Public Comment
SF Bay PCB TMDL's
Deadline: 6/4/09 by 12 noon

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June 3, 2009

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SWRCB EXECUTIVE

Ms. Jeanine Townsend
Clerk to the Board
State Water Resources Control Board
1001 I Street
Sacramento, CA 95814

Re: Comment Letter – San Francisco Bay PCBs TMDL

Dear Ms. Townsend:

GE appreciates the opportunity to provide comments to the State Water Resources Control Board (the State Board) on the proposed Regional Water Quality Control Board's (the Regional Board) Basin Plan Amendment for San Francisco Bay establishing a total maximum daily load (TMDL) for PCBs and an Implementation Plan for PCBs in San Francisco Bay (collectively the "TMDL"). GE commends the Regional Board Staff and members of the State Board for the effort they have put into development of the TMDL, their willingness to discuss and entertain potential solutions, and to resolve certain issues of concern. GE provided comments to the Regional Board on August 20, 2007 and January 22, 2008.[1] All of GE's prior comments, testimony and submittals, are fully incorporated by reference herein. GE focuses its comments today to new information not previously considered during the Regional Board process.

In sum, GE believes that the TMDL as proposed has several significant flaws that, if not ordered by the State Board to be corrected on remand, could lead to enormously costly decisions that are not supported at this time by good science, good economic analysis, or applicable law. At any time, these circumstances could lead to serious missteps. In this nation's and this State's current precarious, economic climate, a $10,000,000,000[2] misadventure would be far worse.

GE is prepared to continue to work collaboratively with the Regional Board, the State Board, and affected stakeholders. GE respectfully asks the State Board to deny approval of the PCBs TMDL as proposed on the ground that, after the correction of certain erroneous scientific assumptions, the TMDL is unnecessary. The alleged impaired use will self-correct itself within a timeframe similar to what the TMDL proposes to achieve. Implementing the TMDL as it now stands will alternatively be costly and burdensome to the regulated community with little to no

[1] GE also presented testimony at the Regional Board Hearings of September 12, 2007 and February 13, 2008. In addition, at the Request of the Regional Board at the September 12, 2007 Hearing, on October 31, 2007, GE submitted a white paper on the use of economic factors in basin planning, as well as a report from Dr. David Sunding.

[2] The Regional Board estimates that costs of compliance could be $500,000,000 a year for 20 years.

commensurate benefits. In the alternative, GE requests that the State Board remand the TMDL back to the Regional Board with instructions to modify it to correct its defects, consistent with GE's prior and current comments. If remanded, the State Board should further order the Regional Board to present a revised PCBs TMDL in accordance with the State Board's instructions to the Board Members at a public hearing, after adhering to proper notice and comment procedures called for by the Water Code.

GE believes there are five remaining economic, technical, and procedural issues regarding flaws in the PCBs TMDL, any or all of which support GE's request for denying as proposed, or remanding, the PCBs TMDL back to the Regional Board. A brief summary of each issue is presented here. For more detailed explanation, please see the attached expert technical comment letters by Dr. David Sunding, economist [3] and from Dr. John Connolly of QEA Anchor.[4] (Attached hereto as Appendices A and B respectively).

Those issues are:

1. ***The Regional Board has not met its burden under Porter-Cologne to properly consider economics in the development of the TMDL.***

Dr. Sunding's prior comments on the Regional Board's draft TMDL demonstrated that the Regional Board failed to adequately incorporate a solid economic analysis in developing the TMDL. He pointed out that the Board failed to adequately characterize or analyze potential compliance costs or discuss them rigorously in relation to expected benefits. "All of these errors and omissions place the [Regional Board's] Staff Report analysis outside the bounds of any form of standard economic analysis." (Appendix A, Dr. Sunding Comments at page 1.) He further noted that true TMDL costs could be in the hundreds of millions or billions of dollars (id. at page 2), and would result in an unacceptably high level of costs compared to benefits achieved. The Regional Board has stated that TMDL compliance costs could be $500,000,000/year over a twenty-year period (SF Bay PCB TMDL Feb. 2008 Staff Report, pages 123-124), a cost that Dr. Sunding regards as wholly disproportionate to any little benefit that might be achieved. (Dr. Sunding Comments at pages 2 and 4.)

In his new comments here, Dr. Sunding brings to the State Board's attention three new developments since August 2007 that further support his prior opinions: the State Little Hoover Commission report, The *Arcadia II* decision, and new data on angler fisherman in the Bay.

First, he discusses the State's Little Hoover Commission ("Commission") report finding that the State Board and Regional Boards should employ a more rigorous approach to estimating and analyzing costs and comparing them with the expected benefits of improvements in water quality. (Id. at page 2.) In fact, the Commission cites a recent article co-authored by Dr. Sunding, as a "roadmap for how to better incorporate economics into the regulatory process."

[3] An article co-authored by Dr. Sunding, discussed in Section 1 below, along with his curriculum vitae, is attached to Dr. Sunding's comments.
[4] Various figures discussed in the text of Dr. Connolly's letter, as well as the curriculum vitaes for Dr. Connolly and his colleague, Elizabeth Lamoureux, are attached to Anchor QEA's comments.

(Id.) A copy of Dr. Sunding's and Dr. David Zilberman's article, "Consideration of Economics Under the California Porter-Cologne Act" Hastings West-Northwest Journal of Environmental Law & Policy (2007): 73-116, is attached hereto with Appendix A and incorporated by reference.

Second, he discusses the recent *Arcadia II* decision mandating that the State and the Los Angeles Regional Water Quality Control Board consider economic factors when adopting or refining water quality standards. *City of Arcadia v. State Water Resources Control Board*, No. 06CC02974 (Orange County Super. Ct., July 2, 2008).

Dr. Sunding summarizes the meaning of the Little Hoover Commission's Report and the *Arcadia* decision as follows:

> Both . . . are supportive of the basic theses of my earlier testimony, namely that some robust form of economic analysis of proposed water quality standards is required under Porter-Cologne. Further, the Little Hoover Commission Report finds that increased use of economic analysis, as required by the Legislature, will improve the performance of the water boards by allocating scarce resources to the water quality problems that pose the greatest threat to the public, and by avoiding large expenditures on compliance with regulations that have little public benefit. (Dr. Sunding's comments at page 3.)

Third, he also describes, as does QEA in its comments, new angler and PCB fish tissue concentration data that has become available and is relevant to the PCBs TMDL. He notes that, based on new information received from the Recreational Fishing Network (RECFIN) on particular species actually sought and caught by anglers in San Francisco Bay, the benefits of the proposed TMDL are "insubstantial" and "miniscule", because less than one percent of anglers are seeking the two specific reference species used to develop the TMDL. (Id. at pages 3-4.) Dr. Sunding concludes, similarly to QEA, that "the Regional Board's use of these two reference species does more than provide a margin of safety, rather it is wholly unrealistic as the basis for public decision-making, particularly in view of the likelihood of large compliance costs . . ." (Id. at page 3.)

2. *The PCBs TMDL does not properly account for the ongoing natural recovery of San Francisco Bay.*

QEA's technical memorandum makes use of new Regional Monitoring Program (RMP) data to show that, due to the ongoing natural recovery of the Bay, the northern portion of the Bay has already reached the sediment target level of 1 microgram per kilogram (equivalent to one part per billion ("ppb")) PCBs, while the average sediment concentrations in the central and southern portions of the Bay have declined on average from 3 to 5 ppb. The additional data provided by the 2006 RMP data "provide further evidence that surface sediment PCB concentrations in the central and southern parts of the Bay drop in half approximately every 10 years" (Appendix B, QEA Comments at page 2), rather than the 56 years used by Regional Board Staff. Moreover, QEA analyzes the new and existing data to show that the natural sediment recovery trends are consistent with decline rates seen in Bay mussels, the Bay's water column and in shiner surfperch data. (Id. at pages 3-5, accompanying figures 1 through 3.)

3. *The PCBs TMDL does not properly characterize the assimilative capacity of San Francisco Bay.*

QEA renews its earlier comments regarding a major flaw in the 1-Box Model used by the Regional Board, explaining that it results in an "arbitrary adjustment to PCB outflows" and thus "inaccurately predicts that current PCB loadings will delay recovery of the Bay by 100 years." (Id. at page 5.) QEA opines that, without correcting the 1-Box Model to apply a scale factor to the Bay outflow volume to reduce the PCB loss through outflow and exchange (id. at page 5, footnote 3), the model utilized by the Regional Board does not "closely match what is happening in the Bay" (id. at page 5, see also Comment No. 1, above). QEA concludes, "Given that the current loading is estimated at 33 kg/yr, the corrected 1-box model suggests Bay sediments will [naturally] reach the target at the current loading in approximately 40 years . . . even if no regulatory-required actions are taken to reduce PCB load." (Id. at pages 6 and 7, see also figure 4.) Finally, QEA notes:

> While the corrected [by QEA] 1-box model is better able to represent actual observed rates of PCB declines, we understand a multi-box model is under development to improve the understanding of the long-term fate of PCBs in the Bay (SFEI 2008b). When the multi-box model has undergone the sufficient quality assurance/quality control (QA/QC) validation, it should be considered in future analyses (e.g., if the TMDL moves into the Adaptive Implementation (AI) process. (Appendix B, QEA Comments at page 6.)

In summary, and regarding the critical importance of the two above-described technical issues, QEA states:

> The first two issues are important because they impact the PCB load allocation and our technical opinions regarding the timeframe for recovery of the Bay. By failing to properly account for natural recovery and the assimilative capacity of the Bay, the necessity and benefit of the TMDL has been significantly overestimated. Thus, the [Regional Board] has overestimated the time benefit of the prescribed TMDL (i.e., the extent to which loading reductions will accelerate achieving the goals of the TMDL.) Further, the [Regional Board] has overestimated the extent to which PCB loads need to be reduced. (Id. at page 1.)

4. *The PCBs TMDL uses two species of fish that are rarely consumed by anglers, to assess current and future attainment of the already conservative PCBs TMDL fish tissue target concentrations.*

As noted in Dr. Sunding's expert opinion, summarized above, the "TMDL's usage of white croaker and shiner surfperch to evaluate achievement of the TMDL target means that the TMDL is requiring exposure concentrations lower than deemed necessary to achieve its stated objectives. Current data suggest that the more commonly-consumed species of Bay fish have either already met the target or are much closer to meeting the TMDL target than these two rarely-consumed specifies (Id. at pages 1-2 and 6-7; see also David Sunding's comments below, re angler data.) In addition, QEA opines that the fish tissue target chosen by the Regional Board goes far beyond permissible margin of safety analyses:

> The [Regional Board's] final Staff Report revisions indicate that the TMDL is intended to be protective of one allegedly impaired beneficial use – commercial and sports fishing (COMM) – while maintaining all existing beneficial uses . . . . In order to protect the impaired COMM beneficial use, the fish tissue target derived by the [Regional Board] used several conservative assumptions (QEA 2007). Thus, it is already conservative. However, and most significantly, the [Regional Board's] use of two rarely-consumed species further introduces additional and unnecessary conservatism that constitutes a misuse of the TMDL's permissible margin-of-safety analysis. (Appendix B, QEA Comments at pages 7-8; see also footnote 6, noting that State Board Staff has apparently gone beyond the Regional Board's findings in the final Staff Report, in an attempt to claim that three other beneficial uses are impaired, a finding which the Regional Board could not make and took out of its final Staff Report.)

5. The public is not afforded an opportunity to comment on the Regional Board's decision, up to 10 years after implementation of the Basin Plan, to either modify the TMDL or not modify the TMDL.

The Regional Board stated in the February 2008 Basin Plan Amendment that, within 10 years of the effective date of the TMDL, the Regional Board "will consider a Basin Plan Amendment that will reflect and incorporate the data and information that is generated [during the Adaptive Implementation process] in the intervening years. Regardless of how the State Board resolves the substantive TMDL issues before it, the TMDL should be remanded and the Regional Board should be ordered to modify the Basin Plan Amendment to provide affected stakeholders with adequate procedural protections and judicial review of a Regional Board decision to continue or modify the proposed TMDL. This comports with Porter-Cologne's typical administrative or judicial processes.

GE believes that these procedural due process guarantees could be assured on any remand with the State Board's direction to the Regional Board to proceed through a formal notice and comment process when it determines whether to amend the PCBs TMDL in the future, based upon new information developed during the Adaptive Implementation process. Thus, at the end of that evaluative process, the Board Members of the Regional Board would have to issue a formal resolution if they decide not to amend the PCBs TMDL at that time, just as they would have to do in order to approve an amendment to it. We believe that all affected Stakeholders would benefit from this clarified and enhanced procedure. In addition, we trust that Staff and Board Members would appreciate and support a more transparent and fair process with full opportunity for public comment and debate, rather than a decision made solely by Staff.[5]

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[5] It may be that the Regional Board intended to provide these procedural protections by way of its earlier comment, quoted above. If so, making these intentions clear and binding, should not be controversial. However, if the Regional Board did not intend that its process during the AI period would be as proposed,

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GE appreciates the opportunity to provide the State Board and the public with these comments, and the attached expert opinions of QEA and Professor Sunding. GE is prepared to work with State Board Staff and Board Members to address the PCBs TMDL issues outlined in this letter and in our earlier comments to the Regional Board.

Sincerely,

James A. Bruen

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then a remand ordering it to make the procedural changes described above, become all the more important to bring fairness, transparency and consistency to the Regional Board's subsequent decision-making processes.

Berkeley Economic Consulting

June 4, 2009

Jeanine Townsend, Clerk to the Board
State Water Resources Control Board
1001 I Street
Sacramento, CA 95814

RE: Comment Letter – San Francisco Bay PCBs TMDL

Dear Ms. Townsend:

I am pleased to submit these comments regarding the TMDL for PCBs proposed for the San Francisco Bay region.

My background and qualifications are listed on the curriculum vitae attached as an exhibit to this comment. Currently, I am the Graff Professor of Natural Resource Economics and Policy at UC Berkeley, and the Co-Director of the Berkeley Water Center. I have worked in these areas for approximately the past 20 years. I am also a director of Berkeley Economic Consulting, Inc., an independent economic research firm specializing in energy, labor, environmental and natural resource economics. I have written over one hundred articles and reports in the areas of water resources, land use, and environmental policy. From 1996 to 1997, I served as senior economist at President Clinton's Council of Economic Advisers, where I had responsibility for environmental, agricultural, natural resource and energy policy.

On August 20, 2007, I submitted written comments to the San Francisco Regional Board concerning the economics of the draft TMDL under consideration at that time. In that testimony, I offered several observations that are summarized as follows:

- Regional Board staff had not met its burden under Porter-Cologne to properly consider economics in the development of the TMDL. The plan for implementing the proposed regulation was not described in enough detail to permit an adequate calculation of costs. The report made no mention of who will bear the costs of complying with the regulation (for example, public or private entities), or of the potential regional economic implications of the action. The report did not acknowledge the potential employment impacts of the proposed TMDL, or the effect of the cleanup plan on competitiveness of California businesses. It did not attempt to gauge the significance of the action and did not discuss costs in relation to the level of benefits likely to be achieved. There was no mention of discounting, let alone any actual attempt to control for the fact that positive and negative impacts will occur over a period lasting perhaps decades into the future. All of these errors and omissions placed the Staff Report analysis outside the bounds of any form of standard economic analysis.

- The costs of the proposed regulation were not adequately described in the staff report. Available information demonstrated that the assertions of the Staff Report regarding the costs of compliance were significantly understated and misleading. For example, the report did not accurately reflect dredging costs at other locations in the Bay and nationwide. The report also mischaracterized the actual costs of impounding and treating stormwater to the levels required by the TMDL. Using more accurate information, the costs of the TMDL could reach into the hundreds of millions or billions of dollars.

- The Regional Board staff erred in its description of the benefits of the proposed TMDL. The proposed screening levels were based on a flawed survey of recreational anglers, and the survey results were misapplied to the problem at hand. Controlling for actual exposure to PCBs in fish tissue, and recognizing that the proposed TMDL is designed to benefit only a small group of people engaging in an assumed, wholly unrealistic behavior, I concluded that the action would not significantly reduce human health risk, and therefore would not result in significant benefits. This circumstance would be in violation of the State requirement that major regulations are subject to a demonstration of economic value.

- The proposed action was likely to result in an unacceptably high level of costs in relation to the actual benefits achieved. The staff report failed to demonstrate that the Regional Board considered alternatives to the proposed TMDL that would be less burdensome, or that it considered the relative cost effectiveness of alternative standards. This was inconsistent with basic principles of economic analysis of regulation, and in contradiction to established federal guidelines promulgated by the US Environmental Protection Agency and the Office of Management and Budget. It was also inconsistent with the stated objectives of the proposed action listed in the staff report.

Since I submitted my testimony in August 2007, there have been some significant developments with respect to consideration of economics under Porter-Cologne that I would like to bring to Staff's and the Board's attention. Earlier this year, the State's Little Hoover Commission released a report detailing the results of its investigation into the performance of the SWRCB and Regional Water Quality Control Boards.[1] One of the Commission's principal findings was that the State should employ a more rigorous approach to estimating the costs of compliance with proposed water quality standards, and compare these costs with the expected benefits of improvements in water quality. The Commission cited to my recent article on consideration of economics under Porter-Cologne as a roadmap for how to better incorporate economics into the regulatory process. A copy of that article is attached as an exhibit to this letter, and is incorporated into my testimony by reference.

In addition, the recent Arcadia II Court decision mandated that the SWRCB and Los Angeles Regional Water Quality Control Board consider economic factors when adopting or refining water quality standards. The Arcadia II case, City of Arcadia v. State Water Resources Control Board, No. 06CC02974 (Orange Co. Sup. Ct.), was brought by a group of Southern California cities and building industry groups that opposed the

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1 State of California Little Hoover Commission. *Clearer Structure, Cleaner Water: Improving Performance and Outcomes at the State Water Boards.* Report #195, January 2009.

application of numeric water quality standards to stormwater runoff. The plaintiffs argued that the water quality standards contained in the Basin Plan were not intended to apply to stormwater and that the Los Angeles Regional Water Quality Control Board had implemented the standards without reviewing their reasonableness, as required by State law. According to the plaintiffs, the Los Angeles Regional Board should have conducted this analysis during its 2004 Triennial Review of the Basin Plan. The Regional Boards, however, have long contended that the Triennial Review process is not the proper venue for evaluating the reasonableness of water quality standards. The Court agreed with the plaintiffs, finding that the Regional Board should have included consideration of the factors set forth in Water Code sections 13241 and 13000, including the practicability and economic impact of the water quality standards. The court ordered the Regional Board to set aside the order concluding the 2004 Review. During the reopened 2004 Review, or during the next scheduled Triennial Review, the Los Angeles Regional Board must review and revise the Basin Plan's stormwater quality standards in light of the above described statutory factors. A stakeholder process is now underway to provide technical and economic information to the Los Angeles Regional Water Quality Control Board on water quality standards and other basin planning issues as directed by the Court.

Both the Little Hoover Commission report and the Arcadia II decision are supportive of the basic theses of my earlier testimony, namely that some robust form of economic analysis of proposed water quality standards is required under Porter-Cologne. Further, the Little Hoover Commission report finds that increased use of economic analysis, as required by the Legislature, will improve the performance of the water boards by allocating scarce resources to the water quality problems that pose the greatest threat to the public, and by avoiding large expenditures on compliance with regulations that have little public benefit.

In the months following my previous testimony, new information relevant to the economic impacts of the TMDL for PCBs has become available. For example, the Recreational Fishing Network (RECFIN) has released new information on particular species actually sought and caught by anglers in the San Francisco Bay. This data strengthen my previous conclusion that the benefits of the proposed TMDL are insubstantial.

RECFIN data indicate that only a small percentage of anglers in the San Francisco Bay are seeking the two specific reference species used to develop the TMDL: shiner surfperch and white croaker.[2] Table 1 provides data on species sought from 2006 to 2008 (the 2008 data was just released). In all three years, shiner surfperch and white croaker are sought by only a small minority of anglers, less than one percent of all anglers according to the most recent data from 2008. Similarly, newly released RECFIN data displayed in Table 2 show that few anglers in the San Francisco Bay actually catch the two particular reference species. In 2008, less than one percent of Bay anglers report catching either the shiner surf perch or white croaker. Thus, the Regional Board's use of these two reference species does more than provide a margin of safety, rather it is wholly unrealistic as the basic for public decision-making, particularly in view of the likelihood of large compliance costs, as I discuss below.

2 The RECFIN Database collects information related to fish catch, angler population, species sought, and a variety of other information related to sport fishing. Data are compiled by field observations as well as intercept interviews and phone interviews. *www.recfin.org/*

Table 1: Percent of Anglers Seeking Reference Species

Species	2006	2007	2008
Shiner Surfperch	0.56%	0.14%	0.12%
White Croaker	1.57%	0.61%	0.58%
Total	2.13%	0.75%	0.69%

Source: RECFIN

Table 2: Percent of Reference Species Caught

Species	2004	2005	2006	2007	2008
Shiner Surfperch	0.64%	0.37%	0.29%	0.40%	0.10%
White Croaker	3.91%	1.07%	0.87%	0.37%	0.88%

Source: RECFIN

Newly released information on PCB concentrations in the reference species also reinforces my earlier conclusion that the actual benefits of the proposed TMDL are miniscule. The San Francisco Estuary Institute (SFEI) catalogs all Regional Monitoring Program results on their website. The data contain the PCB concentration levels for the shiner surfperch and white croaker, among other species.[3] As a result the average PCB concentrations can be calculated for the reference species. The most recent data, for 2006, reports an average tissue concentration for shiner surfperch of 94.2 ng/g wet weight, and white croaker 323.7 ng/g wet weight. This information is generally consistent with earlier estimates of PCB concentrations used in my previous testimony.

Table 3: PCB Concentrations in Species of Concern (ng/g ww)

Species	1994	1997	2000	2003	2006
Shiner Surfperch	110	216	161	157	94
White Croaker	230	259	206	228	324

Source: SFEI RMP data

Available information, including the recently released data described above, overwhelmingly suggests that human exposure to PCBs in fish tissue is minimal. The proposed TMDL is designed to benefit only a small group of people engaging in a behavior that is more hypothetical than real. Indeed, there is no evidence to suggest that any recreational anglers are exposed to the levels of PCBs assumed in the Final Staff Report. Therefore, the proposed TMDL does not significantly reduce human health risk, and does not result in significant benefits. This circumstance is in violation of the State requirement that major regulations are subject to a realistic demonstration of economic value.

3 SFEI data are collected from stations expected to be representative of the entire Bay. Data are collected every three years. *http://www.sfei.org/rmp/*

There is also new information available in the Final Staff Report that is relevant to the potential costs of the TMDL. The Final Staff Report accompanying the proposed Basin Plan Amendments states that substantial load reductions are required to attain wasteload allocations for stormwater.[4] Specific best management practices (BMPs) and control measures to be considered include the following:

- Abatement of PCBs in runoff from areas with elevated PCBs in soils/sediments:
    - Investigate on-land PCBs contaminated soils and/or sediments;
    - Improve system design, operation, and maintenance to increase capture of fine sediments;
    - Strategic runoff treatment retrofits; and
    - Urban stormwater runoff treatment via municipal wastewater treatment systems.
- Abatement of PCBs in runoff from all areas:
    - Control/oversee removal and disposal of PCBs-containing equipment; and
    - Control/manage removal and disposal of PCBs from building materials and waste during demolition/remodeling.

These BMPs and control measures are expected to be implemented in phases as NPDES permits are issued and reissued over the 20-year life of the implementation plan. In the first five-year permit term, stormwater permittees will be required to implement control measures on a pilot scale to determine their effectiveness and technical feasibility. Pilot-scale implementation costs are not discussed in the Final Staff Report. The Final Staff Report simply acknowledges that the largest implementation costs are anticipated to result from implementation of the stormwater runoff allocation portion of the TMDL, but does not contain any meaningful estimate of what those costs would be.[5] Nonetheless, it is clear from the above list of actions that the actual implementation costs associated with the TMDL could be enormous and out of proportion to any benefits achieved.

In conclusion, the basic content of my 2007 testimony to the Regional Board remains valid today. Indeed, my expert opinions are reinforced by recent information on benefits and implementation costs made available after I submitted my earlier testimony, as

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4 *Total Maximum Daily Load for PCBs in San Francisco Bay: Final Staff Report for Proposed Basin Plan Amendment*. California Regional Water Quality Control Board, San Francisco Bay Region. February 13, 2008.

5 Similarly, I note that the State Board's Draft Staff Report repeats the Regional Board's earlier statement that removing PCBs will also remove other pollutants that adhere to soils. The Draft Staff Report asserts that this circumstance will reduce the compliance costs attributable to the PCBs TMDL, as some costs can be reasonably allocated to other TMDLs or legal authorities governing cleanup of other pollutants. Like the Regional Board's Final Staff Report, the State Board's Draft Staff Report provides no meaningful analysis or quantification of this proposition.

described in this letter. I encourage the State Board Staff and Board members to review my earlier analysis, and consider the additional information identified in this letter.

Please do not hesitate to contact me if you have any questions.

Sincerely,

David Sunding
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Director, Berkeley Economic Consulting, Inc.
2531 Ninth Street
Berkeley, CA 94710

CURRICULUM VITAE

DAVID L. SUNDING

April, 2009

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EMPLOYMENT

Professor, Department of Agricultural and Resource Economics, UC Berkeley, 2002 – Present.

Co-Director and Founder, Berkeley Water Center, 2005 – Present.

Associate Professor, Department of Agricultural and Resource Economics, University of California at Berkeley, 2000 – 2002.

Cooperative Extension Specialist, Department of Agricultral and Resource Economics, University of California at Berkeley, 1997 – Present.

