AC 2009-1393: NONTRADITIONAL UNIVERSITY RESEARCH PARTNERS THAT FACILITATE SERVICE LEARNING AND GRADUATE RESEARCH FOR SUSTAINABLE DEVELOPMENT

Maya Trotz, University of South Florida

Dr. Maya A. Trotz is an Assistant Professor in the Department of Civil and Environmental Engineering at the University of South Florida. Her area of interests include the development of treatment technologies for inorganic contaminant remediation with a special emphasis on arsenic in drinking water and in landfill leachate; investigating the effect of climate change on mercury fate in aquatic environments; and understanding the effect of water storage containers on water quality in developing countries. She has an ongoing interest in multidisciplinary projects that encourage sustainable development and provide affordable and efficient technology to developing areas, especially with respect to improving water quality and reducing the incidence of water borne diseases and water related diseases and other health complications. She believes in holistic approaches to providing engineering solutions which incorporate women's perspectives and needs and which build local capacity. In Guyana, she works on projects with NGOs like WWF-Guianas, Conservation International Guyana and the Guyana's Citizen's Initiative. She is the faculty advisor for USF's Chapter of Engineers for a Sustainable World, a 2008 Kiran C. Patel Faculty Fellow and is a consulting faculty for USF's Department of Women Studies.

Amy Stuart, University of South Florida

Dr. Amy Stuart is an Assistant Professor in the departments of Environmental & Occupational Health and Civil & Environmental Engineering at the University of South Florida. Her professional experience also includes appointments as an air quality engineering consultant with Environ Corporation, a postdoctoral fellow hosted jointly by the Institute for International Studies and the Geological and Environmental Sciences program at Stanford, and a Research Scientist and Graduate Faculty at the Atmospheric Sciences Department of Texas A&M University. Dr. Stuart's scholarly interests are primarily related to air pollution and its impacts on human health and the environment. Through her research, she seeks to understand the multi-scale interactions of air pollutants with the natural and built environments and to elucidate the effects of these interactions on public health and on sustainability. Her current research project topics are interactions between transportation infrastructure, air quality, and health equity; and mercury and sustainability in the Tampa Bay and in Guyana. She is a recipient of an NSF Career Award.

Daniel Yeh, University of South Florida

Dr. Daniel Yeh is an assistant professor in the Department of Civil and Environmental Engineering at the University of South Florida. He is also appointed as a Patel Research Fellow by the Dr. Kiran C. Patel Center for Global Solutions. He worked as a Postdoctoral Research Associate with Stanford University under the National Science Foundation's Center of Advanced Materials for Purification of Water with Systems (WaterCAMPWS). Dr. Yeh is a registered professional civil & environmental engineer with research and teaching interests in water & wastewater engineering, global water management, water/energy nexus, infrastructures and green buildings. In particular, he develops and applies membrane and biological processes for water purification, wastewater treatment and reuse, and energy recovery. He is an investigator on two of the four recently funded Sustainable Healthy Communities: Water Dimension interdisciplinary projects sponsored by the USF Graduate School. He is the Engineering faculty advisor for the Emerging Green Builders (EGB) USF Chapter, as well as faculty advisor for Engineers Without Borders (EWB) at USF.

Helen Muga, University of South Florida

Dr. Helen E. Muga is a postdoctoral research associate in the Department of Civil & Environmental Engineering at the University of South Florida. Her research interests are in green

engineering, sustainability, and appropriate management of water and wastewater. She is a two-time winner of the Mondialogo Worldwide Engineering Contest.

Linda Phillips, University of South Florida

Ms. Linda Phillips is a Lecturer and Patel Associate in the Department of Civil and Environmental Engineering at the University of South Florida. She has over 20 years experience in construction management. Ms. Philips began her teaching career in 1997 at Virginia Tech and then moved to the University of Minnesota before going to Michigan Tech, teaching classes in Project Management, Professional Practice and Capstone Design. In 2000, at the request of her students, Ms. Philips started the International Senior Design (ISD) taking over 170 students to developing world countries to do their Capstone design projects (http://cee.eng.usf.edu/ICD). Ms. Philips is a lead author of the book Field Guide in Environmental Engineering for Development Workers: Water, Sanitation, Indoor Air, (American Society of Civil Engineers (ASCE) Press, 2009).

