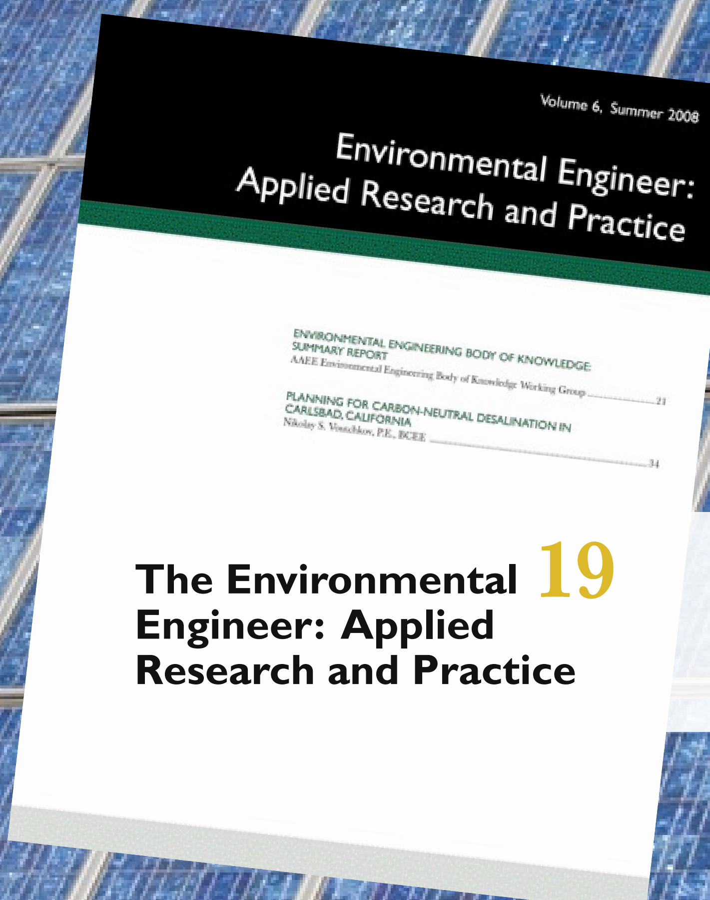
THE MAGAZINE OF THE AMERICAN ACADEMY OF ENVIRONMENTAL ENGINEERS®

ENVIRONMENTAL ENGINEER

VOLUME 44 NUMBER 3 — SUMMER 2008


Volume 6, Summer 2008

Environmental Engineer: Applied Research and Practice

Dan Okun Memorial Symposium

Friday

November 7, 2008

10:00 am–5:00 pm

University of North Carolina at Chapel Hill

School of Public Health

Department of Environmental Sciences & Engineering

Auditorium
133 Rosenau Hall

Visit our website

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- to learn more about the symposium
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ENVIRONMENTAL ENGINEER

BY WILLIAM P. DEE, P.E., BCEE

THE NEW PARADIGM OF ENVIRONMENTAL ENGINEERING

We also need to reinforce our commitment to be involved with the global environmental community to research and develop practical applications from science and technology to solve our common problems.

I HAVE WRITTEN MANY TIMES ABOUT THE IMPORTANCE OF THE ACADEMY and its place in representing the best environmental engineering professionals in the United States. Now with 2500 members strong, our opportunity to make an impact has never been greater. However, as we progress through the 21st century, it is incumbent upon us to take a more forward-looking view of how we relate to the issues, opportunities and challenges presented by the global environmental community.

In previous centuries, Spain, France, and the United Kingdom dominated the world scene; throughout the 20th Century, the US maintained a position of power and prestige. Now we are faced with the emergence of China and India as geo-political economies that will influence and perhaps dominate the world environment in the foreseeable future. This creates a whole new paradigm for environmental engineers. As has been pointed out to me several times by Harvey Ludwig, one of our Honorary Diplomates, the US environmental engineering field, including our professional organizations, needs to begin to address problems more holistically, recognizing that we are all part of a very interconnected and interdependent world environment.

Over the past three years, I have attended leading environmental conferences in Sydney, Beijing, Amsterdam, and Vienna. These conferences provided an opportunity to interact with some of the best minds in the world in the environmental engineering and sciences arena. They also are a forum for presenting new ideas, advances, and breakthroughs that have been developed collaboratively throughout the world. This collaboration includes utilities, governments, industries, consultants, and academia. As a country and a profession we need to be open to exploring and developing these new technologies and innovations. We also need to reinforce our commitment to be involved with the global environmental community to research and develop practical applications from science and technology to solve our common problems.

The Academy has undertaken several strategic initiatives to expand our thinking and interactions with the global environmental community. For several years we have sought out premier environmental engineering professionals in different countries to be Honorary Diplomates in the Academy. More recently we have partnered with the International Water Association (IWA) to identify the best environmental projects in the world through its Project Innovation Awards (PIA). The AAEE Excellence in Environmental Engineering Award winners are automatically eligible for the PIA competition as the North American entries. These biennial awards, most recently handed out in Vienna, Austria in September 2008, recognize projects that contribute significantly to the advancement of technology, the quality of the environment and water, and the efficiency of managing these resources. They truly exemplify the global knowledge-sharing that is necessary to address the new global environment.

In addition to these efforts, the Academy's recently adopted Strategic Plan includes an initiative to expand our credential recognition and membership to a broader global representation. Just as environmental challenges know no geographic boundaries, our profession should allow for the free-flow of ideas and solutions. I will be working with the IWA on this concept and approach over the next two years. Our vision is to align the best environmental professionals in the world to encourage collaboration, creative thinking, research, and practical application of forward looking ideas and concepts to solve our most pressing environmental problems. It is through such cooperation and programs that the United States will maintain its proper place of influence on the world environmental stage. A

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2008 AAEE BOARD OF TRUSTEES MEETING

AAEE will hold its 2008 Annual Board of Trustees Meeting on November 7 in at the Renaissance Westchester Hotel in West Harrison, New York, beginning with a welcome dinner on November 6.

Registration packages have already been mailed to Officers & Trustees, Committee Chairs, and State Representatives. In addition to the board meeting, events include a President's Reception, dinner, and the installation ceremony of the 2009 Officer and Trustees. The Annual Board of Trustees Meeting is open to the full membership. Registration deadline is October 15, 2008. If you are interested in attending, please contact Sammi Olmo at Academy Headquarters.

SPECIALTY CERTIFICATION RENEWAL

The 2009 Specialty Certification Renewal packages will be sent in early September. It is important that it be completed and returned with payment as soon as possible. Some of our members missed their opportunity to be listed in the 2008 *Who's Who in Environmental Engineering* because they did not submit their Specialty Certification Renewal and Member Data before the deadline.

At the last Board of Trustees Meeting, a decision was made to increase all membership dues by $5. Effective as of the 2009 Specialty Certification Renewal cycle, the annual fees will be as follows:

BCEE and BCEEM (Active and Inactive) – $165

Emeritus – $45

Member (formerly Affiliate Members) – $80

For **Life BCEE** & **BCEEM** (Active and Inactive) and **Student Members**, the fee is still $0.

ENVIRONMENTAL ENGINEER: APPLIED RESEARCH AND PRACTICE

Included in this issue of Environmental Engineer is the sixth volume of *Environmental Engineer: Applied Research and Practice* (page 19). This edition includes Planning for Carbon-Neutral Desalination in Carlsbad, California by Nikolay S. Voutchkov, P.E., BCEE and the Environmental Engineering Body of Knowledge: Summary Report by AAEE's Environmental Engineering Body of Knowledge Working Group.

Journal Editor, C. Robert Baillod, Ph.D., P.E., BCEE, along with the Editorial Board, invites authors to submit their papers. In particular, the Board is interested in papers focused on practical research and use case studies related to environmental engineering.

ABET PROGRAM EVALUATOR SESSION 2008

A training session for those wanting to be Program Evaluators in accreditation of environmental engineering education programs has been scheduled for Sunday, October 19, 2008. The course lasts all day and will begin at 8:00 a.m. and conclude at 5:00 p.m.

The course registration of $150 includes breakfast, lunch, breaks and copies of course materials. To register, please contact Sammi Olmo at AAEE Headquarters, 410-266-3311 or on-line as part of the WEFTEC registration at http://www.weftec.org.

- Completion of this approved training course is mandatory to become qualified to be a Program Evaluator.
- ABET and the Academy strongly recommend those who are currently approved to perform evaluations to participate in the course for continuing professional development.
- The details of accreditation are continuing to change.
- The course instructor, Dr. Joseph F. Malina, Jr., P.E., BCEE, is authorized by ABET to offer this instruction and it qualifies for CPD credits for the Academy's certification program.

Faculty wanting to learn about accreditation requirements are welcome to register and participate.

Campaign 4000

Donation/Pledge Form

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Thank you for your financial support in helping the AAEE sustain its continuing growth.

HUGH J. CAMPBELL, JR., PH.D., P.E., BCEE, has been transferred to Active status as of July 25. Dr. Campell is currently an Environmental Engineer at DuPont Specialty Chemical in Wilmington, DE. He has been certified in Water Supply and Wastewater Engineering since 1985.

WALTER R. NIESSEN, P.E., BCEE, is the 2008 recipient of the Pioneer Award. The award was presented at the 27th Annual International Conference on Thermal Treatment Technologies. Mr. Niessen is currently President of Niessen Consultants in Andover, MA. He been certified in both Air Pollution Control and Solid Waste Management since 1974.

YVES E. POLLART, P.E., BCEE, has been elected to the Board of Directors of RETTEW Associates, Inc. Mr. Pollart is currently Director of Environmental Engineering at the firm's Camp Hill, PA location. He has been certified in Water Supply and Wastewater Engineering since 1997.

IN MEMORIAM

THEODORE E. BRENNER, P.E., BCEE, of Rumson, NJ, passed away on August 5, 2007. Mr. Brenner had been certified in Water Supply and Wastewater Engineering since 1983.

JOHN (JACK) S. LAGARIAS, P.E., BCEE, passed away on March 17, 2008. At the time of his death, he was President of Lagarias Associates in Walnut Creek, CA. Mr. Lagarias was a Life Member and had been certified in Air Pollution Control since 1969.

WILLIAM O. LYNCH, SC.D., P.E., BCEE, of Cazenovia, NY, passed away on Tuesday, April 8, 2008. Dr. Lynch, a retired partner of Stearns & Wheler, was an Emeritus Member. He was originally certified in Sanitary Engineering in 1962. A

✯ 2009 ✯ Election Results

The ballots have been counted. While the results will not be official until the Annual Meeting when the Teller's Report is confirmed by the Board, the following individuals have been elected for 2009. Current President-Elect, Debra R. Reinhart, will succeed to the Office of the President; Cecil Lue-Hing will be President-Elect; Brian P. Flynn has been voted as Vice President; and Otis J. Sproul and Sandra L. Tripp have been elected to the two open Trustee-at-Large positions.


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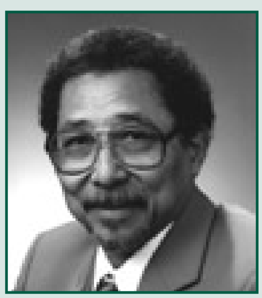
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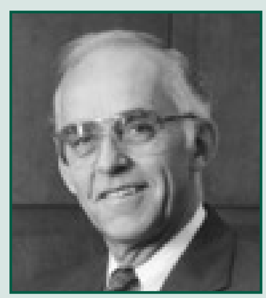
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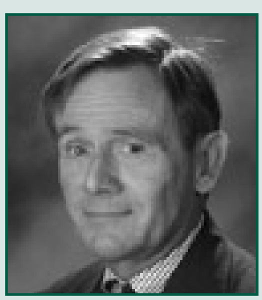
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The American Academy of Environmental engineers is pleased to recognize these individuals who contributed to several Academy funds during the 2008 certification renewal process.

The total contribution to each program or fund are:

Environmental Engineer Magazine — $955
Environmental Engineering Foundation — $5,280
Excellence in Environmental Engineering — $2,150
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M.E. Nosanov .... Oceanside, CA
Glenn L. Odom .... Jackson, MS
William J. O'Shea .... Lemont, IL
Thomas R. Ostrom ....Bel Air, MD
Gerald Palevsky .... Hastings on Hudson, NY
Franics Pandullo ....Northfield, NJ
Stacy J. Passaro .... Mount Airy, MD
Harald C. Pedersen .... Valencia, PA
Robert R. Perry .... Falls Church, VA
Barry L. Pickard .... Liverpool, NY
Stanley V. Plante ....Cleveland, OH
John T. Quigley .... Madison, WI
John M. Rademacher .... Georgetown, TX
Serin R. Rao .... Mapleton, IL
Abdul S. Rashidi ....LaVerne, CA
Ray D. Reaves .... Oklahoma City, OK
Linvil G. Rich .... Anderson, SC
Elmo A. Richardson .... Macon, GA
James Rios .... Corte Madera, CA
Robert F. Robertson ....Northbrook, IL
Dale L. Rohe .... San Diego, CA
Richard M. Rollins .... Portela Valley, CA
John L. Rose .... East Chatham, NY
Timothy B. Rose .... Boiceville, NY
August Rossano .... Redmond, WA
Dolph Rotfield .... Tarrytown, NY
Jon M. Rueck .... Silver Lake, KS
Dominick D. Ruggiero ....Larchmont, NY
Jane Ryckman-Siegwarth .... Roswell, GA
Robert A. Ryder ....Kentfield, CA
Joseph J. Salvatorelli .... Cherry Hill, NJ
E. Stuart Savage .... Brunswick, ME
John H. Scarino .... Teaneck, NJ
Steven S. Schneiderman .... Murray, KY
Karl B. Schnelle .... Brentwood, TN
Robert J. Schoenberger ....Dowingtown, PA
Henry G. Schwartz .... St. Louis, MO
Edgar F. Seagle .... Rockville, MD
Timothy G. Shea .... Chantilly, VA
Ranjit Sinha .... Kendall Park, NJ
David W. Sloan .... Ft. Worth, TX
Willard J. Smith .... Saudi Arabia
Michael Soderquist .... Newberg, OR
Shinji Soneda .... Honolulu, HI
Thomas J. Sorg .... Cincinnati, OH
Otis J. Sproul ....Durham, NH
Vernon T. Stack ....Thorndale, PA
James F. Stahl ....Rancho Palos Ve, CA
Morton Sterling ....Farmington Hills, MI
Prescott A. Stevens .... Switzerland
Albert H. Stevenson ....Towson, MD
John S. Stock .... Livonia, MI
Frank E. Stratton .... Eastsound, WA
Cheng-Feng Su ....Cerritos, CA
Scott M. Summers ....Rochester, NY
James N. Tarr .... Rolling Hills Estates, CA
J. Dwight Thompson .... Cincinnati, OH
Lial F. Tischler ....Round Rock, TX
Murli Tolaney ....Arcadia, CA
Eugene T. Tonn ....Jacksonville, FL
Harry A. Tow .... Visalia, CA
Dennis D. Truax .... Mississippi State, MS
N. C. Vasuki ....Dover, DE
Jose F. Velazquez ....Denver, CO
Guido von Autenried ....Norwood, NJ
Alfred T. Wallace ....Moscow, ID
J. Thomas Watt .... York, PA
Peter J. Waznys .... Centerport, NY
Jeffrey G. Wendle ....Harrisburg, PA
George M. Wesner ....San Clemente, CA
Maurice C. West ....Lakewood, CO
Robert W. Wheeler .... Morgantown, WV
C. Leslie Wierson ....Portland, OR
Robert C. Williams ....Norcross, GA
Melvin Wolkstein ....Springfield, NJ
Joseph Ming-Lup Wong ....Richmond, CA
Yuefeng Xie ....Middletown, PA
Kevin D. Yard ....Bedford, TX
Jehangir Zakaria .... Virgin Islands
Kent E. Zenobia ....Sacramento, CA
Hooshang Zeyghami ....Weston, WI

KAPPE LECTURE

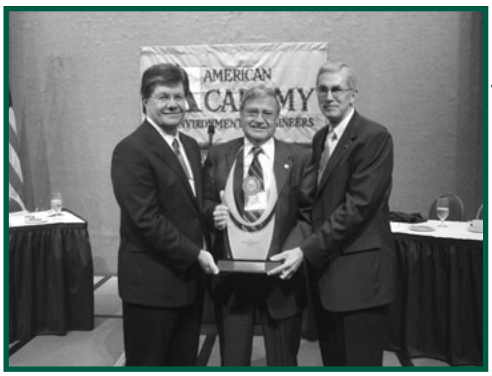
Lilia A. Abron .... Rockville, MD
Michael J. Barbachem .... Virginia Beach, VA
Richard W. Bentwood .... Glendora, CA
Edward H. Bryan ....Chevy Chase, MD
Charles A. Buescher Jr. ....Chesterfield, MO
Keith E. Carns ....Oakhurst, CA
Jeffrey J. Chen ....Palo Alto, CA
Richard F. Cole .... Brookeville, MD
Paul A. Dombrowski ....Holyoke, MA
Michael D. Hungerford ....Edwardsville, IL
Michael C. Kavanaugh .... Emeryville, CA
Ulf M. Lindmark .... Long Beach, CA
Charles Liu ....Dix Hills, NY
Cecil Lue-Hing ....Burr Ridge, IL
Earl H. Masteller ....Vero Beach, FL
Shyam S. Mohanka .... Schenectady, NY
Edward W. Monroe .... Pittsburgh, PA
C. Eric Mulkey ....Oak Ridge, TN
Charles F. Niles .... Haines City, FL
Parnell O'Brien ....Homer Glen, IL
Dale L. Rohe ....San Diego, CA
William A. Rosenkranz .... Alexandria, VA
Seymour J. Ryckman .... Dayton, OH
C. Joseph Touhill ....Jamison, PA
N. C. Vasuki ....Ddover, DE
Ira L. Whitman .... East Brunswick, NJ
Yuefeng Xie ....Middletown, PA
James C. Young .... Fayetteville, AR

2008 Annual AAEE Awards Banquet

The 2008 Annual AAEE Awards Banquet was held on Wednesday, April 30, at the National Press Club in Washington, D.C.

