Public Comment
1,2,3- TCP
Deadline: 4/21/17 by 5pm

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SWRCB Clerk

April 20, 2017

Ms. Jeanine Townsend
Clerk of the Board
State Water Resources Control Board
1001 I Street, 24th Floor,
Sacramento, CA 95814

Via Email and personal delivery: commentletters@waterboards.ca.gov

Re: Public Comments on Proposed Maximum Contaminant Level (MCL) for 1, 2, 3 Trichloropropane (TCP)- "SBDDW-17-001"

Dear Ms. Townsend:

The California Manufacturers & Technology Association (CMTA) and the American Chemistry Council (ACC) have asked Dr. Richard Belzer to prepare the attached comments on the State Water Resources Control Board (SWRCB) proposal to adopt an MCL for TCP in drinking water. CMTA and ACC ask that the Board consider these comments before proceeding with action on the proposed MCL for TCP.

For further communications relevant to these comments please contact the undersigned.

Sincerely,

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Independent Review of
California State Water Quality Control Board Regulatory Impact Analysis
for the Proposed 1,2,3-Trichloropropane
Primary Drinking Water Standard

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Richard B. Belzer

Dr. Richard Belzer has been an independent consultant in regulation, risk, economics and information quality since 2001. Previously he was a visiting professor of public policy at Washington University in St. Louis and staff economist in the Office of Information and Regulatory Affairs at the Office of Management and Budget (OMB). He received his Ph.D. in public policy from Harvard University (1989), Master's in Public Policy (MPP) from the John F. Kennedy School of Government (now Harvard Kennedy School) (1982), and M.S. and B.S. degrees in agricultural economics from the University of California at Davis (1979, 1980).

Dr. Belzer's research and consulting work is highly multidisciplinary. He often collaborates with biologists, toxicologists, epidemiologists, and other professionals to solve problems that cross disciplinary boundaries. Current original research includes the evaluation of biomedical test procedures as inputs to human health risk assessment and benefit-cost analysis; the identification and use of objective indicators to identify adverse human health effects; the critical review of carcinogen classification schemes; the objective incorporation of human health risk assessments into benefit-cost analysis; and the analysis of environmental justice ranking schemes. He recently completed an analysis of potential savings State Medicaid programs could obtain if enrollees who smoke switched to e-cigarettes. Beyond public health, Dr. Belzer has published a benefit-cost analysis of the inclusion of juveniles within sex offender registries. He also is an analyst of patent law and examination practices and the economics of certain innovations in world wine markets.

Dr. Belzer is a regular volunteer contributor to scholarly professions, primarily through journal peer review and service to professional societies. He was elected Treasurer of the Society for Risk Analysis (SRA) in 1998 and 2000; elected Secretary-Treasurer of the Society for Benefit-Cost Analysis (SBCA) in 2008, 2010, and 2012; and elected Treasurer of the SBCA in 2014. He earned multiple awards for exemplary performance during his tenure at OMB and was named a Fellow of the Cecil and Ida Green Center for the Study of Science and Society in 1995. Dr. Belzer was given the SRA's Distinguished Service Award in 2003 and the SBCA's Richard O. Zerbe, Jr., Distinguished Service Award in 2017.

Since 2015, Dr. Belzer has been a member of the U.S. Environmental Protection Agency's Science Advisory Board Economy-wide Modeling Panel. The panel is charged with providing advice to the Agency on the use of sophisticated, data-intensive tools for estimating the full effects of major environmental regulations.

More information concerning Dr. Belzer's work, including seminar presentations and testimony, can be found on his website at www.rbbelzer.com.

This report was prepared on behalf of the California Manufacturers and Technology Association. All professional opinions expressed herein and not otherwise attributed are those of the author.

1. Executive Summary

The State Water Board has the responsibility of setting drinking water standards that are both technologically feasible and economically feasible. The Board has carefully considered technological feasibility of its proposed 5 ppt MCL for 1,2,3-trichloropropane (TCP), it has not performed a similar analysis of economic feasibility. Given the limited information disclosed by the Board, its proposed standard clearly is not economically feasible.

The State Water Board's proposal has serious procedural defects, including conflicting information about the Board's cost-benefit analysis:

- The Board says it did not perform a cost-benefit analysis to determine that the proposed MCL is economically feasible. However, it is impossible to determine economic feasibility without performing a cost-benefit analysis.
- The Board provided documents to peer reviewers clearly indicating that the Board performed a "full cost-benefit analysis." However, the Board did not disclose this analysis to the peer reviewers and has not disclosed it to the public.
- The Board apparently knows how much every household affected would have to pay but has disclosed only average costs by system size for each MCL. This is misleading. Many households would pay more than the average, and the public deserves to know how much more they would pay. This could be substantial, for even the limited information disclosed by the Board indicates that some households served by small systems may have to pay over $8,000 per year.

The State Water Board's determination of economic feasibility is inconsistent with an economic interpretation of this statutory term:

- Any economic determination of economic feasibility would take account of the actual benefits obtained from treatment.
- At the proposed MCL, the average household bears more in cost than it receives in *potential* value even from *theoretical* risk reductions. Excess cost would be substantially greater if the Board had properly estimated risk reduction objectively.

A simple and straightforward methodology can be used to apply *economic reasoning* to determine economic feasibility. The Board produced all the information needed to apply economic reasoning, then chose not to do so:

- For small systems, the Board's estimated cost for the proposed MCL is $97 million per theoretical cancer case averted. This is 10 times the maximum value that the U.S. Environmental Protection Agency routinely uses as its upper bound valuation for averting an actual premature mortality. Even at 150 ppt – the highest MCL considered – the Board's estimated cost is $21 million per theoretical cancer case averted.

- For large systems, the Board's estimated cost for the proposed MCL is $14 million per theoretical cancer case averted. This is almost 2 times the USEPA upper-bound for averting an actual premature mortality. The lowest MCL considered by the Board that is less than the USEPA upper-bound for averting an actual premature mortality is 35 ppt.

When the incremental effects of adjacent MCLs are considered, the evidence against economic feasibility gets even stronger:

- For small systems:
  - The incremental cost of proposing 5 ppt over 7 ppt is $394 million per theoretical cancer case averted.
  - The incremental cost of proposing 7 ppt over 15 ppt is $412 million per theoretical cancer case averted.
  - The incremental cost of proposing 15 ppt over 35 ppt is $99 million per theoretical cancer case averted.
  - The incremental cost of proposing 35 ppt over 70 ppt is $48 million per theoretical cancer case averted.
  - The incremental cost of proposing 70 ppt over 150 ppt is $104 million per theoretical cancer case averted.
- For large systems:
  - The incremental cost of proposing 5 ppt over 7 ppt is $196 million per theoretical cancer case averted.
  - The incremental cost of proposing 7 ppt over 15 ppt is $56 million per theoretical cancer case averted.
  - The incremental cost of proposing 15 ppt over 35 ppt is $48 million per theoretical cancer case averted.
  - The incremental cost of proposing 35 ppt over 70 ppt is $27 million per theoretical cancer case averted.
  - The incremental cost of proposing 70 ppt over 150 ppt is $15 million per theoretical cancer case averted.

These results are sufficient to conclude that the Board's proposal is economically infeasible if this statutory term is given an economic meaning. None of the alternative MCLs considered is economically feasible for small systems. Even under the most generous interpretation, the lowest MCL that might be economically feasible for large systems is somewhere between 35 and 70 ppt.

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2. The Board is Required to Separately Determine Technological Feasibility and Economic Feasibility

The California Safe Drinking Water Act, HSC § 116365, sets forth a complex, multi-part scheme for setting primary drinking water standards. The statute requires separate determinations of technological feasibility and economic feasibility. Technical feasibility may vary by system size, type of source, coincident contaminants or treatment trains in place, and other factors. A treatment technology need not be technologically feasible in every case to be technologically feasible in some cases. Technological feasibility is strictly an engineering question; either a standard can be achieved through a particular treatment method, at the scope and scale required, or it cannot. If the standard cannot be reliably achieved, it cannot be technologically feasible.

Technological feasibility is a prerequisite for economic feasibility. It is easy to imagine technologies that could achieve a given standard at a cost that everyone agrees is exorbitant. What's needed is a rational, consistent and transparent way to determine when treatment cost is "too high." When economic principles are relied upon, a rational, consistent and transparent determination is the result.

The State Water Board considered six alternative MCLs: 0.000005, 0.000007, 0.000015, 0.000035, 0.00007, and 0.00015 mg/l (5, 7, 15, 35, 70 and 150 ppt). However, there is evidence that the Board seriously considered only 5 and 15 ppt.[1] Determining the economic feasibility of each alternative MCL requires comparing the cost of compliance with the value of risk reduction that is reasonably expected to be achieved. The generally accepted method multiplies the number of cases avoided by an appropriate valuation factor. For premature mortality, this is called the Value of a Statistical Life (VSL), and it is routinely used by the U.S. Environmental Protection Agency (USEPA).[2] The VSL is essential because risk reductions must be monetized to be compared with costs.

