3.1 The School Water Audit - Indoor

*Bathroom Faucets, Structured Inquiry*

**Summary:**
Students will determine the amount of water used at bathroom sinks via a structured procedure, learning relevant measurement techniques, unit conversion, and the elements of procedural design. They will examine their data, draw conclusions, and draft recommendations for ways to use water more efficiently.

**Objectives:**
Students will:
- Follow a set procedure
- Measure water flow
- Estimate sink use frequency
- Convert data units
- Analyze data and draw conclusions
- Make recommendations for ways to use water more efficiently

**Materials/Supplies:**

**Warm up**
- *Warm-Up Activity Instructions* (Appendix 3.1.A) (1 per student)

**Part 1**
Per student group
- One ruler

**Part 2**
Per student group
- ~9 in. x 13 in. Rectangular Containers
- Graduated cylinders: 1-1000 ml, 2-100 ml, 3-10 ml if possible

**Activity**

Per student group:
- 1000 ml graduated cylinders
- Bowl with a spout
- Stopwatch
- Faucet aerators
- Pair of pliers
- Flagging (roll)
- 5 gallon bucket
- Masking tape
- Permanent marker
- Drip gauge

**Audit Activity Equipment**
• Measure Bathroom Faucet Flow Rate procedure (Appendix 3.1.D)
• Figuring Your Conversion Factors (Appendix 3.1.E)
• Water Use Calculations and Water Savings Calculations worksheets (Appendix 3.1.F)
• Clipboard
• Pencil

Homework
• Homework Letter to Parents/Guardians (Appendix 3.1.G)

Background for Teachers:
Although faucets come in many types, colors, and styles, each one makes use of one of four different mechanisms to make them work: cartridge, compression, ball or disc. The cartridge-, ball-, and disc-type faucets are referred to as mixing faucets and have a single handle or control. These faucets do not use washers to close the valve. The compression-type faucet usually has two controls. They are built with washers or seals that close against a valve seat to restrict water flow. Leaks from any of these faucets will be due to worn internal parts that are neither expensive nor difficult to replace. While easy to fix, if left unattended, a small leak can add up quickly. A leak of about one drip per 10 seconds results in 13 gallons water lost per day and 4,927 gallons of water lost per year.

Leaky fixtures are an obvious source of water waste. Excessive water flow can be a source of not-so-obvious water waste. Adequate water flow has to do with water quantity and water pressure. According to current plumbing codes, new faucet flow rates cannot exceed 2.5 gallons per minute (gpm) at 80 pounds per square inch (psi) or 2.2 gpm at 60 psi.

A faucet aerator is a great device for maintaining a sense of adequate water flow while reducing the actual quantity of water used. They do this by breaking up the solid flow of water, effectively adding air to the water flow; hence, less water is passed out of the tap each second. Bathroom faucet aerators usually restrict flow rates down to 1.5 to 0.5 gpm. Aerators are inexpensive to replace and can be one of the most cost-effective water conservation measures. For maximum water efficiency, aerators that have flow rates of no more than 1.5 gpm should be used.

Bathroom faucets, especially at school, are used primarily for hand-washing. The Centers for Disease Control urges that, “keeping hands clean is one of the most important steps we can take to avoid getting sick and spreading germs to others.” They recommend washing hands with soap and clean running water for 20 seconds. This piece of advice becomes relevant to this...
lesson when evaluating just how long each person runs water during a hand-washing, on the way to calculating the amount of water used per year in this hygienic effort. You will have the opportunity to sample hand-washing times during the Measure Average Hand-Washing Time Procedure (Appendix 3.1.C). If it becomes impractical to perform this procedure, be sure to discuss with your students whether the CDD’s expert recommendation is a reasonable estimate of hand-washing time for you to use in your calculations.

**Preparation before the activity:**

- Arrange equipment for Warm-up Activity #1.
- Arrange equipment for Warm-up Activity #2.
- Study the procedures, data sheets and worksheets for the Bathroom Faucet Audit activities. (Appendices 3.1.B through 3.1.F)
- Check with other teachers regarding surveying their students for the Survey of Hand-Washing Frequency.
- Poll other teachers regarding typical bathroom breaks in preparation for the Measure Average Hand-Washing Time activity.
- Request general data regarding the school:
  - Number of full school days per year
  - Number of students enrolled at the school

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<tr>
<th>Name</th>
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<tr>
<td>Noah T.</td>
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**Lesson Procedure:**

**Warm up:**

1. Divide the class into cooperative learning groups of 4-5 students.
2. Give each group a copy of the Warm-Up Activity Instructions (Appendix 3.1.A).
3. Direct the students to read the instructions for activity #1, to gather materials for the activity, and to start as soon as they are prepared. Give the students 10 minutes to complete the activity.
4. List the students’ names per level at which the ruler was caught on a flip-chart or overhead.
5. Ask the students, “Why are the distance measurements different for each student?” Answer: Each person’s reaction time is different; the larger the distance the longer the reaction time.
6. Ask the students to define the term: reaction time. Reaction time is the elapsed time between the presentation of a sensory stimulus and the subsequent behavioral response.
7. Instruct the students to read the instructions for activity #2 and to gather materials for the activity. Give them 3 minutes to prepare themselves for the activity.
8. List the student groups per water poured on a flip-chart or overhead.

9. When everyone is ready, tell the students to begin. This activity is not a race. It is most important that everyone closely follow the directions. (Students will be measuring and pouring water into their group’s reservoir.)

10. When the activity is over, compare the amount of water in each group’s reservoir.

11. Ask the students, “Why are the amounts of water different?” Answer: measurement error, individual error adds up; or measurement inaccuracy.

12. Ask the students to define the terms observational error, accuracy and inaccuracy. Observational error is the difference between a measured value of quantity and its true value. Accuracy is the degree of closeness of a measured or calculated quantity to its actual (true) value.

13. Discuss: Both reaction time and measurement error can make data collection inaccurate. Both of these are unwanted effects that can be controlled. That is, their impact on the data collection can be minimized or removed.

