Initial Analysis of Tiered Water Pricing Options for MBTS

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# Introduction

Manchester currently uses a tiered pricing model for water rates, however, the tiers are nearly flat, and do not represent any model of water usage that has any particular relationship to the town’s needs or objectives.

A new tiered model for water rates is needed in order to allow the town to assert a policy with respect to meeting state requirements limiting withdrawal of water from our water sources, as well as revenue goals to support needed infrastructure repairs and improvements.

# Town Water Usage Profile

The town’s water usage profile is central to analysis of water pricing models. Manchester residents tend to use more water per capita than most other communities, and by a large margin. In fact, this is potentially a more global issue that will require more attention from town leaders in the future. The issue of across the board heavier usage is not addressed here, because it likely represents a broader cultural issue that we can’t address with a simple pricing model. The fact that we have higher water usage in general is important when we look at pricing tiers that other towns have put in place in the context of Manchester residents’ water usage.

A salient point about Manchester’s water supply is that the state limits us with respect to how much water we can remove from the aquifer at any given time. Over the past few years, Manchester’s total water usage has begun to trend sharply upwards, and is uncomfortably close to our limit.

The water usage profile shows a sharp variance among customers. Approximately 11% of our water customers account for 50% of all water usage. A graph of the total water usage in 2015 illustrates this:

For most of the town’s 2300 or so water meters, the annual usage increases relatively gradually, but then increases in a completely non-linear manner for a narrow segment of the population.

Manchester’s water usage differs greatly from season to season, with summer months sporting vastly larger water usage then winter months, due to extensive use of finished water for irrigation. A sample of a summer billing quarter vs. a winter billing quarter demonstrates shows clearly that water usage falls off in the winter. Furthermore, what is not clear from the graph is that in winter months, entities that represent aggregate users (for example Manchester-Essex Regional School District) dominate the small group of top end water users, while in the summer, it is individual residents that dominate the high end of the spectrum.

One item of note in the summer vs. winter usage graph is that there is a gap of something like 200 meters. This is due to a combination of factors. First, some residents live here only in the summer months, and their water usage drops to zero or close to it in the winter months. Second, in winter months, irrigation systems are generally off, so those numbers drop to zero, and are not represented in the graph. Thus the apparent number of meters is lower in the winter months.

# A Word on Units

The units used to report water usage vary from community to community, and indeed from one type of report to another. For example, in Manchester, when we talk about the daily usage, we typically use gallons per day, whereas when we specify our water billing rates, we express those rates as dollars per hundred cubic feet. The graphs above actually are in simple cubic feet, so to match these to our billing tiers, you would divide by 100. Many municipalities give their billing rates in dollars per hundred cubic feet, but a significant number express the rates as dollars per thousand gallons.

For the rest of this document, unless otherwise specified, all units of water usage will be in hundreds of cubic feet (HCF).

# Different Pricing Schemes

Pricing schemes for water vary from community to community. Some communities use simple flat rate schemes. Some use fixed tiers. Some use seasonal water rates, with the pricing varying from winter to summer. Some use one price for second water meters on properties (typically used for exterior spigots, and/or irrigation systems). And some communities use more complex hybrid models, though these appear to be rare.

There is no one model fits all, partly because water usage varies greatly from community to community. We’ll see this illustrated pretty clearly when we apply some of the pricing regimes from other municipalities to Manchester’s usage data. There are some very negative effects that come from blindly applying one community’s model to another community.

# Manchester’s Billing System

Manchester currently bills on a quarterly system, following calendar quarters. These mostly match the shifts in seasonal water usage. As mentioned before, Manchester uses a tiered system. At the end of a quarter, the usage numbers for a given account for that quarter are fed into the billing tier, and a bill for that quarter is generated. The usage numbers, for billing purposes, are reset at the start of each quarter. Users pay at the lowest rate for whatever water they use in the lowest tier range, then the next rate for any usage over that amount, up to the limit of the next tier, and so on, until they hit the topmost tier for their usage. The quarterly bill is the sum of all amounts from all tiers used.

This is important, because the distributions of water usage can differ in shape from one season to another, which can affect how one would like to break tiers for billing purposes. This may be way some communities prefer to have seasonal rates. Without seasonal rates, it is necessary to pick a tier system for one set of quarterly data and use it for all quarters. Analyzing the annual usage and building tiers from that will not be accurate at all, if there are strong differences in seasonal usage, such as we have in Manchester.

# Why Use Tiers?

One of the first questions to answer regarding pricing schemes for Manchester is why select tiers as opposed to another model, such as a flat rate, or a system where second water meters are charged a higher rate. The answer to this lies in the distribution of water usage. A flat rate is pretty much what we currently have, and it doesn’t do very much with respect to throttling back usage at the high end. This contributes to our approaching the withdrawal limit. Using a higher rate for second water meters could help, but second water meters are in use by many who are not profligate users of water. If we set a flat rate on second meters high enough to modify the usage patterns of the very high end users, we will end up punishing lower end users who might not be able to withstand the resulting economic shift.

