Title: Chemistry and Environmental Engineering: Water We Doing?

Length of Course: Full Year (2 semesters; 3 trimesters; 4 quarters)

Subject Area – Discipline: Laboratory Science ("d") – Chemistry

CTE Sector: Engineering and Architecture

CTE Pathway: Environmental Engineering

Grade Level(s): 10-12

Course Overview:

This course serves to introduce the principles of chemistry and environmental engineering through an understanding of the behavior of water and its interactions with the environment. Students will use a systems-based approach to understand that all environmental systems consist of matter and will apply this knowledge to solving current and future global water issues. This course seeks to explain the basic chemistry required to understand crucial environmental interactions in order to encourage students to take a critical approach to solving complex water- related issues on a local and global scale. Upon completion of the course, students will be able to integrate the complex questions surrounding the future use and consumption of water and develop possible solutions to this global crisis.

Course Content:

Unit 1

This introductory unit will focus on the structure and nature of matter, atomic structure and the methods of scientific inquiry. Students develop an overview of how the Earth is a single interconnected system through the investigation of case studies focusing on a local water resource, such as Mono Lake in California, and are ultimately able to design and build an apparatus to purify water as if their survival depends on it (stranded on an island scenario).

Unit 1 - Assignments

U1: 1. Matter: All Environmental Systems Consist of Matter

Students research and analyze a case study of anthropogenic effects on natural aquatic systems. They will apply critical thinking skills to the case study through the production and manipulation of a model or map. This consists of identifying a problem (for example: what would happen if a portion of this water was diverted for irrigation?) and hypothesize the effects this would have on the functioning or cycling of the system. Students will then brainstorm solutions to this problem and identify a product that could be engineered to allow both the human use of this resource as well as ensure the health and functioning of the system. <u>The visual display reinforces that all components of a system are made up of matter and the interactions of matter allow a system to function. This leads to the development of an understanding of the cycling of matter, human interactions (cause and effect of choices), and the importance of innovation and critical thinking in remediating anthropogenic influences on the environment.</u> Some other examples may include: Online "Phet" simulations of greenhouse gases or other environmental related interactions. Students can change the inputs (e.g. the amount of greenhouse gases), and watch how the outputs (global temperatures) change over time.

In addition, students will then be given a case study outlining a building proposal adjacent to a natural wetland area. They are to prepare a report outlining the anthropogenic effects of the project and give it a Platinum, Gold, Silver, or worse rating based on US Green Building Council's certification guidelines. Students also need to justify their rating with reasons outlined in their report.

U1: 2. Atomic Structure/Bonding

Students will research the atomic structure of hydrogen and oxygen (elemental components of water) by using their textbooks or variety of online resources provided by the teacher and learn to draw the Lewis diagram and the electron configuration of the first three periods (rows) of elements and as simple molecules. Research includes internet sources, texts, and animations. Students will then complete an activity similar to that of the "alien periodic table" in order to make predictions about elemental properties based on electron configuration. Here, students will be handed a blank periodic table with several "alien" elements filled out.They will use the clues provided to come up with the "alien" elements that correspond to that location on the periodic table.

In addition, students will construct atomic models of water molecules based on teacher's instructions with the molecular model set.Then students will design their own models of a water molecule with household materials as homework (may put a limitations on overall cost), and students will have to present how they designed their models to the class and explain why they chose the materials they did.

U1: 3. Phases of Matter: The Water Cycle

<u>Water Droplet Storybook: Students will write a creative story following a water molecule as it moves through the various phases of the water cycle and ends up falling through the tap of a home and into a glass of water.</u> Throughout the assignment, students must demonstrate a thorough understanding of the atomic structure of a water molecule and how it behaves differently as a solid, liquid and gas by describing and illustrating these in their storyline.

Students must demonstrate water molecule moving through all the stages of the water cycle (precipitation, evaporation, transpiration and condensation) and come full circle to demonstrate the understanding of a biogeochemical cycle.

