS FUTURES models were run using data inputs prior to the announcement of these sites.
3. **Study Area Exclusions**: The third component includes study area-specific areas for exclusion from projected development that were likely not accounted for at the time of the SLEUTH and FUTURES model runs. An exclusion layer was created using Voluntary Agricultural District parcels, existing open water and development areas (from the NLCD 2016 dataset), and NCNHP Managed Areas that are not expected to be developed in the future.

Note that a comparison of the SLEUTH 2060 developed areas and the FUTURES 2060 developed areas showed that the SLEUTH model predicted a larger total area of land use conversion by 2060. In addition, the spatial resolution of the SLEUTH model is coarser than the FUTURES model, with the former typically used for regional and planning purposes only.

Altogether, the base 2060 projected development layer using the SLEUTH and FUTURES model results were amended to include the Megasites and to exclude areas that are less likely for development in the study area. Catchments that were upstream of the projected development areas by 2060 were also identified and prioritized for mitigation because they present an opportunity for DMS to get ahead of downstream development.

The total developed area ratio (as defined earlier) was computed and used as the input for scoring the Future Land Use Change indicator. Based on discussions with DMS, catchments at the onset of future development (where the total develop area ratio is greater than 0 but less than or equal to 20%) and upstream catchments were prioritized for mitigation. Catchments with either zero developed areas or highly developed areas (where the total developed area ratio is greater than 20%) received a score of zero. VHB also manually identified catchments upstream of predicted development by 2060 and assigned these catchments with a score 1 for their potential to help maintain or improve downstream conditions. Overall, catchments containing a high Future Land Use Change score means that the catchment has a low total area ratio of existing to future development and presents an opportunity for mitigation efforts to get ahead of development.

2.5.3 Land Use Conversion Sub-Model Results

Sub-Model Scoring Scheme

The Land Use Conversion sub-model was scored using Future Land Use Change indicator with no additional weighting:

$$Land\ Use\ Conversion\ Score = Future\ Land\ Use\ Change\ Score$$

As such, the Land Use Conversion sub-model score is the Future Land Use Change score. This score is likewise constrained between 0 and 1, with higher scores indicating that the catchment has a low (but not zero) total developed area ratio at the local catchment and at upstream connected catchments.

Sub-Model Results

Figure 2-13 shows the Land Use Conversion sub-model results. The Megasite boundaries are plotted for reference. A majority of the catchment's Land Use Conversion scores are highly concentrated at 0 (approximately 37% of the catchments) and 1 (approximately 25% of the catchments), with the remaining catchments scoring in between (approximately 38% of the catchments). This distribution of the Land Use Conversion scores is expected given the scoring scheme was developed to prioritize mitigation in catchments upstream of future developments (by 2060) which received a score of 1 and catchments at the onset of development (i.e., existing and future developed area percentage by catchment is greater than 0 but less than or equal to 20%) received a negatively linear adjusted score between 1 and 0. As such, the high Land Use Conversion scores typically identified catchments that are upstream of existing and future development, and the low Land Use Conversion scores typically identified catchments that contained a high existing development and may be too degraded for mitigation to be of benefit or have anticipated high future development that may make mitigation difficult from a land management perspective. Geographically, high Land Use Conversion scores tend to be located away from the existing major urban areas (e.g., Siler City, Liberty, Pittsboro), away from the major transportation corridors (U.S. Route 421 and U.S. Route 501), and away from proposed Megasites and highly developed areas by 2060. Existing development and potential future development around major transportation corridors and Megasites would increase the total developed area ratio over 20%, thus making the functional return on mitigation efforts much more challenging.

