Sustainable Water: Development, Delivery and Assessment of K-5 Modules

Alexandre David Wing, Colorado School of Mines

Alexandre is a Masters student at Colorado School of Mines in Environmental Science and Engineering. His research focus includes finding and evaluating opportunities for improving water quality during managed aquifer recharge, a sustainable natural treatment method. Alexandre graduated from Montana State University in 2011 with a BS in Biological Science.

Ms. Cristal Hibbard, Colorado School of Mines

Cristal Hibbard has a B.S. in Engineering with an Environmental Specialty from the Colorado School of Mines. While completing her M.S. in Environmental Science & Engineering, Cristal was a Lead Graduate Fellow for the Bechtel K-5 Educational Excellence Initiative, an element of the Trefney Institute at the Colorado School of Mines.

Prof. Jennifer Strong, Colorado School of Mines

Jennifer Strong is a Teaching Associate Professor in the Department of Applied Mathematics and Statistics at the Colorado School of Mines (CSM). She is also the K-12 Outreach Program Manager for the Trefny Institute for Educational Innovation at CSM, whose goal is to strengthen on-campus endeavors in undergraduate and graduate education and strengthen CSM's leadership role in education research, curriculum development, and assessment.

Prof. Jörg E Drewes, Colorado School of Mines

Jörg E. Drewes is Professor of Civil and Environmental Engineering and Director of Research for the NSF Engineering Research Center on Reinventing the Nation's Urban Water Infrastructure (ReNUWIt). He also serves as Co-Director of the Advanced Water Technology Center (AQWATEC) at the Colorado School of Mines, which he co-founded in 2007. Prof. Drewes' research and scholarly activities have been in four areas for which he is internationally and nationally recognized and which are closely related based on the common thread of drinking water augmentation with water of impaired quality: (1) design and operation of managed aquifer recharge (MAR) systems including riverbank filtration and soil-aquifer treatment, (2) monitoring strategies for bulk organic carbon and emerging trace organic chemicals in natural and engineered systems, (3) performance modeling and optimized operation of energy-efficient high-pressure membranes including nanofiltration and low-pressure reverse osmosis, and (4) beneficial use of co-produced water.

Dr. Junko Munakata-Marr, Colorado School of Mines

Dr. Munakata Marr is an Associate Professor of Civil and Environmental Engineering at the Colorado School of Mines in Golden, Colorado. She received her BS degree in Chemical Engineering from the California Institute of Technology and her MS and PhD degrees in Civil Engineering from Stanford University. Her research and teaching interests revolve primarily around microorganisms in engineered environmental systems, including biological wastewater treatment and methanogenesis from unconventional sources. She has nearly 20 years of experience in bioremediation. Other interests include sustainable water infrastructure, increasing diversity among STEM students and faculty, and sustainable community development.

Sustainable Water: Development, Delivery and Assessment of K-5 Modules

Abstract

During the summer of 2012, a recently awarded National Science Foundation Engineering Research Center (ERC) paired with a university K-5 outreach program to bring cutting-edge topics in urban water systems to local elementary classrooms. The ERC is an interdisciplinary and multi-institutional collaboration between academic, non-profit and industrial partners with the goal of transforming urban water infrastructure into more sustainable systems. The university K-5 outreach program pairs graduate students in math, physics, and engineering with K-5 elementary school teachers in a local school district. During the school year, the graduate students, known as fellows, assist the teachers in their classrooms with the instruction and understanding of math and science. The program also includes a two week workshop in the summer that is mandatory training for all of the elementary teachers and graduate fellows participating in the program. During this workshop, elementary school teachers learn advanced science topics, receive instructional materials (with guidance) to take back to their classrooms, and get to know their designated graduate fellow.

For two days (four two-hour sessions) of the 2012 Workshop, the ERC group introduced water sustainability topics to the participating K-5 teachers. ERC faculty, graduate students, and fellows associated with the outreach program collaborated in teams to develop and present lectures, lessons, and demos for each session/module. The four modules were “Natural Systems,” “Water Cycle and Water Treatment,” “Water Conservation and Re-use,” and “Taste Test and Hungry Bugs.” The modules covered a wide range of water topics including the water cycle, drinking water treatment, biological treatment of water and wastewater, pollution sources and water conservation, illustrated through fun and exploratory activities such as bottled vs. tap water tasting, edible aquifer parfaits, a “hungry bugs” game, and swabbing and culturing microbes. Participating teachers were asked to provide feedback on the presentations and were given a multiple choice pre- and post-test on the content of the sessions to evaluate how effective each presenter was at communicating their information. Results of these assessments, together with feedback from the use of the lessons in the elementary classrooms during the fall semester, are presented.