In addition, the requirement of the termination of the story allows students to gather background information of how humans have impacted the water cycle by including the components of how water is extracted from a collection site, moves through a water treatment facility, is transported via pipeline to a central water agency and distributed to homes. Students may also include the pumping of groundwater via a well and into the home. This exposes students to man- made systems that have been engineered to transport and purify water as they will learn more about in the units to follow.

U1: 4. Scientific Method: Properties of Water- Capillary Action

Hydro-Station Project: Students will design and build a system that uses capillary action of water to transport water from one location to another. This assignment includes exploring the scientific method and engineering design as it relates to problem solving, design and evaluation. Prior to building their system, students must research and write a one- page preface outlining their understanding of hydrogen bonds and capillary action that will segway into the design and choice of materials to be used to accomplish the task.

Possible applications of student understanding of capillary action and hydrogen bonds include: a) The design of a product that will transport water from a low point to a high point and capturing the energy created through a simple turbine as it falls back down (as a closed- loop system) b) The design of a product that will transport water from one cup to another across a horizontal distance. Students will be asked to manipulate the distances and materials used in order to analyze the efficiency of their designs and how these changes can improve the overall functioning of their product.

- Possible Activity: Provide students with a problem generated by fictitious clients who have hired the students as engineers to solve the problem and present their solutions.

U1: 5. Properties of Water: Density

Students will research the various densities of common water pollutants (plastic solids, petroleum oil, etc) and identify where these pollutants would be found in a column of water by drawing a poster.

To demonstrate their learning, students will then build a density column using a large graduated cylinder with multiple dyed liquids chosen for their various consistencies (water, molasses, cooking oil, corn syrup, etc). Students will record the relative densities of the liquids and later compare their values to the actual densities. To further understand the principles of density, students will place various objects representing pollutants (nuts, marbles, feathers, rubber stoppers, etc) in the column to determine the indirect relative densities of these objects with respect to the known density of the liquid layer in which they settle.

U1: 6. Properties of Water: Density, Surface Tension, Polarity

In this assignment, students will study the polarity of water molecules and how this relates to water density and surface tension by attempting to design a way to make a paper clip float on water. Students may do this by designing a mini- boat or other flotation device . They can then test to see what would happen to their design if the surface tension is broken by the introduction of another substance (example: soap). Students will then submit a lab report discussing the chemistry principles used in their decision making and the effectiveness of their design.

Possible extension: Walk-On-Water Design Challenge:

- Students design a device that allows them to walk on water. This design challenges students to tackle the concepts of the chemical structure of water, surface tension principles, density, buoyancy, and polarity.Students will have a designated spending limit and must research various materials that may be used to build their device. The device must be worn by one of the group members as they attempt to walk across a body of water without sinking or falling over. Student teams will test their devices and make modifications as needed until a final product is reached. Students may do this project on their own and videotape the process if a pool is not available at school.
- Students will submit a laboratory report following the scientific method and outlining the decisions they made and the scientific background that led to their design. They will evaluate the effectiveness of their design and propose remediations to improve upon their design.
- Testing of prototypes and final model can be conducted at a pool on- site or may be videotaped at a local public pool as homework and shared in class.

U1: 7. Distillation: Manipulating water's physical properties to purify it

Students will get into groups of 3-4 and research different methods/techniques scientists use to purify substances (chromatography, distillation, magnetism, filtration, centrifugation, reverse osmosis, and crystallization) and present the research to their classmates (each group will sign up for one technique and do a 8-10 slide PowerPoint presentation on the purification technique.)

In addition, students will practice a simple distillation lab or a fractional distillation lab- Students will be distilling ethanol and separate ethanol molecules from the water/ethanol mixture by manipulating the difference between ethanol and water's boiling point. Ethanol's boiling point is 78 degree Celsius while water's boiling point is 100 degree Celsius, so alcohol will boil and turn into a gas before water will.

Finally, students design and build an apparatus to purify water as if their survival depends on it (stranded on an island scenario). The objective is to create a water purification system that can successfully filter out particulates from a dirty water sample. Students apply their knowledge and research to construct this apparatus. Materials should be restricted to household or organic materials, and the cost should not exceed $20.