James Mihelcic, University of South Florida

Dr. James R. Mihelcic is a Professor of Civil & Environmental Engineering and a State of Florida 21st Century World Class Scholar at the University of South Florida. In 1997 he founded the very first Peace Corps Master's International engineering program and now directs such a program at USF (http://cee.eng.usf.edu/peacecorps). As an engineer, he has led a large group of dedicated faculty and students who want to effect social change and sustainable development, but acknowledge the need to work closely with colleagues in public health, anthropology, geography, and economics.

He is the past President of the Association of Environmental Engineering and Science Professors (AEESP; www.aeesp.org). He is also a member of the U.S. Environmental Protection Agency Science Advisory Board Environmental Engineering Committee and a Board Certified Member of the American Academy of Environmental Engineers (AAEE; www.aaee.net). Last summer he co-edited a special issue of Environmental Science & Technology titled "The World's Water." He has studied environmental policy as an AAAS-EPA Environmental Fellow and traveled extensively in the developing world to conduct research and work on development issues related to water, sanitation and global health. He is lead author of two new books: Environmental Engineering: Fundamentals, Sustainability, Design (John Wiley, 2009) and Field Guide in Environmental Engineering for Development Workers: Water, Sanitation, Indoor Air, (American Society of Civil Engineers (ASCE) Press, 2009).

Non-traditional University Research Partners that Facilitate Service Learning and Research for Sustainable Development from the Undergraduate to Graduate Level

Abstract
Goal 7 of the United Nations Millennium Development Goals addresses the need for safe water, sanitation, and hygiene by aiming to halve the proportion of people without access to safe water and adequate sanitation from 1990 benchmarks by 2015. One key for successfully integrating university research with global development is to develop strategic partnerships with non-traditional academic partners that have a strong community presence. Here we use case studies to demonstrate how these partnerships are integrated with undergraduate and graduate education and research to develop sustainable solutions for global problems.

An NSF research project situated in Bolivia allows undergraduate and doctoral graduate students to work with a non-government organization and rural community water committees to research issues of water supply, water scarcity, sanitation, and watershed management. An interdisciplinary graduate course allows students to investigate concepts of sustainability and research methods using a case study focus that focuses on mercury in Guyana and research approaches across disciplines, implement population surveying methods, and apply simple systems modeling. These cases provide opportunities for meeting globalization and sustainability outcomes as elaborated in the proposed Environmental Engineering BOK.

Introduction
International Science and Engineering (S&E) partnerships for research and education are essential for maintaining U.S. competitiveness in the 21st century (National Science Board, 2008) and existing engineering program outcomes like globalization, contemporary issues, and sustainability lay the foundation upon which these needed international partnerships can be built. Unfortunately, a recent survey of engineering undergraduates found that less than 2% viewed globalization and contemporary issues as one of the five most important engineering outcomes and only 30-36% felt "well" or "very well" prepared to incorporate global context or contemporary issues into engineering practice respectively (Atman, 2007). Outcome 11 of the draft BOK for Environmental Engineers addresses globalization and contemporary issues citing "awareness of the impact of inadequate sanitation on public heath in many parts of the developing world and the impact of human activity on climate change" as examples of issues that are both global (integration of processes or delivery systems that transcend national, cultural and language differences) and contemporary (problems and topics of emerging importance or recent discovery). Outcome 8 recognizes the critical role of environmental engineers in the emerging sustainable engineering sub discipline and requires the "integration of sustainability into the analysis and design of engineered systems"

The global challenges that graduates must be prepared to solve are illustrated in the United Nations Millennium Development Goals (MDGs) and these provide

motivation for integrating international experiences with engineering education (United Nations, 2000; UN Millennium Project, 2005). For example, Goal 7 of the MDGs addresses the need for safe water, sanitation, and hygiene by aiming to halve the proportion of people without access to safe water and adequate sanitation from 1990 benchmarks by 2015. These targets present technological and socio-political challenges (Zimmerman et al., 2008) and to meet them, more non-traditional partnerships and funding mechanisms are emerging that include non-governmental and civic organizations (Hokanson et al., 2006; Mihelcic, et al., 2005, 2006). Table 1 lists examples of partnerships in the Civil and Environmental Engineering program at the University of South Florida (USF) that include experiences for undergraduate, master's and doctoral students.

Table 1: Examples of non traditional international partnerships at USF, including participant demographics and applicable education levels of program.