Senior Economist,
President's Council of Economic Advisers,
Washington, DC, 1996–1997.

Assistant Adjunct Professor, Department of Agricultral and Resource Economics, University of California at Berkeley, 1992–1996.

Assistant Professor, Department of Economics and School of Law, Boston College, 1989–1992.

EDUCATION

Ph.D., Agricultural and Resource Economics, UC Berkeley, 1989.
M.A., African Area Studies, UCLA, 1986.

B.A., Economics, Claremont McKenna College, 1983.

COURSES TAUGHT

Risk, Technology and the Environment (Graduate)
Environmental and Resource Economics (Graduate)
Natural Resource Economics (Undergraduate)
Economics of Public Law (Boalt Hall School of Law)
Environmental Policy (Undergraduate)
Public Finance (Graduate)
Microeconomic Theory (Graduate and Undergraduate)
Law and Economics (Boston College School of Law)

UNIVERSITY SERVICE

Co-Director, Berkeley Water Center, 2005 – Present.

Member, UC Division of Agricultural and Natural Resources Strategic Planning Committee, 2008.

Reviewer, California Policy Research Center, UC Office of the President, 2007.

Member, Forestry Search Committee, Ecosystem Sciences Division, Department of Environmental Science, Policy and Management, 2005-2006.

Member, Giannini Hall Seismic Retrofit Design Committee, 2005 – 2006.

Member, Academic Senate Committee on Amrican Cultures Requirements, 2004-2005.

Member, CNR Executive Committee, 2003-2005.

Member, CNR Committee on Directions, Opportunities and Initiatives, 2003.

Co-Director, Center for Sustainable Resource Development, College of Natural Resources, UC Berkeley, 1997 – 2004.

Faculty, Beahrs Environmental Leadership Program, 2001-2005.

Member, CNR Dean Search Committee, 2001-2002.

Chair, Specialist Search Committee, Department of Agricultural and Resource Economics, 2001-2002.

Member, CNR Advisory Board Development Committee, 2001-2002.

Member, Faculty Search Committee (International Trade), Department of Agricultural and Resource Economics, 1999-2000.

Member, CNR Dean Search Committee, 1999–2000.

Member, Workgroup Review Committee, University of California Division of Agriculture and Natural Resources, 1999–2002.

UC Berkeley Representative, Academic Assembly Council, University of California Division of Agriculture and Natural Resources, 1999–2001.

Departmental Affirmative Action Representative, 1999–2000.

Member, Faculty Search Committee (Environmental Health), Department of Agricultural and Resource Economics, 1998–2000.

PROFESSIONAL SERVICE

Advisory Board, Water Policy Institute, 2008 – Present.

Advisory Board, American Groundwater Trust, 2008 – Present.

Reviewer, Delta Risk Management Study (DRMS), California Department of Water Resources, 2007-2008.

Member, Economic Advisory Committee on North of Delta Offstream Storage, California Department of Water Resources, 2006-2007.

Member, Panel on Illegal Competitive Advantage Economic Benefit, Science Advisory Board, U.S. Environmental Protection Agency, 2004-2005.

Mentor, American Economic Association Pipeline Project for Minority Graduate Students, 2004 – 2005.

Member, Science Advisory Board, National Center for Housing and the Environment. 2003 – 2005.

President, International Water Resource Economics Consortium, 2002-2005.

Member, Expert Panel on Cost Allocation, CalFed Bay-Delta Program, 2001-2002.

Member, National Academy of Sciences Panel on Water Conservation and Reuse, 2001-2002.

Member, Technical Advisory Committee on Water Use Efficiency, CalFed Bay-Delta Program, 1997–1998.

Referee: *Agricultural Economics, American Journal of Agricultural Economics, California Agriculture, Contemporary Economic Policy, Environmental and Resource Economics, Journal of Agricultural and Resource Economics, Journal of Business and Economic Strategy, Journal of Environmental Economics and Management, Journal of Political Economy, Journal of Public Economics, Journal of Regulatory Economics, Land Economics, Natural Resources Modeling, Resource and Energy Economics, Review of Economics and Statistics, Social Choice and Welfare, Water Resources Research.*

AWARDS

Thomas J. Graff Chair of Natural Resource Economics and Policy, Department of Agricultural and Resource Economics, UC Berkeley, 2009 – Present.

Giannini Foundation. "Economics of Groundwater Storage in Southern California." $24,000. 2008-2009.

Invited Participant, Rosenberg International Forum in Water Policy, Valencia, Spain, 2008.

Energy Biosciences Institute. "Development of Biofuel Productivity Potentials for Economic Analysis Under Changing Climate, Land Use, and Societal Demands." $154,000. 2007-2009.

U.S. Bureau of Reclamation, "Independent Review of Fisheries Restoration Programs." $380,000. 2007-2008.

U.S. Department of Energy, "Joint Modeling of the Water and Energy Sectors." $200,000. 2006-2009.

Invited Participant, Rosenberg International Forum in Water Policy, Banff, Canada, 2006.

Giannini Foundation. "Multimarket Impacts of Water Transfers in Areas of Origin." $18,000. 2005 – 2006.

Giannini Foundation. "Land Use Regulation and Housing Market Dynamics." $20,000. 2004-2005.

United States – Israel Binational Agricultural Research and Development Fund. "Dynamic Intraseasonal Irrigation Management Under Water Scarcity, Water Quality, Irrigation Technology and Environmental Constraints." $200,000. 2003-2004.

Giannini Foundation. "Economics of Water Conservation in Agriculture." $20,000. 2003-2004.

U.S. Environmental Protection Agency. STAR Grant. "Mechanisms for Risk Trading." $206,000. 2002-2003.

Food Systems Research Group. "Optimal Commodity Promotion in Markets with Imperfect Competition and Differentiated Products." $40,000. 2002-2003.

Outstanding Journal Article Award, AAEA, 2001.

Giannini Foundation. "Economic Benefits of Joint Management of Surface and Ground Water Storage Facilities." $17,000. 2001–2002.

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U.S. Environmental Protection Agency. "Economic Incentives to Reduce Nonpoint Source Loads in Nevada's Truckee River Basin." $98,500. 1995–1997.

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Peer-Reviewed Publications

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Economic Importance of Organophosphates in California Agriculture. With Brent Hueth, Grazyna Michalska, and David Zilberman. California Department of Food and Agriculture. August 1998.

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"Regulation and the Shadow Value of Housing." With Aaron Swoboda. Revision requested by *Regional Science and Urban Economics.*

"The Economic Impacts of Critical Habitat Designation: Evidence from the Market for Vacant Land." With Maximillian Auffhammer and Maya Oren.

"Prices Vs. Limits." With Nicholas Brozovic and David Zilberman.

"Endangered Species Regulation as an Implicit Tax on Development." With Haley Jones.

"Federal Land Use Regulation and the Planning Anticommons." With Aaron Swoboda and Jonathan ter Horst.

WORKING PAPERS

"Regional Strategies for Implementing the Endangered Species Act in Urbanizing Areas." With Haley Jones and Jonathan ter Horst.

"The Value of Groundwater Storage with Spatial Arbitrage."

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"Water Savings from Adoption of Precision Technology." With Karina Schoengold and Georgina Moreno.

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"The Incidence of Environmental Regulation of the Food Processing Industry." With Steve Hamilton.

INVITED PRESENTATIONS

"The Role of the Private Sector in Water Resource Management." American Law Institute – American Bar Association. Denver, CO. March 2009.

"Economic Analysis of Water Resources." American Bar Association Annual Water Law Conference. San Diego, CA. February 2009.

"Benefits of Drought-Resistant Seed Varieties." Conference on Biotechnology and Water Use. Gates Foundation and Giannini Foundation. Berkeley, CA. January 2009.

"U.S. Agriculture in Transiton." Northwest Food Processing Association. Portland, OR. January 2009.

"Economic Perspectives on Water Resources." Water Policy Institute. Washington, DC. October 2008.

"Climate Change and Groundwater Resources." Groundwater Resource Association. Sacramento, CA. August 2008.

"Climate Change, Energy Prices and California's Water Resources." BWC Conference on Biofuels and California Agriculture. Parlier, CA. May 2008.

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"Consideration of Economics Under Porter-Cologne." Urban Water Institute. Newport Beach, CA. April 2005.

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"Bad Neighbors: The Economics of Conflict Over New Housing." Conference on Urban Policy. Berkeley, CA. January 2005.

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"Wetlands Protection Beyond Section 404." American Law Institute – American Bar Association Wetlands Conference. Washington, DC. May 2003.

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Consideration of Economics Under California's Porter-Cologne Act

David Sunding and David Zilberman*

Introduction

Under the Porter-Cologne Water Quality Control Act, the State Water Resources Control Board has the ultimate authority over state water rights and water quality policy.[1] The Act also establishes nine Regional Water Quality Control Boards ("Regional Boards") to oversee water quality on a day-to-day basis at the local and regional level.[2] The Regional Boards engage in a number of water quality functions in their respective regions. One of the most important is preparing and periodically updating water quality control plans, also known as basin plans.[3] Each basin plan establishes beneficial uses of water designated for each water body to be protected; water quality standards, known as water quality objectives, for both surface water and groundwater; and actions necessary to maintain these standards in order to control non-point and point sources of pollution of the state's waters.[4] Permits issued to control pollution (i.e., waste discharge requirements and NPDES permits) must implement basin plan requirements (i.e. water quality standards), taking into consideration beneficial uses to be protected.[5]

The Regional Boards regulate all pollutant or nuisance discharges that may affect either surface water or groundwater. Any person proposing to discharge waste within any region must file a report of waste discharge with the appropriate regional board.[6] No discharge may take place until the Regional Board issues waste discharge requirements, or a waiver of the waste discharge require-

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1. CAL. WATER CODE, Div. 7, Water Quality.
2. CAL. WATER CODE § 13200.
3. CAL. WATER CODE § 13225.
4. CAL. WATER CODE §§ 13240-13241.
5. CAL. WATER CODE § 13263.
6. CAL. WATER CODE § 13260.

ments, and 120 days have passed since complying with reporting requirements.[7]

Under the auspices of the U.S. Environmental Protection Agency ("EPA"), the State Board and nine Regional Boards also have the responsibility of granting Clean Water Act National Pollutant Discharge Elimination System permits, commonly known as NPDES permits, for certain point source discharges.[8] In summary, California routinely issues NPDES permits to selected point source dischargers and either waste discharge requirements or conditioned water quality certification for other discharges. The nine Regional Boards differ somewhat in the extent they choose to apply waste discharge requirements and other regulatory actions.

Before a Regional Board can impose these requirements, however, the Act requires that it "shall take into consideration" the following factors: "the beneficial uses to be protected, the water quality objectives reasonably required for that purpose, other waste discharges, the need to prevent nuisance, and the provisions of Section 13241."[9] Section 13241 in turn lists six "factors to be considered," including "economic considerations" and "water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area."[10]

While the requirement to consider economics under the Porter-Cologne Act is absolute, the legislature and the courts have done little to particularize it. This article is an attempt to fill the gap and provide the State and Regional Water Boards with some guidance as to how economics can and should be considered as required by Porter-Cologne. We begin the paper with a discussion of why economic analysis is important for sound rulemaking, and how economic insights can provide a roadmap toward more effective and efficient interventions. At the federal level, economic analysis in regulation is well established, and federal agencies are often required to at least consider economic impacts prior to taking action. It is also illuminating to review economic analysis of federal environmental regulations; after all, there is now a track record from over two decades' worth of research.

We then turn to a description of how water quality regulations can affect the economy. Some of these impacts are fairly obvious and easy to quantify. Others are subtle, or depend on interactions among firms or sectors of the economy. Economic impacts can sometimes be limited to a small number of well-defined groups. Often, however,

7. CAL. WATER CODE § 13395.

8. CAL. WATER CODE § 13370.5.

9. CAL. WATER CODE § 13241.

10. *Id.*

many groups will be implicated, especially if impacts are propagated through market interactions.

Next, we treat the economics of environmental benefits resulting from water quality regulations. While we are not advocating that a full cost-benefit analysis be performed in every case (and are certainly not suggesting that the Regional Boards adopt only regulations that pass a strict cost-benefit test), the Regional Boards are required by Porter-Cologne to consider the "beneficial uses" to be protected by their actions; those uses should include the economic impact.

Following our detailed treatment of economic costs and benefits, we turn to the practical question of how the Regional Boards can and should put it all together, namely what steps should be followed to gather and use information on economic impacts. While adoption of these procedural steps would be an advance, they do not answer the question of *how* economic impacts are to be measured. Despite the frequent complexity of actual impacts, one of our main goals in this paper is to articulate and defend a baseline set of measurements that need to be performed to achieve the minimally adequate "consideration" of economic impacts under Porter-Cologne. We propose a series of economic impact tests that are relatively easy to interpret and are at least rough measure of the economic impacts caused by water quality regulations.

Of course, in some situations, it will be apparent that water quality regulations have large economic impacts, and more detailed analysis will be required. In these cases, our general discussion of the economic effects of water quality regulation will provide guidance to analysts at the Regional Boards and in the regulated community. It is worth reinforcing that traditional economic analysis may not always be adequate to capture the effects of regulation. In particular, water quality regulation may alter competition in an industry; result in firms relocating to other areas; cause delay, loss of flexibility, and insolvency; result in unintended risks; have dynamic consequences (especially when regulations result in capital replacement); and affect the operation of public sector facilities. These effects are all somewhat outside the bounds of traditional economic analysis of regulation, but are examples of factors that should be considered in the case of Porter-Cologne.

1. Why Consider Economics?

Over the last two hundred years, economists have developed a rigorous methodology to assess the impacts of government actions. The approach derives from the basic principles of public finance and welfare economics, and it adopts a holistic perspective by considering the well-being of many groups in society. Fundamental to most economic impact analyses is an articulation of the tradeoffs involved with policy alternatives. The economist's approach to assessing government actions also combines considerations of efficiency and equity, and it has been widely applied to problems of environmental regulation.

At its heart, economic analysis of regulation is an accounting of the consequences of a governmental action. This accounting is often quantitative, but a number of economic analyses also treat impacts qualitatively, especially for non-standard commodities.[11] Ideally, the economic analysis will also give information on the distributional impacts of the intervention, or a description of the level of impacts on certain groups in society that are affected by the action.

A requirement to "consider economics" is not the same as a directive to adopt only those regulations that pass a cost-benefit test. Agencies can use the results of economic analysis, but not be bound by "bottom-line" numbers. Most economists would hesitate to argue that quantified costs and benefits tell the whole story, or that precise measurements of either are possible. But when economic analysis reveals low or non-existent benefits and high costs, something is likely amiss. It would seem that the California legislature sought to avoid such a socially undesirable outcome by mandating a consideration of economics when making water quality regulation.

While the notion that economics should have a seat at the table when forming water quality regulations in California is controversial, it should be noted that we are largely past this point with respect to many federal regulations. The federal government has maintained a decades-long commitment to economic analysis of regulation. This policy began in the Nixon Administration, which initiated Quality of Life Reviews of federal regulations in 1971.[12] The two main events in the history of economic analysis at the federal level, however, occurred in the Reagan and Clinton Administrations. President Reagan issued Executive Order 12,291, perhaps the most decisive step in the cost-benefit record.[13] This Executive Order established a set of principles for agencies to follow "to the extent permitted by law," including a commitment to cost-benefit analysis. The order required Regulatory Impact Analysis of major rules, and also established a formal mechanism for Office of Management and Budget ("OMB") oversight of interventions.

11. *See generally* WILLIAM J. BAUMOL & WALLACE E. OATES, THE THEORY OF ENVIRONMENTAL POLICY (Cambridge University Press 2d ed. 1988).

12. Memorandum from George Schulz, Dir., Office of Mgmt. and the Budget, October 5, 1971.

13. Exec. Order No. 12,291, 46 Fed. Reg. 13,193 (Feb. 17, 1981).

In 1993, President Clinton issued Executive Order 12,866, which reaffirmed the basic commitments to economic analysis and conferred bipartisan legitimacy.[14] This order also introduced some reforms to the economic analysis process that were designed primarily to assuage fears of industry capture. These reforms included procedures for conflict resolution and inclusion of equity considerations.

Sunstein has articulated a notion of "default" principles for statutory interpretation that describe what agencies are permitted to do when implementing carrying out regulatory programs.[15] In brief, these principles allow federal agencies to

1) Allow *de minimis* exceptions to regulatory requirements;
2) Authorize agencies to permit "acceptable" risks, departing from a requirement of "absolute" safety;
3) Permit agencies to take account of both costs and feasibility; and
4) Allow agencies to balance costs against benefits.

Taken as a whole, Sunstein argues that the default principles are making a substantial difference in regulatory policy, both because of their effects in litigated cases and because of their systematic consequences for policy. The default principles have, in effect, emerged as a central part of the federal common law of regulatory policy.

A general point about the emergence of the default principles is that they indicate a general acceptance of the notion that cost-benefit analysis of regulation is desirable. Sunstein notes that the debate about the acceptability of cost-benefit analysis appears to be "terminating with a general victory for its proponents, in the form of a presumption in favor of their view, signaled above all, perhaps, by President Clinton's substantial endorsement of cost-benefit balancing via Executive Order."[16] The analysis in this article exemplifies a second-generation inquiry into how cost-benefit analysis should be conducted. In particular, we are concerned with the development of a consistent methodology for assessing the economic impacts of water quality regulations and identification of ways to streamline potentially burdensome procedural requirements to consider economics. Other examples of second-generation questions include how to value human life and health, how to deal with the welfare of future generations, and how to value changes in environmental quality.

What has economic analysis of regulation uncovered so far? Without prejudging what economists will find in the case of Califor-

14. Exec. Order No. 12,866, 58 Fed. Reg. 51,735 (Sept. 30, 1993).
15. Cass R. Sunstein, *Cost-Benefit Default Principles*, 99 Mich. L. Rev. 1651-1723, (2001).
16. *Id.* at 1655.

nia water quality regulations, the results have been quite revealing. The findings also indicate why Congress and a series of Presidents have required economic analysis of regulation.

The most basic finding of economic analysis is the large aggregate cost of federal regulation. Since 1981, OMB has reviewed 249 major rules with estimated costs and/or benefits to the private sector or state and local governments of over $100 million annually.[17] OMB calculates that in the past 25 years, over $123 billion of annual direct costs have been added by the major regulations issued by the executive branch agencies.[18] Total regulatory costs are on the order of $200 billion annually.[19]

Another major finding is that despite the federal government's general commitment to economic analysis, regulation is not uniformly efficient.[20] This overall pattern of noncompliance with cost-benefit principles is a cause for concern, even for those who doubt the wisdom of economic analysis but merely want more coherent regulation and better use of agency resources. Hahn and Sunstein, among others, argue that a review of the federal record finds many successes in the form of regulations and other interventions that deliver significant benefits at reasonable prices. But in many cases, regulations seem to do more harm than good. In their review, Hahn and Sunstein conclude that the most serious problem at the federal level is "exceptionally poor priority-setting, with substantial resources sometimes going to small problems, and with little attention being paid to some serious problems."[21]

A review of some regulations is illustrative of this general point. Table 1 from Hahn and Sunstein displays the net benefits of some interventions, defined as annual benefits minus costs. The results display a remarkable lack of consistency among regulations, and also reveal that, despite federal provisions requiring economic analysis, at least some regulations do not pass muster.[22]

17. Office of Mgmt. and Budget, *Draft 2006 Report to Congress on the Costs and Benefits of Federal Regulation*, at 26, *available at* http://www.whitehouse.gov/omb/inforeg/reports/2006_draft_cost_benefit_report.pdf

18. *Id.* at 27.

19. Robert W. Hahn, *The Economic Analysis of Regulation: A Response to the Critics*, 71 U. Chi. L. Rev. 1021, 1021-54 (2004).

20. Robert W. Hahn & Cass R. Sunstein, *A New Executive Order for Improving Federal Regulation? Deeper and Wider Cost-Benefit Analysis*, 150 U. Pa. L. Rev. 1489, 1489-1552 (2002).

21. *Id.* at 1490.

22. As discussed earlier, the federal commitment to economic analysis of regulations is longstanding and bipartisan. Too often, however, this commitment is superficial and, in some ways, symbolic. The solution, Hahn and Sunstein argue, is institutional reform, embedded in a new executive order and some statutory changes, that would increase the role of economic analysis in regulatory policy.

The point about a lack of consistency has been made even more forcefully in the work of Tengs et al., who gathered information on the cost-effectiveness of over 500 life-saving interventions.[23] These interventions were defined as "any behavioral and/or technological strategy that reduces the probability of premature death among a specified target population." Interventions were classified by type and included both regulatory and non-regulatory life-saving measures.

Table 1: Economic Impacts of Some Recent Federal Regulations[24]
(Net benefits, in millions, adjusted to 1996 dollars)

Regulation	*2000*	*2005*	*2010*	*2015*
Exposure to methylene chloride	-60	-60	-60	-60
Roadway worker protection	0	0	0	0
Financial assistance for municipal solid waste landfills	-100	-100	-100	-100
Pulp and paper effluent guidelines	-150 to 0	-150 to 0	-150 to 0	-150 to 0
Ozone standards	0	-235 to 240	-840 to 1,190	-9,200 to – 1,000
Child restraint system	-40 to 40	-40 to 40	-40 to 40	-40 to 40
Vessel response plans	-220	-220	-220	-220
NOx emission from new fossil fuel fired steam generating units	-57 to 29	-57 to 29	-57 to 29	-57 to 29

23. Tammy O. Tengs et al., *Five Hundred Life-Saving Interventions and Their Cost-Effectiveness*, 15 Risk Analysis 369, 369-82 (1995).

24. Hahn and Sunstein, supra note 20, at 1491.

Tengs and her co-authors defined cost-effectiveness as the net resource cost of the intervention per life-year saved. Several findings of their analysis are important. First, the authors uncovered an enormous disparity in terms of the efficiency of alternative life-saving interventions.[25] Some measures prevented premature death at a trivial cost per life-year saved — less than $10,000. Other measures, however, cost in excess of $1 billion per life-year saved. This finding suggests that interventions, including regulatory ones, are poorly prioritized.

Another main finding of the Tengs paper is that, as a category, toxin control regulations are a relatively expensive way of preventing premature death. Tables 2 and 3 present some findings relative to this general point. Table 2 shows the median cost per life-year saved of the three basic categories of interventions: medical, injury reduction, and toxin control. The results indicate that toxin control regulations are several orders of magnitude less efficient than medical interventions or injury reduction measures (leading some to ask why society is rationing access to medical care while at the same time promulgating an increasing number of environmental regulations). Table 3 shows the cost-effectiveness of regulations by agency. A similar conclusion follows from this analysis, namely that despite the federal commitment to cost-benefit analysis, there appears to be a serious discrepancy among types of interventions in terms of cost-effectiveness. This suggests that a change in priorities could save more lives at less cost than current policies.[26]

Table 2: Median Cost per Life Saved for Different Types of Interventions

(Cost per life-year saved in 1995 dollars)

Medical Interventions	$19,000
Injury Reduction	$48,000
Toxin Control	$2,800,000

Source: Tengs & Graham at 369.

25. See also John F. Morrall, III, *Saving Lives: A Review of the Record*, 27 J. Risk & Uncertainty 221 (2003); Cass R. Sunstein, *Risk and Reason: Safety, Law and the Environment*, (Cambridge University Press 2002); Stephen Breyer, *Breaking the Vicious Circle: Towards Effective Risk Regulation* (Harvard University Press 1997).

26. This point was made forcefully by Tengs and John Graham. *See* Tammy O. Tengs & John Graham, *The Opportunity Costs of Haphazard Social Investments in Life-Saving*, Risks, Costs and Lives Saved: Getting Better Results from Regulation (Robert W. Hahn ed., Oxford University Press and AEI Press 1996). Tengs and Graham argue that the present pattern of investments in 185 life-saving interventions considered results in the loss of $31.1 billion, 630,000 life-years, or 61,200 lives every year.

Table 3: Median Cost of Regulation per Life Saved for Different Agencies

(Cost per life-year saved in 1995 dollars)

Agency	Cost
FAA	$23,000
Consumer Product Safety Commission	$68,000
National Highway Traffic Safety Commission	$78,000
OSHA	$88,000
EPA	$7,600,000

Source: Tengs & Graham at 371.

There is nothing intrinsically anti-regulatory about economic analysis. For example, implicit in the finding cited earlier that regulations vary widely in terms of their cost-effectiveness is the notion that some regulations are highly efficient and achieve their objectives at low cost. Perhaps a better measure of desirability is net social benefits, or benefits minus resource costs. In an influential survey of federal environmental policies, Freeman concluded that some policies are cost-benefit "winners" while others are "losers."[27] Winners include removing lead from gasoline, controlling particulate matter in air pollution, reducing lead in drinking water, cleaning up hazardous waste sites with the lowest cost per cancer case avoided, and controlling CFC emissions. Freeman's losers include mobile source air pollution control, most waterway discharge control, many regulations under the Federal Insecticide, Fungicide, and Rodenticide Act ("FIFRA"), the Toxic Substances Control Act, the Safe Drinking Water Act, Superfund, and policies aimed at controlling ground level ozone.

Hahn has argued that economic analysis can help to lower the cost of achieving given social objectives such as environmental quality.[28] He points to the famous example of market-based approaches for achieving environmental goals.[29] The savings of market-based

27. A. Myrick Freeman, III, *Environmental Policy Since Earth Day I: What Have We Gained?* 16 J. ECON. PERSP. 125 (2002).

28. Hahn, *supra* note 19.

29. Thomas H. Tietenberg, *Emissions Trading: An Exercise in Reforming Pollution Policy*, (Resources for the Future Press, 1985).

versus command-and-control policies result from differences in the cost of compliance with regulations.

