INSIDE

- Exhibition Overview
- Preparing for Your Visit
- Educational Standards
- Student Activity Sheets
Table of Contents

IN THIS GUIDE

Exhibition Overview ................................................................. 3
Preparing for Your Visit .......................................................... 4
Exhibition Map ........................................................................... 5
Exhibition Highlights .............................................................. 7
Related Offerings ..................................................................... 12
Online Resources ..................................................................... 15
Educational Standards ............................................................ 17

ACTIVITY SHEETS

Grades K – 2 ............................................................................. 18
Grades 3 – 5 ............................................................................. 20
Grades 6 – 8 ............................................................................. 21
Grades 9 – 12 .......................................................................... 25

For school reservations, call Science Central: 617-723-2500.
For field trip planning assistance, contact the Educator Resource Center: library@mos.org.
Introduction

Visit this permanent exhibition at the Museum of Science and explore the connections between nature and engineering on the Charles River. Humans make engineering decisions that change the river’s flow and landscape to meet our needs. When engineering solutions, we need to account for the naturally changing river system and consider the impact on animals and plants that share this environment. By exploring unique challenges presented by an urban center situated in a diverse river ecosystem, visitors learn that there are no perfect solutions to the challenges created in these constantly changing environments.

The presence of live animals and other natural phenomena in the Yawkey Gallery on the Charles River encourages students to think like scientists. By making observations, asking questions, and constructing explanations, students embody several key science practices. This exhibition also features interactive learning stations that highlight the engineering habits of mind, allowing students to design and build possible solutions to real-world engineering problems. After testing their solutions, students can modify their initial design to improve its performance while also considering the environmental impact of their design.

Educational Goals

Observe: Visitors engage in observation activities to interpret the interactions between the natural and engineered parts of the Charles River.

Engineer: Visitors engage in engineering design process activities and test the impacts of their engineering decisions to solve problems encountered by scientists and engineers in the Charles River watershed.

Connect: Visitors are inspired to think about the connections between the natural and engineered parts of systems present in their everyday lives.

Credits

This new gallery has been made possible through a generous lead gift from the Yawkey Foundations, major gifts from the Institute of Museum and Library Sciences, Ann and Ed Kania, Payson and Jane Swaffield, and numerous other contributors.

Photos © Nicolaus Czarnecki, © Studio Nouveau, © Ashley McCabe, © TMP Images
Roles of Teachers and Chaperones Visiting with Students:

- Chaperones are required to stay with their smaller chaperone-size groups while touring the exhibition.
- Encourage students to pursue their own questions.
- Rotate students through the different exhibit components, recognizing that not all students may be able to complete an activity due to time limits.
- Ensure the safety of the students and exhibit components during the visit.

Tips on Visiting:

- Plan for your students to spend about 30 minutes in this exhibit so they can participate at each of the different activity stations. We recommend a maximum of 30 students visit the exhibit at a time, in groups of 5 to 8 students.
- Most of the engineering activities involve water, and your students may get wet. If needed, bathrooms with hand dryers are located nearby in the Blue Wing, Lower Level.
- When preparing students for their experience, you can use the exhibit entrance on the Lower Level of the Blue Wing. (Note that the space just inside the Museum entrance on Level 1 is used for field trip lunch preparation and can get very crowded.)
- The Yawkey Gallery on the Charles River incorporates the principles of Universal Design to provide accessibility above and beyond the ADA Standards for Accessible Design. All exhibit components have audio handsets and/or speakers that provide recordings of the label text and descriptions of the images and activities. The numerous interactive exhibits incorporate audio, visual, and tactile elements to create multisensory learning experiences. The closest elevator to the exhibit is located in the Blue Wing near the bathrooms.

Please contact the accessibility coordinator with any questions or concerns regarding access for visitors with disabilities to this, or any other exhibit: accessibility@mos.org, 617-589-3102.
INTRODUCTORY ACTIVITY STATIONS (LOBBY, LEVEL 1)

The rear lobby is an entry point to introduce students and educators to the interplay between the natural and engineered worlds.

Living Plant Wall and Waterfall

Living wall panels surround a 30-foot tall-waterfall. This three-story garden, containing nine different species of plants, creates a work of living art up the left side of the exhibit and exemplifies the theme of uniting the natural and engineered worlds. A kiosk with touchable plants allows students to explore factors needed for the plants to grow (light, water, nutrients, and support) and the technology that provides them (LEDs, water systems, and rock wool). How does this artificial environment compare to those that students would find in their own communities?