Case	Non-Traditional Academic Partner (Location)	#Female	# URM	BS	MS	Ph.D.
1. International Capstone Design	Local community organizations, local government (Bolivia, Dominican Republic)	NA/167	NA/167	X		
2. Master's International Program (MIP)	Peace Corps, local community organizations, local government (global)	16/38	4/38		X	
3. Bolivia Research Experience	Local NGOs and community groups (Bolivia)	13/15 5/8*	0/15 3/8*	X		X
4. Interdisciplinary Graduate Course with International Field Experience	WWF-Guianas, local NGOs (Guyana)	6/10	3/10		X	X
5. UNESCO-IHE	Dr. Kiran C. Patel Center for Global Solutions, UNESCO-IHE (The Netherlands)	2/7	2/7	X	X	X

* Projected US student participation demographics for summer 2009 program. URM – Under represented minority.

This paper discusses the cases that include mixed levels of students (cases 3 and 4). Case 5 will start in May 2009 and is not discussed, even though it includes all levels of university students. The paper will show how these non-traditional partnerships are currently integrated with university level education (undergraduate and graduate) and research to develop sustainable solutions for global problems. Table 2 shows how these two cases map onto two relevant outcomes, globalization and contemporary issues (outcome 11) and sustainability (outcome 8) of the proposed Environmental Engineering BOK (2009). Learning objectives and assessment are presented and discussed in the context of program outcome requirements of the proposed environmental engineering BOK.

Table 2: Application of Case 1 and Case 2 programs to outcomes 11 and 8 of the proposed Environmental Engineering BOK.

	Outcome 11: *Globalization and Other Contemporary Issues*		**Outcome 8:** *Sustainability*	
Cognitive Level	**Case 3**	**Case 4**	**Case 3**	**Case 4**
C1-Knowledge			BS	
C2-Comprehension	BS/M+30	M+30	BS	
C3-Application	BS/M+30	M+30	BS	
C4-Analysis	BS		M+30	M+30
C5-Synthesis	BS/M+30	M+30	PhD	PhD
C6-Evaluation	PhD	PhD	PhD	PhD

Case 3: Bolivia Research Experience

An NSF research project situated in Bolivia allows undergraduate and doctoral graduate students to work with a non-government organization and rural community water committees to research issues of water supply, water scarcity, sanitation, and watershed management. The project objectives are:

1) Pairing undergraduate and experienced graduate students who have a demonstrated interest in issues of sustainable development.
2) Integrating the research experience into education initiatives that are focused on sustainable development.
3) Ensuring the research experience focuses on appropriate technology (defined here as the use of materials and technology that are culturally, economically, and socially suitable to the area in which they are implemented).
4) Using an operational model for sustainable development that is a global partnership, so students understand how to integrate and transfer the best and most appropriate knowledge, methodologies, techniques, and practices between the developed and developing worlds.
5) Partnering with both a Bolivian University and nongovernmental organization to ensure students learn the importance of making research socially relevant.
6) Engaging women and underrepresented minorities in science and technology research that has a focus on sustainability.

This NSF research program pairs 3 U.S. undergraduate and 3 graduate students enrolled at either the University of South Florida or Michigan Technological University who have a demonstrated interest in issues of sustainable development with 6 ecological engineering students and faculty from the Universidad Tecnològica Boliviana (La Paz), and staff from a non-governmental organization. Students must be majoring in engineering, applied anthropology, or public health. M.S. students with a complimentary skill set are considered, however, doctoral students are preferred. Since 2007 students have conducted research in the small rural Bolivian communities of Palos Blancos, Sapecho, and San Antonio (located NE of La Paz near

the Rio Beni River where the Andes begin to meet the Amazon) on topics related to: water supply and treatment, how communities select improvements in sanitation technology, the impact that land use has on water supply, and issues of willingness to pay and public health. Research publications to date from Bolivia research project are: Fuchs et al. (2008), Fry et al. (2008), and Muga et al. (2009).

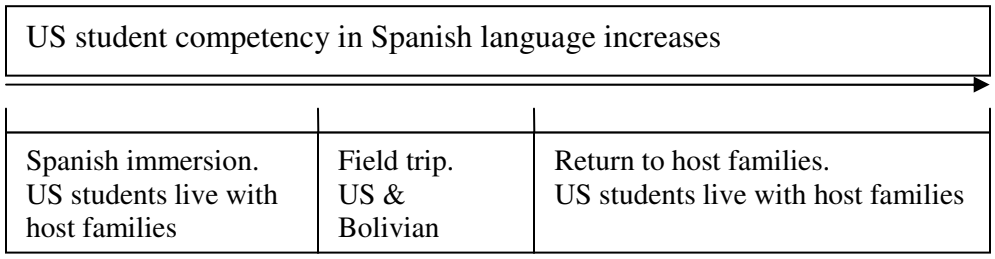

Figure 1: Interventions used to improve cross cultural exchange of Bolivia research program.