14. How can each be minimized or removed from a data gathering activity? Demonstrate making accurate liquid measurements with different graduated cylinders – set the cylinder on a stable horizontal surface, read the bottom of the meniscus (if there is one); pay attention to how close the water level is to the measurement lines, don’t say, “it’s close enough.”

Activity:

Remember the focus question: How can we reduce water use or use water more efficiently at School?

Refer to the decision-making process, the inventory map and brainstormed list of water uses generated via the school tour.

Explain to the students that each of their cooperative groups will audit water uses around the school; compile, analyze and summarize the data; then make recommendations based on the study. The whole class will start by auditing water use at the bathroom faucets. Through this audit, you will learn the elements of good experimental design and you will practice making error-free measurements.

Discuss how water is used in the bathroom sinks and what kinds of things affect when, how, how long, and why the water is used.

For example, are certain sinks used more often than others? Why? For what purposes, other than hand-
washing, are bathroom sinks used?
If sinks are equipped with metered valves (push buttons), are some faucets pushed more/less often than others? Why? Do boys or girls use more/less water to wash their hands? Do younger or older students use more/less water to wash their hands? Do students or staff use more/less water to wash their hands?

Pose the inquiry questions:

1. How much water is used by students and teachers washing their hands at bathroom faucets each year?

2. How much water can be saved each year by using aerators on all bathroom faucets?

In order to answer these questions, many smaller questions need to be addressed:

- What is the average number of times that a student or staff member washes their hands in one day? (X)
- How long is each hand-washing? (t)
- What is the flow-rate in gallons per minute of each faucet? (FR)
- How many students and staff members are there in the school? (N)
- How many school days are in one year, including summer school? (D)

1. Demonstrate why this information is important:

   a. The goal is to arrive at an accurate measure of gallons of water per year consumed by hand-washing across all of the bathroom sinks in the school.
   
   b. If each person in the school washes his/her hands X times per day, and the water runs for an average of t minutes for each hand-washing, then:
      \[ X \times t = \text{min/person/day}, \]
      is the average amount of time, in minutes, that each person runs water for hand-washing each day.
   
   c. If each person uses water for Xt minutes each day, and the average flow rate of each sink is FR gallons per minute, then
      \[ (X \times t) \times FR = \text{gal/person/day} \]
      is the number of gallons that each person uses for hand-washing each day.
   
   d. If XtFR gallons of water is used by each person, each day, and there are N total students and staff at the school, then
      \[ [(X \times t) \times FR] \times N = \text{gal/day} \]
      is the amount of water used by the school each day for hand-washing.
   
   e. Multiplying the water use per day by the number of school-days per year, D, results in
      \[ [(X \times t) \times FR] \times N \times D = \text{gal/yr}, \]
the total number of gallons flowing from the bathroom sinks throughout the school for hand-washing in a year.

2. Provide each student with a copy of the complete set of Bathroom Faucet Audit Procedures (Appendices 3.1.B through 3.1.D). This set of procedures follows the thought process that was modeled mathematically above: 1) the Survey of Hand-Washing Frequency (3.1.B) determines the number of times per person per day that the faucets are used \( (X) \); 2) the Measure Average Hand-Washing Time procedure (3.1.C) is used to determine how long the faucet is on for each use \( (t) \); 3) the Measure Bathroom Faucet Flow Rate procedure (3.1.D) leads to the flow rate of each faucet in gallons per minute \( (FR) \). If the students understand the role and importance of each of these three procedures, they do not need to conduct them in the order given. In the end, with these numbers in hand, the students will be able to calculate the answers to the inquiry questions.

**Survey of Hand-washing Frequency**

Ideally, a scientist would observe and count the number of times the faucets are used in a year. This absolute counting method is not practical, so a well-educated estimate of the number of uses will have to be made. To arrive at this estimate, your students will survey a representative sample of students across classes, ages, and genders.

1. Examine the *Survey of Hand-Washing Frequency Procedure and Data Sheet* (Appendix 3.1.B). Discuss:
   a. Pros/cons for surveying students on frequency of hand-washing vs. direct observation and counting hand-washings. **The first option is easy but less accurate; the second option is more accurate but will take more time.**
   b. Surveying strategies for gathering the most accurate data: **Be specific, and try to identify all inconsistencies (like half days). If a survey is anonymous, people may be more willing to be honest.**

2. Communicate the surveying plan to the students, having them fill in the **plan** section of the *Survey of Hand-Washing Frequency Procedure and Data Sheet* (Appendix 3.1.B).

3. Assign pairs of students to distribute the hand-washing frequency surveys to teachers and classrooms so as to survey either all of the students in the school or the representative sample per your plan. All surveys should be completed during the same class period so that no student is surveyed twice, nor are significant numbers of students missed.
4. Have the student pairs collect the survey from each teacher at the end of the class period.

5. Have each pair of students work to compile the survey data for the classroom(s) from which they collected the surveys, following the instructions in the *Survey of Hand-Washing Frequency Procedure and Data Sheet* (Appendix 3.1.B), including calculating their own data average.

6. As a class, tabulate the averages calculated by each of the student pairs, and then calculate overall, school-wide average number of hand-washings per person per day.

7. Look back at the mathematical model:
   \[
   [(X \times t) \times FR] \times N \times D = \text{gal/yr}
   \]
   and point out that you have experimentally found a value for \(X\)! The next step is to determine the average hand-washing time, \(t\).

**Measure Average Hand-Washing Time**

To arrive at a value for the number of gallons consumed per year, you will need to determine how long the faucets are on for each hand-washing \((t)\). Again, it is not practical to measure the true amount of time spent on each hand-washing across a year. Therefore an educated estimate will have to be made. In this case, hand-washing time will be measured for a representative sampling of students. These times will be averaged and we will make the assumption that the average hand-washing time per person is a good estimate of true hand-washing time per person.