Unit 2

In this unit, students explore how knowledge of chemical bonding, chemical reactions and chemical equilibrium are demonstrated and applied in the waste water treatment industry. Students build upon their knowledge of atomic structure to explore the various forms of chemical bonding that takes place between atoms of different elements and further their understanding of how human beings can manipulate water by examining how human inputs affect chemical bonds and ultimately water quality and the environment.

Unit 2 - Assignments

U2: 1. Investigate Methods for Treating Waste Water

This activity will begin with students using online search engines to find valid sources detailing appropriate methods used to treat waste water in preparation for a tour of a waste water treatment plant. Students will produce a written summary of their sources. This literature review will support student inquiry and help them generate relevant questions to pose to treatment facility personnel about plant operations. Asking questions will clarify information given on the tour and extend their knowledge about local methods used for waste water treatment. Through this process, students will learn how a local facility assesses the water quality at the end stage of treatment and how that treated water is released and used in their community.

During a tour of a waste water treatment plant, students will articulate their questions to the staff and record answers to the questions they have prepared. From this facility, students will collect samples of treated water for later testing in the classroom. Students will also collect samples from other sources in their community such as: tap water, irrigation canals, standing water, etc. then compare and contrast test results for bacteria, pH, nitrates, dissolved oxygen, hardness, lead and copper using a standard testing kit. Throughout the assignment students will keep an engineering notebook to document materials, methods, results and conclusions.

Possible extension activity:

- Students will analyze current events and everyday actions for their impacts on water quality. Examples of current events could include fracking, the Fukushima incident, or the Gulf oil spill. Examples of everyday actions could include use of fertilizers for lawn care, disposal of pet waste, littering, or use of detergents. By reading news articles, they will identify issues caused by human introduction of chemicals into the environment. Students will research how the chemicals that they tested for in the lab impact the environment. Students will distinguish between physical changes and chemical reactions that occurred in the scenario and support their claim using evidence from the passage read.

U2: 2. Measure the Iron Content of Water

Students investigate the question: *Does your drinking water meet safety guidelines for iron?*

To prepare for this activity, students will research the NOAA guidelines for safe drinking water, paying particular attention to vocabulary, format of tables, units of measurement and conversion of units from lab data as necessary. Students must develop an appropriate hypothesis, design an experiment, collect and analyze data, and use their analysis to support or refute their hypothesis. One possible experimental design would use a colorimeter to measure iron content in water samples collected from drinking fountains on campus. Test results will be compared to acceptable levels as listed in the NOAA Screening Quick Reference Tables (SQuiRT). Students will be assessed on their experimental design and their written lab report.

U2: 3. MBARI SOFeX Activity

Students will gather the background information about the biological pump necessary to complete the primary portion of this activity by reading the supplementary text included in the resources section. Based on this text and on students' understanding of chemical equilibrium, students will predict changes in amounts of dissolved CO_2 in the ocean using published models of climate change.

Using the link to the SOFeX activity, students will describe different methods used by scientists to carry out deep-ocean research and explain the rationale, questions, research, technology and people involved in the SOFeX Cruise. Students will read an overview of the SOFeX project, explore the cruise logbook and equipment and personnel sheet, complete an information sheet as guided note taking, prepare a brochure requesting funding for the SOFeX cruise, and present their brochures to the class. The biological pump investigation will build student understanding of chemical cycles, and the brochure will be a means to tie in their understanding of the cause and effect relationship of biotic and abiotic factors in the marine environment. In the written brochure, students will include the balanced chemical equations for CO_2 dissolving in water, for the precipitation and dissolution of iron in marine environments, and for algal photosynthesis.