Tiers allow the town to customize the pricing system to allow for fairness to low end users, at the same time as allowing for the ability to apply economic pressure to top end users when we get too close to our withdrawal limits.

In answer to the question of why we should have higher prices for higher end users, the answer is: the withdrawal limit. If water were an unlimited resource, then we would likely simply set a flat rate that covered all our production costs, plus year over year maintenance costs, and call it a day. But water is a limited resource, and we will be penalized by the state if we exceed our withdrawal limits, not to mention being at serious risk of depleting the watershed that we rely on. Therefore we need to maintain an option to exert economic pressure to assert water usage policy.

It is worth noting that we have, in the past, offered assistance to other communities when they are in need of water, for emergent events. In order to be able to do this, we cannot be floating near the state withdrawal limits.

# Challenges of Tiers

Tiered pricing models come with challenges. Tiers have two degrees of freedom: the breakpoints of the tiers, in terms of usage, and the price for each tier. Both affect the revenue that comes to the town, and they are not exactly independent variables.

Manchester’s current tiers look like this:

|  |  |
| --- | --- |
| Usage (HCF) | Rate ($) |
| 0-30 | 5.43 |
| 31-60 | 5.53 |
| 61+ | 5.65 |

This essentially represents a flat rate for the town. The median usage in one summer quarter in 2015 was about 16.9. So half the people in town used less then 16.9 HCF in that quarter, and half used over that amount. Over 1700 meters would fall into that first tier, and the remaining roughly 500 meters spread across those second two tiers. Furthermore, the difference in pricing in those tiers is less than 20 cents, for a difference in pricing of less than 5%. While this does generate additional revenue for the town, it does absolutely nothing with respect to controlling usage in the upper tiers. The pricing different doesn’t come close to approaching numbers that affect the elasticity of demand at the top of the spectrum. The result of this is that the town can increase rates year over year to keep up with infrastructure maintenance costs, and can count on the revenue coming in as predicted by previous year’s usages.

The first challenge with tiers is selecting the upper and lower usage bounds for the tiers. This will be addressed in much greater detail in a later section. These bounds have a complex relationship with the demographics of the town, and need to be selected very carefully to allow for fair and compassionate pricing for residents.

The second major challenge is related to elasticity of demand. With a roughly flat rate, based on observed usage, we have essentially completely inelastic demand in our total water usage. The problem is that we don’t know what the limits of that are. In any tier system where we want to be able to affect total water usage through economic pressure, we need to be able to have a measure of where the demand begins to become elastic across the higher usage tiers. Once demand becomes elastic, users will, by definition, reduce their consumption in response to upward price changes. If and when that happens, our revenue becomes more difficult to predict. Since we rely on that revenue for capital projects related to water infrastructure, not to mention our water department operational budgets, this can result in significant budgetary instability if we set tier rates inappropriately.

There will also be secondary issues with tiers that have significant differences in price. One immediate issue will be in how we deal with abatements. Currently, we tend to abate sewer costs when there is, say, a water leak for a customer. We don’t take the water rate into account, in general, because the rates are essentially flat. However, a number of the abatement requests that have been processed recently would, under most pricing models that we should be considering, would need to take the tiers into account. Someone suffering a broken pipe, which temporarily pushes their usage up by several tiers, could be exposed to an even more dramatically inflated bill. This would be very arguably unjust, and we would have to establish policy with respect to what tiers their water usage would be billed under, almost immediately. One such policy would be that for abatement requests around an accidental event like a broken pipe, the prevailing water rate for all the usage would be the lowest tier value.

It is probable that we would have to ease into rate increases on the upper tiers to allow us to feel out, empirically, where we begin to make demand elastic. This would be a multi-year effort.

# Examples of Other Tier Systems

A couple of comparative examples of other tier systems point up limitations of applying another municipality’s tier selections to Manchester. While these other systems should not be applied here, it is helpful to see how other communities treat the relationship of higher usage tiers to pricing.

## Framingham

Framingham uses these tiers:

|  |  |
| --- | --- |
| Usage (HCF) | Rate ($) |
| 0-12 | 5.50 |
| 13-27 | 6.11 |
| 28-51 | 7.12 |
| 52-750 | 8.38 |
| 751+ | 10.15 |

Framingham’s tiers suffer from the problem that practically none of our users would fall into the top tier. While this is possibly a desirable outcome in the long run, it is essentially useless to us in the near term, outside of making some implicit statement that no one will really see: don’t go here, or you’ll pay through the nose. Additionally the median usage in Manchester falls into the middle of the second tier, which is likely too high a place for the median to fall, especially if it carries a 10% increase to their rates.

## Hamilton

Hamilton uses these tiers:

|  |  |
| --- | --- |
| Usage (HCF) | Rate ($) |
| 0 - 7 | 3.13 |
| 6.69 – 33.42[[1]](#footnote-1) | 4.28 |
| 33.43 – 334.42 | 7.32 |
| 334.43+ | 9.04 |

Hamilton comes closer, because more of Manchester users would fall into the top tier. However, the top tier would also capture users such as the regional school district, which arguably should not be heavily penalized from a pricing standpoint, because they serve a large aggregate population. Additionally, the median usage amount falls deep into the second tier, which is likely undesirable.

