The Ultimate Commons:
Examining The Connection Between Ways of Life And Waterways

"The invisibility of water in our lives isn't good for us, and it isn't good for water. You can't appreciate what you don't understand. You don't value and protect what you don't know is there."
-Charles Fishman, Author of *The Big Thirst*

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This unit is recommended for:
8th Grade Science

Keywords: water quality, potability, dissolved oxygen, temperature, turbidity, nitrates and phosphates, bio-indicators, river basins, runoff, stormwater, urban stream syndrome, CAFOs, SSOs, marine, ecosystems, stewardship, sustainability

Teaching Standards: See Appendix 1 for teaching standards addressed in this unit.

Synopsis: In this unit students will explore how water shapes our world, and in turn, how their actions shape water. By examining the cascading consequences of their own water "ways" from what they drink, to what they flush, to what they throw away, students will realize that the impacts of small choices are far reaching. The unit is split into two parts: "The Water We Drink," and "The Water That Connects Us." While "The Water We Drink" focuses on water quality, accessibility, treatment, and legislation, "The Water That Connects Us" concerns the migration of water from rivers to marine ecosystems and how our actions in river basins impact both. To connect and engage students both units are framed through a storytelling lens that leverages inquiry to sequentially build. First, students will come to see themselves as characters with something at stake. Next, they will investigate issues that highlight a disconnect between what they learn is right and what they see in practice. Finally, during a unit capstone students partner with local organizations to brainstorm solutions that can change the narrative of their local water systems and the lives those systems support.
Our 8th grade Science team plans to teach this unit to our 270 students this upcoming school year

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Laura Thrash

Introduction

On the surface, many students know that water is important. It satisfies our thirst and sustains our bodies. We use it to clean, to cook, and to play. Water is a central part of our lives, and yet, absent from our everyday thoughts. In Charlotte our access to safe, affordable water has allowed us to take it for granted as a functional resource instead of a relational one. This is especially pertinent to Whitewater Middle, a Title 1 school located in CMS' Northwest learning community. Of our 836 students, 52% are African American, 26% are Hispanic, and 100% are free and reduced lunch. We are less than a mile away from the U.S. National Whitewater Center, but many of our students have never been on the Catawba river. We have potable fountains, but students consume sports drinks and soda instead. Both of these examples highlight a surprising disconnect between people and place: our kids are surrounded by water, but drink less of it than they should. They live in neighborhoods named after creeks but are unaware of where those creeks are, how they drain, and the lives they support. A main rationale of this unit, therefore, is to close the gap between people and place by creating an opportunity for students to explore how water shapes their local neighborhood, and in turn, how their actions shape water

Another motivation is to lend relevance and rigor to a unit that up until now has been broad and general. According to district pacing suggestions, the eight grade Hydrosphere unit is allotted eleven days for students to master four standards encompassing water properties, global water distribution, water quality, water legislation, the importance of stewardship, and water's movement through river basins, estuaries, upwellings, and ocean ecosystems. To make matters more nuanced, eight grade scores are held to End of Grade assessments that contribute to the school's overall report card. For many schools like Whitewater, there is pressure to move through standards at a fast and surface-level pace, giving students just enough background knowledge to master the content on a multiple choice exam, but not enough to generate a deep understanding.

In 2018 Whitewater was chosen by Charlotte Mecklenburg Schools to become an Environmental STEM magnet. Throughout the rebranding process our school underwent the process of rewriting a collaborative mission and vision. When discussing what we want for students our staff arrived at an answer that went beyond passing a test. Our mission is to create students who are "self-aware and socially conscious leaders who think critically, communicate confidently, and act sustainably." Our vision is that these skills enable them to become "creative revolutionaries, who as critical thinkers and empathetic citizens create solutions for a better world." Making this mission and vision live and breathe will be an ongoing process that necessitates a reframing of the Science curriculum through the lens of sustainability and social justice and serves as the final motivation behind this unit's creation.

In Susan Sanstone's work *Reframing the Curriculum Design For Social Justice and Sustainability* she links the United Nations' education for sustainable development program (ESD) with the educating for social justice pedagogy (ESJ) that has become pertinent in marginalized communities with a history of being oppressed. Sustainability and social justice are both loaded terms. For the sake of this unit, I will be adopting the definitions she sets forth.

> Sustainability: **"**Enabling all species to thrive now and into the future in an equitable way within the means of their environment.[1]"
>
> Education for Sustainable Development**:** the process of developing citizens who fulfill the sustainability vision. This pedagogy nests schools within communities and prepares its citizens to play multiple roles from systems thinkers and critical thinkers to effective problem solvers and peacemakers, to empathetic and emotionally healthy individuals.[2]
>
> Oppression: **"**Power + Prejudice." The dominant group consciously or unconsciously enjoys advantages while the subordinate groups are systematically disadvantaged.[3]
>
> Social Justice: The "counter" to oppression. Social justice aims to "dismantle unjust systems and structures" for the outcome of ensuring "full and equitable participation by all matters and social groups."[4]
>
> Educating for Social Justice: A learning process with the aim of supporting child development, ensuring a healthy environment, and addressing institutional inequality.[5]

What these definitions show is that social justice is nested within the concept of sustainability. You cannot be sustainable unless all people have equitable access to the things they need to sustain themselves. ESD and ESJ pedagogies must, therefore, operate in tandem because both emphasize the ability for students to make a life for themselves and a life for their community by replacing the "ecological and social crises they'll inherit" with a better story[6]. In order to prepare students to write a different ending, Sandstone argues for the organization of curriculum around three competency domains:

1. Knowledge: what literacies do students need to understand
2. Skills: what specific competencies do they need to improve their lives and the lives of community members
3. Dispositions: what mindsets and orientations will provide this compass

Together, Sandstone argues, these make the "head, hands, and heart" or learning that will allow students to understand what's at stake, invest in the lives of those impacted, and generate solutions[7]. When reflecting on our Whiewater's demographics, our sustainability magnet designation, and our new mission and vision, the alignment to ESD and ESJ is clear. Therefore, I am taking Sandstone's advice and aligning my unit goals and the strategies I will implement to achieve them to each of the 3 domains.

Unit Goals and Strategies

Goal 1 Knowledge: Students will Achieve Proficiency on Hydrosphere Unit Assessments

Content is the substance of curriculum so despite pursuing loftier goals, I will not lose sight of standards-alignment and strategies that enable students to achieve a baseline understanding of the Hydrosphere standards. In CMS, middle school science classrooms instruct students of varied levels from english language learners and exceptional children to honors without the additional push-in support Math and English Language Arts teachers are provided. In the past at Whitewater we have had integrated classroom models with varied levels in the same room as well as cohorted models where students are grouped into homogeneous EL, EC, Standard, and Honors blocks. With class size ranging on average from 25-30, meeting the needs of all students can sometimes prove challenging. The eighth grade science End of Grade is at its core an inferencing exam. If students have a knowledge of academic vocabulary and the ability to reason through different options, they can demonstrate proficiency. Over the last four years in the classroom I have taken Whitewater science proficiency from 35% to 85% by infusing strategies from the The Sheltered Instruction Observation Protocol (SIOP) and Culturally Responsive Teaching (CRT) models into everyday instruction.

Vocabulary Instruction

When teaching academic vocabulary I use a variety of mnemonics through color-coding, images, and repetition. The Institute for Color Research confirmed that color can improve learning from 55 percent to 78 percent as well as comprehension by as much as 73 percent[8]. Therefore, whenever I introduce a new vocabulary word I color the term intentionally and ask guiding questions to help students deduce the meaning. For example, when introducing a term like " hydrosphere" I color hydro blue and sphere green. Next I ask "Hydro sounds like hydration. When you hydrate, what do you drink? (water)." "Sphere is a globe, like our world, so the hydrosphere is all water on earth." On a cognitive level, around 80 to 90 percent of content the brain absorbs is visual. Studies on memory have found that one of the easiest ways to ensure that learners store information in their long-term memory is to pair concepts with meaningful images.[9] After revealing the definition of a term I accompany it with a visual. For hydrosphere, that image is typically a water droplet next to a globe. Repetition of information strengthens connections in the brain, and the brain encodes information most efficiently when content is repeated in multiple ways.[10] After I introduce the definition I have students repeat it back to me using a fill-in-the blank style call and response. For example, the hydrosphere is all (water) on (earth). The key is that this visual and verbal repetition doesn't stop at the end of the lesson. According to the brain, review of information should happen at gradually lengthening intervals to reinforce neuronal connections. The more practice students have, the stronger these connections become.[11]So every time the term hydrosphere comes up in a future lesson I use the same color coding and image to prime students to give me the correct call and response definition until it becomes automatic.

Inferencing

I also utilize color, visuals, and repetition during implicit vocabulary instruction when students are asked to apply content knowledge in order to make an inference. At the middle school level some students struggle with reading a statement and using context clues to determine whether the question is asking for something good vs something bad. To help close this gap, I will often color “good” signaling words and phrases like “ benefit,” “advantage,” “pro,” or “argument in support of” green and pair them with a green thumb-up visual to imply that the question is asking for something “good.” On the flipside I will use red color-coding for words and phrases that signal “bad” like “concern,” “disadvantage,” “con,” or “argument against” paired with a red thumb down visual to signal the question is asking for something “bad.” After we've identified what the question is asking, we go through the answer options as a class, and students indicate with a thumb up or down whether the context of each statement is good or bad and get practice in using the process of elimination to deduce the answer. As classes grow more confident in their inferencing skills, these scaffolds are removed.

Communicating Content Knowledge

The brain has an inherently social nature so opportunities for social interaction enables learners to increase their comprehension and retention of new information[12] The SIOP Model is a research-based and validated instructional model that has been proven effective in addressing the academic needs of English learners throughout the United States.[13] One of their 8 components, Lesson Preparation, recommended that teachers incorporate both content and language objectives into every lesson.[14] When teaching I adhere to this practice by making sure that every student is asked and given feedback on their ability to read, speak, listen, or write about the topic they learned in class. For example, during one of our first Hydrosphere lessons a content objective is for students to describe the percent distribution of fresh and saltwater on earth while the accompanying language objective is for students to explain orally why even though water is a renewable resource, there can still be water shortages. To maintain alignment to the EOG test, the content objective is typically measured by student proficiency on a multiple choice exit slip. The language objective is slightly different. In this case, one centered on speaking is assessed through my aggressive monitoring of a student's turn and talk where students answer the question in partner groups. Throughout I circulate and use real-time responses to identify any gaps. After the turn and talk, I bring it back whole-class to close these gaps through inquiry. For example, “I heard one scholar say that water shortages can happen because most water is salty. To improve this person’s response what numerical detail might I add?” Or “What vocabulary word can I say instead of salty...Great, so there can be water shortages because 97% of earth’s water is saline.” After addressing misconceptions I ask students to take a moment and write a revised answer making sure it includes specific vocabulary and percentages before having them share with their neighbor again. This act of thinking, speaking, writing, and revising helps solidify content knowledge, while also building communication skills.

Maximizing Participation and Engagement

In Title 1 classrooms where a disproportionate number of teachers are new and inexperienced are higher, it is easy to unconsciously exclude ELs and EC students from class participation. To create a culture of high expectations in my classroom I draw from both SIOP’s recommendations to offer a variety of questions with wait time and appropriate scaffolds, paired with the “No Opt Out” technique drawn from Teach Like A Champion. One example of this is a classroom strategy called roll’em . This activity typically takes place as a check for understanding. I randomly roll a dice and have all students with that desk number stand. Each student is asked at least one question during the series, and no one can sit down until everyone has answered. To ensure wait time I always ask the question first and allow time before calling on one of the standing students to answer. When necessary I may ask that question in their native language to clarify. If a student doesn't know I use the no opt out technique of going to a peer who does know the answer before immediately returning to the original student to repeat the correct response.[15] The randomness of the dice paired with the expectation that all students must answer helps ensure equitable participation.

In addition to wait time and clarifying questions in a native language, SIOP also emphasises the importance of varying grouping configurations and recommends that at least two different grouping structures be used during a lesson.[16] In my classroom I utilize homogeneous pairings during small group support. This is when I pull my lower level students up to the front to build background and comprehension while the others work asynchronously. I use heterogeneous pairings for partner and group conversations, so students have the opportunity to collaborate with peers at different levels. To ensure these conversations are productive I set norms prior to the release, assign specific roles, set timers, and circulate to monitor conversations.