1. Read through the *Measure Average Hand-Washing Time Procedure And Data Sheet* (Appendix 3.1.C) with the students and discuss:
   a. The pros/cons of timing every hand-washing that takes place vs. timing some number of washings and averaging these (The first option is very accurate but would take too long; the second option is less accurate but the time invested can be controlled.)
   b. What is a representative sample?
   c. Who would make up a representative sample of the school population?
   d. Does it matter which sink you use to sample hand washing time? Are some sinks used longer not just more often, than others?
   e. What is randomization?
   f. How could you truly randomize the selection of students and sinks for time measurements? (Assign each sink a number and pull the number of a hat.)

2. Survey other teachers around the school to determine when students typically have bathroom breaks.
3. Schedule appropriate times and time periods for your students to observe actual hand washing duration.

4. Communicate the plan for timing hand-washings and have students complete the plan portion of the data sheet.

5. Divide the class into cooperative groups of 3-4 students and allow one materials person in each group to gather supplies. They will need to designate two timers, and two recorders. They should rotate jobs.

6. Assign groups to bathrooms and set clear expectations for behavior and completion time.

7. When the students return from gathering data, provide some decompression time for completing observations, sharing experiences, and calculating each group’s average hand-washing time. Caution: if hand-washing time was measured in seconds, students may need extra time and assistance to convert it to minutes!

8. As a class, tabulate the cooperative groups’ averages and calculate a school-wide average hand-washing time.

9. Look back at the mathematical model: 
\[ (X \times t) \times FR \times N \times D = gal/yr \]
and point out that now you have values for X and t! The next procedure will determine the average flow-rate of the bathroom faucets, FR.

**Measure Faucet Flow Rate**

Because the number of sinks in the school is limited, it is possible and desirable to directly measure the flow rates of every bathroom sink in the school.

1. Read the *Measure Bathroom Faucet Flow Rate* procedure and data sheet (Appendix 3.1.D) with the students and discuss.

2. Advise the students that they will be installing a water saving device, an aerator, as they conduct the audit in order to save time. A traditional water audit would only measure water use. This audit procedure is unusual also in that, if there is an existing aerator on the faucet, an intermediate measurement is made after removing the aerator to determine whether it is still operating well and to dramatically illustrate the benefit of using an aerator.

3. Review the materials used to measure the faucet flow:
   a. Drip Gauge
   b. 1000 ml graduated cylinder for measuring water after collection
   c. Bowl with a spout for collecting water from the faucet
   d. Clipboards
   e. Pencils
f. Stopwatches for timing water collection

g. Faucet aerators (many local water companies will donate to school projects)

h. Pliers for removing existing faucet aerators (if present)

i. Flagging for marking leaks

j. 5 gallon bucket to hold collected water; will be use for plant watering later

k. Datasheets for bathroom faucets (one per student).

4. In the classroom, demonstrate the procedure for measuring flow rate, drawing attention to procedural details and your efforts to avoid measurement error or the influence of your own reaction time.

a. Overview: The procedure involves capturing water flow for 5 seconds, then measuring the amount of water captured. Knowing how much water flows from the faucet in 5 seconds, you then convert that flow rate to gallons per year via a series of calculations.

b. Details: Place the bowl with the spout in the sink under the faucet. Start the watch and the water simultaneously, quickly turning the faucet to full flow. At the completion of 5 seconds, pull the bowl out from under the flow of water. Pour the captured water into a graduated cylinder and measure the amount captured.

c. Note the three actions involved in collecting water as it flows from the faucet: starting/stopping the stopwatch, holding the bowl under the flow, and starting/stopping the faucet.

d. Discuss: What uncontrolled variables might affect the measurements and how can you reduce or remove their effect? Reaction time between the start of the timer and the full-on state of the faucet; reaction time between the completion of 5 seconds and the turning off of the water.

e. Discuss: what actions can you take to ensure measurement accuracy? Pour without spilling from the bowl into the graduated cylinder; set the graduated cylinder on a stable horizontal surface before reading it; if the water level does not fall exactly on one of the measurement lines, estimate the distance between the lines rather than rounding up or down to one of the lines.

f. In conducting the procedure, water is collected and measured in three scenarios: first without any changes to the faucet to characterize the current condition; second
after removing any existing aerator to characterize water flow without any obstructions; third after installing a new aerator to quantify the water savings associated with installing this water saving device. By comparing these three measurements, you will be able to answer the two inquiry questions!

**g.** While making three different measurements gives the opportunity for each student to take a turn at the various roles, how might role-swapping introduce some unwanted effects? Can you devise a control for those unwanted effects and still give each student a turn?

**h.** Encourage qualitative observations during each flow measurement. Is the spray uniform and directed into the sink? Is some water directed off at an odd angle?

**i.** In the second measurement scenario, you will check for an existing faucet aerator and remove it if one is present (pliers may be needed). If there is not an existing aerator, skip steps 9 and 10 in the procedure and leave column E blank on the data sheet (Appendix 3.1.D).

**j.** Replication - Each measurement should be made three times and an average of the three calculated in order to avoid observational error. Decide if there is time to allow the students to do this and if so have them record all three measurements and a calculated average of the three in columns D, E, and F of the data sheet. If time does not permit this, take a moment to discuss the value of it and to help the students understand why replication will not be done at this time.

5. Regroup the class into their cooperative groups and allow one materials person in each group to gather supplies. They will need to designate a timer, bowl holder, measurer and recorder for each of the measurement scenarios.
6. Assign groups to bathrooms and sinks and set clear expectations for behavior and completion time.

7. When the students return from gathering data, provide some decompression time for completing observations, making data calculations (avg. flow in ml/5sec) and sharing experiences.

**The Audit Data Analysis**

This is where the results of the three procedures are brought together to answer the inquiry questions.

1. Using the *Figuring Your Conversion Factors Worksheet* (Appendix 3.1.E) demonstrate how to convert the 5 ml/sec. measurements to gallons per minute (gpm).