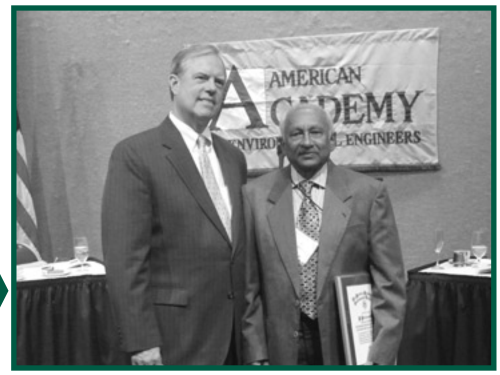
AAEE honored four distinguished environmental engineers (Jeanette A. Brown, P.E., BCEE, R. Tim Haug, Ph.D., P.E., BCEE, Brian P. Flynn, P.E., BCEE, and A. "Sek" Sekarajasekaran, KMN, DIC, FIEM, MICE, MASCE, MIWES, PEng, CEng, MACEM) and revealed the winning entries of the 2008 Excellence in Environmental Engineering Competition. In addition to the newly-redesigned Superior Achievement Award, AAEE handed out six Grand Prize and seven Honor Awards.

Here are some highlights of this year's event.



The Superior Achievement Award winner was CDM's Kay Bailey Hutchison Desalination Facilities. Paul J. Gorder, P.E., BCEE, was the Engineer-in-Charge.

President William P. Dee, P.E., BCEE and Honorary Board Certified Environmental Engineer, A. "Sek" Sekarajasekaran.



1999 Past President John A. DeFilippi and 2008 Stanley E Kappe Award Recipient, Brian P. Flynn.

All representing the Sanitation Districts of Los Angeles County, Stephen R. Maguin, R. Tim Haug, and Trustee-at-Large Michael W. Selna.

President William P. Dee, 2008 Gordon Maskew Fair Award Recipient, R. Tim Haug, and Peggy Haug.

Past President, Stephen R. Kellogg and 2008 Edward J. Cleary Award Recipient and 2004 Past President, Jeanette A. Brown.

2007 FINANCIAL STATEMENT

INDEPENDENT AUDITORS' REPORT

We have audited the accompanying statements of financial position of American Academy of Enviornmental Engineers (a non-profit orrganization) as of December 31, 2007 and 2006, and the related statements of activities and cash flows for the years then ended. These financial statements are the responsibility of the Academy's management. Our responsibility is to express an opinion on these financial statements based on our audits.

We conducted our audits in accordance with auditing standards generally accepted in the United States of America. Those standards require that we plan and perform the audit to obtain reasonable assurance about thether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audits provide a reasonable basis for our opinion.

In our opinion, the financial statements referred to above present fairly, in all amterial respects, the financial position of American Academy of Environmental Engineers as of December 31, 2007 and 2006, and the changes in its net assets and its cash flow for the years then ended in conformity with accounting principles generally accepted in the United States of America.

MULLEN, SONDBERG, WIMBISH & STONE, P.A.
Annapolis, Maryland
April 24, 2008

Note: The accompanying notes are an integral part of these financial statements.

STATEMENTS OF FINANCIAL POSITION
December 31, 2007 and 2006

ASSETS

	2007	2006
CURRENT ASSETS		
Cash and cash equivalents	$ 125,402	$ 73,618
Accounts receivable	21,592	17,352
Unconditional promises to give	6,881	3,668
Prepaid expenses	39,659	44,390
Total current assets	193,534	139,028
PROPERTY AND EQUIPMENT		
Net of accumulated depreciation	3,202	2,753
OTHER ASSET		
Unconditional promises to give, net of discount to present value	5,130	6,842
Trademarks, net of accumulated amortization	10,804	10,888
Total other assets	15,934	17,730
Total assets	$ 212,670	$ 159,511

LIABILITIES AND NET ASSETS

	2007	2006
CURRENT LIABILITIES		
Accounts payable and accrued expenses	$ 7,251	$ 6,006
Due to Foundation	38,171	4,675
Deferred revenue	188,485	203,225
Deferred sponsorship revenue	7,000	2,500
Total current liabilities	240,907	216,406
NET ASSETS		
Unrestricted	(59,474)	(88,132)
Unrestricted – board designated	31,237	31,237
Total net assets	(28,237)	(56,895)
Total liabilities and net assets	$ 212,670	$ 159,511

STATEMENTS OF ACTIVITIES
Years Ended December 31, 2007 and 2006

	2007	2006
REVENUES, GAINS AND OTHER SUPPORT		
Certification fees	$ 345,005	$ 333,172
Publications	66,765	67,204
Contributions	61,562	42,007
Other income	29,884	34,550
Meetings	28,209	11,616
Kappe lecture	8,500	7,549
Environmental engineer	5,665	7,355
Investment income	462	5,950
Total revenues, gains and other support	543,052	510,403
EXPENSES		
Program service expenses:		
Memberships	35,171	38,787
Environmental engineer	34,904	22,641
Publications	19,244	20,715
Certificate/membership	12,762	10,854
Kappe lecture	10,353	9,715
Meetings and seminars	8,051	7,982
Public education	7,204	6,585
Committee expense	1,548	1,589
Total program service expenses	129,237	118,341
Management and general expenses:		
Staff salaries, fringe benefits and contract employment	253,781	224,956
Office expense	96,970	90,251
Legal, accounting and miscellaneous fees	15,566	10,975
Officer and trustee expenses	9,743	12,800
Insurance	4,443	4,235
Depreciation and amortization	3,526	3,914
Awards	748	612
Bad debt expense	380	--
Total management and general expenses	385,157	347,743
Total expenses	514,394	466,084
Change in net assets	28,658	54,840
NET ASSETS AT BEGINNING OF YEAR, as restated	(56,895)	(140,437)
NET ASSETS AT END OF YEAR	$(28,237)	$(56,895)

NOTES TO FINANCIAL STATEMENTS

December 31, 2007 and 2006

Note 1 — Summary of Significant Accounting Policies

Nature and Organization

American Academy of Environmental Engineers (AAEE) was founded in 1955 to improve the practice of environmental engineering by certifying properly-qualified environmental engineering specialists, accrediting university environmental engineering curricula and by informing the public and environmental engineers through lectures, publications and other venues regarding proper environmental practices.

Income Taxes

The Academy is exempt under Section 501(c)(6) of the Internal Revenue Code from paying federal income tax on any income except unrelated business income. No provision has been made for income taxes as the Academy has no net unrelated business income.

Basis of Accounting

The Academy prepares its financial statements in accordance with accounting principles generally accepted in the United States of America. The basis of accounting involves the application of accrual accounting; consequently, revenues and gains are recognized when earned, and expenses and losses are recognized when incurred.

Revenue Recognition

Certification fees and certain other revenues are recorded as deferred revenue upon receipt and are recognized in the period to which the fees relate.

Contributions received are recorded as unrestricted, temporarily restricted, or permanently restricted support, depending on the existence and/or nature of any donor-imposed restriction. Support that is restricted by the donor is reported as an increase in unrestricted net assets if the restriction expires in the reporting period

2007 FINANCIAL STATEMENT

in which the support is recognized. All other donor-restricted support is reported as an increase in temporarily or permanently restricted net assets, depending on the nature of the restriction. When a restriction expires (that is, when a stipulated time restriction ends or a purpose restriction is accomplished), temporarily restricted net assets are reclassified as unrestricted net assets and reported in the statement of activities as net assets released from restrictions. Unexpended grant awards are classified as refundable advances until expended for the purpose of the grants since they are considered conditional promises to give.

Use of Estimates

The preparation of financial statements in conformity with accounting principles generally accepted in the United States of America requires management to make estimates and assumptions that affect the reported amounts of assets and liabilities and disclosure of contingencies at the statement of financial position date and the reported amounts of revenues and expenses during the reporting period. Actual results could differ from those estimates.

Cash and Cash Equivalents

For purposes of the statement of cash flows, cash and cash equivalents represent deposits in checking and savings accounts.

Accounts Receivable

Accounts receivable consists of amounts due for certification fees, royalties and reimbursements at the end of the year. The Academy considers all accounts receivable to be fully collectible. Accordingly, an allowance for doubtful accounts has been established.

Promises to Give

Contributions are recognized when the donor makes a pledge to give to the Academy that is, in substance, unconditional. Contributions that are restricted by the donor are reported as increases in

STATEMENTS OF CASH FLOWS
Years Ended December 31, 2007 and 2006

	2007	2006
CASH FLOWS FROM OPERATING ACTIVITIES:		
Change in net assets	$ 28,658	$ 54,840
Adjustments to reconcile change in net assets to net cash provided by operating activities:		
Depreciation and amortization	3,526	3,914
Forgiveness of debt	--	(7,355)
(Increase) decrease in operating assets:		
Accounts receivable	(4,240)	(5,903)
Due from (to) Foundation	33,496	7,196
Unconditional promises to give	(1,501)	(10,510)
Prepaid expenses	4,731	2,715
Increase (decrease) in operating liabilities:		
Accounts payable and accrued expenses	1,245	(7,510)
Settlement payable	--	(18,000)
Deferred revenue	(14,740)	(10,100)
Deferred sponsorship revenue	4,500	2,500
Net cash provided by operating activities	55,675	11,787
CASH FLOWS FROM INVESTING ACTIVITIES:		
Acquisition of property, equipment and trademarks	(3,891)	(300)
CASH FLOWS FROM FINANCING ACTIVITIES:		
Principal payments on notes	--	(9,605)
Net change in cash	51,784	1,882
Cash and cash equivalents at beginning of year	73,618	71,736
Cash and cash equivalents at end of the year	$ 125,402	$ 73,618

unrestricted net assets if the restrictions expire in the fiscal in which the contributions are recognized. All other donor-restricted contributions are reported as increase in temporarily or permanently restricted net assets depending on the nature of the restrictions. When a restriction expires, temporarily restricted net assets are reclassified to unrestricted net assets.

Property and Equipment

Property and equipment acquisitions in excess of $500 are capitilized and recorded at cost less accumulated depreciation and amortization. When assets are retired or otherwise disposed of, the cost and related depreciation are removed from the accounts, and any resulting gain or loss is reflected in income for the period. The cost of maintenance and repairs is charged to current income as incurred; where as significant renewals and betterments are capitalized. Depreciation and amortization of property and equipment are provided on a straight-line basis. Leasehold improvements are amortized over their estimated useful lives or the life of the lease, whichever is shorter. Furniture and equipment are depreciated over three to ten years.

Program Service Expense

Program service expense represents the direct cost of performing programs. Direct costs do not include salaries and related expenses. Management and general costs have not been allocated to such programs.

Note 2 — Concentration of Cash Balances

At various times during the year, the Academy maintained cash-in-bank balances in excess of the federally insured limit of $100,000.

Note 3 — Unconditional Promises to Give

Unconditional promises to give are as follows at December 31, 2007:

	2007	2006
Receivables in less than one year	$ 6,881	$ 3,668
Receivables in one to five years	5,890	7,332
Total unconditional promises to give	12,771	11,000
Less: discounts to net present value	(760)	(490)
	$12,011	$10,510

Unconditional promises to give are reflected at present value of estimated future flows using discount rates ranging from 4.13% to 4.73%, depending on the date of the original pledge.

Note 4 — Property and Equipment

Property and equipment are summarized below for the years ending December 31:

	2007	2006
Furniture and equipment	$ 210,134	$ 207,548
Leasehold improvements	6,951	6,951
	217,085	214,499
Less accumulated depreciation	(213,883)	(211,746)
Net property and equipment	$ 3,202	$ 2,753

Depreciation expense for the years ended December 31, 2007 and 2006 was $2,137 and $2,350, respectively.

Note 5 — Other Assets

Trade costs incurred by the Academy are amortized over fifteen years. Amoritization expense for the years ended December 31, 2007 and 2006 was $1,389 and $1,564, respectively.

Note 6 — Lease Commitment

The Academy leases office space under a noncancellable operating lease which expires on July 31, 2008. Future minimum lease payments required under the lease for the year ending December 31, 2008 are $27,468

Rent expense for the years ended December 1, 2007 and 2006 amounted to $49,650 and $48,766, respectively.

Note 7 — Settlement Payable

In October 2001, the Academy entered into a settlement agreement with a former employee in a wrongful termination lawsuit. The Academy has agreed to pay a total sum of $108,000 in consideration for the release of all claims known or unknown by the plaintiff against the Academy. The Academy shall pay the settled amount in a total of six annual installments of $18,000 to the defendant's counsel. The first installment payment was made in October 2001. The remaining 5 installments are due by February 15 of each year. The balance of the settlement was paid during the year ended December 31, 2006.

Note 8 — Note Payable

In June 2002, the Academy obtained a note that is payable to a law firm in the amount of $51,084. The note was obtained to pay legal fees incurred in 2001 defending a lawsuit (See Note 7). Monthly installments of $988 including interest at 6% are to repaid over 60 months. During the year ending December 31, 2006, the Academy paid $9,605 towards the outstanding principal and the remaining $7,355 principal was forgiven.

Note 9 — Employee Benefit Plan

The Academy established a 401(k) Retirement Plan in 1997 for all employees meeting certain eligibility requirements. Employees may contribute up to 15% of their eligible compensation to the plan, subject to the limits to Section 401(k) of the Internal Revenue Code. The Academy does not match employee contributions.

Note 10 — Related Party Transactions

The balance due (to) from the American Academy of Enviromental Engineers

Foundation amounted to $38,171 and $4,675, for the years ended December 31, 2007 and 2006 respectively.

Note 11 — Unrestricted Net Assets — Board Designated

It is the policy of the Board of Trustees of the Academy to review its plans for future projects from time to time and to designate appropriate sums to assure adequate financing of such projects.

Snow Fund – represents a $10,000 unrestricted contribution for which the Board of Trustees designated for some future use. The Board directed that the $10,000 principal remain intact and that the interest can only be used for purposes designated by the Board. Total designated funds as of December 31, 2007 and 2006 amounted to $14,528. Total accumulated interests as of December 31, 2007 and 2006 amounted to $4,528. The Academy cashed in the Certificate of Deposit for operating purposes during the year ended December 31, 2000 and intend to reestablish the certificate of deposit when funds are available.

Kappe Fund – represents a $10,000 bequest received from the Estate of Stanley E. Kappe during 1985. This unrestricted bequest is used for the purpose of recognizing the contributions of Stanley E. Kappe to the environmental engineering profession. The Board has designated the fund as a Quasi-Endowment. Hence, the principal portion of this fund is to remain intact and the interest can be spent on funding the Kappe Lecture Series. The Board has also designated additional funds and any annual contributions to the Kappe Lecture to be used to fund the Kappe Lecture Series. Total designated funds as of December 31, 2007 and 2006 amounted to $16,709. Total accumulated interest as of December 31, 2007 and 2006 amounted to $3,694. The Academy cashed in the certificate of deposit for operating purposes during the year ended December 31, 2001 and intends to reestablish the certificate of deposit when funds are available.

Note 12 — Going Concern

These statements are presented on the basis that the Academy is a going concern. Going concern contemplates the realization of assets and the satisfaction of liabilities in the normal course of business over a reasonable length of time. The accompanying financial statements show a current year accumulated deficit in unrestricted net assets of $28,237.

The Academy has developed a plan to reduce expenses and increase revenues. The Academy continues to implement the plan. Management has projected cash flows for one year.

The Academy's continued existence depends on the success of cost reductions and developing new sources of revenue.

Note 13 — Restatement

During the year ended December 31, 2006, the Academy recorded cash contributions as deferred income. The unrestricted net assets as of December 31, 2006 have been restated to include those cash contributions as revenue. The result was a increase of $10,520 in unrestricted net assets. A

LETTERS TO THE EDITOR

This column is provided for all members who wish to comment on the opinions of the Editor, to respond to the President's message, or to present your views on any matter of interest to the Academy or the Environmental Engineering Profession. The right to edit your letter is reserved and all letters will be identified. If you wish to present an "Op-Ed" feature, please make advance arrangements with the Editor. Views and opinions expressed in this section are those of the author and not those of the Academy.

WALTER LYON'S CHALLENGE IS RIGHT ON TARGET. Leadership has shifted from professional engineers to politicians. "Our failure to address the engineering side of these problems imposes a huge cost on the nation." When will we address the energy crisis and make the public aware of the benefits versus risks?

1. Nuclear power plants
2. Yucca Mountain high level radioactive waste storage site.
3. Offshore drilling for oil.

As a footnote, I suggest recognition of Col. William Hardenburg's promotion of the US Army Sanitary Corps in the late 1930's and early 1940's with recruitment of hundreds of Sanitary Engineers for service in WWII.