Understanding of written and spoken Spanish is required of all students and Figure 1 summarizes programmatic interventions used to improve language skills. One modification to the program in Year 2 was that students completed a 1 to 2 week language and culture immersion in Bolivia prior to the start of their one month assignment. Students are housed with student families of the Bolivian student participants. A field trip at the start of the program further develops the relationship between US and host students who are required to work together on assignments after which students return to their host families for the remainder of the project. As Table 1 shows, the first two years of the program attracted a high percentage of female participants from engineering. The third year (summer 2009) will have participation from students in engineering, health, and applied anthropology and there is an increase in the number of underrepresented minority students projected mainly due to the addition of USF as a new partner institution. Graduate students will also be drawn from USF programs that allow students to obtain a dual graduate degree in environmental engineering, global public health, and applied anthropology.

Student feedback was solicited through a survey consisting of three parts, including multiple choice questions and two essay type questions. Over the course of the research program, 100 % of the students said that (1) their understanding of sustainability issues related to household/community level increased, (2) their understanding of sustainability issues related to global level increased, (3) their research skills to solve sustainability problems increased and, (4) they were more likely to continue by education because of this experience.

All of the students agreed with the statement "Using an operational model for sustainable development that is a global partnership, students will learn to understand how to integrate and transfer the best and most appropriate knowledge, methodologies, techniques, and practices between the developed and developing worlds to ensure a sustainable future." Examples of their answers are below:

"Working, learning, and being with peers who focus on similar subjects allows partnerships to be created easily, even on an international level. There were many aspects of the project that were new for me; host family, working with such a diverse team, field research, and living in a developing country."

"By partnering with Bolivian students and a Bolivian NGO, we were definitely able to use different approaches and come to different solutions than we may have been able to if we had worked alone. For example, working with the NGO allowed for easy access into the communities where research was being conducted and build on work that previous students had done with the NGO. Additionally, the partnership with Bolivian students improved communication, because they were fluent in both Spanish and English."

Some of the barriers identified in the other essay question included language, educational background of students, and limited time in country. Some student responses to these barriers and how they overcame them are described below.

"One of my favorite experiences was visiting Sararia and talking to the actual community members. I felt this was the one opportunity we really got to be involved with the communities affected by the research performed. Having a stronger grasp of Spanish would have helped in this situation, but working with a Bolivian student made this experience more rounded and better overall."

"Language was the largest barrier to overcome and I wish I would have been able to better communicate with the Bolivians. It helped that many of the students spoke English, but this was no help for me when we needed to converse with members of the community."

When asked for additional comments, students generally praised the project and suggested more like it integrated into undergraduate curriculum, longer times in country, and the provision of similar type projects for Bolivian students in the US.

The graduate student feedback implied that students 1) learned how to mentor undergraduate students in research projects, 2) better understood how to partner with scientists and engineers located outside the U.S. after participating in the program, and 3) saw how to integrate international experience into graduate level research after participating in the program. Some reflections of the influence of the research experience on their professional goals after graduation are:

"Before participating in this project, it was hard to imagine how this kind of research could be organized and conducted, given difficulties in communication, travel, and coordination. Through this experience I learned how some of the challenges can be overcome by building a strong partnership with an in-country NGO and university."

"I am now, more than ever, interested in educational programs that have a mentoring relationship designed into them. Mentoring is valuable in any type of new experience

or learning environment, and I plan to use this example in programs I design and direct in the future."