2. Instruct the students to work through the *Bathroom Faucet Water Use Calculations Worksheets* (Appendix 3.1.F). There is a separate worksheet for each measurement scenario so as to focus the students’ attention on the meaning of the values being calculated i.e. the amount of water used in each scenario. Note: each cooperative group’s calculations are based on the average flow from the faucets that the group evaluated, NOT a school-wide average.

3. Allow the groups to share their numbers with the class. Compare values between the groups and discuss:
   a. If any of the sinks were leaking, how do the leaks impact the overall water-use and water-savings calculations?
   b. Are there variations between the different groups’ values? What might account for those variations?
   c. How should the individual groups’ values be rolled into a school-wide representation of water use and potential water savings?
   d. What is the best way to graph this data? Demonstrate graphing the data.

4. Collaboratively develop a graph that shows the baseline data, the “without aerator” data, and the “with aerator” data. If possible, represent the leak data as well.

5. Have the cooperative groups graph their portion of the data on the graph.

6. Analyze the data – look for trends, unique data points, compare the data from the three measurement scenarios.
7. Does the data indicate that the changes made (installing new aerators) will improve water efficiency at the school?

**Wrap-up**

**Assign Homework:**
Review the homework assignment, described in the blue side bar, with the students. Send the *Homework Letter to Parents/Guardians* (Appendix 3.1.G) home with the students.

**Assessment via Notebooking/journaling:**
Ask students to summarize the bathroom faucet audit by writing a recommendation for technological and/or behavioral modifications that can be made to improve the school’s water efficiency. The recommendation must be supported by evidence from the data collection.

Students should share their recommendations in small groups other than their data gathering groups.

**Homework Assignment:** Give each student at least two faucet aerators. Ask them to go home and conduct a water audit of at least two home faucets with their parents or guardians. Just as they measured the faucet flow rates at school, ask them to measure the full-on flow for 5 seconds. Ask them to make sure that they do something useful with the water collected. Then if an aerator is not already installed, install one and re-measure. If an aerator is installed, remove it and install the new one. Re-measure. Leave the aerator that uses the least amount of water on the faucet. Bring results and leftover aerators back to school the next day.

Note: *City and town water departments as well as private water companies are interested in getting low water use fixtures out to their constituents. They may provide faucet aerators and toilet tablets to your students for free.*

Appendix 3.1.A

Warm-Up Activity Instructions Part 1

Reaction Time Experiment

Objective: Determine the reaction time of each student
Materials: 1 ruler

Procedure:
1. Assign the roles of Holder, Catcher, and Scribe.
2. **Holder**: Hold the ruler perpendicular to the floor, at approximately chest height, by the end with the highest number. Allow the “zero” end of the ruler to hang towards the floor.
   - **Catcher**: Place your fingers and thumb on either size of the ruler with your index finger at the level of the “zero.” Do not touch the ruler until the Holder releases it.
3. **Holder**: Let go of the ruler at any time between zero and five seconds.
   - **Catcher**: Grab the ruler with your fingers and thumb, as fast as you can, after it is released.
4. **Scribe**: Record the level - the inch or centimeter mark of the catcher’s index finger - at which the ruler was caught. This number represents the Catcher’s reaction time.
5. Repeat the test twice for a total of 3 trials using the same Holder and Catcher. The Holder should vary the time of dropping the ruler within the 5 second "drop-zone."
6. Switch the roles of Holder, Catcher, and Scribe until each person has had a chance to test their reaction time.

Discussion: Did every student catch the ruler at the same point? Why or why not?
Warm-Up Activity Instructions Part 2
Measurement Error, Accuracy and Inaccuracy Experiment

Objective: Measure 750 ml of water into a bucket
Materials: 1 tray or pan ~9 in x 13 in; 1-1000 ml graduated cylinder, 2-100 ml graduated cylinders, 3-10 ml graduated cylinders, 1 bucket, 1 pitcher water

Constraints:
- Only the 100 ml and 10 ml graduated cylinders may be used to measure and pour the water before switching stations.
- Each student in the group must measure and pour some of the water.
- All pouring must be done over the 9 inch x 13 inch tray.

Procedure:
1. Decide how much water each student will measure and pour, making sure that the total amount of water to be poured equals 750 ml.
2. Using only the 100 ml and 10 ml cylinders, have each student measure their portion of water from the pitcher and pour it into the bucket.
3. Leaving all water and supplies behind, rotate to another group’s station.
4. Pour the contents of the new station’s bucket into the 1000 ml cylinder.
5. Write the amount of water measured from the other group’s bucket onto the results chart on the board.

Discussion: Did every group measure exactly the same amount of water? Why or why not?
Appendix 3.1.B

Survey of Hand-Washing Frequency Procedure and Data Sheet

Objective: To determine the number of times per day that individuals use the bathroom faucets for hand-washing.

Materials: Hand-washing Frequency Survey Form; calculator

Survey Plan:

# Full school days/year _____
# of students enrolled at the school ______ # of adults employed at the school ______
Total # of students and adults who will be surveyed ______

If the surveyed group is a representative sample of the total population, describe the breakdown of the sample by entering the numbers of boys and girls in each grade level in the chart below. The last row is for adults so that you can include the number of teachers and staff that you will survey.

This chart represents all of the people at school surveyed by your class, not just those surveyed by your team. HIGHLIGHT the rows on the plan for which your team is responsible.

Plan for How to Survey Hand-Washing Time

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<th>Grade Level</th>
<th>Boys</th>
<th>Girls</th>
<th>Room #s</th>
<th>Owner: Team</th>
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Procedure and Data Sheet cont.

Procedure:
1. Distribute the Survey Forms to the classrooms and teachers that have been assigned to you.
2. At the time designated by your teacher, collect the completed survey forms from your assigned classrooms and teachers.
3. Transfer the data to the data table below.

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<tr>
<th>Room # ____________</th>
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Total= _____  
Avg.= _____

4. Calculate the average number of hand-washings per person per day for your sample.
5. Working as a class, average the results from each student group to calculate the school-wide average number of hand-washings per person per day.