Sherwood Davies, P.E., MPH
Troy, New York

A

DATES TO REMEMBER:

Registration for 2008 Annual Board of Trustees Meeting
October 15, 2008

Specialty Certification Renewals
December 31, 2008

2009 Selection Guide Reservations
December 31, 2008

Excellence in Environmental Engineering Competition
February 1, 2009

Application Packages
March 31, 2009

Volume 6, Summer 2008

Environmental Engineer: Applied Research and Practice

Instructions to Contributors

PURPOSE AND SCOPE

Environmental Engineer: Applied Research and Practice, is a peer-reviewed journal focused on practical research and useful case studies related to the multi-disciplinary field of environmental engineering. The journal strives to publish useful papers emphasizing technical, real-world detail. Practical reports, interesting designs and evaluations of engineering processes and systems are examples of appropriate topics. Papers relating to all environmental engineering specialties will be considered.

MANUSCRIPT REQUIREMENTS:

Manuscripts should follow the general requirements of the ASCE authors' guide (http://www.pubs.asce.org/authors/index.html#1) and should be submitted electronically in WORD format to the Editor and Assistant Editor.

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Editor e-mail: baillod@mtu.edu
Yolanda Moulden
Assistant Editor email: YMoulden@aaee.net

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ATTN: Yolanda Moulden
(410) 266-3311
(410) 266-7653 (Fax)

REVIEW PROCESS

All papers submitted to the journal are subject to critical peer review by three referees, who have special expertise in a particular subject. The Editor will have final authority over a paper's suitability for publication.

CATEGORIES

Papers may be submitted in the following areas:

Applied Research

Original work presented with careful attention to objectives, experimental design, objective data analysis, and reference to the literature. Practical implications should be discussed.

Review

Broad coverage of an environmental engineering application or a related practice with critical summary of other investigators' or practitioners' work.

Practical Notes

Novel methods that the author(s) have found to be sufficiently successful and worth recommending.

Case Studies

Recently completed projects or studies in progress that emphasize novel approaches or significant results.

Design/Operation

Conceptual or physical design or operation of engineering systems based on new models or techniques.

Management

Papers describing novel approaches to problems in environmental management, or to the global, sustainability or business asects of environmental engineering.

ABSTRACT

An abstract of up to 200 words should be provided, including a statement of the problem, method of study, results, and conclusions. References, tables, and figures should not be cited in the abstract. Up to six key words or terms should be included for use by referencing sources.

PHOTOGRAPHIC CONSENTS

A letter of consent must accompany all photographs of persons in which the possibility of identification exists. It is not sufficient to cover the eyes to mask identity.

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ENVIRONMENTAL ENGINEERING BODY OF KNOWLEDGE: SUMMARY REPORT

AAEE Environmental Engineering Body of Knowledge Working Group[1]

ABSTRACT

To better define the knowledge and skills required for the practice of environmental engineering, the American Academy of Environmental Engineers (AAEE) sponsored a Body of Knowledge Working Group (BOKWG) to define the knowledge, skills and abilities needed to practice environmental engineering at the professional level. The Working Group adopted an outcomes based approach and identified 18 outcomes. Bloom's Taxonomy enhanced by the Daggett Rigor/Relevance Framework™ was used to identify the cognitive rigor and applicative relevance level expected for each outcome at the baccalaureate, masters (or equivalent) and after 4 or more years of professional experience. The Working Group Draft Report summarized here is undergoing a peer review by educators and practitioners. Comments are welcome and should be directed to Dr. Debra Reinhart at reinhart@mail.ucf.edu.

I. INTRODUCTION

In 2005 the American Academy of Environmental Engineers (AAEE) celebrated its 50th anniversary. The practice of Environmental engineering certainly predates AAEE; however, it had traditionally been viewed as "sanitary engineering," a subset of civil engineering. In the latter half of the twentieth century, particularly in the 1980's and 1990's, environmental engineering evolved into a stand-alone engineering discipline.

An environmental engineer must have a broad array of technical and non-technical knowledge, abilities, skills, and attitudes. Although the knowledge and skills required of environmental engineers were the focus of several Environmental Engineering Education Conferences, (AAEE and AEESP 1986, 1991 and 1996) there has not been a comprehensive effort to identify and describe them in terms of outcomes. In 2005, the American Academy of Environmental Engineers established a Body of Knowledge Working Group (BOKWG) charged with: "defining the BOK needed to enter the practice of environmental engineering at the professional level (licensure) in the 21st century taking into account other issues, including, but not limited to, the impact on AAEE, on the profession, on environmental engineering academic programs (undergraduate and graduate), and on accreditation of environmental engineering programs at the basic and advanced levels."

The Environmental Engineering BOK Working Group Draft Report (AAEE, 2008) summarized here describes the knowledge and core competencies integral to the understanding and practice of environmental engineering. Acquiring the EnvE BOK could lead to environmental engineering licensure and specialty certification or to related careers that do not require licensure. The EnvE BOK builds on outcomes applicable to all engineering specialties and adds outcomes specific and unique to environmental engineering. The outcomes identified will help educators to design curricula that provide the basis to gain the competencies needed for professional practice and will assist licensing boards to determine the expertise required for licensure.

In 2008, the American Society of Civil Engineers published the second edition of the Civil Engineering Body of Knowledge for the 21st Century (ASCE, 2008). The Environmental Engineering Body of Knowledge has many things in common with the Civil Engineering BOK, and the AAEE BOK Working Group acknowledges the help received from ASCE, particularly the contributions of ASCE Honorary member Stu Walesh.

II. BACKGROUND

A. Definition of Environmental Engineering

Various definitions of environmental engineering have appeared in the literature, and these have been summarized by Baillod et al. (1991). The following definition adapted from Gilbertson (1973) is used herein:

Environmental engineering is defined as that branch of engineering concerned with the application of scientific and engineering principles for:

- Protection of human populations from the effects of adverse environmental factors;
- Protection of environments, both local and global from the potentially deleterious effects of natural and human activities; and
- Improvement of environmental quality.

Environmental engineers practice in both the public and private sectors. Typical duties of environmental engineers are:

- Evaluation of environmental quality, especially when it involves a risk to public health, and/or when degradation has or may occur as a result of anthropogenic activities – e.g., quality of water, air, soils;
- Development of strategies and methods to prevent environmental degradation or public health risk;
- Development of regulations and requirements for performance of

pollution prevention or environmental quality improvement, protection, or remediation projects:

- Design of facilities or programs for pollution prevention or environmental quality improvement, protection, or remediation;
- Evaluation of the results of pollution prevention or environmental quality improvement, protection, or remediation; and
- Assessment of the economics and efficiency of processes and procedures used in pollution prevention or environmental quality improvement, protection, or remediation.

B. Education for Environmental Engineering

Most practicing environmental engineers have post-baccalaureate education, frequently earning masters degrees. Civil engineering programs have traditionally emphasized specialization at the graduate level, and many programs still use the "civil" descriptor for programs that emphasize environmental engineering. However, an increasing number of institutions now offer baccalaureate and masters degrees designated as Environmental Engineering. Even though the number of baccalaureate degrees designated as environmental engineering is increasing (726 in 2005-2006), the number is small compared to civil engineering (8,935 in 2005-2006, ASEE, 2007). Accordingly, a common entry route to environmental engineering is via a baccalaureate degree in civil or other related engineering or science discipline followed by a masters degree in environmental engineering. While an appreciable number of baccalaureate graduates in environmental and related engineering disciplines begin employment in environmental engineering directly following the baccalaureate degree, more and more (estimated by the BOKWG as 35 percent) of them earn graduate degrees either directly following the baccalaureate degree or during their first few years of employment. A significant increase in knowledge applicable to environmental engineering has taken place over the past 50 years, while the number of credits required for the typical baccalaureate engineering degree has decreased. Accordingly, education beyond the baccalaureate degree is necessary for the engineer to understand processes and relationships essential to environmental engineering. An increasing number of employers of environmental engineers are recognizing this. Moreover, recent changes in the National Council of Examiners for Engineering and Surveying (NCEES) model licensure law require post-baccalaureate education prior to licensure by 2015. Licensing boards of some states are considering adoption of the post-baccalaureate education provisions of the model law.

C. Employment Sectors

Environmental engineers are employed in government service, consulting service, industry, and education. Although the skills and duties required of environmental engineers in each sector are similar, there are some differences.

- **Education** – The education sector is broad, ranging from continuing citizen and professional education provided by community colleges to graduate instruction provided by research universities.
- **Public Service** – Environmental engineering positions in public service cover a broad spectrum of duties ranging from operational management of water, wastewater or solid waste utilities at the city or regional level to administration of environmental regulations at the state and federal level, to environmental research. Most environmental engineers in responsible public service positions have post-baccalaureate education.
- **Industry** – Many environmental engineers are employed in the manufacturing, construction, and energy industrial sectors. Although compliance with environmental regulations is typically a major responsibility, many of these positions also have some responsibility for treatment facility operation and minor design.
- **Consulting Engineering Service** – Facility design has traditionally been a major responsibility for environmental engineers in consulting service. However, environmental engineering consulting has expanded to include more emphasis on Brownfield investigations, pollutant transport, regulatory guidance, sustainability, and facility operation. Most environmental engineers in responsible charge have masters degrees and an increasing number of environmental engineers in the consulting field have doctoral degrees. A growing number of consulting environmental engineers in responsible positions are becoming board certified by the AAEE.

D. Importance of Licensure and Specialty Certification

Licensure, like accreditation, is a credential of minimal acceptable engineering competence for protection of the public. Generally (and with some exceptions) engineering licenses are issued by State Boards of Engineering Examiners without limitation on the fields of engineering in which a person may practice. Some states exempt engineers working in industry and certain types of public service from licensing requirements, even though they may be involved in projects where public health, safety and welfare are issues. On the other hand, Specialty Certification identifies engineers who have been certified by their professional peers as having special capabilities in one or more areas of engineering practice. In 1965, AAEE began the first engineering peer specialty certification program in the United States. Although specialty certification does not carry any right or privilege, the Board Certified Environmental Engineer (BCEE) title does assist the public in identifying an engineer's technical expertise.

The importance of licensure and specialty certification varies among engineering disciplines and is generally most important in civil and environmental engineering. This importance also varies among environmental engineering employment sectors and is highest for consulting engineering service. Nevertheless, licensure and specialty certification are important as a visible professional credentials in all sectors to emphasize the engineer's responsibility for protecting public health, safety and welfare.

E. Technical Specialties of Environmental Engineering

Currently, most environmental engineering specialties have traditional roots that correlate to the historical development of the field from sanitary engineering and/or the promulgation of federal and state laws and regulations that divide the environment into silos (e.g., air, waste, drinking water, etc.). The result is that many professionals in consulting firms and government agencies work within groups that have similar traditional boundaries with titles often associated with a single medium or application within a medium. These boundaries are also reflected in the titles of various professional associations such as the Water Environment Federation, the American Water Works Association, and the Solid Waste Association of North America.

Berthouex et al., (1986) recognized the limitation of the traditional single media approaches and recommended integrated, air-water-land approaches to environmental engineering problems. Since then, environmental engineers have learned more about how ecosystems function, and how connected every component of the ecosystem is to the other. As a result of this emerging understanding of complexity, traditional specializations are being stretched and integrated to include knowledge from across specializations and in many cases across traditional disciplines. For example, assessing the fate and hazards associated with contaminants and their releases might have traditionally been the purview of an environmental engineer working with geochemists; today, this team may well include toxicologists, risk analysts, ecologists, and even social and political scientists. Thus, the areas of specialization within the environmental engineering discipline are changing in response to the demands from society for professionals to address complex environmental processes with a more comprehensive scope.

There is a trend away from specialization by media to provide a broader systems-based perspective on the nature of the problems and solutions relevant to environmental engineering. Although traditional media based areas of competence will continue to be used, many schools and consulting firms are describing their areas of competence in much more innovative and diverse ways such as.

- **By the nature of the contaminants** (toxic/carcinogenic, animal (including human) excreta, household wastes, etc.) – the nature of contaminant sources, releases, fate in the environment, treatment and risk all vary substantially based on the fundamental source of the contaminants. The biochemical oxygen demand, pathogen and nutrient loading problems associated with early sanitary engineering could identify a continuing area of specialization. However, toxic contaminants behave quite differently, are generally detected at much lower concentrations but still pose significant human and ecosystem risks, and require very different treatment or remediation technologies.
- **By the broad system of interest** – this has been defined as the natural versus engineered systems or the non-built and built environments. However, these distinctions are becoming blurred as green infrastructure and hybrid eco-design processes become more common. Many future environmental engineers will be characterized by the systems (both ecological and technological) being utilized in the design process rather than the traditional applications being designed.
- **By the nature of the processes being designed** – these could include biological, physical-chemical, fluid flow and transport. Fundamental transformation and transport processes are common across natural and engineered systems. A technical specialization in biological processes, for example, would require depth in microbial processes ranging from the molecular to the reactor scale. This specialization could lead towards the application of these processes to constructed wetlands, municipal wastewater treatment processes, solid waste landfills or in-situ groundwater remediation design. The fundamental science and engineering would be common across all of these application areas.
- **By the nature of the intervention** – such as minimization (including management practices or engineered solutions), treatment, or assimilation. Engineered solutions can take many forms. Many environmental engineers now consider themselves specialists in the area of minimizing releases or waste generation, while others focus primarily on environmental assimilation of pollutants.

In addition to the changes in the way we segregate the current practice of environmental engineering into specializations; new specializations are also emerging based on recent innovations in research and the expansion of the discipline. Areas of emerging research, innovation and practice in environmental engineering include ecological engineering, restoration engineering, sustainability engineering, and risk assessment engineering. These emerging areas of specialization utilize approaches that may include green infrastructure design and sustainability design.

III. FUTURE ROLE OF THE ENVIRONMENTAL ENGINEER

The future of humankind on the earth will, based on currently available historical information, be profoundly influenced by two phenomena, continued human population growth and depletion of natural resources, particularly fossil fuels. These two phenomena may, in turn, influence climate and lead to water and food scarcity. Environmental engineers must be prepared not only to react to changes in climate and resource availability but also to help manage that change through sustainable engineering.

A. Population Growth and Declining Resources

A plot of human population from prehistoric times to the present shows that we are in a period of unprecedented growth in the numbers of humans inhabiting earth. The current population is six billion and is increasing by 80 million per year. This growth has resulted in increased use of fossil fuels, water, and mineral resources for agriculture, transportation, materials, heat and other human needs. Environmental engineers will need to assist society in the management, design and development of the built environment for more humans while making more efficient use of water, land, materials, and energy. At the same time, they will have to manage the by-products of society while helping to provide for more renewable energy sources.

B. Climate

The earth's climate has changed throughout history and currently is in a warming period (IPCC, 2007). Society will have to adapt to an altered climate. Violent weather events may become more frequent. The boundary between cold and warm regions and between wet and dry regions may shift. Throughout these events, humankind may be stressed, but will adapt. Increased water scarcity will probably be one of the most serious impacts of population growth and climate change, and will likely be felt most acutely by agriculture and by cities located in arid regions. Indirect water reuse will become the norm, and direct, large-scale potable water reuse will begin. The potential of the seas will be brought into play as a major water supply source. Environmental engineers will need to enhance their competence related to water reuse, disinfection, and distribution. They will also need new skills for coping with adverse climatic and weather conditions.

C. Water, the Developing World and Human Health

Clean water and environmental sanitation are intrinsically related. Much of the world's population does not have access to either clean water or adequate sanitation facilities. Consider the following:

The United Nations (UNEP, 2007; UN Water, 2007) and World Health Organization (WHO and UNICEF 2004) report that:

- Approximately 2.5 billion people do not have access to improved sanitation facilities, and 1.1 billion people lack access to clean water.
- By 2025, nearly 2 billion people will be living in regions of absolute water scarcity, and two-thirds of the world population could be under conditions of water stress.

Epidemiological studies reported by Clasen and Cairncross (2004) estimate that waterborne diarrheal diseases:

- Kill 2.5 million people per year, mostly children under five years old (Kosek et al. 2003);
- Account for about 5.7% of the global disease burden with 4 billion cases per year (Pruess et al. 2002); and
- Account for 21% of deaths of children under five years old in developing countries (Parashar et al. 2003).

Clearly, the water scarcity, sanitation and health problems are most acute in the developing world, and these problems can lead to conflict. Environmental engineers are already working on these problems and this activity will increase as more attention and resources are directed at these problems.

D. Sustainability

Sustainability is the ability to meet human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and enhancing environmental quality and the natural resource base essential for

FIGURE 1 BOK and the Education and Professional Development of an Environmental Engineer

the future (ASCE, 2008). Sustainable engineering meets these human needs. Humankind is becoming aware that sustainability is important, but so far has taken only limited action toward achieving sustainability. More serious actions will be taken in the future as resources become more depleted. The environmental engineer will need to be a leader in implementing actions that enhance sustainability. The role of the environmental engineer in this effort will most likely focus on water and on sustainable material and energy use in the built environment.

E. Multi- and Interdisciplinary Interactions

It is apparent from the foregoing discussion that addressing the environmental impacts of population growth, resource depletion, climatic change, water scarcity, and sanitation will require a team approach. Many engineering specialties will be involved as well as scientists, politicians, government personnel, and a variety of stakeholders. The environmental engineer will be best equipped to lead and coordinate the multidisciplinary engineering team in addressing environmental impacts. It follows that the environmental engineer practicing at full professional capacity should have the technical breadth to relate to engineers and specialists from other disciplines as well as the non-technical breadth to positively influence society and stakeholders.