2.5.4 Lessons Learned

In addition to the Key Considerations discussed in Section 2.1.1, there are specific lessons learned from the Land Use Conversion sub-model analysis. The key lessons learned are documented below:

- **Other Potential Data Sources**
  - In the development of the Land Use Conversion sub-model, other datasets were evaluated but not included in the current analysis due to a combination of reasons (see Table B-1 in Appendix B). However, it may be useful for DMS to consider some of these data sources for future watershed planning efforts. More specifically, VHB recommends looking into the travel demand models that are available for certain regions of North Carolina. These models use current travel behavior to predict future travel patterns, which can be used as a proxy for potential development hotspots. In addition, VHB recommends investigating projected population growth using a combination of historical and current census data. While the USGS FUTURES model accounts for population growth, the model itself uses county-level population

inputs. If DMS desires for a finer scale projected population growth analysis, the census data may be analyzed at the block group level.

- **Future Research Opportunities for Development Models**
  - While both the USGS SLEUTH and USGS FUTURES models are comprehensive development models, the existing model results are limited in two ways. First, these models are typically designed to address larger regional development questions. As such, the spatial resolution of the data inputs and model results tends to be coarser than desired for site-specific studies. For the Cape Fear study area, corrections had to be made to include proposed Megasites and to exclude site-specific features. Note that VHB's corrections are limited because these corrections were simply added or subtracted as overlays from the existing model results. A better approach is to update the models themselves to include these corrections for a more accurate growth projection. Second, there is a disadvantage in using previously run model results in terms of data accuracy. Both the USGS SLEUTH and USGS FUTURES models were run in the early 2010s using data inputs prior to this period. As such, any land use, transportation, population, and other inputs used to initialize the growth models would not have captured conditions after the model release date. Therefore, conditions between the early 2010s and the time of the current study period are not captured in these two models.
  - While it was not within the scope of the current analysis, it may be beneficial to modify and to re-run the USGS SLEUTH and USGS FUTURES models to better reflect site-specific features and current conditions. The level of effort needed to run both models are very high, and as such, this may be a good future research opportunity for DMS and its partners.

2.6 Focus Area Total Scoring Approach and Results

The Focus Area Total Scoring Approach section includes a discussion on the Focus Area Total Scoring Weighting (Section 2.6.1) used on the sub-models, the Focus Area Results (Section 2.6.2) with discussion on key improvements made since Task 1, the observed Overlap with Preservation Areas (Section 2.6.3), Considerations for Task 4 (Section 2.6.4), and Resources for Future Watershed Planning Efforts (Section 2.6.5).

2.6.1 Focus Area Total Scoring Weighting

VHB's approach to developing the Focus Area Total Score is to normalize the sum of the four contributing sub-models. With concurrence from DMS, equal weighting was used because each sub-model is expected to have equal relevance in the prioritization of catchments for mitigation. The Total Score is as follows:

$$\begin{aligned}&Focus\ Area\ Total\ Score\\&\qquad = (Water\ Quality\ Score + Habitat\ Score + Hydrology\ Score\\&\qquad + Land\ Use\ Covnersion\ Score)/4\end{aligned}$$

Note that the above normalization constrains the Focus Area Total Score between 0 and 1, with higher scores indicating that the catchment is more desirable for mitigation due to a combination of watershed impairment metrics, mitigation feasibility, and potential resource values.

2.6.2 Focus Area Results

Figure 2-14 shows the results of the Focus Area Total Scores. The Water Quality and Habitat sub-model scores have Gaussian distributions, while the Hydrology and Land Use Conversion sub-model scores are more concentrated at certain values given the scoring schemes. Figure 2-15 below shows a histogram of the composite Focus Area Total Scores, which have a bimodal Gaussian distribution as a result of these differences (Figure 2-15). More specifically, the Land Use Conversion scores appears to be a driving factor in the separation of scores given that 62% of the catchments either had a score of 0 or 1. In other words, while the Land Use Conversion sub-model only accounts for 25% of the Focus Area Total Scores, its behavior is driving the separation in the final catchment score. Overall, by design of the sub-model combination and the LUC scoring, the Focus Area results are not surprising.

