M.CUBED
POLICY ANALYSIS FOR THE PUBLIC AND PRIVATE SECTORS

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Date: December 10, 2020

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Re: Review of swrcb_waterlossmodel_12november2020_v3

Introduction

The State Water Board's draft economic model for use in its rulemaking for water loss aims to determine the amount of economically feasible water loss reduction for urban retail water suppliers. The model will be used to calculate the economically feasible cumulative water loss reduction between 2020 and 2027, which is the primary determining factor for the proposed water loss volumetric standard. The Regional Water Authority (RWA) requested M.Cubed to review Version 3 of the model, released by the State Water Board on November 12, 2020. This memorandum presents the results of our review. First we present a brief summary of our findings. This is followed by a more detailed and quantitative discussion of each of the major points.

Summary of Findings

- The model is not robust. Small changes to model inputs result in large and implausible changes in model outputs. As one example, when the infrastructure condition factor is greater than 1.7, the model can generate negative water savings.
- The model overstates benefits and understates costs of water loss management.
    - The model overstates benefits by using unjustifiably high estimates of avoided water supply cost and escalation. As a result, the model estimates an average unit benefit of $2,263/AF despite the fact that the average variable cost of production for water suppliers subject to the regulation is $510/AF.
    - The model understates costs by ignoring market dynamics that will drive up initial costs of water loss management following adoption of the regulation and failing to escalate future leak detection and repair costs. As a result, the model estimates that 47% of suppliers will have unit costs of compliance under $250/AF.
- Because the model overstates benefits and understates costs, it generates implausibly high benefit-cost ratios for most water suppliers. The median 30-year BCR generated by the model is 9 while the average is 14. For a quarter of water suppliers, the 30-year BCR is greater than 16. These rates of return on water loss management are simply not credible.
- The model generates arduous water loss reduction targets for a non-trivial number of suppliers.
    - 119 suppliers would be required to reduce their water loss by more than 50%.

  - Of these 119 suppliers, 52 would be required to reduce their water loss by more than 70% and 5 would be required to reduce their water loss by more than 90%.

  It is fair to question both the technical and economic feasibility of reductions of this magnitude.

- It does not appear the Water Board has taken into account the implicit uncertainty in the model's outputs in setting the water loss reduction standards for water suppliers. As a result, the Water Board is proposing substantially different standards for water suppliers who are unlikely to have any statistically significant difference in the benefits and costs of water loss management.

Review of Default Input Values

There are 22 model inputs that drive the model. These are divided into three categories:

- 5 data inputs from water loss reports submitted by urban retail water suppliers.
- 14 default inputs determined by the Water Board that can be replaced by supplier-specific values provided the Water Board accepts the supplier's justification for the alternative values.
- 3 default inputs determined by the Water Board which may not be modified by suppliers.

Inputs Determined by the Water Board

The three inputs determined by the Water Board are:

- Real discount rate
- Average annual rise in avoided cost of water
- Effective timeline for lifecycle benefit-cost analysis

Real Discount rate

The real discount rate is used by the model to convert the future streams of costs and benefits of water loss management to their present value equivalents. The real discount rate strongly influences the model's benefit-cost results, which in turn determine the supplier's water loss standard. The choice of the discount rate is therefore very important. In previous model versions, the Water Board had proposed using a 1% real discount rate, which was much too low for multiple reasons.[1] In response to stakeholder input, the Water Board is now proposing to use a 3.5% real discount rate. Based on our review of the social discount rate literature, we believe this choice is appropriate.[2]

Average Annual Rise in Price of Water

This input determines the real growth (i.e. net of inflation) in avoided water supply costs, which the model uses to value the water savings from water loss management. Given the model's 30-year time horizon, this input has a large effect on the model's calculation of benefits.

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[1] See M.Cubed (2019), Review of discount rate and valuation of water loss management benefits proposed by State Water Board for use in establishing urban retail water supplier water loss objectives. Technical memorandum to Peter Brostrom, Water Use Efficiency Branch Manager, California Department of Water Resources, dated October 30, 2019.

[2] Ibid.

The Water Board is proposing to set this input to 5.9%, on the basis of the real change in Metropolitan Water District's Tier 1 rate for treated water service between 2008 and 2020. The Water Board's proposal is not defensible for several reasons.

First, in a state as large and diverse as California, there will be significant variability in the rate at which future water supply costs are likely to change. While some communities may see rapid escalation, others may see little if any. This input should be based on each supplier's expected change in future water supply costs, not on a single supplier's historical change in its price of treated water. Even though Metropolitan indirectly serves a large fraction of the state's population (about 50%), the suppliers delivering this water to homes and businesses only account for just over one-third of the retail water suppliers subject to the proposed water loss standards. This level of water supplier coverage is too narrow to use as a basis of justification for such an important input to the Water Board's economic model.

Second, the historical rate of change in Metropolitan's Tier 1 rate does not measure the historical change, let alone the future change, in the avoided cost of water. To put it another way, the historical change in the Tier 1 rate is not measuring what the Water Board thinks it is measuring. To understand why, it is important to first note that Metropolitan uses average cost pricing. With average cost pricing, the price is determined by dividing the expected costs of service by the expected sales:

$$Price = \frac{Expected\ Cost\ of\ Service}{Expected\ Sales}$$

Note there are two ways in which price could rise. Price could rise because costs are expected to go up or price could rise because sales are expected to go down. For the historical period used by the Water Board, the price rises have been driven mostly by sales going down, not by costs going up. Figure 1 shows Metropolitan's treated water sales over the period being used by the Water Board. Since 2007 Metropolitan's treated water sales have decreased by 52%, or, on average, by about 5.9% per year. This necessarily forced Metropolitan to increase its rates over this period because approximately 80% of its costs are fixed.[3] **It is not a coincidence that the average annual rise in the Tier 1 rate estimated by the Water Board, 5.9%, is the same as the average annual percentage change (in absolute value) in the volume of treated water sales**. The rise in the Tier 1 rate was driven by decreasing treated water sales rather than by increasing system costs. Indeed, the reduction in treated water sales explains 90% of the observed increase in the treated water rate, as shown in Figure 2. Thus, the change in Metropolitan's treated water rate since 2007 has had little to do with rising costs and a lot to do with falling water sales. If you are spreading your predominantly fixed costs over fewer units of water, your rate per unit is necessarily going to increase. This will be true when your costs are unchanging and can even be true when your costs are decreasing. The historical change in Metropolitan's Tier 1 rate doesn't say much, if anything, about the historical change in avoided water cost.