# How to Select Tiers

The selection of tiers is, to some extent, arbitrary, but there can and should be some rationale to the process. The tiers that we want need to satisfy the following criteria, at a minimum:

* Demonstrably be covered by the entire population of water meters (no empty tiers, no sparse tiers sprinkled about)
* Be even-keeled to the majority of the population (no big jumps near the median values)[reword this]
* Reward low water usage
* Provide economic pressure to guard our withdrawal limits
* Luxury water usage should fund infrastructure in greater proportion than median water usage

Tier selection is something that is likely to vary from year to year in response to usage patterns, in particular if and when we explore the boundaries of elastic demand in the top tiers. Thus whatever method we use to select tiers should, ideally, be based on some clear definitions, so that the methodology can be easily re-applied in later years to generate new tiers with predictable results in revenue and behavior.

Building tiers by hand is doable, but also time consuming, and error prone. Automated tier selection is possible by various means, and one will be presented in detail here.

For the tiers to be most flexible for price setting, they should somewhat closely fit the distribution of water usage at peak months. Put differently, you don’t want a single tier that covers the entire tail of the distribution, where usage amounts leap wildly. Perhaps the best way to illustrate what might be desirable is to show a graph in which we have drawn straight-line segments that have been calculated to fit the actual water usage numbers predictably closely, with a limited number of segments. Each segment represents a tier. This ensures that each tier will contain a significant number of users, and that the segments do not contain wildly differing populations of usage. Here is such a graph, with five straight-line segments fitted to a summer quarter in 2015:

This next bit gets extremely technical and describes the precise method for fitting the tiers, for those who care. We take the raw usage data, sorted ascending. Starting from the left, we progressively do least squares regression fit into the usage population. When we observe the R^2 value for the regression fit begin to decline, we stop, and break out a tier, provided that we have a minimum range of usage values in the tier. We don’t want tiers that span only 10 HCF, for example. Additionally, we force a break at the beginning when we hit the median point of the population, to ensure that the median value will fall at the end of the first tier (this needs a little more thought). When we break a tier out, we restart the progressive least squares regression where we left off, to build the next tier. Finally, we sweep across the resulting set of tiers, combining tiers that have too few users in them. So if two neighboring tiers have, say, 10 customers each, we would combine them into one.

Here is a resulting tier structure from the above method. In fact, this is what is actually graphed in the linear fit graph above:

|  |  |
| --- | --- |
| Usage (HCF) | Rate ($) |
| 0 – 17 | 5.43 |
| 18 – 57 | 6.0 |
| 58 – 100 | 7.0 |
| 101 – 136 | 8.0 |
| 137 – 271 | 9.0 |
| 272+ | 10.00 |

The prices for this system were chosen somewhat arbitrarily: we set the lowest tier to our current lowest tier value. Then we ramp the prices up to roughly twice that price across the remaining tiers. Framingham provided an example of a system where higher tiers were, in fact, charged double the rates of the lower tiers.

# Work To Be Done

The tiers this generates are pretty reliable across the sort of exponential usage distribution that we have here in Manchester. However, there remains some considerable validation work. In particular, we need to validate the pricing of the tiers. We need to run the tiers through a few years of known usage data for Manchester, and see it reliably generates comparable or better revenue. We need to do some scenario testing regarding elasticity. To be conservative, we need to run some models with selected pricing where we interject some reduction in water usage by the top, and even some of the intermediate tiers.

It is possible that if we push top end users too hard, they could simply rebel, drive a private well for irrigation, and remove themselves permanently from the town revenue pool. It would be a good idea to model some of these outcomes.

We need to include in the final number crunching the year over year 4% total increases that we have in our current model to fund infrastructure. The tiers and pricing should allow for us to easily and reasonably adjust prices within the tiers to keep the criteria previously described.

One thing that is missing from the tiers is a reward tier at the bottom for people who use well under the median usage. This is interwoven, to some extent, with the longer-range issue that Manchester water users tend to use far more than the median users in other communities. That same reward tier might also cover, reliably, fixed income populations. Ideally, we’d combine the water users database with some voter registration database to prove such a correlation, and possibly include that as a policy element: attempt to hold the tiers to provide price relief to the retired population.

[Manchester Housing Authority shows up as an aggregate water account. We should check on how residents at the housing authority are billed for water to make sure the tiers don’t harm them]

# Caveats

Some things are not captured well by this model. For example, houses with second water meters show up in our raw data as two different meters. So a house that uses 24 HCF on one meter and 35 HCF on the other would both fall into tier 2 in the model above, where if treated as one, they would be in the third tier. This should have a negligible revenue impact. In general, most of the heavy usage cases will have a second meter that dwarfs the primary meter.

1. Hamilton expresses their rates in $/thousand gallons. These have been converted here to HCF, for comparison purposes, hence the fractional numbers. [↑](#footnote-ref-1)