Given that it often takes years for mitigation projects to develop and to complete, the inclusion of the future land use conversion in the Focus Area results was determined to be essential for the achieving the long-term watershed planning goals of this RWP. While the current analysis is designed to identify future hotspots for mitigation opportunities using the Focus Area result, DMS and VHB acknowledge that the Focus Area results may be evaluated in a number of ways to achieve different mitigation goals or other relevant priorities. Below, VHB has provided a list of potential ideas for interested stakeholders to expand on the sub-model and Focus Area analysis:

- **Identification of Existing Hotspots using Sub-Model Results**
  - The sub-model results for Water Quality, Habitat, and Hydrology may be used independently without the Land Use Conversion sub-model to identify existing hotspots for targeted water quality, habitat, or hydrology mitigation opportunities.
- **Identification of Future Hotspots using Sub-Model Results**
  - The sub-model results for Water Quality, Habitat, and Hydrology may be used independently with the Land Use Conversion sub-model to identify future hotspots for targeted water quality, habitat, or hydrology mitigation opportunities.
- **Identification of Existing Hotspots using Focus Area Results**
  - The Water Quality, Habitat, and Hydrology sub-model results may be combined without the Land Use Conversion sub-model to identify mitigation opportunities in areas where all three watershed components are prioritized.
- **Land Use Conversion Overlay for Other Priorities**
  - The Land Use Conversion sub-model results may be used as an overlay with other mitigation datasets to improve future planning efforts by prioritizing catchments at the onset of development (e.g., developed area between 0 and 20 percent of the total catchment area).
  - The Land Use Conversion sub-model scores may be reversed (e.g., 1 – LUC score) in order to develop an alternative overlay for mitigation opportunities or other

priorities that may want to focus on existing heavily develop areas or areas that are expected to be developed heavily in the future.

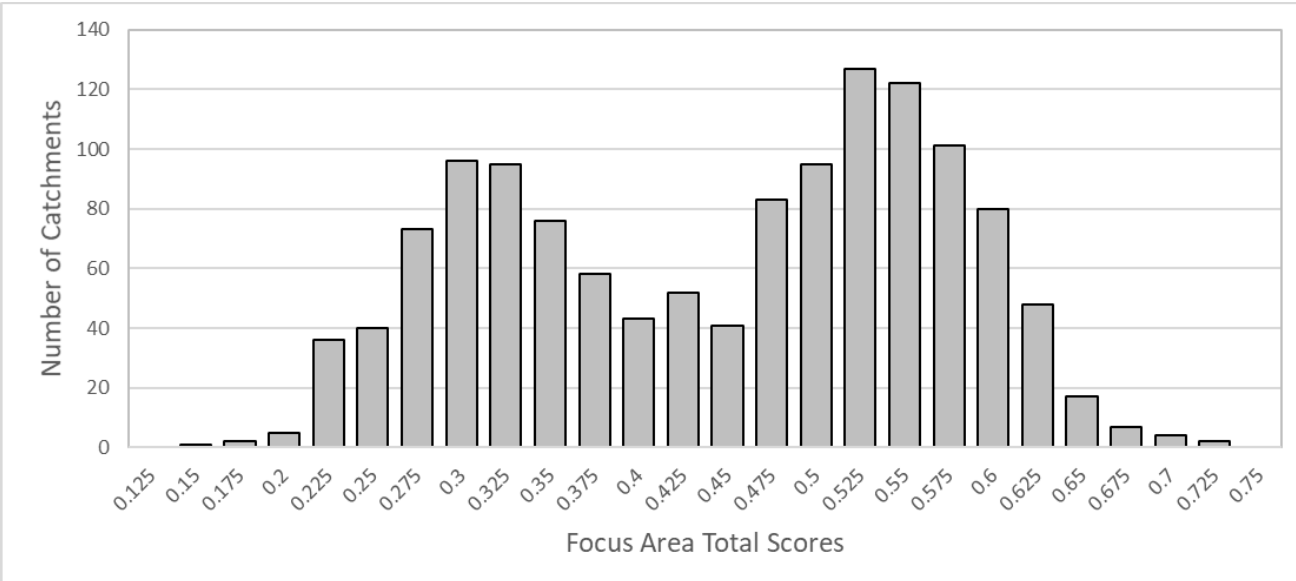

Figure 2-15. Histogram of the Focus Area Total Scores.