U2: 4. Graphing Iron Data

This activity will help students understand how scientists assess the impacts of iron on ecosystem processes. Iron is a limiting factor for phytoplankton growth. These producers are extremely small—only one cell in size, so it would not be possible to count them all. Instead, scientists measure the amount of chlorophyll in the water. Since chlorophyll is made by living plant cells, more chlorophyll indicates more phytoplankton present. In this activity, students will look at a spreadsheet of data collected from buoys in Monterey Bay. These buoys collect information on many different chemicals present in the water; the focus of this lesson is the iron and chlorophyll levels. Students will be tasked to identify the relevant data, then create a labeled graph of that data to see if there is a connection between these two factors. Students will summarize the results of their graph in a written paragraph to communicate understanding of the cause and effect relationship. This activity reinforces the concepts explored in the SOFeX Activity.

U2: 5. MBARI Mystery Spill Activity

Students will carry out a multi-part investigation of a massive bird death event in the Monterey Bay. Students will use real time data to test predictions, demonstrate understanding of harmful algal blooms, explain how HABs impact coastal ecosystems and use vector analysis to illustrate the use of high frequency radar. Students will produce a vector analysis of HFR data, and present a valid conclusion of what caused "mystery Spill" with data to support it. Students will use their understanding of intermolecular interactions to describe how affected birds lost the ability to remain dry and insulated. At this activities conclusion, students will construct several paragraphs detailing the cause of the massive bird death, and will support their conclusion with evidence synthesized from the case studies, reports, and analyses they carried out in the activity.

This activity can be scaled to accommodate class resources and timeline, but can include reading and analysis of multiple sources, a case study, a hands on lab investigating the effect of a surfactant on bird feathers, and vector analysis.

Unit 3

Building on knowledge acquired from the previous units on the properties and characteristics of water, students will analyze acids and bases, types of mixtures, and will revisit the phases of matter and how variables such as temperature, pressure and volume affect them. They then apply this learning to their developing knowledge of water as a system and its role in the environment by engineering a RAIN BARREL container that can regulate water temperature, determining the best type of filtration device to filter and purify water, and analyzing car exhaust in order to examine and understand Ph.

Unit 3 - Assignments

U3:1. Phases

Building on the Water Droplet Storybook assignment from Unit 1, students will conduct an experiment that demonstrates the transformation of water through phase changes by melting an ice cube and boiling the resulting liquid water. Two types of data will be collected and graphed; the temperature of the sample each minute, and the time that melting started, melting ended, and boiling started. Upon completion of the experiment, students will research the theoretical atmospheric conditions for their community in which water should change phases by locating the atmospheric pressure within their immediate location and using a phase diagram of water to extrapolate the corresponding temperatures for these changes. Students will compare their experimental findings with the theoretical data and write a paragraph explaining possible sources of experimental error that could account for discrepancies between the values. Based on both sets of data, students will design and build a scaled prototype of a water storage container that would be appropriate for storing water intended for human consumption within this range of temperatures. Upon completion, the students will test their prototypes to determine the structure's ability to regulate the water temperature and ideally prevent freezing and vaporization.

U3:2. Mixtures - making solutions, solute-solvent, concentrations, properties of mixtures i.e. boiling point and freezing point.

Students will locate and retrieve a sample of untreated water from sources that may include local creeks, lakes, or reservoirs. Using a standard water testing kit, the water samples will be analyzed for the presence of various particulates and contaminants. Referencing back to the distillation research and activity from Unit 1, student samples will then be compared to determine the average concentrations of the particulates. While working in small groups, students will be given the same water sample that will be tested for various metals, ions, pH, nitrogen levels, and bacteria. Each group will test for an assigned contaminant type and then determine what methods should be used for the filtration/purification that are considered "safe" levels for potable water. Student groups will then design and build a purification system that will eliminate their contaminant from the sample. Once multiple filtration devices are built, the student groups will join together to form teams that, in entirety, will include all the filtration components necessary to clear contaminates of all five substance types from the sample. Identical water samples will then be run through each team's set of devices and then will be tested again for the presence of each contaminant type. Local municipality representatives may be utilized as guest speakers or to provide onsite demonstrations at their local water treatment plants. The winning team is the group whose water ends up closest to the acceptable safe levels. Each student group must provide the design specification in a written format with justification of design choices and the physical and/or chemical principles at work in their purification device.

