2017

POLICY PAPER: Fiscal and flooding risk caused by climate change in the City of Medford

Measuring the potential consequences of climate change on property value and tax revenue

This document contributes with Medford's Energy and & Environment Office in building its Climate Change Vulnerability Assessment. It develops a model to measures the fiscal risk generated due to revenue loss in property tax caused by flooding risk property value depreciation motivated by climate change.

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1 - Introduction

The impact of climate change and its consequences has been on the rise. Flooding, droughts, increased precipitation, heat waves and other phenomena affect differently each geographical area and sector, especially coastal cities. According to the EPA[1], in the northeast region of the US "*sea level rise and more frequent heavy rains are expected to increase flooding and storm surge*". Coastal cities in particular are sensitive to *sea level rise, changes in the frequency and intensity of storms, increases in precipitation and warmer ocean temperatures*[2].

As a result, the climate change impacts faced by local communities with important coasts are huge, as their economic activities and assets will be highly affected. According to the Union of Concerned Scientist last report (2017), **the State of Massachusetts will face high-tide flooding within the next few decades that will be chronic and extensive, and Medford is not exempt**.

According to the projections made in its Climate Change Vulnerability Assessment (CCVA), **the City of Medford will be facing rising temperatures, sea level rise and increased precipitation, among the most important effects produced by climate change**. Sea level is expected to rise 9 inches between 2030-2050, 21 inches between 2050-2100 and 36 inches from 2070-onwards. Although the Amelia Earhardt Dam, located between Somerville and Everett on the Mystic River, protects Medford from up to 5.6 feet in sea level rise or storm surges, by 2070, the 100-year storm is likely to overtop the dam, leading to flooding throughout a large part of Medford (CCVA Medford). Similarly, rainfall is expected to increase in a 10-year, 24-hour storm from its historical (1971-2000) 4.9 inches to 5.6 inches by the 2030s, and 6.4 inches by the 2070s.

By 2070 Medford will be a chronically inundated community according the projections of the "high" scenario in the model of the UCS (2017). The UCS defines a limited-use or chronic inundation zone as any area where tidal flooding occurs 26 times per year (on average, twice a month—although flooding events tend to cluster, not to occur at neat intervals). **UCS considers a community to be chronically inundated when 10% or more of its usable, nonwetland area floods at or more than that twice-monthly average frequency. In the case of Medford, 13% of the land will be chronically inundated in 2070**[i]. Furthermore, in the UCS's intermediate scenario, Medford will have 15% of its usable non-wet land flooded more than twice-monthly for the year 2100.

Like other local governments, property tax represents a significant amount of Medford's resources and any potential decrease of property values, means an important fiscal risk to the municipality. Consequently, flooding risk and its potential effects on property values is a problem for the people of the City but also for the government, because it challenges its future capacity to provide citizens with the basic public goods and services.

[1] https://www.epa.gov/climate-impacts/climate-impacts-northeast
[2] https://www.epa.gov/climate-impacts/climate-impacts-coastal-areas

Therefore, assessing the impact that flooding risk will have on local property value and, subsequently on tax revenue, has a crucial importance. Despite its relevance, there are almost **no models studying the fiscal impact of climate change flooding on tax revenue in local governments**. According to Palmer (2014), the topic of natural disasters and their impact on tax policy is a neglected area, with scarce attention having been paid to natural disasters in the economics and political science literature.

This document fills the gap by developing a model to measure fiscal risk caused by revenue loss on property tax motivated by property depreciation caused by flooding risk enhanced by climate change.

2 - Fiscal policy and climate change: Fiscal risks

The impact that flooding risk will have on property values, either due to extreme weather events or chronic floods, and its consequences on Medford's fiscal revenue and budgetary balance is a fiscal risk. **Fiscal risk is defined as a source of financial stress that could face a government in the future (Brixi & Shick, 2002**). According to the fiscal risk matrix developed by Brixi & Mody, the sources of fiscal risk can be classified into four groups: direct versus contingent liabilities, and explicit versus implicit ones. In that classification, natural and environmental disasters are an "implicit and contingent" liability because they depend on the occurrence of a future event and on government willingness to act (2002: 22).

The IMF (2016:6) states that natural disasters are a *modest and relatively frequent source of fiscal risks*, costing 1.5% of GDP on average and 6% of GDP in extremis for the countries. Furthermore, within the fiscal risk, they are classified as a product of an external source with a discrete possible incidence (2016: 13). Lis and Nickel (2009) found that the impact of large scale extreme weather events affect the public budget balance, depending on certain country characteristics, in a range between 0.23% (all sample) and 1.1% of GDP (developing countries sample). As it can be appreciated, extreme weather events and natural disasters can posit a fiscal risk because they generate significant variations in public deficit.
Climate change fosters this source of fiscal risk. As climate change will cause more natural disasters, increases in see level rise, storm surge and heavy rainfall, both disaster relief spending and investments to protect, repair, and relocate infrastructure will need to be made by governments (OMB, 2016). According to the Office of Management and Budget (2016:7), annual expenditures due to climate change will total $34-$112 billion per year by late-century, the equivalent of $9-$28 billion per year in today's economy.

Furthermore, not only expenditures will be affected but also the revenue. **According to the OMB (2016:7) the revenue impacts in an unmitigated climate change scenario appear to be significant, as climate change is projected to reduce economic output in the United States, which means lost revenue.** In numerical terms, the estimated loss of

Federal revenue ranges from roughly $340 to $690 billion per year depending on the portion of global losses that occur in the United States, in the 4% global economic loss estimate at 4 degrees Celsius warming (OMB 2016: 8).

There has been little academic focus on the links between tax policy development and responses to natural disasters (Palmer, 2014:1). D*etermining the appropriate tax response to a natural disaster involves multiple complex decisions that often need to be made under time pressure with limited information* (Palmer 2014:1). There are three stages of identified: pre-disaster, disaster response, and post-disaster recovery.