Another insight from economic analysis of regulation is that risk-reducing policies may themselves impose risks that are frequently not considered by regulators. In Sunstein's terminology, "Risks never exist in isolation. They are part of systems. For that reason, any effort to reduce a single risk will have a range of consequences, some of them likely unintended."[30] Hahn cites examples including fuel economy standards for automobiles that are designed to reduce environmental risks but make automobiles less safe, banning the manufacture and use of asbestos that led companies to use more dangerous substitutes, and efforts to remove asbestos from public buildings that may cause risks to workers.[31] When such risk-risk tradeoffs are dealt with explicitly through economic analysis, they often result in regulators taking a closer look at proposed interventions.

Economic analysis makes the regulatory process more transparent. In his early work on regulatory impact analysis, Hahn concluded that there were numerous problems with the presentation of information.[32] Documents frequently did not summarize findings or include an assessment of the costs and benefits of the regulation. To counter this deficiency, he helped develop a "scorecard" for regulation. This scorecard summarizes key aspects of a regulation such as agency estimates of both qualitative and quantitative costs and benefits.[33] The use of the scorecard helps promote agency accountability at the federal level by allowing OMB and the public to evaluate how well agencies are performing. OMB is now required to produce scorecards that operate in a similar way.[34]

Hahn also argues that the use of scorecards can promote the establishment of institutions that hold regulators accountable.[35] One such idea is a "regulatory budget" that would limit the costs an agency can impose on the public through regulation.[36] A variant would also consider benefits and give agencies a defined budget in terms of net benefits. As long as they implement regulations with positive net benefits, the budget is not depleted. However, a policy

30. Sunstein, *supra* note 15, at 1653.

31. Hahn, *supra* note 19.

32. *Id.*

33. Hahn & Sunstein, *supra* note 20.

34. The Budget and Fiscal, Budget, and Program Information, 31 U.S.C. § 1105 (2006).

35. Hahn, *supra* note 19, at 1045-46.

36. Eric A. Posner, *When Reforming Accounting, Don't Forget Regulation*, AEI-Brookings Joint Center Policy Matters 02-35 (2002), http://www.aei-brookings.org/policy/page.php?id=104.

that has an apparent negative net benefit would be costly to the agency.

Consistent with these observations regarding economic analysis of regulation, the California legislature required consideration of economics and environmental benefits when establishing water quality standards, and again when issuing discharge permits.[37] A Regional Board must take a second look at water quality standards before issuing a permit.[38] It must look at the standards themselves and at the factors that were initially considered when the standards were established, including the costs of the requirements it is imposing, as well as environmental benefits that are ultimately to be gained from control of all discharges.[39]

The desirability of considering economics at the permitting stage is worth considering. Regional Boards develop water quality standards at the basin level, which may cover up to thousands of square miles.[40] For example, there is only a single basin plan for the area regulated by the Los Angeles Regional Board; within this area there are numerous rivers and streams.[41] Further, local conditions, both economic and environmental, can vary widely throughout the basin. What makes sense basin-wide may not make sense in a particular location, or for a portion of a particular stream.

2. Costs of Water Quality Regulations

Economic analysis of regulation typically quantifies both how an intervention affects the overall well-being of society, as well as how these impacts are distributed among various groups. Often, the costs of regulation are simple to calculate, for example, in cases where the regulation entails a small increase in an industry's cost of production without affecting its operations or competitive conditions in a fundamental way. But when regulation results in basic changes in production techniques, reduced competitiveness, spillover effects to other industries, or other effects, more sophisticated analysis may be required. Affordability and the threat of bankruptcy raise other important concerns that may not be fully addressed in textbook analysis, but are treated here.

The challenge facing economists considering water quality regulations is how to develop procedures based on these general approaches and determine in advance what impacts need to be empha-

37. CAL. WATER CODE § 13241 (2006).

38. *Id.* § 1258.

39. *Id.* §§ 1253, 1257.

40. *Id.* § 13200.

41. *Id.* § 13200(d).

sized. The starting point of the design of an economic impact methodology is to identify the various categories of costs and benefits that may result from regulation. While we introduce a large number of potential impacts of regulation, it is worth emphasizing that not all of these will occur in every situation.

One of the key features of economic analysis is its capacity to assess the impacts of policy on various groups. The theory of welfare economics provides the intellectual foundation to the applied analysis of regulation.[42] This approach entails a partitioning of society into individual units of analysis. These units include consumers, producers, suppliers of inputs to production, and people who consume environmental amenities. The theory suggests that the aggregate impact of a policy is the sum of its impacts on these various groups.

While environmental quality regulations are imposed on producers and firms for the most part, impacts do not end there. Rather, economic consequences are transmitted via market interactions to other groups, most importantly consumers. The propagation of the impacts of a regulation through the economy is well documented and can be quantified by economic analysis.

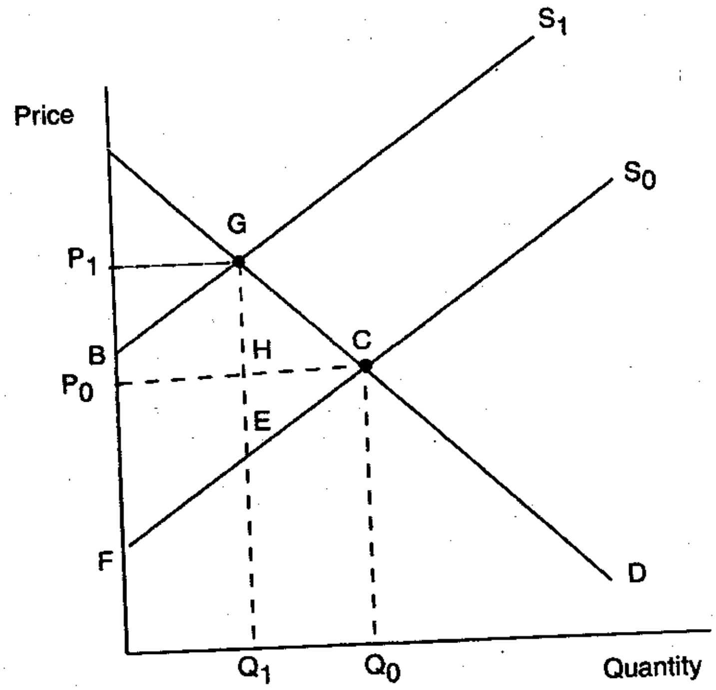
Economists typically distinguish between regulations that are directed at the private sector and those that are directed at the public or not-for-profit sectors. For example, regulations limiting chemical use in farming are targeted mainly at private businesses. Regulation of flood control or navigation infrastructure targets mostly public sector activities. Regulations targeting the public sector may affect agents in the private sector (e.g., elimination of roads to protect wetlands affects the economic activity and the well-being of consumers and firms). Similarly, regulations of industry may affect the cost of operation of entities in the public sector. With this in mind, we deconstruct the incidence of water quality regulations into several categories.

Producer Surplus

Producer surplus is a measure of the economic welfare of producers, and it is most simply defined as the difference between revenue and variable cost over the relevant range of output. Producer surplus is best interpreted as a measure of the rent accruing to the unique assets of firms in an industry or of their economic profit. Water quality regulation that increases the cost of production has a direct negative effect on producers through the resulting increase in variable costs, and a positive effect if it increases output prices.

42. ANDREU MAS-COLLEL, MICHAEL D. WHINSTON, & JERRY R. GREEN, MICROECONOMIC ANALYSIS 817-56 (Oxford University Press 1995).

In Figure 1, the increase in price due to the regulation increases producer surplus by the area ABDH, the increase in costs is the area FEGB, and lost profit is represented by the area P_0HBP_1. Producers may actually gain from water quality regulations if they face a demand that is not price sensitive.



S_0 = supply before regulation

S_1 = supply after regulation

D = demand

Q_0, Q_1 = quantity before and after regulation

P_0, P_1 = price before and after regulation

Figure 1

The reduction in output resulting from the higher costs of production because of the regulation will lead to a substantial increase in output price, and the increased revenue may more than compensate for the higher costs of operation. Situations where demand is inelastic in the long run are not very likely. A firm or region may temporarily have a monopoly in production of a product due to specific human capital or technological advantages, but as these erode, other producers or regions of production will enter the market.

Regulation can also result in out-of-pocket expenses for negotiating and obtaining needed permits.[43] These so-called transaction costs of regulation act in the same way as other cost increases resulting from regulation and add to other effects such as the need to alter production technologies or substitute inputs.

Because industries often consist of many players and the chain of production can have several layers, the analysis of producer surplus may need to be multidimensional. In particular, it should address the following considerations.

Interstate and International Competition

Given the major industries where California's firms are competing within international and national markets, producer surplus analysis of water quality regulations affecting industries such as computers, some sectors of agriculture, and biotechnology, may need to consider supply and demand in a global context. As Figure 2 suggests, the demand for major products is met by the sum of California's supply (SC) and the supply of the rest of the world (SR), forming the global supply (SG). The initial equilibrium had a price of P_0 and a quantity of Q_{G0} with California production of Q_{C0}. The initial producer surplus of California is ABC.

Strict regulation of water quality in California may reduce the supply of its producers, and that result is the shift of California's supply to SC_1. That will lead to reduction of the global supply which will shift to SG_1. The reduced supply will lead to higher P_1 and a lower global production of Q_{G1}. The higher prices will increase the output produced outside California, while production in the state will decline to Q_{c1}. The lower output of California producers and the higher costs are likely to result in a significant reduction in producer surplus, which becomes BFC in Figure 2, while the producer surplus of the rest of the world is enhanced.

43. David Sunding & David Zilberman, *The Economics of Environmental Regulation by Licensing: An Assessment of Recent Changes to the Wetland Permitting Process*, 42 NAT. RESOURCES J. 59, 74-82 (2002).

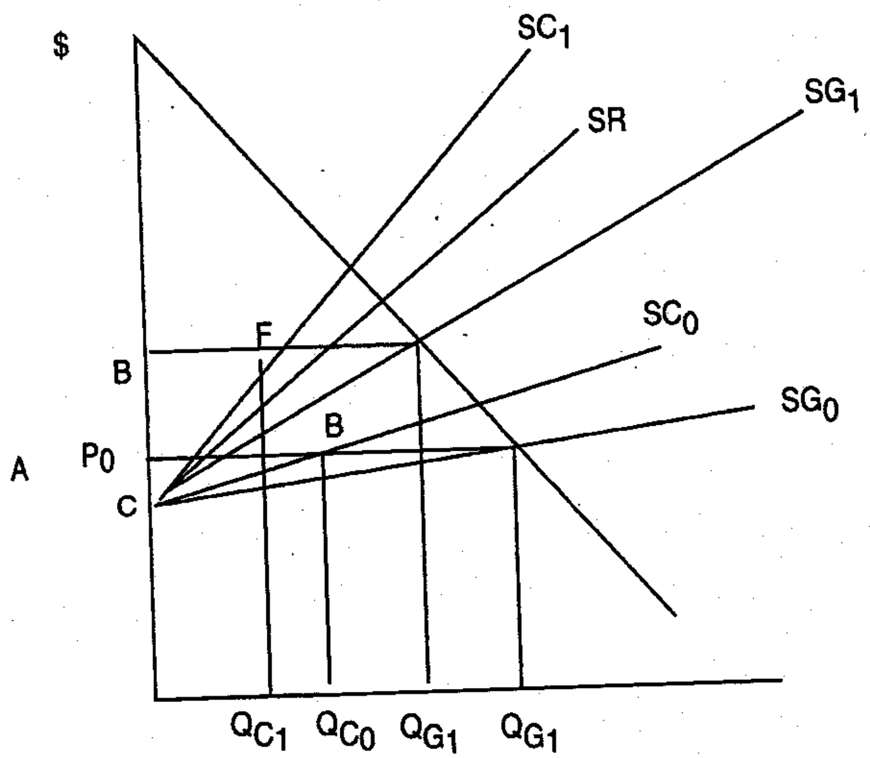


Figure 2

Heterogeneity of Impacts Within the State

Water quality regulations will not affect all firms and regions in California equally. These differentiated impacts should be recognized in the derivation of producer surplus.

California's firms that have to modify their water management practices in response to the regulations have increased costs, lower sales, and are likely to lose from the regulations (unless demand is very inelastic and price effect is drastic). On the other hand, the firms not affected by water quality regulations gain profit as they produce more (taking away market share from the affected firms) and as market price increases.

Several models introduce methodologies to analyze these distributional impacts of natural resource regulations on producer surpluses across regions.[44] Water quality standards frequently target a subset of regions or firms in a particular market. Higher water quality standards that have strong negative affects on, say, tomato growers in the San Joaquin Valley may benefit growers in the Sacramento Valley because of the output price effect. Sunding shows that while the relative impact of a regulation on the aggregate producer surplus across the state may be moderate, its relative impacts on the producer surplus of firms in some regions may be highly significant.[45] Identification of the most affected regions should be an important priority for impact assessment.

Impacts Along the Chain of Production

The standard analysis of policy impacts distinguishes between two major groups of economic actors — consumers and producers. However, the providers of goods and services are multilayered. Producers of consumer goods rely on manufactured input. In some situations, it is valuable to distinguish between *firm* and *consumer* surplus levels. For example, this distinction is relevant in the analysis of regulations affecting the use of pesticides and other chemical pollutants affecting water quality. These regulations may have different effects on chemical manufacturers, as opposed to farmers or industrial users of the chemicals. To a large extent, the impacts on each group will depend on the availability and efficacy of substitutes.[46] The existence of viable substitutes makes manufacturers of the regulated product more vulnerable to regulation at the same time it makes users less affected by regulation.

The distribution of impacts within the production chain also depends on the structure and organization of the industry and assignment of liabilities within various firms among other things. Sunding and Zilberman developed a framework to analyze situations where environmental quality is affected by residue of chemicals used in production, and distinguished between the impacts of regulation on the producer surplus of chemical manufacturers and users.[47] The analysis suggests that both the overall impact of water quality regulations and their distribution among the various parties vary depending on allocation of liabilities and market structure. Outcomes of regulation differ when the chemical is produced by a monopoly or when a competitive firm produces it.

44. David Sunding, *Measuring the Marginal Cost of Nonuniform Environmental Regulations*, 78 AM. J. AGRIC. ECON. 1098, 1100-07 (1996).

45. *Id.* at 1106-07.

46. *Id.* at 1106.

47. David Sunding & David Zilberman, *Allocating Product Liability in a Multimarket Setting*, 18 INT'L REV. L. & ECON. 1, 2-11 (1998).

Competitiveness

Compliance with water quality regulations may be costly and, as we have seen, this cost has many dimensions. Nonetheless, one concept that can summarize much of these costs is competitiveness. While environmental amenities and water quality may make a region more attractive, excessive regulation can also hinder the performance of firms in the region relative to firms residing elsewhere.

Some of the equilibrium effects of regulation are captured by traditional market analysis through, as we have seen, loss of consumer surplus and producer surplus. But in many cases, market information about supply and demand at the present cannot provide the information needed to assess the impact of regulation because there may exist *potential* competition that has not yet become actual. If, for example, the cost of manufacturing electronic components in California increases as a result of regulation, Texas may develop productive capacity in these areas, even though it has not produced these products in the past.

Baumol introduced the notion of contestable markets, arguing that potential entrants play an important role in setting prices that are close to the competitive level. That is, even a monopolist is restrained by the threat of new competition. Here, we suggest that the notion of competitiveness and potential competition restricts the capacity of the industry to raise prices in response to regulation, as the profit opportunities caused by reduction of supply by incumbents will attract new entrants. That suggests that it is important to recognize conditions where water quality regulations will drastically affect cost of production of the local industries that have significant market power, and in these cases it is valuable to assess not only impact of existing competitors but also the threat from potential new entrants.

The impact of water quality regulations on competitiveness has other dimensions. If the implementation of water quality regulations is time consuming and significantly restricts the capacity of industries to respond in a timely manner to new knowledge and new commercial opportunities, it may eventually lead to significant cost. Firms may elect to relocate from California or to reduce their investment in the state if their flexibility and speed of response to opportunities is reduced by regulation. Therefore, it is important to have a good handle on the delay and delay cost of water quality regulation. It is important, for example, to know how much extra time it will take a computer manufacturer to build a new facility because of regulation.

Having financial resources is crucial for firms' capacity to invest in new technologies and new enterprises. Modern industries invest in capital goods that have a short economic life, and while firms may have a significant amount of short-term profits, part of those go to pay debts and part go for use as a capital base for new investment. High-cost water quality regulations may be evaluated in terms of their impact on ability to pay debt and accumulate capital. When this capacity is significantly eroded, it affects firms' ability to survive and grow, and ultimately, the state's competitiveness.

A related impact of water quality regulation on competitiveness is its impact on labor. Labor mobility within the state is an important element of flexibility and enables quick response of industry and the economy to new opportunities. The flexibility of industry is not only restricted by its capacity to build or modify facilities in a timely manner, but by the capacity to provide housing to workers to allow smooth operation of new enterprises. Workers and consumers both demand and deserve high-quality water and related water amenities, but their choice of employment and response to opportunities is also dependent on availability of housing.

Water quality regulations may affect competitiveness for resources available to the public sector. Local governments have to balance expenditures between various objectives, including education, health, roads, and the environment. High cost (water quality regulations) may lead to reduction in expenditures on other items such as education or infrastructure, resulting in reduced capacity to compete and reduced productivity of the private sector.

Insolvency

In the previous section, we argued that frequently water quality regulations might reduce marginal cost of production and reduce supply. However, as long as revenues are greater than costs, it is efficient for the firm to continue operation. Nevertheless, firms have financial obligations and, even though they may have short-term profit, if they cannot pay their debts they will go bankrupt. In theory, if revenues are greater than costs, someone will buy the firm after bankruptcy, and it will continue to operate. In this way, bankruptcy would not seem to affect resource allocation. More recent research suggests otherwise, namely that the costs of insolvency are real. The work of Kahneman and Tversky, for example, established that decision makers have loss aversion, and there is a significant cost to financial losses.[48] Bankruptcy also requires significant costs of readjustment for the affected property owners and employees.

Previous research suggests some avenue for exploring the insolvency implications of water quality regulations. Hochman and Zil-

48. Daniel Kahneman & Amos Tversky, *Prospect Theory: An Analysis of Decision Under Risk*, 47 ECONOMETRICA 263, 274-89 (1979).

berman studied the impact of tighter water quality standards on dairies in the Chino region of Southern California.[49] They suggested that requirements to increase the disposal acreage make the operation of a certain number of growers (less than 10 percent) unprofitable in that the operational cost will be smaller than the revenue. However, they realized that firms have to pay their debts and, even if the revenue after accommodating the regulation exceeds the variable cost, the surplus is not sufficient to meet the financial obligations of the firms. Thus, some firms may be forced to close. The same study found that under reasonable assumptions about the distribution of the debt-equity ratio among producers, the owners of more than thirty percent of the land might not be able to meet their financial obligations resulting from the regulation.

One of the methodological challenges facing economists is to quantify the cost of insolvency. At present, economic theory does not suggest totally satisfactory, formal measurements of the economic costs of insolvency. At a minimum, however, it is useful to develop an estimate of the percentage of business establishments whose solvency may be threatened by water quality regulations.

One regulatory approach to deal with insolvency and ability to pay has been to assess the affordability of water quality regulations under different assumptions about the cost of implementation. In essence, this approach estimates how much firms in the industry can afford to pay for cleanup. An alternative approach that we favor is to estimate of what percentage of the firms will become insolvent after regulation, and what percentage of productive capacity will be affected by insolvency after regulation. This will require information about the debt structure of firms in the industry as well as the distribution of profitability.

Dynamics

Economists realize the importance of technological rigidity. Investments in capital goods often affect the ability to control effluent, but short-term adjustments in the capital stock may be very costly and limited in their effectiveness. This observation implies a need to collect information on the age of the system (i.e., capital stock vintage) and the time and cost required before replacement of existing technology. It may be worthwhile to emphasize changes in waste management brought by a new design, rather than to require heavy investment in structures that will otherwise become obsolete. Some-

49. Eithan Hochman & David Zilberman, *Two-Goal Environmental Policy: An Integration of Micro and Macro Ad Hoc Decision Rules*, 6 J. OF ENVTL. ECON. AND MGMT. 152, 152-174 (June, 1979).

times it may be worthwhile to provide the incentive for the firm to engage in research to find a technological solution, rather than impose high costs within an existing suboptimal system — improve the next vintage rather than the current one. For example, if a plant lasts 10 years and a problem is discovered in the eighth year, unless the problem is severe, it may be desirable to tolerate pollution in the short term and push for improvements in the stock of replacement capital.

The impacts of water quality regulations frequently take years to materialize and thus should be analyzed within a dynamic framework, taking into account the projected changes in the economic situation over time. The state of the economy affects prices of inputs required for activities needed to comply with regulation. For example, the prices of labor and raw materials needed for construction of, say, a drainage disposal facility is likely to increase during periods of high economic growth. The economy affects the impacts of compliance with water quality regulation on output prices and consumer and producer welfare. For example, when an intervention leads to substantial reduction of supply of an affected industry, it may lead to a substantial increase in consumer prices in periods of high economic growth and strong demand, but may have a small effect in periods of low economic growth when demand is sensitive to consumer income.

Finally, the impact of regulation on the economic well-being of affected firms and their capacity to survive extra costs of production and additional constraints on operations depends on macroeconomic conditions. For example, macroeconomic conditions affect the interest rate and the ability of firms to raise capital. Exchange rates affect the earning of California's producers overseas as well as their earning capacity, and thus their ability to invest in compliant technologies.

Compliance with some water quality regulations requires a large investment and a long-term response. In this case, dynamic analysis is paramount. It is important that assumptions about economic growth and macroeconomic conditions are transparent. Because of uncertainty about the future, it is also important to consider several competing scenarios. When possible to assign probabilities to various situations, it may be worthwhile to analyze policy impacts through simulations that will derive the statistical distributions of impacts over time and to develop estimations of their expected values and their variability. Note also that when it is possible to identify several distinct scenarios in terms of the macroeconomy and economic growth, it may be feasible to introduce policy implementation policies that are conditional on the performance of the economy.

Public Sector Expenditures

Water quality regulations frequently affect activities conducted by public or semi-public agencies. Water provision and treatment, flood protection, and construction and maintenance of roads serve the public and are provided by public or semi-public agencies. Many schools and hospitals are to a large extent supported by public monies, and are frequently part of the public sector. Stricter discharge limits and other forms of water quality regulations affect the operation costs of public sector entities. Water quality management by the private sector may affect the cost of public agency management. Discharge regulations that reduce waste generated by firms and consumers may reduce the costs of a sewage district. The change in the expenditure of these nonprofit agencies is an important impact category.

It is important to distinguish between impacts of water quality regulations on public sector expenditures (which are discussed in the previous paragraph) and the impacts of regulations that target public sector activities. Regulations that target activities of public sector entities may affect the private sector to the extent that the output of the public sector changes as a result of the water quality regulation. If the regulation does not affect the output of the agency, but does affect its cost of providing these outputs, then the water quality regulation impacts the level of public sector expenditures. For example, if a Department of Public Works needs to increase expenditures to meet water quality regulations, and a government has a balanced budget constraint, either the government has to increase its revenue to meet the extra expense or the government has to somehow cut its costs.

In most cases raising taxes is difficult, so the increase in cost of complying with water quality regulations leads government agencies to reduce expenditures elsewhere. These reduced expenditures have significant welfare impacts. In particular, they may lead to reductions in producer or consumer surplus. For example, an increase in the cost of compliance with water quality regulations may reduce expenditures on health services, education, or maintenance of roads. If governments are able to raise taxes to meet the extra compliance cost, then that will lead to a reduction of the consumer and producer surpluses of affected taxpayers.

One way to assess the importance of extra water quality regulations is to compare the extra cost of affected public sector agencies to the overall budget of these agencies. Policymakers need to know what percentage of agency budgets must be dedicated to comply with extra water quality regulations.

Price Increases and Consumer Effects

Most environmental regulations affect the per-unit cost of producing output, and thus lead to higher market prices. Consumer surplus is the difference between the maximum amount that consumers would be willing to pay for quantities they consume and the actual price they pay. For example, if a person is willing to pay $100 for a suit, and the actual price is $60, then the consumer surplus would be $40. Technically, consumer surplus is the area between the demand curve and the market price. Regulations that lead to increased variable cost result in loss of consumer surplus as well as producer surplus.

A product may be sold to several groups in the economy. Each has its own demand curve. Consider a typical situation where there is a high-income group of consumers whose demand is not price sensitive, and a low-income group whose demand is very sensitive to price changes. Regulations that increase the market price of the commodity would likely cause a much larger relative reduction in the surplus of the lower-income group.

Delay Costs

An extensive regulatory process can be time consuming and can slow the execution of new projects and the utilization of resources. Frequently, land resources lay idle during the period of regulatory assessment and proposal evaluation. The costs of the economic surpluses lost during periods of delay may be quite substantial. If implementation of new water quality regulation may lead to a two month delay in completion of a road or a housing development, the losses to consumers, producers, and the public sector may be substantial.

The delay cost depends both on the extra time needed to assess the action that needs to be taken in light of new water quality regulations, as well as the time needed to implement these extra regulations. For example, extra protection of habitats or stricter wetland regulation may slow the time it takes to obtain a permit and may increase the amount of time that it takes to implement the project. Thus, the developers have to pay more interest and, more importantly, the consumers and producers who benefit from the new development lose all consumer and producer surplus during the delay period. A quantitative estimate of the impact of a new water quality regulation on the time it takes to obtain a permit and to implement a project is very important as a first step in assessing the delay cost. This information should also be available to the public as a way to assess the performance of the Regional Boards.