Improvements from Task 1 Focus Areas Analysis

A comparison of the Task 3 Focus Areas (Figure 2-14) and the Task 1 Focus Area Clusters (Figure 1-3) shows differences between these results. Most notably, in Task 1, the Land Use Conversion indicator was designed to score catchments containing Megasites as high for potential mitigation opportunities. As a result, these catchments often were identified as Focus Areas. In comparison, in Task 3, the Land Use Conversion indicator was refined per discussions with DMS to give catchments a linearly adjusted score based on a total developed area ratio that favored less developed catchments or catchments at the onset of development. As a result, catchments containing Megasites in Task 3 were often not identified as Focus Areas because they have a high potential for development, which may render mitigation efforts less effective in the future.

In addition, the Task 3 Focus Areas are likely different because many of the Task 1 Focus Areas indicators were either refined or removed. Moreover, new indicators were added to Task 3 as new datasets became available. Overall, the list below highlights the similarities and key changes that VHB made to improve the Task 3 Focus Areas analysis:

- **Indicators Retained from Task 1**
  - The Impaired Streams indicator was the only indicator retained and carried forth from Task 1 to Task 3.

- **Indicators Improved from Task 1**
  - The SPARROW-derived water quality indicators were reworked extensively between Task 1 and Task 3 to expand the analysis to evaluate both incremental and cumulative pollutant loads and to evaluate them based on mitigable pollutant sources, such as from agricultural and developed areas.
  - The Buffer indicator was improved significantly using two new and higher resolution datasets to identify degraded buffers by both tree density and tree canopy height at the stream-reach level.
  - The Erosion indicator was expanded to include four potential sub-indicators for identifying potential erosion in a catchment. Task 1 only used the USDA K Factor as a proxy to determine a catchment's susceptibility to erosion.
  - The Field Habitat indicator was improved to address data gaps in the NCDWR Fish Assessment and Benthic Macroinvertebrate habitat scores identified in Task 1. In Task 3, VHB performed both targeted field investigations and developed regression relationships to determine habitat scores for the whole study area.
  - The Crossings indicator was improved to identify all potential streams crossings in a catchment using the higher quality NCDOT ATLAS Stream datasets. The scoring for this indicator was also updated to better align with DMS' approach for assessing stream crossings using a structure length to stream length ratio.
  - The Potentially Suitable Habitat indicator was improved using new datasets and guidance directly from USFWS.
  - The Future Land Use indicator was improved to predict potential future development over a longer model horizon and using multiple land use conversion models as inputs.
- **Indicators Not Carried Forth in Task 3**
  - The Fish Assessment and Benthic Macroinvertebrate Biological Integrity Class indicators were not carried forth due to the observed data gaps that could not be addressed.
  - The Stream Type indicator was not carried forth due to concerns about the data quality of the perennial and intermittent stream classification in the USGS NHDPlus V2 dataset.
  - The Stream Order, Developed Area, and Agricultural Area indicators were not carried forth as standalone indicators because they were used in the refinement/development of the other Task 3 indicators.
  - The Water Supply Watershed was not carried forth in Task 3 but it may be used as a potential favorable factor in Task 4 for prioritizing restoration strategies.
- **New Indicators in Task 3 Only**
  - Two Ponds indicators were developed for the Habitat and Hydrology sub-models using the USGS Ponds dataset that was made available after Task 1.
  - The Potential Wetland Areas indicator was developed and added to Task 3 in order to identify potential wetland restoration opportunities.

- The Dams indicator was developed for the Hydrology sub-model using a combination of the new SARP Dams and existing NCDELMR Dams datasets.
- The Floodplain Area indicator was developed for the Hydrology sub-model in order to identify potential areas for improving hydrologic connectivity.