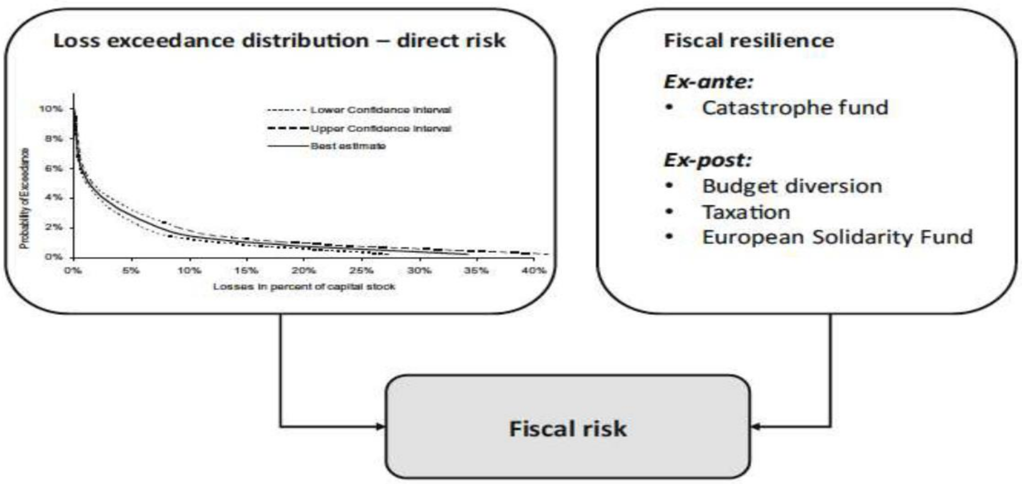
Taxation has two distinct roles in the pre-disaster phase according to the author. The first is to raise revenue to fund future disasters responses, including mitigation activities. The second role that taxation might play is to incentivize property owners and others to make the desired level of pre-disaster investment (Palmer 2014: 6). In the response/disaster phase, governments may use emergency support payments and may also allow individuals or firms to defer (or disregard) tax payments. Finally, in the post-disaster phase, governments usually must decide to finance emergency-related spending and balance-of-payments shortfalls, or to reduce or divert spending to cover immediate needs (Palmer 2014:7). **The disaster's effects on fiscal sustainability is important for making informed decisions as natural disasters will probably require that national and local governments establish a macroeconomic management scheme to tackle fiscal and current account effects, such as lower tax revenues, higher public spending, lower exports, and higher imports (The World Bank, 2004 on Palmer 2017: 8).**

The increase in fiscal risk due to the recurrence of disasters and their magnitude modifies the coping capacity of governments to deal with risk. Once an accepted idea, the Arrow-Lind postulate, in which governments should be risk-neutral in terms of disasters as their capacity to refinance quickly, makes it efficient to plan for and reserve for average costs incurred over longer time horizon (Mechner et al. 2016: 6) is being challenge. This fact turns governments from a risk-neutral position to a position of risk management. In other words, they stop acting as if natural disaster are "an act of God" and start managing disaster and fiscal risk.

Fiscal management ensures that governments have the cash available to meet their obligations and deliver on their policies, under any likely conditions (Brixi & Mody 2002: 29). According to the fiscal hedge matrix in Mechler (2016: 9), the tools available for this specific risk are: reserve funds, contingent credit lines, and sovereign insurance-traditional or alternative-. When managing fiscal risks from natural disasters specifically, the IMF recommends that governments develop strategies for natural disaster prevention, mitigation, and management. Specifically, this strategy should "*assess natural disaster risks; establish a framework for monitoring disaster risks including through early warning systems; put in place disaster preparedness and response mechanisms; and identify mitigating measures to reduce exposure to risks*" (IMF 2016: 38).

To properly face fiscal risk management responses, some authors have developed very sophisticated approaches to fiscal risk and natural risk management (Hochrainer et al., 2013; Mechler et al., 2016). Based on the model proposed by Hochrainer et al (2013), it is possible to model future fiscal stress from climate-related events by linking climate risk estimates (such flooding risks) and climate scenario analysis building in countries. **This model, called IIASA CATSIM, uses probabilistic modelling of disaster risk to understand current and future stress imposed on the fiscal position, and support the development and implementation of fiscal policy options.** In figure 1 (Mechler et al., 2016) we can observe how fiscal risk is composed of the loss distribution and the fiscal resilience function.

Figure 1 - Fiscal risk in the CATSIM framework (Mechler et al., 2016)



Despite the advancement made on this technical understanding, risk management today is still strongly focused on ex-post response, and the uptake of ex-ante risk management today dwarfed by spending on post-disaster recovery and reconstruction (Mechler et al., 2016:17).

2.a - Partial conclusions

- Fiscal risk caused by flooding risk is enhanced by climate change. As climate change will cause more natural disasters, sea level rise, heavy rainfall and chronic flooding.

- Natural disasters, such as floods, are a modest and relatively frequent source of fiscal risks, costing 1.5% of GDP on average for countries.

- Extreme weather events increase budget deficit 0.23% on average.

- Fiscal risk can be mitigated or hedged by Fiscal Risk Management.

- Despite many technical advances to understand and manage of fiscal risk, post-disaster recovery and reconstruction is the most usual response, a rather basic risk management strategy.

3 - Flooding risk and property values

As climate change is expected to amplify the prevalence and severity of flood risk, due to changes in winter precipitation, sea levels, storm surges and extreme weather events, it is important to understand how the price of a unit of housing associated would change as a result (Pryce, Chen & Galster 2011: 259).

This section analyzes the literature on the impact of floods (flooding risk) on properties' value in order to get property depreciation estimates. Most of the estimates shown in this section are based on hedonic regression results. This is a special regression technique that relates the price of a house to its characteristics -size, number of bedrooms, number of bathrooms, and so on- (Wooldridge 2013: 677). This type of model is mostly descriptive and allows the researcher to estimate the impact of flooding risk on property values holding constant other home features.

Hedonic theory assumes that the household will choose a dwelling that maximizes expected utility, wherein the various attributes of the dwelling and environs are assessed in evaluating utility (Pryce, Chen & Galster 2011: 260). According to the theory, utility reduction (and thus home price) from flooding depends on the spatial, temporal and hydrological aspects of the flood reduction. With rare flooding, house prices fall immediately after a flood event and then recover fully after repairs and remain at this higher level until the next rare flood. In this case, over the long-term, neither past nor prospective flood damages are capitalized-i.e. incorporated to the price- (Pryce, Chen & Galster 2011: 261). At the other extreme with flooding occurring so frequently that housing utility has insufficient time to recover much if at all, house prices remain low. In this case, flood damages have been almost completely capitalized into house prices after the event (Pryce, Chen & Galster 2011: 261).