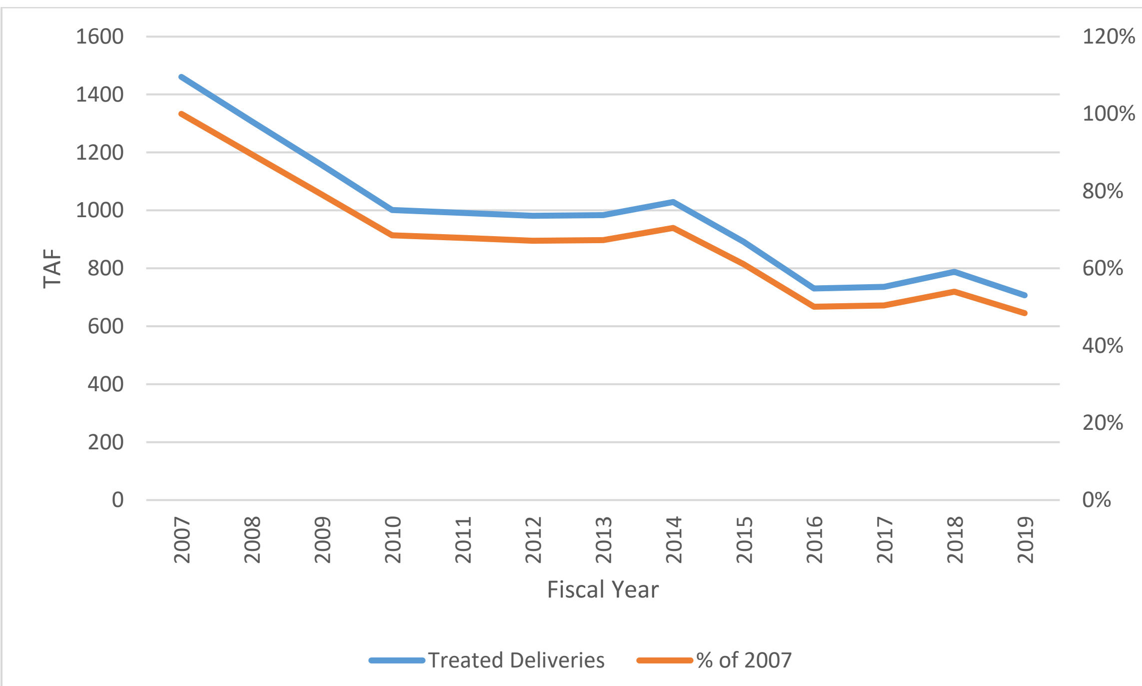
Third, even if one uses changes to Metropolitan's Tier 1 rate as the basis for escalating future water supply costs, which we definitely do not recommend doing, why treat past as prologue? Metropolitan

[3] For example, in Metropolitan's most recent cost of service report for FY 2020/21 and 2021/22, 83% of costs were classified as fixed versus 17% as variable. See Schedule 16 of Metropolitan Water District of Southern California, Fiscal Years 2020/21 and 2021/22 Cost of Service Report for Proposed Water Rates and Charges, May 2020.

routinely generates 10-year forecasts of its Tier 1 rate.[4] The current forecast is shown in Table 1. We have converted the nominal increases (i.e. including inflation) to real increases (i.e. excluding inflation) using the CPI forecast for Los Angeles County prepared by California Economic Forecast for use in Caltrans Socioeconomic Forecast Models.[5] The average annual real rate of increase is 1.3%, or 78% lower than what the Water Board is using for the economic model.

Fourth, given how the Water Board is estimating future avoided water supply cost, future changes in Metropolitan's Tier 1 rate are largely irrelevant even if these changes were primarily being driven by increasing costs rather than decreasing sales. The Water Board's default alternative supply cost is a composite of four types of water supply: (1) stormwater capture, (2) indirect potable reuse, (3) brackish water desalination, and (4) Metropolitan's Tier 1 treated water. Each is given equal weight in the composite and thus Metropolitan's Tier 1 rate only accounts for 1/4 of the composite cost. Predicting the future path of Metropolitan's Tier 1 rate would therefore seem to be much less important than predicting the future cost path of the other three types of water supply, which account for 3/4 of the composite cost. The costs for these types of projects will be dominated by (1) future construction costs, (2) future energy costs, and to a lesser degree (3) future labor costs.

Figure 1. Metropolitan Water District Treated Water Sales (2007-2019)



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[4] For example, see http://www.mwdh2o.com/PDF_Who_We_Are/Proposed%20Biennial%20Budget,%20Rates%20and%20Charges,%20Ten-Year%20Forecast,%20AV%20Tax%20Limit%20Presentation%20(FI%20Committee,%20Apr.%2013,%202020).pdf#search=Tier%201%20sales

[5] https://dot.ca.gov/programs/transportation-planning/economics-data-management/transportation-economics/long-term-socio-economic-forecasts-by-county

Figure 2. Metropolitan Water District Tier 1 Rate vs Treated Water Deliveries (2007-2019)