The Board attempts to compare benefits and costs, but gets mired in confusion:

> Tables 2-4 set out the costs associated with each alternative, and while they show some costs savings when the MCL is set at a higher level, those costs savings per service connection are relatively insignificant. Therefore, choosing an MCL at a higher level would be inconsistent with HSC section

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[1] *Compare* State Water Resources Control Board (2017e), p. 28 (claiming having considered six alternatives) and State Water Resources Control Board (2016) (acknowledging having considered only 5 ppt and 15 ppt).

[2] For condensed treatment of the VSL concept, *see* Viscusi (1998). For a comprehensive (albeit dated) review of the scholarly literature, *see* Viscusi (1993). For the most recent U.S. Environmental Protection Agency guidance on the choice of valuation factors, *see* U.S. Environmental Protection Agency (2016).

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> 116365, would be somewhat less protective of public health, and would not result in significant cost savings.[3]

This description is inconsistent with established economic principles and practices, including those published in guidance by USEPA. The Board's approach fails to identify any guiding principle for decision-making. Whereas the statute directs the Board to ensure that MCLs are both technologically feasible *and* economically feasible, the Board appears to have wholly subordinated economic feasibility to technological feasibility.[4] The inconsistent application of a rule-based determination is indistinguishable from an arbitrary, *post hoc* decision.

2.1. Comparing alternative MCLs

Which of the alternatives considered would have met the test of economic feasibility had the State Water Board correctly applied economic principles depends on relevant facts. Nonetheless, if it is true that the proposed MCL is economically feasible, then every less-stringent alternative must be economically feasible as well. This is because costs rise exponentially as the MCL approaches the PHG, but benefits (at least as calculated by the Board) are essentially constant across all potential MCLs.

2.2. Peer review

California Health and Safety Code § 57004(b) requires the State Water Board to secure an "external scientific peer review of the scientific basis for any rule proposed for adoption." The term *scientific basis* is further defined as "those foundations of a rule that are premised upon, or derived from, empirical data or other scientific findings, conclusions, or assumptions establishing a regulatory level, standard, or other requirement for the protection of public health or the environment."[5] The scientific basis "shall be deemed to have complied with this section if it complies with the peer review processes established pursuant to these statutes."[6] If the peer reviewer(s) conclude that the Board "has failed to demonstrate that the scientific portion of the proposed rule is based upon sound scientific knowledge, methods, and practices, the report shall state that finding, and the reasons explaining the finding…" However, the Board "may accept the finding of the external scientific peer review entity, in whole, or in part, and may revise the scientific portions of the proposed rule accordingly," or if it "disagrees with any

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[3] State Water Resources Control Board (2017e), p. 28.

[4] The Board claims that economic feasibility had a larger role than technological feasibility in the selection of the proposed MCL. *See* State Water Resources Control Board (2017e), p. 19 ("In determining the feasibility of the alternatives considered, the economic feasibility of the proposed alternative weighed more heavily than considerations of technical feasibility"). The evidence for this in the Board's documents is scanty as best, and in any case, it is refuted by the analysis presented in Section 4.

[5] Health and Safety Code 57004 .

[6] Health and Safety Code 57004 (b).

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aspect of the finding of the external scientific peer review entity, it shall explain, and include as part of the rulemaking record, its basis for arriving at such a determination in the adoption of the final rule, including the reasons why it has determined that the scientific portions of the proposed rule are based on sound scientific knowledge, methods, and practices."[7]

The key task for the peer reviewers was to review the scientific basis of the Board's determination of economic feasibility. However, the peer reviewers were severely handicapped. The Board did not disclose its cost-benefit analysis, and none of the reviewers was trained in economics.

3. Procedural Deficiencies in the State Water Board's Proposal

3.1. General lack of transparency in the documents disclosed by the State Water Board

The documents disclosed by the State Water Board are wholly inadequate for reproducing its work, and that makes it impossible for the public to conduct a proper review and provide informed comments. The Board's inadequate disclosure contrasts notably from the information disclosed by the Division of Drinking Water in a recent previous rulemaking.[8]

First, the Board disclosed virtually no data. Even where the Board discloses data, they are often inconsistent. In the Initial Statement of Reasons (ISOR), the Board identified 289 sources that would be affected by the proposed MCL. However, on the Board's website, 562 sources are so identified. Similarly, in the ISOR the Board reports that 103 systems would be affected but 94 systems are identified on the Board's website.[9] No explanation is given for these discrepancies, and they raise serious doubts about the reliability and accuracy of the Board's calculations.

Second, its Cost Estimation Methodology[10] provides only the briefest summary of the Board's analytic approach. Results presented in the attached tables cannot be reproduced or validated. If this were a proposed *federal* Safe Drinking Water Act primary drinking water standard, U.S. Environmental Protection Agency would have "shown its work" because doing so is explicit USEPA policy.[11]

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[7] Health and Safety Code 57004 (d)(2).

[8] *Compare*, e.g., the 1,2,3- TCP cost estimation methodology, State Water Resources Control Board (2017d) (28 pp. including tables) with the hexavalent chromium cost estimation methodology, California Department of Public Health (2013) (84 pp. Including tables).

[9] *Compare* State Water Resources Control Board (2017e), Table 4, with State Water Resources Control Board (2017b).

[10] State Water Resources Control Board (2017d).

[11] U.S. Environmental Protection Agency (2002a).

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3.2. The Board did not disclose a credible economic feasibility analysis, and denies having conducted the cost-benefit analysis that was necessary to perform an economic feasibility analysis

The State Water Board did not disclose a *bona fide* economic feasibility analysis or a cost-benefit analysis, which is a prerequisite for determining economic feasibility. The Initial Statement of Reasons contains brief sections titled "economic feasibility," but these sections do not include actual *analyses* of economic feasibility.[12] Most of the text merely summarizes the Board's cost estimates. In lieu of what the law requires, the Board offers unsupported, boilerplate assertions without any reasoned basis.

The Board states that it "does not perform a cost-benefit analysis when evaluating economic feasibility,"[13] but nowhere does the Board clearly explain exactly what it *did* do. This is especially peculiar given that the Board recognizes that it has a separate obligation to conduct an analysis pursuant to Government Code § 11340 *et seq.*, and that this report "should include the benefits of the regulatory action."[14] How this is to be done without conducting cost-benefit analysis is not explained. Moreover, the Division of Drinking Water has previously acknowledged in many previous drinking water rulemakings that cost-benefit analysis is essential.[15]

The Board's denial that it has conducted a cost-benefit analysis is contradicted by documents it supplied to peer reviewers. In a document describing how data from water sources were "filtered to remove sources that are not active drinking water sources," the Board acknowledges that it performed a "full cost-benefit analysis":

> This worksheet has been filtered to highlight small water sources with average source concentrations of 1,2,3-TCP of more than 150 ng/L. Small water sources (or SWS) are for this analysis water systems with <200 service connections, which is used as a separator in some regulations. In the full version of the cost-benefit analysis the filtering of concentration and service

[12] State Water Resources Control Board (2017e), pp. 13-16 (on monitoring) and pp. 17-19 (on treatment).

[13] State Water Resources Control Board (2017a), p. 6. A similar statement can be found in the Standardized Regulatory Impact Analysis. *See* State Water Resources Control Board (2016), Attachment A, p. 5.

[14] State Water Resources Control Board (2017e), p. 5.

[15] *See*, e.g., California Department of Health Services (1999a), California Department of Health Services (1999b), California Department of Health Services (1999c), California Department of Public Health (2008), California Department of Public Health (2013), State Water Resources Control Board (2015).

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> connections occurs later in the process, but for ease of understanding the source narrowing has been performed now.[16]

The implied existence of a "full cost-benefit analysis: is acknowledged a second time:

> Three versions of this worksheet (Small Water Systems, Large Water Systems, and Treated Water Systems) are included to help better illustrate the final cost-benefit results.[17]

Thus, it appears that the State Water Board conducted a cost-benefit analysis of the form it denies is required by law and denies having performed. Given the limited information the Board did disclose, the inability of the public to reproduce the Board's results based on this limited disclosure, and the fact that what the Board did disclose came from Excel spreadsheets[18] that were not themselves disclosed, it is reasonable to infer that the Board performed, but did not disclose, a full cost-benefit analysis.

3.3. The Board does not have a reasoned basis for the economic feasibility determinations it made

Whether treatment is economically feasible for any alternative MCL ought to be determined using economic principles. This is not how the Board proposes to decide, however.

Figure A illustrates such a model, assuming a linear no-threshold risk model as used by Office of Environmental Health Hazard Assessment (OEHHA) to derive the PHG. The benefit of treatment per connection (shown in green) is linear and intersects the origin. However, cost (shown in red) rises as the MCL becomes more stringent. Any MCL lower than T* is economically infeasible because it delivers less benefit than cost. For any fixed technology, the higher the risk posed by the contaminant, the higher on the graph the green benefit line will be and the closer to zero T* will be located.[19] A simplified way to implement the model is shown in Figure B, which displays the benefit information in cost-effectiveness units (i.e., cost per unit of benefit).