Pryce, Chen & Galster (2011: 271) found that in areas that are currently experiencing low flood risk but soon will experience significantly increasing flood risk, the average house prices will at first only slowly diverge from continuing low-risk prices. **However, the adjustment may be severe and unpredictable, hitting tipping points where prices suddenly collapse.** This non-linear market adjustment to intensifying risk is an important and worrying prospect because it potentially compounds the impact of other tipping points associated with the rapidity of climate change (and hence flood risk), which have already been identified as plausible trajectories for global warming (Pryce, Chen & Galster 2011: 276). **Consequently, governments should be aware of reducing the magnitude of tipping-points in house price adjustment which could have destabilizing effects in the local housing market as well as the local government.**

The U.S. Army Corps of Engineers reviewed existing academic literature on hedonic price models of the floodplain real estate market. In addition, two hedonic price model cases were studied to answer some of the questions raised in the literature review. In the case studies, the US Army Corps used price data from existing Corps projects in Abilene, Texas and South Frankfort, Kentucky. They found from the literature review that the case studies are insufficient to conclude that flood damages borne by floodplain activities either are or are not capitalized into the fair market value of floodplain properties

Fridgen and Shultz (1999) use hedonic valuation method (HVM) to quantify the impact of the threat of flooding on housing values in Fargo, North Dakota and Moorhead, Minnesota. They looked at prices of 3,783 Fargo-Moorhead homes sold between 1995 and 1998, and regressed their selling value against structural housing characteristics, neighborhood, and environmental indicators, and three flood risk variables. Their **main findings are that being located in the 100-year floodplain lowered the sale price of an average home by $8,990 (8.8%).** Approximately 81% of the price depreciation was associated with required flood insurance premiums.

Harrison et al. (2001) based their analysis on the valuation of approximately 30,000 homes located within 100-year flood plains in Alachua County (Florida). They found that the parcels in the FEMA's Special Flood Hazard Areas (SFHA) show a lower selling price, an average of $985 (0.02 s.d.) than those that sold are before the National Flood Insurance Reform Act (1994). Moreover, those in the 100-year flood plain that were sold after 1994 exhibit a $2,126 (0.04 s.d.) lower value. For the entire period, **the discount of the home values on the flood plain were exacerbated after the NFIR Act. Homes in the SFHA zone for the complete sample were worth an average of $2.893 (2.9%) less than those that were not in SFHA zone.**

Dickes and Crouch (2015) examine the relationship between lake level changes and property values for properties located in the six counties that are adjacent to Lake Thurmond (Georgia and South Carolina). They found that as the lake is closer to full pool, there are statistically significant changes in sales price. The lower the lake label is Below the Full Pool (BFP), the higher the value of the houses. **At .64 feet BFP, the selling price increases 4.2% and at 3.7 feet it increases 10.4%.** However, when the lake levels go more than 8 feet BFP, prices of homes go down too.

Troy and Romm (2004) used hedonic analysis to estimate the effects of flood hazard disclosure under the 1998 California Natural Hazard Disclosure Law (AB 1195) on property values throughout California. The authors found that **the average floodplain home sold for 4.1% less ($7,978) than a comparable non-floodplain home following AB 1195** while before that law there was no significant price differential.

Bin and Polasky (2004) used hedonic property price function to estimate the effects of flood hazards on residential property value. Using data from sales of 8,000 single-family residential homes between 1992 and 2002 in North Carolina, they found that a house located within a floodplain has a lower market value than an equivalent house located outside the floodplain. On average, **being in a flood plain lowers the house selling price by $7,463 (5.7%). After Hurricane Floyd, the property in the flood-plain decreased its selling value and sold for $10,825 less.**

Bin et al. (2008), using data from sales of 8,000 single-family residential homes between 1992 and 2002 in Pitt County, North Carolina (classified as a flooding area by 1999), found that houses located within a floodplain have a lower market value: the average property's value is $11,598 less (7.8%) than an equivalent house located outside the floodplain. Moreover, **location within the flood zone with 100-year flood plain lowered the average property's value by $12,325 (0.16 s.d.) whereas location within a 500-year floodplain lowered average property value by $9,849 (0.13 s.d.).**

Bin and Landry (2013), by using data from 8,000 house selling prices in North Carolina, found that no market risk premium was found for the presence of a flood zone. Nevertheless, they found significant price differentials after major flooding events (hurricanes). Also, they found that the effect diminishes over time, essentially disappearing about 5 or 6 years after last hurricane. For all flooding risk, people payed on average $13.136 dollars (-5.7%) less after the last hurricane, while in the 100-year flood risk area people pay on average $19.064 dollars (-8.8%) less after the hurricane. For the 500-year flood risk area they found that people pay on average $2,879 dollars less after the hurricane.

Eves (2002) also found that flood-liable property has less value that similar properties that are flood-free in Australia during a period of 17 years of analysis. Nevertheless, he also found that this differential varies year by year and is greatest over the period of over-flooding and reduces after a period when no flood/minimal flood has been recorded. The average annual difference was $10,120. Before experiencing floods, property value average difference was $4,229 while following a period of flooding it jumped to an average of $25,008.

Daniel et al (2009) made the most comprehensive review found on flooding risk and housing values. By using 19 hedonic pricing studies, predominantly for the US, and with 117 estimates and their associated standard errors, they performed a meta-analysis. They found that an increase in the probability of **flood risk of 0.01 in a year is associated with a difference in transaction price of an otherwise similar house of 0.6%. The standardized relative change in house price due to location in the 100-year flood plain ranges between −52% and +58%, but on average it equals −2.6%[3].** The absolute value of the estimated price differentials is, as a rule, smaller than 20%. This means that the marginal effect of flood risk associated is negative and the amounts to a decrease in effect size with the decrease in risk. The variation between the 100 and 50-year floodplain corresponds approximately to an increase in risk of occurrence per year of 0.01. They also found that the marginal effect of risk exposure is enhanced (in absolute magnitude) when a recent flood has occurred.

[3] This is the standardize effect size. The effect size of most studies performed is the estimated relative difference in the price of a house associated with location in a specific zone at risk, due to this specific risk. Because functional forms of hedonic regressions are different, the risk levels vary in some of the studies. To enhance comparability, the effect size was standardized with the risk probability. The standardized effect size is equal to the effect size×(risk probability×100)−1

Lamond and Antwi (nd) examined the evidence from previous studies in the UK, US, Canada, Australia and New Zealand to determine the range of measured flood effects and detect any broad patterns. The magnitude of estimated impacts varies widely across and studies, partly because both flood events and floodplain designation have been considered, and partly due to the quantity and quality of data available but also due to the highly local nature of floods and the risk awareness of house purchasers under different disclosure regimes. Some of their estimates of past studies in the U.S. are included in Daniel et al. and in the literature.

The last two studies in this section analyze the impact of sea level rise on property value and the importance of flooding risk perception on housing prices. Although this two factors will not be taken into account, they are important for further analysis.

