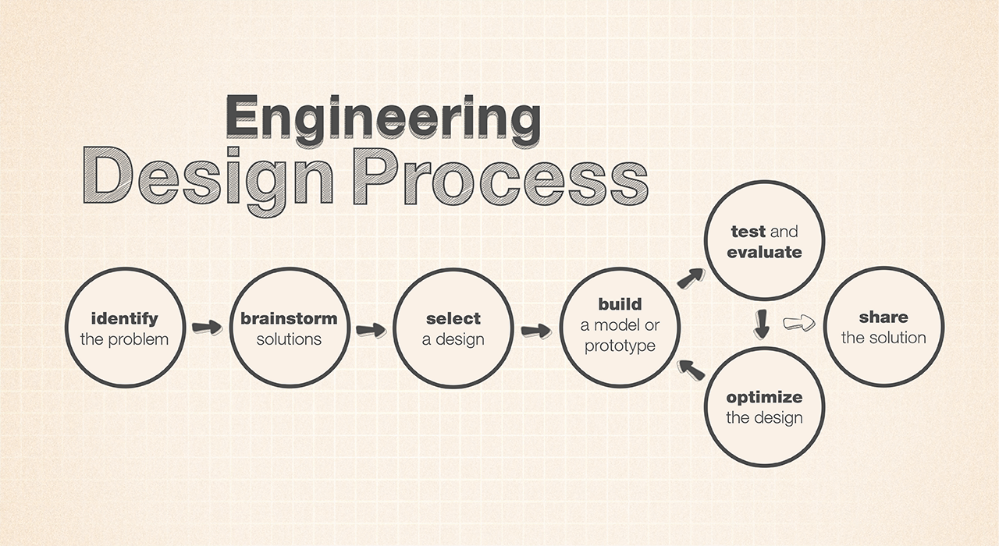
**Engineering Design 101**

**Background**

Developing a talented, diverse workforce of STEM professionals is imperative for addressing society’s most pressing challenges. Engaging youth in STEM programs, especially before middle school, is critical for strengthening the STEM talent pipeline. Engineering design activities with real-world context build youth’s problem-solving and technical communication skills and introduce youth to STEM career pathways. The engineering design process is a framework for addressing challenges transferrable across engineering disciplines (i.e., transdisciplinary). The engineering design process involves identifying and understanding a problem; applying concepts and skills from multiple STEM disciplines to design, build, test, and optimize a solution; and communicating the design process and impacts of their solution. With this process at the core of learning activities, STEM educators can provide multiple opportunities to apply different STEM principles and skills and explore different career pathways by swapping in different problems with associated design criteria and constraints.

**Engineering Design Process**

***Engineering design*** is defined in the International Technology and Engineering Educators Association (ITEEA) 2020 Standards for Technological and Engineering Literacy as “the systematic and creative application of scientific and mathematical principles to practical ends, such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems.” The engineering design process is an iterative, systematic approach to understanding and solving problems in engineering fields. ITEEA (2013) defined the engineering design process in 12 steps: 1.) Define the problem, 2.) Brainstorm possible solutions, 3.) Research ideas and explore possibilities, 4.) Identify criteria and constraints, 5.) Consider alternative solutions, 6.) Select an approach; 7.) Develop a design approach, 8.) Make a model or prototype, 9.) Test and evaluate, 10.) Refine the design, 11.) Create the solution, 12.) Communicate results. Figure 1 is a simplified version of the engineering design process, which can be used to introduce this process to learners.



***Figure 1***: Simplified engineering design process (Source: NASA Jet Propulsion Laboratory)

**Real-World Contexts for Engineering Design Activities**

ITEEA and its Council on Technology and Engineering Teacher Education 2020 identified eight contexts in the most recent Standards for Technological and Engineering Literacy. These contexts represent common content areas within engineering education to which the engineering design process can be applied. The following series of engineering design activities are aligned with these contexts and provide examples of activities of how students apply the engineering design process to various problems with different design criteria and constraints. Use the following activities as stand-alone grab-and-go activities or build a larger program out of activities aligned with each goal.

1. Computation, Automation, Artificial Intelligence, and Robotics
   * [Healthy oceans](https://microbit.org/teach/lessons/healthy-oceans/) (micro:bit)
2. Material Conversion and Processing
   * [Fork it over! Create Biodegradable Plastic](https://smile.oregonstate.edu/sites/smile.oregonstate.edu/files/plasticfork_interactive.pdf) (Oregon State University)
   * [Algaculture and Biofuel](https://agclassroom.org/matrix/lesson/629/) (National Agriculture in the Classroom)
3. Transportation and Logistics
   * [Design Streets for Everyone](https://stride.ce.ufl.edu/k-12-workforce-development/transportation-engineering-design-activities-for-grades-5-to-12/) (University of Florida Southeastern Transportation Research, Innovation, Development, and Education Center)
   * [Inspired by nature: an engineering design-based biomimicry activity](https://www.tandfonline.com/doi/full/10.1080/00368121.2021.1918049#abstract) (vehicle design) (*Project and Curriculum Ideas in STEM Classrooms*) – use air quality data from the [EPA’s outdoor air quality monitoring network](https://www.tandfonline.com/doi/full/10.1080/00368121.2021.1918049#abstract)
4. Energy and Power
   * [Solar Water: Heat it Up!](https://www.teachengineering.org/activities/view/cub_solarenergy_lesson01_activity1) (TeachEngineering)
   * [Amped Up Engineering](https://4-h.org/programs/stem-challenge/power-protectors/) (National 4-H STEM Challenge Power Protectors Kit)
5. Information and Communication
   * [Introduction to Cyber Securityunits](https://microbit.org/teach/lessons/cyber-security/) (micro:bit)
   * [Health Tech units](https://microbit.org/teach/lessons/health-tech-unit-of-work/) (micro:bit)
6. The Built Environment
   * [Raise Them Up](https://highways.dot.gov/safety/pedestrian-bicyclist/step/step-stem-lessons) (FHWA Highway Safety Program)
   * [Curb Design: Create an Enjoyable Downtown](https://stride.ce.ufl.edu/k-12-workforce-development/transportation-engineering-design-activities-for-grades-5-to-12/) (University of Florida Southeastern Transportation Research, Innovation, Development, and Education Center)
7. Medical and Health-Related Technologies
   * [Biological Engineering through Popping Boba](https://app.box.com/s/n4r7qp76lyvh7w0hqqzfxu1hqehsb6lq) (Purdue University Agricultural and Biological Engineering) – Modify to include the context of encapsulating drugs. Set design criteria based on the suggested dependent variables. Teams should develop designs to meet these criteria by modifying the suggested independent variables
   * [Artificial Heart Design Challenge](https://www.teachengineering.org/activities/view/mis_heartbloodflow_act) (TeachEngineering)
   * [The New and Improved Nanotube: Fighting Breast Cancer](https://www.teachengineering.org/makerchallenges/view/rice2-2502-nanotube-breast-cancer-design-challenge) (TeachEngineering)
   * [Clearing a Path to the Heart](https://www.teachengineering.org/activities/view/cub_biomed_lesson03_activity1) (TeachEngineering)
8. Agricultural and Biological Technologies
   * H2Officers: Groundwater Detectives [Procedure](https://app.box.com/s/8xpt89wyog86jd3usnkb0d4xd4gwg552) and [Presentation](https://app.box.com/s/dq27h39fz93oyulmb4zfphppgh52lb2c) (Purdue University Agricultural and Biological Engineering)
   * [Engineering Inexpensive Mechanized Farm Tools](https://www.teachengineering.org/activities/view/uod-2754-mechanized-farm-equipment-design-activity) (TeachEngineering)

