CITY OF SEATTLE DEPARTMENT OF PLANNING & DEVELOPMENT

SEATTLE UNREINFORCED MASONRY RETROFIT POLICY:
Benefit Cost Analysis

Prepared by Gibson Economics and CollinsWoerman

APRIL 11, 2014

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LIMITATIONS: The economic analysis services described in this report were performed based on available information. No warranty is made as to the professional advice included in this report. This report provides an overview of benefit cost issues and does not address individual building's risk, costs, or benefits. This report has been prepared for the exclusive use of the City of Seattle's Department of Planning and Development and is intended to inform the decision-making of city policy makers. It is not intended for use by other parties and does not contain sufficient information for purposes of other parties or their uses.

This report is in no way intended to guide or indicate the structural integrity of any building. These results are based upon the information available at the time and do not purport to represent a complete picture of the issues, properties, or impacts of an earthquake disaster on any or all buildings in Seattle.

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APPENDICES

UPDATE – APRIL 11, 2014

This is an updated version of the Seattle Unreinforced Masonry Retrofit Policy Benefit Cost Analysis. The most significant change is a clarification that more accurately reflects the probability of earthquakes in Seattle. This change in probability cascades throughout the analytics conducted for this document and creates higher values for avoided losses. Those higher values improve the benefit cost ratio but not enough to change the basic nature of the original findings. These amended values are reflected in the tables throughout the report.

There were also a number of comments from the earthquake engineering community that the impact of the earthquakes as modeled by HAZUS was lower than expected. The general feedback seemed to be that these results were probably within the low range that could be expected. In particular, several reviewers believe that HAZUS does not fully account for the extended duration of a Cascadia Subduction Zone earthquake. These long duration earthquakes can continue for 100 seconds and more. This kind of continuous shaking could impact URMs structural integrity. As stated in the report, HAZUS is a widely used modeling tool for estimating earthquake impact that does model both intensity and duration, as reflected in the substantially higher contents damage for Cascadia. Yet some reviewers are not persuaded that the HAZUS characterization of the Cascadia quake goes far enough. To account for these concerns, both the original and amended version of this report includes sensitivity analyses that test the inherent uncertainties in the inputs. This updated report expands the range of sensitivities tested for shaking and damage and many other parameters to try and capture the outer bounds of the uncertainty.

Other comments from reviewers have been carefully considered and where appropriate changes have been made accordingly. For example, the multipliers used by FEMA to account for deaths and causalities have been escalated to reflect the five years of inflation since the official FEMA numbers were last published.

INTRODUCTION

Unreinforced masonry buildings (URMs) are historic reminders of Seattle's past. For more than a century URMs have been host to shops and hotels, apartments and schools, entrepreneurs and small businesses. Even today URMs continue to play an ongoing role in the life of the city. People are attracted to their diversity of character and human scale.

Unfortunately, URMs are vulnerable to earthquakes. When shaken, bricks and mortar can crumble, floors can collapse, and parapets can fracture and break putting tenants and owners at risk of injury or death.

City leaders want to protect the health and safety of citizens and at the same time assure that URMs will continue to be part of Seattle's future. Toward that end Seattle's Department of Planning and Development convened a URM Policy Committee to develop a series of recommendations for URM buildings to protect life safety. The Policy Committee recommended a seismic retrofit policy that would require URM building owners to apply a "Bolts Plus" standard to reinforce URMs. The Policy Committee recommended a compliance schedule and three categories of URM buildings (medium risk, high risk, and critical). The committee also proposed that the City undertake a benefit cost analysis to further understand the impacts of such a policy. In addition, the City sought to identify potential incentives that might tip the balance towards retrofit for URM building owners.

The result of the benefit cost analysis is below. It shows that the financial burden to retrofit URMs is significant. The cost to owners can range from $20 to $50 per square foot. For a small number of owners this may be a manageable, particularly those who have identified a market that can afford higher lease rates. But except in this limited situation, the cost of a seismic retrofit would be very large and would significantly exceed the expected increase in benefit.

The economics of retrofits are particularly tough because the avoided costs of damage to buildings and avoided deaths and injuries are only experienced if there is an earthquake - and the likelihood of an earthquake large enough and long enough to cause significant damage is only 4.1 percent in any given year. Thus a mandatory policy would require a 100 percent chance of spending dollars to retrofit with only a minimal expectation of benefit in any year thereafter.

This economic reality makes seismic retrofits unattractive to most owners. Ironically, this analysis shows that if the city were to require retrofits there is a very real risk of losing more URMs to owner demolition than to the earthquakes.

The challenge before the city is to develop a suite of strategies that make sure that URMs continue to contribute to the diversity, character, and aesthetics of our city for years to come while protecting public health and safety. This report is designed to give insight to Seattle policy makers and staff on that challenge.

Following the Report Synopsis are a series of task memos that define the analysis. They describe the assumptions, parameters, and results. Task 1 defines three alternative approaches to retrofitting URMs: business-as-usual, "Bolts Plus", and "beyond Bolts Plus". The intent of these three alternatives is to bookend the analysis results. Task 2 identifies the ranges of impacts and who bears the costs of seismic events as well as the costs and benefits of a mandatory retrofit policy. Impacts include repair costs, damage to building contents, displacement and loss of neighborhood character among several others. Task 3 defines the seismic framework for the analysis, describing the representative earthquakes and how URMs respond differentially to increased shaking in each event. Task 4 calculates and quantifies the crucial impacts on URMs from the three modeled earthquakes, addressing potential building damage, economic loss and casualties. Task 5 is broken into two sub-tasks. In Task 5.1 it all comes together as the costs for damage and the costs and benefits of retrofits are compared, based on the full range of projected scenarios. The results in Task 5.1 are then tested to see how sensitive they are to different assumptions used in the analysis. These sensitivity analyses indicate that the results change very little based on a reasonable range of alternative assumptions. Task 5.2 clarifies how reality might play out on the ground because of owner choices in responding to a mandatory policy. These choices range from retrofit to demolition to avoiding compliance as long as possible. Task 6 evaluates a suite of incentives that might be deployed by the city to encourage and incentivize retrofits for URM building owners.