Ayyub et al. (2012) analyzed the impact of sea level rise (SLR) on properties and infrastructure of Washington, DC. They made a linear model that projected SLR from 2020 to 2150. For 2050, their projections current projections of SLR was 0.12 meter by 2050 and 0.27 meter by 2100. Nevertheless, by using climate change models' projections for SLR, their estimates are modified. **Should SLR be 0.1 meter, approximately 103 properties will be damaged, with a cost of $2.1 billion dollars.** If SLR goes to 1 meter the estimated number of buildings damage are 180 with a value goes to $4.2 billion dollars. Even using a modest SLR of 0.1 m, their data shows a relatively negative impact on the city.

O'Neill et al. (2016) found that distance to the perceived flood zone (perceived flood exposure) is a crucial factor in determining flood-risk perception, both the cognitive and affective components. The authors analyzed a series of surveys and found that, as **distance to the perceived flood zone increases, flood-risk perception decreases.** Consequently, there is a misperception between risk perception and risk reality. This is important from a flood risk management perspective because it is most likely that individuals who are in a flood zone, but perceive themselves as outside of it, won't be taking the necessary precautions.

3.a - Partial conclusions

- Most of the literature found that flooding risk has a significant but relatively small effect on property values.

- Flooding risk effect is amplified when extreme weather events (hurricanes, floods, etc.) have recently happened and fades slowly to lower levels after some years.

- Some authors found that the idea that markets correctly account for flooding risk discount on property values might be wrong. The distance perceived from a flooding area and not being in a flooding area might have more impact on home owners and their respective house selling value.

- The most robust point estimates of flooding risk impact on the average property value generated by a meta-analysis of the literature is 2.6% (Daniel et al. 2009).

Table 1 synthesizes the literature estimates on the impact of flooding risk on the average property value in a comparable way. They are illustrative of the potential magnitude of the discount at which houses could be sold if their flooding risk is 1% (or more) per year (100-year floodplain).

Table 1- Flooding risk impact estimates on property value

Author	**impact**								
	Average price differential (absolute value in dollars)	**Average lower property value (standard deviations)**	**Average lower property value (%)**	**100-year average price differential (absolute value in dollars)**	**100-year average lower property value (standard deviations)**	**100-year average lower property value (%)**	**500-year flood event plain (absolute value in dollars)**	**500-year average lower property value (standard deviations)**	**500-year average lower property value (%)**
US Army Corps of Engineers (1998)				-	-				
Fridgen and Shultz (1999)				-$8,890		-8.87%	-$3,123		
Harrison et al. (2001)	-	-	-2.9%	-$2,893	0.06	-	-	-	-
Troy and Romm (2004)				-$7,978		-4.1%			
Bin and Polasky (2004)	-	-	-	-$7,460	0.1	-5.7%	-	-	-
Bin et al. (2008)	-$11,598	0.15	-7.3%	$12,325	0.16	-7.8%	-$9,849	0.13	-6.2%
Daniel et al (2009)			−2.6%			-3.27% **			
Bin and Landry (2013) *	-$13,136	0.15	-5.7%	19,064	0.21	-8.8%	-$,2879	0.03	-0.9%

*the estimates used are after Hurricane Fran and average values/s.d. are for the period 1999-2002

** Comes from adding the average standardize effect (-2.6%) to the multiplication between the risk of occurrence per year to the mixed-effect coefficient of the meta-regression -0.0327= -0.026+ [0.01*(−0.637)]
estimate

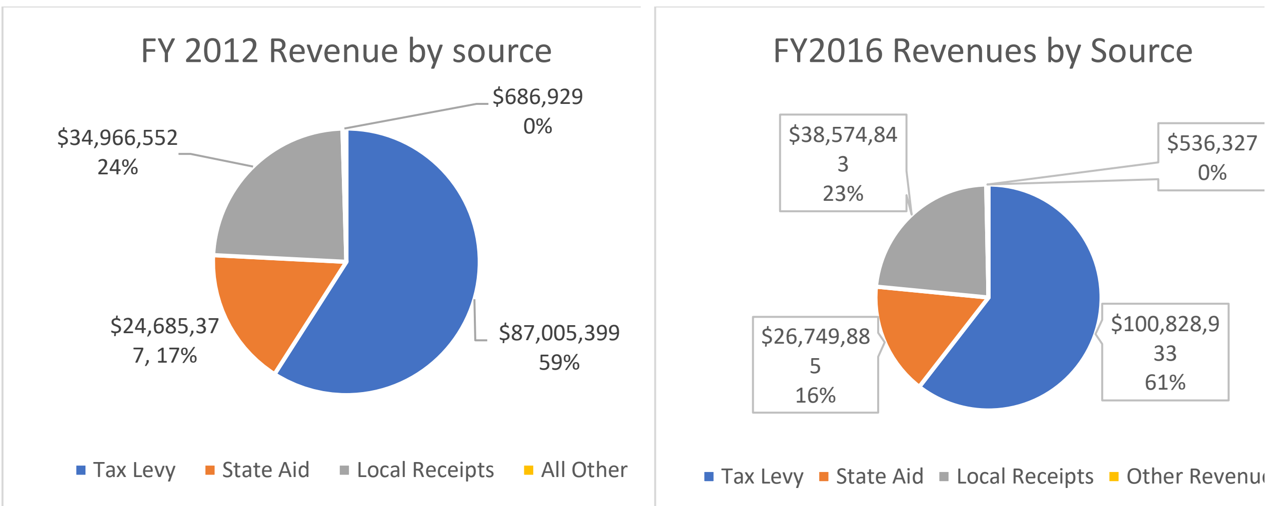
4 – Medford's fiscal and flooding data

4.a- Medford's fiscal data stylized facts

The section develops the main fiscal facts of Medford. Data was retrieved from the Massachusetts government municipal databank[4]. As the projections and predictions are made with assessor's data from the year 2012, this section will show fiscal data from the year 2012. Also, fiscal data for the year 2016 will be shown to put 2012 data in contrast.

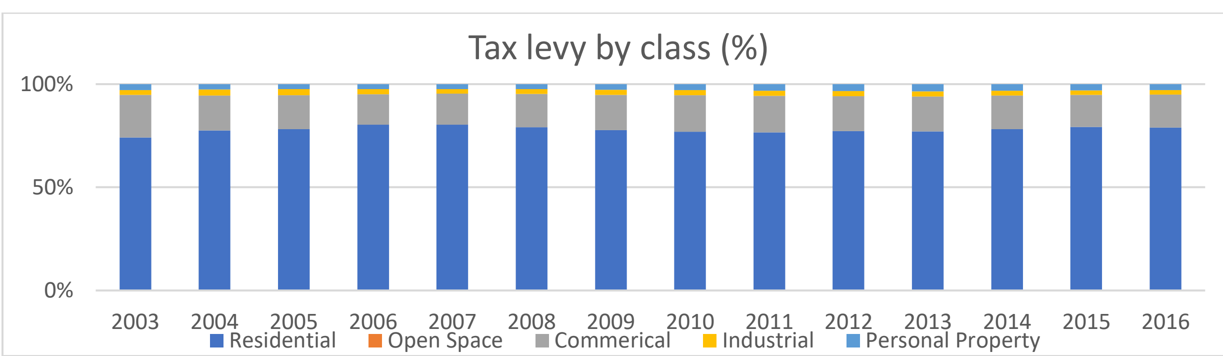
In terms of the revenue side, the most important source of revenue comes from taxes (60%), followed by local receipts (24%) and state aid (16%).