In addition to no-opt out strategies, wait time, and grouping configurations, the final component of maximizing student engagement is a strategy known as aggressive monitoring. Aggressive monitoring takes place during the independent practice portion of a lesson. I circulate the room 2-3 times with a pen in hand to provide real-time feedback to students on select questions. I use standardized marking codes to communicate with students. For example, my students know that if they have a check their answer is correct, if they have a dot there is some aspect of the answer they need to fix. When the student response falls short I name a quick fix to address the learning gap and then circulate quickly enough to follow up with that student in the next round. To make sure providing the "fix" is fast, I script an exemplar response beforehand and plan for error around common misconceptions. Other considerations for successful aggressive monitoring include having a set pathway that views higher level student responses first. While this may seem counterintuitive, the reasoning for this method is to catch whole-group misconceptions early on: if my highest students are struggling, everyone else likely is too[17].

Lesson Flow and Feedback

The human brain runs on 90 to 120 cycles called ultradian rhythms which influence things like attention, interest, cognition, memory, visual perception, and behavior. On an instructional level, it is important to accommodate these cycles by varying activities every 12 to 15 minutes.[18] This is also a recommendation of SIOP which suggests that teachers divide content into meaningful short chunks with the opportunity to receive teacher feedback.[19] To honor both, my standard lesson flow typically follows a modified version of the 5E Model. The 5E model has 5 key components: engage, explore, explain, extend, and evaluate.[20] While the true 5E model may take place over the course of a couple of weeks, due to pacing constraints I have modified the model to take place within a single class. To honor the brain's time clock, each component is typically broken into 10-15 minute parts with at least two opportunities for real-time feedback The "engage" is a warm up question intended to grab students' attention, gauge background knowledge, and introduce the objective. During the "explore" portion of the lesson students are cast out to investigate an aspect of the objective either independently or in partner groups.

During the “explain” I check for understanding and address misconceptions. In the “extend” students are released again to apply the aspect of the objective they just explored to a real-world scenario**.** In the final portion of the lesson, the “evaluate,” I used data gathered during my aggressive monitoring rounds to address common misconceptions before moving students on to independently complete their exit slip. In addition to varying the activity, I also make sure to vary the sources for each of the 5Es. Throughout a single lesson it is not uncommon for students to analyze one topic using articles, videos, images, data tables, graphs, and charts.

Goal 2 Skill: Students Will Utilize Systems Thinking To Propose Solutions To Local Problems

The overarching hydrosphere standard addresses the interconnectedness between humans and water by requiring students to understand how their actions impact local systems and how hydrosphere impacts them. If students have a baseline understanding of content knowledge from goal 1, then on a surface level they will understand that nothing exists in isolation and that they are members of an ecological community. But in order to move from “understanding” into the action that ESD and ESJ propose, then students must also have the skill of systems thinking and the dispositions of efficacy.

For students in Title 1 schools like Whitewater the development of higher order thinking skills is especially important. In her work *Culturally Responsive Teaching and the Brain*, Zaretta Hammond notes that underserved English learners, poor students, and students of color “routinely receive less instruction in higher order skills development than other students,” and that their curriculum is “less challenging and more repetitive.” [21] On an individual level this “denies” students the opportunity to engage in the “productive struggle” that actually grows their brainpower. On a larger scale, this denial contributes to an “epidemic of dependent learners” who are “unprepared to do higher order thinking and creative problem solving.[22]” In other words, if we were to stop at effective vocabulary and inferencing strategies outlined in goal 1, we would be doing enough for students to regurgitate information and pass an End of Grade test, but not doing enough to live out our vision and develop students with the creative and critical thinking skills needed to make solutions for a better a more equitable, sustainable, and just world.

Systems Thinking hinges on interconnectedness. In order to model interconnectedness from a lesson planning standpoint, I have chosen to infuse standards into our Hydrosphere unit that up until now have been taught in isolation. For example, looping in our standard 8L1 on bacteria when focusing on how E Coli outbreaks due to sewage runoff could impact the water of students in Union County. Including our 8P1 standard on chemical reactions when explaining how grease can bond with calcium to form fatberg, which clogs pipes and leads to sanitary swerve overflows, and infusing standards from 8L3 when investigating how the migration of plastics from roads to storm drains to rivers and oceans negatively impacts marine ecosystems. I have also enlisted the support of teachers to make content taught in this unit interdisciplinary in nature. For example, as part of their unit capstone project, some students will partner with ELA and Math classes for the goal of reducing single use plastic on campus. In Math 1, students will track the number of plastic bottles our school recycles through our partnership with Envision Charlotte’s Send Me On My Way program. Using this data they will create a school wide PSA for reducing the use of single use plastic bottles in favor of reusable ones, and write a reusable bottle “donors choose” for students who need them. In ELA, students reading Trash Vortex will draw inspiration from 2014's Keeping Watch Plastic campaign to create plastic pollution "sparkwork" to showcase in our cafeteria and bring awareness to waste.[23] In science they will combine the plastic bottle data points collected in math, statistics from Trash Vortex, and knowledge gained in class in order to petition CMS nutrition to ban the ordering of plastic-spork-straw packets in favor of more sustainable utensil options. Through investigating the same problem, trash, through different science standards and different contents lenses students will gain an educational experience that models the interconnectedness of the local school and ecological systems in which they belong.

On a more specific level, I will have students practice systems thinking when investigating issues of water quality and access through national case studies just prior to the start of the unit. Instead of viewing each study in isolation, students will be asked to view them together in order to pinpoint replicating patterns. For example, when students study Toxic algae bloom in Toledo and aquifer depletion in California they will study the science behind what happened as well as the legislation or lack of legislation that was in place. The pattern they will be able to deduce is that both lack of legislation (like California's delay in regulating groundwater until 2014), or lack of complete legislation (like the Clean Water Act's omission of nonpoint source pollutants) enabled water problems to happen and continue happening. In each case, they will also have the chance to identify another pattern--that people and community organizations step up when the government falls short. Throughout each case I will ask students to consistently consider the questions, What happened? Who is impacted? Who is responsible? And what is needed to make it right? What I hope to have students deduce from these ongoing questions is that issues of water are complex and go far beyond the personal stewardship our standard proposes. It involves individual citizens, members of the community, and local and federal governments working together as partners. Throughout the unit itself the theme of interconnectedness will appear again when students complete lessons that show their impact on the water quality downstream, and CAFOs impact on our water quality upstream. During the capstone opportunity in lesson 6, students will have the chance to pursue further relationships with local community partners that mirrors the cooperation students identified from class work is necessary for success. For example, grease down the sink and the flushing of baby wipes are two of the main blockages identified by Charlotte water as causes of sewage overflow. [24] Charlotte water has agreed to partner with us to help explain the nature of this problem and enlist the support of our students in helping to spread awareness in their home and school communities to stop damaging behavior through creative PSAs. Sandstone argues that "optimism is essential for students to believe that there is power in changing the story at hand.[25] The capstone projects on plastic reduction and sewage therefore serve two purposes: first the opportunity for students to apply systems thinking to a problem, and second, to create a learning experience that puts students in the role of positive change agents with an increasing sense of efficacy.

Goal 3 Dispositions: Students will Demonstrate Growth in Empathy and Social Consciousness as Measured by Panorama Data

Sandstone argues that while systems thinking can help students become better thinkers it will not matter unless students are invested in the people and places around them.[26] This is where empathy and social consciousness come into play. While empathy entails the ability for students to individually perspective-take, social consciousness pushes this further by asking students to consider the particular injustices faced by groups.[27] Enabling students to practice flexing their empathy muscle requires repeated opportunities to "think, reflect, and compare" one's own experiences with others.[28] To accomplish this I plan on having my students begin with the 'who' instead of the 'what' as the lesson hook. For example, in the first lesson of the unit students will begin by empathizing with students in Union county whose school closed due to an E Coli outbreak before exploring the geography of NC river basins and how a sewage overflow in their community due to the improper disposal of grease could have contributed to this problem directly. To develop social consciousness students will be asked to examine how local legislation, corporate interests, and ignorance towards streams has threatened the quality of the very river that runs through their community: The Catawba.

While I want students to be able to empathize with the stories of others, I also want to instill the belief that the stories they hear in class are also pertinent to their own. The importance of investment is also mirrored in the EPA's Urban Water's Strategic Framework which argues that in order to improve water quality and revitalize communities we must first connect and engage them.[29] To generate investment, I will adopt Sandstone's suggestion that teachers reframe their lessons into a three-part story metaphor that leverages inquiry to sequentially build.[30] During part 1 lessons students will come to see themselves as characters with something at stake. Next, they will investigate issues that add intrigue and highlight a disconnect between what they learned is right and what they see in practice. Finally, students will be given the time and space to brainstorm local solutions.[31] District panorama questions aligned to the dispositions of empathy and social consciousness will be gathered in the fall and spring to measure growth.

Due to the breadth of the Hydrosphere curriculum I will split the unit into two stories: "The Water We Drink," and "The Water That Connects Us." While "The Water We Drink" will focus on water quality, accessibility, treatment, and legislation, "The Water That Connects Us" will center on the migration of water and how our actions on land impacts the ecosystems those waterways support. While the second story is more directly linked to the topic of Urban Waterways, the first story does lay the groundwork for the skills and dispositions mentioned above and lends significance and content knowledge to the unit. Due to the link between the two I have outlined both in my section on content research.

Content Research Prerequisites

Eighth grade science standards require students to describe how water properties like polarity, cohesion, adhesion, and high specific heat impact the role water plays in the spheres. In order for students to see themselves as characters, I will use station activities to model the role water plays in the biosphere, specifically, our bodily functions. After exploring how water works in our bodies, students will investigate what makes water "good". As per unit standards, students will explore the relationship between water quality indicators like temperature, dissolved oxygen, turbidity, nitrates and phosphates, pH, and bioindicators. Next they will use these indicators to test various water sources on campus in order to determine which has the highest quality.

After testing school water students will be asked to examine their own beverage consumption in order to answer the question: If we know that water is essential for our bodies, then why aren't we drinking enough of it? In their math classes students will track their beverage intake and map them on histograms in order to determine whether their community is dehydrated. In Science, they will combine this data with sources about how teens in their demographic are advertised sugary drinks at a higher rate. They will test the pH of those acidic sugary drinks in order to conclude that some of the beverages they currently consume increase their risk of health problems like cavities and childhood obesity. At the conclusion of part 1 students will be given the opportunity to change the narrative by entering Charlotte Water's "Make Water Iconic" competition. Using their knowledge of water properties and qualities they will create a short video advertising tap water consumption to youth. If they place, they will win our school's second hydration station, thereby increasing access to potable water on campus.

During part two lessons students will investigate issues of water accessibility in order to determine that while we have access to potable water in our building, others around the world do not. Lessons in this portion will start large and zoom in. Internationally we will examine the water cycle, global water distribution, and the impact of climate change on extreme droughts and floods. We will highlight that even though water is renewable, it is not equally distributed and freshwater is at risk of depletion. On a national level I have chosen to focus on case studies that address some of the most common threats to Urban Waterways: sedimentation, heavy metal contamination, bacteria, and nutrients like nitrogen and phosphorous. At this point, students will not have learned about urban waterways or concepts like urban stream syndrome and therefore will view these contaminants strictly through a potability lens. Students will examine erosion and aquifer depletion in Arizona and Los Angeles, toxic algae blooms from nutrients in Toledo, and metal contamination in Flint. Embedded within each case study will be information on standards like water legislation, the point vs nonpoint pollutant sources, methods of maintaining water quality, and the importance of stewardship. During the final lesson of part two students will investigate the last major threat to urban water, bacteria, by considering a recent E Coli outbreak in Union County. This particular lesson will be the first of the Urban Waterways unit and will serve as the bridge that connects water potability from story one with local waterways in story two.