River Loom Kinetic Sculpture

Suspended from the ceiling, the River Loom's movements evoke the complex waves seen through the gallery windows, which are formed by the river lapping against the engineered riverbanks. Students can get different perspectives of the sculpture on all three levels of the exhibit, including the bridge between the Green and Blue Wings on Level 2. They can simulate the mechanics of a transverse wave with the Wave Machine on Level 1.

Reaction-Diffusion Media Wall

At an array of twenty-four 55" video monitors, students can control the parameters of a real-time simulation and explore how computer simulations help us understand the natural world.

Two-Level Bridge LED Media

Two digital screens mounted to the ceiling showcase animated interpretations of technology interacting with the natural world. Witness the Alvin submersible as it travels underwater, watch the International Space Station orbit the Earth, and more.
OBSERVATION ACTIVITY STATIONS (LOWER LEVEL)

Interactive and reflective exhibit components enable students to cultivate observation skills using the Charles River as a case study.

River Observations

Charles River observations can be made in many capacities. Labels mounted to the windows prompt students to look toward the river, and benches are situated throughout. Students can observe natural and human-made changes on and around the river by viewing time-lapse videos showing daily and seasonal changes. Students can also listen to a broadcast soundscape of the Charles River.

Animals and Aquariums

By observing and connecting with creatures that live in and around the urban river system, visitors make connections to the impacts of human engineering decisions. Two large aquariums under the circular staircase feature a variety of Charles River fish, including native and introduced species, that comprise the engineered fish population living in the river today. Students can crawl underneath the observation tanks for a better view of the fish and the painted turtles, a reptile species that continues to thrive in the river. The crawl space also houses a sewer scene diorama perfect for young learners.

Opposite the large aquariums is a wall of smaller tanks featuring animals that have been impacted by human engineering in a variety of ways, including snakes, frogs, salamanders, and a variety of invertebrates. How might our interactions with the environment impact animal habitats?
Monitoring the River

This area introduces students to several kinds of measurements and data collection tools scientists use to study river health. Visitors are also prompted to interpret real data from the Charles River.

**Conductivity:** Flip switches to observe the conductivity of four water samples. *Which water sample is most conductive?*

**Turbidity:** Raise a patterned secchi disk to observe the turbidity of three water samples. *What impacts the visibility of the disks?*

**Depth:** Lower a chain down a covered column to gauge water depth without being able to see the bottom of each tube. *How can you tell which tube is the deepest?*

**River Dashboard:** A digital screen displays data about the river’s current health, including parameters collected from several sources:

- a seasonal buoy placed in the river by the Environmental Protection Agency
- the US Geological Survey gauge at the New Charles River Dam
- data from the Charles River Watershed Association
ENGINEERING ACTIVITY STATIONS (LOWER LEVEL)

Students can practice the engineering habits of mind and test the impact of engineering decisions with examples from a river system.

Sampling the River: Engineer a river sensor

Scientists design tools to collect representative samples from various depths of the water column. Students face this same challenge as they decide what sample to collect (surface, middle, or bottom) and then modify a sensor bottle by attaching floats and weights. They will test their sensor by placing it in a tube of water and seeing where in the tube it floats. Can they make adjustments to their design to better meet their goal?

Altering the River Flow: Engineer a water path

Learn how engineers modify the flow of water to allow fish species to travel through a passage and over a river-blocking dam. Using the engineering design process, students will adjust the flow of moving water. They will place barriers to construct a flow path in an inclined channel with running water, then test their design by releasing a ball at the top of the incline and observing how it moves through the path they constructed. How does the ball model how an animal would move through the water path?

Want to Make Further Connections?

Pre/Post visit and on-site activity sheets (ranging from grades K – 12) can be found on pages 18 – 30.
Exhibition Highlights (continued)

Building in the River: Engineer a bridge support

Engineers must take natural constraints into account when designing bridge supports in moving water. Students will need to consider some of these same constraints in their design, such as river width and velocity of water flow, as they build a structure that can support a bridge. They will place supports in a channel with flowing water and test the stability of their design by completing roads at three points along the model river.