Figure 2 - Revenues by source FY 2012 and FY 2016



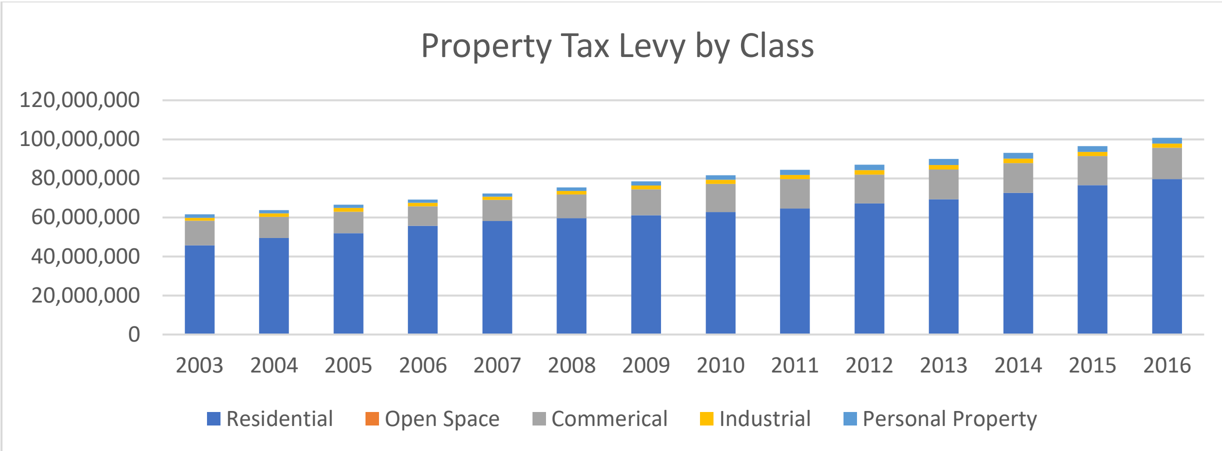
In terms of the tax levy by class, on average in the period 2003-2016, the most of it comes from residential tax, representing approximately 77%, while commercial property represents 16%, tax on industrial property 2.5% and personal property tax is 2.8%.

Figure 3 - Tax levy by class (%)



[4] http://www.mass.gov/dor/local-officials/municipal-databank-and-local-aid-unit/

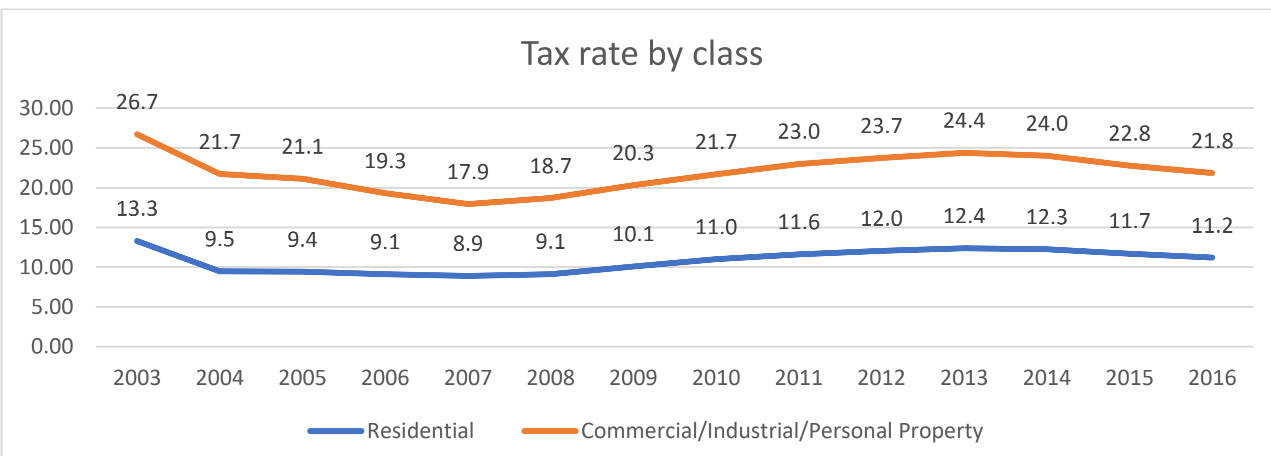
Figure 4 - Property tax levy by class



For the year 2012 specifically, residential tax levy represented 67.1 million dollars, commercial tax levy represented 14.8 million dollars, industrial 2 million dollars and personal property 2.8 million dollars. In the year 2016

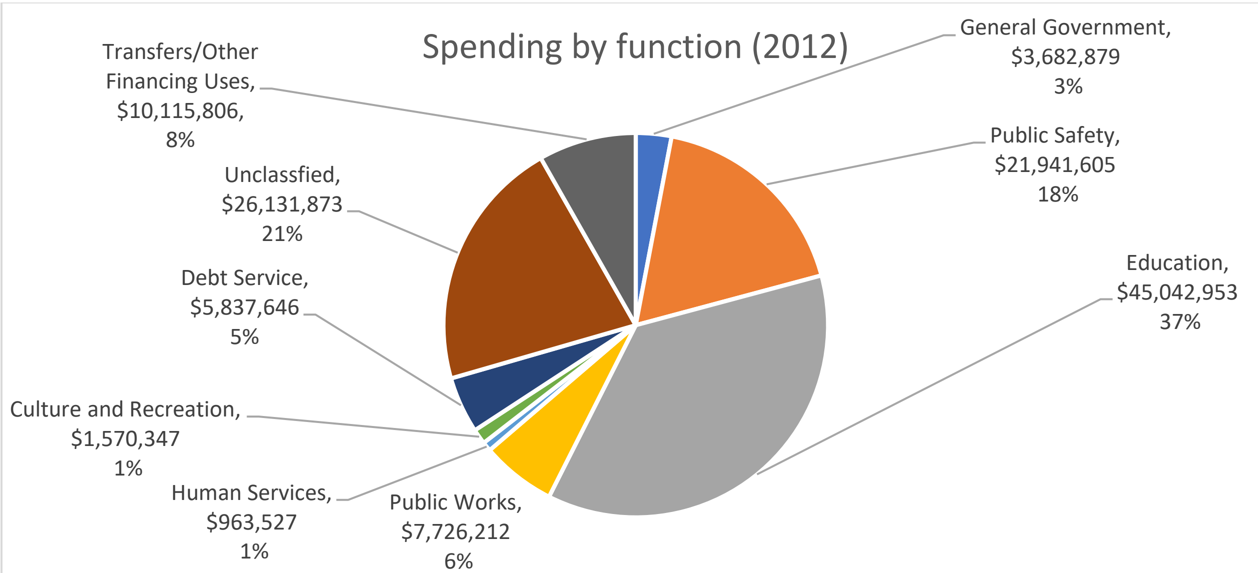
In Medford, **the residential tax rate in Medford in the period 2003-2016 was 10.8% on average, while the commercial was approximately 22%, the same as industrial property rate and personal property.**