Lesson 1 Content Research

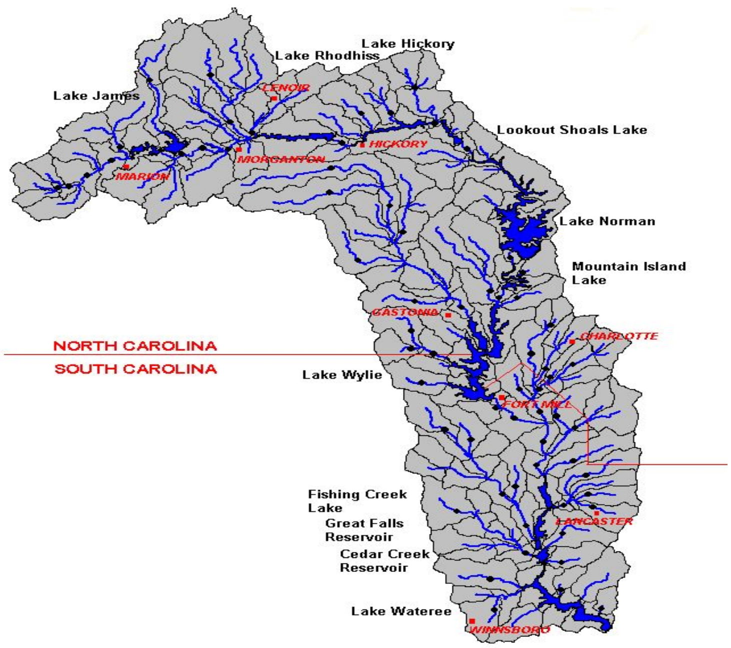
In lesson one students will have to describe the geography of NorthCarolina using key terms like tributary, river, and river basin. Next they will have to apply their understanding of vocabulary in order to explain how their actions on land could potentially impact the water of students in Union County. In terms of background knowledge, the teacher must know that tributaries are freshwater streams and creeks that feed into rivers and that most rivers are formed by many tributaries. River basins are larger areas of land that drain downhill into rivers. The final destination of the water drained by a river basin is an estuary or an ocean. Every land dweller lives in a river basin, and therefore actions on land impact actions of water quality and quantity downstream.North Carolina contains 17 river basins that drain into the Atlantic and North of Mexico.[32] See figure 1 below.

Figure 1

Mecklenburg County is located predominantly in the Catawba river basin, while about a third drains into the Yadkin.[33] We have nearly 3,000 miles of creeks, 1,000 miles of which hold water year-round. While the waterways were influential enough to shape Charlotte's settlement and transportation patterns, they went largely unprotected and were subject to pollution so much so that the 1950s Charlotte Water director, Barry Gullet, claimed it "standard practice to design city sewer systems to allow overflows into lakes, rivers or streams." In 1972, the federal Clean Water Act began to control pollution from industrial and sewer pipes. Today, our biggest threats aren't industry pollution from point sources sanctioned by the CWA, but rather nonpoint source pollution from rooftops and pavement, bacteria from feces and sewage overflow, and sediment from runoff.[34]

Charlotte sources water from Mountain Island Lake and Lake Norman, both located to the north of our city (See figure 2). Water flows downstream, so while a hypothetical sewage leak in our area would not negatively impact our water source, it could impact the potability of those downstream. To get students to understand this concept I will introduce the E.coli outbreak in Union county and ask them to consider how a hypothetical sewage leak containing E.coli in our area could end up in their water.

Figure 2



On March 12th Union County Public Works customers received news of a boil water advisory after the presence of E Coli was found in a routine water sampling. In response, Union County Public Schools closed.[35] The Union County Public Works Water System (UCPW) is a provider of drinking water to citizens of Union County and helps meet water demands by grandfathering water from the Catawba river (see figure 3).[36] When looking at a google map image of our own community students will see our proximity to Long creek, a tributary that feeds into the Catawba river (See figure 4A). When zooming out further, our map shows how a hypothetical sewage overflow near our school could continue flowing downstream until it reaches the area in which Union County sources water (indicated by a star in figure 4B below).

Figure 3

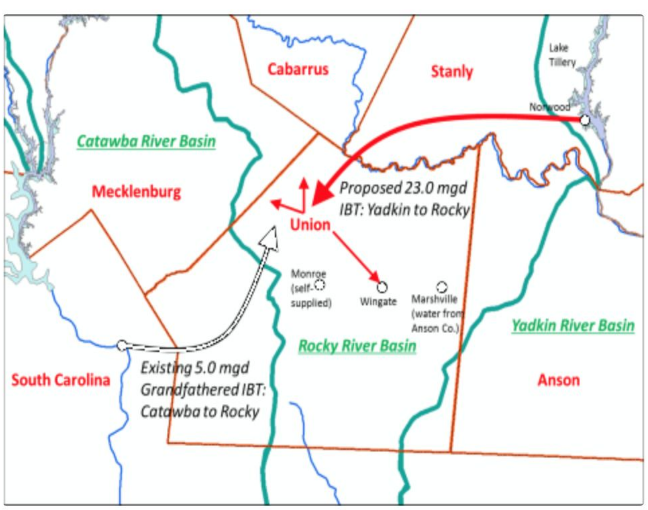


Figure 4A

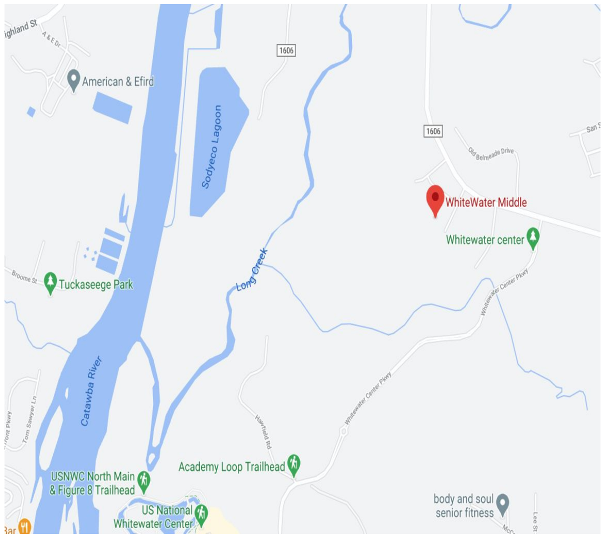
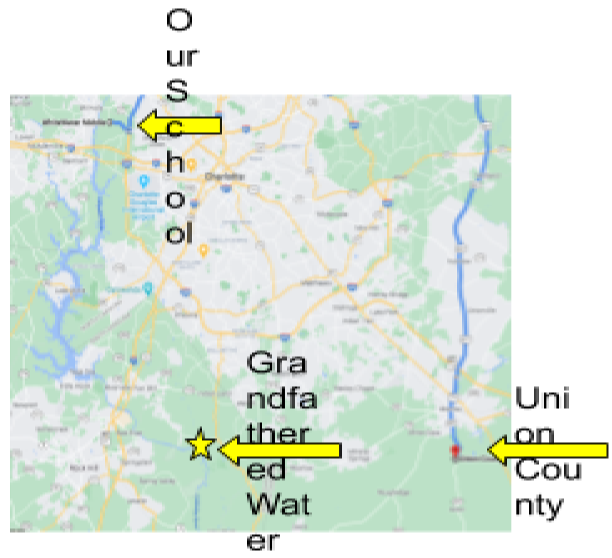


Figure 4B



Lesson 1 Plan and Activities

Content Objective: Students will use maps and text evidence to describe the geography of North Carolina using key terms like tributary, river, and river basin

Language Objective: Students will be able to explain orally and in writing how their actions on land could potentially impact the water of students in Union County

Engage: At the start of class the teacher will introduce the lesson's essential question and objective by stating, "We know from our case studies that issues of water quality and access impact people on the global and national scale, but could it happen here? To answer this question we will examine a recent outbreak of E Coli in a neighboring school district. By the end of this lesson you will be able to apply your knowledge of North Carolina geography to explain both orally and in writing how our actions on land could impact the E Coli levels of water consumed by students in the Union County."

Explore**:** For the first release students will explore the nature of the problem using two sources: a news clip from WCNC[37], and an article[38] about the causes and consequences of E Coli in water. Using these sources they will answer the following questions individually:

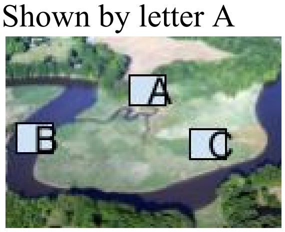
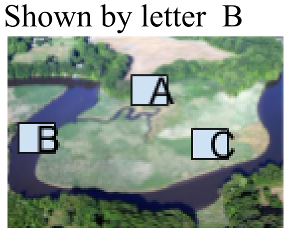
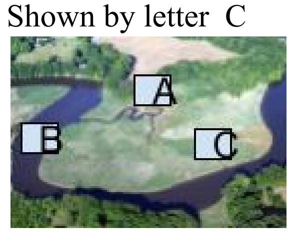
1. What happened?
2. Who was impacted by this crisis?
3. How did the city respond? The school system?
4. What are the causes of E Coli in water? What are the consequences (symptoms) if consumed?

At the end of the individual work time students will have the opportunity to practice communicating their content knowledge with peers in four person table teams with the person at table number 1 communicating their answer to question 1, the person at table number 2 the answer to question 2 etc. Students will be asked to listen to their peers' response first, and then indicate whether they agree, disagree, or have something to add. The teacher will circulate throughout the student share out to gauge student comprehension.

Explain: After students explore their sources the teacher will bring the class back together to quickly review exemplar answers.When reviewing question 4, however, the teacher will push students to empathize with Union County residents by connecting current content to prior microbiology units. Using a combination of no-opt out cold calls and volunteer responses the teacher will state, “We know from microbiology that bacteria are living so they reproduce. How? (through binary fission) Is this reproduction fast or slow? (fast). Normally when diagnosed with a bacterial infection what can you take? (antibiotic). But let’s look at a key excerpt from the text. It states here that E Coli should not be treated with antibiotics because it slows down digestion and could allow more time for your body to absorb the toxins. What is the treatment ment then if you are diagnosed with a serious case? (blood transfusions/dialysis). And what were some of the symptoms again? So given all of this information, how would you feel if you were a student in Union County and found out that this was in your water?

After tapping into students' empathy, the lesson will shift to social consciousness by the teacher asking: “How could our actions on land here add E Coli to Union County’s water? Especially given that E Coli is the result of fecal contamination. In order to answer this let’s consider North Carolina’s geography.” The teacher will move into a period of direct instruction and define key terms like river, tributary, and river basin using the SIOP strategy of providing a student friendly definition that is color coded and paired with a meaningful visual. The visual will also serve as a check for understanding. After previewing each definition Students will have to match each term to the correct letter on the image: A, B, or C. S*ee Figure 5 below*.

Figure 5

	Tributary	River	River Basin
Definition	A small stream that feeds into a larger river	A larger stream of flowing water	Land that drains into a river
Check For Understanding	Shown by letter A 	Shown by letter B 	Shown by letter C 

Extend: For their next extension students will work in partner teams to examine various maps of NC in order to visually infer the answers to the following questions on nearpod, a digital platform that allows students to enter their responses through typing or drawing. The teacher will monitor groups responses in real time using aggressive monitoring. Depending on the class the teacher may choose to allow students to work at a self-guided pace, or move lower level blocks on a teacher guided pace.

1. How many river basins does NC have? What is the name of our river basin? *Students will use image from figure 1 in content research section above*

2. What do you notice about water in the Catawba River Basin? Do you think water flows up or down?*Students will use image form figure 2 in content research section above*

3. Look at Whitewater Middle School. What tributary is it near? What river? Draw arrows to show how water could drain from the river basin around our school into the tributary and then into the river *Students will use image form figure 4A in Content Research Section Above*

4. Look at the map of Union County water sources. How is it connected to the Catawba River? *Students will use image form figure 3 in Content Research Section Above*

5. Look at the proximity of our middle school to union county. What do you notice about the yellow star in figure 4B compared to the white arrow in figure 3?