**Engineering Design Activities Aligned with Industry in Indiana**

1. **Motorsports** 
   * [Designing An Edible Derby Car](https://app.box.com/s/lea8zdfo8v4yai2zjd6jmq10orq6sh0z)
2. **Hypersonics** 
   * [Trash Can Rocket Ship](https://www.afosrstem.org/s/Hypersonics-Lesson-Plan-Grades-3-5-Trash-Can-Rocket-Ship.pdf) (Grades 3-5)
   * [Safety at Hypersonic Speeds](https://www.afosrstem.org/s/Hypersonics-Lesson-Plan-Grades-3-5-Safety-at-Hypersonic-Speeds.pdf) (Grades 3-5)
   * [Hypersonics: A Systems of Systems](https://static1.squarespace.com/static/638e4ab84460f61414edfba1/t/65568dc436a59660edab33d3/1700171204940/Hypersonics+Lesson+Plan+Grades+6-8+-+Hypersonics+A+System+of+Systems.pdf) (Grades 6-8)
   * [Designing to Balance Thrust and Drag](https://static1.squarespace.com/static/638e4ab84460f61414edfba1/t/6722a113bf878066654378c5/1730322707235/Hypersonics+Lesson+Plan+Grades+6-8+-+Designing+to+Balance+Thrust+and+Drag.pdf) (Grades 6-8)
   * [RFP: 5T3M Satellite Launch Vehicle](https://static1.squarespace.com/static/638e4ab84460f61414edfba1/t/6744e6ee0d7982588e039008/1732568814432/Hypersonics+Lesson+Plan+Grades+6-8+-+RFP+5T3M+Satellite+Launch+Vehicle.pdf) (Grades 6-8)
   * [Redesigning for Max Glide Distance](https://static1.squarespace.com/static/638e4ab84460f61414edfba1/t/6722a3476fca1454ef0b1e68/1730323271383/Hypersonics+Lesson+Plan+High+School+Engineering+-+Redesigning+for+Max+Glide+Distance.pdf) (Grades 9-12)
   * [RFP: 5T4R Satellite Launch Vehicle](https://www.afosrstem.org/s/Hypersonics-Lesson-Plan-HS-Engineering-RFP-5T4R-Satellite-Launch-Vehicle.pdf) (Grades 9-12)
3. **Manufacturing** 
   * [Assembly Line](https://discovere.org/engineering-activities/assembly-line/) (Grades 6-8, 9-12)
   * [Pen Factory](https://discovere.org/engineering-activities/pen-factory/) (Grades 6-8, 9-12)
   * [Let the Chips Fall](https://www.scalek12.org/scale-k-12-resources/let-the-chips-fall) [microchip manufacturing] (Grades 6-8, Grades 9-10)

**Outlines for Creating Engineering Design Activities**

As part of the engineering design process, teams evaluate and select appropriate approaches to address identified project goals. Some engineering design activities are more open-ended, providing design criteria and constraints and encouraging teams to apply STEM principles to develop a solution. In practice, engineers may select from a set of design approaches that are standard in the industry/discipline and then adapt the solution based on project characteristics. For instance, a stormwater engineer is unlikely to develop a novel stormwater management practice to capture and treat stormwater for a proposed housing development; rather, this engineer will pick from standard stormwater management practices (i.e., wet retention ponds, stormwater wetland, bioretention cell, dry detention basins) and adapt the selected practice based on site characteristics and project goals. Local, state, and federal regulations may also set available design approaches. For example, a stormwater engineer may only be able to select from stormwater management practices that are eligible for stormwater credits in their jurisdiction.

Students need to practice addressing more open-ended scenarios and selecting and justifying the best design approach based on the presented problem. The following outlines are for student worksheets to support engineering design activities. The first version is more open-ended, while the second version is designed to prompt students to select the best design approach from a set list. Aspects of the worksheet that need to be customized are highlighted in yellow. Following these outlines is an example of how this outline was customized for an activity on stream restoration engineering.

Communicating results is also a critical step in the engineering design process. Engineers should be able to convey the problem, design process, and final solution to diverse stakeholders. The provided engineering design frameworks provide an outline to help students prepare a presentation or report but do not specify the format for communicating results. See the examples below of innovative communication formats for design teams to share their results.

1. Pecha Kucha presentation: uses 10 or 20 slides displayed for 20 seconds each. The slides should contain very few words, ideally just one or more images.
2. Elevator pitch: use a concise verbal pitch, supported by referencing the physical prototype.
3. Storyboard: create a storyboard with sketches, diagrams, and photos to narrate the design process and resulting design visually.
4. Design process infographic: summarize each stage of the engineering design process with an infographic, using icons, flowcharts, and concise text.
5. Make research-style posters and host a mini-conference.