Figure 5- Tax rate by class



The major levy comes from residential property which represents approximately 5.8 billion dollars for each year of the period 2003-2016. The other three categories combined averaged 268 million for each year of the period. Also, the parcel count explains the difference in property tax levy, as the 18.084 parcels that were in Medford by the year 2016, 91% are residential and 3% were commercial and industrial combined. The rest were exempt.

Figure 6 - Government spending by function



For the year 2012, government spending in Medford adds up to 123 million and most of it (37%) was allocated to education, followed by unclassified spending and public safety.

4.b – Medford's flooding data stylized facts

This section describes Medford's parcel data under flooding risk. Flooding risk data comes from the Boston Harbor Flood Risk Model (BH-FRM) generated by UMass Boston scientists and Woods Hole Group for the Central Artery/ Tunnel (CA/T) Vulnerability and Adaptation Assessment (2015) commissioned by the Massachusetts Department of Transportation (MassDOT) and the Federal Highway Administration (FHWA). This model provides the likelihood of a particular location experiencing saltwater flooding in a given year for three different years: 2013, 2030 and 2070. Also, it provides the depth of saltwater flooding in a location during a 1% high water event during a given year (hundred-year flood), and the depth of saltwater flooding in a location during a 0.1% high water event during a given year[5]. Parcel data on the maps was reclassified for this policy paper by its fiscal characteristic (residential, commercial, industrial and exempt) in order to quantify the fiscal risk.

Compared to 2013, there is no difference between the number of properties with flooding risk by 2030 as just 35 properties, were under flooding risk. Furthermore, only 33 of them are residential and pay taxes, which represents a 0.2% of the total residential parcels. The other 2 parcels are exempt.

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[5] http://www.bostonharbornow.org/what-we-do/work/climate-change-preparedness/maps/

However, by 2070 the number of properties at risk of flooding increases substantially to 2477, 14% of all properties. The situation differs by property type, as 61% of the Industrial property is under flooding risk by 2070, 21% of the Commercial property and 14% of the Residential property.

Table 2 - Flooding risk parcel by property tax type

	Parcel by property tax type			
Year	**Residential**	**Commercial**	**Industrial**	**Exempt**
2013	33	0	0	2
2030	33	0	0	2
2070	2,248	135	46	48
Total	16,210	632	75	579

Table 3 - Current revenue at risk in flooding risk scenarios by property type (millions)

Variable	Residential	Commercial	Industrial	Total
Collected Tax	$67.11	$14.47	$2.20	$83.78
Collected tax in flood risk area (2030)	$0.13	-	-	$0.13
Collected tax in flood risk area (2070)	$10.20	$5.77	$0.70	$16.67

As it can be appreciated, **property tax revenue coming from parcels that will be affected by floods is small for the year 2030. Nevertheless, for the year 2070, the scenario changes substantially**. There are more properties at risk of flooding and, therefore, there is more potential revenue that might be affected. For residential property, this adds up to $10.2 million dollars (14% of its current revenue). Also, 40% of commercial property tax current revenue and 32% of industrial property tax are at risk in the 2070 flooding risk.

According to the data in section 4.a, the revenue at risk represents approximately 13% of total spending, or the addition of Medford's spending in public works and transfers.

5 –The fiscal impact of flooding in Medford

5.a - Estimations

This section estimates the future assessed value (properties, land, etc.) that is at risk of being flooded by 2030 and 2070. Also, estimates the potential new revenue that will be collected according to the new assessed values (by asset class) and the potential lost revenue. Due to the difficulty of establishing point estimates in long term projections, all the estimations will have a 95% confidence interval.

Despite calculating the assessed value of all parcel by type (commercial, residential, industrial and exempt), only the assessed value of residential, commercial or

industrial parcels was considered when calculating the revenue loss due to flooding risk. Exempt values are obviously not considered. Also, what is usually called "personal property" (equipment within commercial and industrial buildings) is not considered because it is assumed that, despite it is taxes, as movable object it could potentially be removed from the risk zone. Finally, it was assumed that the depreciation caused by flooding risk in a parcel where there is an apartment building was the same for each unit within the building, so the impact on the revenue is the homogeneous.[6].

Based on Daniel et al. (2009), this section considers that the value of properties which have flooding risk of 1% (or more) per year (i.e. that they were in the 100-year floodplain), will be on average 2.6% less than the properties with no risk. The 95% confidence value ranges between 3.18% and 2.02%[7]. As this is a point estimate, this section also considers the 95% confidence interval to have the most accurate picture of the property value depreciation and, its consequent tax revenue loss. As no studies were found on the impact of flooding risk on industrial and commercial property, **this depreciation interval and point estimate was applied homogeneously to all classes of assessed values (residential, commercial, and industrial), despite it was only calculated for residential properties.**

5.a.1. - Property values in the 2030 and 2070 flooding risk scenario

As expected, **the 2030 flooding risk scenario does not vary much from 2012,** it is the 2070 scenario that is more relevant in its fiscal impact. All assessed value (residential, commercial, industrial, and exempt property and land) for the year 2012 is $6.8 billion while the estimation for 2030 is almost the same $6.8 billion.