On the following page is a detailed synopsis of the analysis.

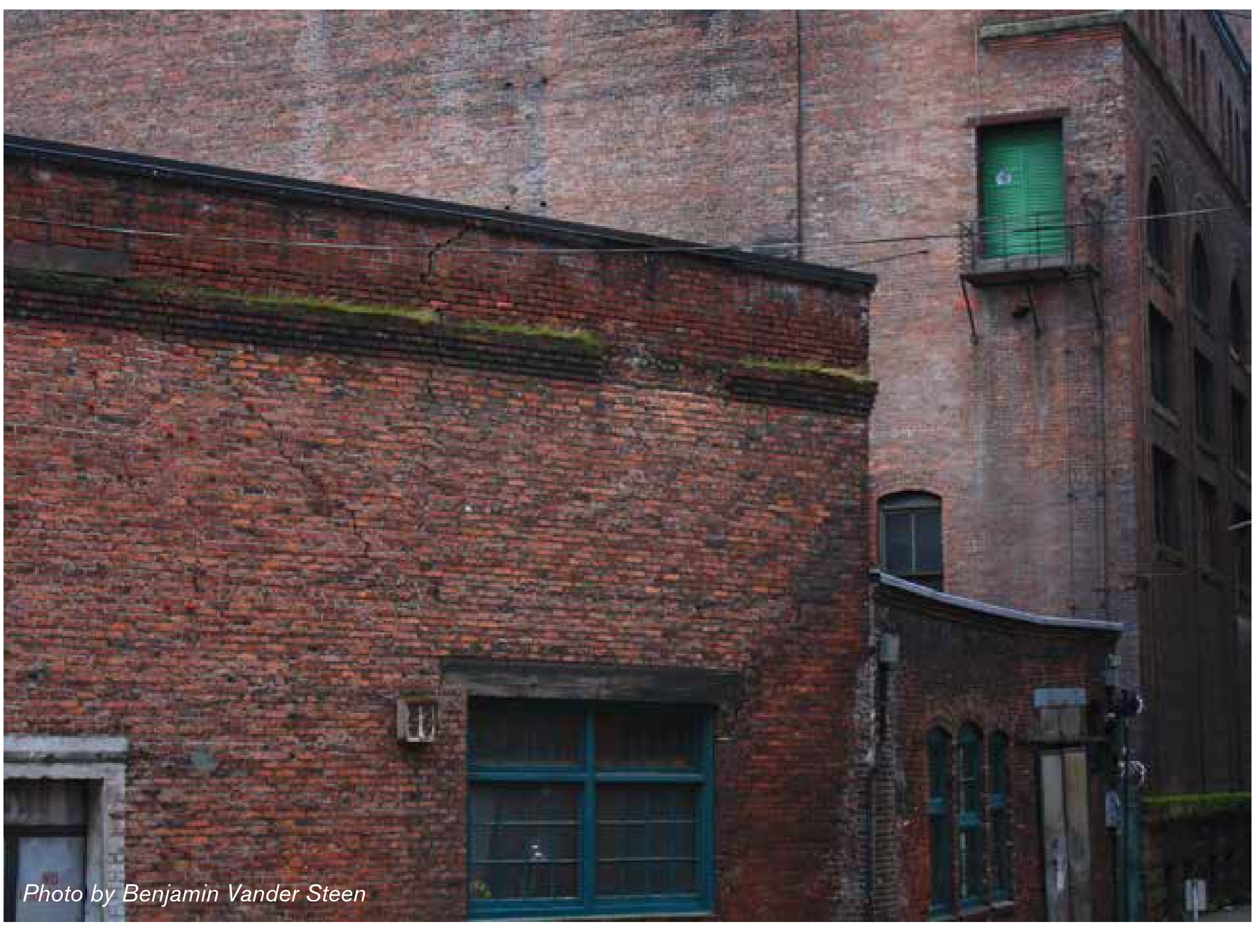


Photo by Benjamin Vander Steen

REPORT SYNOPSIS

This report is intended to give insight to Seattle policy makers and staff as the City of Seattle considers a mandatory retrofit policy for unreinforced masonry buildings. There are many factors at play, but a dominating factor affecting the outcome is that a mandatory policy would create nearly a 100% certainty of a major cost to the URM building owner yet the probability of experiencing an earthquake in any given year is only about 4.1%. The probability of sustaining significant losses in those earthquakes is still lower. The inclusion of casualty reduction impacts and neighborhood cohesion impacts as additional benefits of retrofits improved the benefit-cost disparity, but only to a limited extent.

While the benefit-cost analysis does not lend strong support to a mandatory seismic retrofit policy, there remain a range of seismic retrofit policy options for URMs between a current policy and a city-wide mandatory retrofit policy. The results of these analyses suggest that a targeted array of incentives might be applied strategically to encourage retrofits without a full-scale mandatory requirement. The annual risk of an earthquake is a risk that can never be precluded but that can be managed in a context with all the other risks that impact life safety in the city.

A number of sensitivity analyses were conducted to test the impact of various assumptions used in the analysis.

The impacts of retrofits for individual buildings were recognized to vary considerably, with some much closer to voluntary retrofit decisions than others. Accordingly, a suite of incentives was identified that may be used to incentivize compliance of owners of URMs, and evaluated for their potential value in voluntary or mandatory programs. In addition, some thoughts were offered about how additional policy options might be considered based on these results.