IV. DEVELOPMENT OF THE ENVIRONMENTAL ENGINEERING BODY OF KNOWLEDGE (EnvE BOK)

A. Outcomes Based Structure of the BOK

The EnvE BOK is defined by outcomes consistent with ABET 2000 Criteria, but placed in the context of environmental engineering. For each outcome, performance levels are specified, and relevant knowledge domains are identified. As used herein:

- An **Outcome** states or describes an ability to perform a task,
- A **Performance Level** defines the intellectual depth of the task and relates to Bloom's cognitive levels.
- A **Knowledge Domain** is an organized field of human cognition such as history or mathematics.

Core competencies are defined in outcomes; knowledge areas required for each outcome are identified for each outcome. The EnvE BOK provides a guide for curriculum development and reform, and provides a means for employers to better understand the knowledge base of environmental engineers. The competence and skill requirements are in agreement with those identified at the 1991 and 1996 Environmental Engineering Education Conferences (Baillod et al, 1991; Marini, 1996).

B. Education for the BOK

The EnvE BOK is fulfilled through a combination of baccalaureate-level work, masters-level work, and professional experience. Fulfillment of the EnvE BOK does not require a BS EnvE degree; those with BS degrees in science or other engineering fields could meet the baccalaureate-level requirements as part of their post-baccalaureate education. Fulfilling the EnvE BOK will prepare one not only for professional licensure, but also for alternate careers that do not require licensure. Therefore, the BOK was designed to broadly prepare professionals for practice of EnvE that includes, but is not limited to, planning,

TABLE 1 Environmental Engineering BOK Outcomes

Outcome Number and Title	Outcome
Foundational Outcome	
1. Basic Environmental Math & Science (BEMS) Knowledge	Mathematics; physics; chemistry; biological science; earth science, mass, energy and momentum conservation and transport principles needed to understand and solve environmental engineering problems.
Enabling Knowledge and Skills Outcomes	
2. Design and Conduct Experiments	Design and conduct experiments necessary to gather data and create information for use in analysis and design
3. Modern Engineering Tools	The techniques, skills, and modern engineering tools necessary for engineering practice
4. In-Depth Competence	Advanced knowledge and skills essential for professional practice of environmental engineering
5. Risk, Reliability and Uncertainty	The risks associated with human or environmental exposure to contaminants in our environment and uncertainty and reliability principles as they affect the engineered systems designed, built or operated to protect the environment and the public health, welfare and safety
6. Problem Formulation and Conceptual Analysis	Problem formulation and analysis based on proper environmental engineering problem identification, obtaining background knowledge, development and analysis of alternatives, understanding existing requirements and/or constraints and recommendation of effective solutions
7. Creative Design	Design of a system, component or process to meet desired needs related to a problem appropriate to environmental engineering.
8. Sustainability	Integration of sustainability into the analysis and design of engineered systems
9. Multimedia Breadth and Interactions	Application of BEMS to predict and determine fate and transport of substances in and among air, water and soil as well as in engineered systems
10. Societal Impact	Societal impact of public policy affecting environmental engineering issues and solutions.
11. Contemporary and Global Issues	Globalization and other contemporary issues vital to environmental engineering
Professional Outcomes	
12. Multi-disciplinary Teamwork	Skills and expertise of multiple disciplines used to address complex engineering problems as a team
13. Professional and Ethical Responsibilities	Professional and ethical issues in environmental engineering
14. Effective Communication	Effective communications when interacting with the public and the technical community
15. Lifelong Learning	Life-long learning leading to enhanced skills, awareness of technology, regulatory, industrial, and public concerns
16. Project Management	Principles of project management relevant to environmental engineering
17. Business and Public Administration	Business knowledge and communication skills necessary to the administration of both private and public organizations
18. Leadership	Engagement, motivation and leadership of others to achieve common vision, mission and goals

design, teaching, applied or fundamental research, public administration, or operations. It was recognized that individuals receiving a degree in EnvE may not elect to pursue post-baccalaureate education related to EnvE and may never practice EnvE, but rather may seek other professional degrees, such as law or medicine, and follow an entirely different career path. Therefore some paths beginning with a baccalaureate degree in EnvE may not lead to complete BOK fulfillment. With this in mind the baccalaureate-level work comprising the BOK was designed to provide comprehensive undergraduate preparation for a broad range of careers. Figure 1 shows the role of the EnvE BOK in the education and development of an environmental engineer.

C. Environmental Engineering Outcomes

The Environmental Engineering Outcomes have been arranged in three groups as shown in Table 1. The **first group** includes an outcome that provides foundational basis for environmental engineering education. This fundamental outcome ensures abilities in science, mathematics, and areas of discovery and design that will enable environmental engineers to succeed in a future of technological change and innovation.

The **second group** identifies outcomes essential to the problem-solving process. Problem solving involves problem definition, identifying constraints and alternatives, analyzing alternatives, selecting and optimizing the appropriate solution, and implementation. The process is iterative, requiring problem redefinition and refining as information is acquired, followed by verification of results during implementation and after the solution is implemented. Problem solving involves both analytical and creative skills. Analytical skills include the ability to comprehend, define and analyze the problem, while creativity is necessary in identifying alternative solutions and envisioning possible unanticipated consequences of the solution. Environmental engineering problem formulation and solution must be accomplished in the context of sustainability, must meet societal needs, and be sensitive to global implications. The ability to envision the individual steps in a solution and their results can only be gained through practice, acquisition of subject specific knowledge and understanding, and experience using state-of-the art tools.

The **third set of outcomes** defines professional skills, knowledge and attributes that environmental engineers must have to successfully implement solutions. Fulfilling these outcomes will enable them to communicate well, to effectively manage projects, and to successfully engage other engineers and the public. Throughout their careers, environmental engineers must remain cognizant of changing technology and issues. The public must appreciate the role environmental engineers may play as leaders as well as society - particularly when the solutions to environmental engineering issues recommended require policy changes. Public confidence in these solutions requires that environmental engineers conduct themselves ethically.

D. Knowledge Domains

Knowledge domains identify specific areas of learning that are essential to accomplishing the outcome. They are not necessarily curricular courses. They may, for example, represent a single lecture within a course, or

FIGURE 2 Matrix of Outcomes and Knowledge Domains

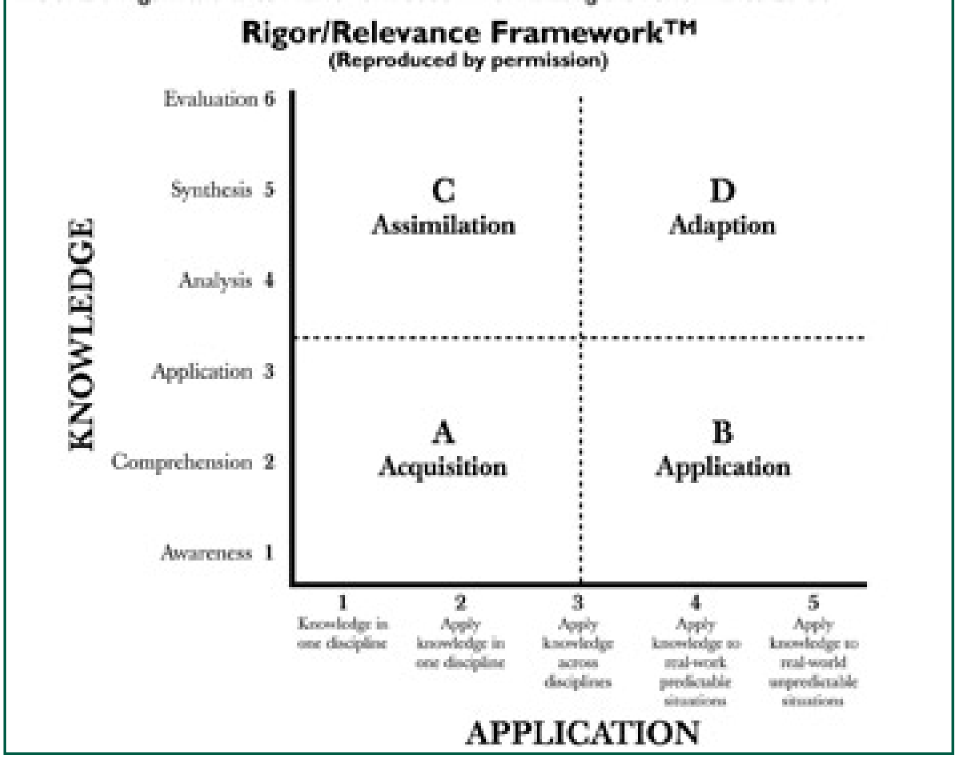
Knowledge Domain Required	Outcome																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Mathematics, Computer Languages	■	■	■	■	■	■	■	■	■	■	■				■			
Physics, Mechanics	■	■		■	■			■	■	■	■				■			
Chemistry	■	■		■	■	■	■	■	■	■	■				■			
Biology and Ecology	■	■		■	■		■	■	■	■	■				■			
Conservation of Mass	■			■	■	■	■	■	■		■				■			
Conservation of Energy	■			■	■		■		■		■				■			
Mass Transport	■			■	■		■		■		■				■			
Heat Transport	■			■	■						■				■			
Fluid Mechanics	■			■	■		■	■	■		■				■			
Earth Science	■			■	■	■		■	■		■				■			
Systems Analysis	■	■	■	■	■	■	■	■	■	■	■				■			
Probability and Statistics		■	■		■			■	■		■				■			
Humanities, Social Studies						■	■			■	■		■	■	■	■	■	■
Economics							■	■	■	■	■				■		■	■
Business Management						■		■	■		■	■	■		■		■	■

they may be topics within multiple courses taught at different levels. Figure 2 provides a rubric with knowledge domains identified and mapped to the 18 outcomes.

E. Performance Levels

Fulfillment of outcomes occurs at three points in the professional development of an environmental engineer, at the completion of a baccalaureate degree in environmental engineering, at the completion of a masters degree or 30 hours post-baccalaureate, and after four years of professional practice. A level of achievement for BOK fulfillment at each of these points is described using a two-dimensional scale that characterizes performance of the outcome in terms of its cognitive rigor and its practical relevance. The Rigor/Relevance Framework™ (Figure 3) was created in 1997 by Willard R. Daggett, Ed.D. of the International Center for Leadership in Education (Daggett, 2005). The application of this scale is more clearly seen in the EnvE BOK Report Appendix where Outcomes are mapped to cognitive levels and practical relevance.

FIGURE 3 Rigor/Relevance Framework Used in Formulating the Performance Levels



The Y-axis of Figure 3 utilizes Bloom's Taxonomy to describe cognitive levels of learning and application. This taxonomy was first developed in 1956 by Benjamin Bloom, who headed a group that developed a classification of levels of intellectual behavior important in learning.

Bloom identified six levels within the cognitive domain, from the simple recall or recognition of facts, as the lowest level, through increasingly more complex and abstract mental levels, to the highest order which is classified as evaluation. Unfortunately, Bloom found that over 95 percent of typical test questions students encounter require them to think only at the lowest possible level – knowledge and the recall of information. In the EnvE BOK, it is clear that the capacity to use this knowledge for engineering applications, synthesis and evaluation of alternatives must be defined. Each of the cognitive levels is defined below.

1. Knowledge (C1)

Knowledge is defined as the remembering of previously learned material. This may involve the recall of a wide range of material, from specific facts to complete theories.

However all that is required is the bringing to mind of the appropriate information – nothing further. Knowledge represents the lowest level of learning outcomes in the cognitive domain.

2. Comprehension (C2)

Comprehension is defined as the ability to grasp the meaning of material. This may be shown by translating material from one form to another (words to numbers), by interpreting material (explaining or summarizing), and by estimating future trends (predicting consequences or effects). These learning outcomes go one step beyond the simple remembering of material, and represent the lowest level of understanding.

3. Application (C3)

Application refers to the ability to use learned material in new and concrete situations. This may include the application of such things as rules, methods, concepts, principles, laws, and theories. Learning outcomes in this area require a higher level of understanding than those under comprehension.

4. Analysis (C4)

Analysis refers to the ability to break down material into its component parts so that its organizational structure may be understood. This may include the identification of parts, analysis of the relationship between parts, and recognition of the organizational principles involved. Learning outcomes here represent a higher intellectual level than comprehension and application because they require an understanding of both the content and the structural form of the material.

5. Synthesis (C5)

Synthesis refers to the ability to put parts together to form a new whole. This may involve the production of a unique communication (theme or speech), a plan of operations (research proposal), or a set of abstract relations (scheme for classifying information). Learning outcomes in this area stress creative behaviors, with major emphasis on the formulation of new patterns or structure.

6. Evaluation (C6)

Evaluation is concerned with the ability to judge the value of material (statement, theory, equation, research report) for a given purpose. The judgments are based on definite criteria. These may be internal criteria (organization) or external criteria (relevance to the purpose) that may need to be determined or already defined. Learning outcomes in this area are highest in the cognitive hierarchy because they contain elements of all the other categories, plus conscious value judgments based on clearly defined criteria.

Studies have shown that students understand and retain knowledge best when they have applied it in a practical, relevant setting. A teacher who relies on lecturing does not provide students with optimal learning opportunities. Instead, students go to school to watch the teacher work.

Daggett extended the commonly used Bloom's taxonomy scale to include a second dimension related to the relevance or applicability of the material. The relevance scale spans from knowledge in one discipline to application of knowledge in real world unpredictable situations as described below:

1. Knowledge in one discipline (A1)
2. Apply knowledge in one discipline (A2)
3. Apply knowledge across disciplines (A3)
4. Apply knowledge to real world predictable situations (A4)
5. Apply knowledge to real world unpredictable situations (A5)

Combining the cognitive rigor (C levels), with the applicative relevance (A levels) gives the four quadrants of Figure 3. Students need to begin with knowledge in single disciplines (quadrant A) and move upwards and to the right towards quadrant D. These quadrants include:

- **Quadrant A – Acquisition (typical C2, A2)**: Students gather and store bits of knowledge and information. Students are primarily expected to remember or understand this knowledge.
- **Quadrant B – Application (typical C2, A4):** Students use acquired knowledge to solve problems, design solutions, and complete work. The highest level of application is to apply knowledge to new and unpredictable situations.
- **Quadrant C – Assimilation (typical C4, A2):** Students extend and refine their acquired knowledge to be able to use that knowledge automatically and routinely to analyze and solve problems and create solutions.
- **Quadrant D – Adaptation (typical C5, A4):** Students have the competence to think in complex ways and to apply their knowledge and skills. Even when confronted with perplexing unknowns, students are able to use extensive knowledge and skill to create solutions and take action that further develops their skills and knowledge.

As with many professions, the combination of education, training and experience needs to help guide an engineer through these quadrants in order to operate at the highest levels of both cognitive function and relevant applications in order to meet the expectations of a professional engineer. Thus, the expected performance levels for the various outcomes have been described using the two dimensional cognitive rigor (C dimension) and applicative relevance (A dimension).

V. DETAILED DESCRIPTION AND PERFORMANCE LEVELS FOR OUTCOMES

A more detailed description and application of the rigor/relevance framework for the Outcomes listed in Table 1 is given in the Appendix. For each outcome, the expected performance is described at three career levels:

- **Baccalaureate Level:** This applies to engineers earning the Bachelor of Science in Environmental Engineering degree.
- **M/30 Level:** This applies to engineers who hold baccalaureate degrees in environmental engineering or in other engineering or science specialty and who have earned a masters degree or at least 30 semester credits beyond the baccalaureate. It is assumed that these individuals would also meet the baccalaureate level outcomes. It is understood that engineers holding baccalaureate degrees in fields other than environmental engineering may require more then 30 semester credits to attain this performance level.
- **After Professional Experience:** This applies to engineers who meet the M/30 level and who have had at least four years of professional environmental engineering experience with mentoring from more experienced engineers.

At each level of expected performance, the rigor and relevance of the outcome are identified using Bloom's Cognitive Level

TABLE 2 Rigor/Relevance Performance Matrix Table for Draft Outcome 1

Foundational Outcome						
Level of Achievement						
Cognitive Level:	**C1 Knowledge**	**C2 Comprehension**	**C3 Application**	**C4 Analysis**	**C5 Synthesis**	**C6 Evaluation**
Practical Relevance:	**A1 Within Discipline**	**A2 Within Discipline**	**(B):A2 (M30):A3 Across Disciplines**	**A3 Complicated Situations**	**A5 Complex Situations**	**A5 Complex Situations**
Outcome 1						
Basic Environmental Math & Science (BEMS) for Environmental Engineering	***Define*** key factual information related to the knowledge of domains of mathematics, physics, chemistry, biology, ecology, conservation and transport principles, and earth sciences (BEMS) (B)	***Explain*** key concepts and problem-solving processes involved in each knowledge domain of the BEMS. (B)	***Apply*** each knowledge domain of the BEMS to solve well-defined problems appropriate to environmental engineering. (B) Apply knowledge domains of the BEMS, as necessary, to analyze and solve a predictable problem appropriate to environmental engineering. (M/30)	***Analyze*** a complex problem to determine relevant BEMS knowledge domains. (M/30)	***Create*** new ways to apply BEMS knowledge domains to environmental engineering. (E+*) *beyond four years of experience	***Evaluate*** innovative engineering approaches to solve real-world problems appropriate to environmental engineering **using knowledge domains of the BEMS.** (E)

(C1 to C6) and Daggett's Relevance Level (A1 to A5).