When assessing delay cost, it is important to recognize that the operations of some industries depend on the weather and thus may be seasonal in nature. For example, there is much less construction activity during the rainy season. Water quality regulations that lead to minor delays for compliance may nevertheless cause a developer to miss an entire construction season. In this case, the regulation may lead to significant delay costs because of the seasonal nature of the industry.

The delaying effects of regulation can also affect economic well-being through their impact on competitiveness. California is the home of some of the most dynamic industries in the world, and they have a fast rate of innovation and many short-lived products. A firm may lose "first mover advantage" and potential market share if its product introduction is delayed because of extra regulatory requirements. It instructive to compare the time it takes to comply with water quality regulation to the expected length of the economic lives of manufacturing facilities and other infrastructure of various industries.

Costs to Regulatory Agencies

Governments have to expand their staff, conduct studies, and establish mechanisms and organizational capacity to monitor and enforce compliance. In particular, new water quality regulations may affect the costs of processing requests for land-use modifications, other natural resource management, and some industrial and infrastructure projects. The regulatory costs incurred in periods of transition to new water quality regulations may be especially high.

If new water quality regulations are introduced without increasing the budget of the regulatory agency, this may lead to stretching its resources and may affect overall performance. The efficiency of agencies in implementing effective regulation may be reduced as the result of expanded mandates. The cost of the water quality regulation may be borne by individuals directly affected by these regulations and also by those affected by other regulations, but are underserved because of the work overload associated with the new regulation. Implementation of regulation is not costless. The regulatory agency has its own cost, and the regulated public also experiences associated transaction and delay costs.

Risk-Risk Tradeoffs and Unintended Environmental Costs

Risks never exist in isolation, and action to combat one risk may create others. At the federal level, agencies are now permitted to consider substitute risks. In the U.S. Supreme Court case *Whitman v. American Trucking Association*, for example, it was argued that while ground-level ozone creates certain health risks, it also reduces others, mainly because it provides protection against skin cancer and cataracts.[50] The EPA responded that it lacked the authority to consider the risks created by regulation. On its own, the statutory text seemed to support the EPA's view. It provided that ambient standards must be based on "criteria" documents that are supposed to include the "latest scientific knowledge" useful in indicating the kind and extent of all identifiable effects on public health or welfare which may be expected from the presence of such pollutant in the ambient air, in varying quantities.[51] The EPA argued that the phrase "identifiable effects" of "such pollutant" was meant to refer to the adverse effects of the "pollutant."

An even more suggestive case is *Competitive Enterprise Institute v. National Highway Transportation Safety Administration* where the plaintiff charged fuel economy standards on the grounds that the agency had failed to consider the adverse effects of such standards on automobile safety.[52] In the face of an ambiguous statute, the court reasoned that a full explanation was required for a decision that would seem to create substitute risks. As a result of this decision, the National Highway Traffic Safety Administration is now required to consider health-health tradeoffs in setting fuel economy standards.

Water quality regulation that aims to improve environmental quality can have unintended consequences that harm the environment and natural resources. The reallocation of water from one location to another, to meet water quality regulation, may reduce the well-being of fish and wildlife dependent on the water in the source region. Reduction of use of chemical pesticides that reduce farm productivity may lead to an increase in utilized land and expansion of the utilized land base to wilderness areas. Diversion of water resources to meet environmental quality objectives may reduce the capacity to utilize this water in provision of environmental amenities. We will discuss the economics of changes in environmental quality later in the paper.

User Cost

Water quality regulations may affect natural resources that are either renewable or nonrenewable. For example, reduction in the concentration of chemicals in a certain body of water may require pumping groundwater from an aquifer. The user costs in this case are the future costs of changes in availability of water from the aqui-

50. *Whitman v. American Trucking Ass'n*, 531 U.S. 457, 495 (2001).

51. *Id.* at 473.

52. *Competitive Enter. Inst. v. Nat'l Highway Traffic Safety Admin.*, 45 F.3d 481, 484 (D.C. Cir. 1995).

fer as a result of this activity. The reduction in the aquifer at present would reduce the availability of water in the future and increase the cost of pumping as the aquifer drops farther below the surface. Similarly, one can compute the user cost of reducing the fish population at present (which includes the cost of having the fish in the future, and the lost value of the population growth).

Employment and Multiplier Effects

Any regulatory cost has a direct economic affect on relevant consumers and producers and other economic agents. Regulatory costs may indirectly affect the economy as they affect the income of various parties, which will allow parties to further spend money and engage in other economic activities. There are methodologies to look at this multiplier effect and assess the direct and indirect impact of regulations. In particular, these methodologies can also assess secondary impacts on employment. In most of our analysis, we would not address this multiplier effect but one must be aware of its existence and how it can be derived.

3. General Observation on Cost Analysis

Now that we know the basic cost categories, we can discuss some of the principles of aggregate analysis. In fact, the two methodologies are closely related. In principle, cost effectiveness is nested within cost-benefit analysis. A cost-effectiveness analysis compares interventions in terms of resources expended to achieve some basic objective such as life-years saved or units of habitat restored. Cost effectiveness takes the water quality objective as given, while cost-benefit analysis compares the net economic merits of alternative objectives. A cost-benefit, welfare improvement analysis measures the value of benefits achieved versus the cost of the intervention.[53]

The notion of efficiency is a critical element of economic analysis. Outcomes are said to be efficient if the regulatory objective cannot be met with lower overall costs. Thus, the efficiency criteria merge the overall economic performance of a project or regulation. The efficiency effect of a water quality regulation is a net economic benefit or cost, taking into account all the impacts. For example, a water quality regulation that bans chemicals may affect the wellbeing of consumers and producers, and yet improve the water quality of a river and result in improved human and environmental health.

53. In economic terminology, these modes of analysis are called "Second Best" and "First Best."

The difficulty of estimating environmental and resource costs led Baumol and Oates to propose an alternative approach for policy evaluation.[54] They suggest that environmental policy selection will aim to meet environmental policy targets at least cost, and the policymakers are assumed to select these targets. The notion of cost effectiveness is consistent with this approach. It suggests that the market cost of a water quality regulation is a good measure of attaining the environmental policy objective behind them.

Another approach to evaluate the effectiveness of water quality regulation is to consider *internal consistency*.. This is especially effective when the main impetus of a regulation is to reduce a certain type of risk (for example, the risk of loss of human lives). By computing the number of expected lives saved, as well as the market cost of compliance to the regulation, one can derive the implicit value of human lives saved. It is desirable that regulations be established so that the value of life saved will be consistent across locations. In cases where the implicit value of life saved is low, the regulation should be stricter. Where it is too high, the regulation should be more lenient.

Scale of Analysis

An impact assessment of water quality regulations can be done from various perspectives, and the assessment of a regulation may vary if it is done from a national versus a regional perspective.[55] For example, water quality regulations that reduce water available to agriculture in California may reduce supply, and thus increase prices and reduce consumer surplus. When most of the buyers of the affected product are out of state, the consumer surplus loss is not taken into account in the impact assessment taken from a California perspective, but is considered in the impact assessment from a national perspective. Similarly, when it comes to goods that are exported abroad, ignoring the impact on consumer surplus of foreign buyers may lead to underestimation of a policy effect. Thus, the national perspective is different than both the regional and the global perspectives.

In most cases, the impact of water quality regulations is local and, therefore, the significance of aggregate analysis is limited. This observation suggests that analyses should be conducted on water basin levels or even lower levels of aggregation. It is important to pinpoint areas that are most affected and have some structure of the distribution of impacts across regions. A certain water quality regula-

54. *See generally* BAUMOL & OATES, *supra* note 12.

55. David Sunding, David Zilberman & Neal MacDougal, *Water Markets and the Cost of Improving Water Quality in the San Francisco Bay/Delta Estuary*, 2 HASTINGS W.-NW. J. ENVTL. L. & POL'Y. 159, 163-64 (1995).

tion may seem to not affect California as whole because it may lead to migration of industries from one region to another. However, as Kahneman and Tversky argue, for a change of a given magnitude, the economic cost of loss outweighs the economic benefits of gain.[56] Therefore, the analysis of distributional effects within the state is very valuable.

The type of information needed in economic analysis may change at different levels of analysis. For example, employment and secondary impacts may be much more important when considering the regional effects of a policy than the national or global impacts. The specific set of distributional impacts needed for different levels of analysis may also be different.

Costs Depend on Implementation

The establishment of water quality standards by themselves is only the beginning of the policymaking and implementation processes that will determine ultimate impacts. First, the regulated public will not modify its behavior merely because regulations are introduced, rather, it has to be convinced that these regulations will be implemented and be aware that there is a system of monitoring and enforcement associated with the regulation. Thus, economic analysis has to develop a system that will predict who will respond to the new regulations and how, given a designed system of implementation. Second, the capacity of agents to adjust to new regulations depends on the existing rules and constraints faced by the regulated public. Water quality regulation is only one part of a system of rules and regulations that producers may face, and the impact of water quality regulations depends on interaction with other rules and regulations. For example, the impact of a policy that restricts access to certain water supplies will be different whether or not farmers have the capacity to trade or buy water in markets. Sunding et al., showed that the cost of reducing the agricultural water supply due to the Central Valley Project Improvement Act would be 60 percent less if broad-scale water trading were allowed.[57]

Third, the impact of water quality regulations depends on the structure of the markets that are affected by the regulations. In some cases, water quality regulation may affect competitive industries with many small producers, each with a limited capacity to conduct research and development or to construct technologies to adapt to the new regulation. In this instance, public supported research that will

56. Daniel Kahneman & Amos Tversky, *Prospect Theory: An Analysis of Decision Under Risk*, 47 ECONOMETRICA 263, 274-89 (1979).

57. *See* David Sunding et al., *Measuring the Costs of Reallocating Water from Agriculture: A Multi-Model Approach*, 15 NAT. RESOURCE MODELING 201, 220 (2002).

help the industry establish technologies and procedures to deal with the regulation may be very valuable. In other cases, regulated industries may consist of large corporations with a high degree of market power and research capacity, and they may have the internal capacity or know-how to develop effective strategies to respond to regulation.

Costs Depend on Constraints

Entities affected by water quality regulations may be constrained in their ability to raise funds. For example, many water quality regulations affect public sector entities such as counties and cities that operate with limited budgets.[58] The expense needed to meet environmental quality objectives may crowd out the funding needed to pay for education or maintain health services. The extra cost needed to improve water quality to enhance the probability of survival of wildlife may conflict with resources needed to enhance quality of life or health of residents who depend on county services.

These observations imply that a cursory measure of the impact of a new environmental regulation is to assess its share relative to the total budget of the county and the affected agency. Further, it will be useful to compare cleanup expenses with other major budget items of the affected agency.

A more rigorous approach is to assess the incremental value of the public budget. Economists have long recognized that in most instances an extra dollar of cost buys more than an extra dollar of benefits.[59] Minimally, the deadweight loss from taxation should be considered. The bottom line is that the public agency impact must be adjusted, and cases where regulations affect agencies under financial stress must be noted.

In the case of private companies, the principal constraint is solvency. Thus, it is important to consider the effects of regulations on the likelihood of bankruptcy and what it entails in terms of employment, resource use, and income in the region. An important indicator is the extra cost relative to the revenue base or budget of the affected firm. Since 10 percent is a roughly normal rate of profit, an expenditure that is 5 percent of revenue is 50 percent of profit, and may lead to bankruptcy and significantly constrain growth.

58. *See, e.g.*, CAL. WATER CODE § 13247 (West 1992).

59. *See* ANTHONY ATKINSON & JOSEPH STIGLITZ, LECTURES ON PUBLIC ECONOMICS (McGraw-Hill Companies 1980).

4. Economics of Environmental Benefits

Like many other types of environmental regulation, the benefits of water quality regulation (i.e., the economic value of the beneficial uses protected or enhanced) can be divided into several categories. The most useful distinction is between use benefits and nonuse benefits.[60] Use benefits may be consumptive benefits (in the case of fishing) or non-consumptive benefits. One can develop market-related measures to quantify the value of most use benefits.[61] It is more difficult to develop quantitative estimates of nonuse benefits. Demonstrated evidence of willingness to pay for environmental amenities is one indicator of the value of nonuse amenities.[62] Stated willingness to pay provides another type of evidence, but has well-documented problems of reliability and questionable theoretical justification.[63]

Differences Between Market and Non-market Benefits

Much of the beneficial impact of water quality regulations may be on goods that are not necessarily traded in markets. For example, reduction in water supply from a certain location in a river may affect recreational opportunities and the natural ecosystem both of which may provide non-market benefits. As a rule, it is much easier to compute impacts of regulation affecting markets, as opposed to non-market impacts because market prices are usually good indicators of social value.[64] If a policy reduces the availability of certain amounts of traded goods that have a given price, then the product of the price and the quantity is a first-order approximation of the impact. Market prices are not good measures of social values in situations when the market structure is mostly noncompetitive, for example, there is monopolistic pricing. Market prices are also not good indicators of social values in cases of market failures and externalities.

In the case where the water quality regulation generates non-market impacts, the researcher must be creative in developing measures of non-market benefits. Fortunately, several useful approaches have been introduced in the recent years to meet this challenge. Whenever possible, it is useful to infer the value of non-market bene-

60. A. MYRICK FREEMAN III, THE MEASUREMENT OF ENVIRONMENTAL AND RESOURCE VALUES: THEORY AND METHODS (2d ed. 2003).

61. *Id.* at 151-52.

62. *Id.* at 153.

63. Report of the NOAA Panel on Contingent Valuation, 58 Fed. Reg. 4601, 4602-09 (Jan. 15, 1993).

64. MAS-COLLEL ET AL., *supra* note 42.

fits from market prices.[65] For example, the value of environmental amenities associated with access to bodies of water may be inferred from the values of properties that are similar in all features, except in their distance from the body of water. The hedonic price approach entails inferring the value of various product characteristics from the prices of market goods that may include these characteristics at various proportions.[66] The travel cost method infers the value of characteristics of a certain body of water by the extra cost associated with traveling that people are willing to pay.[67]

Rather than attempting to compute the value of non-market impacts in monetary terms, it may be beneficial to take an indirect approach and estimate some of the consequences in terms of human and environmental health or other impacts. For example, when considering several alternatives in water quality standards, one may present the market cost and expected lives saved with each policy and stop short of ascribing a monetary value to these changes.

Human Health Impacts

There is a growing body of work on quantifying the health risk posed by environmental contamination to help regulators allocate limited agency resources and set priorities.[68] This work is part of a new form of analysis called risk assessment, a key element of which is the notion of a risk-generating function.[69] Risk is defined as the probability of mortality or other serious damages to the health, and is generated by a sequence of processes including contamination (disposal of chemicals in water), transfer and fate (movement of toxins within water systems), exposure (consumption of contaminated water), and dose/response (vulnerability to exposure).[70] Each of these processes is affected by various factors, including heterogeneity among people, randomness (e.g., weather conditions), and uncertainty about key parameters. Each process may be affected by policy intervention. For example, contamination can be reduced by stricter pollution control, transfer and fate can be affected by barriers to movement, exposure can be changed by introducing alternative sources of water, and dose/response can be affected by availability and quality of medical intervention.

65. *See* FREEMAN, *supra* note 55, at 392-94.

66. James N. Brown & Harvey S. Rosen, *On the Estimation of Structural Hedonic Models*, 50 ECONOMETRICA 765, 765-768 (1982).

67. *See* FREEMAN, *supra* note 55, at 123-24.

68. *See* Erik Lichtenberg & David Zilberman, *Efficient Regulation of Environmental Health Risks*, 103 Q. J. OF ECON. 167, 167-78 (1988).

69. *See Id.*

70. *Id.* at 168-69.

The impact of water quality regulations can be estimated within the existing institutional and policy framework. Given the size of the affected population, the risk can be translated to statistical lives or accidents, and thus the impact of regulation on human health can be quantified. For example, consider the impact of a ban on a chemical that has a probability to cause one in a million cases of disease a year. With an affected population of 7 million people, the ban on the chemical may result in seven fewer cases of the disease on average. If we have a monetary measure of the cost of a case of disease or a statistical value of a life, we can translate the impact into monetary terms. If each case of the diseases costs society $1 million, then the ban on the chemical will result in a gain of $700,000.

Ecosystem Impacts

In the same manner that risk assessment is used to assess damages to human health, it can also be used to assess benefits to wildlife. For example, the expansion of water available to a fishery may reduce mortality and, with quantitative relationships measuring water availability and risk, one can estimate the impact of water quality regulations that enhance water availability on the viability of the fish population. Similarly, one can develop models that assess the impact of various types of regulations on wetland health and various wildlife species. Translating physical measures of environmental health to monetary terms is challenging, but it is easier when there are monetary estimates of values of units of wildlife or members of a species. In some cases, water systems provide recreational benefits that can be estimated, and it is possible to derive the impact of water quality regulations that affect these activities. Diversion of water from one region to another may reduce water availability to recreational activities. The value of the recreation lost is one estimate of the environmental costs.

Neighborhood Effects and Environmental Justice

It is now well known that certain socioeconomic groups often seem to be relatively more concentrated near environmental hazards than in the surrounding community.[71] Since water quality regulations do not have the same effect everywhere, understanding how they address problems of environmental justice is an important aspect of economic impacts that must be addressed.

71. Trudy A. Cameron & Ian T. McConnaha, *Evidence of Environmental Migration*, 82 LAND ECON. 273, 273-290 (2006).

Recent economic research paints a more complex picture of environmental justice considerations than has been available previously. In particular, snapshot cross-sectional statistical analyses cannot reveal how residential mobility for different social groups reacts to changing public perceptions of environmental hazards.[72] Using decennial panel data over four census periods for census tracts surrounding seven different urban Superfund localities, Cameron and Crawford examine how ethnicities, age distribution, and family structure vary over time with distance from these major environmental hazards.[73] If the slope of the distance profile decreases over time, the group in question could be argued to be "coming to the nuisance."

While it appears to be hard to make many generalizations across localities, Cameron and Crawford find a lot of "statistically significant movement, including some evidence of minority move-in and increasing relative exposure of children, especially those in single-parent households."[74] Viewed in this way, environmental justice would appear to be linked with the problem of housing affordability. Some low-income and minority families appear to choose more polluted locations due to the lower housing prices in such neighborhoods. Thus, the analyst must pay careful attention to the impact of water quality regulation on housing affordability, and then use this information to understand the incidence of regulation across various groups in society.

Additional Funding Required to Produce Benefits

Environmental economists have advocated an approach to policy that views the environment as created by a production process, much like more traditional goods. This notion is important in the area of water quality, as regulation is often insufficient to produce the desired beneficial uses. For example, the quality of water in the Los Angeles River may be dramatically improved through more stringent regulation, but there will not be much meaningful improvement in the environment without other accompanying investments in restoration. Pure water flowing through a concrete channel (much of which is fenced and posted with "No Trespassing" signs) will not produce a lot of habitat or be an inviting spot for recreation.

Since both improvement in water quality and accompanying investment are required to produce beneficial uses like swimming and other recreational opportunities, these additional investment needs

72. Trudy A. Cameron & Graham D. Crawford, *Superfund Taint and Neighborhood Change: Ethnicity, Age Distributions, and Household Structure* 2 (Univ. of Or. Econ. Dep't., Working Paper 38, 2003).

73. *Id.*

74. *Id.*

should be called out by the Regional Boards when making decisions. The magnitude of additional investment, together with potential funding sources, would be illuminating in many cases.

5. A Flexible Approach to Economic Analysis Under the Porter-Cologne Act

For statutes like the Porter-Cologne Act in which economic impacts are to be "considered," there is a minimum level of assessment that should be performed. What types of analysis are minimally sufficient to meet the baseline consideration of economics? How should such analysis be accomplished? We now turn to these questions.

Procedure

We believe that the Regional Boards should follow a particular procedure for consideration of economics. The steps in this procedure are the following:

1) A listing of the affected parties, including private industry and government agencies, together with a qualitative description of the impacts;
2) Solicitation of data from the public regarding potential compliance and related costs for the proposed policy;
3) The public's reported cost of compliance in relation to the revenue, cost, and profit margin of affected firms; and relative to the total budget of affected public entities;
4) A statement of what the Regional Board staff thinks the costs are likely to be, which specifically considers the data solicited from the public and the reasons for the Board's estimate;
5) A statement of potential factors that could affect the estimate, such as technological uncertainties, monitoring limitations, etc.;
6) A description of competitive conditions in the affected sectors, and an assessment of whether water quality regulations are likely to place California firms at a significant competitive disadvantage;
7) A statement of the average time needed to obtain permits from the various Regional Boards, and a qualitative assessment of the impacts of delay.
8) A statement of the goals to be achieved by the proposed regulation and an explicit consideration of these goals given the costs (i.e., at least a statement that "the Board believes

that $XX million represents a reasonable expenditure to achieve YY."). This description would include the types and numbers of beneficiaries, and an identification of other investments beyond those resulting from the regulation that are needed to produce the beneficial uses.

Gradual Analysis

It is unlikely that a complete economic analysis will be required in every case. Economic analysis can be expensive, and it is important to be cost-effective when implementing regulation. Rather, we propose a phased approach that distinguishes between minimum analysis and more complex investigations. In particular, we distinguish between:

- *Initial assessment* to identify possible situations with potential for major impacts. Initial probing will consist of completing a standardized form, providing mostly descriptive information and qualitative assessment.
- *Deeper investigation* of isolated situations. Analysis will be tailored to situations. Rarely will a complete monetization of costs and benefits be required. Instead, we argue for a reliance on quantitative tools used to assess isolated situations where quantitative information is important to policy making.

We are proposing an interactive process for policy assessment. Policy makers will solicit information from the public regarding the magnitude of costs and determine when and how to proceed with analysis (what issues to probe further) based on initial analysis. If the public feels compelled to conduct a deeper and more detailed analysis of impacts, then the Regional Boards should consider these. In cases where aggregate impacts are likely to be significant, or there may be very harmful effects on subsets of firms in an industry, then the Regional Boards should discuss the findings of studies provided by the public or, preferably, present the results of their own analysis.

Elements of a Form for Initial Impact Assessment

In every case, we recommend that the Regional Boards gather a minimum amount of information to ensure that the they live up to the minimum requirements imposed by the Porter-Cologne Act. One approach is to complete a standardized form that will be made public. This form would indicate that the Regional Board staff at least understands economic impacts, and, as discussed earlier, may be used as a trigger for more complete analysis.

Following is an outline of the types of questions that could be included on such a form. Note that we distinguish between impacts on private entities and publicly-owned enterprises.

For Impacts on the Private Sector

1. Identify the affected industry/region combination (e.g., Dairy/Riverside, Electronic Equipment Manufacturing/Sacramento, etc.)
2. Questions for each Industry/Region
    a. Percentage of productive capacity (i.e., output, plants) that is
        i. Affected significantly (more than 5% increase in production cost to accommodate regulation)
        ii. Affected moderately (below 5% increased production costs)
        iii. Not affected
    b. Among those *affected significantly*, what is the relative increase in production cost because of compliance (allow a distribution)
        i. 10% increase for 50% of capacity
        ii. 15% increase for 50% of capacity
        iii. Etc.
    c. Impact of regulation on output price
        i. Negligible
        ii. Low (below 2%)
        iii. High (2% or above)
    d. Cost of initial adjustment to regulation
        i. Negligible
        ii. Modest
        iii. High (explain)
    e. Percentage of firms that may face insolvency problems
        i. None
        ii. Less than 5%
        iii. Between 5-10%
        iv. Higher (give a rough estimate)

For Impacts on Publicly-Owned Activities

1. Identify the affected agency/region combinations (e.g., S.F. Unified School District, Fresno Sewage District, etc.)
2. Questions for each Agency/ Region
    a. Percentage of activities (i.e., output, plants) that are

i. Affected significantly (more than 5% increase in cost)
ii. Affected moderately (below 5% increase in cost)
iii. Not affected

b. Among those *affected significantly*, indicate the relative increase in cost because of compliance (allow a distribution)
   i. 10% increase for 50% of capacity
   ii. 15% increase for 50% of capacity
   iii. Etc.

c. Availability of new fees or other income to pay for regulation
   i. Unavailable
   ii. Increased budget allocation will pay for ________% of extra cost
   iii. Higher fees will pay for ________% of extra cost

d. Impact of regulation on services provides (both on volume and quality)
   i. Negligible
   ii. Low
   iii. High (explain)

e. Percentage of clients that may not be served
   i. None
   ii. Less than 5%
   iii. Between 5-10%
   iv. Higher (give a rough estimate)

f. Cost of initial adjustments to regulation
   i. Negligible
   ii. Modest
   iii. High (explain)

Other Impacts – Completed for All Regulations

1. Employment effects
   a. Positive
   b. Negligible
   c. Small (between 1 and 5%)
   d. High (above 5%)
2. Effects on resources and the environment
   a. None
   b. Minor
   c. Major (specify)
3. Impacts on expansion or future investment

   a. None
   b. Minor
   c. Major (specify)
4. Delay of expansion (when appropriate) because of compliance requirements. For each major activity,
   a. Specify it
   b. Length of delay (in units of days and month)
   c. Relative magnitude of delay
      i. Negligible
      ii. Minor
      iii. Major (explain)

6. Conclusions

The California Porter-Cologne Act regulates the discharge of waste into ambient waters and authorizes Regional Boards to impose requirements on waste dischargers. Before a Regional Board can impose these requirements, however, it "shall take into consideration" the following factors: "the beneficial uses to be protected, the water quality objectives reasonably required for that purpose, other waste discharges, the need to prevent nuisance, and the provisions of Section 13241."[75] Section 13241 in turn lists six "factors to be considered," including "economic considerations" and "water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the area."[76]

While the requirement to consider economics under Porter-Cologne is absolute, the legislature and the courts have done little to particularize this requirement. A main objective of our paper is to describe the ways in which water quality regulations can affect the economy. Some of these impacts are fairly obvious and easy to quantify. Others are subtler, or depend on complex interactions among firms or even sectors of the economy. Economic impacts can sometimes be limited to a small number of well-defined groups. Often, however, many groups will be implicated, especially if impacts are propagated through market interactions.