The analyses that lead to the findings of this report were extensive. A carefully constructed series of analytical steps are described in this report in a series of task memos. Each task builds upon the other. Parameters of the analysis are discussed and analyzed below for the purposes of illuminating the benefits and costs of a new URM policy.

Task 1 Memo sets the basis for the analysis by defining and providing physical descriptions of three alternative approaches to the retrofitting of URMs: Business-as-Usual where there is little-to-no retrofitting of URMs (representing current policy[1]); Bolts Plus, a set of specific strengthening measures reflected in the proposed mandatory retrofit policy outlined by DPD based on work by DPD's technical and policy committees in order to enhance public health and safety; and, Reinforced, a place-holder for "beyond Bolts Plus" that represents the highest level of structural retrofits to significantly reduce damage from Seattle's earthquakes.

Task 2 Memo provides information on the range and types of key impacts associated with seismic events, seismic retrofits, and a mandatory policy requiring retrofits. These impacts include both costs and benefits, and are intended to support the subsequent benefit-cost analyses. Ironically, some impacts are both, as a cost to one party might be seen as a benefit to another. The memo discusses how some costs and benefits are quantifiable, while others are more suited to qualitative description. Both are valuable for policy evaluation.

Among the costs associated with seismic events, building repair costs are the largest, but the impacts considered also include damage to building contents, displacement of tenants, loss of business during repair, and loss of community benefits such as neighborhood character and historical value of certain significant URM buildings. Casualties and deaths to building occupants are also included, and presented in both qualitative and quantitative terms.

Benefits associated with seismic events are measured and described as the reduction of losses that would otherwise occur absent a retrofit. This information is developed through comparative analysis of seismic impacts for buildings with and without retrofits.

Costs associated with retrofit of a URM to the Bolts Plus standard were also identified as critical for analysis. In reviewing several case studies and after discussion with structural engineers and building owners, estimates for a Bolts Plus retrofit were determined to be in the $20 - $50/ per square foot range. Each building has a unique set of physical opportunities and constraints, so the breadth of the range fits best with expert opinion on the level and building-by-building variability of likely overall costs to owners.

Additionally, a number of both benefits and costs were identified that would be associated with a mandatory retrofit policy itself. This memo pointed out that there is a range of second-best choices a URM owner would consider if required to meet a Bolts Plus standard. Those choices range from compliance to demolition to delay and non-compliance. The impacts of a mandatory policy are linked to the distribution of such choices that would be made by building owners.

Task 3 Memo describes the key parameters needed for

1 Current policy does require retrofits when substantial alterations or new land uses are proposed for URMs. Also all existing URMs are required to brace their parapets but this is not universally done by building owners.

the benefit cost analysis and developed baseline values and sensitivity ranges for each. First, this phase of the analysis determined how buildings of varying seismic strength would perform in earthquakes of different intensities that could occur in the Seattle region. "Fragility curves" are typically used to indicate how certain buildings perform in earthquake events of different intensity. Different curves have been developed by structural engineers for different construction types. A new Bolts Plus fragility curve was developed for this study. All buildings perform differently depending on the characteristics of the quake's severity and location as well as building height and underlying soil stability. To measure the difference before and after, retrofit fragility curves were created or selected for several subcategories of buildings, to sort out the different ways that differently configured buildings react to the shaking.

Second, a fully representative set of typical earthquake events large enough to impact URMs in Seattle was determined, together with their respective probabilities of occurrence. Recurrence intervals provided by Dr. Art Frankel of USGS were used to estimate the annual probabilities of each of the different representative Seattle earthquakes. The three representative quakes selected for the analysis (in increasing order of severity to Seattle) are: i) the Nisqually-type earthquakes of magnitude 6.8., ii) Cascadia Subduction Zone quakes of magnitude 9.0, and iii) Seattle Fault quakes of magnitude 6.7.

Estimated recurrence intervals over 50 years for these quakes are 84%, 14%, and 5% respectively. Uncertainties regarding event probabilities are high even for experts, so the impacts of higher and lower probabilities were also tested as part of the benefit-cost analysis to see if the results changed significantly. As each of these types of quakes could happen in any given year, taken together there is an annual 4.1% probability of an earthquake of these magnitudes. The least damaging Nisqually-type quake accounts for most of this probability. The large and very large quakes together have an annual probability of just 0.4%. Even lower magnitude quakes are much more probable, but they were not included in the analysis as they were considered less likely to significantly affect URM stability.

Third, a set of economic parameters for the analysis were developed. Given that most URMs are more than 75 years old, the remaining building life for URMs was assumed to be an additional 20-50 years. Some may last much longer but others may not. The analysis used discount rates of 3% - 10% for the analysis, recognizing that different building owners might measure the value of money spent sooner versus later in different ways. The impact of the ranges for each of these parameters was tested in a subsequent sensitivity analysis to determine if the results shifted dramatically.

Task 4 Memo presents estimates of the building damage, economic, and casualty impacts of the three representative earthquakes on the potential URM buildings included in a database provided by DPD.

The URM database identified 929 buildings that met the visual criteria as URM. These were analyzed in the alternative assumptions: as un-retrofitted URMs, as URMs retrofitted to Bolts-Plus levels, and as similarly sized and located reinforced masonry (RM) buildings. It is recognized that this list of potential URMs is imperfect and may over-state or under-report the actual number of URMs in Seattle. To address this issue, analytical results were presented based on the average benefits versus the average costs. Their variability was also noted as a critical feature of the information for building-by-building application. While the aggregate total of impacts and costs might change with more or fewer buildings, the average levels of benefits and costs, and thus the aggregate benefit-cost ratio, are more likely to stay stable even with a change in the size of the URM inventory.