Introduction

Proficiency in STEM education has been identified by the federal government and federally-commissioned committees as essential to US competitiveness in the global marketplace¹. In addition, having a scientifically literate workforce of engineers and technicians is imperative to ensure that infrastructural resources are effective and resilient enough to face dynamic and challenging environmental and economic forces. Few examples better represent this looming issue than our country's aging urban water infrastructure. Outdated treatment plants and distribution systems are in extreme disrepair at a time where water scarcity, budget deficits, emerging contaminants and population shifts to arid metropolitan centers are dwindling the ability to provide drinking water in the near future². These challenges represent an opportunity to address shortcomings in STEM education while fostering the growth of creative, scientifically literate generations with the ideas and abilities necessary for solving our country's greatest problems. Recognizing this prospect, a recently awarded National Science Foundation Engineering Research Center (ERC) paired with a university K-5 outreach program to bring cutting-edge topics in urban water systems to local elementary classrooms. This paper showcases the partnership, its educational features, a performance assessment, and teacher feedback.

The Bechtel Program

The Bechtel K-5 Education Excellence Initiative is the primary elementary-school component of the Colorado School of Mines' (CSM) outreach approach. Through a \$2.5 million grant from the Bechtel Foundation, CSM students and faculty interact with teachers and students in the Adams 50 school district to enhance mathematics and science instruction in the classroom. Graduate fellowship students, or Bechtel Fellows, are paired with one or two elementary school teachers and spend 10-15 hours per week in their classrooms presenting interactive lessons they have developed or assisting with math and science instruction. The summer before their partnership school year, participating teachers must attend the 'Teaching Earth, Energy and the Environment in Elementary Mathematics and Science' (TEEMS) Workshop. If the teacher chooses to participate for a second year they attend the second workshop that covers additional topics. During the workshops, teachers attend presentations by various CSM faculty and students who provide information, lessons, and activities that the teachers can then take back to their classrooms. The teachers have the option of requesting the presenters visit and present in the classrooms during the school year. The workshops also give teachers that may not have a technical background a solid knowledge base of more advanced science topics. These workshops can provide credit for teachers moving towards certifications in technical disciplines.

ReNUWIt

Urban water infrastructure in the US is in extreme disrepair, needing an estimated 1.7 trillion dollars in investment over the next 40 years in buried infrastructure (i.e. pipelines) alone³. Unfortunately, much time and energy has been spent making water treatment and delivery invisible to the public eye, with clean drinking water generally taken for granted and viewed as an assured resource. In addition to aged and defective buried pipelines, our wastewater treatment

plants are outdated and are not prepared to remove emerging contaminants from discharges to rivers⁴, contaminants which then pass through conventional treatment plants that provide our drinking water⁵. All of these issues come at a time of increasing water scarcity². Fortunately, there is room for improvement: new technologies and treatment strategies can address emerging contaminants and treat for specific uses. New approaches to managing our limited freshwater resources improve efficiency by viewing wastewater as a valuable resource and by recognizing the disconnect between treatment and use. For example, less than 3% of residential drinking water is used for potable uses, while 66 percent is used for toilet flushing and irrigation, requiring addition of nutrients that were originally present but were removed during drinking water treatment⁶.

The National Science Foundation (NSF) Engineering Research Center for Re-inventing the Nation's Urban Water Infrastructure (ReNUWIt) addresses technological, economic, policy, and social deficiencies in urban water systems. The ERC is comprised of four partner institutions in the US: Stanford University, the University of California – Berkeley, Colorado School of Mines, and New Mexico State University, along with several international and industrial partners. Through research on barriers between promising technologies and their successful implementation in urban water systems, ReNUWIt works to accelerate the pace at which aging US water infrastructure is replaced with the most innovative and efficient treatment options. However, technological advances alone will not solve the developing problems with US water infrastructure. Public awareness of water resources, including the myriad issues at hand from emerging contaminants to water scarcity and wasted resources, is essential to reinvention. Further, as modern society continues to grow and develop, reliance on innovative water managers, engineers, entrepreneurs, and technicians to provide safe and reliable water will increase. For these reasons, public outreach and successful STEM education are ReNUWIt priorities.