In addition to the tabular text descriptions of the Outcomes given in the Appendix, the Draft BOK also describes the outcomes using Rigor/Relevance Performance Matrix Tables. This is shown in Table 2 for Draft Outcome 1. The matrix tables are convenient for comparing expected performance between levels and outcomes.

VI. IMPLEMENTATION OF THE EnvE BOK

Educators, students, young engineers and senior practitioners all share responsibility in implementing the EnvE BOK. Educators and students should be familiar with the EnvE BOK because it defines the outcomes of an environmental engineering education. From a faculty point of view, the EnvE BOK can guide curriculum and expectations of students; from a student point of view, the EnvE BOK can guide expectations of their technical and non-technical educational experience. As stakeholders in engineering education, practitioners, managers, and leaders of public and private engineering organizations should be familiar with the EnvE BOK. The depth and breadth of the young environmental engineer's early professional experiences are critical to fulfilling the EnvE BOK. Senior practitioners should take an active role to help young environmental engineers continue the learning process toward fulfillment of the EnvE BOK and professional licensure.

The development of the EnvE BOK is a continuous process of testing and improvement. As it is implemented, practitioners and educators must evaluate the EnvE BOK and determine whether all issues necessary to the practice of environmental engineering have been addressed and whether the outcomes can be achieved at the level recommended at the point in professional development indicated. It is recommended that such evaluation be accomplished utilizing task forces created by organizations serving significant numbers of environmental engineers, such as the AAEE sponsoring organizations. Practitioner task forces should examine the EnvE BOK to ensure that engineers will be educated to meet the needs of the future, that the practitioner's role has been correctly identified, and that the levels of achievement are correct. Educators should conduct a curriculum reality check. A representative number of EnvE undergraduate and graduate programs should be identified and asked to evaluate whether curricula can be reasonably designed to adopt the EnvE BOK. Educators should also determine whether the levels of achievement are correctly applied. Finally, it is recommended that an implementation task force be created to make recommendations regarding how the EnvE BOK should be used for accreditation, licensing, and promotion of the profession.

The draft EnvE BOK summarized here is currently undergoing a peer review by environmental engineering educators and practitioners. Comments are welcome and should be directed to Dr. Debra Reinhart at reinhart@mail.ucf.edu.

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APPENDIX — DRAFT OUTCOMES

Outcome 1: Basic Environmental Math and Science (BEMS) Knowledge for Environmental Engineering

Mathematics; physics; chemistry; biological science; earth science, mass, energy and momentum conservation and transport principles needed to understand and solve environmental engineering problems

Outcome Explanation: Underlying the professional role of the environmental engineer as the master integrator and technical leader is a firm foundation in mathematics, physics, chemistry, biology, ecology, and earth science. The environmental engineer draws on these knowledge domains along with principles of conservation and transport of mass, momentum and energy to analyze natural systems and to design, construct, and manage engineered systems.

Baccalaureate Level:

- **Define** key factual information related to the knowledge domains of the BEMS. (C1, A1)
- **Explain** key concepts and problem-solving processes involved in each knowledge domain of the BEMS. (C2, A2)
- **Apply** each knowledge domain of the BEMS to well-defined problems appropriate to environmental engineering. (C3, A3)

M/30 Level:

- **Analyze** a complex problem to determine relevant BEMS knowledge domains. (C4, A3)
- **Apply** knowledge domains of the BEMS, as necessary, to analyze and solve a predictable problem appropriate to environmental engineering. (C3, A3)

After Professional Experience:

- **Evaluate** innovative engineering approaches to solve real-world problems appropriate to environmental engineering using knowledge domains of the BEMS. (C6, A5)

Outcome 2: Design and Conduct Experiments

Design and conduct experiments necessary to gather data and create information for use in analysis and design

Outcome Explanation: An experiment is a procedure carried out in order to discover information, to test or establish a hypothesis, or to determine characteristics of environmental media or processes. Environmental engineers frequently conduct experiments to gather data and create information for use in analysis and design. Such experiments may be conducted in the field or the laboratory or may involve numerical simulation. These experiments would involve some direct measurements or simulations of physical, chemical and biological characteristics of water, air and soil or processes used in their treatment, remediation or restoration. To efficiently design and conduct experiments, the environmental engineer must be familiar with the appropriate tools and should have the ability to interpret the results.

Baccalaureate Level:

- **Identify** the procedures and equipment required to conduct common experiments appropriate to environmental engineering. (C1, A1)
- **Explain** the purpose, procedures, equipment and practical application of experiments appropriate to environmental engineering. (C2, A2)
- **Conduct** experiments appropriate to environmental engineering. (C3, A2)
- Use statistics to **analyze** experimental uncertainties and error and interpret results. (C4, A2)
- **Design** an experiment based on accepted procedures and measurements to develop specific information or to test a specific

hypothesis appropriate to environmental engineering.(C5, A2)

M/30 level:

- **Design and conduct** experiments using appropriate state-of-the-art tools to develop specific information or to test a specific hypothesis related to a predictable problem appropriate to environmental engineering. (C3, C5, A3/A4)
- **Analyze and interpret** the results and explain the resulting information using appropriate communication tools. (C4, A3/A4)
- **Design** an experiment to develop specific information or to test a specific hypothesis related to a complex problem appropriate to environmental engineering.

After Professional Experience:

- **Evaluate** the effectiveness of an experiment designed to obtain information related to a complex problem appropriate to environmental engineering, communicate the evaluation to stakeholders. (C6, A5)

Outcome 3: Use of Modern Engineering Tools

The techniques, skills, and modern engineering tools necessary for engineering practice

Outcome Explanation: A practicing environmental engineer must be able to apply state-of-the-art tools in analyzing problems and creating solutions and designs. Such tools include, as examples, measurement tools and techniques, programming languages, and software for graphics, GIS, modeling, statistical analysis and risk analysis.

Baccalaureate Level:

Identify and **describe** the engineering tools available to appropriate issues in environmental engineering problems. (C1, A1)

- **Select** the most appropriate tool for application to various types of engineering problems and projects. ((C2, A2)
- **Apply** modern engineering tools to the various elements of engineering problem solving and project analysis for well-defined problems. (C3, A2)

M/30 Level:

- **Recognize** the limitations of the various tools with respect to appropriateness, accuracy, consistency, sensitivity. (C2, A2)
- **Apply** modern engineering tools to multidisciplinary environmental engineering problem solving. (C3, A3)

After Professional Experience::

- **Evaluate** the benefits, risk, and uncertainty associated with the use of specific tools in analysis of environmental engineering projects. (C6, A5)

Outcome 4: In-Depth Competence

Advanced knowledge and skills essential for professional practice of environmental engineering

Outcome Explanation: In-depth competence based on advanced knowledge and skill is essential for professional practice of environmental engineering. This competence may be attained in a traditional specialty such as water/wastewater, it could span a range of traditional specialties, or it could focus on an emerging or non-traditional area such as ecological engineering or aspects of sustainability.

Baccalaureate Level:

- **Recognize and describe** the need for in-depth competence for solution of complex environmental problems. (C1, A2)
- **Describe** the traditional specialties as well as some emerging specialties appropriate to environmental engineering. (C2, A2)
- **Apply** specialized tools, methodology or technology to solve well-defined problems. (C3, A2)

M/30 Level:

- **Analyze** a predictable environmental process or system in a traditional or emerging area. (C4, A4)
- **Design** a predictable environmental process or system in a traditional or emerging area. (C5, A3)

After Professional Experience:

- **Design** and **implement** a complex system or process in a traditional or emerging area. (C5, A4)

Outcome 5: Risk, Reliability, and Uncertainty

The risks associated with human or environmental exposure to contaminants in our environment and uncertainty and reliability principles as they affect the engineered systems designed, built or operated to protect the environment and the public health, welfare and safety

Outcome Explanation: From an environmental engineering context, risks to humans or environmental systems can occur from exposure to physical, chemical and biological hazards or from the failure of engineered systems designed to protect the environment and the public health, welfare and safety. Risk is often defined as a measure of the probability and severity of adverse effects. Its assessment includes definition of context and system, exposure assessment, hazard identification, quantification of risk, and assessment of risk relative to specified criteria. Environmental engineers must use these assessments to determine what can be done, what options are available, and, the associated trade-offs in terms of costs, benefits, and risks, and the impacts of current decisions on future options (University of Virginia Center for Risk Management of Engineered Systems: http://www.sys.virginia.edu/risk/overview.html).

Baccalaureate Level:

- **Identify** potential hazards, exposure pathways, and risks to the environment and the public health, welfare and safety associated with exposure to physical, chemical and biological hazards. (C1, A1)
- **Identify** the modes for failure of a system engineered to protect the environment and the public health, welfare and safety and the resulting consequences of such a failure. (C1, A1)
- **Explain** the significance of uncertainties in data and knowledge on the performance and safety of an engineering system. (C2, A2)
- **Apply** the principles of probability and statistics to the design of a simple engineered component using data or knowledge-based uncertainties. (C3, A3)
- **Determine** the potential exposure and risk to the environment and the public health, welfare and safety for well-defined chemical and biological exposure and hazards. (C3, A3)

M/30 Level:

- **Analyze** the potential exposure and risk to the environment and exposed populations for multiple chemical and biological exposure routes and hazards. (C4, A4)
- **Analyze** the modes for failure of a system engineered to protect the environment and the public health, welfare and safety and quantify the resulting consequences of such a failure. (C4, A4)
- **Design** an engineered system applying the principles of probability and statistics to uncertainties in data or knowledge. (C5, A4)

After Professional Experience::

- **Assess** the risks of various engineering alternatives and integrate this assessment into the recommendation of an alternative. (C6, A5)
- **Employ** quantitative tools to analyze risk and reliability. (C6, A5)

Outcome 6: Problem Formulation and Conceptual Analysis

Problem formulation and analysis based on proper environmental engineering problem identification, obtaining background knowledge, development and analysis of alternatives, understanding existing requirements and/or constraints and recommendation of effective solutions

Outcome Explanation: Conceptual design includes assessing the engineering situation, articulating the problem through technical communication (written and/or oral), formulating alternative approaches, evaluating the alternatives, and recommending feasible solutions. Approaches should include systems analysis, development of solutions, both routine and creative; evaluation of alternative solutions and their environmental and economic consequences; and use of iterative process analysis and selection of the most appropriate solution(s), employing critical thinking and synthesis of fundamental knowledge appropriate to environmental engineering.

Baccalaureate Level:

- **Explain** key concepts related to problem recognition, articulation and solution. (C2, A2)
- **Recognize** difficulties requiring innovative problem definition and solutions. (C2, A2)
- **Analyze** a well-defined problem to identify the root cause. (C4, A2)

M/30 Level:

- **Apply** advanced level technical knowledge and problem analysis/solving skills to complex multidisciplinary problems. (C3, A3/A4)
- **Analyze** problems appropriate to environmental engineering having unpredictable or incomplete parameters to determine their root causes. (C4, A3)
- **Analyze** feasibility and appropriateness of predictable solutions as alternatives to conventional solutions to problems. (C4, A3)

After Professional Experience:

- **Synthesize** experience-acquired knowledge and skills to anticipate and identify unpredictable problems. (C5, A5)
- **Develop** means for supplementing inadequate data or definition. (C5, A5)
- **Evaluate** innovative solutions to complex real world problems and compare with conventional solutions based on environmental and economic consequences of implementation. (C6, A5)

Outcome 7: Creative Design

Design of a system, component or process to meet desired needs related to a problem appropriate to environmental engineering.

Outcome Explanation: Design is a creative and discovering process using iterative steps. Activities such as problem definition, stipulating problem specifications, analysis, performance prediction, implementation, and assessment are parts of this process. The design process is open-ended, frequently with a number of feasible solutions. Successful design requires creative and critical thinking, appreciation of uncertainties involved and use of engineering judgment.

Baccalaureate Level:

- **Define** problem objectives and specify design criteria. (C2, A3)
- **Recognize** realistic constraints such as economics, environmental, social, political, ethical, health and safety, constructability and sustainability factors appropriate to environmental engineering. (C2, A3)
- **Apply** creativity and knowledge domains of BEMS to design a system or process to meet desired needs. (C3, A3)
- **Analyze** predictable situations to determine design needs and requirements. (C4, A3)

M/30 Level:

- **Apply** creativity and knowledge domains of BEMS to design a real world system or process to meet desired needs. (C3, A4/A5)
- **Analyze** real world situations to determine design needs and requirements. (C4, A3/A4)
- **Assess** compliance with customary standards of practice, client's needs, and relevant constraints appropriate to environmental engineering to develop solutions to real world problems. (C5, A4)

After Professional Experience:

- **Assess** the needs of the public and other stakeholders in formulating design constraints and objectives. (C4, A3/A4)
- **Understand** the design of a predictable system, component or process appropriate to environmental engineering. (C5, A4)
- **Understand** the interactions among planning, design, life-cycle assessment, construction and operational management appropriate to environmental engineering. (C6, A4)
- **Evaluate** design proposals appropriate to environmental engineering as part of the peer review process. (C6, A4)

Outcome 8: Sustainability

Integration of the sustainability into the analysis and design of engineered systems

Outcome Explanation: As defined by several engineering professional societies, the constraints imposed by the long-term sustainability of our natural and social systems must be a critical factor in the design and selection of engineered systems. For example, in June 2002, AAES, AIChE, ASME, NAE, and NSPE signed the following declaration (NAE, "Dialog on the Engineers' Role in Sustainable Development – Johannesburg and Beyond," 2002).

> *Creating a sustainable world that provides a safe, secure, healthy life for all peoples is a priority for the US engineering community. … Engineers must deliver solutions that are technically viable, commercially feasible and, environmentally and socially sustainable.*

This has led to a statement adopted in 2006 by NSPE that was added to its Code of Ethics as a professional obligation of engineers:

> *Engineers shall strive to adhere to the principles of sustainable development in order to protect the environment for future generations.*

For the purposes of this document, the term sustainability is defined (ASCE, 2008) as:

> *Sustainability is the ability to meet human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and enhancing environmental quality and the natural resource base essential for the future. Sustainable engineering meets these human needs.*

The environmental engineer has a critical role in the emerging subdiscipline of sustainable engineering. It is expected that environmental engineers have sufficient understanding of natural system processes, that is - how our earth functions, to help define the extent of environmental alteration that may result from different engineered systems. At the same time, they must also integrate sustainability principles into the engineered systems they themselves design, build or operate to protect environmental and human health and well being.

Baccalaureate Level:

- **Recognize** life-cycle principles in the context of environmental engineering design. (C1, A2)
- **Identify** components in an engineered system that are not sustainable. (C2, A2/A3)
- **Explain** the scientific basis of natural system processes and the impacts of engineered systems on these processes. (C2, A2/A3)
- **Explain** the need for and ethics of integrating sustainability throughout all engineering disciplines and the role environmental engineers have in this. (C2, A2/A3)
- **Quantify** environmental releases or resources consumed for a given engineered process. (C3, A3)

M/30 Level:

- **Analyze** the sustainability of an engineered system using traditional or emerging tools (e.g., industrial ecology, life cycle assessment, etc.). (C4, A3/A4)
- **Ascertain** where new knowledge or forms of analysis are necessary for sustainable design. (C4, A3/A4)
- **Design** traditional or emerging engineered systems using principles of sustainability. (C5, A4)

After Professional Experience:

- **Design** a complex system, process, or project to perform sustainably. (C5, A5)
- Evaluate the sustainability of complex systems, whether proposed or existing (ASCE, 2008). (C6, A5)

Outcome 9: Multimedia Breadth and Interactions

Application of BEMS to predict and determine fate and transport of substances in and among air, water and soil as well as in engineered systems

Outcome Explanation: Environmental engineers must have a holistic view of the environment so that pollutants removed from one medium do not cause problems by transfer to another. They must be able to apply fundamental principles to fate and transport of substances not only within a single medium but also to the transfer between media in natural or engineered systems. It follows that environmental engineers must understand the principles that govern inter-media transfer and must be able to consider the impact of this transfer in problem formulation and design. The situation is complicated by laws and regulations that consider only single media.

Baccalaureate Level:

- **Explain** how inter-media transfer is relevant to environmental engineering problems. (C2, A2)
- **Apply** conservation and transport principles to determine the fate of substances in air, water, and soil for well-defined situations. (C3, A3)
- **Apply** the fundamental principles governing transfer of substances between phases to well-defined situations e.g. where equilibrium assumptions apply. (C3, A3)

M/30 Level:

- **Apply** fundamental principles governing inter-media transport and fate of substances to a complex situation, e.g. where mass transfer is rate limited. (C3, A4)
- **Analyze** a system that incorporates inter-media transport and fate of pollutants. (C4, A3/A4)

After Professional Experience:

- **Design** a system that incorporates inter-media transport and fate of substances. (C5, A5)
- **Appraise** the laws and regulations that pertain to the air, water and land environment applicable to a specific practice area. (C6, A5)

Outcome 10. Societal Impact and Environmental Policy

Societal impact of environmental engineering issues and solutions; engineering and communication skills that influence and implement public environmental policy

Outcome Explanation: Public policy consists of political decisions for implementing programs to achieve societal goals (Cochran, C.L. and Eloise F. Malone (2005), *Public Policy: Perspective and Choices, Third Edition*, Lynn Rieneer Publishers, Boulder, CO.). As concluded in NAE's *The Engineer of 2020*, as technology becomes more ingrained in our lives, the convergence of engineering and public policy must increase. Because environmental engineers are regularly involved in the implementation of public environmental policy, they have a unique understanding of the elements of good environmental policy. It follows that they should be involved as stakeholders in the process of establishing environmental policies. Further, environmental engineers should recognize societal impacts of engineering activities, should communicate these impacts to stakeholders, and should consider stakeholder inputs in developing solutions.