2.6.3 Overlap with Preservation Areas

Figure 2-16 shows the results of the Focus Area Total Scores with the Preservation Area Clusters (a total of 390 catchments identified from Task 1). These results showed that 70 out of 1304 catchments (or 5%) scored high in both the Focus Areas (Total Scores greater than 0.5) and have also been identified as a catchment with preservation potential.[18]A driving factor in these overlapping catchments is the Land Use Conversion sub-model scores. The Land Use Conversion sub-model favors catchments that are less developed or at the onset of development. As a result, this scoring scheme likely identified catchments that have existing watershed qualities that were used to identify the Preservation Areas (e.g., high natural areas, managed areas, critical habitats, forested areas, wetlands, and etc.). Overall, these overlap catchments present an excellent opportunity for DMS' partners (e.g., Triangle Land Conservancy, NCNHP, etc.) to identify areas where they may want to consider preservation opportunities..

2.6.4 Resources for Future Watershed Planning Efforts

As documented in Key Considerations (Section 2.1.1) and the respective Lessons Learned under the sub-model sections, DMS may use the approaches that VHB developed to address a number of challenges that may arise in future planning efforts. These resources include:

- Identification of 60+ data sources, data tools, and data models that may be used as a resource in future planning efforts.
- Sixteen indicator methodologies for assessing water quality, habitat, hydrology, and land use conversion issues.
- Detailed method for water quality assessment using a baseline approach.
- Strategy for targeted field investigations and extrapolation methods for addressing data gaps.
- A range of scoring schemes (e.g., positively linear, negatively linear, piecewise linear, exponential, and threshold response) based on the underlying watershed issues and how they may be linked to mitigation.
- Prioritization of mitigation from multiple angles (e.g., as watershed stressors, potential resources, and feasibility).

[18] Per discussion USFWS and NCNHP, some catchments were manually flagged as Preservation Areas in order to improve habitat connectivity in the study area. These catchments automatically received the highest Preservation Area scores. For the high scoring Focus Area comparison, these artificially inflated Preservation Areas were not counted.

3

Mitigation and Restoration Recommendations

The North Carolina Division of Mitigation is charged with managing the in-lieu fee, or compensatory mitigation, program for the state. Per the United States Environmental Protection Agency (USEPA), compensatory mitigation is defined as the "restoration, establishment, enhancement, or in certain circumstances preservation of wetlands, streams, or other aquatic resources for the purpose of offsetting unavoidable adverse impacts."[19] The purpose of compensatory mitigation is to offset unavoidable adverse impacts which remain after all appropriate and practicable avoidance and minimization of impacts have been achieved. Overall, the objective of Task 4 of the Regional Watershed Plan is twofold: 1) to connect the evaluation and scoring performed in Task 3 to potential mitigation strategies and to aid DMS in the prioritization and selection of future mitigation

[19] https://www.epa.gov/sites/default/files/2015-08/documents/compensatory_mitigation_factsheet.pdf

opportunities; and 2) to provide relevant stakeholders and providers recommendations for restoration strategies and prioritization.

3.1 Introduction to Compensatory Mitigation

The first steps when considering adverse impacts from development are to avoid and to minimize these impacts as much as possible. After every appropriate and practicable measure to obtain avoidance or minimization has been achieved, there still may be additional unavoidable impacts due to human activity. In cases such as these, compensatory mitigation may be required to offset any negative effects to the environment. According to the USEPA, there are four methods of compensatory mitigation:[20]

- **Restoration** refers to the re-establishment or rehabilitation of a wetland or other aquatic resource with the goal of returning natural or historic functions and characteristics to a former or degraded aquatic resource.
- **Establishment** refers to the development of a wetland or other aquatic resource where one did not previously exist through manipulation of the characteristics of the site.
- **Enhancement** refers to activities conducted within existing aquatic resource areas that heighten or improve one or more functions.
- **Preservation** refers to the permanent protection of ecologically important aquatic resources through the implementation of appropriate legal or physical means, such as conservation easements.