In contrast to this economic model of economic feasibility, which has a solution that can be determined using data that the Board has on file, the model used by the Board cannot be shown graphically, calculated quantitatively, or coherently described verbally.

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[16] State Water Resources Control Board (2017c), p. 1 (emphasis added).

[17] State Water Resources Control Board (2017c), p. 6 (emphasis added).

[18] *See* the embedded comment on p. 4 of State Water Resources Control Board (2017c) ("Missing text was added "...estimate the overall monitoring costs." that had been previously cut off in conversion to a pdf document from Excel").

[19] MCLs below MCL_b, the PHG, are not permitted by law.

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Figure A:
Economic Feasibility of Treatment

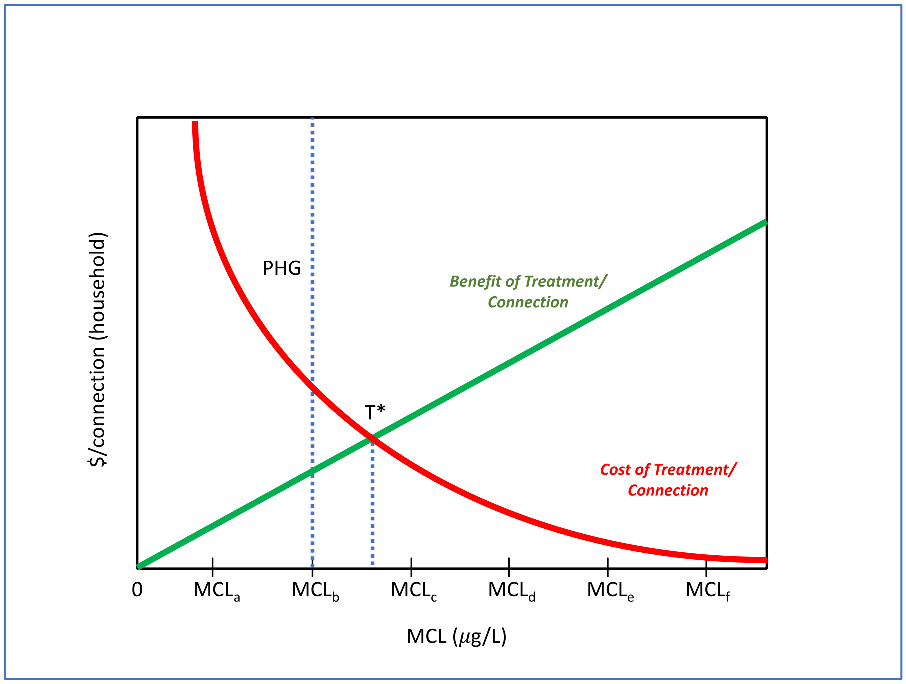
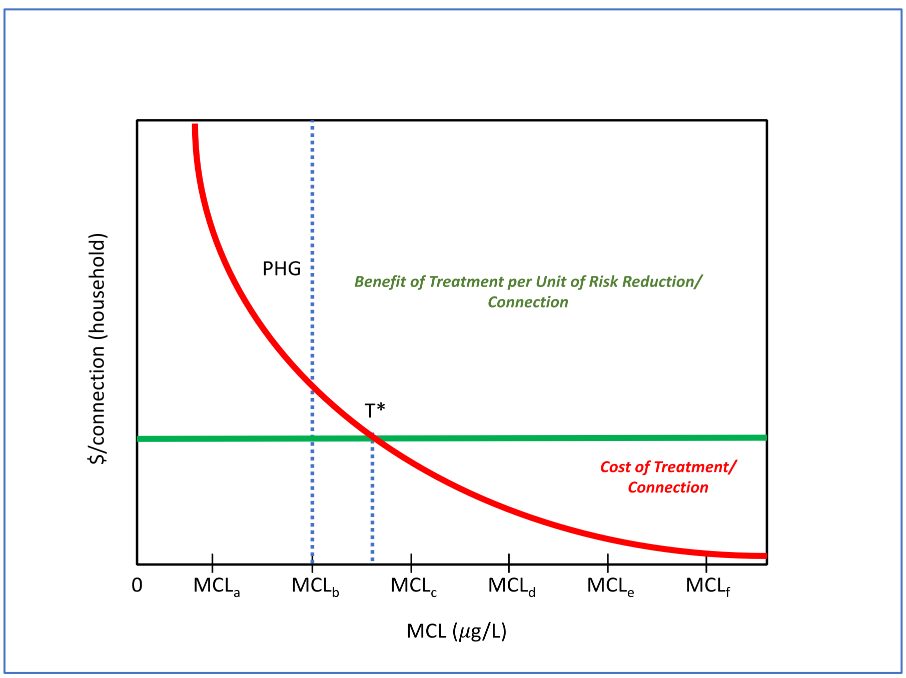


Figure B:
Economic Feasibility of Treatment (Simplified)



The Board reports estimated costs per source, system, and connection for each alternative MCL, and estimates cost per "theoretical" cancer case avoided. But nowhere does the Board provide a reasoned basis for concluding that the proposed MCL (or any other MCL) is economically feasible, nor does the Board reveal the criteria it used to make this determination. The closest thing to a reasoned basis is the Board's assertion that there are no "significant changes" in the *cost per connection* as the MCL approaches the PHG:

> The State Water Board considers an MCL of 0.000005 mg/L to be economically feasible. The State Water Board evaluated the costs of compliance with the proposed MCL to public water systems, customers, and other affected parties. The evaluation included the cost per connection and aggregate cost of compliance using the best available technology. The proposed MCL is not anticipated to place a significant economic burden to the State of California as a whole. The evaluated MCLs did not indicate significant changes in cost on a per-connection basis as the evaluated MCL was increased.[20]

This argument has several flaws. Most obviously, cost per connection is an inappropriate metric for measuring economic feasibility. First, it ignores risk reduction, the achievement of which is the purpose of the regulatory standard. Second, it has no stopping point: there is no reasoned basis for deciding how high cost per connection must be before the Board would conclude that it is economically infeasible. A decision rule without a rational stopping point is inherently arbitrary.

Third, the Board's expressed concern about the high cost of the proposed MCL for small systems demonstrates confusion about the difference between cost and net benefit. The estimated average $609 cost at 5 ppt is "high" because it produces no more than $27 in reduced health risk. Households get nothing in return for the remaining $582. This is not merely a wasteful diversion; it may have the unintended (and clearly undesirable) effect of *increasing other health risks*, particularly among the poor.[21]

Of course, there are circumstances in which spending the additional $609 would be economically feasible. For example, If the risk posed by 1,2,3-TCP were 100 times greater than calculated by OEHHA, a household might gain as much as $2,790 worth of benefits from reduced risk at the 5 ppt MCL. In that case, a 5 ppt MCL clearly would be economically feasible. For every dollar increase in the household's water bill, it would gain $4.42 in benefits from risk reduction. Under the Board's proposal, however, each dollar increase in the household's water bill returns less than five cents in risk reduction benefit.

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[20] State Water Resources Control Board (2017e), p. 22. "[A]s the evaluated MCL was Increased" appears to mean was "made more stringent."

[21] *See*, e.g., Keeney (1990), Keeney (1994) and Lutter and Morrall III (1994).

Fourth, the Board's exclusive focus on averages ignores variability across systems. If the average cost per connection for small-system customers is $609 for a 5 ppt MCL, for many households cost will be much higher. A hint about just how high can be gleaned from the Board's calculations. Setting the MCL at 35 ppt instead of 70 ppt brings in additional eight connections into the treatment regime, but at an annualized cost of $70,173, or $8,772 per connection. Obviously, this is very different from the Board's $632 average small-system cost per connection at 35 ppt. Yet these extraordinary costs per connection do not go away if the MCL is set below 35 ppt. All that changes are the number of connections over which cost is averaged.

If every system is like every other system, then averaging will accurately describe the effects that the public can expect. But the more that systems are different, the more misleading the average will be. Large net benefits realized by a few systems can disguise a widespread pattern of net costs. Statewide aggregation is especially inappropriate because it hides all the variability.

The State Water Board appears to have sufficient information to report estimated annualized cost for each system. It has not done so, however; the Board only reports averages. Yet we know from the 70 ppt to 35 ppt comparison described above that cost per connection among small-system customers varies by at least a factor of 25, and quite possibly much more.

4. Economic Feasibility of Treatment as Indicated by Cost-Effectiveness

Using the model described in Section 3.3, an MCL may be economically feasible if benefits exceed costs. Further, the smaller the unit of analysis, the more likely this result is valid. Calculations per household should be performed at the system level, where costs are borne, and systems should be ranked.