Case 4: Interdisciplinary Graduate Course with International Field Experience
Through a current internal grant, colleagues from Civil and Environmental Engineering, Public Health and Geography, have developed a two-course sequence of graduate level classes that integrate sustainability teaching with research using inquiry-based and experiential learning. Each course uses a specific case around which the course content is focused; the first course focused on mercury issues in the Tampa Bay area and the second is focused on mercury issue in Guyana, a developing country in South America. The courses take an interdisciplinary approach and are taught by the three faculty PIs. Student participation from multiple colleges is achieved through course cross-listings. Sustainability concepts are initially taught with a constructivist approach, with students actively participating through reading, discussion, and writing to explore alternative definitions of sustainability. In addition to learning about a few general sustainability study tools (life cycle assessment, footprint calculators, target plot indicators), the classes focus on learning and applying methods from each of the disciplinary expertise areas of the faculty involved (environmental measurement, systems modeling, and population surveys). Students actively use these methods for case research through field work, laboratory analysis, computer modeling, and analysis of collected data on the course case focus. Field work in the first course was through regular research trips within the local area and through a week-long class trip to the international site in the second course. Students prepare a group research report and give a presentation on the study case research and outcomes.

The second course included a field experience in Guyana, South America for one week over the 2009 spring break period. Course learning objectives state that by the end of the course students should be able to: 1) discuss and evaluate definitions of sustainability, 2) discuss developing country perspectives on sustainability, 3) discuss aspects of the developing country context that affect and shape projects with sustainability goals, 4) identify and integrate sustainability research approaches (and/or experts) across disciplines, 5) apply Hg environmental sampling, population surveying, and systems modeling methods, and 6) evaluate the value (and limitations) of the above methods from both scientific and social perspectives.

Ten students participated in this course, 60% were female, 20% were African American, and 40% were at the master's level. Four were from the college of public health, one was a geography student and the rest were from engineering. The field site was chosen based on existing partnerships between one of the PIs and entities in Guyana involved in small scale gold mines and mercury use that include Non Governmental Organizations (NGO). Mercury is a global pollutant and the second largest user of mercury is small scale gold mining, especially prevalent in developing countries like Guyana. WWF-Guianas is leading efforts in Guyana, Suriname and French Guiana (the Guianas) to reduce the use of mercury in small scale gold mining through research, education and training programs and one of the PIs has already

worked with them on projects that also involve faculty from the Environmental Studies Unit at the University of Guyana. Since 2005, three doctoral students have been recruited to USF's engineering school from the University of Guyana and two are currently taking this course. These students lead discussions on local culture and customs and shared relevant experiences on the class topics to prepare the class for the field trip. They were critical at the field site location in terms of identifying key informants through local contacts, especially given a logistical glitch that prevented the WWF representative from being at the field site. In addition to working in an active mining area, the students first visited a biodiversity conservation reserve, Iwokrama (www.iwokrama.org), where illegal mining is a concern for the livelihood of indigenous populations along the area's periphery and where staff wanted training on water quality monitoring.

On learning of opportunities in Guyana the students suggested visiting the Iwokrama international research site which they felt better represented their diverse interests in terms of sustainability. The million acre reserve supports ecotourism, a butterfly farm, and a sustainable (FSC certified) logging operation and has a local indigenous population of 200 living within its boundaries. The first three days were spent in Iwokrama where students and staff of Iwokrama were trained in environmental sampling (Iwokrama was starting a water quality monitoring program) and population survey methods. Student teams were already formed prior to arriving in Guyana, with leaders being the graduate research students on the project. After training in the field, slight team rearrangement occurred to better match students with tasks. Given the short time in country, the teamwork made the work more efficient. The second site was in Madia, a gold mining town of ~2000 persons and the group spent two nights there with only one day dedicated to visiting 5 different small and medium scale gold mining operations. Based on internet searches, communications with people in Guyana and feedback from the Guyanese students in the class, students expected Madia to lack infrastructure (solid waste collection, available potable water), and have high incidence of health issues like malaria. Whilst these things were true of the area, the openness of miners, accessibility to sites, and scale of the operations quickly changed student concerns. Group discussions on perceptions of the areas visited and the experience whilst in the field, highlighted that students really appreciated the opportunity to visit the two different sites which had contrasting approaches to sustainability and expressed an interest in visiting comparable sites close to the university like the phosphate mines. Further class evaluations are currently underway and will be examined from the perspective of lessons learnt for working in a developing country (e.g. importance of local community contacts, flexibility needed in planning etc.), the benefits or drawbacks of the interdisciplinary nature of research and education, and changing perspectives on sustainability as applied in real world situations outside the US.