U3: 3. Acids-Bases - what are they, strength, water as amphoteric, neutralization

Students will perform a two part experiment determining the concentration of acid rain. Based on their knowledge of chemical reactions introduced in Unit 2, students will attempt to simulate a causality of acid rain within an initial lab activity. To do so, students will spray water through the gas emanating from a vehicle's internal combustion exhaust pipe. Water from the spray will be collected as a liquid within a container that will be used by students to perform a pH test. The next part of the lab will use a sample created by the instructor that matches the pH of the exhaust solution. Students will complete a titration on the matched sample of acidified water. Using a standardized base of known concentration, students will determine the unknown concentration of the acid. From the titration results, they will determine the concentration of the acid and learn the experimental technique used in the water industry. Their lab report, along with the calculated value, will be the final product used to determine if the concentrations correspond to acceptable industry standards for safe drinking water.

Unit 4

In this unit, students will develop an understanding of the general properties and forms of energy (kinetic and potential), focusing on the laws of thermodynamics and how energy flows through a system. Students will continue to formulate an understanding of chemistry principles to gain a concrete understanding of energy in its various forms, using water molecules to explore energy principles, including specific heat capacity through work like an oceanic heat sink activity and making ionic solutions for construction of rudimentary batteries and using photovoltaic cells to charge hydrogen fuel cells via electrolysis of water molecules.

Unit 4 - Assignments

U4: 1. Ocean Heat Sink

In this lab activity, students will explore the high specific heat capacity of water and it's associated properties as a heat sink and medium for storing energy by measuring the time it takes to heat given volumes of water to boiling, in comparison to other materials. Data from this experiment will be used to create graphs illustrating the high specific heat of water relative to the other materials being tested. To help students make the connection between the role that ocean water plays in climate change and delays in environmental effects, students will use their results to predict the amount of energy it would take to effect change on the temperature of the ocean as a whole, the amount of time it would take to absorb amounts of energy in that quantity, and how this would contribute to delayed environmental effects from the ocean as an energy heat sink. The data analysis and conclusions will be written in their engineering notebooks using a standard lab report format.

U4: 2. Calorimetry Lab

Building on the concepts of specific heat capacity and energy stored as heat in Unit 3, students will work in small groups to measure the amount of energy contained in various samples. Students will construct a functional calorimeter that uses the change in water temperature to measure the amount of energy released from burning fuel to break bonds within the device. The lab supports the understanding that energy can be stored within chemical bonds as well as that of specific heat of water at the same time in the operation of the calorimeter. Students will propose hypotheses about the energy contained in each test sample, a diagram of the calorimeter device, data, and reflections on the findings explaining why the values that were found varied as they did in their engineering notebooks.

U4: 3. Photovoltaics

In this activity students use a variety of fruit juices and pigments to create multiple photovoltaic cells. They measure the voltage and amperage from each on a multimeter and graph the results from data collected. They compare and contrast their results and hypothesize why some cells perform better than others, followed up by designing their own experiment that would further test that hypothesis. They demonstrate the theory of the photoelectric effect and variable photon absorption of the electromagnetic spectrum as they create their array of juiced photovoltaic cells and subsequently perform the follow up experiment comparing the energy capture from sunlight. Reflection of the implications of this activity on the environment and reduction of pollutant gases using PV in place of burning of fossil fuels is analyzed in students notebooks at the end of this project in a standard lab report.

U4: 4. Batteries

In exploring forms of potential chemical energy, students will create batteries using PVC pipes, water, bleach, and metals demonstrating energy storage. The activity will illustrate the storage and subsequent use of chemical energy through chemical reactions. It will use ionic solutions as a medium of electron exchange. The students will measure the output of the battery using a multimeter and demonstrate its usefulness by lighting a small LED. Students will write and balance chemical equations for the reactions involved and analyze the relationship between the battery they create and other batteries that are commonly available. Students will record diagrams, equations and report their findings and battery analysis within a lab report in their engineering notebook.