The analysis recognizes that the intensity of damage would vary for URM buildings of different heights, so the analysis disaggregates the database into sub-groups of shorter versus taller URMs. Underlying soil types also affect building performance - i.e., damage - in earthquakes, so the analysis assembled information on buildings located in liquefaction zones.

Location also plays a role as proximity to the epicenter of the quake impacts to the building. This is most pronounced in a Seattle Fault earthquake as the epicenter is directly under the city and a difference of a few miles could magnify or reduce the impact. The other two representative earthquakes have epicenters further from downtown Seattle, and each produces more uniform levels of shaking (one producing more, the other less) throughout the City because of the greater distance from any Seattle location to their respective epicenters. Longitude and latitude information on each building was included to capture the differential effects of their proximity to the epicenters.

Location plays a role, too, in race and social justice concerns regarding both earthquakes' and retrofit policies' potentially differential impacts. Seattle neighborhoods tend to have persistent profiles of racial diversity or income levels. This perspective was examined through an evaluation of URMs' locations. Two maps are included in **Task 4** that show the location of URMs vis a vis racial diversity and income based on 2010 US Census data. In both cases, it appears that

URMs in Seattle are similarly represented in areas with above and below average incomes, and in areas with above and below average racial diversity. The concentration of commercial use URMs in central core areas increases the overall representation of URMs in those areas, but that does not relate directly to the residential focus of the race and social justice issues.

An important tool used to analyze the impacts of major disaster is FEMA's HAZUS risk assessment module, which has been used for previous earthquake impact studies in the region. We used the most detailed option among the HAZUS models, the Advanced Engineering Building Model and applied it to over 135 cases involving different subsets of buildings, earthquakes, and assumed building conditions, to provide impact information on various subsets of Seattle URMs.

The results show, as expected, that building damage, economic losses and casualties are lower with Bolts Plus reinforcement. The HAZUS damage estimates provide crucial information on the difference in those impacts, which support the benefit-cost analysis in the **Task 5.1 Memo**. Detailed findings of the HAZUS runs are included in the Appendices 4a-4c. Among the interesting results of this analysis was the finding that the majority of unretrofitted masonry buildings in Seattle would survive even the largest earthquakes modeled.[1, 2]

Task 5.1 Memo presents the baseline benefit-cost analysis of seismic retrofits to URM buildings. It combines the impacts estimated in the **Task 4 Memo** with retrofit cost information described in **Task 2 Memo**, and uses the economic analysis parameters described in **Task 3 Memo**. It also includes a set of sensitivity analyses. It calculates these results under the assumption that all potential URMs were unreinforced and all owners complied and implemented Bolts Plus retrofits.

The benefits of Bolts Plus come at a steep price. The analysis determined that for every $100 spent by a building owner to retrofit a URM, the long-term benefit in avoided losses (in present value) is $3.30. When death and casualties are monetized using FEMA multipliers, the total benefit more than doubles, but is still only $7.60 for every $100 spent.

How do these results differ if different assumptions are considered? A number of sensitivity analyses are included in **Task 5.1** including a range of retrofit costs from higher to lower, higher and lower building values, different content values, displacement and business disruption values, higher and lower discount rates, shorter and longer time horizons, and higher and lower likelihood of earthquake events. In each case, the range of calculated values hovers very near the original results.

The baseline results in **Task 5.1** Memo assume that all the buildings in the DPD database were indeed URMs and it assumes that all URM building owners would retrofit to the Bolts Plus standard. Yet we know that the data base is incomplete and we know that building owners have more than one choice in responding to a mandatory retrofit policy.

Thus **Task 5.2 Memo** looks at the benefits and costs of a mandatory retrofit policy, taking into account the range of alternative owner responses to a mandatory retrofit policy. Their choices range from retrofitting their building to the Bolts Plus standard, to demolishing and building a new building, to demolishing and leaving the site vacant, to deferring action and disregarding the code as long as possible. **Task 5.2** identifies the benefits and costs of each of these various second-choice options of owners and identifies characteristics of the building and the location that might influence their choices. Among the key findings of **Task 5.2** is that the switch to a second-best option would allow many owners to improve the benefit-cost results relative to simply retaining their URM building and performing a seismic retrofit, although they would still sustain net economic losses.

Task 6 Memo addresses the potential for incentives that might encourage property owners to retrofit and comply with the policy intent of Bolts Plus. The task covers a range of alternative levies and a list of most promising incentives for seismic retrofits. Incentives selected for additional consideration are a federal historic tax incentives, a King County tax exemption for costs to upgrade historic buildings, a new potential property tax exemption for URMs that comply with Bolts Plus retrofits, and a potential site density bonus for property owners who retrofit their URM to a Bolts Plus standard. Transfer of development rights (TDRs) were considered but were not attractive given the likelihood of competition with affordable housing programs by exacerbating the oversupply of transferable rights. **Task 6** includes estimates of the range of incentive values that might be generated by these programs separately and together, and finds that while certain types of buildings would have the greatest opportunities for incentive assistance, the level of that assistance could in some cases be substantial.

A number of **Appendices** are included in the report for those most interested in the specifics of the various analyses contained in this report.

1 This is based on HAZUS runs for un-retrofitted URMs, which found that the percentages of such buildings experiencing either no damage, or only slight or moderate damage, would be 90%, 85%, and 55% for the Nisqually, Cascadia and Seattle representative quakes, respectively, while only 10%, 15%, and 45% would sustain either extensive damage or total destruction in those same quakes.

2 The impact on URMs may be under represent for a Cascadian Subduction Zone quake by HAZUS, according to some experts, as HAZUS may not adequately account for the long duration of these massive quakes.

A modest unreinforced masonry building serves as a sales office in an industrial area of Seattle.