4.1. The Board improperly included "treated" sources for which there is no exposure, thus exaggerating its calculated number of theoretical cancer cases averted

Table 4 in the Initial Statement of Reasons (ISOR) includes two boxes within the results for each alternative MCL considered.[22] One box applies to the Board's estimates of the costs of treatment:

> Costs are for systems requiring treatment. Monitoring costs for non-contaminated sources and contaminated sources without treatment are not included.

A second box applies to the Board's estimate of theoretical cancer cases averted thorough treatment:

[22] State Water Resources Control Board (2017e).

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> Includes estimated reduction in theoretical cancer case per year for existing 1,2,3-TCP treated systems[.]

These approaches are analytically inconsistent. The Board's cost estimate includes only "systems requiring treatment" but its calculation of risk reduction appears to include cancer cases averted by treatment systems already in place. This apples-to-oranges comparison violates elementary principles of economic analysis, which require that the same baseline be used for both sides of the ledger. It is highly misleading to count benefits that cannot exist, and the Board must remove them.

4.2. The Board's own analysis shows the proposed MCL is not economically feasible regardless of system size

Figure C and Figure D follow the simplified model presented in Figure B to show the Board's estimated cost per "theoretical" cancer case avoided for small and large water systems, respectively.[23] After considerable research, analysis and peer review by its Science Advisory Board, the U.S. Environmental Protection Agency (USEPA) has established an upper-bound value for avoiding the premature mortality of a random person in a population whose members face small unit risks. The USEPA "value of a statistical life" (VSL), updated to 2016 dollars,[24] is superimposed in green on both graphs. Average valuations for each alternative MCL are identified, and the trend in values is represented by a smoothed curve for easier visualization. Economic feasibility requires that the red curve be lower than the green line.[25]

For households served by large water systems, at the proposed MCL treatment produces no more than $0.63 in *theoretical* benefit from risk reduction for every *tangible* dollar spent on treatment. Only the 35, 70 and 150 ppt MCLs produce greater *theoretical* benefit than *tangible* cost. At the proposed MCL, it takes treatment at more than 554,000 connections to prevent a single *theoretical* cancer case.

For small water systems, none of the MCLs considered by the Board is economically feasible. Depending on the MCL, each dollar in *tangible* cost produces from $0.09 to $0.41 in *theoretical* benefit per *tangible* dollar in cost. At the proposed MCL, it takes treatment at nearly 160,000 connections to prevent a single *theoretical* cancer case.

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[23] State Water Resources Control Board (2017e), Table 4.

[24] U.S. Environmental Protection Agency (2016), p. 7-8 ($7.9 million ($2008) multiplied by the ratio of the 2016 and 2008 GDP deflators (112.216/99.808) yields $8,879,600. The USEPA VSL applies to *tangible*, not merely *theoretical*, premature mortality risks.

[25] The curve for small water systems displays a hitch that suggest the potential for material error in the Board's analysis. A more stringent MCL should never be less expensive.

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Figure C
Board-Estimated Cost per Theoretical Cancer Case Avoided (SWS)
[data labels: MCL in ppt; $ millions per theoretical cancer case avoided]

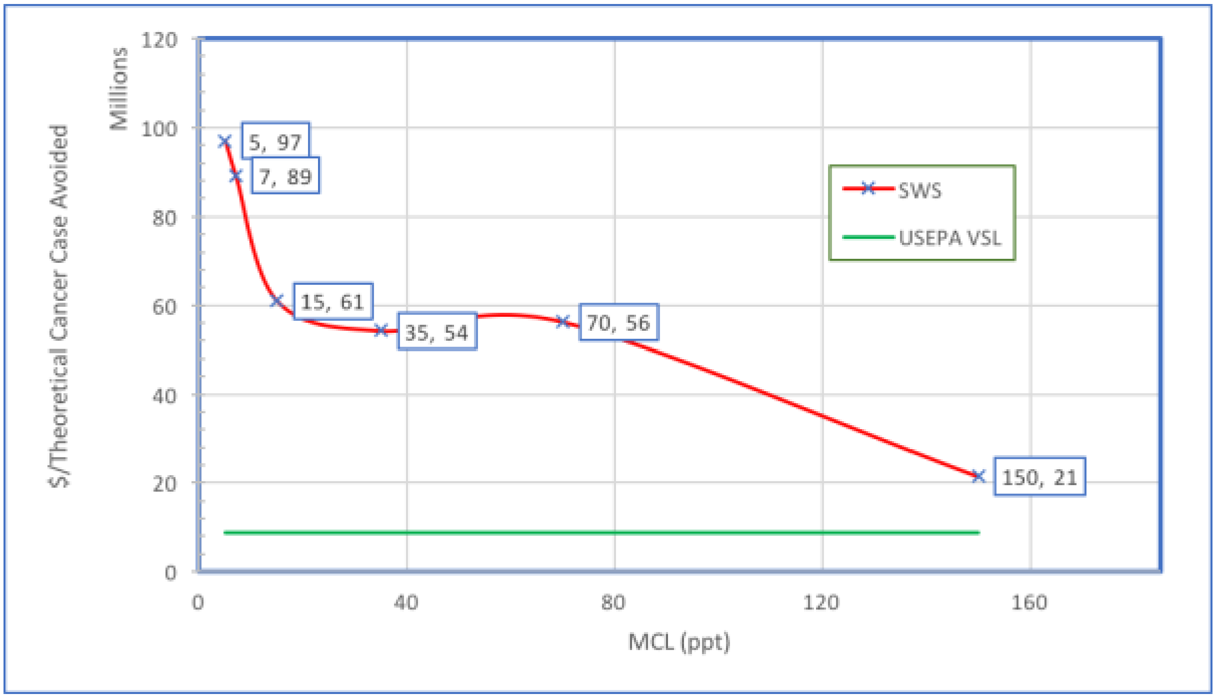
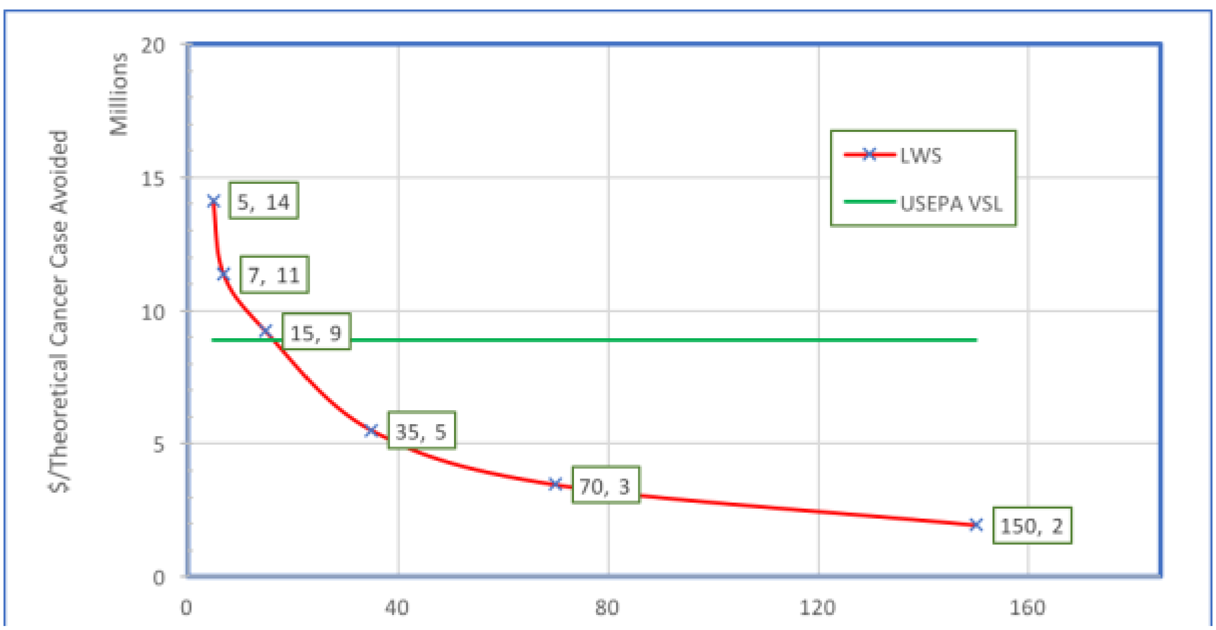


Figure D:
Board-Estimated Cost per Theoretical Cancer Case Avoided (LWS)
[data labels: MCL in ppt; $ millions per theoretical cancer case avoided]



4.3. Comparing adjacent alternative MCLs shows that each incremental progression to greater stringency exacerbates economic infeasibility

The analysis in Section 4.2 provides insight only about the *average* effects of each alternative MCL. Greater insight can be gleaned by comparing the incremental costs and risk reductions obtained by moving from any alternative MCL to its next more stringent neighbor.