Despite the frequent complexity of real-world economic impacts, one of our main goals in this paper is to articulate and defend a baseline set of tasks that need to be performed to achieve the minimally adequate "consideration" of economic impacts under Porter-Cologne. We propose a several-step procedure for compiling information on economic impacts. This procedure entails an interactive approach to decision-making that would allow the public a

75. CAL. WATER CODE § 13241.

76. *Id.*

chance to air its concerns and present relevant data, and would oblige agencies to give a rationale for their decisions without imposing any requirements about how the results of economic analysis figure into final decisions.

While adoption of these procedural steps would be an advance, they do not answer the question of *how* economic impacts are to be measured. We propose a series of economic impact tests that are relatively easy to interpret and are at least rough measure of the economic impacts caused by water quality regulations.

Of course, in some situations, large impacts will be apparent, and more detailed analysis will be required. In these cases, our general discussion of the economic effects of water quality regulation will provide guidance to analysts at the Regional Boards and to the regulated community. It is worth reinforcing that traditional economic analysis may not always be adequate to capture the effects of regulation. In particular, water quality regulation may alter the conditions of competition in an industry, result in firms relocating to other areas, may cause delay and result in lost flexibility, cause insolvency, result in unintended risks, have dynamic consequences (especially when regulations result in capital replacement), and affect the operation of public sector facilities. These effects are all somewhat outside the bounds of traditional economic analysis of regulation, but are examples of factors that should be considered in the case of Porter-Cologne.

Appendix

Effective modeling of the impacts of water quality regulations raises a number of technical issues, particularly with regard to calculation of the benefits of improving water quality. Three issues that come to mind immediately are modeling of risk generation, discounting, and sensitivity analysis. Risk generation refers to the physical and biological processes that produce risk to water users and the environment. Understanding the economics of risk generation is essential for adequate modeling of the impacts of policy interventions that can improve water quality. This is an under-researched area in environmental economics, but one with a great deal of potential.

Discounting and sensitivity analysis are better understood, although few water quality regulations have been analyzed with state of the art treatments of these issues. Discounting is especially important since the choice of alternative discount rates can have a large effect on the calculated net benefits of a regulation. Issues that should be considered by the analyst include the choice of an appropriate public sector discount rate, and the wisdom of using a time-invariant discount rate as opposed to a discount rate that falls over the time horizon of the analysis.

Effective Modeling of the Risk Generation Process

Water quality regulations frequently aim to reduce risk to the health of humans and wildlife. Much of the literature on risk analyzes financial risk, and modeling environmental health risks requires its own framework that is interdisciplinary in nature and takes into account the scientific knowledge on the processes that threaten the health and survival of living system. Such a framework would introduce the study of public health and is used in the process of risk assessment by environmental agencies.[77] Lichtenberg and Zilberman have developed an economic decision-making framework that utilizes the risk-generation model of the risk assessment literature.[78]

In our context, risk is defined as probability that a member of a population will die or get ill during a certain period of time. For example, it may be the probability of deaths from drinking water during a season. The key element in the risk assessment literature is the risk-generation function which presents this risk as a final product of several processes, including contamination (which is a disposal of

77. *See* Kenneth T. Bogen, Uncertainty in Environmental Health Risk Assessment (Taylor & Francis 1990).

78. *See* Erik Lichtenberg & David Zilberman, *Efficient Regulation of Environmental Health Risks*, 103 Q. J. of Econ. 167, 167-78 (1988).

waste product or toxic material to a body of water at certain locations and given points in time), transfer and fate (which is the process of movement of contaminants over a space in time), exposure (the intake of toxic materials by vulnerable species, and dose-response (the measure of vulnerability to the toxic material that can be affected by treatment). Each of these processes can be affected by policies:

Contamination is affected by pollution control incentives and regulation. For example, the amount of animal waste that can reach a body of water can be reduced by barriers imposed by law or by incentives that may reduce population size or lead to a better containment of waste material.

Transfer and fate may be affected by barriers (including dams, walls, nets, and filters) that may be built in a response to incentives that may vary over time.

Exposure is determined by the behavior of the vulnerable species and can be affected by infrastructure (filtering facilities to protect water quality) and extra caution (by consuming alternative sources of water, including bottled water, that may be induced by policy and by wearing protective clothing to reduce dermal exposure).

Dose response is the vulnerability to dosage, which varies among individuals according to weight, health, and can be affected by medical treatment.

Each element of the risk-generation process is subject to variability. The sources of variability may be random. For example, the contamination and transfer and fate processes are highly influenced by weather conditions. The variability may be the result of heterogeneity. For example, the dose-response process depends on the characteristic of individuals involved. Furthermore, the policy analyst doesn't have full information about the parameters governing these four processes. The uncertainty about various parameters contributes to the variability of the risk estimates. Formally, if R is risk the risk generation function is

$$R = f_1(X_1, \varepsilon_1) * f_2(X_2, \varepsilon_2) * f_3(X_3, \varepsilon_3) * f_4(X_4, \varepsilon_4)$$

where $f_1(X_1, \varepsilon_1)$ is the contamination component, and it is a function of pollution control policies denoted by and the random element ε_1. Similarly, $f_2(\cdot,\cdot), f_3(\cdot,\cdot), \text{and} f_4(\cdot,\cdot)$ denote the transfer and fate, exposure, and dose response elements of the risk generation function, respectively.

Quantitative risk assessment generates estimates of risk with certain degrees of variability. These estimates may be the expected value of the risk or a certain point of the risk distribution. For example, one estimate of risk is the probability of deaths of members of the population that would occur with a probability smaller than 5 percent. The cost of the regulation is a function of the policy measures denoted by $C(X_1,X_2,X_3,X_4)$. In this formulation, $\bar{R}$ denote the level of risk attained with a probability α, and $\bar{C}$ is the upper limit of regulatory cost. The optimization problem is

$$\min_{\bar{R},X_1,X_2,X_3,X_4} \Pr\left[(R<\bar{R})\right] \le \alpha$$

$$\text{subject to } C(X_1,X_2,X_3,X_4) \le \bar{C}$$

With this formulation, there is a tradeoff between the degree of reliability of the containment of the risk and the upper bound imposed on risk with this reliability factor. Namely, there is a tradeoff between $\bar{R}$ and α. An increase in the cost constraint $\bar{C}$ is likely to reduce the upper bound of risk $\bar{R}$ for any degree of reliability.

The Importance of Consistency in Risk Regulation

Economic analysis requires a significant amount of judgment and creativity in designing and implementing assessment procedures, but one must avoid arbitrary choices in doing so. The same set of problems should be analyzed using the same procedures and decision criteria. For example, the same techniques should be used to assess non-market benefits and non-market costs. If hedonic prices are used to assess the cost of loss of a certain category of environmental amenities, they should also be used to assess benefits of gaining the same category of environmental amenities. Similarly, when risk estimates are derived, they will be obtained with the same degree of statistical significance.

Since much of the water quality regulations are aimed to control a random and risky outcome, it is important that the modeling of the risk-generating process in various applications will be consistent. The estimators of the parameters of the risk generation process (i.e., the parameters of contamination, transfer and fate, exposure, dose/response, etc.) are shrouded with a high degree of uncertainty. Frequently, policy analysts may not use the expected value of the unknown parameter as an estimate, but rather a value at the tail of the distribution that has a very low likelihood to be exceeded.

For example, the value of the 95th percentile of the distributions of the exposure and dose/response parameters may be used to compute a risk estimator. This will lead to high estimators of risk. When the policymakers are not aware of the estimation approach, these high values will lead to strict regulation. Thus conservative estimation techniques are leading to "creeping safety."[79] It is useful to require the technical risk estimates to be used in policy analysis will be consistent in the sense that they will present the same point at the final risk distribution. For example, if policymakers are more comfortable to use the 95th percentile of the overall risk distribution as an estimator of risk, so be it as long as all studies are using the same point of the risk distribution.

The treatment of risk estimates is related to another important policy choice regarding the design of water quality regulations addressing risky outcome. Policymakers sometimes may apply the so-called "precautionary principle," and establish regulation to eliminate all risk or reduce the likelihood of risk to a negligible level. Since one cannot avoid risk, an attempt to eliminate risk may result in high economic cost and may generate new risks.

Discounting

The impact of water quality regulations may last over a long period of time, thus it is especially important to have weighted indicators that account for temporal differences. Discounting is used for this purpose and the net present value (NPV) of any benefit or cost category is a sum of the benefit and cost discounted. For example, the measure of producer surplus in our analysis is the NPV of producers' surplus over a period of time. Let PS_t define the temporal producer surplus at period *t*, PS, which is the net value of producer surplus, is:

$$PS = PS_0 + \frac{PS_1}{1+r} + \frac{PS_2}{(1+r)^2} + \frac{PS_3}{(1+r)^3} + \ldots \frac{PS_n}{(1+r)^n}$$

where *r* is the interest rate. The choice of this discount rate matters. Higher discount rates reduce weight given to future stream or benefits or cost. Thus, if the costs of building a dam are immediate and the benefits are far into the future, the transition from a discount rate of 6 percent to 10 percent may lead to a transition from a positive NPV that support undertaking the project to a negative NPV that suggests that the project is not economically efficient and, from an economy perspective, it is better that money will be spent on other projects.

The interest rate reflects human impatience and preference to consumers sooner rather than later, and the productivity of assets that results from investment choices. The interest rate is an equilibrium outcome reflecting a balance between the demand of borrowers

79. *See* KENNETH T. BOGEN, UNCERTAINTY IN ENVIRONMENTAL HEALTH RISK ASSESSMENT (Taylor & Francis 1990).

and the supply of lenders. In reality, there are many interest rates reflecting different conditions and contingency associated with various loans and investments. In assessing water quality regulations we have to distinguish between the interest rate used to assess the NPV of a firm that has to invest in pollution control equipment and the social benefit from improved environmental conditions over time. When considering the interest costs of a specific firm, one has to use the interest rate that the firm is paying. A risk-free interest rate paid or received by consumers is appropriate for discounting consumer benefits over time. If the benefits are projected in nominal terms and one expects inflation, the interest rate should be the real interest rate (a risk-free interest rate paid to consumers for savings accounts or government bonds) plus the rate of inflation. For example, an appropriate interest rate for the period 2000-2004 is between 5 percent and 6 percent. The real interest rate for consumer was about 4 percent with a 2 percent inflation rate.

Recent studies have shown that consumers' behavior frequently is not consistent with assuming a uniform interest rate that applies to choices of different duration. People behave in a manner consistent with hyperbolic discounting.[80] Namely, the interest rate declines over time. People are more willing to delay consumption from tomorrow to the next day than from today to tomorrow. We do not have sufficient empirical information to operationalize this concept. However, it suggests that the benefits in the far future should be evaluated with a lower interest rate than benefits in the short term.

Sensitivity Analysis

Impact assessment is not a precise science, especially given the high degree of variability resulting from the macroeconomic cycles, political uncertainty, randomness of weather, and the uncertainty about human behavior and the value of key parameters that drive the system. Therefore, it is important to investigate the robustness of results of economic analysis to changes in value of key parameters. That suggests that economic analysis will result in computerized routines that can be modified and easily adjusted to conduct sensitivity analysis. Several aspects of the systems should be emphasized in the sensitivity analysis.

1. *Sensitivity of results to specification of cost and demand parameters*
   Policies with a strong effect on the private sector are likely to impact the economy through their impacts on the welfare of both consumers and producers, and both depend on the specifications of demand and supply functions of

80 M. Weitzman, *Gamma Discounting*, 91 AM. ECON. REVIEW 260 (March 2001).

various goods. In these situations, the robustness of the water quality regulation is likely to depend to a large extent on the sensitivity of results to demand and cost parameters.

2. *Sensitivity of results to assumptions of value to statistical life and risk parameters*
   The main purpose of water quality regulations is to reduce human and environmental health risks and their costs. Policymakers need to have some estimate on the likelihood that proposed regulation will reach their objectives and, if not, what can be done about it.
3. *Discounting and treatment of capital expenditure*
   The impact of regulation overall and specifically on the affected industries depends to a large extent on the treatment of discount factors' use and how capital expenditures are treated. That is especially the case in projects with long economic life and where large investment are taken early in life of the project.
4. *Underlying economic conditions*
   The macroeconomy has been recognized as the main driver of some of the more export-oriented sectors of the California economy. The demands of all sectors of water depend on the macroeconomic conditions and precipitation. Comparative analysis that will present estimates of sensitivity of outcomes to macroeconomic conditions will allow us to identify situations where the performance will be problematic and suggests what to do about it.

Madrone

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* * *

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June 4, 2009

Ms. Jeanine Townsend
Clerk to the Board
State Water Resources Control Board
1001 I Street
Sacramento, CA 95814

Re: Comment Letter – San Francisco Bay PCBs TMDL
Project Number: GENfra:110

Dear Ms. Townsend:

The purpose of this letter is to summarize the major outstanding technical issues associated with the San Francisco Bay (Bay) Total Maximum Daily Load (TMDL) for polychlorinated biphenyls (PCBs) for the State Water Quality Control Board (SWRCB) to consider in its decisions regarding San Francisco Bay Regional Water Quality Control Board's (SFBRWQCB) PCBs TMDL, including proposed modifications to the Basin Plan Amendment and the SFBRWQCB's Implementation Plan. In addition, we provide updated information and analysis - to bring the latest technical information since our last comments on these subjects to the SFBRWQCB – to the attention of the SWRCB. Anchor QEA previously commented on many PCB TMDL issues before the SFBRWCB (see, e.g., QEA 2004, QEA 2007, QEA 2008). Anchor QEA focuses here on three issues for which updated analyses are presented:

1. The TMDL does not take proper account of ongoing natural recovery of the Bay
2. The TMDL does not properly characterize the assimilative capacity of the Bay
3. The TMDL uses two species of fish that are rarely consumed and have unusually high PCB levels to assess attainment of the already overly-conservative TMDL fish tissue target

The first two issues are important because they impact the PCB load allocation and our technical opinions regarding the timeframe for the recovery of the Bay. By failing to properly account for natural recovery and the assimilative capacity of the Bay, the necessity and benefit of the TMDL have been significantly overestimated. Thus, the SFBRWQCB has overestimated the time benefit of the prescribed TMDL (i.e., the extent to which loading reductions will accelerate achieving the goals of the TMDL). Further, the SFBRWQCB has overestimated the extent to which PCB loads need to be reduced.

The third issue is important because the TMDL's usage of white croaker and shiner surfperch to evaluate achievement of the TMDL target means that the TMDL is requiring exposure concentrations lower than deemed necessary to achieve its stated objectives. Although the Regional Monitoring Program (RMP) data are limited, the data suggest that the more commonly-consumed species of Bay fish have either already met the target or are much closer to meeting the TMDL target than these two rarely-consumed species.

In summarizing the technical issues, this memo incorporates evidence from new data that have become available, as well as a revision of the San Francisco Estuary Institute (SFEI) 1-Box Model used to determine the TMDL and the time to achieve compliance with the objectives of the TMDL. The new data include 2006 sediment, water, and fish monitoring data made available through the RMP.

ISSUE 1. THE TMDL DOES NOT PROPERLY ACCOUNT FOR NATURAL RECOVERY

In the TMDL for PCBs in the San Francisco Bay Final Staff Report for Proposed Basin Plan Amendment (Staff Report), the SFBRWQCB estimated that the Bay-wide average sediment PCB concentration is 4.6 micrograms per kilogram (µg/kg) (SFBRWQCB 2008a).[1] Based on this average, Bay surface sediment PCB concentrations are within a factor of five of the sediment target. The new 2006 RMP data indicate that the northern part of the Bay has

[1] The basis for this average, and the layer of sediments it represents, is not provided (the Staff Report cites a 2007 SFEI memorandum which is not publicly available), but it is comparable to the values seen in the 2006 RMP sediment data. Given that these data are based on grab samples, it is assumed that this represents the active sediment layer (0 – 15 cm). In the previous version of the Staff Report, the Bay-wide average surface sediment PCB concentration was estimated to range from 22 – 35 µg/kg (SFBRWQCB 2007). This was based on an analysis of data collected in the 1990s through the Bay Protection and Toxic Cleanup Program (Smith and Reige 1998), the RMP's predecessor.

already reached an average surface PCB sediment concentration of 1 µg/kg, and thus meets the sediment target. These data also indicate further declines in average PCB surface sediment concentrations in the central and southern parts of the Bay to values of 3 and 5 µg/kg in 2006, respectively. Prior to the addition of the 2006 RMP data, we calculated that surface sediment PCB concentrations have been dropping in half every 12 and 9 years[2] in the central and southern portions of the Bay, respectively (QEA 2007). With the addition of the 2006 RMP data, sediment trends indicate that average sediment PCB concentrations in these parts of the Bay drop in half every 8 to 11 years (Figure 1). Thus, the addition of the 2006 data provide further evidence that surface sediment PCB concentrations in the central and southern parts of the Bay drop in half approximately every 10 years.

The rates of decline seen in Bay sediments are consistent with the decline rates seen in mussels. Mussel PCB concentrations drop in half every 6 to 12 years (Figure 2a). To demonstrate that the rates of decline are similar, regardless of the data source, Figure 2a shows the rates of decline calculated in three ways: based on the State Mussel Watch (SMW) data only, based on the RMP data only, and based on the RMP and SMW data combined. That the rates of decline are similar, regardless of whether they are calculated from the older SMW data alone, the new RMP data alone, or the combined data set, shows that the measured declines are not merely a "problem of inter-calibration between the old mussel data and the new mussel data" as stated by Board Member McGrath at SFBRWQCB's February 13, 2008 Hearing to adopt the PCBs TMDL (McGrath statement to SFBRWQCB, 2008b). If Board Member McGrath was correct, we respectfully submit that we would not see similar rates of decline measured from the older SMW data and the more recent RMP data alone.

At the same hearing, Board Member McGrath compared our analysis to the analysis presented in the Staff Report (SFBRWQCB 2008b). However, while mussel data are presented in the SFBRWQCB's Staff Report, there is no attempt to measure or assess data trends. To estimate the rate at which mussel PCB concentrations are declining, we aggregated the data spatially and took annual averages to minimize the noise in the data

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[2] A half-life refers to the time it will take for a concentration to drop in half due primarily to tidal flushing and/or deposition of cleaner sediment material over the active sediment layer. For example, PCB concentrations of 10 µg/kg in 1990 and 5 µg/kg in 2000 decline at a rate consistent with a half-life of 10 years.

expected from spatial and seasonal variations. On a specific location basis, as presented in the Staff Report, you can still observe that more recent concentrations are lower than historical concentrations, but it is harder to estimate at what rate these concentrations have been declining, due to the noise in the data, which our analysis controls for.

Board Member McGrath also expressed concern that the log-based presentation of these data somehow compromised its "robustness" (SFBRWQCB 2008b). The same data we present on Figure 2a are presented on a linear scale on Figure 2b; this plot shows a clear difference in historical concentrations and recent concentrations, but it is hard to see more recent changes in concentration due to the scale on the vertical axis. The large range in concentration from the historical data to the more recent data requires a large range on the vertical axis; this is the reason we presented the data on a log scale. The more recent RMP mussel data are presented alone on Figure 2c on a linear scale; as shown, these data still show a clear decline.

New 2006 RMP PCB data are also available for the water column. The addition of these data to the RMP water column data set reveals declines at rates similar to those seen in sediments and mussels; water concentrations drop in half every 6 to 13 years (Figure 3). These rates are consistent with those measured previously, and thus further support a finding of continued downtrend in water column PCB concentrations.

The above-cited rates of decline are consistent with those reported by the SFEI, on the basis of long-term trends in PCB concentrations in sediments and water at individual fixed monitoring stations (SFEI 2007). Significant declines with half-lives ranging from 10 to 25 years in water column PCB concentrations were measured at all 5 stations with continuous data. Half-lives ranging from 5 to 40 years were measured for sediment PCB concentrations at 7 stations with continuous data, and the declines were statistically significant for 6 of these stations. Differences in the number of years it takes for sediment and water concentrations to drop in half indicate that concentrations are declining faster in some locations than others.

Board Member McGrath contended at the February 13, 2008 SFBRWQCB Hearing that he had "spent 15 years in the RMP working with the data" but did not "read this as a steady downtrend." Presumably, this statement refers to our earlier analysis of the RMP data. However, SFEI has since conducted a detailed analysis on the same data, and has measured significant declines at nearly all locations with continuous records, at rates that bracket the rates that we have calculated and described above. These declines make sense, as our estimates represent averages in each of the three regions of the Bay that we looked at. Thus, it is true that PCB concentrations may not be dropping by half every 6 to 12 years at every location in the Bay; the SFEI analysis suggests that the Bay-as-a-whole range may be as wide as 5 to 40 years. However, the fact that we see significant declines at every location, and at similar rates in sediment, water, and mussels, provide irrefutable evidence of a steady downtrend in PCB levels in the various sampled Bay media.

The decline is also seen in recent shiner surfperch data; from 2003 to 2006, PCB concentrations dropped at a rate indicating a halving of concentration every 9 to 14 years in this species. Changes in monitoring locations confound interpretation of data collected before 2003. Recent data do not show declines in white croaker PCB concentrations; however, this could be due to natural variability during this time period. New 2006 RMP fish data are limited; several of the monitored species were dropped from the program "in favor of a greater emphasis on select indicator species for the different contaminants of concern" (SFEI 2008a). Discontinued species include jacksmelt, leopard shark, and California halibut, any of which would be better indicator species for the Bay's recovery, as described below. In 2003, these species were either at or approaching the TMDL PCB target concentration for fish. Moreover, the most commonly-consumed species, striped bass, was collected but inexplicably was not analyzed for PCBs. Thus, due to the RMP's apparent decision to stop continuous monitoring of species other than the two that the SFBRWQCB has arbitrarily chosen to base TMDL success on, sufficient monitoring data are not available to measure trends in the commonly-consumed species.

ISSUE 2. THE TMDL DOES NOT ACCURATELY CHARACTERIZE THE ASSIMILATIVE CAPACITY OF THE BAY.

As we have commented previously, the 1-box model used in the TMDL Staff Report to project the recovery of Bay sediments is flawed because of an arbitrary adjustment to PCB outflow[3] (Connolly et al 2005; QEA 2007). This adjustment causes the model to trap PCBs in

[3] The adjustment occurs by applying a scale factor to the Bay outflow volume to reduce the PCB loss through outflow and exchange.

the Bay and under-predict the rate at which surface sediments are recovering. With this methodological flaw, the 1-box model inaccurately predicts that current PCB loadings will delay recovery of the Bay by 100 years (Figure 28; SFBRWQCB 2008a). This iteration of the presentation of the model is new to the revised TMDL. While no documentation is provided, Figure 28 of the Staff Report clearly shows the model has been adjusted to incorporate the revised average PCB concentration in the active layer of 4.6 μg/kg. In the previous version of the TMDL Staff Report the 1-box model relied on an average PCB concentration of 31 μg/kg in the active layer.

Based on information provided in the comment responses to the 2007 Staff Report, the model has also been revised to incorporate an attenuation rate of 56 years for PCB external loads, but has not been revised to eliminate the arbitrary PCB outflow adjustment. Only by eliminating the methodological flaw, does the model closely match what is happening in the Bay (Figure 4). The vertical axis shows PCB mass in kilograms (kg). This is arrived at by taking the PCB concentration in the active layer (surface sediments) and multiplying it by the amount of sediments in the active layer. Thus, the TMDL sediment target of 1 μg/kg is equivalent to a Bay-wide PCB mass in sediments of 160 kg; this is shown as the dotted horizontal line. The horizontal axis refers to time in years. Year 0 represents the current condition; at year 0, the PCB mass in the Bay is approximately 650 kg, which is equivalent to a PCB sediment concentration of 4.6 μg/kg. The average 6- to 12-year half-lives that bracket the declines seen in the RMP data are shown on this plot as dotted and dashed lines, respectively. For example, the line representing the 6-year half-life is 650 kg at year 0, and in 6 years, it is 325 kg; 6 years after that, at year 12, it is 162.5, and so on. The solid blue and green lines represent the output of the corrected 1-box model at 20 and 30 kg/year (yr) PCB loading, respectively. The corrected model shows that 20 and 30 kg/yr loadings are approximately equivalent to the 10 and 20 kg/yr loadings, respectively, of the uncorrected model.[4] The green line representing the 30 kg/yr loading crosses the dotted line representing the TMDL sediment target in about 35 years (Figure 4). Given that the current loading is

[4] This comparison is based on running the 1-box model with and without the factor that restricts the outflow of PCBs. The basis for the 1-box model results presented in the Staff Report is unclear. Figure 28 in the Staff Report indicates that, even with the elimination of all PCB loads, the system would not recover within the range of rates corresponding to half-lives of 6 to 12 years.

estimated at 33 kg/yr, the corrected 1-box model suggests Bay sediments will reach the target at the current loading in approximately 40 years.

While the corrected 1-box model is better able to represent actual observed rates of PCB decline, we understand a multi-box model is under development to improve the understanding of the long-term fate of PCBs in the Bay (SFEI 2008b). When the multi-box model has undergone the sufficient quality assurance/quality control (QA/QC) validation, it should be considered in future analyses (e.g., if the TMDL moves into the Adaptive Implementation (AI) process).