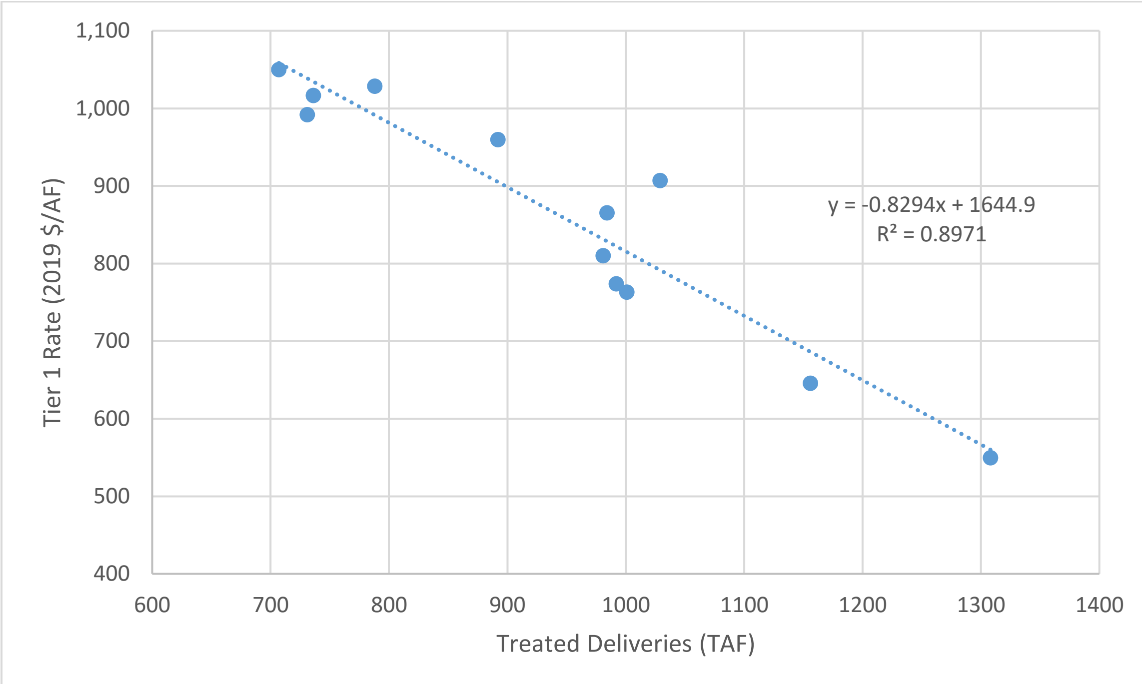


Table 1. Nominal and Real Rates of Increase in Metropolitan Water District Water Rate

FY	Projected Nominal Increase in MWD Rate	LA County Inflation Forecast	Projected Real Increase in MWD Rate
2020	3.0%	1.9%	1.1%
2021	3.0%	1.4%	1.6%
2022	4.0%	2.3%	1.7%
2023	5.0%	2.6%	2.4%
2024	5.0%	2.6%	2.4%
2025	4.0%	2.5%	1.5%
2026	3.0%	2.4%	0.6%
2027	3.0%	2.3%	0.7%
2028	3.0%	2.3%	0.7%
2029	3.0%	2.3%	0.7%
2030	3.0%	2.3%	0.7%
		Mean	1.3%

The Army Corps of Engineers Civil Works Construction Cost Index System (CWCCIS) provides a useful gauge of future expected changes in water-related construction costs.[6] The forecasted average annual rate of increase in civil works construction costs between FY 2020 and FY 2050 is 2.9%. With long-range

[6] See https://www.usace.army.mil/Cost-Engineering/cwccis/

general price inflation projections generally in the 2-2.5% range, the expected real rate of increase is in the range of 0.4 to 0.9%.

The California Energy Commission's current forecasts of electricity rates indicate that between 2020 and 2030 real rates of increase in commercial and industrial electricity rates charged by the state's major providers (PG&E, SCE, SDG&E, SMUD, and LADWP) are expected to be significantly less than 0.5% annually, except for LADWP where the projected rate of increase is 1.7%.[7] Regardless, none of the projections are anywhere near 5.9%.

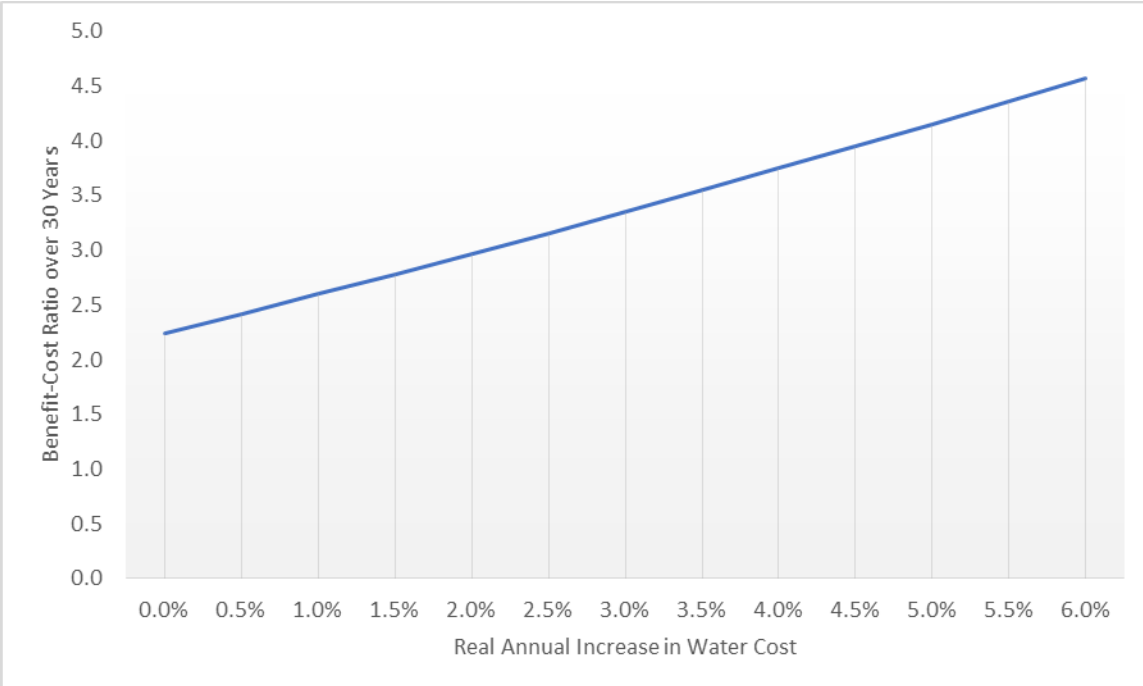
Labor could constitute another driver of water supply costs, but we are unaware of any reputable forecast suggesting that labor costs will grow in real terms by more than 1 or 2% annually over the long-term.

Taken together, these data suggest that real costs for three of the four supply options comprising the Water Board's avoided water cost composite are unlikely to escalate in real terms by much more than 1%. Add to this that Metropolitan Water District is projecting a 1.3% real rate of increase in the Tier 1 rate and we simply do not see any evidence for the Water Board's assumption that future avoided water supply costs will escalate in real terms at 5.9% annually. A real rate of increase of 1-1.5% is economically defensible. Anything greater than 2% should require far more justification than what the Water Board has put forward.