This number will be transferred to the Water Use Calculations Worksheet (Appendix 3.1.F).
Hand-Washing Frequency Survey Form

Our class is conducting a water audit of our school. That means that we are trying to assess the amount of water that is used overall in one year. To do this we need to know the frequency of use in the different areas of the school.

Currently, we are working on bathroom faucet use. We would like to ask you to take a moment to think about how many times you use a bathroom faucet each day. When you can answer that question, please complete this short survey.

Grade Level (circle): 6th  7th  8th  9th  10th  11th  12th

Gender (circle): Male  Female

How many times do you wash your hands at a bathroom faucet on an average day of school? 

____________

Thank you from:
Appendix 3.1.C

Measure Average Hand-Washing Time

Procedure and Data Sheet

Objective: To develop a best estimate of the time required (in minutes) for each hand-washing at a bathroom sink. This best estimate is the average observed time of a sampling of hand-washings.

Materials: Clipboard, stop watch, watch or clock

Constraints:
- Do not hand-pick students to observe as this introduces bias into the data collection. Instead, time every student who starts to wash his/her hands within a 10-minute time window.
- The students observed will be a representative sample of the entire student population.
- In order to come as close to the desired sample population as possible, you may need to visit more than one bathroom during your data-collection time.
- In order to arrive at the most accurate data, students should be observed hand-washing during a regularly scheduled bathroom break. Try to schedule observations to coincide with normal bathroom breaks.
- If this process is too intrusive, you may assume that the experts-recommend time of 20 seconds for adequate hand washing is your school’s average hand-washing time. If made, this assumption should be noted in student data.

Measurement Plan:
Describe the desired sample population. This chart represents the class-wide sampling plan, not just those to be observed by your cooperative group. Highlight the sub-groups that you will attempt to monitor.

<table>
<thead>
<tr>
<th>Grade Level</th>
<th># Boys</th>
<th># Girls</th>
<th>Bathroom</th>
<th>Owner: Group</th>
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<td>Adult</td>
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<td>Total</td>
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</table>

Plan your data-collection schedule by indicating which bathrooms your group will visit and the approximate time that you will arrive at each.

<table>
<thead>
<tr>
<th>Bathroom Location</th>
<th>Start time</th>
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<td>Return to the classroom by . . .</td>
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</table>

The University of Arizona Cooperative Extension
Procedure and Data Sheet cont.

Procedure:
1. Observe students as they wash their hands after using the bathroom.
2. Timer: start the stop watch the moment the water turns on.
3. If the student leaves the sink with the water still running, do not stop the stopwatch. Continue to time until the faucet turns off.
4. Record time for each hand-washing on a separate line on the data sheet.
5. If a second student starts hand-washing before another student has finished, time the second student’s hand-washing with a separate timer.

<table>
<thead>
<tr>
<th>Bathroom Location</th>
<th>Grade Level</th>
<th>Boy / Girl</th>
<th>Time</th>
</tr>
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<tbody>
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</table>

Total
Average (sec.)
Average (min.)

6. Calculate the average amount of time during which water flows per hand-washing.
7. If the average time is in unites of seconds/hand-washing, convert to minutes/hand-washing. See Appendix 3.1.E.
8. Working as a class, average the results from each cooperative group to calculate the school-wide average amount of time during which water flows per hand-washing.

<table>
<thead>
<tr>
<th>School-wide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. time/hand-washing (min/hand-washing)</td>
</tr>
</tbody>
</table>

This number will be transferred to the *Water Use Calculations Worksheets*. 
Appendix 3.1.D

Measure Bathroom Faucet Flow Rate
Procedure and Data Sheet

**Objective:** To determine the average flow rate in ml/5sec for a selected group of bathroom faucets.

**Materials:**
- 1000 ml graduated cylinder; bowl with a spout; stopwatch, faucet aerators; pair of pliers; flagging; 5 gallon bucket; masking tape; permanent marker; drip gauge.

**Procedure:**
1. Enter the identifying information at the top of the data sheet: student name, teacher name, class period, group #, date, bathroom location and the number of faucets in the bathroom.
2. Number the faucets on your data sheet from left to right.
3. Examine the type of faucet at each sink; draw a check-mark on the data sheet beside each metered (push-button) faucet.
4. For each faucet in turn, complete the following steps.
   a. Look and feel around the faucet as well as under the sink along the drainpipe.
   b. Check the “Leak?” box on the data sheet if a leak is found.
   c. Mark any leaks with flagging.
   d. If possible, capture the leaking water in a drip gauge for 5 seconds.
   e. Record the leakage level and the associated gallons per year (gpy) in the comments field of the datasheet.
5. Measure the flow of water from the faucet for 5 seconds:
   a. Place the bowl with spout in the sink under the faucet.
   b. Faucet controller: turn the water flow to full-on AND Timer: start the stopwatch simultaneously.
   c. Timer: count aloud 1, 2, 3, 4, 5 in time with the stopwatch.
   d. Bowl holder: when the timer calls out “5,” immediately remove the bowl from the flow of water without spilling any of the water.
   e. Turn the water off.
   f. Pour the water from the bowl into the graduated cylinder.
   g. Read the water level from the cylinder and record the measurement in milliliters (ml) per 5 seconds on the datasheet in Column C, Baseline Flow.
   h. Pour the water from the graduated cylinder into the 5-gallon bucket. This water will be poured over plants rather than down the drain at the end of class.
   i. Repeat steps a-h two more times for a total of three measurements if replicate measurements are being made.
6. Check for an existing faucet aerator and make note of its condition.
7. If an old aerator is on the faucet, remove it (pliers may be needed).
8. Repeat steps 6. a-i, recording the data in Column D, Flow Without Aerator.
9. Install a new aerator
10. Repeat Steps 6. a-i again, recording the data in Column E, Flow With New Aerator.

*Repeat steps 5-11 to audit every faucet in your team’s assigned location.*
Procedure and Data Sheet cont.

11. Remove the numbered tape from every sink.
12. Pour the collected water over plants outside.
13. Calculate the total water loss due to leaks in gpy by adding all of the gpy values in Column F.
14. Calculate the average baseline flow for the faucets that your group evaluated. Calculate the average flow without an aerator, and the average flow with a new aerator.
15. Copy these numbers from the data table into the chart below.