ISSUE 3. MISUSE OF THE TMDL "MARGIN OF SAFETY"

Given that the current Bay monitoring program has been refocused by the RMP on fish that make up a small fraction of actual angler consumption, attainment of the fish target by the Bay fish that people eat most frequently may not be correctly recognized because the monitored species have the highest PCB concentrations. In 2003, average PCB concentrations in the most commonly-consumed species, striped bass, ranged from 5 to 7 times the TMDL target in the northern, central, and southern regions of the Bay, while PCB concentrations in white croaker and shiner surfperch ranged from 20 to 50 and 5 to 20 times the target in these regions. The RMP collected striped bass data in 2006, but they were not analyzed for PCBs. However, average concentrations measured in 5 out of 6 species collected as part of a special study[5] were at or below the TMDL target. Based on the average decline rates measured in sediment, mussels, and water of 6 to 12 years, 2003 average striped bass PCB concentrations of 50 to 70 parts per billion (ppb) should reach 10 ppb in approximately 12 to 30 years, from 2003. Data are insufficient to measure declines directly in this species. However, the weight-of-evidence suggests that striped bass PCB concentrations will reach the TDML target, without any of the actions called for by the TMDL, in less than 40 years, the timeframe in which the sediment target is further expected to be achieved, based on the above-described trends in sediments, water, and mussels, and the corrected projections of the 1-box model.

[5] A special study was initiated in 2003 to evaluate contaminants in additional Bay species. These include barred surfperch, brown rockfish, black surfperch, Chinook salmon, rubberlip surfperch, walleye surfperch, and northern anchovy. These fish have not been collected historically and are not among the most commonly-consumed fish species. Anchovy was the only species with PCB concentrations above the target.

The SFBRWQCB's Final Staff Report revisions indicate that the TMDL is intended to be protective of one allegedly impaired beneficial use - commercial and sports fishing (COMM) - while maintaining all existing beneficial uses, such as estuarine habitat (EST), preservation of rare and endangered species (RARE), and wildlife habitat (WILD).[6] In order to protect the impaired COMM beneficial use, the fish tissue target derived by the SFBRWQCB used several conservative assumptions (QEA 2007). Thus, it is already conservative. However, and most significantly, the SFBRWQCB's use of two rarely-consumed species further introduces additional and unnecessary conservatism that constitutes a misuse of the TMDL's permissible margin-of-safety analysis.

SUMMARY

In summary, due to the outstanding, remaining technical issues described and updated herein, the Bay PCBs TMDL, as adopted, is scientifically unsound and unnecessarily overprotective. Given that Bay surface sediment PCB concentrations are clearly declining and are approaching the goal of the TMDL, the TMDL would be more scientifically defensible if this natural recovery was taken into account. The 1-box model used in the TMDL Staff Report to project the recovery of Bay sediments, when corrected for a mass balance flaw, predicts trends in line with those seen in sediment, water, and mussels and indicates that the TMDL sediment target will be met within 40 years, even if no regulatory-required actions are taken to reduce PCB load. Thus, if a corrected and validated multi-box model that reproduces the observed trends in the data was used to predict the time to achieve the sediment target, the TMDL would be more realistic. Additionally, the use of more commonly-consumed fish species is essential to the evaluation of whether the TMDL's PCBs target has been achieved. Finally, properly addressing and analyzing these issues within the AI phase of the TMDL through a plan that relies initially on natural recovery, accurate modeling, and monitoring of consumed species would likely result in lower net costs to achieve the benefits sought.

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[6] The State Board's Staff Report appears to go beyond the Regional Board's findings in the final Staff Report; see Cal. Chamber/GE comment No. 67 regarding draft Staff Report (letter dated June 22, 2007) and the Regional Board's Responses to Comments, pages 83-84, in Appendix D to the Staff Summary Report (dated February 13, 2008) and Final Revisions to Basin Plan Amendment.

Thank you for the opportunity to bring these updated comments to your attention at the SWRCB level.

Sincerely,

John P. Connolly, Ph.D.
Anchor QEA, LLC

Attachments: Figures and Curriculum Vitaes

JPC:tmm

REFERENCES

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San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). 2008a. Total Maximum Daily Load for PCBs in San Francisco Bay, Final Staff Report for Proposed Basin Plan Amendment. San Francisco, CA. February 13, 2008.

SFBRWQCB. 2008b. Proposed Amendment to the Water Quality Control Plan (Basin Plan) to Establish a Total Maximum Daily Load (TMDL) and Implementation Plan for Polychlorinated Biphenyls (PCBs) in San Francisco Bay. February 13, 2008 meeting minutes.

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SFEI. 2008b. A Model of Long-Term PCB Fate in San Francisco Bay. Model Formulation, Calibration, and Uncertainty Analysis Version 2.1. January 2008.

San Francisco Estuary Institute (SFEI). 2007. The 2006 RMP Annual Monitoring Results. San Francisco Estuary and the Regional Monitoring Program for Water Quality in the San Francisco Estuary. SFEI Contribution No. 542. San Francisco Estuary Institute, Oakland, CA.

Smith R.W. and L. Riege. 1998. *San Francisco Bay Sediment Criteria Project: Ambient Analysis Report.* Prepared For the San Francisco Bay Regional Water Quality Control Board, Oakland, CA.

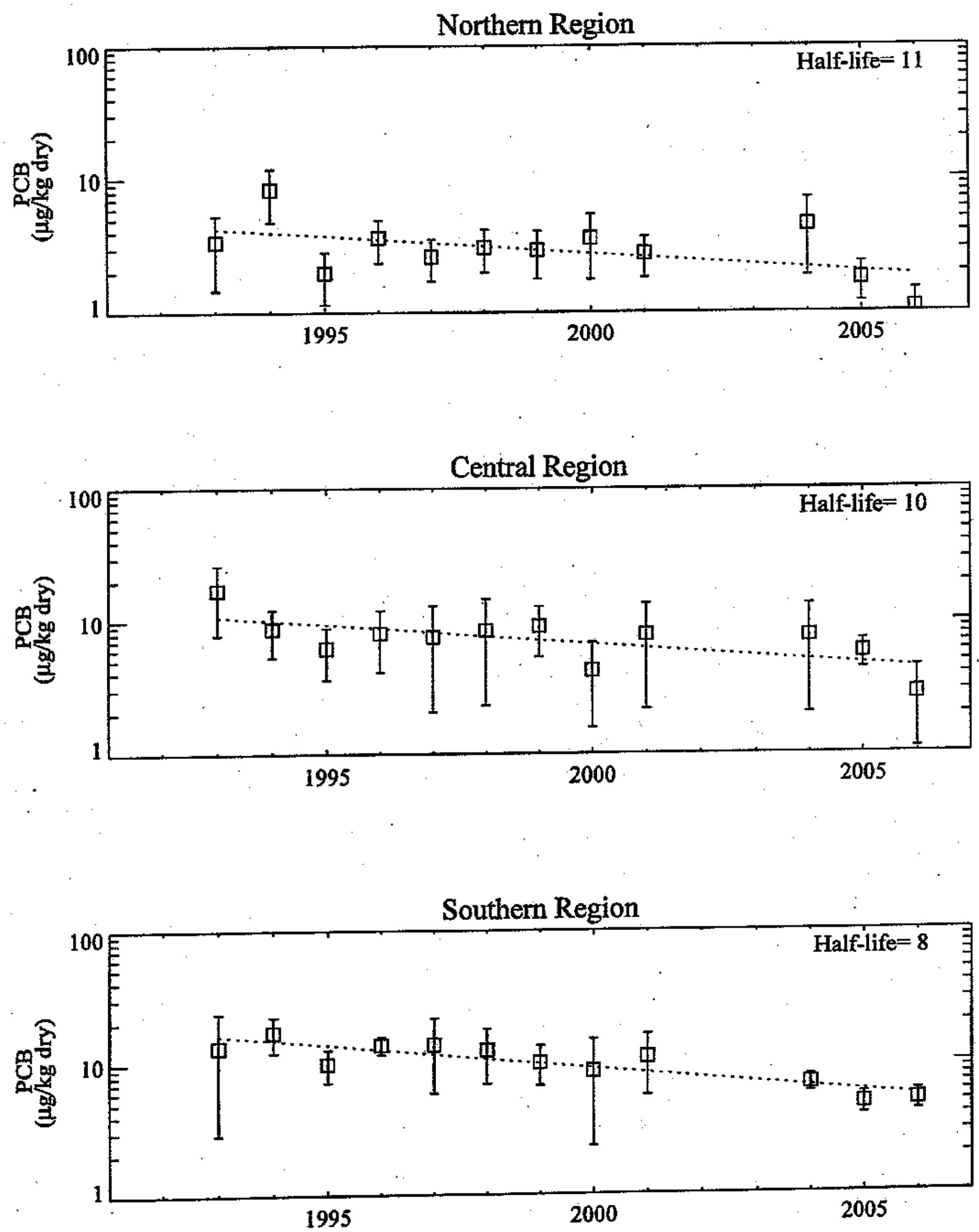

Figure 1. Trends in PCB concentrations in San Francisco Bay: Surface sediments.

Data Source: RMP (10/2008)

Nondetects set to the mean detection limit of all PCB congeners.

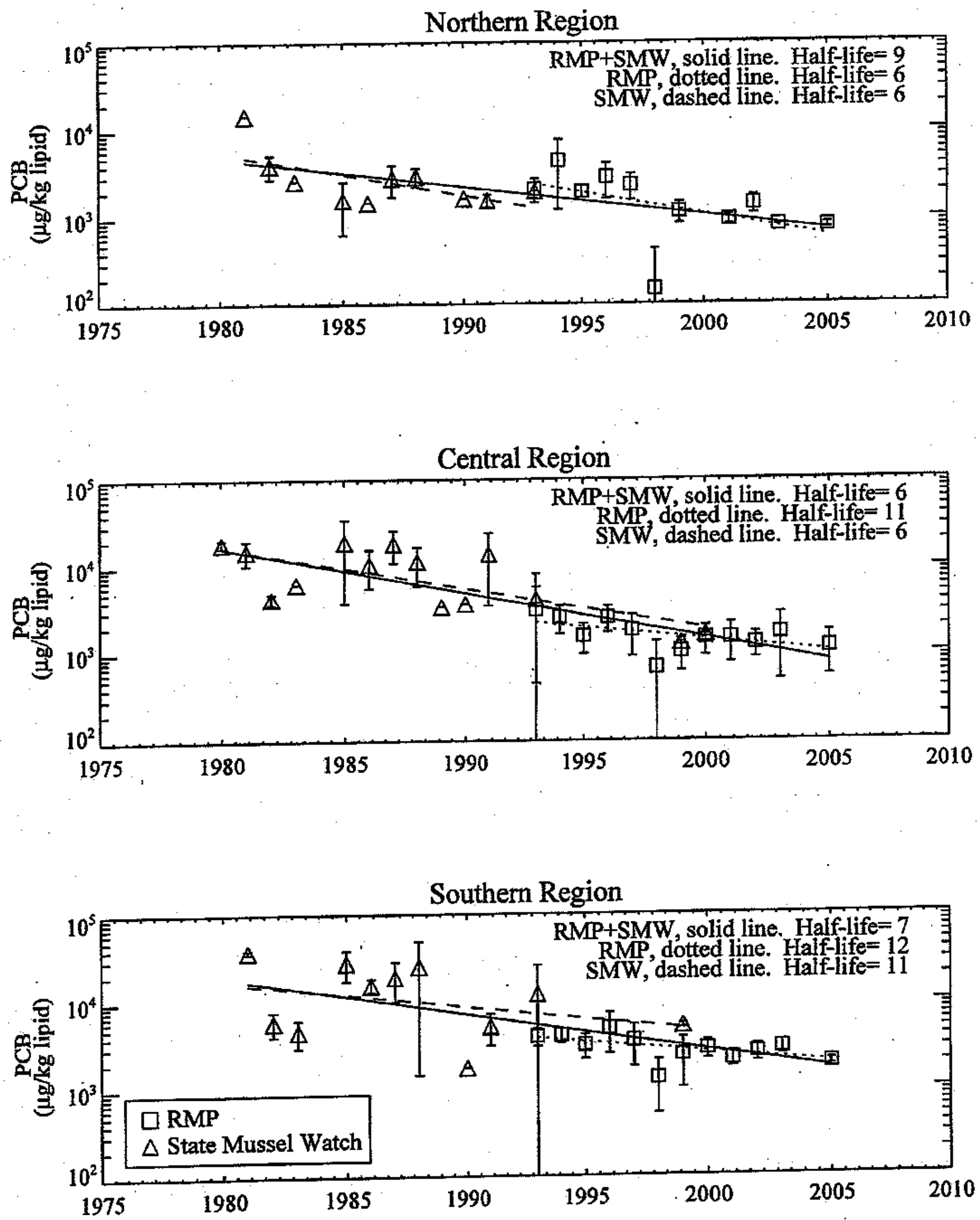

Figure 2a. Trends in PCB concentrations in San Francisco Bay: Transplanted mussels.

Data Sources: RMP (10/2008) and State Mussel Watch

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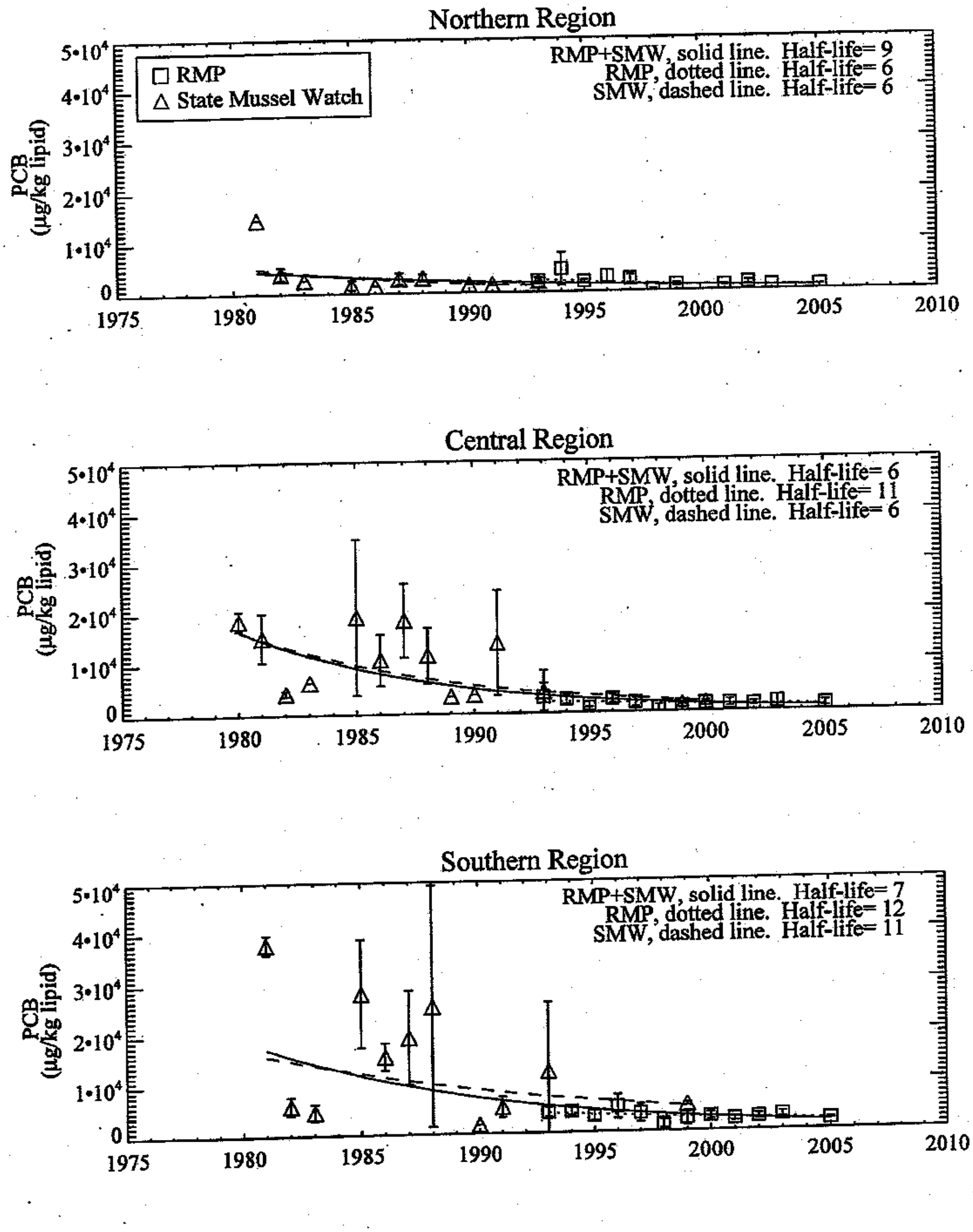

Figure 2b. Trends in PCB concentrations in San Francisco Bay: Transplanted mussels.

Data Sources: RMP (10/2008) and State Mussel Watch

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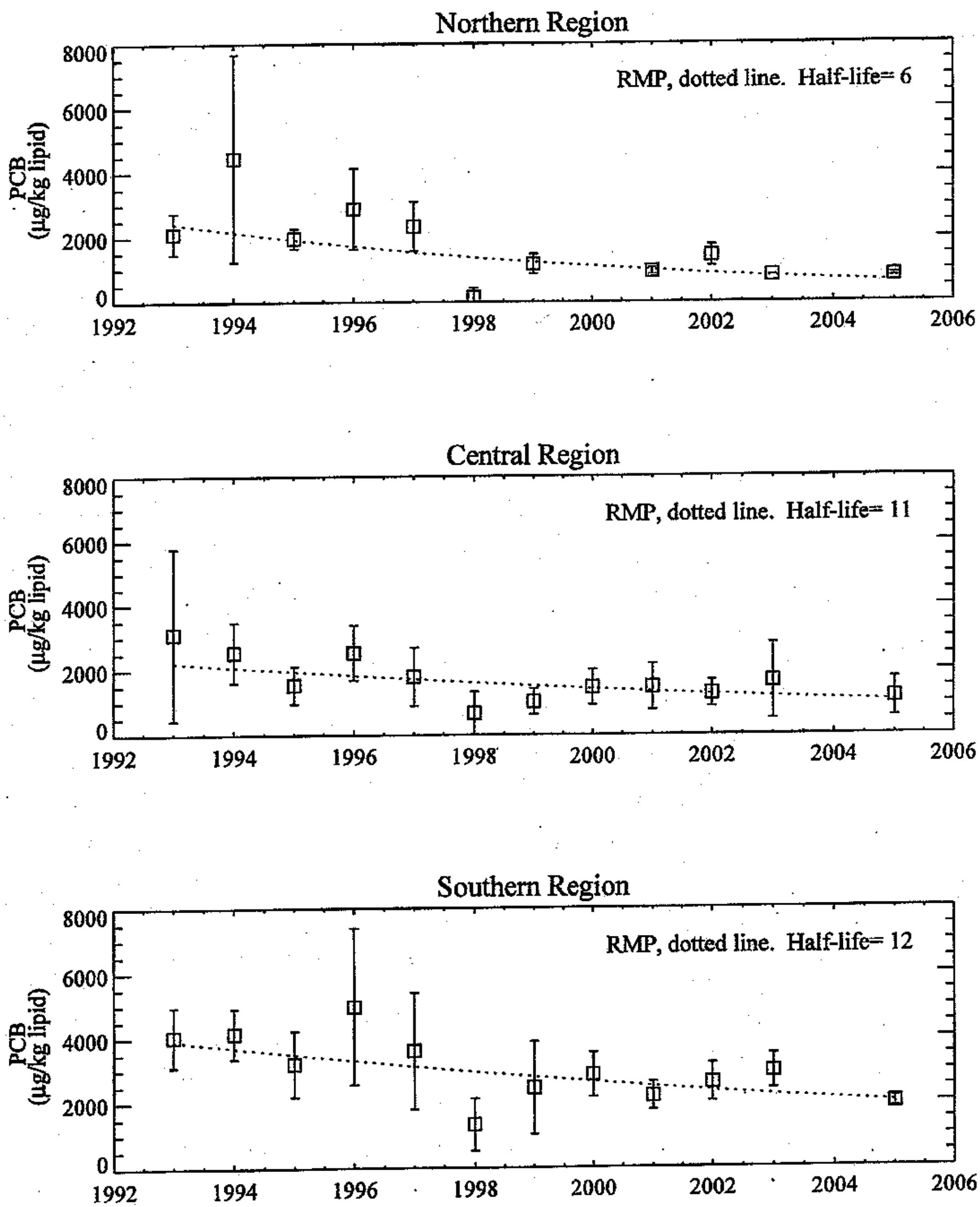

Figure 2c. Trends in PCB concentrations in San Francisco Bay: Transplanted mussels.

Data Sources: RMP (10/2008) and State Mussel Watch

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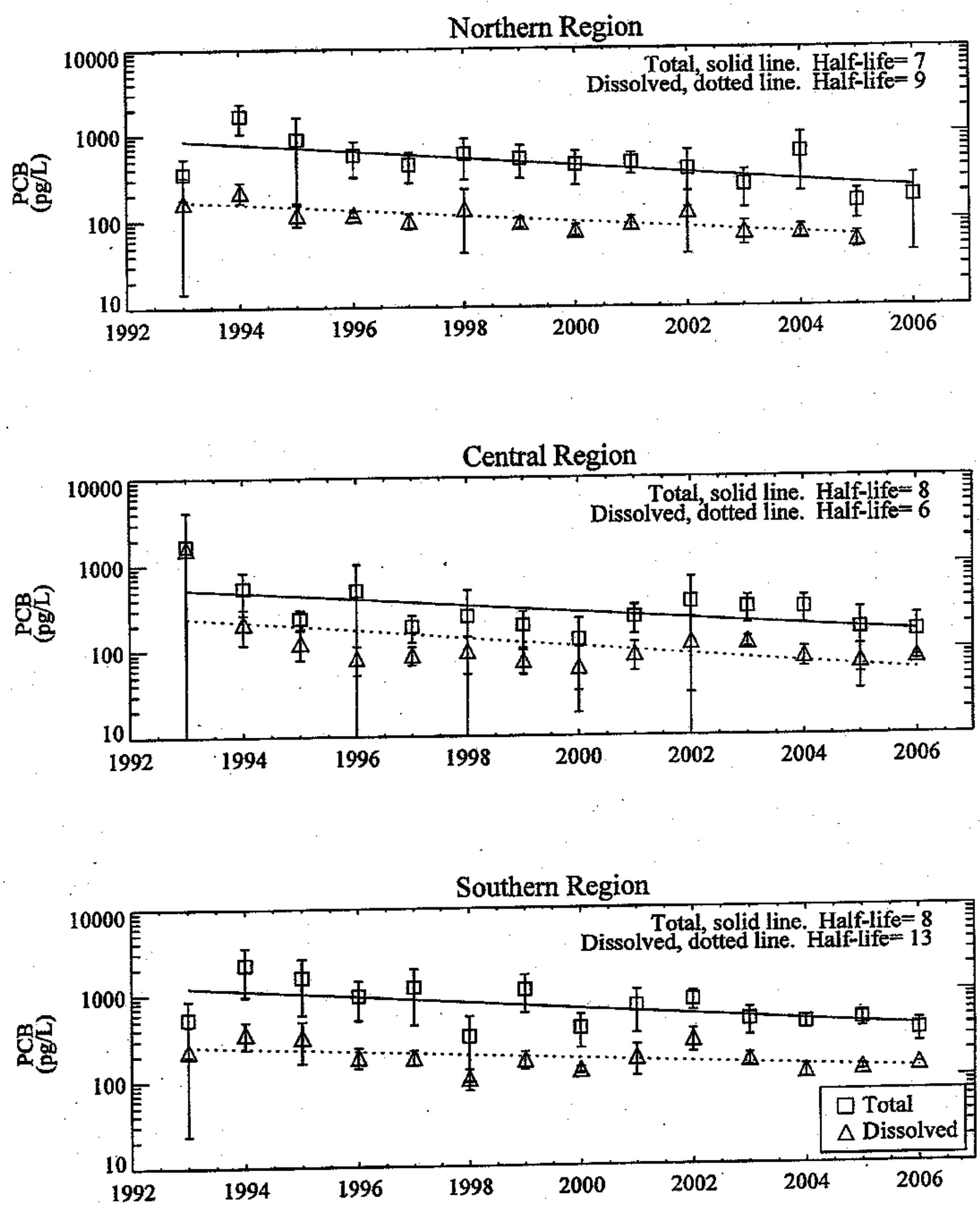

Figure 3. Trends in PCB concentrations in San Francisco Bay: Water.

Data Source: RMP (10/2008)

Nondetects set to the mean detection limit of all PCB congeners.