U4: 5. Hydrogen Fuel Cells

Clean energy technology is dependent upon viable means of energy storage. In this assignment, students perform an electrolysis lab that stores energy by splitting water molecules into oxygen and hydrogen. The stored hydrogen energy is then used to power a model fuel cell car. The project helps students understand how energy can be stored through the electrolysis of water as chemical potential energy and later released in a hydrogen fuel cell reaction to generate electricity. This drives motors as the reaction culminates in the release of kinetic energy. Students will demonstrate understanding of the flow of energy through the processes of electrolysis, gas storage,hydrogen fuel cell storage, and subsequent conversion. They will do this by calculating energy used to perform hydrolysis, measuring the volume of gases generated, calculating expected potential energy stored in the gases, and actual energy measured as output kinetic energy resulting from reacting the gases in the model fuel cell car. (Assess) Students reflect in engineering notebooks about the difference in energy potential and energy production of Hydrogen Fuel Cells.

U4: 6. Turbines

Students will create a simple turbine capable of generating electricity that is measurable on a multimeter in terms of voltage and alternating current. Throughout the design, build, and testing phases of this project, students will record their work in an engineering notebook, taking special note of modifications and improvements that can be made along the way. Various mechanisms for turning the blades of a turbine (steam, flowing water, wind) will be used in the experiment to demonstrate the relationships between the forms of energy generation as well as to gain exposure to the principles involved with each method (phase change, conversion of potential energy to kinetic).

U4: 7. Nuclear Energy

Students will write a research paper including the history and development of nuclear energy to produce electricity. In their reports, they will compare the energy released in both fusion and fission and identify the benefits and concerns of using nuclear energy to produce electricity. Students will be asked to pay specific attention to pollution mitigated by avoiding fossil fuels versus waste products created as a result of the nuclear processes. The research and evaluation of case studies will be required in relation to nuclear disasters and the resulting effects on surrounding water sources and environment. Students will present their findings to peers through a PowerPoint or similar media presentation.

U4: 8. Multimedia project - Water Energy Connection

Students will select one of the examples of water's use in the production and storage of energy covered in this unit to showcase their understanding of the essential nature of water to the generation and storage of energy for societal consumption. Over the course of this unit, students will have documented their findings and products in the lab activities by taking pictures of and collecting data from their activities. Additionally, they will research an example of energy producing or storage technology using water and apply this to relevant examples of water usage in society. They will capture this content in a multimedia project that illustrates the concepts learned throughout this unit.

Unit 5

The final unit of the comprehensive chemistry-based course will culminate in an environmental engineering design challenge. Students will identify water-related challenges as they exist in the world and implement principles of the engineering processes that include collaboration, research and analysis, problem solving skills, and design solutions.

Unit 5 - Assignments

U5: 1. Research and Development

Students will research local, regional, national, or global water issues and create a top ten list of potential project topics. Some potential issues that students may find include safe drinking water in Haiti, salinization of Mono Lake, water transport to areas of drought or flood, water production, thermal pollution, etc. As a class, students will use their lists to brainstorm all of the possible topics that could be addressed in their design challenge. In small groups, students will decide which water issue they will explore. Each group will address a different water issue. Once the groups have their topics chosen, they will then conduct further research on the history of the issue (when and how did it become an environmental issue), contributing factors (why is it an issue), urgency (how pressing is the issue), current technologies in use (what is currently being done to remediate or diminish the issue), and explain how it connects to the principles of chemistry learned in the previous units.

U5: 2. Propose, Design and Build

Student teams will propose, design, and build a working model of a potential device that incorporates one or more of the chemistry principles covered in previous units to help alleviate or hypothetically resolve the issue. Students will test the product of their devices against industry standards and based on the initial round of test results, student groups will redesign their devices. The products of their devices will be evaluated for how close they are to industry standards, such as safe drinking water, efficient use of water for energy production, efficient water delivery, etc.