Engineering in a River System: Observe the tradeoffs of engineering decisions within a river system

Located next to the Natural Mysteries exhibit entrance, the River Table is an interactive space that uses projection, lighting, and animation to model a virtual river ecosystem. Students will make engineering decisions at five scenes along the River Table and receive feedback about the social, economic, and environmental effects of their decisions. They will use physical pieces that, when put in place, alter the animations projected on the River Table surface and give live audio feedback about the consequences of their decisions. In one scenario, visitors can decide whether they should place a parking lot or a flowerbed next to a riverside restaurant, and see how the resulting runoff affects the river ecology, or how lack of parking affects the business.

The River Table brings together the engineering design decisions and observation skills used throughout the exhibit, illuminating how these two worlds interact as one interdependent system. Can you prompt students to examine the tradeoffs associated with each of the interactions?
Related Offerings

DROP-IN ACTIVITIES ACROSS THE MUSEUM

Stop by during program hours for these drop-in, hands-on activities related to themes of the natural and engineered worlds. A typical stay for a school group is from 10 to 20 minutes. Due to capacity limits, groups of 20 or more may wish to contact us for scheduling advice. Activities may not be reserved but, for Design Challenges, the topic of the day can be requested, based on availability.

Fee: Free with Exhibit Halls admission. Programs not available during holidays or Massachusetts school vacation weeks. Schedule for weekdays only is subject to change without notice. Details: mos.org/drop-in-activities.

Charles River Field Station

Yawkey Gallery on the Charles River; Lower Lobby

GRADES PRE K - 12 Join a Museum educator for a variety of hands-on investigations, ranging from investigating the chemical and biological factors of river ecology to exploring the natural history of the Greater Boston area.

No reservations accepted. Activities available most school-day mornings. Capacity: 5 – 8 (small groups can rotate through as other students explore the surrounding exhibit). Details: mos.org/daily-schedule.

Design Challenges

Engineering Design Workshop; Blue Wing, Level 1

GRADES 2 – 12 Dive into the engineering process through a drop-in, hands-on 20-minute activity to design, build, and test a prototype solution to a given problem. With advance communication, school groups can request a specific design challenge for the day of their visit.

Email designchallenges@mos.org at least two weeks in advance to request a topic. Available: Daily. Time: 10:00 a.m. – 12:00 p.m. Capacity: 40.
**Related Offerings (continued)**

**Hands-On Laboratory**
_Suit/Cabot Lab; Red Wing, Lower Level_

**GRADES 2 – 12** The Hands-On Laboratory is a fun, interactive learning laboratory program that encourages visitors of all ages to explore various topics using many of the same tools and techniques as real scientists. View the Museum’s daily schedule for program times and topics.

No reservations accepted. For scheduling advice for larger groups, contact ehi-requests@mos.org. Available: Tuesday through Friday, October through May. _Time:_ 10:30 a.m. – 12:30 p.m. _Capacity:_ 15 – 20.

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**LIVE PRESENTATIONS: ON THE DAILY SCHEDULE**

_Schools and general audiences are invited to a number of live shows offered daily in the Exhibit Halls._ For detailed program descriptions and curriculum connections, visit mos.org/live-presentations. For the daily schedule, visit mos.org/daily-schedule. Fee: Free with Exhibit Halls admission.

**Live Animal Presentation**
_Shapiro Family Science Live! Stage; Green Wing, Lower Level_

**GRADES K – 12** Explore the adaptation, behavior, and ecology of animals—as well as the environments they live in—with the furry, feathered, and scaly residents of our _Live Animal Care Center_. (Note that on Mondays only, we offer _Live Animal Story Time_, in which our younger visitors listen to a story before meeting its animal star.)

No reservations required. _Available:_ Monday – Friday. _Length:_ 20 min. _Capacity:_ 125.
CONNECTIONS TO OTHER MUSEUM EXHIBITS

These exhibits and presentations can connect to the Yawkey Gallery on the Charles River, helping students apply the ideas they have learned about the natural and engineered worlds. Visit mos.org for the latest updates on live presentations and other programming related to this exhibit.

A Bird’s World Green Wing, Lower Level

• What sorts of birds live around the New England waterways?

Conserve @ Home Blue Wing, Level 2

• Explore buoyancy, drains, water conservation, and how a toilet works. How does your water use affect the environment?