Education and outreach at ReNUWIt is focused on providing education to students at every level, from kindergarten to teachers and professionals. Every ReNUWIt researcher is thus required to spend 40 hours per year on education and outreach, and each ReNUWIt institution is partnered with local schools. This allows ReNUWIt to create programs and activities tailored to meet each school's interests and needs. During the summer of 2012, CSM ReNUWIt graduate students and faculty partnered with the Bechtel program to use urban water systems as a vehicle for addressing state requirements for science, math, and writing with lessons and activities.

TEEMS: The four modules

In the summer workshop for Adams County K-5 teachers, Bechtel graduate fellows teamed up with ReNUWIt graduate researchers and faculty to develop four teaching modules. Each module consists of (1) a presentation to broaden elementary teachers' understanding of topics in water systems, (2) lessons that incorporate State of Colorado learning standards, and (3) demonstrations to be taken into the classroom with or without assistance of the fellow. A summary of the modules is presented in Table 1. The fellows assisted ReNUWIt students to translate state-of-the-art research topics into language accessible to teachers who may not have a science or engineering background. The workshop consisted specifically of eight returning teachers who are passionate about the program and have previously integrated workshop lessons

into their classrooms successfully. In addition to the teachers, four graduate fellows attended and participated in Workshop II.

Table 1. Modules and corresponding presentations, lessons, activities, and demonstrations.

Module	Presentations & Lessons	Activities & Demonstrations
Water Cycle & Water Treatment	Intro. to Water Water Cycle Water Quality	Water Cycle Bracelets Inflatable Globe Conductivity Circuit Kool-aid Disinfection
Water Conservation and Reuse	Conserving Water Water is a Resource Water Reuse	Water Budget Water Bead Activity Water Reuse Activity
Taste Test and Hungry Bugs	Wastewater Treatment Bottled vs. Tap Water Quality	Hungry Bugs Taste Test
Natural Systems	Microbial Transformation Sources of Contamination Engineered Natural Systems	Agar Plate Activity Pollution coloring activity Edible Aquifer Parfaits Aquifer Recharge and Recovery Demo

Water Cycle & Treatment

A major barrier to addressing problems with urban water infrastructure is a lack of public understanding of how water gets from the environment to the tap and back to the environment through the drain. This knowledge gap makes communicating issues and potential fixes to the public difficult, and necessitates further education of the urban water cycle and water treatment. The water cycle and treatment module consists of three presentations: an introduction to water, the water cycle, and water quality. The objective is to teach students about the water cycle, allow them to examine the differences between fresh and salt water, and learn how water is treated so that we can safely drink it. This module includes brainstorming activities requiring students to think of all of the daily uses of water and how much is available, constructing bracelets with beads representing steps in the water cycle, and completing electronic circuits by adding conductivity to deionized water. Another activity works through the steps in drinking water treatment, using Kool-aid to represent and help visualize disinfection processes (i.e. diffusion and mixing of chlorine). Using the water cycle to teach complex interactions between Earth, the sun, and humans' dependency on limited natural resources, this module specifically addresses the Colorado Department of Education Earth systems science standards.

Figure 1: An electric motor demonstrates the concept of conductivity to measure purity of water

Water Conservation and Reuse

Water conservation and reuse are two of the greatest tools of water managers and engineers for ensuring water supplies as increasing water scarcity and demand converge. While water conservation methods are well established in parts of the U.S., water reuse is quickly gaining hold as a tool for assuring water supplies in the face of prolonged drought. The modules covering water conservation and reuse were divided into three presentations titled “Conserving Water”, “Water is a resource” and “Water

Reuse”. Lessons include “How much do we use?”, a water bead activity that involves allocating colored beads to represent the different usage fractions in a household out of the total daily use, a water budget activity where students calculate water savings by installing different household fixtures (i.e. a water-saving faucet), and a water reuse activity involving Venn diagrams. This module addresses state and district math standards using statistics, data analysis, probability and graphical displays of information to investigate water scarcity.