Engineering Design Framework (Open-Ended)

**Student Worksheet**

**Add scenario, including design criteria and constraints**

**Define the problem**

Describe the problem, including why solving this problem is important. Include findings from research on the problem.

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**Brainstorm possible solutions**

Brainstorm potential solutions to the problem. Record at least three potential solutions to the problem.

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5. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Research Potential Solutions, Contrast Solutions, & Select an Approach**

Research these potential solutions using reliable sources. Summarize research on these design approaches below. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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Compare these initial solutions. What are the strengths and weaknesses of each potential solution?

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| **Solution** | **Meets Design Criteria and Constraints?** | **Strengths** | **Weaknesses** |
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Select the best approach. Justify why you selected this solution.

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**Design**

Sketch a detailed design of the chosen approach, including labels for the dimensions and materials.

What are the environmental or sustainability considerations for this design?

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**Build a model or prototype**

What materials and tools will you need to construct the model or prototype?

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Describe how you will construct this model or prototype to represent the proposed design.

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**Test and evaluate**

How will you test your prototype?

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What types of data will you collect during testing?

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Conduct the test. Describe and analyze results from testing.

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**Refine the design**

Based on your test results, how will you modify your design?

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If time permits, build and test the revised design. Record your results from testing.

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**Implement the solution**

What steps will you take to develop and implement the final solution?

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**Communicate Results**

Outline the problem, design process, and final solution to share the results.

Problem: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Solution & rationale for solution: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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Design process: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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Final design: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**Engineering Design Framework (Select from Design Approaches)**

**Student Worksheet**

**Add scenario, including design criteria and constraints**

**Define the Problem**

Describe the problem, including why solving this problem is important. Include findings from research on the problem.

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Identify the design criteria (requirements for success) and constraints (limitations). \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**Research Potential Solutions & Select A Design**

Which 2-4 design approaches are most appropriate for the project? (Circle your choices)

a. \_\_\_\_Design Approach 1\_\_\_\_\_\_\_\_\_\_

b. \_\_\_\_Design Approach 2\_\_\_\_\_\_\_\_\_\_

c. \_\_\_\_Design Approach 3\_\_\_\_\_\_\_\_\_\_

d. \_\_\_\_Design Approach 4\_\_\_\_\_\_\_\_\_\_

e. \_\_\_\_Design Approach 5\_\_\_\_\_\_\_\_\_\_

f. \_\_\_\_Design Approach 6\_\_\_\_\_\_\_\_\_\_

g. \_\_\_\_Design Approach 7\_\_\_\_\_\_\_\_\_\_

Write a design brief (3-4 sentences), outlining the problem, project goals, potential approaches, and preliminary design ideas.

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Research the potential design approaches that you selected using reliable sources. Summarize research on these design approaches below.

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Compare these initial solutions. What are the strengths and weaknesses of each potential solution?

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| **Solution** | **Meets Design Criteria and Constraints?** | **Strengths** | **Weaknesses** |
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Select the best approach. Justify why you selected this solution.

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**Design**

Sketch a detailed design of the chosen approach, including labels for the dimensions and materials.

What are the environmental or sustainability considerations for this design?

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**Build a model or prototype**

What materials and tools will you need to construct the model or prototype?

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Describe how you will construct this model or prototype to represent the proposed design.

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**Test and evaluate**

How will you test your prototype?

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What types of data will you collect during testing?

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Conduct the test. Describe and analyze results from testing.

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**Refine the design**

Based on your test results, how will you modify your design?

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If time permits, build and test the revised design. Record your results from testing.

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**Implement the solution**

What steps will you take to develop and implement the final solution?

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**Communicate Results**

Outline the problem, design process, and final solution to share the results.

Problem: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Solution & rationale for solution: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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Design process: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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Iterations: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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Final design: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**Example of Translatable Engineering Design Framework**

The following example of an engineering design activity using this adaptable framework for engineering design activities is focused on stream restoration. This engineering design activity is prefaced by evaluating a locally degraded stream (*Stream Geomorphology: Math in Action*). Students then use this primary research to inform their approach to restoring the stream. Student teams evaluate approaches to stream restoration and select the best approach based on their prior evaluation of the degraded stream. Teams then build and test this design using a stream table.

**Stream Geomorphology: Math in Action**

**Overview:** Students will assess stream geomorphology to practice mathematical and statistical concepts in an applied context. This stream assessment is an opportunity to leverage local ecosystems for environmental education.

Assessment of stream geomorphology typically involves surveying equipment, but the following outline only requires surveying tape and a telescoping rod. A regular tape measure and PVC pipe with measurements will also suffice. Select a shallow, wadable stream with banks that permit easy entry and exit. Ensure that there are enough adult chaperones to manage the group.

**Background information:** Streams and rivers are conduits for water and sediment. Stream geomorphology (e.g., fluvial geomorphology) is the study of how streams and rivers are shaped, including in response to human-caused and natural disturbances. Stream variables that interact to determine the physical form of the channel include:

* Discharge, or the volume of water per unit of time.
* Sediment supply
* Sediment size
* Channel width
* Channel depth
* Water velocity
* Slope
* Roughness of channel materials

The geology, topography, soils, climate, and land use in the watershed impact these variables that drive the physical form of channels.

Assessing the physical form of streams provides critical information for scientists and engineers. Understanding channel geometry is also essential for understanding stream discharge and sediment transport. The assessment helps them identify sources of impairment that can be addressed through stream restoration. Healthy streams should 1.) have a balance of sediment aggradation and erosion, maintaining a somewhat stable form over time, 2.) support flows that spill out onto the floodplain at a recurrence interval of at most every 1.5 to 2 years, and 3.) supports habitats with different stream depth, width, velocity, and substrate throughout the channel.

Characterizing the geomorphology of less impaired streams in the region can provide critical insights into how to design a stream restoration for a nearby degraded stream. This approach of aiming to restore streams to have geomorphic characteristics like those in more pristine streams in the region is known as *Natural Channel Design*. Scientists and engineers often focus on the bankfull level when assessing stream geomorphology for projects using Natural Channel Design. In pristine streams, the bankfull level is the top of the bank. In entrenched streams that have been degraded from excessive erosion, the bankfull level is often below the top of the bank. These entrenched streams are often found in developed areas and watersheds with intensive agriculture. The following stream geomorphic characterization will be based on bankfull levels.