These numbers will be transferred to the Water Use Calculations Worksheet.

<table>
<thead>
<tr>
<th>For Your Cooperative Group Only</th>
</tr>
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<tbody>
<tr>
<td>Avg. baseline flow</td>
</tr>
<tr>
<td>Avg. flow w/o aerator</td>
</tr>
<tr>
<td>Avg. flow w/new aerator</td>
</tr>
<tr>
<td>Total annual loss due to leaks</td>
</tr>
</tbody>
</table>
### Appendix 3.1.D: Measure Bathroom Faucet Flow Rate Data Sheet

**Inquiry Question**: How much water is used by students and teachers washing their hands at bathroom faucets *each year*?

**Location**
- Location 1: ____________________________________________
- Location 2: ____________________________________________

<table>
<thead>
<tr>
<th>Faucet #</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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<tbody>
<tr>
<td>☐ if metered</td>
<td>☐ ☐ ☐ ☐</td>
<td>☐ ☐ ☐ ☐</td>
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<tr>
<td>☐ if leaking</td>
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<td>☐ ☐ ☐ ☐</td>
<td>☐ ☐ ☐ ☐</td>
<td>☐ ☐ ☐ ☐</td>
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- Baseline flow rate (existing condition i.e. with old aerator or no aerator)? (How many ml in 5 seconds?)
- Flow rate without aerator? (How many ml in 5 seconds?)
- Flow rate with new aerator? (How many ml in 5 seconds?)

<table>
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<tr>
<th>Location 1</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Avg</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<th>3</th>
<th>Avg</th>
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Teacher Name: ____________________________  Student Name: ________________________________  Class Period: ___  Group #: ___  Date:_____________
Appendix 3.1.E  

**Figuring Your Conversion Factors**

Conversion factors are used to change units of measurement. We measured faucet flow in milliliters per 5 seconds (ml/s), but we really want to know the sink’s flow rate in gallons per minute (gal/min). To determine our conversion factors, we need to know some numbers.

- How many ml are in 1 gallon?
- How many seconds are in 1 minute?

**Converting the amount of water from ml to gallons:**

We can use a conversion table to look up the fact that 1 L = 0.264 gal and we know that 1000 ml = 1L. These equalities can be used as conversion factors (fractions that can be multiplied by your original number in order to change its units) i.e.

$$\frac{0.264 \text{ gal}}{1 \text{ L}} \text{ and } \frac{1 \text{ L}}{1000 \text{ ml}}$$

For example, if we have 500 ml of water, how many gallons do we have?

$$500 \text{ ml} \times \frac{1 \text{ L}}{1000 \text{ ml}} \times \frac{0.264 \text{ gal}}{1 \text{ L}} = 0.132 \text{ gal}$$

**Converting the amount of time from sec to minutes:**

We know 60 sec = 1 min., so our conversion factor is: \(\frac{1 \text{ min}}{60 \text{ sec}}\)

For example, if it took 5 seconds to capture the water, how many minutes did it take?

$$5 \text{ sec} \times \frac{1 \text{ min}}{60 \text{ sec}} = 0.083 \text{ min}$$

**Converting the faucet flow rate from ml/sec to gal/min:**

If we measure 500 ml of water flowing in 5 seconds, what is the flow-rate in gal/min?

$$\frac{500 \text{ ml}}{5 \text{ sec}} \times \frac{1 \text{ L}}{1000 \text{ ml}} \times \frac{0.264 \text{ gal}}{1 \text{ L}} \times \frac{60 \text{ sec}}{1 \text{ min}} = 1.58 \text{ gal/min}$$

You don’t have to use this lengthy equation each time you want to convert the flow rate. If we multiply the three conversion factors together, we derive a single conversion factor to use instead.

$$\frac{1 \text{ ml}}{5 \text{ sec}} \times \frac{1 \text{ L}}{1000 \text{ ml}} \times \frac{0.264 \text{ gal}}{1 \text{ L}} \times \frac{60 \text{ sec}}{1 \text{ min}} = 0.0032 \text{ gal/min}$$

So, if, for example we collect 650 ml of water in 5 seconds during the Measure Bathroom Flow Rate Procedure, we can calculate the faucet flow rate in gallons per minute (gpm) as follows:

$$650 \text{ ml} \times 0.0032 \text{ gal/min} = 2.08 \text{ gpm}$$
Appendix 3.1.D: Measure Bathroom Faucet Flow Rate Data Sheet

Inquiry Question: How much water is used by students and teachers washing their hands at bathroom faucets each YEAR?

| Location | Location 1: ____________________________________________ | Location 2: ____________________________________________ |
|----------|---------------------------------------------------------|
| A        | B            | C            | D            | E            | F            |
| Faucet # | ☑ if metered | ☑ if Leaking | Baseline flow rate (existing condition i.e. with old aerator or no aerator)? (How many ml in 5 seconds?) | Flow rate without aerator? (How many ml in 5 seconds?) | Flow rate with new aerator? (How many ml in 5 seconds?) | Notes and Comments (Leak level / GPY) |
| Location 1 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Location 2 | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Total    | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Average  | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
Appendix 3.1.E

Figuring Your Conversion Factors

Conversion factors are used to change units of measurement. We measured faucet flow in milliliters per 5 seconds (ml/s), but we really want to know the sink’s flow rate in gallons per minute (gal/min). To determine our conversion factors, we need to know some numbers.

- How many ml are in 1 gallon?
- How many seconds are in 1 minute?