Taste Test and Hungry Bugs

This module draws on ReNUWIt resources outside of CSM by incorporating “Hungry Bugs”, a water treatment activity developed at Stanford University. “Hungry Bugs” turns biological treatment of wastewater into a hands-on activity where students group together representing different functional classes of microbes (i.e. primary fermenters, secondary fermenters, and methanogens). Each microbial group “eats” different substrates, represented by colored pompoms, and may have unique requirements that another group must fulfill. For example, the primary fermenters need to remove all of the brown pompoms before the secondary fermenters can begin removing the purple pompoms, and all brown and purple pompoms must be removed before the methanogens can remove the orange pompoms. Only when all pompoms are removed is the water considered clean and counts towards the students’ scores. The activity demonstrates the inter-dependencies of microbial communities, and how microbes are used every day to treat water. The taste test presentation and activity highlight the implications of increased bottled-water usage (e.g. heavy petroleum demand and negative views of municipal water) and put bottled and tap water head-to-head in a taste test. Box 1, below, provides a detailed account of the state standards addressed by the taste test lesson in this module, comparable to that provided with each lesson in the module.

Figure 2: A teacher makes a bracelet representing allocation of different water uses

Figure 3: Teachers and fellows learn the Hungry Bugs activity

Box 1. Taste Test Lesson Plan – Colorado Department of Education Standards Addressed

Science Standards Addressed:

Standard 1: Physical Sciences

5th Grade: Expectation 1 – Mixtures of matter can be separated regardless of how they were created; all weight and mass of the mixture are the same as the sum of the weight and mass of its parts.

Standard 2: Life Sciences

2nd Grade: Expectation 1 – Organisms depend on their habitat's nonliving parts to satisfy their needs.

Standard 3: Earth System Science

5th Grade: Expectation 1 – Earth and sun provide a diversity of renewable and nonrenewable resources

Math Standards Addressed:

Standard 3: Data Analysis, Statistics, and Probability

1st Grade: Expectation 1 – Visual displays of information can be used to answer questions

2nd Grade: Expectation 1 – Visual displays of data can be constructed in a variety of formats to solve problems

3rd, 4th & 5th Grades: Expectation 1 – Visual displays are used to describe data

Social Studies Standards Addressed:

Standard 3: Economics

2nd Grade: Expectation 1 – The scarcity of resources affects the choices of individuals and communities

Expectation 2 – Apply decision-making processes to financial decision-making

4th Grade: Expectation 1 – People respond to positive and negative incentives

Expectation 2 – The relationship between choice and opportunity cost

5th Grade: Expectation 1 – Government and market structures influence financial institutions

Natural Systems

The Natural Systems module begins with an introduction to microbes and their beneficial uses, followed by a presentation on types and sources of pollution and how emerging contaminants reach water supplies. The final presentation in this module describes how natural soil microbes can be used to remove emerging contaminants such as pharmaceutical residues from water during riverbank filtration and managed aquifer recharge. The module includes an agar plate activity where students can grow microbes from soil, the air, and from different surfaces in the classroom. Box 2 provides a sample excerpt of the lesson plan for this activity. An additional activity features coloring sheets to illustrate how pollution reaches water supplies, and an aquarium tank filled with sand and equipped with pumps which allows students to explore aquifer recharge and recovery and the interactions between surface and groundwater. The final activity in the module,

Figure 4: A teacher swabs soil onto an agar plate to grow soil microbes

“edible aquifer parfaits”, is adapted from resources available on the internet and lets students build confined aquifers out of ice cream, ice cubes, sprinkles, and soda, apply pollution in the form of food coloring, and see how pollution can contaminate an aquifer. The Natural Systems module uses the interactions between pollution and microbes in water to address Colorado standards in physical science, life science, and earth systems science.

Box 2: Microbial Transformation Lesson Plan

Students document microorganisms grown over time from soil, air and classroom surfaces mixed with water in an agar plate activity.

Observation Record Sheet

Date: _____

Date: _____

Date: _____

Date: _____

Assessment

To assess the effectiveness of the workshop presentations, identical multiple choice pre- and post-tests are administered to the teachers. Graduate fellows new to the Bechtel program are required to attend the workshop with the teachers and participate in all of the modules as well as complete this assessment. The test features questions from each of the modules that the teachers attend over the two-week workshop. Comparing answers from the first day of the workshop to those provided on the last day helps to show which presentations the teachers are comprehending best and retaining. Presenters are given the compiled result for their respective modules so they can continue to develop and improve their materials to best meet the needs of the teachers and the Bechtel program.

For each ReNUWIt sustainable water module, two questions were included in the test. Table 2 lists questions from the modules, while Table 3 summarizes the results from the pre- and post-tests for both teachers and new fellows. Table 3 shows the number and percentage of participants who correctly answered the questions for each of the modules.