Figure E shows for small water systems the incremental cost per theoretical cancer case avoided for each adjacent pair of MCLs the Board considered. The least expensive marginal tightening occurs moving from 70 to 35 ppt, but even that costs *$48 million* per theoretical cancer case avoided. That is six times the USEPA VSL. The last increment of stringency – from 7 to 5 ppt – costs $394 million per theoretical cancer case avoided, or almost 50 times the USEPA VSL.[26]

Figure F displays the same information for large water systems. The 150 ppt MCL may be economically feasible because the cost per theoretical cancer case avoided is about $2 million. All other incremental changes are not, however. Incremental cost-effectiveness ranges from $15 million to $196 million per theoretical cancer case avoided. None of these incremental cost-effectiveness ratios offers anything close to the USEPA VSL.

4.4. Comparing alternative MCLs not proposed to the Board's 5 ppt proposed MCL

Similar comparisons can be made between the proposed MCL and each of the five alternatives considered by the Board. These comparisons are shown in Figure G (for small systems) and Figure H (for large systems).

For small systems, cost per theoretical cancer case avoided ranges from $135 million (moving from 150 to 5 ppt) to $408 million (moving from 7 to 5 ppt). For large systems, cost per theoretical cancer case avoided ranges from $41 million (moving from 150 to 5 ppt) to $90 million (moving from 7 to 5 ppt).

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[26] Where USEPA expects such an investment at the margin to prevent at least six *actual* premature mortalities, the 5 ppt MCL would prevent at most 2.4 *theoretical* cancer cases.

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Figure E:
Implied Incremental Cost per Theoretical Cancer Case Avoided
when Adjacent MCLs are Compared (SWS)

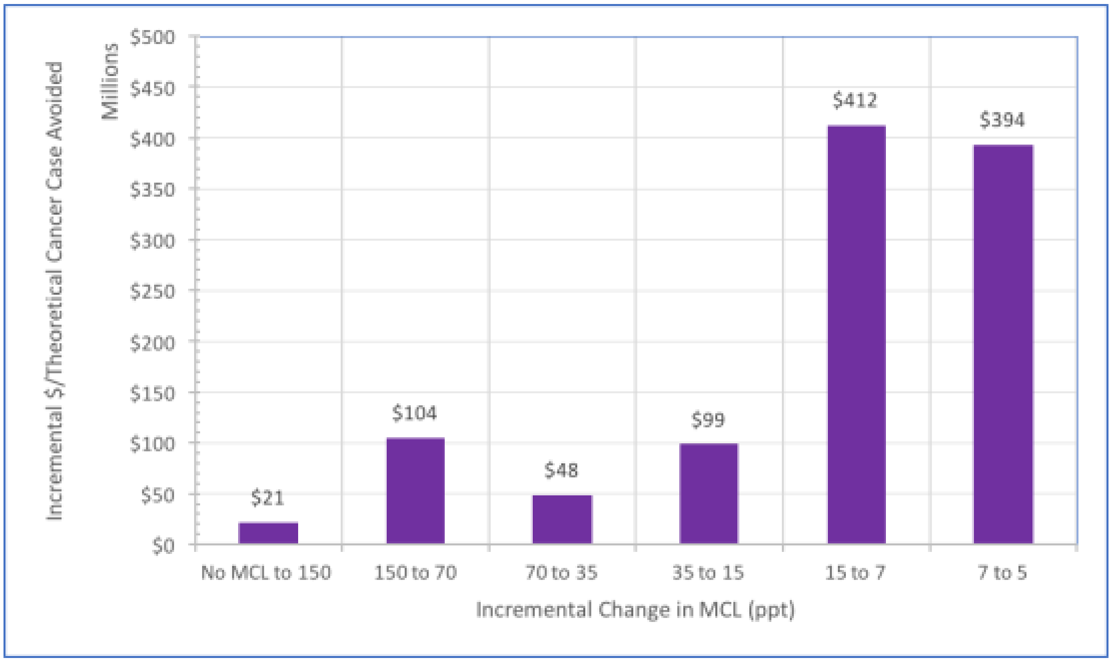

Figure F:
Implied Incremental Cost per Theoretical Cancer Case Avoided
when Adjacent MCLs are Compared (LWS)

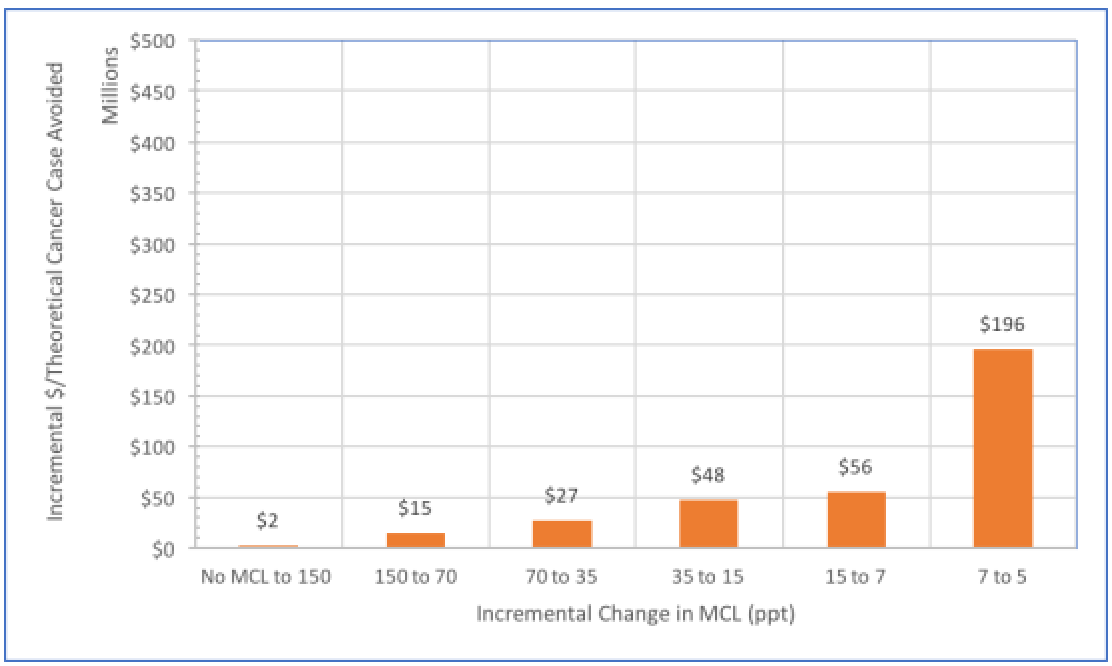

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Figure G:
Cost per Theoretical Cancer Case Avoided if
Moving from Each of the Five Alternative MCLs to the Board's Proposed 5 ppt MCL (SWS)

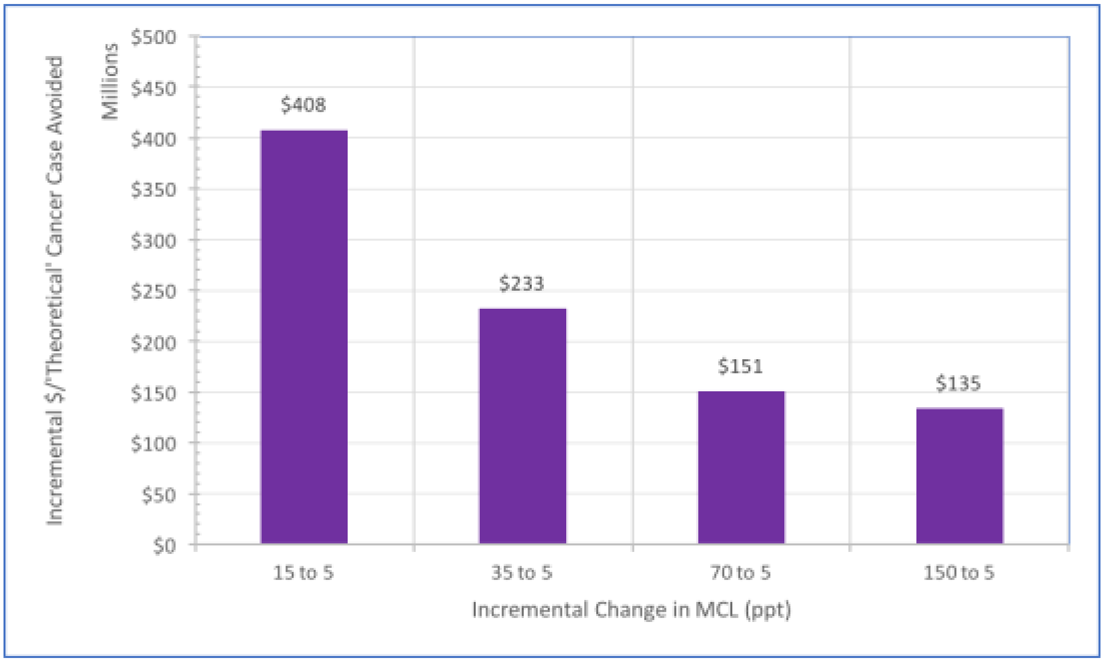
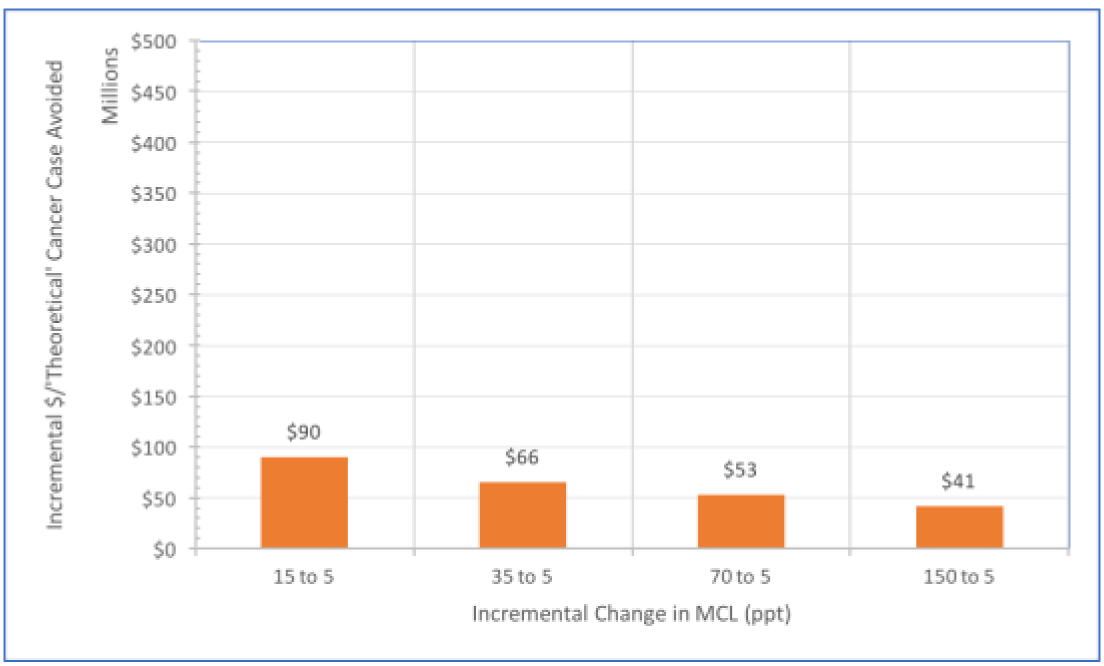