Converting the amount of water from ml to gallons:

We can use a conversion table to look up the fact that 1 L = 0.264 gal and we know that 1000 ml = 1L. These equalities can be used as conversion factors (fractions that can be multiplied by your original number in order to change its units) i.e.

\[
\frac{0.264 \text{ gal}}{1 \text{ L}} \quad \text{and} \quad \frac{1 \text{ L}}{1000 \text{ ml}}
\]

For example, if we have 500 ml of water, how many gallons do we have?

\[
500 \text{ ml} \times \frac{1 \text{ L}}{1000 \text{ ml}} \times \frac{0.264 \text{ gal}}{1 \text{ L}} = 0.132 \text{ gal}
\]

Converting the amount of time from sec to minutes:

We know 60 sec. = 1 min., so our conversion factor is:

\[
\frac{1 \text{ min}}{60 \text{ sec}}
\]

For example, if it took 5 seconds to capture the water, how many minutes did it take?

\[
5 \text{ sec} \times \frac{1 \text{ min}}{60 \text{ sec}} = 0.083 \text{ min}
\]

Converting the faucet flow rate from ml/sec to gal/min:

If we measure 500 ml of water flowing in 5 seconds, what is the flow-rate in gal/min?

\[
\frac{500 \text{ ml}}{5 \text{ sec}} \times \frac{1 \text{ L}}{1000 \text{ ml}} \times \frac{0.264 \text{ gal}}{1 \text{ L}} \times \frac{60 \text{ sec}}{1 \text{ min}} = 1.58 \text{ gal/min}
\]

You don’t have to use this lengthy equation each time you want to convert the flow rate. If we multiply the three conversion factors together, we derive a single conversion factor to use instead.

\[
\frac{1 \text{ ml}}{5 \text{ sec}} \times \frac{1 \text{ L}}{1000 \text{ ml}} \times \frac{0.264 \text{ gal}}{1 \text{ L}} \times \frac{60 \text{ sec}}{1 \text{ min}} = 0.0032 \text{ gal/min}
\]

So, if, for example we collect 650 ml of water in 5 seconds during the Measure Bathroom Flow Rate Procedure, we can calculate the faucet flow rate in gallons per minute (gpm) as follows:

\[
650 \text{ ml} \times 0.0032 \text{ gal/min} = 2.08 \text{ gal/min}
\]
Appendix 3.1.F: Bathroom Faucet Water Use Calculations Worksheet 1: Baseline Condition

**Inquiry Question:** How much water is used by students and teachers washing their hands at bathroom faucets each YEAR?

**Data needed:**

- **a.** Average baseline faucet flow = ________ mL (in 5 seconds)  
  (from 3.1.D, Measure Bathroom Faucet Flow Rate Procedure)
- **b.** Average hand-washing frequency = ________ washes/day  
  (from 3.1.B, Survey of Hand-Washing Frequency Procedure)
- **c.** Average hand-washing time = ________ min/wash  
  (from 3.1.C, Measure Average Hand-Washing Time Procedure)
- **d.** # of hand-washers at the school (students plus adults) = ________ ppl  
  (from 3.1.B, Survey of Hand-Washing Frequency Procedure)
- **e.** # of days that there are people at school = ________ days/year  
  (from 3.1.B, Survey of Hand-Washing Frequency Procedure)

**Conversion factors:** 1 L/1000 mL  0.264 gal/1 L  60 sec/1 min

1. Convert the average flow rate from mL/5 sec. to gal/min. (use a)

\[
\frac{\text{mL}}{5 \text{ sec}} \times \frac{60 \text{ sec}}{1 \text{ min}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{0.264 \text{ gal}}{1 \text{ L}} = \frac{\text{gal}}{\text{min}}
\]

   \[
   \frac{\text{mL}}{5 \text{ sec}} \times \frac{60 \text{ sec}}{1 \text{ min}} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{0.264 \text{ gal}}{1 \text{ L}} = \frac{\text{gal}}{\text{min}}
   \]

2. For how many total minutes does each person run water for hand-washing in one day? (use b and c)

   \[
   \text{min/day}
   \]

3. How much water is used by each person for hand-washing in one day. (use #1 and #2)

   \[
   \text{gal/day/person}
   \]

4. How much water, in total, is used at the school for hand-washing in one day? (use #3 and d)

   \[
   \text{gal/day}
   \]

5. How much water is used at school for hand-washing in one year? (use #4 and e)

   \[
   \text{gal/yr}
   \]

**Summary Statement:** Based on the Baseline Flow Rate of the bathroom faucets, ________ gallons of water are used at this school, for washing hands, each year!
**Appendix 3.1.F: Bathroom Faucet Water Use Calculations Worksheet 2: Without Aerator**

**Inquiry Question:** How much water is used by students and teachers washing their hands at bathroom faucets each YEAR?

**Data needed:**
- a. Average faucet flow without aerator = ________ mL (in 5 seconds)  
  (from 3.1.D, Measure Bathroom Faucet Flow Rate Procedure)
- b. Average hand-washing frequency = ________ washes/day  
  (from 3.1.B, Survey of Hand-Washing Frequency Procedure)
- c. Average hand-washing time = ________ min/wash  
  (from 3.1.C, Measure Average Hand-Washing Time Procedure)
- d. # of hand-washers at the school (students plus adults) = ________ ppl  
  (from 3.1.B, Survey of Hand-Washing Frequency Procedure)
- e. # of days that there are people at school = ________ days/year  
  (from 3.1.B, Survey of Hand-Washing Frequency Procedure)

**Conversion factors:**  
1 L/1000mL  0.264 gal/1 L  60 sec/1 min

1. Convert the average flow rate from mL/5 sec. to gal/min.  
   (use a)  
   
   \[
   \frac{mL}{5\text{ sec}} \times \frac{60\text{ sec}}{1\text{ min}} \times \frac{1L}{1000mL} \times \frac{0.264\text{ gal}}{1L} = \frac{\text{gal}}{\text{min}}
   \]

2. For how many total minutes does each person run water for hand-washing in one day?  
   (use b and c)  
   ________ min/day

3. How much water is used by each person for hand-washing in one day?  
   (use #1 and #2)  
   ________ gal/day/person

4. How much water, in total, is used at the school for hand-washing in one day?  
   (use #3 and d)  
   ________ gal/day