6. Draw arrows on figure 4B to illustrate how water could flow from our school to Union County

Note: the teacher should expect for students to productively struggle through this portion of the lesson, since it largely relies on visual inferencing. This is intended. Allowing students time to explore the route of water on maps using the help of their peers will help them carry the cognitive load. To ensure the struggle isn't too great, however, this activity should have a time limit of 12-15 min prior to the teacher revealing the correct answers. While questions 1 and 2 should be fast and easy share outs, questions 3-6 may go slower in order for students to visualize on a map how the flow of water from Whitewater middle school could go into the Catawba and downstream to the point where it is grandfathered by Union County. To continue building on students' ability to communicate content knowledge the teacher may invite students she saw to correctly illustrate the flow of water to explain their responses with peers

Evaluate: During the final lesson section the teacher will invite students to view an image of Sanitary Sewer Overflows in and around Whitewater Middle School since 2016 and remind students that Ecoli is caused by fecal contamination.[39] Note: SSOs are represented by red dots in figure 6 below

Figure 6

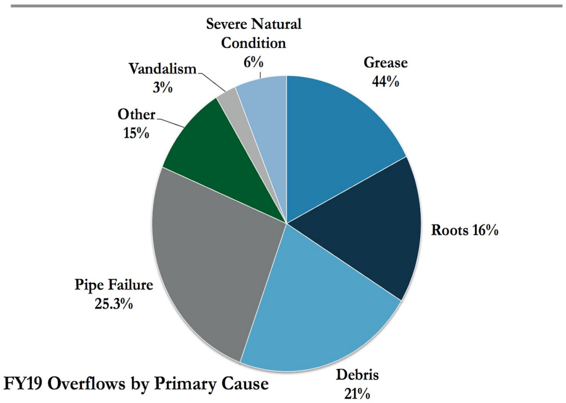
Students will return to the guiding question: How can our actions on land impact the amount of E Coli water of students in Union County? Before asking students to turn and share their answers to this question with a peer, the teacher will scaffold this thought process using a series of questions asked using the roll em' strategy.

1) We know that NC has 17 river basins. What is a river basin? Which one do we live in?
2) If there is pollution like an SSO near whitewater middle school what tributary would it drain into first? What river would it drain into next?
3) Which direction does water flow? So the Ecoli would continue flowing downstream along the Catawba
4) Union County is in a different river basin, the Yadkin, but how is it connected to the Catawba?
5) So let's put it together. Tell your neighbor how E Coli containing SSOs near our school could end up in the water of students in Union County

The teacher will once again circulate to listen to student responses highlighting the use of key vocabulary terms like river basin, river, tributary, and downstream. If there are any misconceptions the teacher will note them to the whole class before releasing students to their exit ticket. For the final assessment students will be asked to describe in writing their answer to the same question: How could E Coli pollution from SSOs near Whitewater middle school get into the water of students in union county? Use the terms river basin, tributary, and river in your response

Lesson 2 Content Research

Figure 7



In lesson 2 Students will need to interpret data from Charlotte Water to identify common causes of sewage blockages, use maps from the Catawba River Keeper's "State of the River" webpage to determine the frequency of Sanitary Sewage Overflows (SSOs) in their home communities, and summarize how the presence of fecal contamination from poultry CAFOs near mountain island lake pose a threat to our water quality here in Charlotte. In order to teach this lesson the teacher should know that in addition to treating drinking water sourced from Mountain Island and Lake Norman, Charlotte Water is responsible for maintaining nearly 4,300 miles of pipes dedicated to wastewater collection from homes, businesses and industries. Wastewater flows through pipes ranging in size from 4" to 66" prior to entering one of the city's five wastewater treatment plants where nearly 91 million gallons are treated per day. In 2018 Charlotte Water had to fix 162 sanitary sewer overflows. The causes of overflows are shown in figure 7 above below with the primary cause being grease.[40]Impacts from blockages range from backups into homes and business, increased costs for cleanups, and spills into nearby creeks bringing bacteria (like E Coli) and litter that impact both aquatic and human life.

The Catawba River Keeper is charged with protecting the 225 miles of the Catawba-Wateree river basin, and the work is challenging. In 2008 the Catawba was designated as the most endangered river in the United States, and in 2012 was deemed the third most endangered river in the Southeast. There are currently more than 460 legal discharges and countless unpermitted sources of pollution threatening its quality. While the disparity of issues facing the river are diverse, bacteria contamination from infected human and animal feces is a main problem so much so that the Catawba River basin has the second-most fecal coliform bacteria of any basin in the state. One source is from Sanitary Sewer Overflows (SSOs) similar to those caused by the blockages in Charlotte Water's pipes. Each year, millions of gallons of raw sewage from flooded municipal systems or septic overflows spill into the Catawba-Wateree River. The Catawba River Keeper monitors spills and works with cities to identify problem areas.[41] One feature of the website allows you to identify the number of SSOs in your area between the years of 2014 and 2016 (see figure 6 above for SSOs near Whitewater). I hope that students can use this map to again lend relevance to the Union County hypothetical scenario, while also allowing students to see the frequency of SSOs in their home communities, and inspire them to collaborate with Charlotte water to spread the word about what can and can not go down the sink.

From a systems perspective, the situation is much more complex. Improper waste storage at Concentrated Animal Feeding Operations (CAFOs) are a primary concern in Catawba even more so than SSOs. In particular, poultry farms each containing nearly 10,000 birds or more pose a threat.[42] From 2006 to 2014, the Catawba River basin in North Carolina has seen a 78 percent increase in poultry. Poultry is particularly heavily concentrated in Alexander County, immediately upstream of Lake Hickory and Lake Norman.[43]When left uncovered, waste can runoff into nearby streams. Waste from poultry farms not only contributes to bacteria, it also fuels algae blooms from nutrient overloads, and contains metals from the pharmaceuticals. It impacts air quality as well, with neighbors of poultry farms reporting difficulty breathing downwind. To prevent pollution the riverkeeper monitors these sights from the air and reports waste storage violations. They also sample water from creeks downstream of the CAFO to test for bacteria, but to truly address the problem more stringent waste laws, called "2T" rule, need strengthening.[44]

Lesson 2 Plan and Activities

Content Objectives: Students will interpret maps from the Catawba River Keeper's "State of the River" webpage to determine the frequency of Sanitary Sewage Overflows (SSOs) in their home communities. Students will be able to use data from Charlotte water to name local causes of SSOs and infer solutions. Students will be able to explain how the presence of fecal contamination from poultry CAFOs near mountain island lake poses a threat to our water quality here in Charlotte

Language Objectives: Students will be able to draft a message to deliver to their families explaining what SSOs are, why they matter, and what they can do at home to reduce their frequency. Students will be able to summarize in their own words how the actions of poultry farmers in Alexander County impact our water quality in Mecklenburg County.

Engage: In lesson 1 students gained an understanding of river basins that allowed them to see how the effects of pollution from sanitary sewage overflows in our school community could impact the water of students in Union County. In lesson 2 they will take this one step further by assessing how their specific actions at home contribute to the SSOs in their community.

The warmup for Lesson 2 will begin by asking students to examine the Native American Proverb: "No River can return to its source, yet all rivers have a beginning." After defining a proverb as a short saying that expresses truth or advice, the teacher will ask students to stop, jot, and share their answers to the following questions:

1. On a literal level how does this proverb connect to what we learned about river basins and rivers last class?
2. On a metaphorical level, what advice or truth do you think this proverb is communicating more broadly about life?

After students share their thoughts the teacher will stamp key points before segueing into the day's objective stating, "We know from last class that rivers and the pollutants they carry from surrounding river basins are constantly flowing downstream. But this proverb is also speaking more broadly about time. Time, just like rivers, can never move backwards. But just because we can't change our actions in the past, it doesn't mean we are doomed to a negative future. Water is flexible, it's course can be rerouted depending on the decisions we make in the present. Today we will examine how we can change the numbers of SSOs entering our local waterways simply by changing the things we put into our wastewater at home."

Explore 1: For the first release students will be asked to examine the number of SSOs near their school and home by typing in the addresses of both locations into the Catawba Riverkeeper's interactive map. Students will be instructed to click on the SSO dots in order to infer why some are bigger than others. After this brief release the students will bring it back to the whole class to discuss the number of spills near the school and home and share out their observations on why the dot sizes vary due to the volume of sewage.

Next students will examine a presentation provided by Charlotte Water that describes wastewater treatment and repair. Using information from the Charlotte Water presentation students will answer the following questions in partner pairs:

1. How many miles of pipes of wastewater is Charlotte Water responsible for maintaining?
2. Where do these pipes ultimately flow? How many gallons of wastewater are treated per day?
3. How many SSOs were there in 2019? How does this compare to the number in your neighborhood?
4. Looking at the pie chart (*in figure 7 above*) what is the main cause of blocked pipes?

Explain 1: The teacher will circulate through aggressive monitoring before bringing it back to the whole class to recap main points and lead students towards solutions. "So we know that Charlotte water maintains over 4,300 miles of pipes. We know that these pipes flow to one of 5 wastewater treatment plants where they filter almost 91 million gallons per day. But we also know that not all wastewater makes it to the treatment plant because of SSOs. In 2019 Charlotte water had to fix 162 sewage overflows. When examining the pie chart we see one of the main singular causes is grease. How many of you have ever poured grease down the sink? Let's take a look at how this could cause blockages. The answer actually lies in a unit we are already familiar with, Chemistry." The teacher will then show a brief video clip, relooping prior units on chemical compounds by pausing at key points to note how fatty acids in grease bond with calcium in seward to form a new compound referred to as fatberg that can clog pipes.[45] Instead of flushing grease, students will interpret visual instructions instead for what to do instead.[46] See figure 8 below

Figure 8

Extend 1: Next students will draft a message to deliver to their families explaining what SSOs are and why they matter, how frequently they occur in their neighborhoods, how grease contributes to the problem, and what to do with grease instead. Students will practice reading their messages aloud to partners before revising and delivering them to their parents that night for homework.

Explore 2: In the second half of the lesson students will continue to build on their understanding of river basins from lesson 1. While In lesson 1 students concluded that SSOs in our neighborhood could impact the water quality of those downstream in Union County, lesson 2 will build on this concept by acknowledging threats to our drinking water posed by poultry Concentrated Animal Feeding Operations upstream from our drinking source.

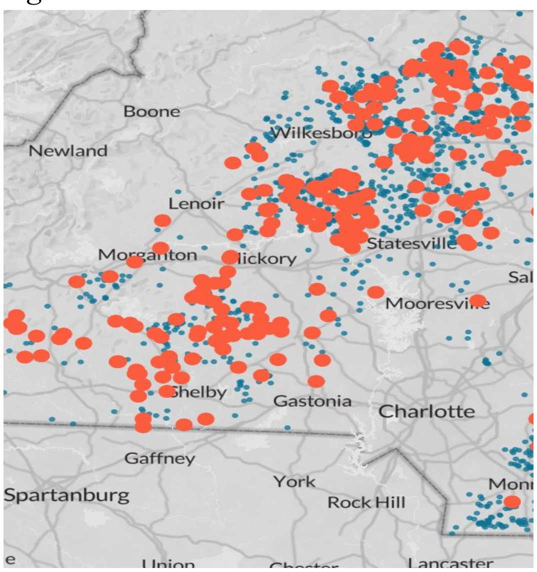
Using direct instruction the teacher will provide context of contamination in the Catawba River and the role of the Catawba riverkeeper shown in the content research section above. Next the teacher will zone in on the fact that the Catawba River basin has the second-most fecal coliform bacteria of any basin in the state, not just because of SSOs, but also due to poultry CAFOs. For the student release the teacher will invite students to explore the nature of the poultry CAFO problem using a jigsaw. *Note:* pairing groups here can vary. The teacher may choose to group high and low students together in a pair. They may also choose to give medium to high students source 1 and lower students source 2 due to the higher number of visuals.

1) One partner pair will skim excerpts about poultry farms in Alexander County from a Charlotte Observer article and highlight key details including the definition of a CAFO, the number of CAFOs in Charlotte, the impact of poultry CAFOs on waterways, and what is currently being done to address the issue..[47] After highlighting their main points

partners will work to summarize aloud the gist of the problem to share with their peers at the end of the timer.