Baccalaureate Level:

- **List** some important environmental policies as stated in international accords and federal laws. (C1, A2)
- **Recognize** potential societal impacts of a solution to an environmental problem. (C2, A3)
- **Discuss** and **explain** important processes involved in setting public environmental policy. (C2, A3)

After Professional Experience:

- **Describe** and **explain** environmental policy in some detail in some area of environmental practice. (C2, A3)
- **Apply** knowledge of societal structure and dynamics when seeking solutions to environmental problems. (C3, A3)
- **Participate** as a citizen stakeholder in the development of public environmental policy. (C3, A3)

Outcome 11: Globalization and other Contemporary Issues

Globalization and other contemporary issues vital to environmental engineering

Outcome Explanation: Contemporary issues are problems and topics of emerging importance or recent discovery. Globalization refers to an integration of processes or delivery systems that transcends national, cultural and language differences. For example, awareness of the impact of inadequate sanitation on public health in many parts of the developing world and the impact of human activity on climate change are issues that are both global and contemporary. The environmental engineer must be able to function in a global system for delivery of engineering projects and services practice, taking into consideration the culturally appropriateness of technology. In addition, the environmental engineer must be aware of emerging contemporary issues and of their impact on the profession.

Baccalaureate Level:

- **Explain** some barriers to the delivery of environmental engineering services in a global context. (C2, A3)
- **Utilize** modern tools to identify and understand contemporary issues. (C3, A3)
- **Define**, **analyze** and **propose** solutions to well-defined environmental engineering problems that are constrained by global and contemporary issues. (C4, A3)

M/30 Level:

- **Describe** how globalization of technology has influenced design and/or project delivery within a technical area of environmental engineering. (C2, A3)
- **Participate** in discussion and debate focused on globalization and contemporary issues and their relationship with and potential impact on public health and the environment. (C3, A3)
- **Synthesize** information on contemporary issues to provide perspective on relevance to environmental engineering problems. (C5, A4)

After Professional Experience:

- **Evaluate** the impact of an important globalization and/ other contemporary issue on design and/or delivery of an environmental engineering project or case study. (C6, A5)

Outcome 12: Multi-Disciplinary Teamwork to Solve Environmental Problems

Skills and expertise of multiple disciplines used to address complex engineering problems as a team

Outcome Explanation: The solutions of most engineering problems require the expertise and participation of a variety of disciplines. The environmental engineer will use management and communication skills to create, manage, and/or participate in teams composed of professionals from a broad range of disciplines. This requires understanding team formation and evolution, individual characteristics, team dynamics, collaboration among diverse disciplines, problem solving, time management and an ability to foster and integrate diversity of perspectives, knowledge, and experiences (ASCE, 2008).

Baccalaureate Level:

- **Identify** disciplines necessary to solve a complex environmental engineering problem. (C1, A3)
- **Describe** the characteristics of an effective team. (C2, A3)
- **Function** in an environmental engineering team to design and implement solutions. (C3, A3)

After Professional Experience:

- **Function** effectively in multi-disciplinary team activities. (C3, A4/A5)

Outcome 13: Professional and Ethical Responsibilities

Professional and ethical issues in environmental engineering

Outcome Explanation: Whereas morals are values relating to how humans ought to treat each other, ethics are rules for how humans ought to treat each other in the absence of detailed moral values or when moral values conflict. Moral behavior, in both personal and professional matters, is expected of all environmental engineers. Professional ethics for engineers is spelled out in the various codes of ethics such as those adopted by ASCE, NSPE, and AIChE. Often these codes provide guidance on how moral dilemmas can be honorably resolved, but sometimes the engineer is asked to make morally-significant decisions that do not have simple or straightforward resolutions. Ethical decision-making is thus a useful and required skill for all professional engineers.

In environmental engineering, professional ethics is complicated by the responsibility engineers have for preserving our natural environment. Natural ecosystems support human existence, and thus service to the public must include the preservation of species and habitats. In addition, environmental engineers recognize that all of nature has intrinsic value and that preventing the despoilment and destruction of the natural environment is part of their professional responsibility.

Baccalaureate Level:

- **Recognize** moral and ethical problems that might arise in engineering practice. (C1, A2)
- **Explain** tenets of professionalism and codes of engineering ethics. (C2, A2)
- **Apply** standards of professionalism and codes of engineering ethics to determine an appropriate course of action for a given environmental engineering situation. (C3, A2)

M/30 Level:

- **Analyze** an environmental engineering situation involving conflicting ethical and professional interests to determine an appropriate course of action. (C4, A4)

After Professional Experience:

- **Describe** a situation based on personal experience with environmental engineering situations and course of action that illustrates professional and ethical behavior. (C5, A5)
- **Assess** personal professionalism and ethical development. (C6, A5)

Outcome 14: Effective Communication

Effective communications when interacting with the public and the technical community

Outcome Explanation: The environmental engineer is frequently the critical link to public understanding and interpretation of environmental policy, issues, and implementation of plans for projects that affect public health and the environment. The environmental engineer must communicate using verbal, written, virtual, and graphical means to describe a concept, an environmental degradation or enhancement issue, and / or a project affecting the environment to technical and non-technical audiences, and receive and interpret communications in return.

Baccalaureate Level:

- **Describe** the characteristics of effective verbal, written, virtual and graphical communications. (C2, A3)
- **Apply** the rules of grammar and composition in verbal and written communications, properly cite sources. (C3, A3)
- **Use** appropriate graphical standards in preparing engineering documents and presentations. (C3, A3)
- **Summarize** the essential points and elements of verbal and written communications received from others. (C4, A3)
- **Organize** and deliver effective verbal, written, virtual, and graphical communications. (C5, A3)

M/30 Level:

- **Make** effective presentations to technical audiences. (C3, A3)
- **Interpret** the intent and content of communications from technical and non-technical stakeholders in a concept or project. (C4, A4)
- **Plan**, **compose**, and **integrate** the verbal, written, virtual and graphical communication of a concept or project to technical and non-technical audiences. (C5, A4)
- **Communicate** the concept of uncertainty and risk to technical and non-technical audiences. (C5, A4)
- **Develop** conclusions that logically follow from data results and discussion. (C5, A4)

After Professional Experience:

- **Make** effective presentations to technical and non-technical audiences. (C3, A3)
- **Evaluate** the effectiveness of the integrated verbal, written virtual and graphical communication of a concept or a project to technical and non-technical audiences. (C6, A5)
- **Evaluate** the accuracy of interpretations of communications from technical and non-technical stakeholders in a concept or project. (C6, A5)

Outcome 15: Lifelong Learning

Life-long learning leading to enhanced skills, awareness of technology, regulatory, industrial, and public concerns

Outcome Explanation: Environmental engineering is an ever-developing profession, where environmental concerns multiply with additional complexity of society, and with the development and use of more complex materials that are frequently toxic or otherwise disruptive to the environment and to public health, welfare and safety. Demand for efficiency in processes, including processes for environmental risk management, requires awareness of impacts and developing technology; accordingly, life-long learning is essential to environmental engineering.

Baccalaureate Level:

- **Define** life-long learning. (C1, A3)
- **Explain** the need for life-long learning. (C2, A3)
- **Describe** the skills required of a life-long learner. (C2, A3)
- **Demonstrate** the ability for self-directed learning. (C3, A2)

M/30 Level:

- **Identify** additional knowledge, skills and attitudes appropriate for continued practice at the professional level. (C4, A3)
- **Integrate** self-directed learning of issues that apply to environmental engineering. (C5, A4)

After Professional Experience:

- **Plan** a regimen of continued learning to maintain proficiency. (C5, A5)
- Regularly **acquire** additional expertise and **maintain** skills and appropriate current knowledge. (C6, A5)

Outcome 16: Project Management

Principles of project management relevant to environmental engineering

Outcome Explanation: Project Management is the application of knowledge, skills, tools, and techniques to project activities to meet project requirements. Project management is accomplished through the application and integration of the project management processes of initiating, planning, executing, monitoring and controlling, and closing (Project Management Institute 2004, *A Guide to the Project Management Body of Knowledge – Third Edition*, Newtown Square). Meeting project budget, scope, and schedule are the primary goals of project management.

Baccalaureate Level:

- **List and explain** project management processes and principles. (C1/C2, A2)
- **Explain** how project management and construction relate to the project delivery process. (C2, A2)
- **Solve** well defined project management problems. (C3, A2)

M/30 Level:

- **Apply** project management to a project. (C3, A3)

After Professional Experience:

- **Create** documents to be incorporated into a project management plan as a member of an engineering team. (C5, A5)
- **Create** to project management plans as a member of an engineering team. (C5, A5)

Outcome 17: Business and Public Administration

Business knowledge and communication skills for administration of both private and public organizations

Outcome Explanation: Environmental engineers typically deal with both private and public organizations, and they must understand business fundamentals such as organizational structure, income statements and balance sheets as well as public administration fundamentals such as the political process, regulations, asset management and funding processes. Asset management is a business process and a decision making framework that covers an extended time, and draws from both economics and engineering. Many environmental engineers use asset management principles in managing and maintaining environmental infrastructure.

Baccalaureate Level:

- **List and describe** important fundamentals of business and of public administration related to environmental engineering. (C1/C2, A2)

After Professional Experience:

- **Analyze** problems involving business and public administration as they relate to environmental problems. (C4, A4)

Outcome 18: Leadership

Engaging, motivating and leadership of others to achieve common vision, mission and goals

Outcome Explanation: Leadership is the art and science of influencing others toward achieving common goals (ASCE, 2008). Leadership abilities are important for success in all professional endeavors, and especially where teamwork is involved. Because many environmental engineering projects require that several individuals work collectively toward common goals, leadership abilities are critical for the environmental engineer. Leadership requires technical competence, continuous self-improvement, timely and responsible decision making, self-confidence effective communication, and moral behavior. Attributes of leaders include vision, enthusiasm, energy, commitment, selflessness, discipline, confidence, communication skills, and persistence. These abilities and attributes can be taught and developed in both formal education and engineering practice (ASCE, 2008). Examples of opportunities to develop leadership within the educational setting include leading design teams, team competitions, student organizations, and athletic teams. Leadership should be further developed during the professional career in real-world settings. Senior engineers should mentor junior engineers and provide opportunities for leadership.

Baccalaureate Level:

- **Define** leadership and the role of a leader. (C1, A2)
- **List** leadership skills and attributes. (C1, A2)
- **Explain** the role of a leader, leadership skills, and leadership attributes. (C2, A2)
- **Apply** leadership skills to direct the efforts of a small group. (C3, A2)

After Professional Experience:

- **Organize** and **direct** the efforts of a group to achieve a goal. (C3, A2)

PLANNING FOR CARBON-NEUTRAL DESALINATION IN CARLSBAD, CALIFORNIA

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ABSTRACT

Greenhouse gas (GHG) emissions associated with production of desalinated seawater at the 50 MGD Carlsbad project in California are planned be mitigated by a portfolio of alternative technologies and measures including advanced energy reduction technologies, implementation of renewable energy projects, and carbon dioxide sequestration. This paper describes the methodology used to determine the carbon footprint for the Carlsbad desalination project and presents the scope and costs associated with the various GHG emission initiatives planned for this project.

INTRODUCTION

Over the past five years desalination has gained a significant momentum in California. With more than ten projects in various stages of environmental review, design and construction, desalination is planned to provide 400 MGD to 500 MGD of new fresh drinking water supplies for the state by year 2015.

One of the largest and most advanced projects under development today is the 50 MGD Carlsbad seawater desalination plant (Figure 1). This project is collocated with the Encina coastal power generation station which currently uses seawater for once-through cooling. The Carlsbad seawater desalination project is developed as a public-private partnership between Poseidon Resources and eight local utilities and municipalities.

Since 1999 a team of planners, scientists, engineers, equipment manufacturers and environmental experts have been working on the development and evaluation of the desalination project. The environmental impact assessment and local land use permit for the Carlsbad desalination project were approved in the first half of 2006. In August 2006 the project was granted ocean discharge permit for disposal of the high-salinity concentrate generated during the reverse osmosis membrane separation process, and in November of 2007 the California Coastal Commission confirmed project viability. Project permitting is planned to be completed by September of 2008 and construction is expected to begin by the end of this year. The Carlsbad project is targeted to be in operation by mid-2011 and to supply 6 to 8% of the drinking water in San Diego County. When completed, this project would be the largest seawater desalination plant in the USA.

GREENHOUSE GAS EMISSIONS OVERVIEW

Gases that trap heat in the atmosphere are referred to greenhouse gases (US EPA, 2006). Some greenhouse gases such as carbon dioxide occur naturally and are emitted to the atmosphere through natural processes and human activities. Other greenhouse gases (e.g., fluorinated gases) are created and emitted solely through human activities. The principal greenhouse gases that enter the atmosphere because of human activities are:

- **Carbon Dioxide (CO_2)**: Carbon dioxide enters the atmosphere through the burning of fossil fuels (oil, natural gas, and coal), solid waste, trees and wood products, and as a result of other chemical reactions (e.g., manufacture of cement). Carbon dioxide is also removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.
- **Methane (CH_4):** Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.
- **Nitrous Oxide (N_2O):** Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.
- **Fluorinated Gases:** Hydro fluorocarbons, per fluorocarbons, and sulfur hexafluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases ("High GWP gases").

Changes in the atmospheric concentrations of these greenhouse gases can alter the balance of energy transfers between the atmosphere, space, land, and the oceans and ultimately result in global and local climate variability and permanent changes (NRC, 2001). Many elements of human society and the environment are sensitive to climate variability and change. Human health, agriculture, natural ecosystems, coastal areas, and heating and cooling requirements are examples of climate-sensitive systems.

FIGURE 1 Carlsbad Sewater Desalination Project

The extent of climate change effects, and whether these effects prove harmful or beneficial, will vary by region, over time, and with the ability of different societal and environmental systems to adapt to or cope with the change.

Rising average temperatures are already affecting the environment. Some observed changes include shrinking of glaciers, thawing of permafrost, later freezing and earlier break-up of ice on rivers and lakes, lengthening of growing seasons, shifts in plant and animal ranges and earlier flowering of trees (IPCC, 2007).

Global temperatures are expected to continue to rise as human activities continue to add carbon dioxide, methane, nitrous oxide, and other greenhouse (or heat-trapping) gases to the atmosphere. Most of the United States is expected to experience an increase in average temperature as a result of increase in greenhouse gas emissions (IPCC, 2007).

According to a recent US EPA GHG emission inventory, the primary greenhouse gas emitted by human activities in the United States in 2006 was CO_2, representing approximately 84.8 percent of total greenhouse gas emissions (US EPA, 2008). The largest source of CO_2, and of overall greenhouse gas emissions was fossil-fuel based production of electricity. The second largest source was transportation.

Although production/distribution of drinking water is not one of the top ten energy users in the country, in California 19% of the electric energy used state-wide is associated with water transfers and production (CEC, 2005). The main reason for this unusually high energy demand associated with water supply is that a large portion of the water used in southern California is delivered via long-distance in-state and out-of-state water transfers. To address the increasing global greenhouse emissions challenge, California enacted the Global Warming Solutions Act of 2006 which aims to reduce the greenhouse gas (GHG) emissions of the state to 1990 levels by year 2020. In response to this legislation, Poseidon made the commitment to completely offset the carbon footprint associated with desalination plant operations. The Climate Action Plan described herein outlines a portfolio of operational and design technologies and measures; green energy supply alternatives and carbon emission offset initiatives. The key components of the Climate Action Plan are described below.

ASSESSING PROJECT GROSS CARBON FOOTPRINT

The carbon footprint of the seawater desalination plant is the amount of greenhouse gases that would be released into the air from the power generation sources that will supply electricity for the plant. Usually, carbon footprint is measured in pounds or metric tons of carbon dioxide emitted per year. The total plant carbon footprint is dependent on two key factors: (1) how much electricity is used by the desalination plant; and (2) what sources (fossil fuels, wind, sunlight, etc.) are used to generate the electricity supplied to the plant. Both of these factors could be variable over time and therefore, the Climate Action Plan has to have the flexibility to incorporate such changes.

The Carlsbad seawater desalination plant is planned to be operated continuously, 24 hours a day and 365 days per year, and to produce an average annual drinking water flow of 50 MGD (1.89 x10^5 m^3/day). When the plant was originally conceived over five years ago, the total baseline power use for this plant was projected at 31.3 megawatts (MW) or 3.96 KWh/m^3 (15.03 KWh/1,000 gallons) of drinking water. This power use incorporates both production of fresh drinking water and conveyance, and delivery of this water to the distribution systems of the individual utilities and municipalities served by the plant.