**Additional background reading:**

*Geomorphology: Fluvial Geomorphology*. (n.d.). Minnesota Department of Natural Resources. Retrieved September 15, 2024, from https://www.dnr.state.mn.us/whaf/5-component/fluvial\_geo.html

Doll, B.A., Grabow, G.L., Hall, K.R., Harman, W.A., Jennings, G.D., Wise, D.E. (2003). *Stream restoration: A Natural channel design handbook.* North Carolina Stream Restoration Institute and North Carolina Sea Grant. Retrieved from https://bae.ncsu.edu/wp-content/uploads/2017/07/sr\_guidebook.pdf

**Featured mathematical and statistical concepts**:

Select from the following concepts based on the age group that you are working with:

* Datum//frame of reference for taking measurements
  + Maximum stream depth taken with respect to bankfull elevation
  + Bankfull width taken with respect to bankfull elevation
  + Flood-prone estimated with respect to bankfull elevation
* Slope
  + Definition of slope with stream slope
  + Conversion of slope to a dimensionless ratio
* Ratios
  + Width-to-depth ratio
  + Entrenchment ratio
  + Sinuosity
* Conversion of units
  + Feet-to-miles or miles-to-feet conversion for stream slope
* Dimensional analysis
  + Velocity measurements with orange floats
  + Mean bankfull depth from the cross-sectional area and bankfull width
  + Hydraulic radius from the cross-sectional area and wetted perimeter
* Definitions of area and perimeter
  + Calculate and contrast bankfull cross-sectional area and wetted perimeter
* Area calculations
  + Area of trapezoids by estimating cross-sectional area
  + Area of a rectangle by estimating cross-sectional area
  + Area of a rectangle by estimating mean bankfull depth
  + Area of a rectangle by estimating wetted perimeter
* Summary statistics
  + Measures of central tendency by estimating velocity with orange floats
  + Measures of spread by estimating velocity with orange floats
  + Measure of central tendency by estimating mean depth with channel approximated as a rectangle
* Functions
  + Bankfull shear stress
  + Bankfull discharge via Manning’s Equation
* Reference tables and diagrams
  + Reference table for Manning’s n
  + Using the Shield’s diagram to find sediment competence from shear stress
* Models
  + Contrast measured dimensions to model outputs from regional curves
* Numerical integration
  + Estimating area under a curve with the Trapezoidal Rule

**Stream Assessment Data Sheet**

Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Time: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Team Members: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Stream Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

HUC12: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Location: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Select a representative cross-section for the stream.
2. Identify the bankfull elevation.

Bankfull indicators include 1.) abrupt breaks in slope (indicating a transition from steeper banks to the flatter floodplain surface), 2.) shifts in vegetation, such as surfaces that are bare or have more water-tolerant vegetation to surface with hardier perennial vegetation, 3.) shift in texture of and organic matter content of sediment, 4.) water stains on vegetation or rocks.

The bankfull elevation will serve as the vertical datum, or the reference point used to determine the elevation or depth of all other points. Stake the surveying tape at the bankfull elevation from bank to bank. Orient the surveying tape so that the origin for your lateral measurements is the left bank. The left bank is defined by looking downstream.

Bankfull indicators in this stream: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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A diagram of a flood stage

Description automatically generated

Source: Stream Restoration: A Natural Channel Design Handbook (Doll et al., 2003)

1. Measure the bankfull stream width.

Measure the width of the stream at the bankfull elevation.

Width: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Measure the maximum stream depth.

Maximum stream depth is measured at the thalweg, or the lowest point in the stream cross-section, from the streambed to the bankfull elevation.

Maximum Depth: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Characterize the bankfull cross-sectional geometry.

Measure depth at multiple points in the cross-section, either at specific intervals or where there are noticeable changes in geometry. Create a table for each measurement point, width, and depth. Leave space for three additional columns.

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Create a sketch of the stream cross-section based on the collected data.

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1. Estimate flood-prone width.

Floodplain width for natural channel design is designated as the floodplain width at the elevation of twice the maximum depth of the channel. Use the telescoping rod to mark the flood-prone elevation (i.e., bankfull elevation + maximum bankfull depth). Then, use the surveying tape to walk away from the channel in either direction until reaching where the floodplain surface intersects with the flood-prone elevation. The flood-prone width is the distance between these points of intersection on either side of the stream.

The flood-prone in flat landscapes might be pretty large and need to be measured with a topographic map or digital elevation model.

Flood-prone width: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

A diagram of a flood stage

Description automatically generated

Source: *Stream Restoration: A Natural Channel Design Handbook* (Doll et al., 2003)

1. Estimate the stream velocity.

Velocity is the rate at which an object changes position. Velocity is a vector quantity. In streams, velocity is defined as perpendicular to the stream cross-section. The magnitude of average velocity is represented as the displacement divided by the change in time.

Measure a length of the stream with the survey tape in the direction of flow (i.e., longitudinal). Add an orange or other float to the stream at the upstream end of the survey tape and measure how long it takes for the orange float to reach the end of the survey tape. Repeat this measurement two more times.

Distance traveled: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Trial 1 - Time Taken: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Trial 2 – Time Taken: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Trial 3 – Time Taken: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

What are the units of velocity? Why?

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1. Conduct a tracer experiment.

Add milk as a tracer to the stream. If turbidity sensors are available, record turbidity measurements over time. Alternatively, collect samples at certain times, and measure turbidity later in the lab. If possible, take concurrent measurements at multiple points in the stream.

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Make qualitative observations about transient storage zones. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Sketch a longitudinal profile.

Sketch key features along a representative length of stream (i.e., reach). Extend the survey tape in the direction of flow along the reach. Use the survey tape to determine the station at the start of each riffle, run, pool, and glide to develop a longitudinal profile of the stream.

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1. Describe the sediment in the streambed, especially the sediment size.