2) The other partner pair will examine a series of infographics from the WaterKeeper Alliance to gather information more broadly about hog and poultry farms across our state.[48] Similar to group 1 they will be asked to summarize the gist of the problem. Next this pair will zoom in on Alexander County by examining the waterkeeper's interactive map of poultry farms in NC.[49]Alexander county includes the cities of Hickory, Lenoir, and Morganton located on the figure 10 below.

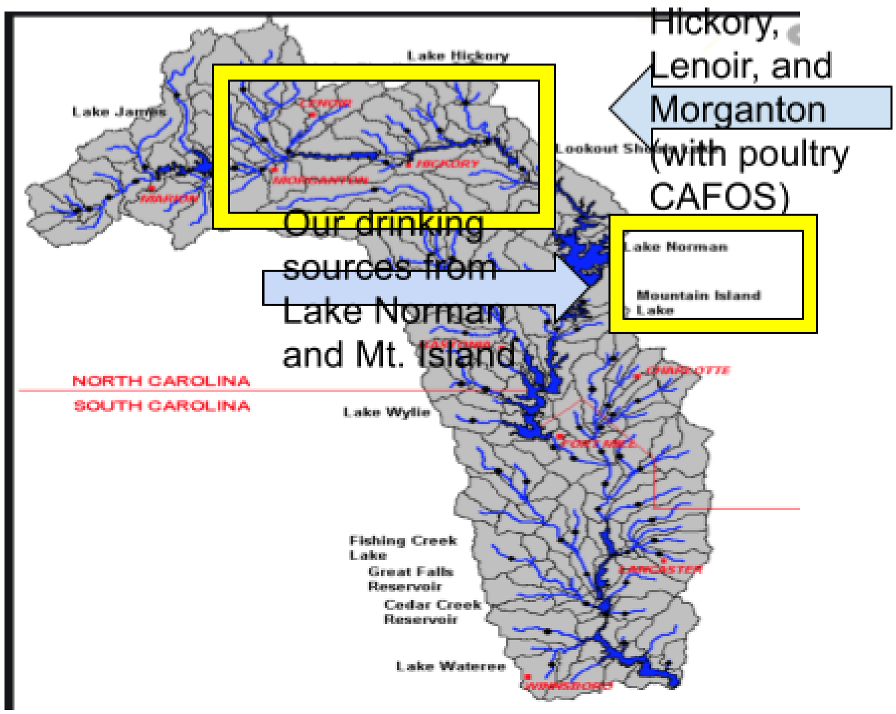
Figure 10



After partner pairs have explored their articles and images they will participate in a table talk to discuss their findings. The teacher will circulate before discussing as a class what they learned about animal waste in North Carolina.

Explain and Extend 2: During this final portion of direct instruction the teacher will pull up a map of the Catawba river basin and highlight Lake Norman and Mountain Island Lake as the source of drinking water located upstream from Charlotte. Next the teacher will ask students to consider the locations of the poultry CAFOs they read about and see noting how they are concentrated in Alexander County near the cities of Lenoior, Hickory, and Morganton. After highlighting these on a map she will probe students and ask. What threats did you learn poultry CAFOs pose to water quality? Given our knowledge of river basins, if waste from poultry CAFOs entered the tributaries near Hickory, Lenor, and Morganton, where would it flow? The answer: downstream into our drinking source. *See figure 11 on the upper right right*

Figure 11

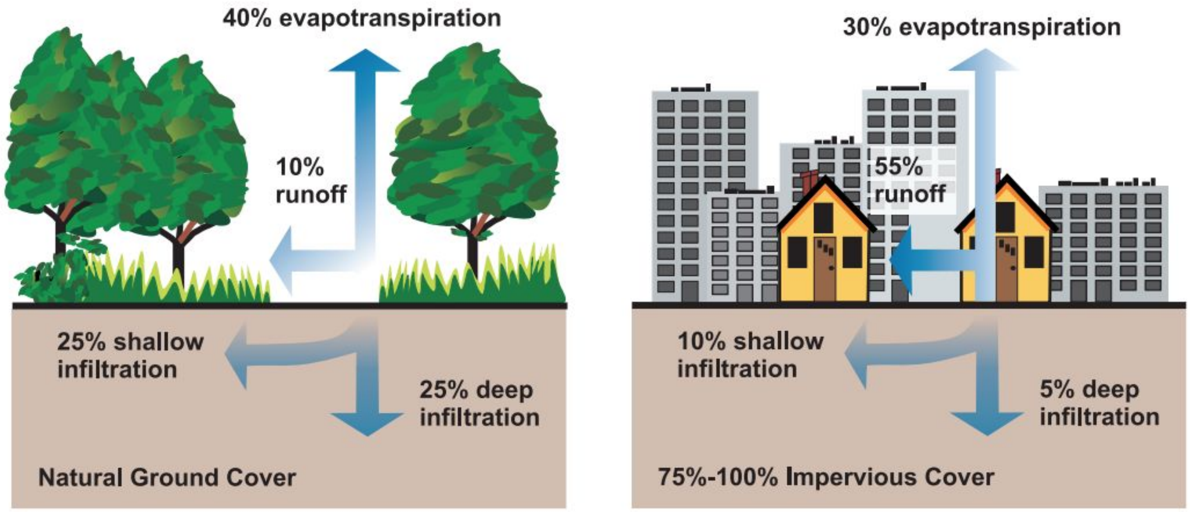


Evaluate 2: As their exit ticket students will consolidate their knowledge by answering the following question in their own words: How do the actions of poultry farmers in Alexander County impact our water quality in Mecklenburg County? Do your best to incorporate key vocabulary like Catawba River Basin, poultry CAFO, animal waste, fecal contamination, tributary, mountain island lake, Lake norman, upstream, downstream

Lesson 3 Content Research

In lesson 3 students will explore how urban stream syndrome impacts the flow of water and pollutants throughout river basins into rivers. Urban stream syndrome is the ecological degradation of streams draining urban land. In contrast to the porous and varied terrain of natural landscapes that trap rainwater and snowmelt enough to filter it slowly into the ground, impervious (nonporous) surfaces like roads, parking lots, and rooftops prevent rain and snowmelt from infiltrating and lead to rapid runoff in unnaturally large amounts.[50] *See figure 12.*

Figure 12



Relationship between impervious cover and surface runoff. Impervious cover in a watershed results in increased surface ruunoff. As little as 10 percent impervious cover in a watershed can result in stream degradation.

As runoff gathers speed it gains erosional power, and when it empties into streams can create a "power blast" that damages streamside vegetation and wipes out aquatic habitats. These increased storm flows can also carry sediment loads from construction sites, higher water temperatures, and an increased variety of pollutants including oil, grease, and toxic chemicals from motor vehicles, pesticide and nutrient waste from lawns, bacteria from pet waste and septic systems, and heavy metals from roof shingles and motor pollution. These pollutants can harm fish and wildlife populations, kill native vegetation, foul drinking water supplies, and make recreational areas unsafe and unpleasant.[51]

In Charlotte the impacts of urban stream syndrome are no exception. When it rains, water blasts aquatic habitats and leftover mud settles and buries whatever once lived in the creek. The effects can be so damaging that Mecklenburg County water quality director Rusty Rozzelle equated it to "shoot[ing] the natural environment in the head with a rifle" In addition to increases in turbidity from sediment, storm water runoff also contains pollution that accumulates into large sources when they wash away and come together into the storm drainage system.[52] Students will be asked to recall how this impacts freshwater ecosystems. For example, increased sediment would increase turbidity (how clear water is), increase temperature (due to absorption of sunlight), reduce dissolved oxygen (due to the spreading of atoms), and result in a decrease in biodiversity (species with sensitive DO ranges would die). Another example could be that nitrates and phosphates from nutrient runoff might increase turbidity due to algal growth thereby increasing temperature, decreasing dissolved oxygen, and damaging biodiversity.

In this lesson students will also be asked to conduct a site inventory of storm water runoff on school grounds. A site inventory is one of the first stages of the design process landscape architects employ. It involves identifying, observing and recording different features on the site such as stormwater flow, vegetation, sun and shade patterns, wildlife habitat, and elevation change. While there are a number of factors that can be observed when conducting an inventory, this lesson will focus primarily on having students locate retention ponds, downspoints, erosion, flow paths,the high point, the low point, impervious surfaces, previous surface, and storm drains on campus.

Lesson 3 Plan and Activities

Content Objectives: Students will be able to define urban stream syndrome. Students will be able to conduct a site inventory of storm-water runoff on school grounds identifying key features like high and low points, permeable vs impermeable surfaces, storm drains, and storm water flow paths

Language Objective: Students will explain orally and in writing how urban stream syndrome increases the volume, speed, and pollutant loads of stormwater runoff and by extension impacts a freshwater ecosystem's turbidity, temperature, nitrates and phosphates, and bioindicators

Engage: In lesson 2 students learned how their method of grease disposal could result in sewage overflows that would negatively impact residents downstream. They also learned how the waste storage of poultry farmers upstream near Alexander County could negatively impact their source of drinking water. Lesson 3 will build on this knowledge by asking students to consider how the impact of fecal contamination from SSOs and CAFOs can be worsened by the permeability of the land within river basins.

In preparation for this lesson the teacher will prepare an erosion demonstration similar to the image in figure 13 to the left but with an additional gallon of soil covered by a large piece of gridded template plastic that mirrors an impervious surface.

Figure 13

For their warm up students will be asked to hypothesize answers to the following questions:

1) Which of the following surfaces would result in the greatest volume of runoff after a heavy storm?

A. Vegetative cover B. Cover with debris C. Soil with no cover, or D. An impervious surface

2) Which of the surfaces would produce runoff with the highest turbidity after a heavy storm?

3) How would an increase in slope impact the volume of runoff? How would a steeper slope impact turbidity levels?

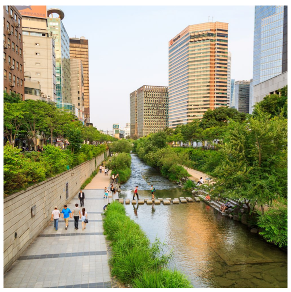
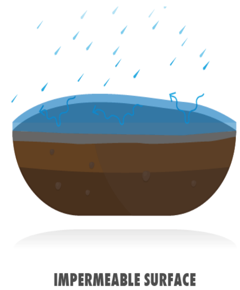
4) Which surface do you think is best for preventing the large volumes of pollutants entering waterways from SSOs and CAFOs after storms? Why?

After recording their individual hypotheses, students will have the chance to briefly discuss their ideas in table teams. Afterwards the teacher performs the demonstration by measuring a standard amount of water (ex. 1000 milliliters) into a watering can or spray bottle or sprayer and distribute uniformly over the surface of the soil. The water should be added over several minutes. The volume of water should be sufficient to generate at least several hundred milliliters of runoff. If it does not, use more than 1000 mL the teacher will keep track of the total amount of water added. After runoff has stopped, the teacher will use the measuring cup to determine the volume of runoff.

Throughout the demonstration the teacher will clarify that the phenomenon they are observing mimics the impacts of urban stream syndrome and the importance of stormwater management. To build background (and also allow time for the demonstration to complete) the teacher will define key terms that are used interchangeably using the SIOP and CR strategies. As a check for understanding the teacher will ask students to apply these vocabulary terms when describing their observations. See figure 14 below for an example of this vocabulary prime that incorporates color-coded definitions paired with visual images and an application question.

Figure 14

Urbanization and Urban Stream Syndrome	Pervious/ Porous/ Permeable Surfaces	Impermeable/ Impervious/ Nonporous Surfaces	Storm Water Runoff
Urban = City Urbanization = The growth of Cities Urban Stream Syndrome = the degradation/decline	Water is permitted to pass through pores inside of the ground through infiltration. Runoff decreases	It is impossible for water to pass through because there are no pores in the ground. Runoff increases	Water that runs above ground after a storm (carry with it surrounding pollutants)

of streams draining urban land			
			
Check For Understanding: Which landscape in the demonstration mimics an urbanized landscape?	Check For Understanding: Which landscape(s) have previous/ permeable surfaces? Do they produce more or less runoff?	Check For Understanding: Which landscape has the most impermeable/imperm eable/non porous surface? Does it produce more or less runoff?	Check For Understanding: What in the demonstration is being used to demonstrate stormwater runoff? How does the stormwater runoff vary according to the permeability of the landscape?