Figure 3 shows the effect that the average annual rise in water price input has on the model's 30-year benefit-cost ratio. Here we are using the input values that were in the model release. The only input that is changing is the average annual rise in water price input. This gives one a sense of the importance to the model's calculation of benefits of this input. Changing the default value from 5.9% to 1.5%, which we believe is on the upper end of being economically defensible reduces the BCR by 63%. This is not a trivial difference. The Water Board's choice to use 5.9% as the average annual real increase in the cost of water results in a large upward bias in the model's calculation of benefits.

[7] See https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2017-integrated-energy-policy-report/2017-iepr, CED 2017 Mid Case Revised Demand Forecast, Form 2.3.

Figure 3. Effect of Real Annual Increase in Water Cost on Economic Model's 30-Year BCR



Effective Timeline for Lifecycle Benefit-Cost Analysis

This input determines the number of years over which the model tallies the costs and benefits of water loss management. The Water Board has set this value to 30 years which cannot be changed by suppliers. This model input cannot be viewed independently from the real rise in the cost of water input. It is the combination of the two that determine the model's calculation of future benefits. The longer the time-horizon, the greater the effect that the real rise in water cost has on the benefit calculation. For example, the difference in avoided water supply cost escalated at 5.9% versus 1.5% after 60 months (5 years) is 25%, after 120 months (10 years) it is 55%, after 240 months (20 years) it is 140%, and after 360 months (30 years) it is 273%.

Thus, the model's long time-horizon amplifies the effect that the highly inflated price escalation input has on the calculation of benefits. This is easily seen by comparing the model's BCRs for 5, 10, 20, and 30 years reported on the model's Output worksheet. Again, using the default inputs that were included with the model release, if we assume zero price escalation the 30-year BCR is half again larger than the 5-year BCR. If instead, we use the Water Board's default price escalation of 5.9%, the 30-year BCR is more than double the 5-year BCR. This shows how the model's long time horizon amplifies the effect of the highly inflated price escalation input value.

By itself, there is nothing inappropriate about a 30-year time horizon for an economic model of this type. Rather, it is the fact that the Water Board is using a highly inflated price escalator in combination with a long time horizon that is the principal cause for concern.

Is the Way the Model Escalates Marginal Water Cost Intentional or a Mistake?

We also note two additional things about the way the model is escalating future water costs. First, the formula the model is using on the Calculations worksheet does not match the description of this formula on the Equations worksheet. The formula the model is actually using is:

$$P_t = P_0\left(1 + \frac{e}{12}t\right) \tag{1}$$

where e is the price escalation rate and t is the number of months from the base period (t=0). The Equations worksheet (see row 22) incorrectly states the formula is:

$$P_t = P_0/\left(1 + \frac{e}{12}t\right) \tag{2}$$

It is also unclear why the model is using a simple rather than a compound growth formula to escalate the real cost of water. More typically, a model of this type would escalate prices using the following formula:

$$P_t = P_0\left(1 + \frac{e}{12}\right)^t \tag{3}$$

In fact, the Water Board is inconsistent in its price escalation treatment. Its calculation of the average historical rate of growth of Metropolitan's Tier 1 treated water rate is based on compound annual growth (equation 3), not simple growth (equation 1). The average rate of escalation from 2008 to 2020 under a simple growth formulation is 8.0% rather than 5.9%. At least by using simple rather than compound growth in the model, the Water Board somewhat mitigates the effect of its overly inflated marginal water cost escalator.

Nonetheless, given the complexity of the model, this sort of obvious mistake makes one wonder what else the model might be doing incorrectly.

Inputs that can be modified by Suppliers

There are 14 inputs that can be modified by suppliers, provided the Water Board approves these adjustments. The Water Board has provided default values for each of these inputs. We review the ones that have the large effects on model results and/or are weakly justified.

Avoided Water Cost

The model uses the default marginal water cost or the supplier's variable production cost of water, whichever is greater, to calculate benefits. As already discussed, the default marginal water cost is a composite cost of four types of water supply: (1) stormwater capture, (2) indirect potable reuse, (3) brackish water desalination, and (4) Metropolitan's Tier 1 treated water. We have already explained why using Metropolitan's Tier 1 treated water rate is inappropriate.[8] What about the other three supply

[8] Metropolitan employs average cost pricing and more than 80% of its costs are fixed. Thus, the Tier 1 rate primarily recovers historical sunk costs that have nothing to do with the avoided cost of water. Most of Metropolitan's costs are not avoidable, which is why the Tier 1 rate has to be increased when sales decrease. The avoidable costs embedded in Metropolitan's Tier 1 treated water rate are on the order of \$200-\$250/AF. This is

types? To us it appears the Water Board has cherry picked water supply alternatives with very high costs to round out its composite marginal cost.

Most suppliers can secure additional water supply at costs lower than $1100/AF, the starting point of the Water Board's composite marginal cost. Water futures on the Nasdaq Veles California Water Index are currently trading around $500/AF.[9] These are FOB prices which don't include transmission and treatment costs. Adding in these costs, however, would still result in prices well under $1100/AF. The average variable production cost reported by water suppliers to the Water Board is $510/AF, 54% less than the model's default starting marginal cost.[10]

More importantly, the Water Board's composite marginal cost oddly ignores one of the principal ways in which water suppliers can extend their supplies. Indeed, it is the primary way that the state wants them to extend their supplies.[11] Namely, water conservation. Water conservation constitutes the least cost supply alternative for most water suppliers, especially smaller suppliers which don't have the scale necessary to make options like recycling, indirect potable reuse, and desalination cost-effective. Large amounts of conservation can be realized at costs well under $1100/AF. According to the data used by the Water Board to develop its composite marginal cost, which it included on the model's CollectedData_References worksheet, marginal conservation costs are low or even negative. Certainly, there is significant conservation potential at prices lower than $1100/AF.

A skeptic might say that using the cost of conservation as the avoided cost is inappropriate because you are simply comparing the cost of saving water two different ways. The response to this is no, I am comparing the cost of generating additional supply two different ways. In one way I generate supply by reducing water waste in the utility's distribution system. In the other way, I generate supply by reducing water waste by the utility's customers. If I generate the supply on the utility's side of the meter, I can avoid the cost of generating it on the customer's side. This is exactly the same as saying if I generate additional supply through water loss management, I can avoid the cost of storm water capture, or indirect potable reuse, or brackish desalination, or buying water from Metropolitan. The benefit of water loss management is the avoided cost of the least-cost alternative.[12] For most water utilities this least cost alternative will not be storm water capture, indirect potable reuse, or brackish desalination, or buying water from Metropolitan. It will be customer-side-of-the-meter water conservation projects. Excluding this alternative from the composite marginal cost used in the model results in a large upward bias in the model's calculation of benefits.