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A table of numbers and letters

Description automatically generated

Source: *Stream Restoration: A Natural Channel Design Handbook* (Doll et al., 2003)

1. Describe the conditions of the banks, including vegetation coverage and sediment texture.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

A diagram of a stream bank endodility factor

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1. Characterize the water quality.

What do you notice about the water in the stream? Include any water quality measurements in the box below. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Water quality measurements:

**Back in the Lab [Advanced]**

1. Estimate bankfull cross-sectional area using the Trapezoidal Rule.

Apply the Trapezoidal Rule, which approximates the area under a curve as a series of trapezoids. The area between each set of points is represented as a trapezoid. Revise your table above to include the height of the trapezoid, which is the lateral distance between each observation. Revise your table above to include the mean depth between each successive point []. Calculate the area of each trapezoid. Record the area of each trapezoid in the table.

Area of a Trapezoid: h

where h = height of trapezoid and b1 and b2 are the bases of the trapezoid.

Find the sum of the areas of the trapezoids to estimate bankfull cross-sectional area.

Bankfull Area:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

How can we get a more accurate measurement of the bankfull cross-sectional area?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Calculate the mean bankfull depth.

Calculate the mean bankfull depth by dividing the stream cross-sectional area by the stream width.

Mean stream width: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Calculate the entrenchment ratio.

The entrenchment ratio is flood-prone width divided by the bankfull width.

Entrenchment ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Use the Rosgen Classification of Natural Rivers below. Classify the entrenchment ratio.

Entrenchment ratio classification: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Calculate the bankfull width-to-depth ratio.

The bankfull width-to-depth ratio is bankfull width divided by the mean bankfull depth.

Bankfull width-to-depth ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Use the Rosgen Classification of Natural Rivers below. Classify the width-to-depth ratio.

Width-to-depth ratio classification: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Approximate the wetted perimeter.

Wetted perimeter is the length along the banks and streambeds that touches water during bankfull flows. The wetted perimeter can be approximated with the following equation:

Where

is the mean bankfull depth

Wetted perimeter: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Based on the formula above, what shape is the channel approximated as?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Calculate the hydraulic radius.

Calculate the hydraulic radius by dividing the bankfull area by the bankfull wetted perimeter.

Hydraulic radius: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Based on the calculation, what are the units for the hydraulic radius?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Calculate channel sinuosity.

Sinuosity is the ratio of stream length to valley length. Valley and stream length can be estimated using hydrography datasets, aerial imagery, or surveying.

Valley length: 2381 feet

Stream length: 2423 feet

Sinuosity: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Use the Rosgen Classification of Natural Rivers below. Classify the sinuosity.

Sinuosity classification: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

A diagram of a stream

Description automatically generated

Source: Stream Restoration: A Natural Channel Design Handbook (Doll et al., 2003)

1. Convert slope.

Slope is the ratio of rise to run. In the case of streams, the rise is the elevation change of the streambed, and the run is the stream length.

Based on Stream Stats, the channel slope is 17.2 ft/mi. Represent channel slope as a dimensionless ratio [1 mile = 5280 feet].

Slope: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Contrast channel geometry to regional curves.

Regional curves are models developed from streams assessed in a region. These models provide an estimate of bankfull geometry based on drainage area.

We used the Central Till Plain Region curve via Stream Stats to estimate bankfull geometry for Elkhorn Creek. This model estimated the following parameters based on the delineated drainage area:

* Bankfull width: 40.9 feet
* Bankfull depth: 2.37 feet
* Bankfull area: 96.3 ft2

How does the measured geometry compare to the predicted geometry?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Why do the model outputs differ from the field measurements?

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A map of the united states

Description automatically generated

Source: *Regional Bankfull-Channel Dimensions of Non-Urban Wadeable Streams in Indiana* (Robinson, 2013)

A diagram of a graph

Description automatically generated

Source: *Regional Bankfull-Channel Dimensions of Non-Urban Wadeable Streams in Indiana* (Robinson, 2013)

1. Calculate summary statistics for velocity.

Calculate the mean and standard deviation for the trials of velocity measurements.

Mean Velocity: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Standard Deviation of Velocity: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Ensure sediment-transport competence.

Sediment competence is the maximum size of sediment that a stream can transport under a given discharge. Shear stress is the force applied across a cross-sectional area that can suspend and move sediment particles and is calculated as follows:

Where τ is shear stress (lb/ft2)

γ is the density of water (62.4 lb/ft3)

R is the hydraulic radius at bankfull stage (ft)

s is the average stream slope (ft/ft)

Shear stress at bankfull stage: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ lb/ft2

Engineers relate shear stress to the diameter of sediment that can be suspended and transported using the Shield’s relationship. Use the Shield’s diagram below to estimate the maximum sediment diameter that can be suspended and transported during bankfull flows.

Grain diameter: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_mm

A diagram of a graph showing the power trend line

Description automatically generated

Source: Part 654 Stream Restoration Design National Engineering Handbook (Chapter 11 Rosgen Geomorphic Design)

1. Estimate bankfull stream discharge based on Manning’s Equation.

Some streams have gauges that measure discharge. Manning’s Equation, which was developed empirically, estimates bankfull discharge with the following formula:

[in metric units]

[in U.S. Customary Units]

Where

n is the Manning’s coefficient (review description of the streambed to inform the selection of a representative Manning’s n from the table below)

S is the slope of the stream (as a unitless ratio)

Modeled discharge: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ cfs or ft3/s