Conclusion

The case studies discussed demonstrate opportunities for addressing real world problems whilst meeting Outcomes 8 and 11 of the proposed environmental engineering BOK. Although the focus of this paper was on these two outcomes, the

cases do or can address a much broader set of the outcomes. They also align strategically with national goals that have documented the rapid social, political, economic, and environmental changes occurring in the world and associated implications for engineering education, research, practice, and importantly, the economic competitiveness of our Nation (see for example, the National Academy of Engineering in Educating the Engineer of 2020, and the American Society of Civil Engineers in 2025 Vision for Civil Engineering). The cases discussed have also demonstrated a record of high female and underrepresented minority enrollments and may serve as models for broadening participation in the discipline.

Acknowledgements
The authors wish to acknowledge the U.S. Peace Corps, NSF for support of the Sustainable Development Research Experience in Bolivia under Grant No. 0623558 and the UNESCO-IHE Research Experience, and the USF Graduate School for support under the Sustainable Healthy Communities Initiative.

Some of the descriptive content of the programs discussed here has also been presented in a recently submitted presentation to the Environmental and Water Resources Institute 2009 Congress.

References
Atman, C. J. (2007) Center for the Advancement of Engineering Education: An Overview of Accomplishments to date. Presented at the 2007 National Academy of Engineering-Center for the Advancement of Scholarship in Engineering Education Dane and Mary Louise Miller Symposium. http://www.nae.edu/nae/caseecomnew.nsf/. Accessed January, 2009.

Fuchs, V.J. and Mihelcic, J. R. (2006) "Engineering Education for International Sustainability: Curriculum Design under the Sustainable Futures Model," Proceedings of 5th Annual ASEE Global Colloquium on Engrg Educ., Rio de Janeiro, Brazil, October 9-12, 2006.

Fuchs, V.J., L.M. Fry, and Mihelcic, J.R. (2008) "Delivering Sustainable Waste Infrastructure in an Urbanizing World," Proceedings of the Third International Conference on Sustainability Engineering and Science, Auckland, New Zealand, December 9-12, 2008.

Fry, L.M., Mihelcic, J. R., Watkins, D. W., Reents, N. (2008) "Assessment of change drivers affecting the sustainability of gravity fed water supply in the Alto Beni watershed of Bolivia," American Geophysical Union Fall Meeting, December 15-19, 2008.

Hokanson, D.R., Phillips, L.D., and Mihelcic, J. R. (2006) Educating Engineers in the Sustainable Futures Model with a Global Perspective: Education, Research and Diversity Initiatives, International Journal of Engineering Education, Sustainability.

Mihelcic, J.R. (2004) "Educating the Future's Water Professional," Water Environment Technology, 16(9):86-92.

Mihelcic, J.R. and Hokanson, D. R. (2005) “Educational Solutions: For a more Sustainable Future,” in Environmental Solutions, Eds: NL Nemerow and FJ Agardy, Elsevier, pg. 25-58.
Mihelcic, J.R., Phillips, L.D., Watkins Jr., D.W. (2006) "Integrating a Global Perspective into Education & Research: Engineering International Sustainable Development", Environmental Engineering Science, 23(3) 426-438.
Muga, H.E., J.R. Mihelcic, N. Reents, S. Morales, “Treatment Performance of Wastewater Lagoons in South Yungas Province of Bolivia,” World Environmental & Water Resources Congress, Kansas City, May 17-21, 2009.
National Science Board (2008) International Science and Engineering Partnerships: A Priority for U.S. Foreign Policy and Our Nation’s Innovation Enterprise. http://www.nsf.gov/pubs/2008/nsb084/nsb084.pdf
The Environmental Engineering Body of Knowledge Task Force (2009) environmental Engineering Body of Knowledge. Draft. http://www.cece.ucf.edu/bok/
Selna, M.W., H.T. Glaser, R.R. Trussell, G.R. Chan, M. Sullivan, “Declining Enrollment has Water and Wastewater Professionals Concerned,” Proceedings of the 79nd Annual Water Environment Federation Conference & Exposition, 2006.
United Nations (2000) United Nations Millennium Declaration. Resolution adopted by the General Assembly. A/RES/55/2. http://www.un.org/millennium/declaration/ares552e.pdf
UN Millennium Project (2005) Investing in Development: A Practical Plan to Achieve the Millennium Development Goals. New York. http://www.unmillenniumproject.org/reports/fullreport.htm
Zimmerman, J.B., J.R. Mihelcic, Smith, J. A. (2008) Global Stressors on Water Quality and Quantity: Sustainability, Technology Selection, and Governance in a Dynamic World. Environmental Science & Technology, 42(4):4247-4254.