However over the lengthy period of project permitting, the seawater desalination technology has evolved. By taking advantage of the most recently available state-of-the art technology for energy recovery and by advancing the design to accommodate latest high efficiency reverse osmosis system feed pumps and membranes, the actual project power use was reduced down to 13.48 KWh/1,000 gallons of drinking water. As a result, the total annual energy consumption for the Carlsbad seawater desalination project used to determine the plant carbon footprint is 246,000 MWh/yr as shown in Line 1 of Table 1. This energy use is determined for an annual average plant production capacity of 50 MGD. As actual production capacity may vary from year to year, so would the total energy use.

Next, in order to convert the desalination plant annual energy use into carbon footprint (CF), this use is multiplied by the electric grid emission factor (Emission Factor), which is the amount of greenhouse gasses emitted during the production of unit electricity consumed from the power transmission and distribution system:

CF ($lbsCO_2/yr$) = Annual Plant Electricity Use (MWh/yr) x Emission Factor (lbs of CO_2/MWh)

The actual value of the Emission Factor is specific to the supplier of electricity for the project, which is San Diego Gas and Electric (SDG&E) for the Carlsbad plant. Similar to other power suppliers in California, SDG&E determines their Emission Factor based on a standard protocol developed by the California Climate Action Registry (CCAR). CCAR was created by California Legislature (SB 1771) in 2001 as a non-profit voluntary registry for GHG emissions and is the authority in California that sets forth the rules by which GHG emissions are determined and accounted for.

Based on information provided in their most recent emissions report (CCAR, 2008) the SDG&E emission factor is 546.46 lbs of CO_2 per MWh of delivered electricity. At 246,000 MWh/yr of energy use and 546.46 lbs CO_2/MWh, the total carbon footprint for the Carlsbad seawater desalination project is calculated at 134.4 million lbs of CO_2 per year (61,100 metric tons CO_2/yr) as shwon in Line 1 of Table 1. This carbon footprint is reflective of the latest energy efficient design of the desalination plant. A more conventional desalination plant design (274,000 MWh/yr) would have a carbon footprint of 68,100 tons CO_2/yr.

It is important to note that the value of the emission factor is reduced with the increase of the portion of renewable power sources in the power supplier's energy resource portfolio. Because of the statewide initiatives and legislation to expand the use of renewable sources of electricity, the emission factors of all California power suppliers are expected to decrease measurably in the future. For example, currently approximately 10% of SGD&E's retail electricity is generated from renewable sources (solar radiation, wind, geothermal heat, etc.). In their most-recent Long-term Energy Resource Plan, SDG&E has committed to increase energy from renewable sources by 1% each year, reaching 20% by year 2017. This reduction will reduce the Carlsbad desalination plant carbon footprint over time, especially taking into consideration that the plant will not be fully operational before mid 2011.

OFFSETTING CARBON FOOTPRINT BY REDUCED WATER IMPORTS

Currently, San Diego County imports 90% of its water from two sources – the Sacramento Bay – San Joaquin River Delta, traditionally known as the "Bay-Delta", and the Colorado River. This imported water is captured, released and conveyed via a complex system of intakes, dams, reservoirs, aqueducts and pump stations (State Water Project), and treated in conventional water treatment plants prior to its introduction to the water distribution system. The total amount of electricity needed to deliver this water to San Diego County via the State Water Project facilities is 10.45 KWh/1,000 gallons (2.76 KWh/m^3), which includes 9.93 KWh/1,000 gallons (2.62 KWh/m^3) for delivery, 0.21 KWh/1,000 gallons (0.06 kWh/m^3) for evaporation losses, and 0.31 KWh/1000 gallons (0.08 KWh/m^3) for treatment.

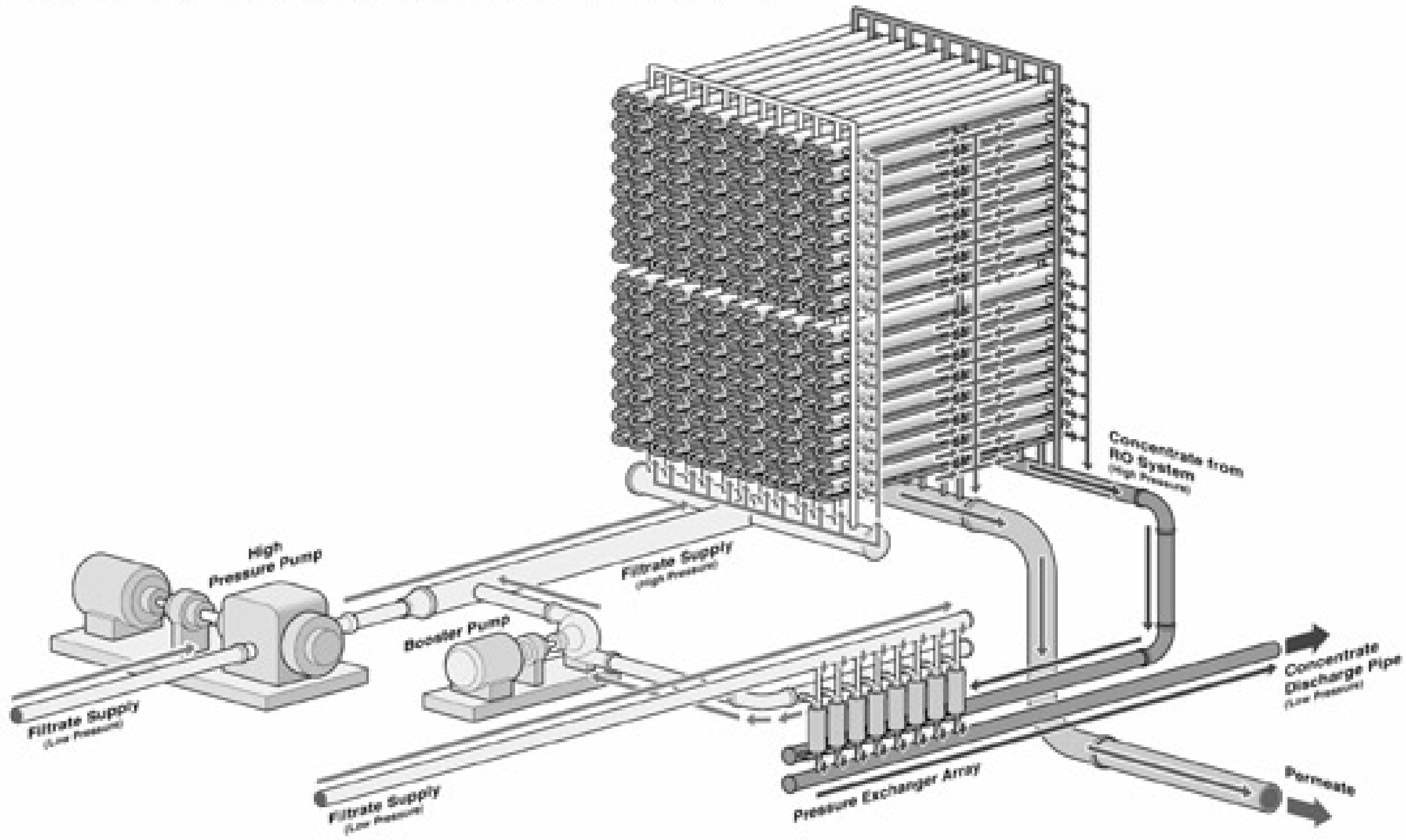
Over the past decade the availability of imported water from the State Water Project has been in steady decline due to prolonged drought, climate change patterns and environmental, and population growth pressures. One of the key reasons for the

TABLE 1 Desalination Project Net GHG Emission Zero Balance

Source	Total Annual Power Use (MWh/year)	Total Annual Emissions (tons CO_2/year)
Carbon Dioxide Emission Generation		
1. Seawater Desalination and Product Water Delivery – High Energy Efficiency Design	246,000	61,100
2. Carbon Emission Reduction Due to Reduced Water Imports	190,700	47,400
3. Total Net Power Use & Carbon Emissions (Item 1 - Item 2)	**55,300**	**13,700**
On-Site Carbon Dioxide Emissions Reductions		
4. Energy Efficient Plant Design	Accounted for in Item 1	Accounted for in Item 1
5. Use of Warm Cooling Water	(12,300)	(3,100)
6. Green Building Design	(500)	(124)
7. On-site Solar Power Generation	(777)	(193)
8. Use of CO_2 for Water Production	NA	(2,100)
9. Reduced Energy for Water Reclamation	(1,950)	(484)
10. Subtotal On-site Power/GHG Emission Reduction (Sum of Items 4 through 9)	(15,527)	(6,001)
Off-site Carbon Dioxide Emission Mitigation		
11. CO_2 Sequestration by Re-vegetation of Wildfire Zones	(NA)	(166)
12. CO_2 Sequestration in Coastal Wetlands	(NA)	(304)
13. Regional Green Power Generation Projects (*see Table 3*)	(2,260)	(561)
14. Other Carbon Offset Projects and Purchase of Renewable Credits	(37,513)	(6,668)
15. Subtotal Off-site Power/GHG Mitigation Reduction (Sum of Items 11 through 14)	(39,773)	(7,699)
Total Net CHG Emission Balance (Item 3 - Item 10 - Item 15)		0

Notes: NA – Not Applicable. Numbers in Parentheses Indicate Reduction.

FIGURE 2 Energy Recovery System for the Carlsbad Seawater Desalination Plant



development of the Carlsbad seawater desalination project is to replace 50 MGD of the water imported via the State Water Project with fresh drinking water produced locally by tapping the ocean as an alternative drought-proof source of water supply. Because the desalination project will offset the import of 50 MGD of water via the State Water Project, once in operation, this project will also offset the electricity consumption of 10.45 KWh/1,000 gallons, and the GHG emissions associated with pumping, treatment and distribution of this imported water. The annual energy use for importing 50 MGD of State Water Project water is therefore, 190,700 MWh/yr calculated as (0.45)(50)(365). At 546.46 lbs CO_2/MWh, the total carbon footprint of the water imports that will be offset by desalinated water is therefore, 104.2 million lbs of CO_2 per year (47,400 metric tons CO_2/yr).

Taking under consideration that the gross carbon footprint of the desalination plant is 61,100 metric tons CO_2/yr, and that 47,400 metric tons CO_2/yr (77.4%) of these GHG emissions would be offset by reduction of 50 MGD of water imports to San Diego County, the Carlsbad desalination plant's net carbon footprint is estimated at 13,700 metric tons CO_2/yr. Lines 1-3 of Table 1 summarize the total annual power use and emissions, the power and emission reduction attributable to reduced water imports, and the net power use and net annual emissions.

CLIMATE ACTION PLAN FOR NET CARBON FOOTPRINT REDUCTION

The main purpose of the Climate Action Plan (CAP) for the Carlsbad seawater desalination project is to eliminate plant's net carbon footprint by implementing measures for: energy efficient facility design and operations; green building design; use of carbon dioxide for water production; on-site solar power generation; carbon dioxide sequestration by creation of coastal wetlands and reforestation; funding renewable power generation projects, and acquisition of renewable energy credits. Project carbon neutrality would be achieved by a balanced combination of these measures.

The size and priority of the individual projects included in the Climate Action Plan will be determined based on a life-cycle cost-benefit analysis and overall benefit for the local community. Implementation of energy efficiency measures for water production, green building design, and carbon dioxide sequestration projects in the vicinity of the project site will be given the highest priority.

The project Climate Action Plan is a living document that has to be updated periodically in order to reflect the improvements in desalination and green energy generation technologies. Once the Carlsbad seawater desalination plant is operational, the actual carbon footprint will be verified at the time of plant startup and will be updated periodically to account for changes in the power supplier's Emission Factor, and to recognize actual performance of the carbon footprint reduction initiatives. Periodic assessment and re-prioritization of these initiatives is important because both desalination technology and green power generation (i.e., solar, wind and bio-fuel-based power) are expected to undergo accelerated development over the next decade as they evolve from marginal to mainstream sources of

FIGURE 3 Tampa Bay Desalination Plant Pelton Wheel Energy Recovery System

TABLE 2 Unit Costs of Carbon Footprint Reduction Alternatives

Alternative	Unit Cost (US$/ton CO_2 reduced)
Green Building Design	3,400
On-site Solar Power Generation	1,900
CO_2 Sequestration in Coastal Wetlands	400
CO_2 Sequestration by Re-vegetation of Wildfire Zones	200
Use of CO_2 for Water Production	70

water supply and power supply, respectively. The specific carbon footprint reduction measures incorporated in the Carlsbad Climate Action Plan, and their key benefits and constraints are discussed below.

Energy Efficient Design and Operations

Over 50% of the energy used at the Carlsbad seawater desalination plant is applied for salt-fresh water separation by reverse osmosis. The seawater desalination project design incorporates a number of features that minimize plant energy consumption. One of them is a state-of-the art pressure exchanger-based energy recovery system that allows recovering and reusing 33.9% of the total initial energy applied for salt separation. After membrane separation, most of the energy applied for desalination is retained in the concentrated stream ("brine") that also contains the salts removed from the seawater. This energy bearing stream (shown as the high pressure condensate from the RO system in Figure 2) is applied to the back side of the pistons of cylindrical isobaric chambers (shown as the Pressure Exchanger Array in Figure 2). These pistons pump approximately 45 to 50% of the seawater fed into the reverse osmosis membranes for desalination. Since a small amount of energy (4 to 6%) is lost during the energy transfer from the concentrate to the feed water, this energy is added back to feed flow by small booster pumps. The reminder (45 to 50%) of the feed flow is pumped by high-pressure centrifugal pumps equipped with high-efficiency motors.

The pressure exchanger energy recovery system is projected to recover 10,200 hp (7.6 MW) of power and yield 2,650 hp (1.98 MW) of additional power savings as compared to the energy that could be recovered using standard energy recovery equipment (pelton wheels). Pelton wheels are presently employed at most large seawater desalination plants worldwide, including at the 25 MGD seawater desalination plant in Tampa, Florida (see Figure 3).

In addition to the state-of-the-art pressure exchanger energy recovery technology, the Carlsbad desalination plant design incorporates variable frequency drives on seawater intake pumps, filter effluent transfer pumps, and product water pumps as well as premium efficiency motors for all large pumps in continuous operation. Installation of premium-efficiency motors and variable frequency drives on large pumps would result in additional 1.26 MW (4%) power savings. Harnessing, transferring and reusing the energy applied for salt separation at very high efficiency by the pressure exchangers allows reducing the overall amount of electric power used for seawater desalination with over 11.5% (3.24 MW) as compared to standard designs of similar facilities. These savings correspond to a total annual electricity use reduction of 28,380 MWh/yr and a carbon footprint reduction of 7,000 tons of CO_2/yr and, as shown in Line 4 of Table 1, are already accounted for by the High Energy Efficiency Design figures used in Line 1 of Table 1.

Over 80% of the desalination plant piping would be made of low-friction fiberglass reinforced plastic (FRP) and high-density polyethylene (HDPE) materials, which in turns would yield additional energy savings for seawater conveyance. The desalination plant operations will be fully automated, thereby reducing plant staff requirements and associated GHG emissions for staff transportation and services.

Use of Warm Cooling Water

Osmotic pressure that has to be overcome in order to produce fresh drinking water decreases with the increase of seawater temperature. Therefore, desalination of warmer seawater requires less energy. The Carlsbad seawater desalination plant will be collocated with the Encina power plant (see Figure 1) and its intake will be connected to the cooling water canal to take advantage of the warmer seawater discharged by the power plant. The difference between the average annual temperatures of the ambient ocean seawater and the warm seawater which will be used as source water for the desalination plant is 5.5° C. Based on pilot testing results, this temperature increment is

FIGURE 4 Solar Panel Rooftop System

TABLE 3 Regional Carbon Footprint Offset Projects

Desalination Project Public Partner (Proponent of Green Power Generation Facility)	Green Power Project Description	Annual Capacity of Green Energy Projected to be Generated by the Project (MWh/yr)
City of Encinitas	95 KW Solar Panel System Installed on City Hall Roof	160
Valley Center Municipal Water District	1,000 KW Solar Panel System	1,680
Rainbow Municipal Water District	250 KW Solar Panel System	420
	Total Green Power Generation Capacity (MWh/yr)	2,260

projected to result in 5% of additional energy savings and carbon footprint reduction, as compared to desalinating cold seawater of ambient temperature. This amounts to 12,300 MWh/yr and 3,100 tons/CO_2 per year energy saving sand carbon footprint reduction. These savings in power and emissions are shown in Line 5 of Table 1.

There are no additional capital and operations costs to use warm water from the power plant once-trough cooling system. Therefore, when the power plant is operational the desalination plant will use only warm cooling water. When the power plant is down the desalination plant intake is designed to collect cold seawater from the same intake.

Green Building Design

The desalination plant will be located on a site currently occupied by a dilapidated unused fuel oil storage tank. This tank and its content will be removed and the site will be reclaimed and reused to construct the desalination plant. Reclaiming the land will reduce project imprint on the environment as compared to using a new undisturbed site.

A key "green" feature of the Carlsbad seawater desalination plant design is its compactness. The desalination plant facilities will be configured as series of structures sharing common walls, roofs and equipment. The total area occupied by the desalination plant facilities would be less than 5 acres. When built, this would be the smallest footprint desalination plant in the world per unit production capacity (5 acres per 50 MGD). By comparison, the 25 MGD Tampa Bay seawater desalination plant occupies 8 acres; the 73 MGD Orange County Groundwater Recharge Project, which also uses a reverse osmosis system, occupies approximately 40 acres; and the 86 MGD Ashkelon, Israel seawater desalination plant, which currently is the largest seawater reverse osmosis facility in the world, occupies 24 acres. A plant with a smaller physical footprint would also yield a smaller construction-related carbon footprint and lower construction material expenditures.