A screenshot of a computer

Description automatically generatedA table with text on it

Description automatically generated

1. Use the information above to classify the stream site based on Rosgen’s Classification of Natural Rivers.

Stream type: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

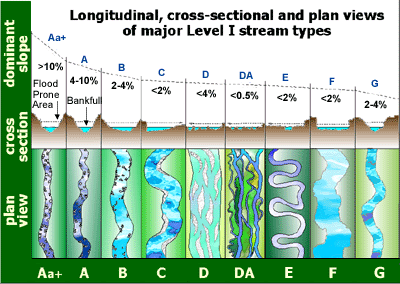
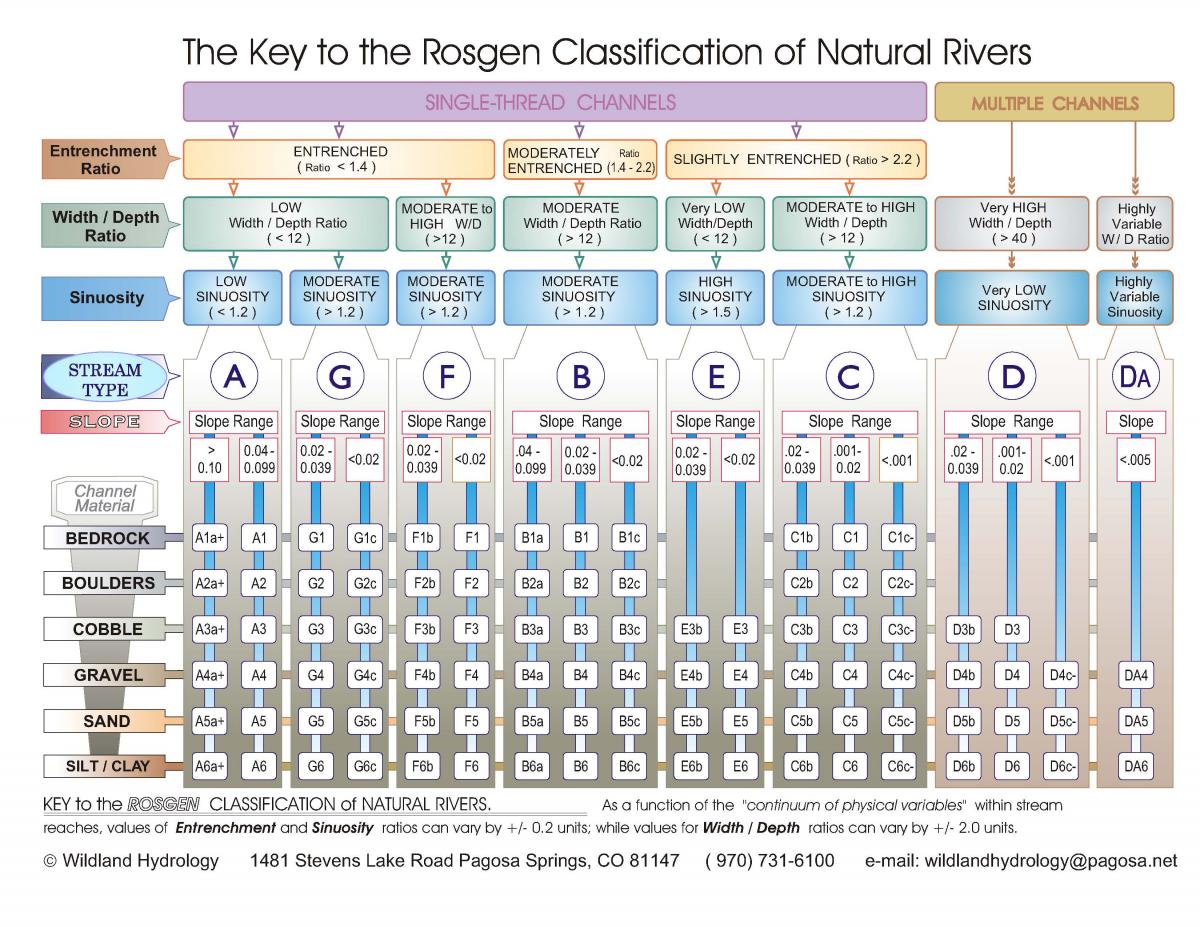


Image Source: Wildland Hydrology



**Back in the Lab [Junior]**

1. Estimate the mean bankfull depth.

Calculate the mean of depth measurements collected in the field.

Mean bankfull depth: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Estimate bankfull cross-sectional area by approximating the channel as a rectangle.

Assume the channel is a rectangle. Use the mean bankfull depth and bankfull width to estimate the cross-sectional bankfull area.

Bankfull Area:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Calculate the entrenchment ratio.

The entrenchment ratio is flood-prone width divided by the bankfull width.

Entrenchment ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Use the Rosgen Classification of Natural Rivers below. Classify the entrenchment ratio.

Entrenchment ratio classification: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Calculate the bankfull width-to-depth ratio.

The bankfull width-to-depth ratio is bankfull width divided by the mean bankfull depth.

Bankfull width-to-depth ratio: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Wetted Perimeter

Wetted perimeter is the length along the banks and streambeds that touches water during bankfull flows. The wetted perimeter can be estimated with the following equation:

Where

is the mean bankfull depth

Wetted perimeter: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Hydraulic Radius

Calculate the hydraulic radius by dividing the bankfull area by the bankfull wetted perimeter.

Hydraulic Radius: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Based on the calculation, what are the units for hydraulic radius?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Sinuosity

Sinuosity is the ratio of stream length to valley length. Valley and stream length can be estimated by hydrography datasets, aerial imagery, or surveying.

Valley length: 2381 feet

Stream length: 2423 feet

Sinuosity: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

A diagram of a stream

Description automatically generated

Source: Stream Restoration: A Natural Channel Design Handbook (Doll et al., 2003)

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Slope: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Calculate summary statistics for velocity

Calculate the mean velocity for the trials of velocity measurements.

Mean velocity: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Use the information above to classify the stream site based on Rosgen’s Classification of Natural Rivers.