Explore: For their first release students will expand on their observations from the demonstration and vocabulary prime by examining an EPA article on the impacts of Urban runoff.[53] Using the article they will answer the questions below independently. The teacher will circulate with a pen in hand to mark the accuracy of student answers through aggressive monitoring.

1. What types of pollutants does stormwater carry?
2. How does runoff in porous landscapes like forests compare to the runoff in impervious surfaces like pavement and parking lots?
3. When powerful streams of stormwater enter waterways what are the impacts on vegetation and aquatic habitats?
4. How does urbanization impact pollution loads?

Note: as a potential modification for lower classes teachers may number paragraphs and provide students with the paragraph number to read in order to answer each question.

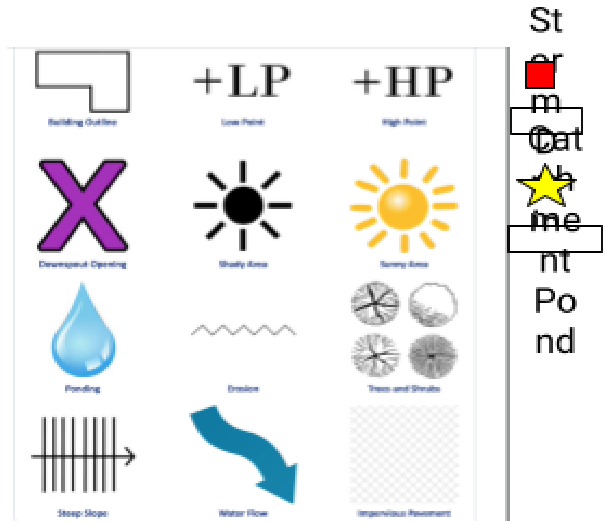
Explain: After their timed release the teacher will bring students' attention back to the whole group in order to combine their new content information on urban stream syndrome with prior knowledge of water quality indicators. Using a series of no-opt-out cold calls the teacher will ask the clarifying questions below, accompanied by powerpoint images that visually depict exemplar student responses.

1. During urbanization does the permeability of surfaces within the river basin increase or decrease?
2. How does this impact the volume of stormwater runoff? The speed?
3. When stormwater moves this way what happens to the pollution loads?
4. When these pollutants enter waterways what happens to vegetation and wildlife?
5. Let's expand on why this happens by linking it back to our water quality indicators. If water is moving at high speeds and carrying a lot of sediment, what will happen to turbidity? If turbidity increases how will this impact dissolved oxygen levels? If dissolved oxygen levels decrease what will happen to bioindicators? Why?
6. If water is moving over nonpermeable urban surfaces will it result in higher or lower amounts of contamination from things like fecal matter and agricultural runoff? When nitrates and phosphates from these pollutants enter water what grows out of control? How do algae blooms impact turbidity? Temperature? Dissolved Oxygen? Biodiversity?
7. So let's put it together. When I say go take 2 min to silently stop and jot your answers to the following questions
    A. How does urbanization alter the volume, speed, and composition of stormwater runoff?
    B. What impacts does this have on biodiversity in local waterways (be specific by naming impacts to our water quality indicators)

After writing students can share information with their peers by reading their responses aloud. The teacher will circulate to emphasize the use of key vocabulary terms and clarify misconceptions in the moment. Note: for students who struggle to write allow them to visually draw their answers to the questions and then share aloud during the turn and talk

Extend: For the second half of class the teacher will ask students to extend their learning by considering how the permeability of land impacts the drainage of storm water on school grounds. Most students in eight grade know that drainage is the poorest near our baseball and football fields. In the past games have been forfeited when it rains so hard the fields flood. To examine why this is the case students will begin by conducting a site inventory.[54] Students will use a satellite image of our school pulled from google maps to start their outlines. Next they will engage in an outdoor walk to identify specific characteristics using the symbols shown in the figure below 15 below. Note: additional symbols were added to the key to include catchment ponds and storm drains

Figure 15

Satellite View of Campus	Site Inventory Symbols
	

To start the procedure the teacher will hand out the Site Inventory Vocabulary Sheet and review it with the students. The features they will be recording include: plants, moving water or ponding, slopes, high points and low points, downspouts, impervious surfaces, buildings, catchment ponds, and storm drains. As their guided practice, each student will be given a map of the school grounds to record their findings. If available, the teacher will give each student a clipboard to use while drawing. Students can work in small groups or individually, but each should produce their own inventory map. If time is limited students may only conduct a site analysis for a portion of the school grounds.

Evaluate: When students return to the room they will have a few moments to make their maps readable. Their assessment will be to answer the following questions:

1. What were some of the observations you made while out on the school grounds?
2. Did you observe any drainage issues in the form of puddles, erosion, or standing water anywhere on the site?
3. Based on our class runoff demonstration, why do you think these drainage issues exist?

Lesson 4 Content Research

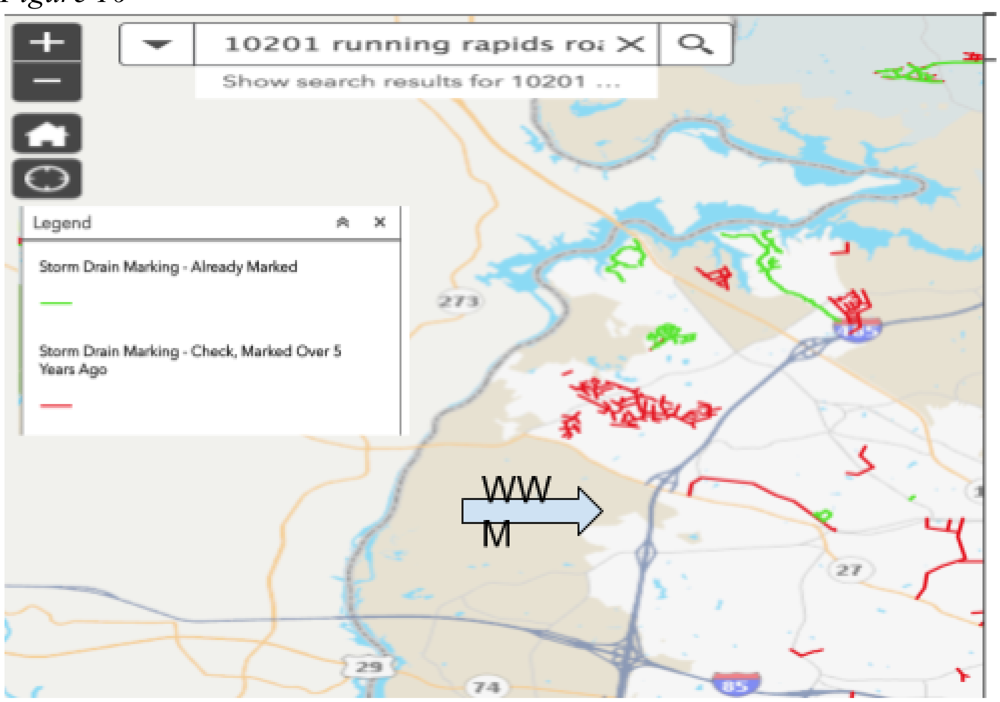
In lesson 3 students investigated how urban stream syndrome could increase the speed and volume of stormwater runoff along with increasing its pollutant loads and erosional impact. Lesson 4 will ask students to use their site inventory maps in combination with the interactive maps from Charlotte Stormwater to identify the exact route stormwater runoff and pollutant takes around our school's campus and eventually into the Catawba river.

According to a 2015 Charlotte-Mecklenburg public opinion survey, approximately 36% of respondents think stormwater is treated and cleaned before it reaches a stream or lake. The truth is that stormwater and stormwater pollution throughout Charlotte and Mecklenburg County drains directly to streams and lakes. [55]According to Charlotte Stormwater, stormwater pollution is the number one source of pollution for local waterways and preventing small sources of pollution from adding up into big problems is far less expensive than trying to restore the water quality after the pollution is there. [56]

To engage students in this process of understanding the movement of pollution through stormwater, I will utilize Charlotte Stormwater' interactive map.[57] Students can type in their address and use the layered map to identify characteristics of local geography--like the presence of wet ponds, buffers, and permeable pavement as well as information on storm drain structures, channels and connectivity see figure At Whitewater, the storm drains in our parking lot connect and flow into the enhanced grass swale and wet pond located behind campus.

Charlotte Stormwater also offers an educational outreach program, storm drain marking,that promotes awareness that the catch basins drain to the creeks and encourages community members not to dump pollutants into catch basins. [58]Using another interactive map, students can see that storm drains near and on our school campus are largely unmarked or marked over five years ago (See figure 16*)*. [59] Participating in this program is another option I want to offer students as a potential capstone project in lesson 6.

Figure 16



Lesson 4 Plan and Activities

Content Objective: Using information from Charlotte Stormwater and their Site Inventory maps from lesson 3, students will be able to identify the above ground and underground routes of storm water around our school's campus.

Language Objective: Students will describe the journey of stormwater around our campus and explain in writing why it is important for people and for ecosystem biodiversity to have drainage systems that manage water effectively after a storm.

Engage: Lesson 4 will pick up where lesson 3 left off. As their warmup students will pin their site inventory maps up on the wall and perform a gallery walk observing one anothers maps. As they walk they will make observations about common trends and note the answers to the following questions:

1. What was the highest point on campus? The lowest point? So how does water flow?
2. Where is impermeable land? How does this impact the flow of water?
3. Where is stormwater being redirected to a pond? To a storm drains?
4. Is there a path of water that does not lead to one of these locations (like a downspout) Where does it end up? How might this contribute to drainage issues on campus?

Afterwards the teacher will introduce the objective stating, "While landscape architects conduct site analysis in order to create spaces that are visually appealing while also functional, employees at Charlotte stormwater use site inventory's too in order to design storm drain management systems that adequately catch runoff and minimize damage to local ecosystems. Today our goal is to combine our site inventory maps from last class with the interactive maps on Charlotte Stormwater's website in order to determine the path stormwater and pollutants take from land into local waterways. Before we do, however it's important to gather some information about where stormwater actually ends up after it is redirected. Where do you think stormwater goes? Let's see how the following images may change our view." The teacher will show students one image at a time in figures 17 and 18 below and use questioning to get students to visually infer that stormwater is not redirected to water treatment centers, but instead enters directly into lakes and creeks.

Figure 17[60]

How many of these parts of the system can you find in your neighborhood?

- ☐ **Slanted roofs** shed water.
- ☐ **Rain gutters** collect the water.
- ☐ **Downspouts** carry the water to the ground.
- ☐ Water on the street flows downhill into **street gutters**, the place where the sidewalk and the street meet.
- ☐ Street gutters carry water to **storm drains** that let water fall beneath the street.
- ☐ The **grates** on storm drains stop large objects (and people!) from falling in.
- ☐ An **underground pipe** carries water out of a city or town.
- ☐ The water pours into **a large waterway**— a lake, river, or sea.

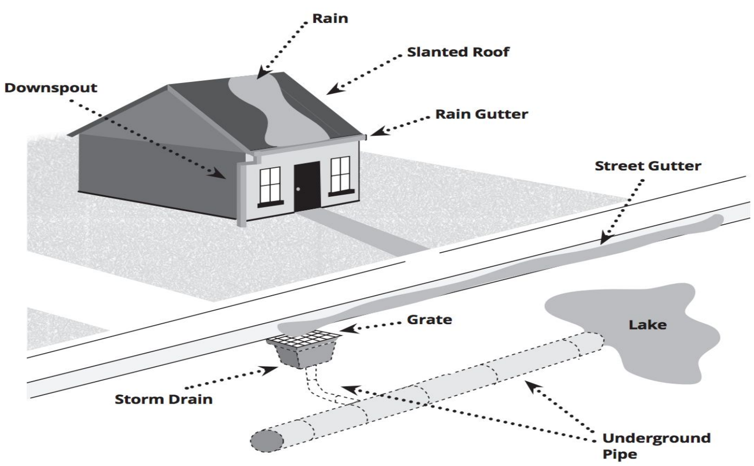


Figure 18 [61]

Explore: To segue into the explore portion of the lesson, the teacher will state: "So if we know that stormwater ultimately is redirected into local waterways and not treatment plants, then what waterways are the storm drains on our campus ultimately leading to? Let's use Charlotte Stormwater's map to find out" The teacher can use his/her discretion to do the following map exploration whole class or in partner pairs. Students will follow the steps below;

Step 1: Go to Charlotte Stormwater's Interactive Map here and type in our school address: 10201 running rapids road

Step 2: Click on the where it says "StormWater BMPs"

BMP stands for best management practices.