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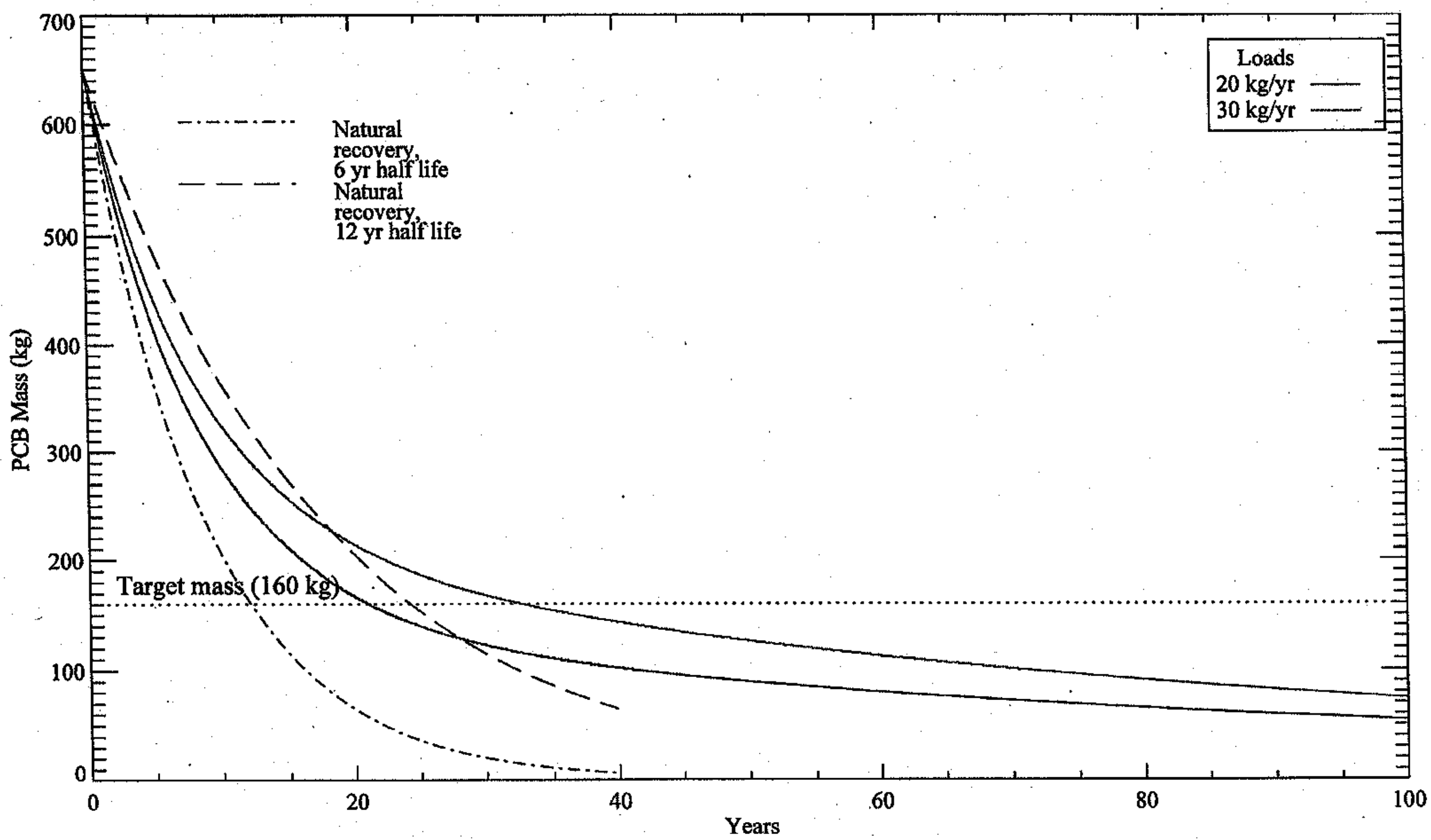

Figure 4. One-box model: PCB mass in San Francisco Bay surface sediments.

Initial PCB mass is 650 kg, following Figure 28 of the Feb 2008 TMDL Staff Report. Model does not include mass factor. Includes load attenuation with 56 yr half life.

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Tue Jan 20 15:54:57 2009

JOHN P. CONNOLLY, PH.D., P.E., BCEE
Principal

PROFESSIONAL HISTORY
Anchor QEA, President and Senior Managing Engineer, February 1998 to present
USEPA Science Advisory Board, 2005 to present
HydroQual, Inc., Principal Engineer, 1993 to January 1998
HydroQual, Inc., Consultant, 1980 to 1993
Manhattan College, Professor, 1992 to 1994
Manhattan College, Associate Professor, 1986 to 1992
Manhattan College, Assistant Professor, 1980 to 1986
U.S. Environmental Protection Agency, Environmental Scientist, 1978 to 1980
Manhattan College, Research Engineer, 1975 to 1977

EDUCATION
The University of Texas at Austin, Ph.D., 1980
Manhattan College, M.E., Environmental Engineering, 1975
Manhattan College, B.E., Civil Engineering, 1973

EXPERIENCE SUMMARY
Dr. Connolly is a nationally recognized expert on contaminated sediments and eutrophication. His work has been directed to surface water and groundwater contamination problems for the purposes of allocation among potential sources, evaluation of remedial options, remedy design or wasteload allocation (TMDLs). He is expert in water quality modeling and has been involved in the development of several models commonly applied to real world problems. He is also recognized for his ability to communicate complex technical results to the range of stakeholders typically involved in projects and is frequently called on to make presentations at regulatory hearings, community meetings and national and regional technical forums. Dr. Connolly has participated in negotiations with regulatory agencies to craft consent decrees governing contaminated sediment sites.

Dr. Connolly is frequently invited to participate in government and industry sponsored workshops. He is a member of the USEPA Science Advisory Board. He has worked throughout the U.S., in Latin America, and in Europe. He has served as an expert witness for industry and government agencies and has provided testimony before the U.S. Congress and the New York State Assembly. He is also a member of the Manhattan College Council of Engineering Affairs.

TESTIMONY

Town of Oyster Bay vs. Northrop Grumman Systems Corp., United States Navy and United States of America.

For defendants United States Navy and United States of America; expert witness testimony at deposition on 6/27/07 regarding the likelihood that PCBs in the soils of a town park originated from a site on Grumman property owned by the United States Navy.

Maine Environmental Protection Board.

Expert testimony given on 5/2/07 regarding the deficiencies of a phosphorus, TSS and BOD TMDL developed for Gulf Island Pond on the Androscoggin River and the contributions of various sources to existing algal and dissolved oxygen problems.

Subcommittee on Water Resources and Environment of the U.S. House of Representatives Transportation and Infrastructure Committee Hearing on Strategies to Address Contaminated Sediments.

Expert testimony given on 7/19/01 regarding the approaches used by USEPA to address contaminated sediments.

Maine Peoples' Alliance and Natural Resources Defense Council, Inc. vs. HoltraChem Manufacturing Company, LLC and Mallinckrodt, Inc.

For defendant Mallinckrodt; expert witness testimony at deposition on 7/3/01 and at trial on 3/12/02 regarding mercury bioavailability in the Penobscot River Estuary.

United States of America vs. Montrose Chemical Corporation of California, et al.

For plaintiff United States of America; expert witness testimony at deposition from 7/13 to 7/17/98 and 4/6/00 and at trial 10/19/00 regarding the transfer of DDT and PCBs from contaminated sediment in coastal waters off Los Angeles to fish, birds and sea lions.

Kalamazoo River Study Group vs. Rockwell International, et al.

For defendant Eaton Corporation; fact witness testimony at deposition on 7/22/97, expert testimony at deposition on 1/26/98 and trial testimony on 8/17 and 8/21/98, 1/19/01 and 2/5 and 2/6/01 regarding technical analyses conducted to evaluate the PCB contributions from Eaton's Battle Creek and Marshall facilities to the Kalamazoo River.

New York State Assembly Standing Committee on Environmental Conservation Public Hearing on PCB Contamination in the Hudson River.

Expert testimony given on 3/19/97 on behalf of the General Electric Company regarding the sources of PCBs observed in Hudson River fish.

Alcoa and Northwest Alloys, Inc. vs. Accident & Casualty Insurance Company, et al.

For plaintiff Alcoa; expert witness testimony at deposition on 2/28 and 3/1/96 regarding the nature, extent and expansion of sediment contamination at Alcoa facilities in Massena, New York and Point Comfort, Texas.

JOHN P. CONNOLLY, PH.D., P.E., BCEE
Principal

REPRESENTATIVE PROJECT EXPERIENCE

Contaminated Sediments Assessment and Management

Peer Review of Contaminated Sediment Remediation Guidance for Hazardous Waste Sites, USEPA

One of three national experts tasked with reviewing the draft guidance document which has been developed to provide technical and policy guidance to project managers and management teams making remedy decisions for contaminated sediment sites.

Source Allocation for Mercury in the Penobscot River Estuary, Mallinckrodt, Inc.

Principal investigator for evaluation of the relative contributions of sediment and water column mercury to mercury found in resident biota. This study involved data analysis and development of a conceptual modeling explaining the probable reasons of the apparent lack of impact of elevated sediment mercury concentrations on biota mercury levels. The work was used to provide litigation support through expert testimony. Subsequent to litigation, work has focused on development of a detailed investigation plan, interaction with a court-mandated Study Panel, technical support for the client's legal team and oversight of planned field work.

Source Allocation for Mercury in the Peconic River, Brookhaven National Laboratory

Principal investigator for investigations to determine the sources of methyl mercury in the fish of the Peconic River. This study involved the design of sampling programs and interpretation of data to determine the relative contributions of background sources and various sediment deposits throughout the river to methyl mercury in the water and fish. This work was conducted to satisfy a diverse group of stakeholders with differing positions on appropriate remediation. It led to a revision of the contemplated remedial action and a convergence of opinion on the best approach for the river.

Investigation of Mercury in Lavaca Bay, Alcoa

Principal investigator for the evaluation of mercury sources and prediction of the impacts of remedial actions and storm events on mercury levels in sediment and biota. The project involves data analysis and the development of linked hydrodynamic, sediment transport, mercury fate and bioaccumulation models. A primary goal is the evaluation of the impact of hurricanes and other rare storms on buried mercury.

Remediation of the Hudson River PCBs Site, General Electric Company

Principal investigator for various aspects of remedial design (RD), including the design and execution of an extensive pre-design sediment sampling program involving the collection of more than six thousand sediment cores, management of the RD database, determination of the dredging prisms, design and execution of the baseline and construction monitoring programs and support of the design of dredging and processing of dredged sediment. This project included the development of sophisticated data entry, data processing and data display systems that were used by the GE design team. Additional activities included direct participation in consent decree negotiations.

Analysis of the Fate of PCBs in the Hudson River, General Electric Company

Principal investigator for extensive data analysis and modeling studies of the dynamics of PCBs in the Hudson River. This study involved field sampling, data analysis and the development of linked hydrodynamic, physical/chemical, sediment transport and food chain models for the purpose of predicting the effects of alternative remediation plans.

Analysis of the Fate of PCBs in the Grasse River, Alcoa

Principal investigator for the determination of the impacts of contaminated sediments and point sources to PCB contamination in resident fish. Efforts include the design of field sampling programs, estimation of PCB fluxes between water and sediment, including the importance of areas of elevated concentrations and the transport and bioaccumulation in the food web. Goal is to provide a technical basis for examination of remedial options.

Assessment of Contribution of PCBs to the Kalamazoo River from Eaton Corporation, Eaton Corporation

Principal investigator for the analysis of data and development of models to evaluate whether either or both of two Eaton facilities contributed measurable quantities of PCBs to the Kalamazoo River. The project involved the compilation and analysis of historical data, design and execution of a sampling program and the development of models to predict the transport of sediment and PCBs through the Kalamazoo River.

Analysis of the Fate of PCBs in the Housatonic River, General Electric Company

Technical advisor for extensive data analysis and modeling studies directed to determining the appropriate remedial solution for the contaminated sediments. This study involves data analysis and the development of linked hydrodynamic, sediment transport, PCB fate and PCB bioaccumulation models. An important aspect of this project is the evaluation of the role of river flooding in PCB fate and impact of flood plain soils.

Modeling of Heavy Metal and Organic Contaminant Fate in the Pawtuxet River to Support a RCRA Facility Investigation, Ciba-Geigy Corporation

Principal investigator for determination of target chemicals by qualitative risk analysis, design of a sampling program and development of a model to evaluate temporal and spatial concentration reductions resulting from remedial action alternatives including excavation and groundwater treatment.

Analysis of DDE and PCB Transfer Pathways in the Southern California Bight Ecosystem, National Oceanic and Atmospheric Administration

Principal investigator for the analysis of data and development of food chain models to study the relationship between sediment contamination and levels of DDE and PCBs in fish, mammals, and birds. The purpose of this work was to establish probable sources of contamination in support of a Natural Resource Damages Assessment.

JOHN P. CONNOLLY, PH.D., P.E., BCEE
Principal

Contaminated Groundwater Assessment and Management

Evaluation of Solvent Plume Migration and Fate at the MW Manufacturing Site, Valley Township of Pennsylvania, *Lucent Technologies*

Principal investigator for the development and application of flow and transport models to be used to predict the movement and decay of a VOC plume composed of PCE, TCE, 1,2-DCE and vinyl chloride. The goal of the project is to estimate whether the plume has achieved a steady-state configuration in response to a non-aqueous phase source and to project discharge rates to a local stream.

Modeling of Groundwater Remediation Using Vertical Groundwater Circulation Technology, SBP Technologies

Principal investigator for the development of a strategy to model the treatment efficiency of *in-situ* vertical groundwater circulation technology. Work included the evaluation of circulation, nutrient dynamics and PAH biodegradation and volatilization. The goal was to develop a modeling framework that could be used to design sampling strategies and evaluate treatment efficiency.

Total Maximum Daily Load (TMDL) Investigations

Evaluation of the Phosphorus, TSS and BOD TMDL for Gulf Island Pond on the Androscoggin River, Maine, Verso Paper Company

Principal investigator for the critique of the TMDL developed by Maine DEP and the examination of the contributions of point and non-point sources to algal and dissolved oxygen problems in the Pond.

San Francisco Bay PCBs, General Electric Company

Principal investigator for the review and critique of a draft TMDL document issued by the San Francisco Bay Regional Water Quality Control Board. This study involved the analysis of data and modeling to provide the Board with the information necessary to correct deficiencies in the draft document with regard to natural recovery and the need for, and effectiveness of, available source control options and to develop an effective implementation strategy. It included the development of presentation materials and a face-to-face meeting with the authors of the document.

Coosa River PCBs, General Electric Company

Principal investigator for the review and critique of a draft TMDL document issued by the State of Georgia. This study involved the analysis of data to provide the State with the information necessary to correct deficiencies in the draft document with regard to natural recovery and the need for, and effectiveness of, available source control options and to develop an effective implementation strategy. It included the development of presentation materials and a face-to-face meeting with the State and with EPA Region 4.

Water Quality/Eutrophication Assessment

Assessment of the Environmental Fate and Impact of ICE-B-GON on Lake Wingra, Wisconsin, Chevron Research Company

Principal investigator for the laboratory determination of the degradation and oxygen utilization kinetics of the de-icing chemical, ICE-B-GON and projection of the effect of the use of this chemical on the dissolved oxygen of receiving waters using Lake Wingra as a case study.

Mathematical Modeling of Water Quality in Lake Erie, U.S. Environmental Protection Agency, Grosse Ile, Michigan

Project Engineer in charge of data analysis development and calibration of an eutrophication model including multiple algal species and zooplankton, and projections of the effects of reduction in point and non-point nutrient loadings on pollution indicators; lake phytoplankton, nutrient, and dissolved oxygen levels.

Analysis of Heavy Metals, Ammonia and Cyanide in the Genesee River, Eastman Kodak Corporation

Project Engineer in charge of data analysis, mathematical model development and assessment of the relative impact of the Kodak treatment plant effluent on water quality in the River.

Analysis of the Fate of Toxic Chemicals in Estuaries, U.S. Environmental Protection Agency, Gulf Breeze, Florida

Project Manager in charge of development of a mathematical model describing the transport and degradation of toxic chemicals in estuarine environments.

Development of Version 4.0 of the Water Analysis Simulation Program (WASP), U.S. Environmental Research Laboratory, Athens, Georgia

The purpose of this project was to modify the USEPA water quality model WASP (3.2) to provide a single modeling framework for use in all types of surface water problems including conventional and toxic pollutants under steady-state or time-variable conditions. Responsibilities included the development of the kinetic routines for the toxic chemical component of the model from those used in EXAMS II, TOXIWASP and WASTOX, integration of the WASTOX steady-state solution into WASP and providing technical assistance on all other components of model development.

Ecological Risk/Natural Resource Damage Assessments

Development of Water Quality Criteria for Wildlife, U. S. Environmental Protection Agency

Principal investigator for the development of methodologies to determine water concentrations protective of aquatic feeding wildlife. Defined methods to relate laboratory toxicity estimates to wildlife species. Efforts included compilation and analysis of toxicity data, development of models to permit extrapolation of laboratory toxicity data to field animals and development of models of the relationship between water column contaminant concentrations and effects in wildlife. Initial work focused on dieldrin and DDT.

Modeling PCBs in the Aquatic Biota of Green Bay, U.S. Environmental Protection Agency
Principal investigator for the development and application of a model of PCBs in the food web of Green Bay. This work is part of the Green Bay Mass Balance Study for the U.S. Environmental Protection Agency. The purpose of these studies was to evaluate the impacts of potential remediation alternatives.

Analysis of PCBs and Metals Contamination in the Biota of New Bedford Harbor, Massachusetts, U.S. Environmental Protection Agency, Region I, Battelle Ocean Sciences
Project manager in charge of developing a mathematical model of the contamination of the lobster and winter flounder and their food chains in New Bedford Harbor and Buzzards Bay. Responsible for linking this model with a hydrodynamic-contaminant fate model developed by Battelle Northwest to project the response of the biota to various remedial action alternatives. This work was part of an EPA Superfund project in New Bedford Harbor.

Analysis of PCBs in the Hudson River Striped Bass and its Food Chain, Hudson River Foundation, New York, NY
Project manager in charge of the development of a mathematical model describing the accumulation of PCBs in the striped bass food chain.

Analysis of Kepone Accumulation in the Striped Bass Food Web of the James River Estuary, U.S. Environmental Protection Agency, Gulf Breeze, Florida
Project manager in charge of the development and application of a mathematical model describing the accumulation of the pesticide Kepone in the striped bass food chain. Projected the response of the food chain to declining exposure concentrations.

Pathogen Fate and Transport

Development of a Framework for Predicting the Fate of Genetically Engineered Microorganisms in Surface Water Systems, U.S. Environmental Protection Agency, Environmental Research Laboratory, Gulf Breeze, Florida
Principal investigator for the development of a model of the population dynamics of bacteria, phytoplankton and zooplankton in surface waters and application of this model to predicting the risk associated with the introduction of genetically engineered bacteria to these environments. Population dynamics models were developed for the Delaware River and Mirror Lake.

Modeling Fate and Transport of Pathogenic Organisms in Mamala Bay, Hawaii, Mamala Bay Study Commission

Principal investigator for review of historical data, design of a sampling program and development and calibration of a mathematical model of pathogen fate in Mamala Bay. Goal is to determine pathogen sources and level of control necessary to meet water quality goals.

Evaluation of Cryptosporidium Sources and Fate in Milwaukee, Wisconsin, Sara Lee Corporation

Principal investigator for the evaluation of the likely contribution of various potential sources to the Cryptosporidium responsible for a disease outbreak in the city of Milwaukee.

Hydraulic Engineering

Hydraulic Analysis of the Fairfield, New Jersey Sewer System, Lee Purcell Associates, Inc.

Project engineer in charge of determining the capacity and flow characteristics of an in-place sewer system. Developed a gradually varied flow analysis for this purpose.

HONORS

Diplomate Environmental Engineer by Eminence, American Academy of Environmental Engineers, 2002

Manhattan College Environmental Engineering Alumni Club Service Award, 1994

PROFESSIONAL ACTIVITIES

Affiliations

American Academy of Environmental Engineers
Sigma Xi - The National Scientific Research Society
Society of Environmental Toxicology and Chemistry
American Society of Limnology and Oceanography
Water Environment Federation

Registration

Professional Engineer, State of Texas (License No. 92122)
Professional Engineer, State of New York (License No. 59428)

Committees and Advisory Boards

2005, USEPA Science Advisory Board
1997, USEPA Technical Qualifications Board to review promotion application
1991-96, New York Water Environment Association Outstanding Paper Award Committee
DuPont Technical Advisory Board for Evaluation of HMPA Releases at their Spurance Plant in Richmond, VA

1990, USEPA Exploratory Research Review Panel

Invited Participation in Technical Workshops

Addressing Uncertainty and Managing Risk at Contaminated Sediment Sites. St. Louis, MO October 26-28, 2004 – Steering Committee Member.

SERDP/ESTCP Contaminated Sediments Workshop. Arlington, VA August 10-11, 2004.

Stability of Chemicals in Sediments. San Diego, CA April 8-10, 2003 – Steering Committee Member.

Sediment Stability Workshop. New Orleans, LA, January 22-24, 2002 – Steering Committee Member.

U.S. EPA Forum on Contaminated Sediments. Alexandria, VA, May 30-June 1, 2001.

National Research Council Workshop on Bioavailability. Washington, D.C., November 12, 1998.

SETAC Pellston Workshop: Re-evaluation of the State of the Science for Water Quality Criteria Development. Fairmont Hot Springs, MT, June 25-30, 1998.

National Academy of Sciences National Symposium on Contaminated Sediments. Washington, D.C., May 27-29, 1998.

SETAC Pellston Workshop: Reassessment of Metals Criteria for Aquatic Life Protection. Pensacola, FL, February 10-14, 1996.

California EPA Workshop on Critical Issues in Assessing Ecological Risk. Asilomar, CA, January 23-25, 1995.

USEPA Workshop on Taura Syndrome. Gulf Breeze, FL, August 2-3, 1994.

USEPA Workshop on Modeling Uncertainty. Buffalo, NY, February 3-5, 1991.

USEPA Workshop on Sediment Quality Criteria. Grosse Ile, MI, March 29-30, 1990.

Industry Sponsored Workshop on the Environmental Impacts of the Deicer Calcium-Magnesium-Acetate. Albany, NY, February 27, 1990.

USEPA Workshop on Biotechnology Risk Assessment. Breckenridge, CO, January 11-15, 1988.

SETAC Workshop on Risk Assessment. Breckenridge, CO, August 17-21, 1987.

Presentations

Overview of the 2005 Grasse River Remedial Options Pilot Study. Fourth International Conference on Remediation of Contaminated Sediments, Savannah, GA, January 22-25, 2007.

Challenges to Monitoring and Assessing Natural Recovery. Third International Conference on Remediation of Contaminated Sediments, New Orleans, LA, January 27, 2005.
Monitoring to Support the Dredging Remedy on the Upper Hudson River. Third International Conference on Remediation of Contaminated Sediments, New Orleans, LA, January 26, 2005.

Adaptive Management as a Measured Response to the Uncertainty Problem. Addressing Uncertainty and Managing Risk at Contaminated Sediment Sites, St. Louis, MO, October 27, 2004

Optimal Use of Conceptual and Mathematical Models at Contaminated Sediment Sites. Addressing Uncertainty and Managing Risk at Contaminated Sediment Sites, St. Louis, MO, October 27, 2004

Sampling of Sediment and Water in the Upper Hudson River to Support the USEPA Dredging Remedy. Hudson River Environmental Society Conference, RPI, Troy, NY, October 5, 2004

Nature and Causes of Non-Particle Related Contaminant Releases in Large River Systems. Workshop on Environmental Stability of Chemicals in Sediments, San Diego, CA, April 10, 2003

Management of Contaminated Sediments. NSF US/Italy Workshop on Sediments, Arlington, VA, December 10, 2002

Use of Sound Science to Develop a Defensible Site Model. U.S. EPA Forum on Managing Contaminated Sediments, Alexandria, VA, May 31, 2001.

A Quantitative Framework for Evaluating Contaminated Sediment Sites. SETAC 20th Annual Meeting, Philadelphia, PA, November 14-18, 1999.

Prediction of Natural Recovery and the Impacts of Active Remediation in the Upper Hudson River. SETAC 20th Annual Meeting, Philadelphia, PA, November 14-18, 1999.

Evaluation of Remedial Alternatives for Contaminated Sediments: A Coherent Decision-Making Approach. National Research Council, National Symposium on Contaminated Sediments, Washington, D.C., May 28, 1998.

Applications of Models to the Risk Assessment Problem. Chesapeake Biological Laboratory, Solomans, MD, November 1, 1996.

Use of Food Web Models to Evaluate Bioaccumulation Data. National Sediment Bioaccumulation Conference, Bethesda, MD, September 11, 1996.

Assessment and Remediation of Contaminated Sediments at MGP Sites. Electric Power Research Institute, Monterey, CA, August 28, 1996.

Modeling the Environmental Fate and Transport of Metals. 26th Pellston Workshop: Reassessment of Metals Criteria for Aquatic Life Protection, Pensacola, FL, February 11, 1996.
Toxicologically Based Ecological Risk Assessment. California EPA Workshop on Critical Issues in Assessing Ecological Risk, Asilomar, CA, January 24, 1995.

Data Requirements for the Development and Use of Water Quality Models. USEPA Conference on Quality Assurance in Environmental Decision Making, IBM T.J. Watson Research Center, Yorktown Heights, NY, November 2, 1994.

Mathematical Modeling of the Bioaccumulation of Hydrophobic Organics. National Biological Survey, Columbia, MO, August 25, 1994.

A Model-Based Evaluation of PCB Bioaccumulation in Green Bay Walleye and Brown Trout. International Association for Great Lakes Research 36th Conference on Great Lakes Research, De Pere, WI, June 7, 1993.

Bioaccumulation Modeling of Micropollutants in the Field. International Workshop on Mechanisms of Uptake and Accumulation of Micropollutants, Veldhoven, The Netherlands, May 25, 1993.

Keynote Presentation. NIEHS Sponsored Workshop on the Bioaccumulation of Hydrophobic Organic Chemicals in Aquatic Organisms, June 29, 1992.

Modeling the Role of Bacteria in Carbon Cycling. Gordon Research Conference, New Hampton, New Hampshire, June 17, 1992.

Calcium Magnesium Acetate Biodegradation and its Impact on Surface Waters. Symposium on the Environmental Impact of Highway Deicing, University of California, Davis, October 13, 1989.

Food Chain Modeling in the Green Bay Mass Balance Study. International Association for Great Lakes Research 32nd Conference on Great Lakes Research, Madison, WI, June 2, 1989.

Modeling the Fate of Bacteria in Aquatic Systems. American Society for Microbiology Annual Conference, New Orleans, LA, May 18, 1989.