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the appropriate value to use if the Tier 1 rate is going to be part of the Water Board's marginal cost composite. By itself, this correction reduces the starting value of the Water Board's marginal cost composite from $1100/AF to $900/AF.

[9] The index value on 12/2/2020 was $486.53/AF. See https://indexes.nasdaqomx.com/Index/History/NQH2O

[10] This is the average variable cost for the 252 suppliers that are assigned a standard by the model.

[11] See page 15 of the California Water Resilience Portfolio (July 2020) which states: "given natural limits on precipitation and the need to provide water for a broad range of beneficial uses, water efficiency, conservation, and reuse should be prioritized to stretch existing water suppliers to meet future demands."

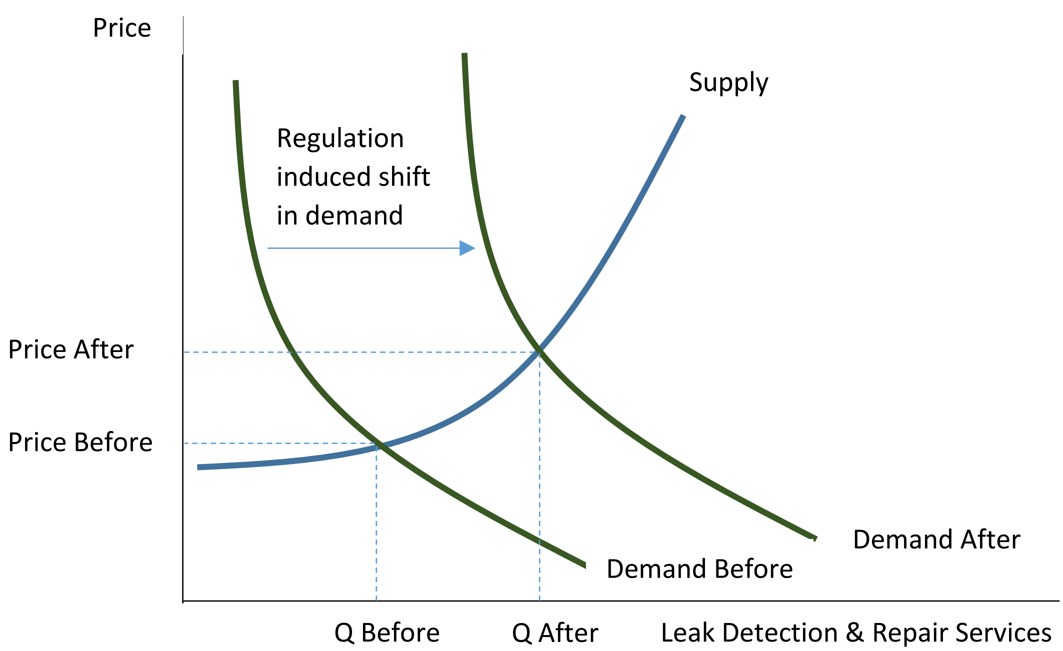
[12] Technically, it is the lesser of the avoided cost and the willingness of customers to pay for additional water supply. Here I am implicitly assuming that customer willingness-to-pay is larger than the least cost alternative supply. This may not always hold, especially if avoided cost is high. Rational customers may prefer to go with less rather than pay high costs for additional water.

Unit Costs of Leak Detection and Repair

There are four inputs that together determine the leak detection and repair costs in the model. These are (1) the average cost per mile for leak detection, (2) the average repair cost for main leaks, (3) the average repair cost for lateral and service line leaks, and (4) the efficiency of leak detection. Our focus here is on the first three inputs. There are two issues that cause a downward bias in the model's calculation of costs. First, unlike avoided supply cost, the model assumes no price escalation for leak detection and repair. In real terms, these costs are assumed to be constant. As discussed above, the Army Corps of Engineers Construction Cost Index System projects that constructions costs will escalate faster than general price inflation. There is little reason to think that leak detection and repair costs would not be subject to the same economic forces driving the escalation of construction costs.

Second, the default unit costs do not account for the large increase in market demand for leak detection and repair services the new standards will engender. Under the draft standards, 252 water suppliers will be required to reduce real water loss by an average of 50%.[13] Needless to say, this will generate a large increase in the demand for leak detection and repair expertise and services. In the short-run, this will put upward pressure on the price of these services. This is Econ 1 supply and demand, as illustrated in Figure 4. The Water Board's economic model does not account for these market dynamics. This is odd because the Water Board uses scarcity arguments to justify escalating the marginal cost of water. The same logic should have led it to conclude that competition engendered by the proposed regulation will also escalate the cost of the primary inputs suppliers will use to reduce their distribution system water losses.

Figure 4. Demand and Supply Before and After Implementation of Water Loss Standards



[13] Based on the water supplier inputs the Water Board used to establish the draft standards.

Infrastructure Condition Factor, Rate of Rise of Leakage, and Survey Rate

The model uses a complex set of calculations to estimate real water losses and water savings and costs of leak detection. Model results are highly sensitive to the value of the inputs used to enact these calculations. **Suppliers should be wary of the model's default inputs if they think they are not appropriate for their distribution system because small changes can have large effects on the model outputs.** We illustrate this with three of the model's inputs used to calculate monthly water savings and costs: (1) the infrastructure condition factor, (2) the rate of rise of leakage, and (3) the monthly survey rate.