TASK 1 MEMO: Retrofitting Unreinforced Masonry Buildings

The purpose of this memo is to document and define the three alternative approaches to seismic retrofits for unreinforced masonry (URM) buildings in the City of Seattle. The three alternatives being considered are:

1. Business-as-usual
2. Bolts-Plus: Moderate seismic retrofit to protect life safety of building inhabitants
3. Reinforced: More extensive retrofit that would be more likely to preserve the building and inhabitants

This report is focused on the URM Technical Committee's Draft URM Retrofit standards. Those standards would be applied on a case-by-case basis. In some instances the "Bolts-Plus" measures described above would be required; in other instances some enhanced measures described as "Beyond Bolts-Plus" would be required. And some buildings would comply without doing any more work because they have already been retrofitted. **The application of these alternatives would differ from building to building and thus would translate to differing seismic retrofit costs per square foot from one building to the next.** Thus a range of costs per square foot will be used for this analysis. That variability will be further illustrated through sensitivity analysis of the assumed retrofit cost.

The application of these alternatives would differ from building to building and thus would translate to differing seismic retrofit costs per square foot from one building to the next.

Alternative 1: Business-as-usual

Currently, the only significant City of Seattle code requirement relating to seismic upgrades for URM buildings outside of substantial alterations relates to parapet bracing. Parapets on URMs must be anchored to the building in such a way that they can sustain the design loads specified in the building code. Unreinforced parapets are considered "unsafe building appendages" and regulated as a public nuisance that are required to be abated. However, this provision is inconsistently enforced as it relates to parapets on existing buildings that are not otherwise in disrepair.

"Substantial alterations" of URMs will trigger a requirement to strengthen the building for seismic loads. The amount of strengthening required is based on a structural engineer's report describing the deficiencies in the building, which then informs DVD as to what is feasible to require.

A diagram illustrating a typical parapet bracing design is shown in **Fig. 1** below. **Fig. 2** illustrates the exterior appearance of a URM building with a braced parapet wall.

Fig. 1: Parapet bracing illustration

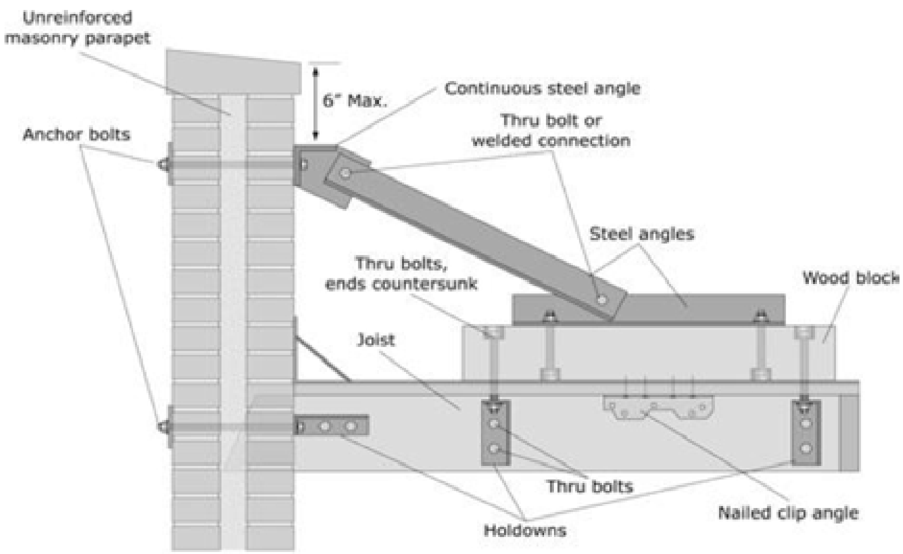


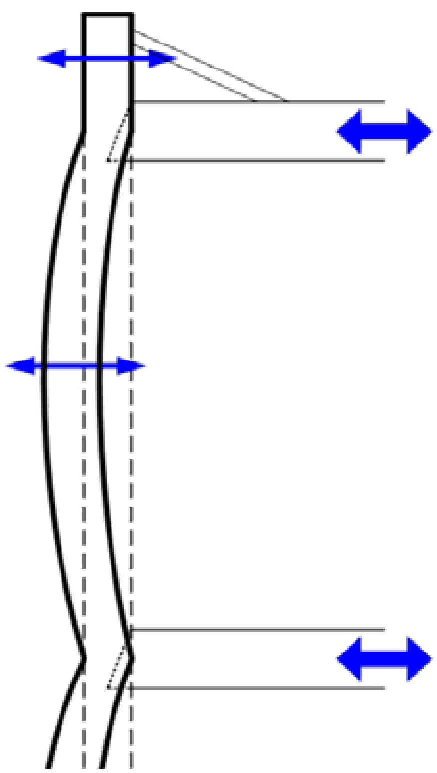
Fig. 2: Exterior of URM with reinforced parapet wall highlighted

Alternative 2: Bolts-Plus– Moderate seismic retrofit to protect life safety of building inhabitants

The “Bolts-Plus” method of seismic retrofit for URMs refers to the program that was adopted by the City of San Francisco in 1992 as part of Ordinance 225-92, completed in 2006.[1] It is generally viewed as the least intrusive program for property owners, and provides some meaningful reduction of risk of building collapse in an earthquake.[2] California’s “Bolts-Plus” standard essentially involves the installation of shear and tension anchors at the roof and floors, and, when required, the bracing of the unreinforced masonry bearing walls. By anchoring these components together, building walls are much less likely to collapse.