5. How much water is used at school for hand-washing in one year?  
   (use #4 and e)  
   ________ gal/yr

**Summary Statement:** Based on the flow rate of the bathroom faucets without aerators, ________ gallons of water would be used at this school, for washing hands, each year, if all bathroom faucet aerators were removed!
Appendix 3.1.F: Bathroom Faucet Water Use Calculations Worksheet 3: *With New Aerator*

**Inquiry Question:** How much water is used by students and teachers washing their hands at bathroom faucets each YEAR?

**Data needed:**

- **a.** Average faucet flow *with new aerator* = ________ mL (in 5 seconds)  
  (from 3.1.D, Measure Bathroom Faucet Flow Rate Procedure)
- **b.** Average hand-washing frequency = ________ washes/day  
  (from 3.1.B, Survey of Hand-Washing Frequency Procedure)
- **c.** Average hand-washing time = ________ min/wash  
  (from 3.1.C, Measure Average Hand-Washing Time Procedure)
- **d.** # of hand-washers at the school (students plus adults) = ________ ppl  
  (from 3.1.B, Survey of Hand-Washing Frequency Procedure)
- **e.** # of days that there are people at school = ________ days/year  
  (from 3.1.B, Survey of Hand-Washing Frequency Procedure)

**Conversion factors:** 1 L/1000mL  0.264 gal/1 L  60 sec/1 min

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td><strong>1.</strong> Convert the average flow rate from mL/5 sec. to gal/min. (use a)</td>
<td>[ \frac{mL}{5\text{ sec}} \times \frac{60\text{ sec}}{1\text{ min}} \times \frac{1L}{1000mL} \times \frac{0.264\text{ gal}}{1L} = \text{gal/min} ]</td>
</tr>
<tr>
<td><strong>2.</strong> For how many total minutes does each person run water for hand-washing in one day? (use b and c)</td>
<td>________ min/day</td>
</tr>
<tr>
<td><strong>3.</strong> How much water is used by each person for hand-washing in one day. (use #1 and #2)</td>
<td>________ gal/day/person</td>
</tr>
<tr>
<td><strong>4.</strong> How much water, in total, is used at the school for hand-washing in one day? (use #3 and d)</td>
<td>________ gal/day</td>
</tr>
<tr>
<td><strong>5.</strong> How much water is used at school for hand-washing in one year? (use #4 and e)</td>
<td>________ gal/yr</td>
</tr>
</tbody>
</table>

**Summary Statement:** Based on the flow rate of the bathroom faucets *with new aerators*, ________ gallons of water would be used at this school, for washing hands, each year if new aerators were installed!
### Appendix 3.1.F: Bathroom Faucet Water Use Worksheet 4: Water Savings Calculations

**Inquiry Question:** How much water is saved each YEAR by installing new aerators on all bathroom faucets?

<table>
<thead>
<tr>
<th>Data needed from worksheets 1-3:</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>**Water use per year in <strong>baseline condition</strong></td>
<td>Water use per year without aerators</td>
<td>Water use per year with aerators</td>
</tr>
<tr>
<td>Ave. baseline faucet flow rate: _____ gal/min</td>
<td>Ave. faucet flow rate w/o aerators: _____ gal/min</td>
<td>Ave. faucet flow rate w/ new aerators: _____ gal/min</td>
</tr>
<tr>
<td>Baseline yearly water use: _____ gpy</td>
<td>Yearly water use w/o aerators: _____ gpy</td>
<td>Yearly water use with new aerators: _____ gpy</td>
</tr>
</tbody>
</table>

1. What is the difference between the water use per year under the **baseline flow** condition and the water use per year with **new aerators** installed?

2. What is the difference between the water use per year **without any aerators** and water use per year with **new aerators** installed?

3. Comment on the water savings that the school will experience in a year because of the installation of new faucet aerators.

4. How effective are new aerators (as compared to old aerators and as compared to no aerators) in saving water?
Appendix 3.1.G

Homework Letter to Parents/Guardians

Below are instructions for a portion of a home water audit and installation of faucet aerators. Please allow your student to show you how to measure your faucet flow rate and install a faucet aerator to reduce the flow. Applying what has been taught in school is an important part of the learning process. Thank you for being a part of our science instruction!

Measure Faucet Flow Rate procedure

1. Examine the faucet for leaks:
   a. Look and feel around the faucet as well as under the sink along the drain pipe.
   b. Indicate the presence of leaks on your data sheet
   c. Mark any leaks with flagging.
   d. If possible, capture the leaking water in a drip gauge for 5 seconds.
   e. Record the leakage level and the associated gallons per year (gpy).
2. Measure the flow of water from the faucet for 5 seconds:
   a. Place the bowl with spout in the sink under the faucet.
   b. With one hand on the faucet and one hand operating the stopwatch, turn the water flow to full-on and start the stopwatch simultaneously.
   c. Count aloud 1, 2, 3, 4, 5 in time with the stopwatch.
   d. When reach the count of “5,” immediately remove the bowl from the flow of water without spilling any of the water.
   e. Turn the water off.
   f. Pour the water from the bowl into a measuring cup.
   g. Read the water level from the measuring cup and record the measurement in units per 5 seconds.
   h. Pour the water from the measuring cup into a bucket.
   i. Repeat steps b – h two more times for a total of three measurements.
   j. Average the three measured values. This is your Baseline Flow.
3. Check for an existing faucet aerator and make note of its condition.
4. If an old aerator is on the faucet, remove it (pliers may be needed).
5. Install a new aerator
6. Repeat Steps 1-2, recording the data. This is your Flow With New Aerator.
7. Compare the Baseline Flow value with the Flow With New Aerator value. The lower of the two values indicates the best aerator.
8. If the Baseline Flow value is lower than the Flow With New Aerator value, then remove the new aerator and replace the original.
9. Repeat steps 1-8 to audit a second faucet in your home.
10. Pour the collected water over plants outside.
11. Report how many faucet aerators were installed at your home. How much water was saved (baseline amount – amount with aerator)?
12. Return unused aerators to school, including “old” aerators that were replaced.