U5: 3. Final Presentation

Students will submit two end products. The first is their revised device and the second is a technical report. This report should include four major components: an introduction of the problem (background research from key assignment 1), the final design specification with an explanation of the chemistry principles involved and justifications of changes made to device (based on initial testing), and the final testing results and comparisons to industry standards related to the water issue or quality.

Course Materials:

Title: District approved Chemistry Book

Supplemental Instructional Materials:

Unit 1 - 5: (Resources With Applications For All Units):
Project WET Curriculum and Instruction Guide 2.0 - ISBN 978-1-888631-80-7

Unit 1
Matter: All Environmental Systems Consists of Matter
Phet Environmental Model with input and output:
http://phet.colorado.edu/en/simulation/greenhouse
LEED Certification criteria from US Green Building Council: http://www.usgbc.org/leed

Properties of Water: Density
Sample Density Column:
http://www.stevespanglerscience.com/lab/experiments/seven-layer-density-column
Walk on water challenge video: https://www.youtube.com/watch?v=4v-7PTZF9mc
Distillation: Purifying Water by Manipulating its Physical Properties
Quick and easy distillation lab from CA Teacher of the Year finalist Paul Groves:
http://www.educreations.com/lesson/view/unit-6-handboiler-distillation/4183377/

Unit 2
Measure the Iron Content of Water
Caltech Community Science Academy: http://csa.caltech.edu/Instruments
DIY Colorimeter Kit: http://www.iorodeo.com/content/educational-colorimeter-kit
NOAA SquiRT:
http://response.restoration.noaa.gov/environmental-restoration/environmental-assessment-tools/squirt-cards.html

MBARI SOFeX Activity
Background Reading on the Biological Pump:

http://www.mbari.org/earth/mar_chem/Iron/bio_pump_lesson.html
Lesson plan: http://www.mbari.org/earth/mar_chem/Iron/pump.html

MBARI EARTH Institute SOFeX Expedition Activity
Background:
http://www.mbari.org/expeditions/SOFeX2002/history&purpose.htm#Cruise%20History%20and%20Background
Activity: http://www.mbari.org/earth/mar_chem/Iron/sofex.pdf

Graphing Iron Data
MBARI EARTH Institute Graphing Iron Data Activity:
http://www.mbari.org/earth/mar_chem/Iron/iron_lesson.html
Iron Time Series Data :
http://www.mbari.org/chemsensor/Data/Monterey%20Bay/lobosFeNuts_web.xls

MBARI Mystery Spill Activity
MBARI EARTH Institute Mystery Spill Activity:
http://www.mbari.org/earth/Coastal/spill/spill.html
Science Sleuths Lab Activity: http://www.mbari.org/earth/Coastal/spill/extension.pdf

Unit 3
Mixtures: http://www.mwdh2o.com/mwdh2o/pages/education/h2o/9-12.html

Unit 4
Heat Capacity of Water: Penn State-Earth 501- "Specific Heat Capacity of Water"
https://www.e-education.psu.edu/earth501/content/p5_p9.html
PhotoVoltaic Cells: "Using Nature to Make A Photovoltaic Cell"
http://www.esf.edu/outreach/k12/solar/2011/labs/dye_cell.docx
Turbines: "The Green Optimist"
http://www.greenoptimistic.com/2010/03/09/build-small-scale-hydroelectric-generator/#.U0hfcl63zQo
Batteries: "Homemade Batteries #36":
http://buelahman.files.wordpress.com/2011/01/homemade-batteries.pdf
Generic Rubric for Project Assessments: (Nuclear Power Report and Multimedia Project)
"Teacher Planet": http://www.rubrics4teachers.com/science

Unit 5
California Department of Water Resources: http://www.water.ca.gov/
EPA Water Science: http://www2.epa.gov/science-and-technology/water-science
United Nations Water: http://www.unwater.org/home/en/
American Groundwater Trust: http://www.agwt.org/
Water.org: http://water.org/water-crisis/water-facts/water/