As part of the San Francisco Building Code (2010 Edition), unreinforced masonry buildings may be strengthened to the Bolts-Plus level by complying with the code that specifies a number of structural requirements. These include requirements for wall anchorage, diaphragm shear transfer, and out-of-plane wall/parapet bracing. Specifically, these requirements include (but are not limited to) that the building does not have certain irregularities, such as a soft or weak story, a specified level of mortar shear strength, wood or plywood diaphragms at all levels above the base, is a maximum of six stories above ground level, and other critical structural considerations. A full explanation of these requirements can be found in the San Francisco Building Code, Chapter 16C, Section 1609C.

Figs. 3 & 4: Diagram of “Bolts-Plus” intended effect on structural performance during an earthquake event. Retrofits keeps walls from bowing out, secures connections between walls and floors, and braces parapets; Exterior appearance of a masonry structure following a “Bolts Plus” type retrofit.



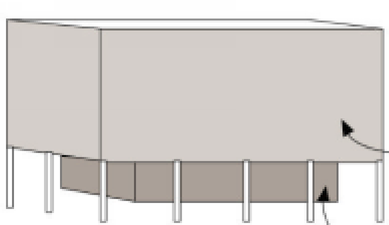
1 This ordinance was funded by a voter-authorized $350M in bonds to fund low-interest loans to URM owners ranging from 2.5 – 8%. The 2.5% interest rate applies to retrofitted buildings with affordable housing; standard retrofit loans carried an interest rate of 8.5%.

2 City of Seattle URM Policy Committee Meeting minutes. March 22, 2012.

In November, 2011, the Unreinforced Masonry Building Technical Committee, with much assistance from the Structural Engineers Association of Washington Existing Buildings Committee (SEAW) recommended that Seattle adopt a modified Bolts-Plus standard for URMs. The technical committee report, "… modifies portions of the San Francisco ordinance that describe the conditions where the prescriptive method may be used. It allows buildings with diaphragm discontinuities such as split-level floors and roofs, and out-of-plane offsets in which one story is offset relative to the continuation of that element in an adjacent story (See Figure below) to use the prescriptive method. It also allows all occupancy groups and buildings with any number of stories to use the prescriptive method. "

Alternative 3: Reinforced –More extensive retrofit that would be more likely to preserve the building and inhabitants

A more extensive seismic retrofit beyond the "Bolts Plus" approach could involve a number of strategies. These include adding seismic bracing or strengthening walls, for example, by coating the unreinforced walls with a reinforced concrete layer, placing reinforced concrete "ribs" or structural plating within the wall, or by using other materials such as a reinforced carbon fiber composite to one or both sides of the walls.[3] These seismic reinforcement techniques can add substantial strength to masonry walls and increase the overall structural integrity of a building during a seismic event. These reinforcement strategies can help save lives and reduce damages that can impact the economic use of buildings. However, they also typically require an extensive (and often expensive) effort to retrofit affected buildings.



One example of such a retrofit was recently completed for King Street Station in Seattle. Cross bracing and steel columns inserted into perimeter walls, new beams, diaphragm bracing and structural plating were installed as part of an extensive seismic retrofit and historic restoration effort. Other retrofit features included high-strength grout for the masonry, steel floor plates installed on upper stories, and new shear walls added in the interior.[4]

The examples shown to the right illustrate a range of anticipated Bolts-Plus retrofit measures.

A fourth alternative included for context in the benefit-cost calculations is reinforced masonry construction. This alternative has been defined primarily to provide an analytical "bookend." It allows for modeled estimation of earthquake damage for the ideal of masonry buildings constructed to modern codes and standards, and provides perspective on how far Bolts-Plus retrofits would move toward that ideal.

Conclusion

The examples shown above illustrate a range of anticipated Bolts-Plus retrofit measures. In some instances the "Bolts-Plus" measures described above would be required; in other instances some enhanced measures described as "Beyond Bolts-Plus" would be required. This would translate to differing seismic retrofit costs per square foot from one building to the next. That variability will be reflected in the cost component of the benefit cost analysis and further illustrated through sensitivity analysis of the assumed retrofit cost. As a result, those two retrofit alternatives will be collapsed into one extended "Bolts-Plus" alternative with an acknowledged level of building-to-building variability underlying a City-wide average cost.

Thus, the quantitative analysis in later sections will focus on a comparison of Bolts-Plus and an assumed Baseline of un-retrofitted URMs. The fourth alternative, reinforced masonry buildings, will be included essentially as a "bookend," although its analysis will also shed light on the seismic damage implications of cases in which URMs are demolished and replaced by reinforced masonry "equivalents."

3 Seattle Department of Transportation.King Street Station Restoration.http://www.seattle.gov/transportation/kingstreet.htm Accessed 5/1/2013.

4 Breiholz, David C. "Rehabilitation Option for CenterCore Strengthening System for Seismic Hazard Reduction of Unreinforced Masonry Bearing Ball Buildings."

Fig. 5: King Street Station (Seattle) Seismic Upgrades – Reinforcement of masonry wall with steel columns and cross bracing

2012-9.9_e7078+79 Reinforcing of tower cross bracing starts at center – 4th floor, north wall. photo: John Stamets

Fig. 6: King Street Station (Seattle) Seismic Upgrades –Steel structural wall plating inserted into masonry walls

2012-9.25_d9045 Elevation view of lobby's south wall with structural wall plating installed. photo: John Stamets

An unreinforced masonry building nestles between two larger and newer buildings in Seattle.

TASK 2 MEMO: Identification of Key Impacts

The purpose of this memo is to identify the key impacts to the various "owners" of benefits and costs associated with seismic events and impacts from potential URM retrofit policy changes. Major "owners" of costs and benefits can include building owners, tenants, members of the community.

Some benefits and costs can be easily measured in terms of financial value; others, especially those with social or environmental implications, may be more difficult to measure and quantify. Identifying a full range of benefits and costs is critical to the analysis of possible alternatives for policy actions. Ideally, the benefits associated with a given policy alternative should outweigh the costs.