Energized! Blue Wing, Lower Level

• Energy supplied vs. environmental impact (hydro/wind).

Hall of Human Life Green Wing, Level 2

• How does the environment affect our human development?

Living on the Edge Blue Wing, Lower Level

• Explore the boundaries between land, air, and sea.

Making Models Blue Wing, Level 2

• Models help us understand systems.

New England Habitats Green Wing, Level 1

• What sorts of animals live around the waterways of New England?

Customize Your Own Guide!

You can also create your own field trip guide, or use one of our pre-selected guides, at mos.org/field-trip-activity-sheets.
DATA SOURCES TO EXPLORE IN YOUR CLASSROOM

EPA – Charles River Data Buoy
epa.gov/charlesriver/live-water-quality-data-lower-charles-river

Charles River Watershed Association
crwa.org/field-science/weather-station

Monthly Bacteria Monitoring
crwa.org/field-science/monthly-monitoring/water-quality-data

USGS Gauge at the new Charles River Dam
waterdata.usgs.gov/nwis/uv/?site_no=01104715

Additional River Gauges Maintained by the USGS
waterdata.usgs.gov/nwis/rt

MWRA water testing data for Massachusetts:
mwra.com/monthly/wqupdate/qual3wq.htm
ARTIST LIST

River Loom Kinetic Sculpture – Reuben Margolin
   reubenmargolin.com

Digital Media Wall – Karl Sims
   karlsims.com/rd-exhibit.html

Bronze Sculptures – Michael Alfano
   michaelalfano.com

Large Scale Photographs – Paul Nguyen
   paulnguyenphoto.com

WATER & WILDLIFE EDUCATION

Project WET
   projectwet.org
   A national education program focusing on water education for teachers.

Project WILD
   projectwild.org
   An international interdisciplinary environmental education program.

Massachusetts Environmental Education Society
   massmees.org
   Promoting environmental education for MA and New England.
Many of the activities in this exhibit connect with the curriculum standards in science, engineering, mathematics, and English language arts. A more complete listing of the connected educational standards is available through the Educator Resource Center. To connect with an educator, visit mos.org/educators.

2016 Massachusetts Science and Technology/Engineering Curriculum Framework Connections

EARTH AND SPACE SCIENCE

GRADES K – 2
K-ESS2-2 Construct an argument supported by evidence for how plants and animals (including humans) can change the environment.

GRADES 3 – 5
5-ESS3-1 Obtain information about ways communities reduce human impact on the Earth’s resources and environment by changing an agricultural, industrial, or community practice or process.

GRADES 9 – 12
HS-ESS3-1 Construct an explanation based on evidence for how the availability of key natural resources and changes due to variations in climate have influenced human activity.

LIFE SCIENCE

GRADES 6 – 8
7-LS2-5 Evaluate competing design solutions for protecting an ecosystem.

GRADES 9 – 12
HS-LS2-7 Analyze direct and indirect effects of human activities on biodiversity and ecosystem health.

TECHNOLOGY/ENGINEERING

GRADES K – 2
1-K-2-ETS1-1 Ask questions, make observations, and gather information about a situation people want to change that can be solved by developing or improving an object or tool.

1-K-2-ETS1-2 Generate multiple solutions to a design problem.

2-K-2-ETS1-3 Analyze data from tests of two objects designed to solve the same design problem to compare the strengths and weaknesses of how each object performs.

GRADES 3 – 5
3.3-5-ETS1-2 Generate several possible solutions to a given design problem.

GRADES 6 – 8
7.MS-ETS1-7 Construct a prototype of a solution to a given design problem.

GRADES 9 – 12
HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs.

HS-ETS1-4 Use a computer simulation to model the impact of a proposed solution to a complex real-world problem.