Application of a Food Chain Model to Evaluate Remedial Alternatives for PCB-Contaminated Sediments in New Bedford Harbor, MA, Superfund '88, Washington, D.C., November 29, 1988.

Modeling the Accumulation of Organic Chemicals in Aquatic Animals. Joint USA/USSR Symposium: Fate of Pesticides and Chemicals in the Environment, The University of Iowa, Iowa City, IA, November 15, 1987.

Modeling Kepone in the Striped Bass Food Chain of the James River. Virginia State Water Control Board, Richmond, VA, August 15, 1983.

Predicting the Effects of Toxic Chemicals in Natural Water Systems. U.S. Environmental Protection Agency, Environmental Research Lab, Athens, GA, November 3, 1982.

Modeling Toxic Substances in Aquatic Food Chains. Clarkson College Environmental Engineering Graduate Program, Potsdam, NY, October 29, 1982.

Predicting the Effects of Toxic Chemicals in Natural Water Systems. U.S. Environmental Protection Agency, Environmental Research Lab, Gulf Breeze, FL, September 13, 1982.

Modeling of Fate of Toxic Chemicals in Aquatic Systems. U.S. Environmental Protection Agency, Office of Toxic Substances, Washington, D.C., March 16, 1982.

Publications

Comment on "The Long-Term Fate of Polychlorinated Biphenyls in San Francisco Bay, (USA)". Connolly, J.P., C.K. Ziegler, E.M. Lamoureux, J.A. Benaman and D. Opydke, *Envion. Toxicol. Chem.* 24:2397-2398, 2005.

p,p'-DDE Bioaccumulation in Female Sea Lions of the California Channel Islands. Connolly, J.P. and D. Glaser, *Continental Shelf Res.* 22:1059-1078, 2002.

A model of p,p'-DDE and total PCB bioaccumulation in birds from the Southern California Bight. Glaser D, J.P. Connolly, *Continental Shelf Research* 22:1079-1100, 2002.

Use of a Bioaccumulation Model of p,p'DDE and Total PCB in Birds as a Diagnostic Tool for Pathway Determination in Natural Resource Damage Assessments. Glaser, D. and J.P. Connolly, *Continental Shelf Res.* In press.

Modeling of Flood and Long-Term Sediment Transport Dynamics in Thompson Island Pool, Upper Hudson River. Ziegler, C.K., P. Israelsson and J.P. Connolly, *Water Quality and Ecosystem Modeling* 1:193-222, 2000.

Modeling of Natural Remediation: Contaminant Fate and Transport. Peyton, B.M., T.P. Clement and J.P. Connolly, In: *Natural Remediation of Environmental Contaminants: Its Role in Ecological Risk Assessment and Risk Management,* Swindoll, C.M., R.G. Stahl & S.J. Ells, eds., SETAC Press, 472 p., 2000.

The Use of Ecotoxicology and Population Models in Natural Remediation. D. Glaser and J.P. Connolly, In: *Natural Remediation of Environmental Contaminants: Its Role in Ecological Risk Assessment and Risk Management,* Swindoll, C.M., R.G. Stahl & S.J. Ells, eds., SETAC Press, 472 p., 2000.

A Model of PCB Fate in the Upper Hudson River. Connolly, J.P., H.A. Zahakos, J. Benaman, C.K. Ziegler, J.R. Rhea and K. Russell, *Environ. Sci. Technol.* 34:4076-4087, 2000.

Modeling the Fate of Pathogenic Organisms in the Coastal Waters of Oahu, Hawaii. Connolly, J.P., A.F. Blumberg and J.D. Quadrini, *J. Environ. Eng.* 125:398-406, 1999.

Bacteria and Heterotrophic Microflagellate Production in the Santa Rosa Sound, Fl. Coffin, R.B. and J.P. Connolly, *Hydrobiologia* 353:53-61, 1997.

Hudson River PCBs: A 1990s Perspective. Rhea, J., J. Connolly and J. Haggard, *Clearwaters,* 27:24-28, 1997.

Modeling the Environmental Fate and Transport of Metals. Connolly, J.P., In: *Reassessment of Metals Criteria for Aquatic Life Protection,* Bergman H.L. and E.J. Dorward-King, eds., SETAC Press, 1997.

The Use of Vertical Groundwater Circulation Technology: A Preliminary Analysis of the Fate and Transport of Polycyclic Aromatic Hydrocarbons in a Shallow Aquifer. Connolly, J.P. and J.D. Quadrini, In: *In Situ Bioremediation and Efficacy Monitoring,* Spargo, B.J. ed., Naval Research Laboratory, NRL/PU/6115-96-317, 1996.

A Model of Carbon Cycling in the Planktonic Food Web. Connolly, J.P. and R.B. Coffin, *J. Envir. Eng.* 121:682-690, 1995.

The Impact of Sediment Transport Processes on the Fate of Hydrophobic Organic Chemicals in Surface Water Systems. Ziegler, C.K. and J.P. Connolly, *Toxic Substances in Water Environments: Assessment and Control,* Proceedings of the Water Environment Federation Specialty Conference, May 14-17, 1995.

JOHN P. CONNOLLY, PH.D., P.E., BCEE

Principal

Uncertainty in Bioaccumulation Modeling. Glaser, D. and J.P. Connolly, *Toxic Substances in Water Environments: Assessment and Control*, Proceedings of the Water Environment Federation Specialty Conference, May 14-17, 1995.

Toxicologically Based Ecological Risk Assessment. Connolly, J.P., In: *Critical Issues in Assessing Ecological Risk*, Summary of Workshop held at Asilomar Conference Center, Pacific Grove, CA, University Extension, University of California, Davis, January 23-25, 1995.

Availability of Dissolved Organic Carbon to Bacterioplankton Examined by Oxygen Utilization. Coffin, R.B., J.P. Connolly and P.S. Harris, *Mar. Ecol. Prog. Ser.* 101:9-22, 1993.

Do Aquatic Effects or Human Health End Points Govern the Development of Sediment-Quality Criteria for Nonionic Organic Chemicals? Parkerton, T.F., J.P. Connolly, R.V. Thomann and C.G. Urchin, *Environ. Toxicol. Chem.* 12:507-523, 1993.

An Equilibrium Model of Organic Chemical Accumulation in Aquatic Food Webs with Sediment Interaction, Thomann, R.V., J.P. Connolly and T.F. Parkerton, *Environ. Toxicol. Chem.* 11:615-629, 1992.

Modeling the Accumulation of Organic Chemicals in Aquatic Food Chains. Connolly, J.P. and R.V. Thomann, In: *Fate of Pesticides and Chemicals in the Environment*, Schnoor, J.L. ed., John Wiley & Sons, Inc., 1991.

Modeling Carbon Utilization by Bacteria in Natural Water Systems. Connolly, J.P., R.B. Coffin and R.E. Landeck. In: *Modeling the Metrobolic and Physiologic Activities of Microorganisms*, C. Hurst, ed., John Wiley & Sons, Inc., 1991.

Application of a Food Chain Model to Polychlorinated Biphenyl Contamination of the Lobster and Winter Flounder Food Chains in New Bedford Harbor. Connolly, J.P., *Environ. Sci. Technol.*, 25(4):760-770, 1991.

The Relationship between PCBs in Biota and in Water and Sediment from New Bedford Harbor: A Modeling Evaluation. Connolly, J.P., In: *Persistent Pollutants in the Marine Environment*, C.H. Walker and D. Livingstone, eds., Pergamon Press, Inc., 1991.

Fate of Fenthion in Salt-Marsh Environments: II. Transport and Biodegradation in Microcosms. O'Neill, E.J., C.R. Cripe, L.H. Mueller, J.P. Connolly and P.H. Pritchard, *Environ. Tox. Chem.* 8(9):759-768, 1989.

A Thermodynamic-Based Evaluation of Organic Chemical Accumulation in Aquatic Organisms. Connolly, J.P. and C.J. Pedersen, *Environ. Sci. Technol.* 22(1):99-103, 1988.

Mathematical Models - Fate, Transport and Food Chain. O'Connor, D.J., J.P. Connolly and E.J. Garland, In: E*cotoxicology: Problems and Approaches.* Lavin, S.A., M.A. Harwell, J.R. Kelly and K.D. Kimball, eds., Springer-Verlag, New York, 1988.

Simulation Models for Waste Allocation of Toxic Chemicals: A State of the Art Review. Ambrose, Jr., R.B., J.P. Connolly, E. Southerland, T.O. Barnwell, Jr. and J.L. Schnoor, *J. Wat. Poll. Con. Fed.* 60(9):1646-1655, 1988.

The Great Lakes Ecosystem - Modeling the Fate of PCBs. Thomann, R.V., J.P. Connolly and N.A. Thomas, In: *PCBs and the Environment, Vol 3,* Waid, J.S. ed., CRC Press, Inc. Boca Raton, Florida, pp. 153-180, 1987.
A Post Audit of a Lake Erie Eutrophication Model. DiToro, D.M., N.A. Thomas, C.E. Herdendorf, R.P. Winfield and J.P. Connolly, *J. Great Lakes Res.* 13(4):801-825, 1987.

Movement of Kepone (Chloradecone) Across an Undisturbed Sediment-Water Interface in Laboratory Systems. Pritchard, P.H., C.A. Monti, E.J. O'Neill, J.P. Connolly and D.G. Ahearn, *Environ. Tox. Chem.*, 5:647-658, 1986.

Bioaccumulation of Kepone by Spot (*Leiostomus xanthurus*): Importance of Dietary Accumulation and Ingestion Rate. Fisher, D.J., J.R. Clark, M.H. Roberts, Jr., J.P. Connolly and L.H. Mueller, *Aquatic Tox.* 9:161-178, 1986.

A Model of Kepone in the Striped Bass Food Chain of the James River Estuary. Connolly, J.P. and R. Tonelli, *Estuarine, Coastal & Shelf Science* 20:349-366, 1985.

Predicting Single Species Toxicity in Natural Water Systems. Connolly, J.P., *Environ. Tox. Chem.* 4:573-582, 1985.

WASTOX, A Framework for Modeling Toxic Chemicals in Aquatic Systems, Part II: Food Chain. Connolly, J.P. and R.V. Thomann, U.S. Environmental Protection Agency, Gulf Breeze, FL, EPA 600/3-85-017, 1985.

A Model of PCB in the Lake Michigan Lake Trout Food Chain. Thomann, R.V. and J.P. Connolly, *Environ. Sci. Tech.* 18(2):65-71, 1984.

WASTOX, A Framework for Modeling Toxic Chemicals in Aquatic Systems. Connolly, J.P. and R.P. Winfield, U.S. Environmental Protection Agency, Gulf Breeze, FL, EPA 600/3-84-077, 1984.

Adsorption of Hydrophobic Pollutants in Estuaries. Connolly, J.P., Armstrong, N.E. and R.W. Miksad, ASCE *J. Envir. Eng. Div.* 109(1):17-35, 1983.

Calculated Contribution of Surface Microlayer PCB to Contamination of the Lake Michigan Lake Trout. Connolly, J.P. and R.V. Thomann, *J. Great Lakes Research* 8(2):367-375, 1982.

Mathematical Modeling of Water Quality in Large Lakes, Part 2. Di Toro, D.M. and J.P. Connolly, Lake Erie, U.S. Environmental Protection Agency, Ecological Research Series, EPA-600/3-80-065, 1980.

The Effect of Concentration of Adsorbing Solids on the Partition Coefficient. O'Connor, D.J. and J.P. Connolly, *Water Research* 14(10):1517-1523, 1980.

ELIZABETH M. LAMOUREUX

Managing Scientist

PROFESSIONAL HISTORY

Anchor QEA, Managing Scientist, January 2003 to present
Anchor QEA, Senior Project Scientist, January 2001 to 2002
Anchor QEA, Project Scientist, August 1998 to December 2000
Marine Sciences Research Center, State University of New York at Stony Brook, Research Assistant, 1995 to 1998
Nassau County Community College, Professor of Environmental Science, 1995 to 1996
Division of Environmental Contaminants, U.S. Fish and Wildlife Service, Dean John A. Knauss Marine Policy Fellow, 1994 to 1995
Marine Sciences Research Center, State University of New York at Stony Brook, Research Assistant, 1991 to 1993
Fanning, Phillips & Molnar, Environmental Scientist, 1990 to 1991
RGM Liquid Waste Removal Corp., Environmental Compliance Officer, 1989 to 1990
Pednault Associates, Department Head of Wet Laboratory, 1987 to 1989

EDUCATION

Marine Sciences Research Center, State University of New York at Stony Brook, Ph.D. Candidate
Marine Sciences Research Center, State University of New York at Stony Brook, M.S., Marine Environmental Sciences, 1995
State University of New York at Buffalo, B.A., Environmental Studies, 1986

EXPERIENCE SUMMARY

Ms. Lamoureux has 17 years of experience as an environmental scientist, with particular expertise in the bioavailability and bioaccumulation of contaminants, as well as in risk assessment. Her work centers on the compilation and management of large databases, the analysis and integration of environmental data, and computer modeling. She also evaluates risk assessment methodology used to develop sediment and water quality criteria and cleanup targets. Her extensive experience in the performance of experimental laboratory studies provides an important foundation for the development of realistic, effective solutions to environmental problems. She has presented technical papers at scientific conferences and participates in local conferences and national societies.

Ms. Lamoureux has experience with the study of environmental problems in the private sector, in government, and in academia. Her Ph.D. research involved the investigation of the role of desorption in controlling the bioavailability of sediment-associated hydrophobic organic contaminants. She acquired invaluable experience in the areas of environmental contaminant fate in biological systems and in environmental risk assessment while working at U.S. Fish and Wildlife Service National Headquarters in Washington, D.C. Her Master's work focused on the use of a source-specific tracer to study the fate and transport of organic matter and contaminants at the 106-Mile Deep Water Disposal Site. Ms. Lamoureux has also worked in the general area of environmental characterization at consulting firms and at an environmental test laboratory.

ELIZABETH M. LAMOUREUX

Managing Scientist

REPRESENTATIVE PROJECT EXPERIENCE

Upper Hudson River Floodplain, General Electric Company

Management and oversight of the development of a Remedial Investigation/Feasibility Study and sampling program design for the Upper Hudson River Floodplain portion of the Hudson River PCBs site. This involved data analysis to develop a conceptual site model (CSM), which also forms the basis for the characterization of floodplain soil PCB concentrations and sampling design.

Watershed Phosphorous Source Assessment, Confidential

Evaluation of the use of metals as tracers of phosphorous from various sources, as part of a larger assessment of the relative importance of these sources to phosphorus levels in an agricultural watershed.

Environmental Assessment for the Harbor Deepening Project, U.S. Army Corps of Engineers

Assisted the Corps of Engineers (USACE) in the evaluation of impacts of the deepening the navigational channels of the New York/New Jersey Harbor on the RI/FS for the Newark Bay Study Area of the Passaic River Superfund Site. This has involved estimating the re-distribution of dioxins and furans and other contaminants, based on the results of a dredge resuspension model.

Analysis of the Fate of Volatile Organic Compounds in an Urbanized River, Confidential

Co-management of an investigation of the fate of highly volatile chemicals seeping from former plant sites into the local river. Designed field program to estimate volatilization losses downstream of plant sites. Managed the development of simple volatilization/dilution model to understand the spatial distribution of volatile chemicals released from local sources.

Upper Hudson River Dredging, General Electric Company

Involved in the development of the baseline monitoring program for Upper Hudson River dredging operation. Currently is involved in the analysis of data generated through the dredge delineation and baseline monitoring program for the evaluation of post-dredging restoration efforts.

Mercury TMDL development for the Sandusky River Watershed, OH, General Electric Company

Worked with Region 5 USEPA in the development of a mercury TMDL for the Sandusky River.

Bioaccumulation Modeling of PCBs in the Upper Hudson River, General Electric Company

Manages the bioaccumulation model developed for the Upper Hudson River. Responsibilities include constructing model inputs, performing model simulations and processing and interpreting model output. Also conducts model projections to evaluate the relative benefits of various source control and dredging scenarios on PCB levels in resident fish.

ELIZABETH M. LAMOUREUX

Managing Scientist

PCBs in the Upper Hudson River, General Electric Company

Currently oversees the management and analysis of Hudson River contaminant databases collected through various monitoring programs. Projects involve looking at the temporal and spatial trends of PCBs and other contaminants in Hudson River sediments and biota.

San Francisco Bay PCBs TMDL review, General Electric Company

Involved in a critical analysis of the mass balance and food web models developed for the San Francisco Bay Total Maximum Daily Load (TMDL). Develops approaches to understand the sources and loadings of PCBs to the Bay and identification of data gaps. Reviews issues related to PCB load allocation and target concentrations for fish and sediment.

Fox River/Green Bay Remedial Investigation and Feasibility Study, ThermoRetec, Inc. for Wisconsin Department of Natural Resources

Ms. Lamoureux was responsible for revision of the PCB aquatic food web bioaccumulation model for the Lower Fox River and Green Bay for the RI/FS.

Bioavailability of Sediment-Sorbed Hydrophobic Contaminants, Hudson River Foundation

Conducted research to further understand the mechanisms that control the bioavailability of sediment-sorbed hydrophobic contaminants to deposit-feeding organisms. Research included a combination of field and laboratory studies; the level of contaminant bioaccumulation measured in the field and laboratory were compared with measured contaminant desorption rates. Experiments were designed to look at the effects of the quality and quantity of organic and soot sediment carbon content, sediment aging, the dynamics of sediment diagenesis, species, organism size, gut surfactant level, and feeding strategy, on contaminant desorption and assimilation efficiency. Results suggest that gut surfactant level is the most important mechanism controlling hydrophobic contaminant assimilation in deposit-feeders, although the quality and quality of organic and soot sediment carbon content also play a major role. Research conducted as part of doctoral work.

Fate and Availability of Linear-Alkyl Benzenes Released from Underwater Electrical Power Transfer Lines, Northeastern Utilities

Conducted an analysis of linear-alkyl benzenes (LABs) in Long Island Sound sediments. Study also involved the analysis of source material and fingerprint matching to identify leaks in underwater electrical power cables. Additionally measured LAB bioavailability to oysters through a transplanting experiment.

Effect of Ship-Derived Coal Wastes on Benthic Habitats, EPRI/Sea Grant

Participated in a project that looked at the effects of coal, taconite, and ash deposited on Lake Ontario sediments as a result of ship washing practices, on the benthic community. Ms. Lamoureux was responsible for the analysis of PAH concentrations and desorption rates, as well as bioaccumulation in the amphipod *Mysis relicta.*

ELIZABETH M. LAMOUREUX

Managing Scientist

FIFRA Review of Pesticide Toxicity Data, U.S. Fish and Wildlife Service

Ms. Lamoureux was responsible for reviewing pertinent toxicity data and providing technical assistance to the USEPA during the registration and re-registration of several pesticides proposed for agricultural use under the *Federal Insecticide, Fungicide, and Rodenticide Act* (FIFRA).

Effect of Increase in Organic Load and Anthropogenic Compounds on Bathypelagic Environments, NOAA

Participated in a multi-disciplinary project to determine the effects that the increased organic load and anthropogenic compounds derived from ocean disposal of sewage sludge at the 106-Mile Deep Water Sewage Sludge Disposal Site had on the local bathypelagic environment. Specifically, Ms. Lamoureux looked at the spatial distribution of organic contaminants, including linear alkylbenzenes, which served as a tracer of sewage sludge inputs

Cycling of Fatty Acids in an Anoxic Estuarine Basin, National Science Foundation

Participated in an intensive study to understand the cycling of volatile fatty acids in the Pettaquamscutt River Estuary, a permanently anoxic basin. Role involved the measurement of fatty acid turnover rates just below the oxycline.

Quantification of Parameter Loadings for Section 303 Permit Compliance, Town of Huntington

Ms. Lamoureux was the project manager for a Section 303 Permit compliance investigation of sources of coliform loadings to Huntington Harbor in Long Island Sound. Loads were determined through shoreline surveys, effluent and stormwater monitoring, overland flow estimates, and enumeration of waterfowl.

Landfill Monitoring, Town of East Hampton

Participated in the design, installation, and analysis of a landfill monitoring system for gas and liquid phase contaminants at the East Hampton Town Landfill on Long Island, NY.

PROFESSIONAL ACTIVITIES

Affiliations

International Association for Great Lakes Research
Society of Environmental Toxicology and Chemistry
New York Academy of Sciences

Presentations

Lipid Normalization in Fish: Why It Does or Doesn't Help and What To Do About It. Lamoureux, B. and D. Glaser. Society for Environmental Toxicology and Chemistry Annual Meeting, Austin, TX, November 2003.

Resistant Desorption of PCBs from Lower Hudson River Estuary Sediments: Implications for Understanding the Distribution and Bioaccumulation of PCB Congeners. Brownawell, B.J and E.M.

Lamoureux, Society of Environmental Toxicology and Chemistry 20th Annual Meeting, Charlotte, NC, 14-18 November, 1999.

Sediment Soot Content as a Control on Bioavailability of Hydrophobic Organic Compounds. Lamoureux, E.M. and B.J. Brownawell, Society of Environmental Toxicology and Chemistry 19th Annual Meeting, Charlotte, NC, 15-19 November, 1998.

The Relationship between Carbon and Contaminant Absorption in Deposit-feeding Invertebrates. Lopez, G., A. McElroy, B.J. Brownawell, E.M. Lamoureux, and M. Ahrens, Society of Environmental Toxicology and Chemistry 18th Annual Meeting, San Francisco, CA,16-20 November 1997.

Assimilation of Sediment-Sorbed Hydrophobic Organic Contaminants by Deposit-Feeders as a Function of Desorption Rate and Extent. Lamoureux, E.M. and B.J. Brownawell, Society of Environmental Toxicology and Chemistry 18th Annual Meeting, San Francisco, CA,16-20 November 1997.

Desorption of PCBs, PAHs, and LABs from Marine Sediments. Lamoureux, E.M. and B.J. Brownawell, American Chemical Society 213th National Meeting, Las Vegas, NV, 7-11 September 1997.

The Effect of Contaminant Desorption on Assimilation of Sediment-sorbed Hydrophobic Contaminants by Deposit-feeders. B.J. Brownawell, E.M. Lamoureux, A. McElroy, G. Lopez, and M. Ahrens, Society of Environmental Toxicology and Chemistry 17th Annual Meeting, Washington, DC, 17-21 November 1996.

The Role of Desorption in Controlling the Bioavailability of Sediment-Sorbed Hydrophobic Contaminants. Lamoureux, E.M., and B.J. Brownawell, Gordon Research Conference, Environmental Science: Water, New Hampton, NH, June 1996.

The Behavior of Linear Alkylbenzenes (LABs) and Other Sewage Sludge Tracers in Sediments Below the 106-Mile Deep Ocean Disposal Site. Lamoureux, E.M., B.J. Brownawell and M. Bothner, Society of Environmental Toxicology and Chemistry 15th Annual Meeting, Denver, CO, 30 October – 3 November 1994.

The Application of Linear Alkylbenzenes as Tracers of Sewage Sludge at the 106-mile Deep Water Municipal Sewage Sludge Disposal Site. Lamoureux, E.M. and B.J. Brownawell, 12th Biennial International Estuarine Research Federation Conference, Hilton Head, NC, 14-18 November, 1993.

Publications

Comment on "The Long-Term Fate of Polychlorinated Biphenyls in San Francisco Bay, (USA)". Connolly, J.P., C.K. Ziegler, E.M. Lamoureux, J.A. Benaman, and D. Opdyke. Environ. Toxicol. Chem. 24(10): 2397-2400, 2005.

The Influence of Soot on Hydrophobic Organic Contaminant Desorption and Assimilation Efficiency. Lamoureux, E.M. and B.J. Brownawell. Environ. Toxicol. Chem. 23(11): 2571-2577, 2004.

The Effect of Body Size on Digestive Chemistry and Absorption Efficiencies of Food and Sediment-Bound Organic Contaminants by the Polychaete Nereis Succinea. Ahrens, M.J., J. Hertz, E.M. Lamoureux, G.R. Lopez, A.E. McElroy, and B.J. Brownawell. Journal of Experimental Marine Biology and Ecology, 263:185-209, 2001.

The Role of Digestive Surfactants in Determining Bioavailability of Sediment-Bound Hydrophobic Organic Contaminants to Two Deposit-Feeding Polychaetes. Ahrens, M.J., J. Hertz, E.M. Lamoureux, G.R. Lopez, A.E. McElroy and B.J. Brownawell, Marine Ecol. Prog. Ser. 212:147-157, 2001.

Chemical and Biological Availability of Sediment-Sorbed Hydrophobic Organic Contaminants. Lamoureux, E.M. and B.J. Brownawell, Environ. Toxicol. Chem. 18(8): 1733-1741, 1999.

Linear Alkylbenzenes as Tracers of Sewage Sludge Derived Inputs of Organic Matter, PCBs, and PAHs, to Sediments at the 106-Mile Deep Water Disposal Site. Lamoureux, E.M., B.J. Brownawell and M.H. Bothner, J. Marine Env. Eng. (2):325-342, 1996.

Comparison of the Relative Desorption of Polychlorinated Biphenyls, Polynuclear Aromatic Hydrocarbons, and Linear Alkylbenzenes from Hudson River Sediments. 1996. Lamoureux, E.M. and B.J. Brownawell, Section III: In Waldman, J.R. and E.A. Blair (eds), Final Reports of the Tibor T. Polgar Fellowship Program. Hudson River Foundation, NY. III-1-III-34, 1995.

The Distribution of Linear Alkylbenzenes, Polychlorinated Biphenyls, and Polynuclear Aromatic Hydrocarbons in Sediments and Biota at the 106-Mile Deep Water Disposal Site. Lamoureux, E.M. Master's Thesis, SUNY at Stony Brook, Stony Brook, NY, 99 pp., 1995.