Infrastructure Condition Factor

The infrastructure condition factor (ICF) is used to calculate the level of background leakage in the model. Background leakage cannot be detected with conventional leak detection methods and the model treats this leakage as unrecoverable.[14] The ICF is the ratio of total background leakage to unavoidable background leakage of a well maintained distribution system. Thus, a well maintained distribution system should have an ICF equal to 1 while less well maintained and older systems typically have ICFs greater than 1. Various methods for estimating the ICF for a system are presented in WSO (2009).[15] For example, the infrastructure leakage index (ILI) can be used as a first approximation of the system-wide ICF.[16] The ILI is an output from the AWWA water loss audit. Simple rules of thumb are often suggested based on the age of the distribution system. For example, WSO suggests the following rules of thumb:[17]

Age of System	ICF
< 50 years	1.0
50-70 years	1.5
> 70 years	2.5

Small changes in the ICF have very large effects on model outputs. This is illustrated in Figure 5 which shows how the 30-year BCR and cumulative water savings change as the ICF changes.[18] Note that the model generates errors for ICF values greater than 1.7. Moreover, once the ICF reaches 1.4, the model starts generating negative benefit-cost ratios. This occurs because the model calculates negative water savings and therefore negative benefits once the ICF is greater than 1.2. By the time the ICF reaches 1.4, the entire stream of future water savings calculated by the model is negative. There appears to be something wrong with the way the model is calculating the water savings with respect to the ICF input.

[14] Pressure management can be used to reduce background leakage.

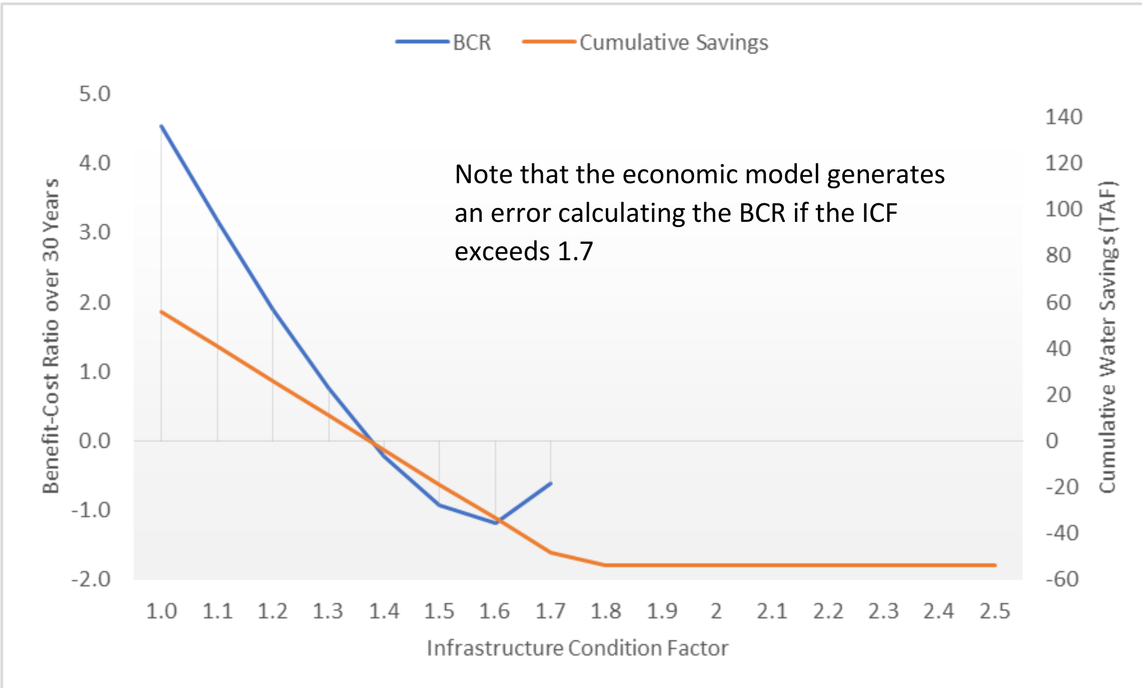
[15] Water Systems Optimization, Inc. (2009), Secondary Research for Water Leak Detection Program and Water System Loss Control Study, Final Report, December 2009.

[16] Ibid, page 25. Also see Fanner, P. and J. Thornton (2005), "The Importance of Real Loss Component Analysis for Determining the Correct Intervention Strategy," Leakage 2005 – Conference Proceedings.

[17] Water Systems Optimization, Inc. (2018), California Water Service 2017 Real Loss Component Analysis, Final Report.

[18] Again, we are using the default inputs that were released with the model. The only input that is changing is the ICF.

Figure 5. Effect of Infrastructure Condition Factor on Economic Model's 30-Year BCR and Cumulative Water Savings



Rate of Rise and Survey Rate

The rate of rise input determines the rate of increase in real water loss assuming there is no water loss management. The Water Board's default is 4 gallons/connection/day per year. In other words, if today real losses average 20 gallons/connection/day, next year they would average 24 gallons/connection/day and the year after that 28 gallons/connection/day, and so on. The Water Board asserts the default input value of 4 gallons/connection/day represents a low rate of rise of leakage for California water systems. But is the really the case?

One way to judge this is to look at the ratio of the assumed rate of rise to the real loss per connection reported by water suppliers. For the 409 water systems in the Water Board's dataset, the average ratio is 0.25 and the median is 0.15. In other words, the Water Board believes that for the typical California water system, water loss is increasing by about 15 to 25% annually. If this were the case, it should show up in the data. We should see a fairly steady increase in the volume of water loss over time. We don't.

We examined 27 water systems of varying sizes located across California that had estimates of non-revenue water stretching as far back as 1980. For each system, we estimated the time trend in annual water loss (expressed in gal/con/day). Of the 27 systems, 14 had no statistically significant water loss trend; 10 had a statistically significant negative trend; and 3 had a statistically significant positive trend. In other words, a consistent increase in water loss was detected in roughly 1 in 10 of the sampled systems whereas 9 in 10 showed either no trend or a negative trend. For the three systems with a positive trend, the average annual increase ranged from 1.5 to 1.9 gallons/connection/day, or about half the rate the economic model assumes by default. For the entire sample of 27 systems, the average increase was -0.5 gallons/connection/day. In other words, there was a slight downward trend in water loss for this sample of water systems. These data do not support the Water Board's assertion that 4 gallons/connection/day represents a low rate of rise of water loss for California water suppliers.

Is the model using the rate of rise input inconsistently?

The model documentation on the Equations worksheet makes what appear to us to be contradictory statements, one right after the other.[19] First it states:

> "Without any intervention, the real loss for the system increases from the initial real loss (three-year average real loss reported by supplier) increases [sic] with time at the natural rate of rise of leakage."