Figure H:
Implied Cost per Theoretical Cancer Case Avoided if
Moving from Each of the Five Alternative MCLs to the Board's Proposed 5 ppt MCL (LWS)



4.5. Adjusting the Board's calculations for compatibility with the assumption in PHG that risk is proportional to lifetime dose

The State Water Board appears to assume that cancer risk reductions are realized immediately after exposure is reduced or eliminated. This assumption would be inconsistent with the cancer risk model OEHHA used to derive the PHG, however. OEHHA's risk model equates an increase of 0.0007 ppb of 1,2,3-TCP ingested at 4 liters/day equivalent for 70 years with a one in 1 million excess cancer risk. Thus, it follows that a decrease in exposure at the same rate for the same period would reduce cancer risk by one in 1 million. But the Board appears to assume that all cancer risk reductions occur immediately, not over 70 years.[27] The correct way to perform this calculation requires taking account of the estimated number of years of exposure reduction for each connection.

In 2015, the median age of California residents was 36.2 years,[28] implying that the median resident whose drinking water is treated would gain 33.8 years of exposure reductions, or 48% of the unit risk reduction.[29] This reduction in calculated cancer risk reduction can be illustrated by reducing the USEPA VSL from $8.9 million to $4.3 million. Figure I shows that this adjustment has no material effect in economic feasibility for small water systems. However, the adjustment matters for large systems, as Figure J shows. The most stringent MCL that is economically feasible is now someplace between 35 and 70 ppt.

[27] This inference is drawn from State Water Resources Control Board (2017d), but it cannot be confirmed because the Board did not show its work.

[28] U.S. Census Bureau (2015).

[29] A more sophisticated adjustment would take account of the age distribution and average weights of persons in each age distribution group. The OEHHA risk model assumes the weight of an adult is 70 kg.

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Figure I:
Board-Estimated Cost per Theoretical Cancer Case Avoided
Adjusted for Years of Exposure Avoided (SWS)
[data labels: MCL in ppt; $ millions per theoretical cancer case avoided]

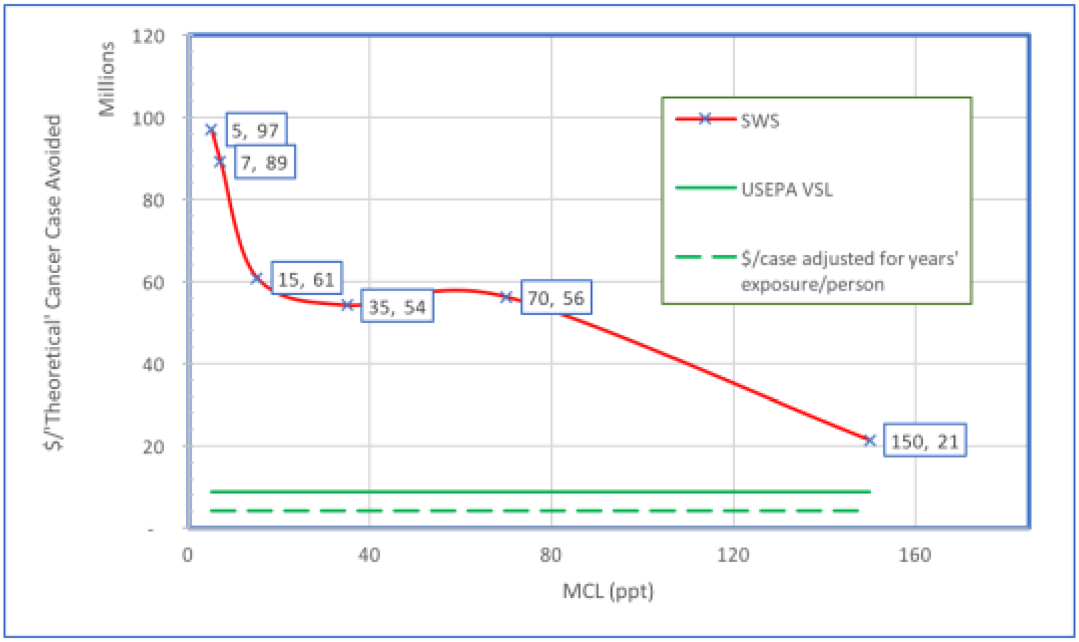
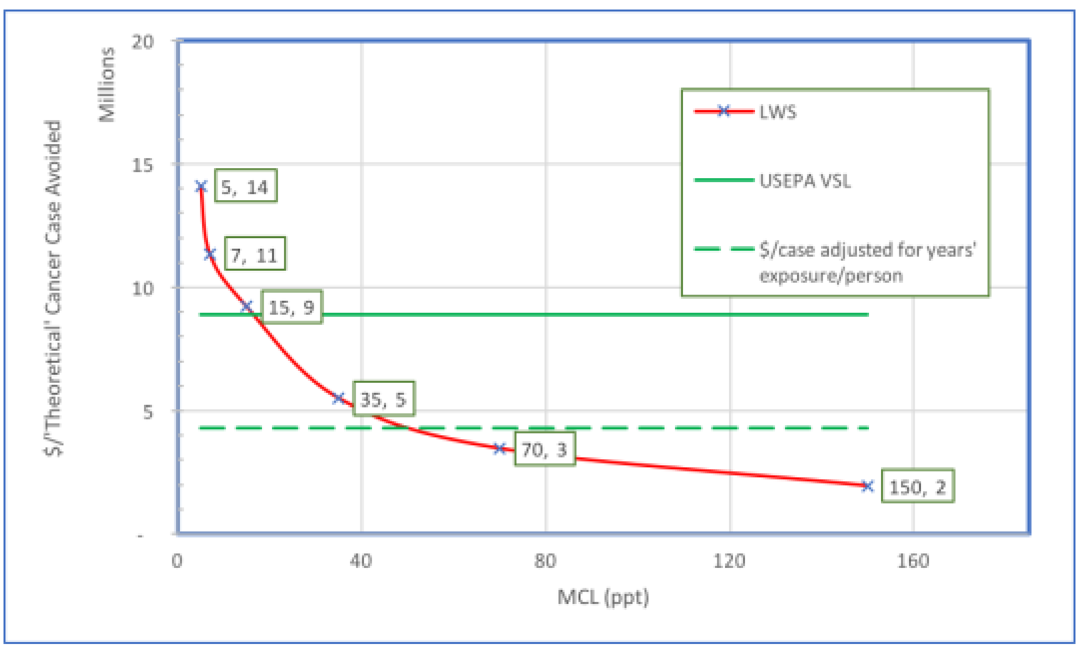


Figure J:
Board-Estimated Cost per Theoretical Cancer Case Avoided
Adjusted for Years of Exposure Avoided (LWS)
[data labels: MCL in ppt; $ millions per theoretical cancer case avoided]



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5. Other adjustments needed to produce a reliable economic feasibility analysis

Additional adjustments are needed to transform the Board's work into a proper economic feasibility analysis. These adjustments follow economic analysis guidance published by USEPA:

> Risk assessors and economists should:
>
> …
>
> 1. Estimate changes in the probabilities of human health or ecological outcomes rather than 'safety assessment' measures such as reference doses and reference concentrations.
> 2. Work to produce expected or central estimates of risk, rather than bounding estimates as in safety assessments. At a minimum, any expected bias in the risk estimates should be clearly described.
> 3. Attempt to estimate the "cessation lag" associated with reductions in exposure. That is, the analysis should characterize the time profile of changes in exposures and risks.
> 4. Attempt to characterize the full uncertainty distribution associated with risk estimates.[30]

Each of these items has an important implication for the State Water Board's analysis, and is discussed in the subsections below.