Potential costs would be incurred from various impacts resulting from a seismic event. A separate set of benefits and costs would be related to performing seismic retrofits. Potential costs and benefits can also be identified in general terms for a potential policy change that would require URM retrofits, without specifically identifying the extent of the retrofits.

Potential Costs and Benefits Associated with URM Retrofits

For this study, identification of costs and benefits associated with URM retrofits resulted from several separate efforts:

- meetings with City staff and Technical Resource Group,
- meetings of the Seattle URM committee,
- input received from building owners and developers, and
- review of previous studies of earthquake impacts.

It is important to recognize that costs and benefits are often closely related and difficult to place in discrete categories – what is a cost to one party might be a benefit to another. For example, a new URM policy might impose enough added costs on building owners to retrofit their buildings that building replacement becomes the best choice. However, this may prove to be a community benefit in areas where redevelopment could create new economic opportunities (along with safer buildings). It could also be viewed as a potential cost to the community in terms of lost historic identity or character.

Another feature of seismic retrofit benefit-cost analysis is that most of the potential benefits are actually reductions in cost. Accordingly, the analyses in Task Memos 3 and 4 organize the quantified estimates of cost and cost-reduction in that format.

The following sections and their summary impact tables provide brief descriptions of these potential costs and benefits, as well as the "owners" of each. They are evaluated both quantitatively and with more thorough descriptions in Task Memos 3-6.

- **Section A - Costs Associated with Seismic Event.** This cost perspective includes the expected costs from a range of possible earthquake events, and can apply to the level of those costs both for URMs in un-retrofitted condition, and for the lower level of those same cost items in the same earthquakes if URM buildings are retrofitted to higher structural standards.
- Key costs include building damage (reflecting costs to repair), earthquake damage to building contents, displacement and loss-of-business costs for residential and commercial tenants during the repair/reconstruction period, loss of community benefits provided by visually distinctive URMs, and costs associated with casualties to building occupants.
- **Section B - Costs Associated with Seismic Retrofits.** This cost category is simpler, consisting mainly of the design, engineering and construction costs of planning and performing seismic retrofits to a specified standard.
- There would also be some displacement and loss-of-business costs in this case, during the period the building was closed for retrofit installation. Such costs could be planned and scheduled, and would occur for a shorter duration than if there were a major earthquake event.
- **Section C - Benefits Associated with Seismic Retrofits**. The benefits associated with seismic retrofits are in some ways an outcome of comparative costs described in the Section A synopsis above. They would consist primarily of reduced levels of certain impacts and the costs associated with those costs.
- Major sub-categories would include savings in terms of building damage, damage to contents, displacement and loss-of-business, and casualties. There would also be reduced probabilities of lost URM buildings and their historic and neighborhood definition values.
- **Section D - Benefits and Costs Associated with A Mandatory Retrofit Policy.** Finally, there would be additional benefits and costs associated with any mandatory retrofit policy, to the extent such a mandate led to outcomes other than straightforward seismic retrofits of URM buildings

- These outcomes could include building demolition, with or without replacement construction, as well as some degree of non-compliance. In each of these cases it is possible to anticipate at least in qualitative terms the range of benefits and costs that might occur, although the choices of what to do in the face of a mandatory policy and the impacts would be quite case-specific.
- The relevant impacts specific to mandatory policy response include the effects on seismic damage exposure, economic consequences for owners, and degree of building preservation.

A. Costs Associated with Seismic Events

These costs are the rationale for considering seismic retrofits or a mandatory retrofit policy. These impacts would have low probabilities of occurring, but in some cases could be very damaging, and costly both in terms of economic loss and loss of life or incidence of other casualties. The categories of these impacts are well-established in the field, and in some cases analytical tools are available to perform estimates of their cost or the numbers of people injured.

Table 1 lists the major categories of these costs. Note that these categories cover the primary sources of loss impacts both in baseline conditions and in the (lower-cost) alternative case of building retrofits.

Table 1. Potential Costs Associated with Seismic Event (w/o Retrofits to URM Buildings)

Source of Cost	Description	Costs Borne By...
Building Damage or building repair costs	Costs to demolish, clean up, and restore a building to occupancy after a seismic event	Building owners, Insurance companies (if earthquake insurance is held)
Reduced property value	Lower value of property if building is damaged or destroyed (may be captured in above item)	Building owners
Loss of life	Lives lost due to failure of building structure – either within the building or outside of the building	Tenants, Community, Insurance companies, Building owners
Other casualties	Cost of medical care for surviving injured building occupants or those injured by building damage, including emergency treatment, hospitalization, long-term care	Tenants, Community, Insurance companies, Building owners
Tenant displacement	Tenants - both residents and commercial businesses - may be displaced after a seismic event, if a building requires repairs, or if building is determined to be unsafe. Businesses would sustain economic losses due to forced closures.	Tenants (cost of relocation), Building owners (cost of covering property expenses such as debt obligations, insurance and other ongoing costs with no source of positive cash flow if tenants displaced). Community (cost of lost economic activity and the appearance/effect of vacant buildings.
Recovery time	Time required to recover after a major seismic event, repair damage to structures, re-occupy buildings, and create positive cash flows (a key element of the preceding cost)	Building owners and occupants

B. Costs Associated with Seismic Retrofits

Seismic retrofits would entail considerable structural engineering and installation costs, with the purpose of reducing the levels of the costs listed in Section A above. These would be building-specific, due in part to individual construction characteristics of buildings and in part to the fact that some buildings have already been retrofitted to some degree.

Table 2 lists the main components of the net cost of seismic retrofits. It includes the primary items noted above, and also highlights the importance of access to financing and potential qualification for financial incentive assistance, which would vary from building to building and from owner to owner depending on their financial health.