Common Core State Standards Connections

<table>
<thead>
<tr>
<th>GRADE BAND</th>
<th>ENGLISH LANGUAGE ARTS STANDARD</th>
<th>MATHEMATICS STANDARD</th>
</tr>
</thead>
<tbody>
<tr>
<td>K – 2</td>
<td>RI 2.1 Reading Informational Text</td>
<td>MP.2 Reason abstractly and quantitatively.</td>
</tr>
<tr>
<td>3 – 5</td>
<td>RI 3.7 Integration of Knowledge and Ideas</td>
<td>MP.4 Model with mathematics.</td>
</tr>
<tr>
<td>6 – 8</td>
<td>RST 6-8.9 Combine and Compare Information from Activities and Text</td>
<td>MP.2 Reason abstractly and quantitatively.</td>
</tr>
<tr>
<td>9 – 12</td>
<td>RST 11-12.8 Evaluate Data, Analysis, and Conclusions in a Science or Technical Text</td>
<td>MP.4 Model with mathematics.</td>
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</tbody>
</table>
ON-SITE STUDENT ACTIVITY (GRADES K – 2)

Using Observation Skills

Draw a picture of one of the animals you see in the animal tanks. Can you label the body parts?

Head to the benches looking out onto the Charles River. At the Observe an Urban Landscape station, listen to the sounds of the river.
Let all of the sounds play together. Which sounds are the loudest?

Next, play each sound one at a time. Which sounds come from nature?

Which sounds are man-made?
ON-SITE STUDENT ACTIVITY (GRADES K – 2)

Be an Engineer

Name: __________________________________________________________ Date: ________________________

Teacher/Class: ___________________________ Additional Information: _______________________

**Go to the Engineering a Water Path or the Engineering a Bridge Support stations.**

How did you change the flow of the water? Draw your design:

Did it work? How else could you change it?

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ON-SITE STUDENT ACTIVITY (GRADES 3 – 5)

Be an Engineer

Name: _____________________________ Date: __________________________

Teacher/Class: _____________________ Additional Information: __________________

Using Observation Skills: Scientists and engineers gather and analyze data throughout every investigation. Choose one of the engineering design activities (Engineering a River Sensor, Engineering a Water Path, and Engineering a Bridge Support).

What problem were you trying to solve in this activity?

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Were there other solutions? Describe another successful design.

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Practicing Engineering Skills: Scientists and engineers look to make their designs better. Choose another engineering design activity.

Sketch how your design changed from when you started to your final design.

<table>
<thead>
<tr>
<th>STARTING DESIGN SKETCH (Label Major Parts)</th>
<th>FINAL DESIGN SKETCH (Label Major Parts)</th>
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</table>
Name: ___________________________________________ Date: __________________
Teacher/Class: ________________________________ Additional Information: ____________________________

**Practice Engineering Skills:** Engineers modify nature to suit a human need or desire. Reflect on one aspect of your life that would be different without any engineering. 
*(For example: How would you get water?)*

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**Making Connections:** What are some examples of objects or structures that have been engineered around where you live? What are some of the potential environmental impacts caused during the design, manufacturing, use, or disposal of these objects?

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<thead>
<tr>
<th>ENGINEERED OBJECT</th>
<th>ENVIRONMENTAL IMPACTS</th>
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**Using Observation Skills:** Now think about a stream or river near where you live. List some of the impacts to the body of water caused by humans.

1. ____________________________________________
2. ____________________________________________
3. ____________________________________________
Humans' interactions with their surroundings could have impacts on the environment. Think about a body of water near where you live (a river, a pond, a reservoir, etc.) and answer the following questions:

How do people use that water resource? How might this usage impact the water's environment?

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If you were a bird in this water habitat, where would you spend your time? If you were an engineer designing a water habitat specifically for birds, what would you add, remove, or change?

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If you were a fish in this water habitat, where would you spend your time? If you were an engineer designing a water habitat specifically for fish, what would you add, remove, or change?

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ON-SITE STUDENT ACTIVITY (GRADES 6 – 8)

Be an Engineer

Using Observation Skills: Scientists and engineers gather and analyze data throughout every investigation. Choose one of the engineering design activities (Engineering a River Sensor, Engineering a Water Path, and Engineering a Bridge Support).

What were some of the criteria you established to determine if your design was successful?

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What were some constraints you had to consider during your design and build phases?

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Practicing Engineering Skills: Scientists and engineers look to improve existing designs. Explore one of the exhibit’s engineering design activities, and then sketch out how your design changed from the initial idea to the final design.

<table>
<thead>
<tr>
<th>INITIAL DESIGN (Sketch or Take a Photo)</th>
<th>FINAL DESIGN (Sketch or Take a Photo)</th>
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How did your final design function better?

______________________________________________________________________________________
Making Connections: The natural and engineered worlds are connected. Explore each station in Engineering in a River System.