5.1. Risk must be estimated in a manner compatible with economic principles to correctly determine economic feasibility

The purpose of the PHG is to identify a "virtually safe dose," an exposure level that "avoids any significant risk to public health."[31] The State Water Board has a different responsibility: determining which MCLs are economically feasible. That requires estimating risk reduction objectively. It is not sufficient to calculate "theoretical" cancer cases avoided, as the Board has done. Reductions in cancer incidence can only be reliably estimated using an objective

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[30] U.S. Environmental Protection Agency (2016), p. 7-5. The "reference dose" is USEPA's version of the safety assessment performed by OEHHA, resulting in the PHG. For more on its methodology, *see* Barnes and Dourson (1988), U.S. Environmental Protection Agency (2002b), U.S. Environmental Protection Agency (2012).

[31] *Compare* Faustman and Omenn (2001), p. 95 ["a dose that gives an 'acceptable level' of risk (e.g., upper confidence limit for 10^{-6} excess risk")] and Office of Environmental Health Hazard Assessment (2009), p.2 ["OEHHA sets PHGs for carcinogens at a de minimis risk level of one in a million (10^{-6})"].

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characterization of dose-response, and the State Water Board did not perform any such characterization.[32]

The Board calculates cancer cases using a formula in the PHG. But the PHG is what USEPA calls a "safety assessment" that yields "bounding estimates" rather than "expected or central estimates of risk." A properly conducted economic feasibility analysis must use "expected or central estimates of risk." Therefore, the Board should compare its cost estimates with estimates of the *actual* number of cancer cases the public can reasonably anticipate will be prevented.

The laboratory studies OEHHA used to derive the PHG have key features that make the PHG inappropriate for directly estimating human cancer risk. First, rats and mice received by gavage doses of 1,2,3-TCP substantially higher than the levels to which humans are exposed via drinking water.[33] Second, these doses likely exceeded what toxicologists call the Maximum Tolerated Dose (MTD). When the MTD is exceeded in a laboratory animal study, cancer often occurs as a secondary result of frank toxicity.[34] And toxicity was evident in these bioassays; there was substantial weight loss and premature mortality from causes other than cancer.[35]

Third, gavage involves direct administration of a large dose of the contaminant, which can have long-lasting effects that would not occur in drinking water.[36] This is very different from drinking water ingestion, which involves a fairly constant concentration. Third, the use of corn oil instead of drinking water as the agent to carry the dose appears to have had its own, independent carcinogenic effects. In the words of peer reviewer Helmut Zarbl, corn oil "synergiz[es] with carcinogens by acting as a co-carcinogen or a tumor promoter, therefore

[32] Had the Board attempted to do so, two of the three peer reviewers had the requisite expertise to opine on whether it had succeeded. The charge to reviewers asked them only to validate the Board's arithmetic, a task not requiring a terminal degree in toxicology or mathematics.

[33] Rats were administered 0, 5, 10 or 30 mg/kg-day 5 days/week. Mice were administered 0, 10, 30 or 60 mg/kg-day 5 days/week. *See* Office of Environmental Health Hazard Assessment (2009), pp. 16-23. These doses are 5-6 orders of magnitude greater than what humans might experience via drinking water.

[34] Eaton and Klaassen (2001), p. 29; Katsonis, Burdock and Flamm (2001), pp. 1064-1065; Pitot III and Dragan (2001), pp, 293, 299; and National Research Council (1993).

[35] Despite its relevance, OEHHA did not discuss whether the studies it relied upon administered doses exceeding the MTD or whether such dosing could have had material effects on the results. *See* Office of Environmental Health Hazard Assessment (2009), and search for "MTD" and "Maximum Tolerated Dose." MTD also is not included in the State Water Board's list of relevant acronyms. *See* State Water Resources Control Board (2017f).

[35] La, Schoonhoven, Ito, et al. (1996), p. 108 ("Gavage administration, which results in high bolus concentrations compared to drinking water exposure, may quantitatively affect toxicokinetics, cytotoxicity, and genotoxicity"); and Tardiff and Carson (2010), p. 1506 ("cancer DWELs are based on corn oil studies and ... corn oil gavage, unlike drinking water exposure, contributes – perhaps extensively – to tumor production"). Concern about bolus doses is not mentioned in the PHG.

overestimating carcinogenicity."[37] Finally, OEHHA relied on a cancer site in rodents – the forestomach of the female mouse -- that does not exist in humans, so its propriety for human cancer risk assessment is controversial.[38]

The product of this series of assumptions is an overstatement of the "expected or central estimates of human cancer risk." If the Board were to follow USEPA's guidance, it would estimate the bias inherent in the PHG and adjust its calculations of cancer cases avoided accordingly. One way to do that is to estimate risk using a model with *less* intentional bias, such as the model by Tardiff and Carson (2010). Instead of relying on a series of default assumptions, this model incorporates mode-of-action information and the weight-of-evidence framework established by the World Health Organisation's International Programme of Chemical Safety into a nonlinear dose-response model. When applied, this model produces an estimate of 200-280 ppb as the drinking water equivalent level that is "considered protective against tumors," and thus it is likely to be consistent with the statutory risk management directive that applies to PHGs.[39]

5.2. Adjusting the USEPA VSL to account for a different health endpoint

USEPA routinely uses the VSL to quantify the benefit of preventing premature mortality. This method does not apply without modification to other health endpoints, and economic analyses must use valuation defaults that match as closely as possible the actual endpoints of interest.[40] The nationwide 5-year survival rate for digestive system cancers in 2006-12 was 44.3%,[41] so an adjustment to the USEPA VSL is necessary and appropriate to account for this difference.

5.3. Cessation lags

For health endpoints such as cancer, there is a "cessation lag" defined as " the time interval between the cessation of exposure and the reduction in risk."[42] USEPA guidance directs analysts to account for cessation lags when valuing reduced mortality risks, and then discount

[37] Versar (2008), p. 11 (comments by USEPA peer reviewer Helmut Zarbl, emphasis in original), possibly based on La, et al. (1996) (potency 1.4 to 2.4 times higher where corn oil was administered). *See also* Tardiff and Carson (2010), p. 1506 ("corn oil gavage, unlike drinking water exposure, contributes – perhaps extensively – to tumor production"). Concerns about gavage administration and the synergistic effect of corn oil are not mentioned in the PHG.

[38] Proctor, Gatto, Hong, et al. (2007).

[39] Tardiff and Carson (2010), p. 1506. A concentration that is "protective against tumors" is similar in intent to "avoid[ing] any significant risk to public health" (HSC § 116365(b)(2)). The concentration estimated to be protective against noncancer effects is 780 ppb.

[40] U.S. Environmental Protection Agency (2016), p. 7-5.

[41] Howlader N, Noone AM, Krapcho M, et al. (2016).

[42] U.S. Environmental Protection Agency (2016), p. x.

appropriately.[43] USEPA's independent Science Advisory Board concurs with this guidance and has further advised the Agency to discount delayed cancer reduction benefits at the same rate used to discount other future benefits and costs.[44]

5.4. Discounting

When a regulatory action has future costs and benefits, both must be discounted in the same manner.[45] This enables apples-to-apples comparisons. The State Water Board used a 7% discount rate for future costs, so 7% is a reasonable discount rate to apply to future benefits.[46] The Board's published analysis compares apples to oranges – discounted costs and undiscounted benefits.

6. Conclusions

This review is constrained by the limited information disclosed by the Board. Nonetheless, even if it is stipulated that the Board's data and cost model are true and correct, the proposed MCL clearly is not economically feasible. Average cost per theoretical cancer case avoided is $97 million for small systems and $14 million for large systems. These ratios are, respectively, 12 and two times the USEPA VSL, and the VSL applies to premature mortality, not cancer.

When the incremental effects of adjacent MCLs are considered, each of the alternative MCLs becomes even more economically infeasible. Moving from 7 ppt to 5 ppt covers an additional 214 small-system and 211,067 large-system connections. It accomplishes this at a price of $394 million and $196 million, respectively, per theoretical cancer case avoided.