What two structures on our campus were deliberately made to reduce the impact of stormwater?

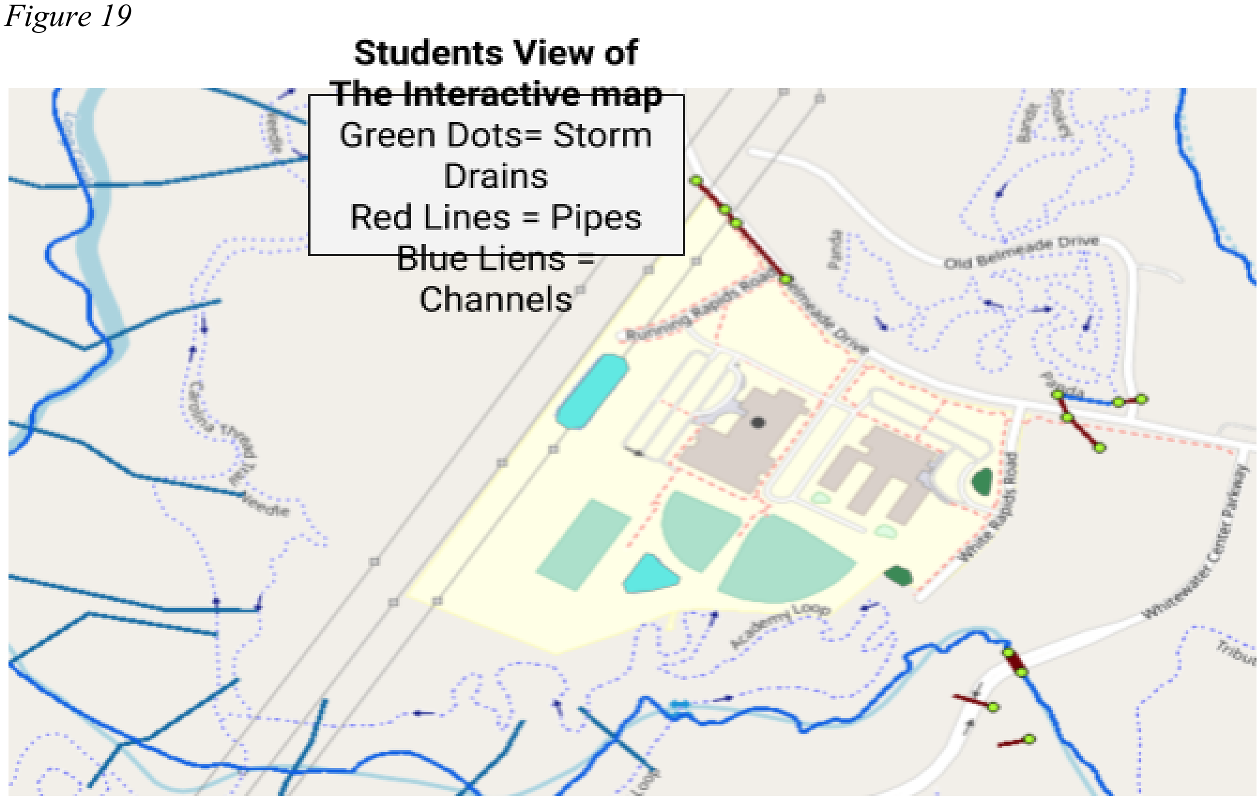
What do you think would happen without these structures?
Note: the exemplar answers are the two wet ponds located to the right of the parking lot and the back left near the football and soccer fields

Step 3: Click on Stormwater dropdown. Select “Storm Structures” “and “Storm Pipes”
What do you notice about the relationship between the two?
Note: the exemplar is that the storm structures (in this case, storm drains) connect to one another through underground pipes

Step 4: Click on the storm channels feature. What do you notice about it’s outline compared to the location of natural tributaries like Long Creek?
Note: the exemplar is that the channel mirrors the creek itself suggesting that channels transport water above ground not under

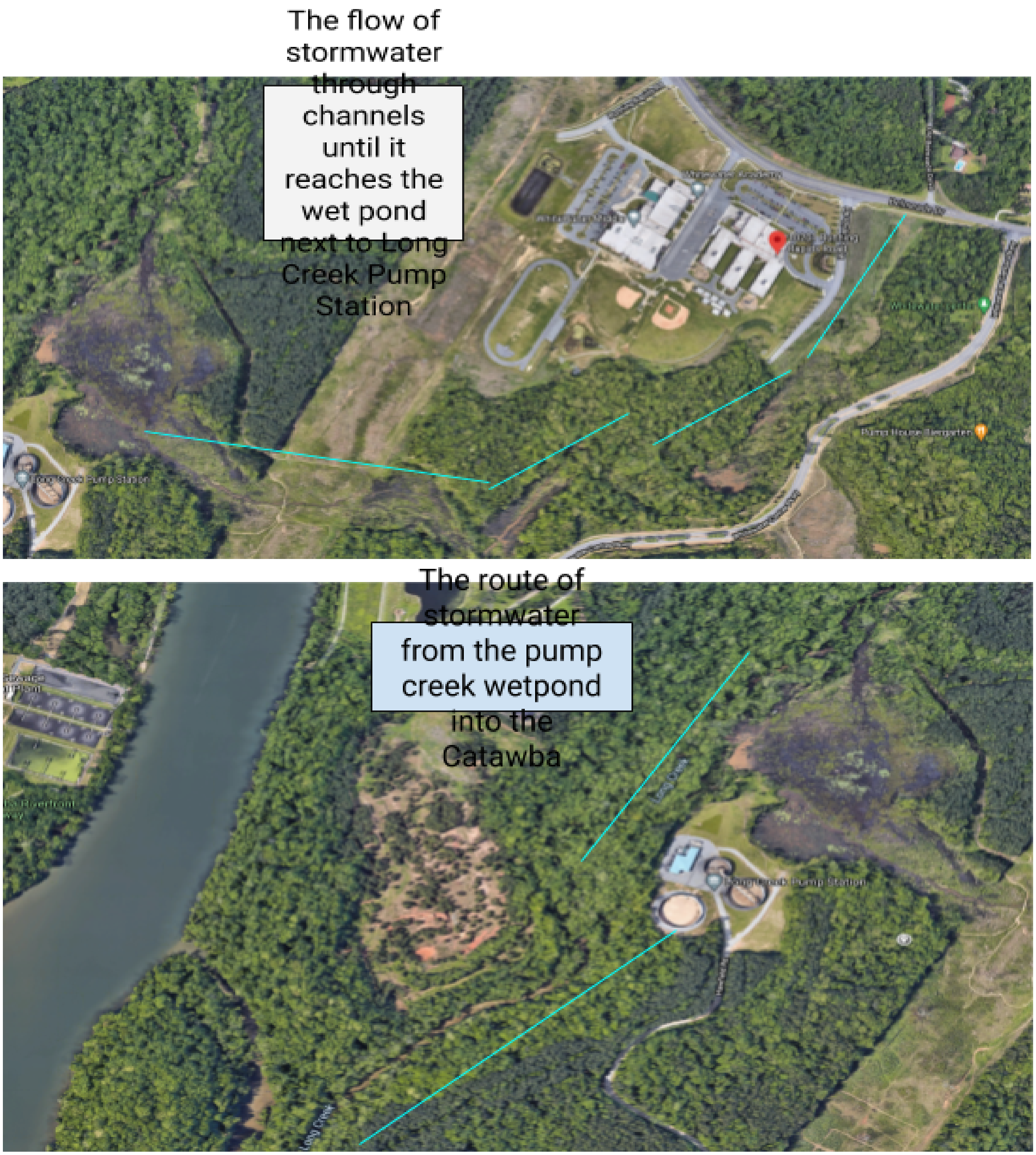
Explain: The teacher will allow students time to generate their own observations before clarifying through direct instruction the exemplar responses shown above: Storm structures (the green dots on figure 19) refer to storm drains that move surface water underground. Pipes (the red lines) connect storm drains underground and ultimately lead directly to natural waterways (that’s why the pipes stop). In contrast storm channels (the blue lines) are above ground and take the form of permanent waterway, designed to convey stormwater runoff. The channel is intended to transport concentrated surface runoff without causing erosion or flooding.

Figure 19



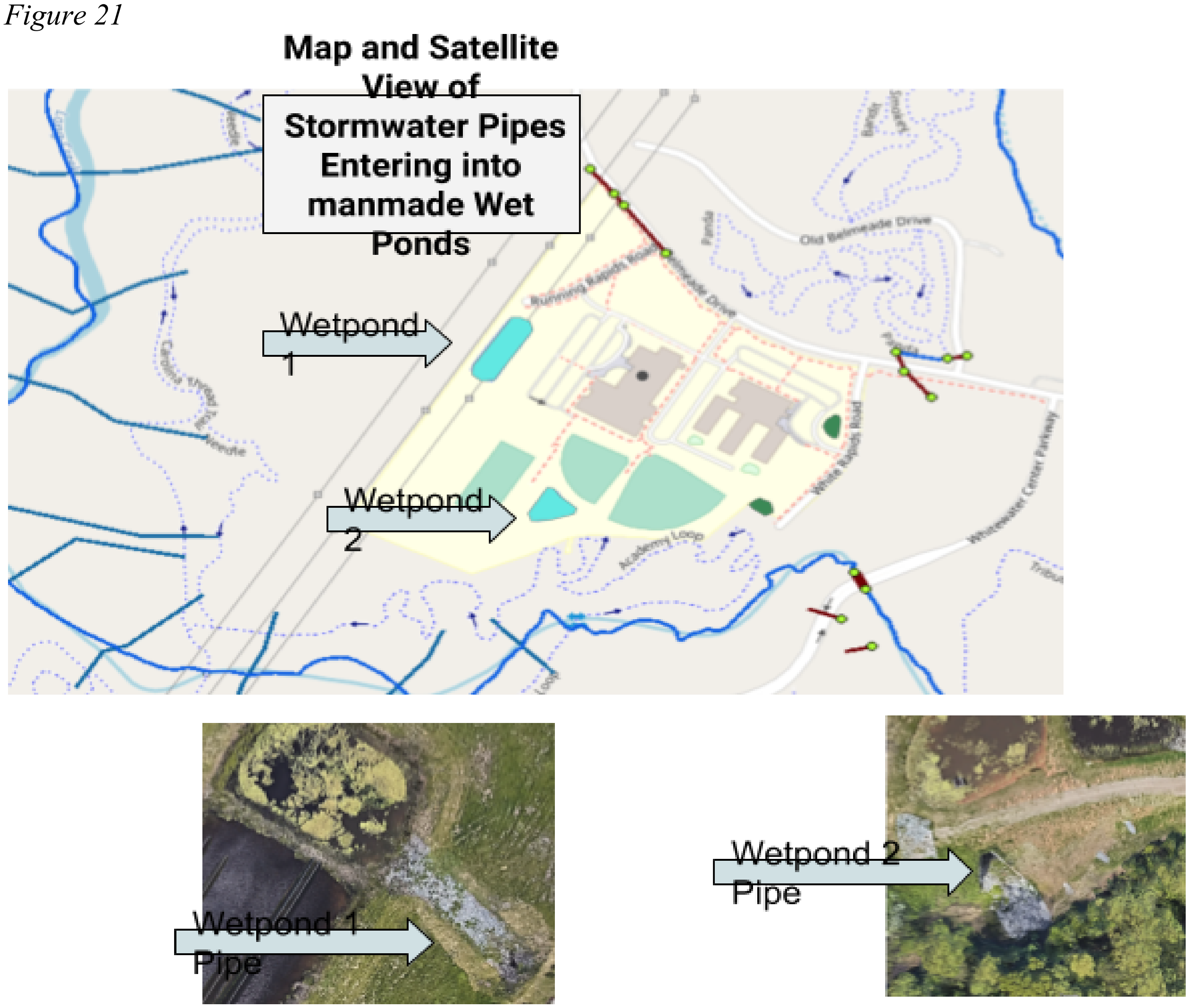
The teacher will couple these channel lines on the map with google satellite images of the storm channels behind our campus. Students will watch as the teacher models how to use satellite images on google maps to track the flow of stormwater channels to Long Creek, a wet pond near Long Creek pumping Station, and eventually into the Catawba River. This path is indicated by the blue lines in the figure 20 below.