Stream type: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

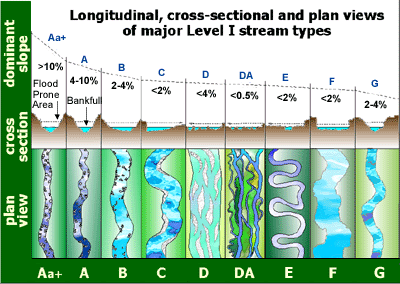
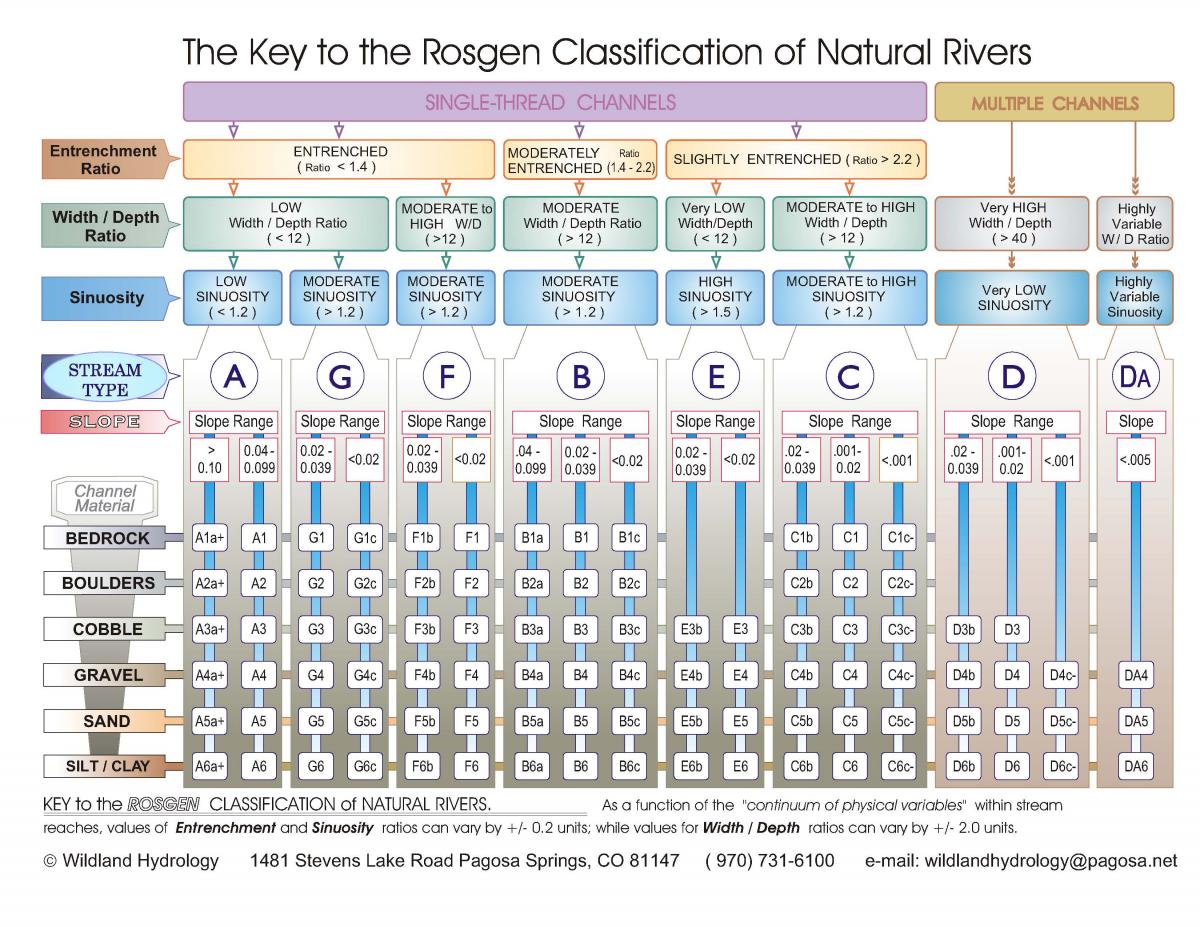


Image Source: Wildland Hydrology



**Potential Extensions:**

* Create a spreadsheet to collect inputs from the field visit and calculate all other parameters.
* Create an interface to help scientists and engineers more easily input their data [i.e., Air Table, Google Form, or mobile application].
* Conduct a stream habitat assessment.
* Rate stream banks based on the Bank Erodibility Hazard Index (BEHI) rating guide.

**Follow-Up Resources for Outdoor Stream Explorations:**

1. Water Quality Monitoring with Hoosier Riverwatch
   * Can check out water quality monitoring kits once training is complete
   * [Find upcoming workshops](https://www.in.gov/idem/riverwatch/hoosier-riverwatch-workshops/)
2. Limno Loan Program with Illinois-Indiana Sea Grant
   * Can check out water quality monitoring kits once the training is complete
   * Consider other [loanable kits from Illinois-Indiana Sea Grant](https://iiseagrant.org/education/loanable-kits/)

**References**

Doll, B.A., Grabow, G.L., Hall, K.R., Harman, W.A., Jennings, G.D., Wise, D.E. (2003). *Stream restoration: A Natural channel design handbook.* North Carolina Stream Restoration Institute and North Carolina Sea Grant. Retrieved from https://bae.ncsu.edu/wp-content/uploads/2017/07/sr\_guidebook.pdf

*Geomorphology: Fluvial Geomorphology*. (n.d.). Minnesota Department of Natural Resources. Retrieved September 15, 2024, from https://www.dnr.state.mn.us/whaf/5-component/fluvial\_geo.html

Robinson, B.A. (2013.). *Regional bankfull-channel dimensions of non-urban wadeable streams in Indiana*. (Scientific Investigations Report 2013-5078). U.S. Geological Survey. Retrieved from <https://pubs.usgs.gov/sir/2013/5078/pdf/sir2013-5078.pdf>

**Stream Restoration & Engineering Design**

**Learning Objectives:**

* Analyze field observations and measurements to identify goals for a project.
* Apply engineering design principles to develop a solution that addresses a specified problem.
  + Evaluate and select appropriate design approaches to address identified goals.
  + Develop initial design ideas that align with project goals.
  + Build, test, and improve the selected design.
  + Communicate the specified problem, iterations, and final design to stakeholders.

**Materials**:

* Stream model (to test designs)
  + Build a low-cost stream table ([Example](https://www.mrhollisterphoto.com/stream-table.html))
  + Build smaller stream models with available materials (e.g., [paint trays](https://scied.ucar.edu/activity/mississippi-river-delta))
* Sand, pea gravel, and gravel (to represent stream sediment of different sizes)
* Sticks (to model brush and tree trunks)
* 3-D printers, printer filament, devices to use 3-D design software (to model structures) [alternatives to 3-D printing: modeling clay, LEGOs]
* Model riparian and aquatic vegetation (i.e., trees, shrubs, grasses, moss) [alternatives: have students construct their own model vegetation from craft supplies or design and 3-D print model vegetation]
* Tubing (to model culverts and other drainage infrastructure)

**Pre-Work**

Visit a local stream or river, making sure to identify potential impairments. Use the stream data collection sheet provided in the previous module or other stream data collection sheets, such as from [Hoosier RiverWatch](https://ecm.idem.in.gov/cs/idcplg?IdcService=GET_FILE&dID=83366809&dDocName=83369014&Rendition=web&allowInterrupt=1&noSaveAs=1).