Plant building design will follow the principles of the Leadership in Energy and Environmental Design (LEED) program. This is a program of the United States Green Building Council and is developed to promote construction of sustainable buildings that reduce the overall impact of building construction and functions on the environment by: (1) sustainable site selection and development; (2) energy efficiency; (3) materials selection; (4) indoor environmental quality, and (5) water savings.

Consistent with the principles of the LEED program, the desalination plant buildings will include features and materials that minimize energy use for lighting, air conditioning and ventilation. For example, a portion of the walls of the main desalination plant building will be equipped with translucent panels to maximize daylight use and views to the outside. Non-emergency interior lighting will be automatically controlled to turn-off in unoccupied rooms and facilities. A monitoring system will ensure that the ventilation in the individual working areas in the building is maintained at its design minimum requirements. In addition, building design will incorporate water conserving fixtures (lavatory faucets, showers, water closets, urinals, etc.) for plant staff service facilities and for landscape irrigation. The plant buildings will utilize low emitting paints, coatings, adhesives, sealants and carpet systems. The building design team will include professional engineers that have achieved the LEED Accredited Professional designation and are well experienced with the design and construction of green buildings.

The additional costs associated with the implementation of the green building design as compared to the costs for a standard building are estimated at US$5 million and the potential energy savings are approximately 500 MWh/yr. The potential carbon footprint reduction associated with this design is 124 tons of CO_2 per year (0.9% of the net power plant footprint). The unit cost of carbon footprint reduction associated with green building design was estimated for project life of 30 years and 6.5% interest (capital recovery factor of 0.07657). At capital costs of US$5 million, the annualized cost of this capital investment is US$382,850/yr. Because of the higher level of complexity and automation of the "green building" design, as compared to conventional design, the additional O&M costs associated with the "green" systems of the building are US$34,650/yr. Therefore, the total annual costs associated with this design are estimated at US$417,500/yr. At 124 tons of CO_2 reduction per year, this annualized cost corresponds to unit carbon footprint reduction cost of US$3,400/ton CO_2 as shown in Table 2.

The total actual energy reduction that would result from green building design will be verified by a LEED compliance review during plant commissioning. The LEED-review process will be completed by an independent third party consultant certified to complete such reviews.

On-site Solar Power Generation

One enhancement of the green building design is the installation of rooftop photovoltaic (PV) system for solar power generation (see Figure 4). The main desalination plant building would have a roof surface of approximately 50,000 square feet, which would be adequate to house a solar panel system that could generate approximately 777 MWh/yr of electricity and reduce the net carbon footprint of the desalination plant by 193 metric tons of CO_2 per year, which is approximately 1.4% of the net desalination plant carbon footprint of 13,700 tons of CO_2 per year.

The construction cost of the rooftop solar power system is estimated at US$4.1 million. The annualized capital cost of power generation using this alternative is US$313,937/yr (@ 30 years and 6.5%). In addition, the annual operation and maintenance costs for this system are estimated at US$52,763/yr. Therefore, the total annual costs for operation of this system are estimated at US$366,700/yr, which /yr which corresponds to unit cost of generated electricity of 47.2 cents/kWh (US$366,700/yr /(777,000 KWh/yr = US$47.19/KWh). This unit cost is approximately five times higher than the cost of power supply from the electric grid. The unit cost of carbon footprint reduction for this alternative is US$1,900/ton of CO_2 as shown in Table 2.

Use of Carbon Dioxide for Water Production

Approximately 2,100 tons of CO_2 per year are planned to be used at the desalination plant for post-treatment of the fresh water (permeate) produced by the reverse osmosis (RO) system. Carbon dioxide in a gaseous form will be added to the RO permeate in combination with calcium hydroxide or calcium carbonate in order to form soluble calcium bicarbonate which adds hardness and alkalinity to the drinking water for distribution system corrosion protection. In this post-treatment process of RO permeate stabilization, gaseous carbon dioxide is sequestered into soluble form of calcium bicarbonate. Because the pH of the drinking water distributed for potable use is in a range of 8.3 to 8.5 at which CO_2 in a soluble bicarbonate form, the carbon dioxide introduced in the RO permeate would remain permanently sequestered in this form and ultimately would be consumed with the drinking water.

A small quantity of carbon dioxide used in the desalination plant post-treatment process is sequestered directly from the air when the pH of the source seawater is adjusted by addition of sulfuric acid in order to prevent RO membrane scaling. However, almost all is obtained from commercial suppliers. Depending on the supplier, carbon dioxide is produced either by a Generating Plant or a Recovery Plant. Generating Plants use various fossil fuels (natural gas, kerosene, diesel oil, etc.) to produce this gas by fuel combustion. Recovery Plants produce carbon dioxide by recovering it from the waste streams of other industrial production facilities which emit CO_2-rich gasses: breweries, commercial alcohol (i.e., ethanol) plants; hydrogen and ammonia plants, etc. Typically, if these gases are not collected via a CO_2 Recovery Plant and used in other facilities, such as the desalination plant, they are emitted to the atmosphere and therefore, constitute a GHG release.

The Carlsbad desalination plant will use only carbon dioxide produced by CO_2 Recovery Plants. This requirement will be enforced by requiring the commercial supplier of carbon dioxide for the desalination plant operations to provide a certificate of origin of each load of this water treatment chemical delivered to the plant site. This would encourage and incentivize the commercial suppliers and manufacturers of CO_2 to recover this gas from industrial waste streams rather than to generate new gas by combustion, and thereby to prevent its release to the atmosphere. Sequestration of CO_2 at the desalination plant by its conversion from gaseous to chemically bounded soluble form is therefore considered a desalination plant carbon footprint reduction alternative. By sequestering 2,100 tons of CO_2 per year in the desalination plant post-treatment process (see line 8 of Table 1), the net carbon footprint of the plant (13,700 tons of CO_2/yr would be reduced by 15.3%). At annual expenditure for carbon dioxide supply of approximately US$147,000/yr, this carbon footprint reduction alternative is very cost-competitive (US$70/ton CO_2) as shown in Table 2.

Carbon Emissions Offset by Reducing Energy Needs for Water Reclamation

The Carlsbad Municipal Water District owns and operates a 4 MGD water reclamation plant which consists of advanced tertiary treatment facilities for the entire flow plus a 1 MGD brackish reverse osmosis water desalination system, which at present uses 1,950 MWh of electricity per year. The purpose of the brackish water desalination plant is to reduce the salinity of the treated effluent from 1,400 mg/L to below 1,000 mg/l in order to make the effluent suitable for irrigation. The current high level of salinity of the reclaimed water is mainly due to the relatively high salinity of the City's drinking water which could reach 1,000 mg/l at times.

Once the Carlsbad seawater desalination plant is in operation and completely replaces the existing high-salinity drinking water, the salinity of the City's reclaimed water is projected to be reduced by half. Therefore, the replacement of the existing City high-salinity imported water supply with desalinated water would eliminate the need for operation of the 1 MGD brackish water desalination plant at the Carlsbad Water Recycling Facility. This in turns would reduce the carbon footprint of the Carlsbad Water Reclamation Facility by 1,950 MWh x 546.46 lbs of CO_2 /MWh =

1,065,957 lbs of CO_2/yr (484 tons of CO_2/yr). Since this GHG reduction is directly credited to the seawater desalination plant operations, the Carlsbad desalination plant's carbon footprint could be reduced by 3.5%. The carbon footprint credit associated with reduced energy for water reclamation is presented in line 9 of Table 1.

Carbon Dioxide Sequestration by Re-vegetation in Wildfire Zones

Almost every year parts of San Diego County are exposed to measurable loss of forest, urban and suburban trees due to large wildfires. For example, in 2007 San Diego wildfires burned over 35,000 acres, including forests, tree farms, and urban forestry. A specific annual carbon offset program required by the California Coastal Commission is the revegetation of areas in the San Diego region impacted by the wildfires that occurred during the fall of 2007. In response to this program Poseidon has committed to investing US$1.0 million in reforestation activities.

More specifically, when Poseidon updates Carlsbad desalination plant's net carbon footprint for the preceding year, it will calculate the cost of offsetting that year's net carbon emissions at a rate equal to the purchase of such carbon offsets through a Green-e type process. Poseidon will then pay the amount resulting from this calculation to either the San Diego County Air Pollution Control District or another entity identified by the California Coastal Commission as responsible for administering a San Diego area wildfire revegetation program. Poseidon will continue making its annual offset payments to the revegetation program until the cumulative total of such payments equals $1 million, at which time Poseidon may elect to direct annual offset payments to other projects, so long as those projects satisfy accepted standards for offsetting carbon emissions.

According to the Tree Guidelines for Coastal Southern California Communities issued by the USDA Forest Service (McPherson, et. al., 2000) the average annual costs for tree planting and care increase with mature tree size and for medium-size trees range between US$16 and 23 per tree (avg. US$19.5/tree). Average annual maintenance costs for trees are estimated at US$3 to US$5 (avg. US$4/tree). Updated for inflation, the year 2008 average tree planting cost is US$26.7/tree and the average annual maintenance cost is US$5.5/tree. Assuming tree maintenance costs for 25 years @ US$5.5/tree, the total lifecycle maintenance expenditure per tree is US$137.5. When added to the three planting cost of US$26.7, the total cost for planting and maintaining of the trees included in the reforestation project would be US$164.2/tree. At commitment of US$1.0 MM ($35,000/yr averaed over 30 years) and total costs of US$164.2/tree, the total amount of trees planned to be replanted is 6,090 (204 per year). At an annual tree sequestration rate of 60 lbs/tree over 25--year period of the desalination plant operations, the total annual carbon footprint reduction associated with the tree sequestration project is estimated at 365,400 lbs (166 metric tons) of CO_2 per year as shown in Line 11 of Table 1. This is approximately 1.2% reduction of the net desalination plant footprint. At an annual expenditure for tree reforestation of approximately US$33,500/yr, the unit carbon footprint reduction cost for this alternative would be US$200/ton of CO_2 as shown in Table 2.

Carbon Dioxide Sequestration in Coastal Wetlands

As a part of the Carlsbad seawater desalination project, Poseidon Resources is planning to develop 37 acres of new coastal wetlands in San Diego County. These wetlands will be designed to create habitat for marine species similar to these found in the Agua Hedionda Lagoon (see Figure 1), from which source seawater is collected for the power plant and for desalination plant operations. Once the wetlands are fully developed, they will be maintained and monitored over the life of the desalination plant operations. The cost of the wetland restoration project is estimated at US$3.0 million.

In addition to the benefit of marine habitat restoration and enhancement, coastal wetlands also act as a "sink" of carbon dioxide. Tidal wetlands are very productive habitats that remove significant amounts of carbon from the atmosphere, a large portion of which is stored in the wetland soils. While freshwater wetlands also sequester CO_2, they are often a measurable source of methane emissions. By comparison, coastal wetlands and salt marshes release negligible amounts of greenhouse gases and therefore, their carbon sequestration capacity is not measurably reduced by methane production.

Based on a detailed study completed in a coastal lagoon in Southern California (Brevik & Homburg, 2004) the average annual rate of sequestration of carbon in coastal wetland soils is estimated at 0.03 kg of C/m^2.yr. Another source (Truilio, 2007) indicates that in addition to accumulating CO_2 in the soils, central and southern California tidal marshes could also sequester 0.45 kg of C/m^2.yr in the macrophytes growing in the marshes and 0.34 to 0.63 kg of C/m^2.yr in the algal biomass. Taking under consideration that the total area of the proposed wetland project is 37 acres (149,739 square meters) and the maximum sequestration capacity of the coastal wetlands could be 1.11 kg of C/m^2.yr, the wetland carbon sequestration capacity would be up to 83 tons of C/yr. With a conversion factor from carbon to carbon dioxide of 3.664 the estimated offset of the desalination plant carbon footprint by the wetland project is estimated at 304 tons of CO_2/year as shown in Line 12 of Table 3 (a 2.2% reduction of the net carbon footprint). At a total annual cost for wetland development and maintenance of approximately US$120,000/yr, the unit carbon footprint reduction cost for this alternative would be US$400/ton of CO_2) as shown in Table 2.

Site-specific research is planned to be completed in order to quantify the actual carbon sequestration capacity of the proposed wetland system, once the wetland project is completed and is fully functional. Typically it takes three to five years for a coastal wetland project to be fully functional and to begin to yield enhanced habitat and GHG sequestration benefits.

Carbon Emission Offsets by Investing in Regional Renewable Energy Projects

Poseidon plans to invest in a number of green power projects with its public partners who will be receiving desalinated water from the Carlsbad seawater desalination Plant. Table 3 presents the various green power project opportunities and associated GHG offsets that would ultimately be applied against the carbon footprint of the Carlsbad seawater desalination project.

Based on the projects described in Table 3, the total carbon footprint offset for the desalination plant is projected at 2,260

MWh/yr or 561 tons of CO_2/year (4.1% of net carbon footprint). This credit is shown in Line 13 of Table 1.

Other Carbon Offset Projects and Renewable Credits

For the remainder of the Project's carbon emissions, Poseidon will purchase a combination of carbon offset projects and Renewable Energy Credits (RECs). Contracts for offset projects provide more price stability and are typically established for longer terms (10-20 years) then RECs (1-3 years).

About one-and-half-to-two years before operations begin, Poseidon will develop and issue a request for proposal (RFP) for carbon offset projects and renewable energy credits. Poseidon will then select the best mix from the responses and contract for their acquisition or development. The exact nature and cost of the offset projects and RECs will be known once the RFP process is complete. The offset purchases and REC's are estimated as 6,668 tons CO_2/year as shown in Line 14 of Table 1. Offsets or RECs would be used as the swing mitigation option to "true-up" annual changes to the project's net carbon footprint.

PROJECT ANNUAL NET-ZERO CARBON EMISSION BALANCE

Table 1 summarizes the total and net carbon footprint estimates of the Carlsbad seawater desalination project and quantifies GHG emission reduction and mitigation options that are planned to be implemented in order to reduce the plant net carbon emission footprint to zero. Up to 40% of the net GHG emissions will be reduced by on-site reduction measures and the remainder will be mitigated by off-site mitigation projects and purchase of renewable energy credits. It should be noted that the contribution of on-site GHG reduction activities is expected to increase over the useful life (i.e., in the next 30 years) of the project because of the following reasons:

- The power supplier (SDG&E) is planning to increase significantly the percentage of green power sources in its electricity supply portfolio, which in turn will reduce its Emission Factor and the net desalination plant carbon footprint.
- Advances in seawater desalination technology are expected to yield further energy savings and carbon footprint reductions. Over the last 20 years the use of power for production of one gallon of fresh water by seawater desalination has decreased by more than 50%. This trend is projected to continue in the future.

The mitigation costs of the various alternatives are summarized in Table 2. The lowest unit cost of carbon footprint reduction can be achieved by using carbon dioxide for post-treatment of the desalinated water (US$70/ton CO_2). The most costly carbon footprint reduction options are green building design (US$3,400/ton CO_2) and installation of rooftop solar power generation system (US$1,900/ton CO_2). Development of new coastal wetlands is a very promising carbon footprint reduction option (US$400/ton CO_2). Similarly, reforestation could also be a cost-competitive GHG reduction alternative (US$200/ton CO_2). As compared to green power generation alternatives (solar and wind power) reforestation and wetland mitigation have added environmental benefits. For example, the new coastal wetlands developed in relation to seawater desalination project could be designed to create habitat for species that are impacted by the intake operations of the desalination plant via impingement and entrainment of these species on the intake screens.

SUMMARY AND CONCLUSIONS

Greenhouse gas emissions associated with production of desalinated seawater at the Carlsbad seawater desalination project in Southern California are planned be mitigated by a portfolio of alternative technologies and measures: including use of carbon dioxide for water production, green building design, advanced energy recovery technology, green energy projects and carbon dioxide sequestration by reforestation and new coastal wetlands. The mix of GHG reduction alternatives will be prioritized and implemented under a Carbon Action Plan which defines a roadmap for carbon-neutral seawater desalination.

The total gross carbon footprint of conventional desalination plant design for this project is 68,100 tons of CO_2/yr. Approximately 69.6% of the total carbon footprint will be offset by reduction of water transfers from Northern California. Energy efficient design and use of advanced energy recovery technologies eliminate an additional 10.3% of the gross carbon footprint. The remaining net carbon footprint of 13,700 tons of CO_2/yr is planned to be offset by using warm water from the power plant with which the desalination plant is collocated (22.6% of net footprint); by sequestering CO_2 in the water production process (15.3% of net footprint); and by various off-site and on-site renewable energy generation projects (9% of the total footprint). In addition, the project will employ green building design, and carbon dioxide sequestration by reforestation and wetland development to offset another 4.3% of the net carbon footprint. The remaining 48.8% of the net footprint (9.9% of the gross footprint) of the project will be offset by purchasing renewable credits and investing in off-site renewable energy projects.

Estimates of the costs of CO_2 emission offsets indicate that use of warm cooling water is most cost effective because it does not require additional expense. Use of CO_2 for water production is also very cost effective at US$70/ton of reduced CO_2. Green building design and solar power generation were least cost effective at US$3,400/ton and US$1,900/ton, respectively.

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