Figure 20



The teacher will stamp learning stating, “So we know that stormwater can flow above ground into our wet ponds or along the channels into the Catawba river, but what about the water that actually goes underground by entering storm drains? Where does it end up? ” To get students thinking about this, the teacher will ask “What did you notice about the location of storm drains on your site inventory in comparison to the interactive map?” The answer students will uncover is that the stormwater map is actually incomplete because it does not include the storm drains located on school grounds in our parking lots. For the next few minutes students will be charged with using google satellite to infer where the stormwater pipes underground actually carry stormwater collected from our campus drains. The exemplar answer is that the pipes empty into the two manmade wet ponds that students identified earlier as the features of Charlotte water’s BMP. Images are shown below in figure 21

Figure 21



Extend: As their extension, students will bring their explorations back to the issue of water quality. The teacher will release students to answer questions using the Charlotte Observer article

"Can Charlotte Learn To love It's Lacework of Small Streams?[62] To ease facilitation and note time, the article will be shortened to focus on the excerpts relevant to the following questions:

1) We saw the images of creeks around our campus, but how many miles of creeks are there in Charlotte?
2) How did Charlotte's creeks influence how our city was developed?
3) How did locals threaten the water quality of the creeks we once depended on?
4) What did the Clean Water Act do to prevent pollution? Did this solve the problem?
5) How does stormwater impact the turbidity of the creek? How is this reflected in our satellite images?
6) Think back to our old unit--if turbidity increases what happens to dissolved oxygen in creeks? What happens to biodiversity?

Depending on the level of the class the teacher may choose to use aggressive monitoring to give independent feedback before moving students onto the exit slip, or may choose to review the answers to the questions whole group before moving students on to their final evaluate assignment.

Evaluate: For their exit slip question students will be asked to answer the following questions through a stop, jot, and share: First, describe the journey of stormwater around our campus . Second, explain why it is important for people and for ecosystem biodiversity to have drainage systems that manage water effectively after a storm.

Lesson 5 Content Research

In lesson 4 students considered the flow of stormwater from land into local waterways. In lesson 5 they will consider the flow of plastic pollutants into marine ecosystems and the negative impacts they cause once they get there. Based on standards unpacking students will know that river basins drain into rivers, which feed into estuaries, and eventually lead out to sea. This migration is the reason why plastic pollution on land eventually ends up in oceans. According to the EPA's Trash Free Waters program, trash from consumer goods makes up the majority of what eventually becomes marine debris (*See figure 22*)[63]The program focuses on reducing the land-based types of products and packaging (primarily single-use disposables) that end up as marine debris through source reduction [64] Debris is transported throughout the ocean through geostrophic currents, or ocean currents that travel at right angles from high to low pressure gradients. When coupled with atmospheric and oceanographic processes, convergence zones are created and trash accumulates in areas like the Great Pacific Garbage Patch. Debris accumulation has a variety of impacts that can be broken down into different categories including habitat, chemical, biological, human and economic. [65]

Figure 22

Courtesy of Ocean Conservancy. Find out more about Coastal Clean-Up Day.

Habitat: As debris accumulates, habitat structure may be modified, light levels may be reduced in underlying waters, and oxygen levels may be depleted. These changes can undermine the ability of open water and benthic habitats to support aquatic life. As benthic habitat-forming species decline, there may be indirect impacts on open water species. For example, degradation of coral reefs globally has the potential to undermine the survival of a diverse array of invertebrates, fish, and vertebrates that depend on this limited resource, including many threatened and endangered species. [66]

Chemical: The accumulation and transport of bioaccumulative and toxic (PBTs) contaminants, such as PCBs and pesticides is a chemical impact associated with plastic aquatic trash. Aquatic plastic debris has been found to accumulate contaminants at concentrations that are thousands to millions of times greater than the surrounding environment. Based on a number of studies, including those conducted by EPA, plastics have the potential to absorb chemicals from the environment, and transport them globally to marine food chains and potentially to humans who eat seafood. As a result of UV radiation, mechanical forces and weathering ,contaminants accumulated on the surface of plastic particles as well as those within the plastic can be released to the environment when the plastics break down . Evidence is also showing that plastic debris transfers PBTs to organisms when consumed. For example, one study shows Puffinus gravis, a seabird known to ingest plastic, had PCB concentrations in fat tissues corresponding to the amounts of plastic found in their stomachs.[67]

Biological: Aquatic plastic debris has harmful effects on river and marine organisms. Causes of harm range include physical hazards from ingestion and entanglement, and toxicological threats from ingestion of contaminants attached to and trapped within plastic particles. At least 267 species globally, including 86% of sea turtles, 44% of seabirds, and 43% of marine mammals are at risk. [68]

Human and Economic: The human and economic impacts of plastic aquatic debris include interfering with navigation, decreasing commercial and recreational fishing, threatening health and safety, and reducing tourism. For example, in 1988 New York and New Jersey closed their beaches to protect the public from medical waste that washed ashore. It was estimated that the loss of revenue from beach closures in 1988 to New Jersey alone was in the range of $706 million to nearly $3 billion. Aquatic trash also reduces the aesthetic and recreational values of rivers and beaches. This is a specific concern for coastal cities since unsightly debris and entangled marine life can reduce the area's attractiveness to local residents and tourists. Cleaning debris from beaches comes at a cost. In 2012 EPA conducted a study to quantify the cost spent by 90 coastal cities in California, Oregon and Washington to clean up litter and prevent trash from entering the ocean or waterways leading to it. West Coast communities spent more than $520 million dollars a year to combat litter and prevent trash from becoming marine debris. [69]

Lesson 5 Plan and Activities

Content Objectives: Students will be able to explain how pollutants like plastics can travel from land, to rivers, to oceans. Students will be able to create an infographic that summarizes the cause and effects of plastic pollutants on human and marine and ecosystems.

Language objectives: Students will be able to summarize data from the EPA's Trash Free Waters website and the NOAA website when collecting information for their infographics.

Engage: In order to build empathy the teacher will show students a series of images of marine debris. Images selected may include wildlife entanglement and plastic ingestion, large garbage patches, and polluted shorelines. Afterwards the teacher will state, "Given our knowledge of river basins and the flow of pollutants through storm drains, how do you think plastic got into the ocean?" After students hypothesize the teacher will show an image that depicts the Catawba river's ultimate path to the Atlantic and introduce the day's objectives.

Explore: As their explore students will participate in station work that has an experiential component designed to generate empathy, and a research component designed to let students summarize data for their infographics.

Station 1: Biological Impacts

In order to empathize with entanglement each student will receive one rubber band. They will twist the rubber band around the thumb and pinky finger until it is secure. Next the teacher will ask students to take 1 minute and try to escape just by using their hands. Afterwards the teacher will ask students to reflect on how they felt and ask students to imagine some of the things they would no longer be able to do if they were an ocean bird or fish who was entangled.[70]For the research portion students will read an excerpt from the "Biological" impacts section from the Trash Free Waters website and summarize in their own words the impact of marine debri on aquatic life.[71]

Station 2: Chemical

In order to empathize with the dangers of ingesting plastic each student pair will receive a bowl with a lentil and rice mixture. The lentils represent plastic while the rice represents food. Each pair will be given 15 seconds to spoon out as much food and as little plastic as they can in the bowl. After time's up students will calculate the ratio of plastic to food.[72] For the research portion, students will read an excerpt from the "Chemical" and "Problems Associated with Ingestion of Plastic Particles" sections from the Trash Free Waters website and be asked to summarize in their own words the impact of bioaccumulation on aquatic food chains and humans.[73]

Station 3: Habitat

In order to mirror the extent of plastic pollutants in marine habitats students will be given a jar of water with lots of pepper flakes (representing microplastics) and large plastic pieces (representing larger sources of pollution). They will have 1 minute to try to use paper towels and spoons to clean out the pollutants. For the research portion. students will read an excerpt from the "Currents" and "Habitat" section of the Trash Free Waters Website in order to summarize how pollution impacts features like light and oxygen levels and by extension Marine food webs. Next they will watch a clip about the Great Pacific Garbage Patch and microplastics in order to infer that the best solution is prevention.[74]

Station 4: Human and Economic

In order to reflect on human impact students will view an image of the top 10 sources of pollution collected during ocean cleanups (see figure 22), Next they will hypothesize whether the resource has to be sent to a landfill (1 pt), recycled (2pts), or can be reused (3pts). The group with the most points will win. For the research portion students will read and excerpt from the "human and economic" section of the trash free waters website in order to summarize how plastic pollution impacts businesses and municipal fees. [75]

Explain: Instead of explaining content to the whole group, the teacher will circulate throughout student groups at the end of each station to review responses and provide feedback.

Extend and Evaluate: For the extend and evaluate portion of the lesson students will be asked to consolidate their station research into an infographic aimed at informing other Whitewater students about the causes and impacts of marine debri. Students will use the free platform PiktoChart to create their products. To receive full credit their infographic must include sections detailing the primary sources of plastic pollution, how plastic travels from land to oceans, and the negative economic, biological, chemical, and habitat impacts of plastic pollutants. To prepare students for this the teacher may consider showing students samples of plastic pollution infographics and exploring how the visuals and template support the story the text and data are telling.

Lesson 6 Plan and Activities

For the final lesson students will select one of the sample research questions posed in lessons 1-5 to choose to investigate further. This project will continue into their next unit on Earth History. Working in teams they will continue researching the problem of their choice and generate solutions. At the end, select groups will enlist the feedback and help of relevant community stakeholders.

Lesson 1-2 Questions

- How might we partner with Charlotte Water to reduce the frequency of SSOs in our neighborhood by educating our neighbors about proper grease disposal?
- How might we partner with the Catawba River Keeper to spread awareness and take action against poultry CAFOs in our basin?
- How might we partner with Stowe Regional Wastewater facility to learn how fecal contamination from SSOs and CAFOs are filtered during the treatment process?

Lesson 3 Questions

- How might we expand our site inventory into a site analysis and propose solutions to improve flooding and erosion on campus?
- How might we partner with Tree Store Charlotte to increase vegetation and reduce erosion in flood-prone places at school and home?

Lesson 4 Questions

- How might we partner with Charlotte Stormwater's Storm Drain marking program or Adopt a Stream program to collect data about storm drains in our community and inspire people around them to prevent stormwater pollution?

Lesson 5 Questions

- How might we partner with CMS nutrition to reduce the use of single use plastics in our cafeteria?
- How might we partner with Envision Charlotte's precious plastics program to upcycle plastic bottles collected on campus?
- How might we leverage our Verizon lab and the design-thinking process to propose innovations to storm drain designs that prevent plastic pollutants from entering waterways?

Appendix 1: Teaching Standards

North Carolina Essential Standards: Grade 8 Science

8.E.1: Understand the hydrosphere and the impact of humans on local systems and the effects of the hydrosphere on humans

8.E.1.1 Explain the structure of the hydrosphere including:

- Water distribution on earth
- Local river basins and water availability

8.E.1.2 Summarize evidence that Earth's oceans are a reservoir of nutrients, minerals, dissolved gases, and lif forms:

8E13: Predict the safety and potability of water supplies in North Carolina based on physical and biological factors including:
- Temperature
- Dissolved Oxygen
- pH
- Nitrates and Phosphates
- Turbidity
- Bio-indicators

8.E.1.4 Conclude that the good health of humans requires:
- Monitoring of the hydrosphere
- Water quality standards
- Methods of water treatment
- Maintaining safe water quality
- Stewardship

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