**Module 1: Introduction to Stream Restoration**

Stream restoration are active interventions to repair degraded streams, aiming to improve stream ecosystem services. Stream restoration projects may design streams to look more like pristine streams in the region. Other stream restoration designs include features that may not be typical of streams in the region or features that are not found in streams naturally, such as culverts and bioengineered banks, to meet design goals based on the current watershed conditions.

Introduce stream restoration with the case study of Muddy Creek in Edgewater, Maryland via [video](file:///\\nas01.itap.purdue.edu\ag_ces\Restricted%20Shared\State%204-H%20Office\Dani%20L\Volunteer%20and%20Educator%20Training\2024%20Youth%20Staff%20Pre-Conference%20Workshop\The%20Restoration%20of%20Muddy%20Creek) or book (ISBN-10: 1493866788).

**Career Connections**: Ecological Engineers, Civil Engineers, Environmental and Natural Resources Engineers, Fluvial Geomorphologists, Ecologists

**Module 2: Define the Problem & Select an Approach**

Funds are available to restore Elkhorn Creek. Review observations from the field visit and findings from researching the site to identify impairments and determine restoration goals. Examples of impairments include bank erosion, disconnection from the floodplain, impaired water quality, or inadequate fish passage.

1. Select 1-2 design approaches to address your impairment based on the identified goals (circle intended approaches).
   1. Reshape the stream channel
   2. Restore the riparian buffer zone
   3. Stabilize the stream banks
   4. Install in-stream structures
   5. Install fish passage solutions or structures to deter invasive species
2. Write a design brief (3-4 sentences), outlining the current problems with the stream, restoration goals, chosen approaches, and preliminary design ideas.

**Module 3: Research Potential Solutions & Select a Design**

1. Research design ideas based on the selected approach.
2. Select a design and justify this choice.

**Module 4: Design & Prototype**

1. Develop a detailed design, either drawing by hand or with computer software. The design should include dimensions and materials.
2. Construct a physical prototype based on the design plans:
   1. Stream Channel Design: build a model stream channel in a container with sand or other materials.
   2. In-Stream Structure/Fish Passage Solutions: build in-stream structures for the model stream

**Module 5: Test**

1. Test the prototype by simulating design conditions. Examples include rainfall simulation on a riparian buffer or pumping water through a stream change to evaluate channel design or in-stream structures.
2. Collect data. This data may be more qualitative, such as noting excessive erosion or channeling. Students will propose how they might evaluate the stream with better equipment/more resources.
3. Analyze results from testing. Assess if prototypes are meeting design goals.

**Module 6: Refine the Solution**

1. Based on the testing results, modify the design to improve outcomes and meet specified goals and criteria.
2. Test the new design.

**Module 7: Communicate**

1. Prepare final presentations with the rationale for selecting that solution, design process, final design, and any iterations. The instructor can select the format for the presentation (see below).
2. Present the project to the group, supporting this discussion with the prototype.

***Presentation Ideas:***

1. Pecha Kucha presentation: uses 10 or 20 slides displayed for 20 seconds each. The slides should have very few words, ideally just containing one or more images.
2. Elevator pitch: use a concise verbal pitch, supported by referencing the physical prototype.
3. Storyboard: design a storyboard with sketches, diagrams, and photos to narrate the design process and resulting design visually.
4. Design process infographic: summarize each stage of the engineering design process with an infographic, using icons, flowcharts, and concise text.
5. Make research-style posters and host a mini-conference.

**Reflection and Assessment:**

1. What did you learn about stream restoration techniques?
2. Reflect on the engineering design process. How did the engineering process help you understand the challenge with this stream and develop an effective solution?

**Student Worksheet**

**Stream Restoration Design**

**Scenario:** Funds are available for restoration. Review observations from the field visit and findings from researching the site to identify impairments and determine goals for the restoration. Examples include bank erosion, disconnection from the floodplain, impaired water quality, or inadequate fish passage.

**Define the Problem & Select an Approach**

Name of the local stream or river visited: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

List 3 potential impairments you observed:

a. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

b. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

c. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

After learning about Muddy Creek, list two key lessons you learned about stream restoration:

a. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

b. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Based on your field visit observations, what are the main goals for restoration? (Check all that apply)

[ ] Reduce bank erosion

[ ] Reduce streambed erosion

[ ] Reduce excessive sediment deposition

[ ] Reconnect stream to floodplain

[ ] Improve water quality

[ ] Enhance fish passage

[ ] Prevent the passage of invasive species

[ ] Enhance aquatic habitat

[ ] Enhance riparian habitat

[ ] Other: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Which 1-2 design approaches have you selected? (Circle your choices)

a. Reshape the stream channel

b. Restore the riparian buffer zone

c. Stabilize the stream banks

d. Install in-stream structures

e. Install fish passage solutions or structures to deter invasive species

Write a design brief (3-4 sentences), outlining the current problems with the stream, restoration goals, chosen approaches, and preliminary design ideas.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**Research Potential Solutions & Select A Design**

Research design options for the restoration design approach(es) that you selected.

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List 3 key design ideas from your research:

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b. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

c. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Select a design. Why did you select this design?

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**Design & Prototype**

Sketch your detailed design here (including dimensions and materials):

Describe how you will represent this design with a physical prototype.

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**Test**

How will you test your prototype?

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What types of data will you collect during testing?

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How would you evaluate the success of the stream restoration with better equipment/resources?

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Conduct the test. Describe and analyze results from testing.

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**Refine the Solution**

Based on your test results, how will you modify your design?

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If time permits, build and test the revised design. Record your results.

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**Communicate**

Outline your presentation.

Current stream impairments: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Solution & rationale for solution: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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Design process: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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Iterations: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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Final design: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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