Table 2. Multiple choice questions and answers (in bold) by module.

Natural Systems	Water Conservation & Reuse	Water Cycle & Water Treatment	Taste Test & Hungry Bugs
Of the following processes, which is most responsible for chemical removal? a. Biotransformation b. Filtration c. Sorption d. Dilution	The sector that uses the most water in the U.S. is: a. households (residences) b. agriculture c. manufacturing d. power generation	Approximately how much of the Earth's surface is water? a. 33% b. 50% c. 55% d. 75%	A microorganism that obtains its carbon source from CO ₂ gas is a(n): a. autotroph b. heterotroph c. chemotroph
_____ is a major source of pollution in the South Platte River just east of Denver, CO. a. Treated municipal wastewater b. Agricultural runoff c. Chemical plant effluent d. Oil spills	The household fixture that uses the MOST water is: a. shower/bathtub b. washing machine c. dishwasher d. toilet	What is desalination? a. Removal of salt and other minerals from saline water. b. Forming salt crystals from soil. c. When water currents affect the Earth's rotation. d. None of the above.	The average American consumes approximately _____ gallons of bottled water every year. a. 15 b. 18 c. 21

Table 3. Number and percent of participants who correctly answered questions by module.

Module	Teachers (n=8)				Fellows (n=4)			
	Pre		Post		Pre		Post	
	#	%	#	%	#	%	#	%
Natural Systems	3	37.5	0	0	2	50	1	25
	4	50	5	62.5	1	25	2	50
Water Conservation & Reuse	1	12.5	5	62.5	3	75	2	50
	1	12.5	6	75	4	100	4	100
Water Cycle & Water Treatment	7	87.5	8	100	4	100	4	100
	8	100	8	100	4	100	4	100
Taste Test & Hungry Bugs	2	25	4	50	4	100	3	75
	5	62.5	2	25	2	50	4	100

The questions included in the multiple-choice assessment were developed by the presenters with help from the graduate fellows. Because the presenters do not see questions from other presenters in the workshop, issues may arise related to context and overlapping between questions. For example, the Natural Systems module featured a question relating to chemical removal (Table 2). While the correct answer is true in the context of aquifer recharge, the question did not state this context. After many presentations on different methods of water treatment throughout the workshop and multiple contexts (i.e. natural treatment vs. membrane

filtration), more than one answer actually ended up being correct, and reflected poorly upon the pre- and post- results.

Each year, presenters are encouraged to reword their questions or refocus their presentations depending on the results of the previous workshop's tests. While some of the ReNUWIt presentations show great growth on the pre- and post-test results, some did not. This could be attributed to confusing wording of questions and a flood of new information on similar topics (water treatment/filtration/desalination, etc.). The ReNUWIt presenters are able to learn from these results, reword their questions and make sure that information across the presentations clearly lead to consistent correct answers. This may also be a lesson in focusing the presentations to cover core topics and not incorporate too much information.

Teachers are also asked to provide written feedback on the modules using a "Keep, Quit, Start" method in order to learn what the Bechtel program should continue to do, cease doing, and consider including for future TEEMS Workshops. Many of the presenters at the workshops have been participating for several years, refining their modules based on teacher feedback. The water sessions fared very well for being brand new modules. Teachers gave very positive "keep" feedback on many of the hands-on activities, especially the Edible Earth Parfaits, Water Cycle Bracelets and Song, Aquifer Recharge and Recovery Demo (Sand Filtration Tank), Inflatable Globe, Agar Plate Activity, and the Salinity/Conductivity Circuit Activity. These activities were each mentioned multiple times as things that the teachers found to be useful and interesting, and that should be included in future workshops. The hands on activities in general were applauded for not only clarifying and reinforcing the water topics, but held the attention of the teachers through fairly long sessions.

As far as features that the presenters should change, many teachers mentioned making sure the presentations were "low-level" enough for people with minimal science backgrounds to understand and retain, possibly by including a vocabulary discussion. They also discussed making sure activities meet specific content standards, especially literacy, by including more children's book connections or writing opportunities in the lessons. On the other hand, some commented that presentations on content they are very familiar with (e.g. the water cycle) should be skipped to move straight to the activity for the students. One teacher recommended adding to the Natural Systems modules some activities to reinforce pollution prevention and how students can address pollution every day at home, school, the park, etc. Also, concerns were expressed about the use of reagent-grade alum in the classroom, so the coagulation activity should be altered to use easier-to-obtain chemicals.