In the very next sentence it says:

> "Without any intervention, it is assumed that suppliers would maintain the current or baseline real loss for the system (three-year average of real loss reported by supplier)."

We read the first sentence to say that without any intervention, real loss would steadily increase by the rate of rise. We read the second sentence to say that without any intervention, real loss would remain unchanged. So either the rate of rise is zero or water suppliers are already managing their systems to mitigate any rate of rise. If the latter is the case, why does the rate of rise factor into the calculation of water savings due to leak detection and repair? Water suppliers are already doing what is necessary to mitigate any rate of rise. The other possibility is there simply is no rate of rise, so why does it factor into the calculation of water savings?

In the actual calculations, the model assumes there is a rate of rise with intervention but there is no rate of rise without intervention. This does not make sense to us.

The rate of rise and survey rate inputs strongly affect model results

The economic model estimates substantially different costs and benefits depending on the rate of rise and survey rate inputs. The survey rate refers to the number of miles of the system surveyed each month. Put another way, it is the total number of months taken to survey the entire system once. The default survey rate varies by system size. But for 90% of suppliers subject to the proposed standards, the model default survey rate is between 24 and 30 months. In Tables 2 thru 4, we show how the 30-Year BCR, monthly compliance cost, and water loss standard depend on the rate of rise and survey rate. We have circled in each table what the model would estimate by default.[20] These tables illustrate how important it will be for water suppliers to replace the model's default inputs with their own values when these differ from the defaults.

It is also useful to point out again that the model generates negative benefit-cost ratios (see the lower right quadrant of Table 2). This should be impossible because costs are always positive and benefits should always be non-negative. The only way benefits can be negative is if the model is generating negative water savings.

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[19] See rows 196 to 222 on the Equations worksheet.

[20] Again, we are using the default inputs that were released with the model. The only things changing are the rate of rise and survey rate inputs.

Table 2. 30-Year BCR as Function of Rate of Rise and Survey Rate Inputs

	Survey Rate in Years				
Rate of Rise (gal/con/day)	1-Year	2-Years	3-Years	4-Years	5-Years
0.0	4.6	8.8	12.7	16.3	19.6
0.5	4.4	8.2	11.3	14.0	16.2
1.0	4.2	7.5	10.1	12.0	13.3
1.5	4.1	7.0	8.9	10.2	10.8
2.0	3.9	6.4	7.9	8.6	8.6
2.5	3.8	5.9	7.0	7.1	6.6
3.0	3.6	5.5	6.1	5.8	4.9
3.5	3.5	5.0	5.3	4.6	3.3
4.0	3.4	4.6	4.5	3.6	1.9
4.5	3.2	4.2	3.8	2.6	0.6
5.0	3.1	3.8	3.2	1.7	-0.5
5.5	3.0	3.5	2.6	0.8	-1.6
6.0	2.9	3.2	2.0	0.0	-2.6
6.5	2.7	2.8	1.5	-0.7	-3.5
7.0	2.6	2.5	1.0	-1.4	-4.3
7.5	2.5	2.2	0.6	-2.0	-5.1
8.0	2.4	2.0	0.1	-2.6	-5.8

Table 3. Monthly Cost ($000) as Function of Rate of Rise and Survey Rate Inputs

	Survey Rate in Years				
Rate of Rise (gal/con/day)	1-Year	2-Years	3-Years	4-Years	5-Years
0.0	159	82	56	43	35
0.5	162	85	59	46	38
1.0	166	88	62	48	40
1.5	169	91	65	51	43
2.0	172	94	68	54	46
2.5	175	97	71	57	49
3.0	178	100	73	60	52
3.5	181	103	76	63	55
4.0	184	106	79	66	57
4.5	187	109	82	69	60
5.0	191	112	85	72	63
5.5	194	115	88	74	66
6.0	197	118	91	77	69
6.5	200	121	94	80	71
7.0	203	124	97	83	74
7.5	206	127	100	86	77
8.0	209	130	103	89	80

Table 4. Draft Water Loss Standard as a function of the Rate of Rise and Survey Rate

	Survey Rate in Years				
Rate of Rise (gal/con/day)	1-Year	2-Years	3-Years	4-Years	5-Years
0.0	20	20	20	20	20
0.5	20	20	21	21	21
1.0	20	21	21	22	22
1.5	21	21	22	23	24
2.0	21	22	23	24	25
2.5	21	22	24	25	26
3.0	21	23	24	26	27
3.5	22	23	25	27	29
4.0	22	24	26	28	30
4.5	22	24	27	29	32
5.0	22	25	27	30	32
5.5	23	25	28	32	32
6.0	23	26	29	32	32
6.5	23	26	30	32	32
7.0	23	27	30	32	32
7.5	24	27	32	32	32
8.0	24	28	32	32	32

Are the Economic Model's Results Sensible?

The Water Board's economic model is complex and for the majority of users will be a black box. It is therefore useful to consider whether the outputs from the model appear to be sensible. We tested the sensibility of the model's results as follows:

1. We downloaded the water supplier dataset used by the Water Board to calculate the draft standards
2. Using this dataset, we ran the model for each water supplier using the model's default input values and the water supplier's values for baseline real loss, length of mains, number of service connections, variable cost of water, and average operating pressure
3. We then examined the distribution of model outputs

The following summarizes our findings.

Required Percentage Reduction in Real Losses

Table 5 shows the distribution of water suppliers in terms of the percentage reduction in real water loss that the draft standards would require. 157 water suppliers would not be required to reduce their water loss. For the remaining 252 suppliers, the required reductions range from 10% to over 90%. For a nontrivial number of suppliers, meeting their proposed standard will be a very heavy lift:

- 119 suppliers would be required to reduce their real losses by more than 50%

- 52 suppliers would be required to reduce their real losses by more than 70%
- 5 suppliers would be requires to reduce their real losses by more than 90%

It is fair to ask whether reductions of this magnitude are technically feasible or economically justified. We suspect they are not. For the reasons previously discussed, we believe the economic model is upwardly biasing the calculation of benefits and downwardly biasing the calculation of costs. It also is unclear whether it is generating realistic estimates of water savings. At the very least, the estimates it generates are highly sensitive to the underlying input values used in the calculations.