Select one of the stations:

- Hydroelectric Dam
- Pest Management
- Fish Passages
- Land Use
- Sewer System

Make a claim about which engineering solution you believe is the best for that station. Justify your selection, addressing the potential environmental impacts.

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With each engineering endeavor, there is never a perfect solution.

Imagine that you are one of the following citizens:

- Town Engineer
- Home Owner
- Business Owner
- Fisherman
- Environmental Activist

What selection would you now prefer for the engineering station? What tradeoffs do you need to take into account?

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Charles River Buoy Data

Using Observation Skills: Every year the EPA places a seasonal buoy in the Charles River. Located just outside the Museum of Science, the buoy has a series of instrumentation (temperature, specific conductance, pH, dissolved oxygen, turbidity, chlorophyll, and phycocyanin) that periodically analyzes water samples from the river. Data from the buoy can be viewed at: epa.gov/charlesriver/live-water-quality-data-lower-charles-river.

Go to the website and explore how you can plot historical test results. Choose three of the test parameters and generate a graph for a period of at least three months. Make sure you label the axis!
Analyze Your Graphs: What trends do you see? Are there any surprises?

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Can you make a claim about the relationships between any of the parameters?
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Page 2 of 4 →
**Practicing Engineering Skills:** The Museum of Science sits on top of a dam, originally constructed to maintain a constant upstream water level and eliminate tidal action in the Charles River. A new dam was built further downstream with more advanced technology. Real-time data and historical information about the water levels at this new dam can be found at: waterdata.usgs.gov/nwis/uv/?site_no=01104715

From the website, review the tidal changes data—the distance between the low and high tides. Analyze six months’ data and fill in the table:

<table>
<thead>
<tr>
<th>MONTH</th>
<th>MINIMUM TIDE HEIGHT</th>
<th>MAXIMUM TIDE HEIGHT</th>
<th>AMOUNT OF TIDAL CHANGE</th>
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AVERAGE

Explain why you think there are variations in the amount of tidal changes:

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**Making Connections:** As a result of global climate change, scientists have observed that sea levels are rising. Over the last 100 years, the relative water levels in Boston have risen about 10 inches. Learn more about the rise of water levels in Boston: 

Based on the website information, make a prediction about what will happen to Boston—or any community located on the ocean—as the sea level continues to rise. What will happen to the shorelines? The underground infrastructures?

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What engineering measures can be taken to address the rising water levels?

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What preventive environmental measures can be taken to lessen the rising water levels?

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______________________________________________________________________________________
Engineer a River Sensor

Practicing Engineering Skills: Scientists and engineers look to improve existing designs.

Plan, create, test, and improve your sensors as you create:

a) a vertical sensor
b) a horizontal sensor
c) two different-sized sensors that both reach the same depth

How did you attach materials to achieve vertical floating? Horizontal floating? How were they different?

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Are there similarities and/or differences between the two sensors at the same depth? Why or why not?

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Describe how you would design two identical sensors: one that floats vertically at the surface, and one that hovers horizontally at the bottom.

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POST-VISIT STUDENT ACTIVITY (GRADES 9 – 12)

Be a Consulting Engineer

Name: ____________________________________________________________  Date:________________________________
Teacher/Class: ______________________________________   Additional Information:________________________________

Using Observation Skills: Within this exhibit, you were able to design and build three different engineering items: a fish ladder, a water sensor, and a bridge. Choosing one of these activities, describe how you might design a different solution to the challenge. How would this design be better than what you created at the Museum?

Engineering Activity: __________________________________________________________________
______________________________________________________________________________________
______________________________________________________________________________________

Practice Engineering Skills: At the River Table, you experienced trade-offs with different engineering alternatives (hydroelectric dams, pest management, fish passages, land use, and a sewer system). Since your visit, have you changed your opinion as to which engineering alternative would be considered the “best”? If so, which one would you want to change and why? If not, why do you think your selection remains the strongest?

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Making Connections: Think about construction occurring around your town/city/region. After visiting this exhibit, think about the connections between the engineering that went into the design and the environmental impact. Identify one construction project that you have recently seen.

Observed Construction Project: __________________________________________________________

Possible Design Criteria: ________________________________________________________________
______________________________________________________________________________________

Possible Design Constraints: _____________________________________________________________
______________________________________________________________________________________