This year included a unique opportunity to invite back a teacher that had been in the program for two years to participate for a third. Because this teacher had already attended most of the presentations in both Workshop I and II, the teacher was asked to give detailed feedback on the modules. The teacher filled out an evaluation sheet for each module that addressed the following questions:

1. In what type of class and at what level would the contents for this session be useful?
2. Are the standards listed on the lesson plans appropriate? Please list any additional standards you feel could be addressed and explain how the lesson links to that standard.

3. As a teacher, would you have access or be willing to purchase the supplies used in this session?
4. What would you change about this session for next summer?
5. Please list any additional comments about this session.

The feedback provided by the teacher-evaluator is summarized by module below:

Natural Systems

The teacher felt very strongly that the activities provided in this module could be used successfully in the classroom. The supplies were deemed reasonable, applied standards appropriately and students would enjoy learning with them. For next year, the recommendations were to spend more time on the activities while simplifying the presentation, and to include books that could strengthen a literacy connection to these concepts.

Water Cycle and Water Treatment

The evaluating teacher thought the hands-on activities were very engaging. The teacher was impressed by the thorough application of standards and thought this would encourage the module's use in the classroom. However, the evaluator was concerned regarding the availability of motors and fans (for the coagulation and conductivity activities) but thought the beads were a great idea. The teacher recommended making the conductivity lesson more inquiry-based by expanding the materials and letting the students experiment. Also recommended was removing or changing the Kool-aid activity since it might not be clear to everyone what is being demonstrated and that kids might think that adding Kool-aid to water will disinfect. The teacher suggested some additional children's books that could be used with this lesson to strengthen literacy connections.

Water Conservation and Reuse

The teacher-evaluator gave exclusively positive feedback on this presentation, especially because the lessons are valuable for all elementary levels. The evaluator found the presenters did a very good job keeping the session fun and engaging. The teacher also noted appreciation for having the handouts in Spanish as well as English. This is not something the workshop presenters have focused on before but will be considered because this school district has a large number of English as a Second Language (ESL) students in attendance.

Taste Test and Hungry Bugs

The teacher liked the lessons and activities presented in this module, finding that the lessons could be used for all ages, and included some suggestions to expand each of the activities. Changes to the Taste Test activity were recommended to make it simpler for young students. The teacher recommended including a worksheet with the cost of each type of water to incorporate math standards, and suggested adding an additional extension activity.

Conclusion

The four ReNUWIt modules of the TEEMS workshop were effective in teaching STEM concepts through sustainable urban water systems. The modules described in this paper are dynamic and adaptable, and can be used in many K-5 classrooms. Additionally, teacher feedback directly allows revision and refinement to improve the models' effectiveness and implementation. Teachers attending the workshop were excited and motivated to implement the modules, as they provide relevant, meaningful examples and activities through which math and science can be taught. Aging, outdated, and ineffective urban water systems represent a serious national problem that will need to be confronted head-on in the near future. This problem provides an opportunity to instill in young minds a foundation of knowledge required to explore technologies and become engaged in reinventing our water infrastructure. The partnership between ReNUWIt and the Bechtel program is a successful beginning, designed to empower youth with the background and interest in STEM that is essential to a prosperous future in America.

References

1. US Congress Joint Economic Committee (2012). STEM Education: Preparing jobs for the future. Washington D.C.
2. National Research Council (2012). Water Reuse: Potential For Expanding The Nation's Water Supply Through Reuse Of Municipal Wastewater. Washington, DC, Press T.N.A.
3. American Water Works Association (AWWA) (2012). *Buried No Longer*. Retrieved from <http://www.awwa.org/Portals/0/files/legreg/documents/BuriedNoLonger.pdf>. Accessed January 3, 2013.
4. Kolpin, D.W., Furlong, E.T., Meyer, M.T., Thurman, E.M., Zaugg, S.D., Barber, L.B., Buxton, H.T. (2002). Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: a national reconnaissance. *Environmental Science and Technology* 36 (6), 1202-1211.
5. Richardson, S. (2003). Disinfection by-products and other emerging contaminants in drinking water. *TrAC Trends in Analytical Chemistry* 22 (10), 666-684.
6. Denver Water (2012) *Where your water goes*. Retrieved from <http://www.denverwater.org/Conservation/TipsTools/WhereWaterGoes/>. Accessed January 3, 2013.