Table 5. Distribution of Suppliers by Required Percentage Reduction in Real Losses

% Reduction	Freq.	Percent	Cum.
0	157	38.39	38.39
11-20	23	5.62	44.01
21-30	30	7.33	51.34
31-40	33	8.07	59.41
41-50	47	11.49	70.90
51-60	32	7.82	78.73
61-70	35	8.56	87.29
71-80	30	7.33	94.62
81-90	17	4.16	98.78
91-100	5	1.22	100.00
Total	409	100.00	

Unit Cost of Water Savings

Table 6 shows the distribution of water suppliers grouped by the unit cost of water savings. The model generates very low unit costs for a substantial percentage of suppliers. Unit costs are under $200/AF for 38% of suppliers and under $100/AF for 13% of suppliers. This is implausibly cheap water. If it is too good to be true it probably is not true. We strongly suspect the model is underestimating the costs of leak detection and repair for the reasons discussed above.

The model generates high unit costs over $750/AF for approximately 10% of the suppliers. Here we would point out that there are more cost-effective ways these suppliers could generate the water savings. Why compel them through regulation to use ratepayer dollars for less cost-effective approaches?

In Table 7 we show the average percentage reduction in water loss for suppliers grouped by the unit cost of water savings.

- Suppliers with unit costs between $0-$50/AF would, on average, be required to reduce their real losses by 89%
- Suppliers with unit costs between $50-$100/AF would, on average, be required to reduce their real losses by 79%.
- Suppliers with unit costs between $100-$150/AF would, on average, be required to reduce their real losses by 68%.

The magnitude of reduction required for suppliers in these lower echelons of unit costs is gargantuan. How confident can these suppliers be that the model is generating accurate estimates of water savings and cost? If we were in their shoes, we would not be sanguine.

We also question the magnitude of reduction that would be required for the suppliers at the opposite end of the unit cost distribution. Suppliers with unit costs greater than $750/AF would need to reduce real losses by 15% to 25% according to the economic model. Again, we question why the state would compel these suppliers to use ratepayer dollars on this activity when there are more cost-effective ways to save the water.

Table 6. Distribution of Suppliers by Model's Estimate of Unit Cost of Water Savings

$/AF	Freq.	Percent	Cum.
0-50	9	3.57	3.57
50-100	25	9.92	13.49
100-150	42	16.67	30.16
150-200	21	8.33	38.49
200-250	21	8.33	46.83
250-500	66	26.19	73.02
500-750	30	11.90	84.92
750-1000	12	4.76	89.68
1000-1500	16	6.35	96.03
>1500	10	3.97	100.00
Total	252	100.00	

Table 7. Mean Required Percent Reduction in Real Water Loss by Unit Cost of Water Savings

$/AF	mean(pct_red)
0-50	89
50-100	79
100-150	68
150-200	62
200-250	54
250-500	44
500-750	30
750-1000	25
1000-1500	18
>1500	15

Benefit-Cost Ratios

The benefit-cost ratio (BCR) shows the return on investment from water loss management. A BCR of 1 indicates a break-even situation – the benefits exactly offset the costs. Anything less than 1 indicates the investment would not breakeven. Anything greater than 1 indicates the investment would have a positive return. The economic model generates BCRs across 5, 10, 20, and 30 year horizons. Here we focus on the 30-year BCR, as this is the one the Water Board uses to set the proposed standards. Table 8 shows the distribution and sample statistics for this BCR (bcr30 in the table).

The mean BCR is 14 and the median is 9 (rounded to nearest whole number). Just to be very clear, this means the model is estimating that, on average, the benefits of water loss management will exceed the costs by a factor of 14 and for half the suppliers, the benefits will exceed the costs by at least a factor of 9. For a quarter of the suppliers, the model estimates the benefits will exceed the costs by at least a factor of 16! These rates of return are simply not credible. It is basically the same as free money falling from the sky. If the benefit-cost ratios generated by the model are accurate, water managers should be falling all over themselves in their hurry to reduce their system water losses. Compulsory state regulation would be redundant at best. The financial incentives would be more than enough to get the job done. Economics has a well-worn saying – there is no such thing as a free lunch. When you see a policy proposal or an economic model promising a free lunch, it is best to beware.

Table 8. Distribution and Sample Statistics of 30-Year BCRs Generated by Economic Model

bcr30

	Percentiles	Smallest		
1%	1.034173	1.000893		
5%	1.531866	1.005425		
10%	2.229766	1.034173	Obs	252
25%	4.275231	1.074289	Sum of Wgt.	252
50%	8.524178		Mean	13.83874
		Largest	Std. Dev.	20.83996
75%	16.18118	71.00317		
90%	26.49726	116.4106	Variance	434.3039
95%	38.85803	165.9814	Skewness	6.089781
99%	116.4106	218.8174	Kurtosis	51.81051

Turning a Blind Eye to Uncertainty

The Water Board appears to be ignoring the implicit uncertainty in the model's outputs. The model consists of 22 separate inputs woven together through a complex set of dynamic non-linear equations. This is a recipe for the butterfly effect, where small changes in initial conditions can produce large differences in model outputs. The model's non-linear dynamics will propagate and amplify errors in the inputs. As a consequence, the uncertainty band on model outputs is likely to be quite wide.

By ignoring the uncertainty in the model's outputs, the Water Board risks proposing arbitrary and capricious water loss standards. Figure 6 provides an illustration of this. It shows the 30-year BCR on the x-axis and the corresponding real loss reduction assigned to the supplier on the y-axis. Here we are focusing on model results for BCRs near 1. Notice how the model generates knife-edge solutions. Any BCR > 1 results in a reduction requirement while any BCR < 1 does not, regardless of the distance the BCR is from 1. Compare, for example, the supplier with a BCR of 0.98 to the one with a BCR of 1.03. They are both the same approximate distance from BCR=1, but the supplier to the right of 1 is assigned a 15% reduction target while the one to the left is assigned no reduction requirement. Given the uncertainty in the model, however, it is unreasonable to think there is any meaningful difference in the benefits and costs of water loss management between these two suppliers. The model's uncertainty band is certainly going to be greater than +/- 10%, probably much greater. It does not appear the Water Board has taken into account this uncertainty in setting the water loss reduction standards for water suppliers. As a result, the Water Board is proposing substantially different standards for water suppliers who are unlikely to have any statistically significant difference in the benefits and costs of water loss management.

Figure 6. 30-Year BCR vs Required Water Loss Reduction %