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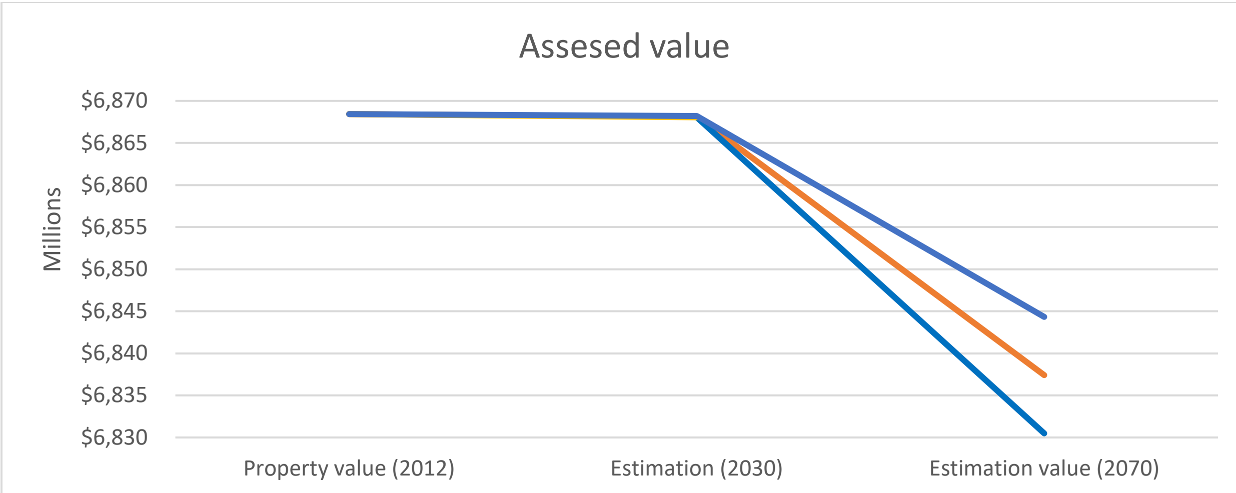
[6] This assumption might be discussed, as the impact on value of properties will probably be higher on the lower units of the apartment building than in the higher ones. Nevertheless, it was used to simplify the model.
[7] Assuming a normal distribution.

Figure 7- Assessed value (current) and estimated for 2030 and 2070



For the 2070 flooding risk scenario, the estimated difference with 2012 assessed value is $30 million dollars in the point estimate. The upper bound confidence interval has $24 million-dollar difference and the lower bound a $38 million-dollar difference. In terms of asset value by class, table 4 shows point estimates and 95% confidence intervals for each of them.

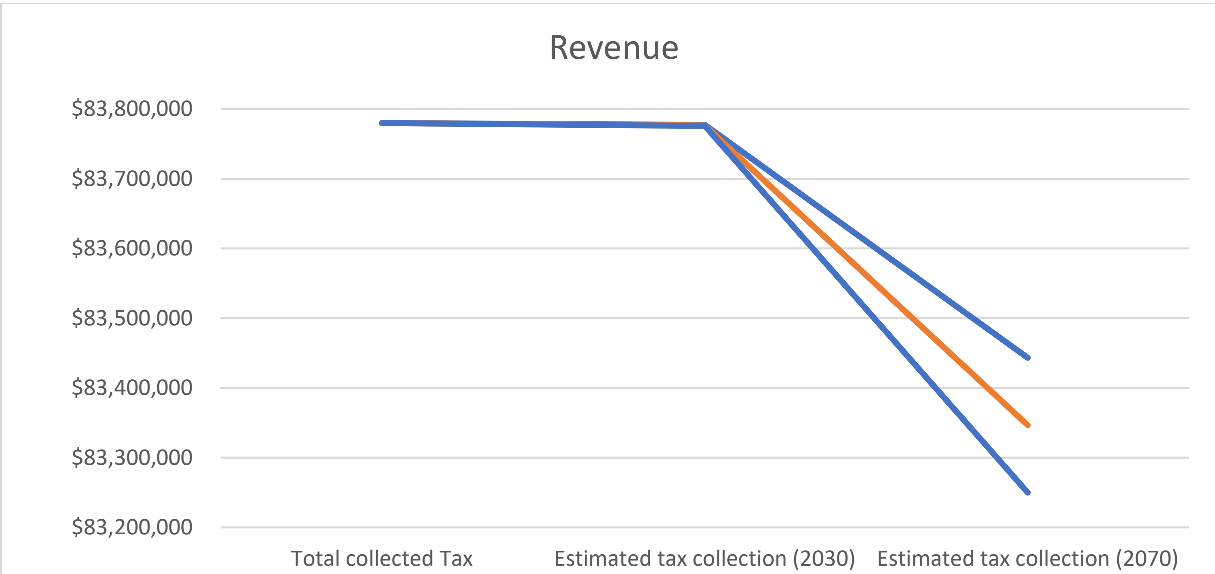
Table 4 - Assessed value by class and assessed value projections 2030 and 2070 (millions)

	Property value (2012)	**Estimation (2030)**	**% difference**	**Estimation value (2070)**	**% difference**	**$ difference**
Upper bound estimation		*$ 5,578.2*	*0.0%*	*$ 5,561.3*	*-0.3%*	*$ (16.91)*
Residential (value)	**$ 5,578.4**	**$ 5,578.1**	**0.0%**	**$ 5,556.3**	**-0.4%**	**$ (21.76)**
Lower bound estimation		*$ 5,578.0*	*0.0%*	*$ 5,551.4*	*-0.5%*	*$ (26.62)*
Upper bound estimation		*$ 610.1*	*0.0%*	*$ 605.2*	*-0.8%*	*$ (4.91)*
Commercial (value)	**$ 610.1**	**$ 610.1**	**0.0%**	**$ 603.8**	**-1.0%**	**$ (6.32)**
Lower bound estimation		*$ 610.1*	*0.0%*	*$ 602.4*	*-1.3%*	*$ (7.73)*
Upper bound estimation		*$ 92.8*	*0.0%*	*$ 92.2*	*-0.6%*	*$ (0.59)*
Industrial (value)	**$ 92.8**	**$ 92.8**	**0.0%**	**$ 92.0**	**-0.8%**	**$ (0.77)**
Lower bound estimation		*$ 92.8*	*0.0%*	*$ 91.8*	*-1.0%*	*$ (0.94)*
Upper bound estimation		*$ 587.2*	*0.0%*	*$ 585.7*	*-0.2%*	*$ (1.45)*
Excent (value)	**$ 587.2**	**$ 587.2**	**0.0%**	**$ 585.3**	**-0.3%**	**$ (1.87)**
Lower bound estimation		*$ 587.2*	*0.0%*	*$ 584.9*	*-0.4%*	*$ (2.29)*
Upper bound estimation		*$ 6,868.2*	*0.0%*	*$ 6,844.3*	*-0.3%*	*$ (23.87)*
Total assesed value	**$ 6,868.4**	**$ 6,868.1**	**0.0%**	**$ 6,837.4**	**-0.4%**	**$ (30.72)**
Lower bound estimation		*$ 6,868.1*	*0.0%*	*$ 6,830.5*	*-0.5%*	*$ (37.58)*

5.b - Property tax collection in the 2030 and 2070 flooding risk scenario

In a similar fashion to the assessed value, the 2030 flooding risk scenario does not vary much from 2012, it is the 2070 scenario that is more relevant.