As part of mitigation efforts in the state of North Carolina, DMS implements three of the above methods to achieve their goals: restoration, enhancement, and preservation. Note that the goals of mitigation and restoration are aligned in this context, and hence the implementation recommendations and prioritization described below will be applicable to both.

3.2 Mitigation and Restoration Approaches

DMS employs a watershed approach to mitigation (and hence restoration) in accordance with requirements set by USEPA. A watershed approach maintains and improves the habitat quality and maintains no net loss of aquatic resources throughout a watershed through strategic selection of potential sites within said watershed. The Focus Areas identification and the modeling strategy discussed in this report was designed to address this goal by providing an overview of the watershed condition with the following considerations:

- Habitat requirements of important species
- Habitat loss or conversion trends
- Sources of watershed degradation
- Current development trends

VHB considered a number of mitigation and restoration approaches for the RWP. These

[20] https://www.epa.gov/sites/default/files/2015-08/documents/compensatory_mitigation_factsheet.pdf

strategies include:

- Stream Restoration
- Barrier Removal (e.g., removal of anthropogenic barriers to hydrology or habitat – dams, berms, culverts, etc.; most often conducted in conjunction with stream restoration)
- Riparian Buffer Restoration
- Wetland Restoration
- Agricultural BMPs
- Stormwater Control Measures (SCMs)
- Nutrient Offset Mitigation

Due to overlap in the contributing factors (see explanation below) and the feasibility constraints of the above approaches, this list was narrowed down to two main strategies that were most practical for DMS and other relevant stakeholders to implement in the RWP study area. These two strategies are:

- Stream and Wetland Restoration
- Riparian Buffer Restoration and Nutrient Offset

Per discussions with DMS, the Stream Restoration and Wetland Restoration strategy was combined into one strategy because indicators for these strategies are closely aligned and often overlap. Consequently, DMS typically implements Wetland Restoration as a part of a larger Stream Restoration effort. Similarly, Riparian Buffer Restoration and Nutrient Offset projects are often performed together because functioning buffers are designed to trap and to process nutrient loads before they become water quality issues. Note that the Riparian Buffer Restoration and Nutrient Offset strategy is only applicable in areas where the North Carolina Riparian Buffer Rule 15A NCAC 02B.0267 applies.[21] In the RWP study area, the Jordan Lake Water Supply Watershed (or the area contained within the Cape Fear 02 boundary) is regulated under the Riparian Buffer Rule. As such, the Riparian Buffer Restoration and Nutrient Offset results will be constrained to the Cape Fear 02 boundary.

3.3 Prioritization for Mitigation and Restoration

Tasks 1 and 3 were focused on scoring the catchments within the study area to identify the greatest potential for functional improvement so that improvement efforts are implemented in areas of high return. Task 4 is designed to identify areas that can be prioritized for practical mitigation and restoration action.

Per discussions with DMS, catchments that fall within the following categories were identified and prioritized for mitigation and restoration:

- **Focus Area Prioritization**: If a catchment is within the Focus Areas identified in Task 3 (defined as the top 40 percent by area of the total scores).
- **Sub-model Prioritization**: If a catchment is within the top 10% (by area) of the three sub-model scores computed in Task 3: Water Quality, Habitat, and Hydrology.

[21] http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2002%20-%20environmental%20management/subchapter%20b/15a%20ncac%2002b%20.0267.pdf

- **Stream and Wetland Restoration Prioritization**: If a catchment contains a high score as computed by VHB's scoring matrix (see Table 3-1).
- **Riparian Buffer Restoration and Nutrient Offset Prioritization**: If a catchment contains a high score as computed by VHB's scoring matrix (see Table 3-2).

The Focus Area Prioritization is designed to identify the top scoring catchments as determined from the Task 3 analysis, with an emphasis on prioritizing mitigation and restoration in areas before the onset of future development (Figure 3-1). The Sub-Model Prioritization is designed to complement the Focus Area Prioritization and to target specific functional categories in a catchment (Figure 3-2 to 3-4). The Land Use Change sub-model was excluded from the Sub-Model Prioritization since it was a key driver in the Focus Area Prioritization.