For small systems, none of the MCLs considered by the Board is economically feasible. For large systems, several errors in the Board's analysis must be corrected to make this determination. Even without these corrections, the lowest MCL that might be economically feasible is somewhere between 35 and 70 ppt.

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[43] U.S. Environmental Protection Agency (2016), p. 7-8.

[44] U.S. Environmental Protection Agency Science Advisory Board (2000). The SAB committee used the term "latency" for the delayed onset of illness after exposure (as EPA's current guidance uses it) and delayed realization of benefits after reduction in exposure (what EPA's current guidance calls "cessation lag"). Different terms are appropriate because there is no biological reason why both delays would be the same. The impetus for the SAB review was a need to inform Agency analysts about how to capture both latency and cessation lag with respect to drinking water regulation.

[45] U.S. Environmental Protection Agency (2016), Chapter 6.

[46] The Board discounted only a 20-year stream of costs. This period may be insufficient to capture all benefits. However, the same time period must be used for both benefits and costs, so of a longer period is used for benefits it also must be used for costs.

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7. References

Barnes DG, Dourson M. 1988. Reference Dose (RfD): Description and Use in Health Risk Assessments. *Regulatory Toxicology and Pharmacology* 8: 471-486.

California Department of Health Services. 1999a. *Final Statement of Reasons: Primary Maximum Contaminant Level for Methyl tert-Butyl Ether*. "R-8-99". Sacramento CA: CDHS; http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/mtbe/MTBEsor.pdf.

California Department of Health Services. 1999b. *MCL Evaluation for 1,2-dibromo-3-chloropropane (DBCP)*. Sacramento CA: SWRCB [November]; http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/mclreview/DBCP-MCLevaluation.pdf.

California Department of Health Services. 1999c. *MCL Evaluation for Trichloroethylene (TCE)*. Sacramento CA: SWRCB [December]; http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/mclreview/TCE-MCLevaluation-12-01.pdf.

California Department of Public Health. 2008. *Final Statement of Reasons: Arsenic MCL Revision Regulations*. Sacramento CA: SWRCB [August 7]; http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/arsenic/DPH-17-04-ArsenicMCL-FSOR.pdf.

California Department of Public Health. 2013. *Procedure for Cost-Benefit Analysis of Hexavalent Chromium*. [August 4].

Eaton DL, Klaassen CD. 2001. Principles of Toxicology. In: *Casarett & Doull's Toxicology: The Basic Science of Poisons* (Klaassen CD, ed). New York: McGraw-Hill Medical Publishing Division, 11-34.

Faustman EM, Omenn GS. 2001. Risk Assessment. In: *Casarett & Doull's Toxicology: The Basic Science of Poisons* (Klaassen CD, ed). New York, N.Y.: McGraw-Hill Medical Publishing Division, 83-104.

Health and Safety Code 57004.

Health and Safety Code 116365.

Howlader N, Noone AM, Krapcho M, Miller D, Bishop K, Altekruse SF, Kosary CL, Yu M, Ruhl J, Tatalovich Z, Mariotto A, Lewis DR, Chen HS, Feuer EJ, Cronin KA. 2016. *SEER Cancer Statistics Review (CSR) 1975-2013*. Available: https://seer.cancer.gov/csr/1975_2013/ [accessed April 8, 2017].

Katsonis F, Burdock G, Flamm W. 2001. Food Toxicology. In: *Casarett & Doull's Toxicology: The Basic Science of Poisons* (Klaassen C, ed). New York: McGraw-hill Medical Publishing Division, 1049-1088.

Keeney RL. 1990. Mortality Risks Induced by Economic Expenditures. *Risk Analysis* 10 (1): 147-159 (http://dx.doi.org/10.1111/j.1539-6924.1990.tb01029.x).

Keeney RL. 1994. Mortality Risks Induced by the Costs of Regulations. *Journal of Risk and Uncertainty* 8 (1): 95-110.

La D, Schoonhoven R, Ito N, Swenberg J. 1996. The effects of exposure route on DNA adduct formation and cellular proliferation by 1, 2, 3-trichloropropane. *Toxicology and Applied Pharmacology* 140 (1): 108-114.

Lutter R, Morrall III JF. 1994. Health-Health Analysis: A New Way to Evaluate Health and Safety Regulation. *Journal of Risk and Uncertainty* 8 (1): 43-66.

National Research Council. 1993. Issues in Risk Assessment. Washington, DC: National Academies Press.

Office of Environmental Health Hazard Assessment. 2009. *Public Health Goals for Chemicals in Drinking Water: 1,2,3-Trichloropropane*. Oakland CA: OEHHA [August].

Pitot III HC, Dragan YP. 2001. Chemical Carcinogenesis. In: *Casarett & Doull's Toxicology: The Basic Science of Poisons* (Klaassen CD, ed). New York: McGraw-Hill Medical Publishing Division, 241-319.

Proctor DM, Gatto NM, Hong SJ, Allamneni KP. 2007. Mode-of-Action Framework for Evaluating the Relevance of Rodent Forestomach Tumors in Cancer Risk Assessment. *Toxicological Sciences* 98 (2): 313-326.

State Water Resources Control Board. 2015. *Frequently Asked Questions about Hexavalent Chromium in Drinking Water*. Available: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/chromium6/chromium_fact_sheet_2015_final.pdf [accessed April 1, 2017].

State Water Resources Control Board. 2016. *Department of Finance Economic and Fiscal Impact Statement (Regulations and Orders) STD. 399: 1,2,3-Trichloropropane Maximum Contaminant Level*. Sacramento CA: SWRCB [October 6].

State Water Resources Control Board. 2017a. *1,2,3-Trichloropropane (1,2,3-TCP) Maximum Contaminant Level (MCL) Regulations: Response to External Scientific Peer Review*. Sacramento CA: SWRCB [February 28].

State Water Resources Control Board. 2017b. *1,2,3,-Trichloropropane; Summary of 1,2,3-TCP Detections*. Available: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/123TCP.shtml [accessed April 20, 2017].

State Water Resources Control Board. 2017c. *Attachment 2A: 1-Data Filtering*. Sacramento CA: SWRCB.

State Water Resources Control Board. 2017d. *Cost Estimating Methodology*. Sacramento CA: SWRCB [February].

State Water Resources Control Board. 2017e. *Initial Statement of Reasons: 1,2,3-Trichloropropane Maximum Contaminant Level Regulations; Title 22, California Code of Regulations*. [February].

State Water Resources Control Board. 2017f. *Maximum Contaminant Level for 1,2,3-Trichloropropane Acronym List*. Sacramento CA: SWRCB.

Tardiff RG, Carson ML. 2010. Derivation of a Reference Dose and Drinking Water Equivalent Level for 1, 2, 3-Trichloropropane. *Food and Chemical Toxicology* 48 (6): 1488-1510.

U.S. Census Bureau. 2015. *American Community Survey 1-Year Estimates; California*. Available: https://censusreporter.org/profiles/04000US06-california/ [accessed March 30, 2017].

U.S. Environmental Protection Agency. 2002a. *Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility, and Integrity of Information Disseminated by the Environmental Protection Agency (EPA/260R-02-008)*. http://www.epa.gov/quality/informationguidelines/documents/EPA_InfoQualityGuidelines.pdf.

U.S. Environmental Protection Agency. 2002b. *A Review of the Reference Dose and Reference Concentration Processes*. Washington, DC: Risk Assessment Forum, U.S. Environmental Protection Agency; http://www.epa.gov/NCEA/iris/RFD_FINAL1.pdf.

U.S. Environmental Protection Agency. 2012. *Benchmark Dose Technical Guidance*. "EPA/100/R-12/001". Washington DC: USEPA [June]; https://www.epa.gov/sites/production/files/2015-01/documents/benchmark_dose_guidance.pdf.

U.S. Environmental Protection Agency. 2016. *Guidelines for Preparing Economic Analyses*. Washington DC: USEPA/NCEE [May]; https://yosemite.epa.gov/ee/epa/eerm.nsf/vwAN/EE-0568-50.pdf/$file/EE-0568-50.pdf.

U.S. Environmental Protection Agency Science Advisory Board. 2000. *SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reduction*. "EPA-SAB-EEAC-00-013". Washington DC: USEPA/SAB [July 27]; https://yosemite.epa.gov/sab%5CSABPRODUCT.NSF/41334524148BCCD6852571A700516498/$File/eeacf013.pdf.

Versar. 2008. *Peer Review Summary Final Report: External Peer Review Meeting on the Toxicological Review of 1,2,3-Trichloropropane (CAS No. 96-18-4)*. Washington DC: USEPA [March 21].

Viscusi WK. 1993. The Value of Risks to Life and Health. *Journal of Economic Literature* 31 (4): 1912-1946.

Viscusi WK. 1998. Rational Risk Policy. Oxford: Clarendon Press.