Figure 8 – Tax revenue 2012 and projections 2030 and 2070



The point estimate difference in revenue between 2012 and 2030 is extremely small, 3 thousand dollars. The 2070 scenario differs more, as there are more properties affected and consequently, its revenue differs more as well. The point estimate difference between the 2012 revenue and the revenue of 2070 flooding risk scenario is $433,368 dollars. The 95% confidence interval differs from the 2012 estimation between $336,692 and $530,040 in its lowest bound.

Table 5 - Tax by class and projections 2030 and 2070 (millions)

	Total collected	Estimated tax collection (2030)	% difference	Estimated tax collection (2070)	% difference	$ difference
Upper bound estimation	$ 67.1	*$ 67.1*	*0.0%*	$ 66.9	*-0.3%*	*$ (0.20)*
Residential (value)	**$ 67.1**	**$ 67.1**	**0.0%**	**$ 66.8**	**-0.4%**	**$ (0.26)**
Lower bound estimation	$ 67.1	*$ 67.1*	*0.0%*	$ 66.8	*-0.5%*	*$ (0.32)*
Upper bound estimation	$ 14.5	*$ 14.5*	*0.0%*	$ 14.4	*-0.8%*	*$ (0.12)*
Commercial (value)	**$ 14.5**	**$ 14.5**	**0.0%**	**$ 14.3**	**-1.0%**	**$ (0.15)**
Lower bound estimation	$ 14.5	*$ 14.5*	*0.0%*	$ 14.3	*-1.3%*	*$ (0.18)*
Upper bound estimation	$ 2.2	*$ 2.2*	*0.0%*	$ 2.2	*-0.6%*	*$ (0.01)*
Industrial (value)	**$ 2.2**	**$ 2.2**	**0.0%**	**$ 2.2**	**-0.8%**	**$ (0.02)**
Lower bound estimation	$ 2.2	*$ 2.2*	*0.0%*	$ 2.2	*-1.0%*	*$ (0.02)*
Upper bound estimation	$ 83.8	*$ 83.8*	*0.0%*	$ 83.4	*-0.4%*	*$ (0.33)*
Total assesed value	**$ 83.8**	**$ 83.8**	**0.0%**	**$ 83.3**	**-0.5%**	**$ (0.43)**
Lower bound estimation	$ 83.8	*$ 83.8*	*0.0%*	$ 83.2	*-0.6%*	*$ (0.53)*

Of all the different type of tax levied by classes, the revenue from Commercial class property is the ones that experiences most fluctuations, as expected by the number of parcels under flooding risk (table 2, section 4.b).

5.d - Partial Conclusion

- As it can be appreciated these figures in relation with the "at risk revenue" represent a small fraction. This difference is anchored in the estimate selected for revaluing the properties that are under flooding risk, which is comparatively small (between 2.2% and 3.18% with an average of 2.6%).

- Medford`s estimated revenue loss in both 2030 and 2070 represents a small percentage of total revenue and a small amount of total spending.

- It is important to take into account that this is a linear analysis of the impact of flooding risk on property value and that there is evidence that the impact might be in fact non-linear. As it was mentioned in section 2, after reaching certain tipping points, property values might all go down suddenly. The complexities of these assumptions are difficult to test with current data.

- Also, it is important to mention that this model does not considerate precipitation related flooding.

6 – Policy Conclusion

This document is part of the Climate Change Vulnerability Assessment of the City of Medford, and it aims to measures the fiscal risk generated due to revenue loss in property tax caused by flooding risk property value depreciation motivated by climate change in the City of Medford.

According to the estimations performed, **no substantial fiscal risk is posed by revenue loss caused by climate change flooding risk in the city of Medford**. Nevertheless, this result should be taken with **caution** as it depends on the **housing depreciation parameter selected to calculate flooding risk on properties, which was quite small**. Also, this document provides a linear analysis, but many authors have argued that **flooding risk might have non-linear impact on property values, generating tipping points after which the generalized value of property go down suddenly.** Future studies should be made analyzing this potential effect both on property values and tax revenue. Also, a special consideration to precipitation related flooding risk and storm surge should be taken in future studies.

7 - Data caveats

To have coherent results with other economic estimations performed for the CCVA, the data used in the estimations of the property values comes from MassGIS, which provides “level 3” assessors data from Medford in the year 2012[8]. This data feeds the Massachusetts Interactive Property Map. This means that the number of parcels and its land, building, other and total valuation comes from this site which guarantees standardization of assessor parcel mapping for 350 of Massachusetts' 351 cities and towns.

The data on the chances of flooding for each parcel comes from the Medford CCVA that uses the estimations done by the Boston CCVA for each parcel. This data provides flooding probabilities for each parcel in the year 2013, 2030 and 2070.

The data from MASSGIS (detailed data by parcel) has also minor discrepancies with the data of the MASS Municipal Databank (fiscal data), despite they should be retrieving their information from the same source. The number of properties differ and, consequently, the total value by property type. As a result, also the calculated revenue by property type. In the table 3 below the amount of properties by type and their valuation for each dataset it shown. As this document works with both point and interval estimations, these discrepancies are not statistically significant.

Table 6 - Discrepancies between MASSGIS data and MUNIMAP data

Variable (dataset)	Residential	Commercial	Industrial
Property value (MASSGIS)	$5,578,378,752	$610,099,520	$92,771,200
Property value (MuniMap)	$5,581,478,578	$624,804,322	$92,612,400
Collected Tax (MASSGIS)	$67,107,896	$14,471,560	$2,200,533
Collected tax (MuniMap)	$67,145,187	$14,820,359	$2,196,766
Properties (MASSGIS)	16,210	632	75
Properties (MuniMap)	16,265	617	75

[8] http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/download-level3-parcels.html

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Resources

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http://www.mass.gov/dor/local-officials/municipal-databank-and-local-aid-unit/databank-reports-new.html

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[i] Assumes moderate rate of ice sheet melt that increases over time and projects an ultimate rise of four feet (1.2 meters) above 1992 levels, globally, by the end of this century and heat-trapping emissions that continue to grow through the middle of this century then decline slowly thereafter)