For both the Stream and Wetland Restoration Prioritization and the Riparian Buffer and Nutrient Offset Prioritization, VHB worked with DMS to develop a scoring scheme using select Task 3 indicators to identify catchments that would be most suitable to prioritize for mitigation and restoration (Figure 3-5 and 3-6, respectively). Table 3-1 and Table 3-2 provide a summary of the selected indicators, weights used, and the final scoring schemes for these two strategies. These scoring schemes were designed to range between 0 and 100, where a 100 represents a catchment most desirable for mitigation and restoration. The weights for the different indicators were, in part, developed based on the quality of the input datasets as well as relevance to mitigation/restoration feasibility. Note that in the study area, some catchments received a null Buffer score in Task 3. These were typically small catchments with no stream segments or only contained large waterbodies. As such, in both scoring schemes, a null Buffer score was equated to a zero Buffer score assuming that these catchments contained no or low functioning buffers.

Table 3-1 Stream and Wetland Restoration Prioritization Scoring Scheme

Select Task 3 Indicators	Weight (W)
Impaired Streams	0.1
Buffer	0.2
Erosion	0.075
Floodplain Area	0.075
Crossings	0.075
Potentially Suitable Habitat	0.075
Land Use Change	0.2
Potential Wetland Area	0.2
Sum of Weights	**1**

Stream and Wetland Restoration Score = (Impaired Streams Score*W_{IS} + Buffer Score*W_B + Erosion Score*W_E + Floodplain Area Score*W_{FA} + Crossings Score*W_C + Potentially Suitable Habitat Score*W_{PSH} + Land Use Change Score*W_{LUC} + Potential Wetland Area Score*W_{PWA})*100

Table 3-2 Riparian Buffer and Nutrient Offset Prioritization Scoring Scheme

Select Task 3 Indicators	Weight (W)
Buffer	0.25
Crossings	0.1
Potentially Suitable Habitat	0.1
Land Use Change	0.2
Agricultural Incremental Contribution	0.25
Agricultural Cumulative Contribution	0.1
Sum of Weights	**1**
Riparian Buffer and Nutrient Offset Score = (Buffer Score*W_B + Crossings Score*W_C + Potentially Suitable Habitat Score*W_{PSH} + Land Use Change Score*W_{LUC} + Agricultural Incremental Contribution*W_{AIC} + Agricultural Cumulative Contribution*W_{ACC})*100	

Overall, the combination of the Focus Area Prioritization, Sub-Model Prioritization, Stream and Wetland Restoration Prioritization, and the Riparian Buffer and Nutrient Offset Prioritization are designed to be used together to aid DMS and other relevant stakeholders in the prioritization and selection of future mitigation and restoration opportunities in the RWP study area.

3.4 Final Thoughts

Development of the Cape Fear 02/03 Regional Watershed Plan provided an opportunity to study the watershed on a more granular scale and to identify and to further evaluate stressors that may not be apparent drivers when working at a larger spatial scale.

Under this task, VHB worked with DMS to pilot the approach of using the results of the Focus Area and Sub-Model Prioritization to inform and to prioritize potential restoration activities. The results provide DMS and its stakeholders a roadmap to implementing restoration and preservation activities in areas where the greatest uplift potential exists, thereby creating more robust, diverse, and stable ecosystems in the future.

VHB's watershed modeling approach provides an opportunity to prioritize those areas at the greatest risk of functional loss so restorative and protective measures can be implemented prior to land conversion or impacts. By providing watershed results at the catchment-scale, DMS can quickly and fairly assess potential mitigation sites presented internally by DMS or externally by outside providers for potential restoration uplift based on its location within the greater watershed.

This RWP has shown that more detailed analysis can provide additional insights and prioritization results and therefore can serve as a template for future plans in other watersheds across the state that may benefit from a more comprehensive review. Through this study, VHB has developed informed approaches that align with the needs and goals of the DMS compensatory mitigation program that can be replicated across North Carolina.