Table 2. Potential Costs Associated with URM Retrofits

Source of Cost	Description	Costs Borne By...
Retrofits – hard & soft costs	Retrofit design, engineering, construction and related costs	Building owners, potentially City and other entities if grants can be found
Tenant displacement	Tenants may be displaced during retrofit activities, depending upon how extensive the retrofits are. Certain types of tenants may be affected more than others, e.g., restaurants.	Tenants, Building owners – tenants may decide to permanently move if temporary displacement is too much of a hardship
Financing barriers	Financing is a dimension of the cost above, but the difficulty - and cost - of financing buildings can vary considerably	Some building owners
Incentives – Private Ownership	These are potential cost offsets, such as: ▪ federal tax credit for re-hab ▪ Revolving loans for retrofits ▪ Tax abatement (federal and county) ▪ A/E grants & resources ▪ Education funding	City, potentially other public agencies, taxpayers
Incentives – Public and Non-Profit	These are also potential cost offsets, the same as above, plus: ▪ FEMA/CDBG/other grants ▪ General obligation bonds ▪ Levies	Taxpayers (both local and others)

Table 3. Potential Benefits Associated with URM Retrofits

Source of Benefit	Description	Benefits Accrue to...
Preservation of expected long-term property value	Decreased probability of future seismic damage to property	Building owners, tenants
Higher rents / lease rates	Higher lease rates as a result of a need to recover costs of retrofit by building owners	Tenants Building owners (to some extent)
Reduction in insurance costs	Possible reductions in insurance costs as a result of lower damage risks, due to structural modifications made to retrofit buildings	Building owners (insurance cost savings) Insurance companies (lower risk of loss)
Increased property values	Potentially higher property values as a result of improvements brought by retrofits: ▪ Retrofits alone may increase building market value by reducing risk of loss ▪ Retrofits along with property redevelopment may further increase values	Building owners; City (tax revenue)
Historic preservation and community cohesion preservation	Higher aesthetic values would result from increasing the probability of preserving buildings, and thus the look, feel, and character of a neighborhood (esp. historic character)	Building owners, community
Improved life safety	Safer conditions for occupants as a result of structural enhancements	Tenants, building owners, community
Time savings	Potential time saved in more rapid housing recovery for building tenants and economic recovery for commercial businesses following a seismic event, which would otherwise have been spent in repairs, relocations and business interruption.	Tenants, building owners, community

D. Benefits and Costs Associated with a Mandatory Retrofit Policy

A complicating factor in the consideration of a mandatory retrofit policy is that the impacts depend on the set of individual outcomes for many buildings, and some of those outcomes would not be retrofitting buildings to a specified code. This category of impacts includes the main alternative building outcomes, and the distinct impacts - both costs and benefits - that would be associated with them.

Table 4 lists several major impact areas where a mandatory code could produce outcomes differing from the costs and benefits addressed in Sections B and C. They are all associated with economically-motivated responses owners might choose in the event of a mandatory retrofit policy, resulting in either demolition or non-compliance. Either would produce different impacts than would simply performing seismic retrofits of the URM buildings.

Conclusion

This memo lists key benefits and costs associated with seismic events, seismic retrofits and potential URM retrofit policy changes. These will be the focus of the analysis in the following sections.

Table 4. Other Benefits and Costs Associated with Mandatory Retrofit Policy

Source of Benefit	Description	Benefits Accrue to...
Redevelopment value stimulated (a benefit to owners through partial offset of retrofit costs)	▪ Some existing URMs are likely to see either retrofit with remodel or demolition with replacement buildings, as the "second best" options for owners who otherwise would retain their URMs in un-retrofitted condition ▪ Possible benefit in terms of value to owners and developers ▪ Possible benefit to community in terms of economic development	Building owners, community
Improved seismic protection	Some URM building owners would demolish and replace with more earthquake-resistant structures. Other URM building owners who otherwise would not have retrofitted would now do so.	Building occupants, community
Historic preservation and community cohesion	Varying economically motivated responses can be anticipated: • A benefit would occur when some building owners elect to retrofit buildings they would not have otherwise, preserving the look, feel, and character of a neighborhood (esp. historic character)	Community, City
Fine Revenues	Fines for non-compliance collected after window for compliance has passed, potentially funding seismic protection programs	City
Source of Cost	**Description**	**Costs Borne By...**
Net costs of seismic retrofits or full redevelopment	Existing URMs would be either retrofitted, demolished and replaced or demolished, as the "second best" options for owners who otherwise would retain their URMs in un-retrofitted condition •Each option would impose net costs relative to the owners' current non-mandated choice (assuming fully-informed current choices)	Building owners
Loss of historically significant buildings and community cohesion	Varying economically motivated responses can be anticipated: • A cost would result when some owners elect to demolish existing URMs, damaging historic character and/or neighborhood feel and cohesion.	Building owners, community, City
Fines	Fines for non-compliance after window for compliance has passed	Building owners

TASK 3 MEMO: Key Parameters for Benefit-Cost Analysis

The purposes of this memo are: i) to identify the key parameters needed for analysis and calculation of the quantitative benefits of seismic retrofits to unreinforced masonry (URM) buildings in Seattle, and ii) to define or select values of each major parameter identified.

The three main categories of parameters are:

1. Fragility of Building Types: Quantitative relationships between earthquakes' severity and the extent of building damage, that are specific to structural type (e.g., URM) and a building's height.
2. Exposure to Earthquake Events: A representative range of earthquakes posing risks to Seattle URMs, together with their respective probabilities of occurrence.
3. Economic Summarization Assumptions: Consistently applied assumptions that support the translation of impacts from multiple potential events over an extended future into accepted economic summary measures.

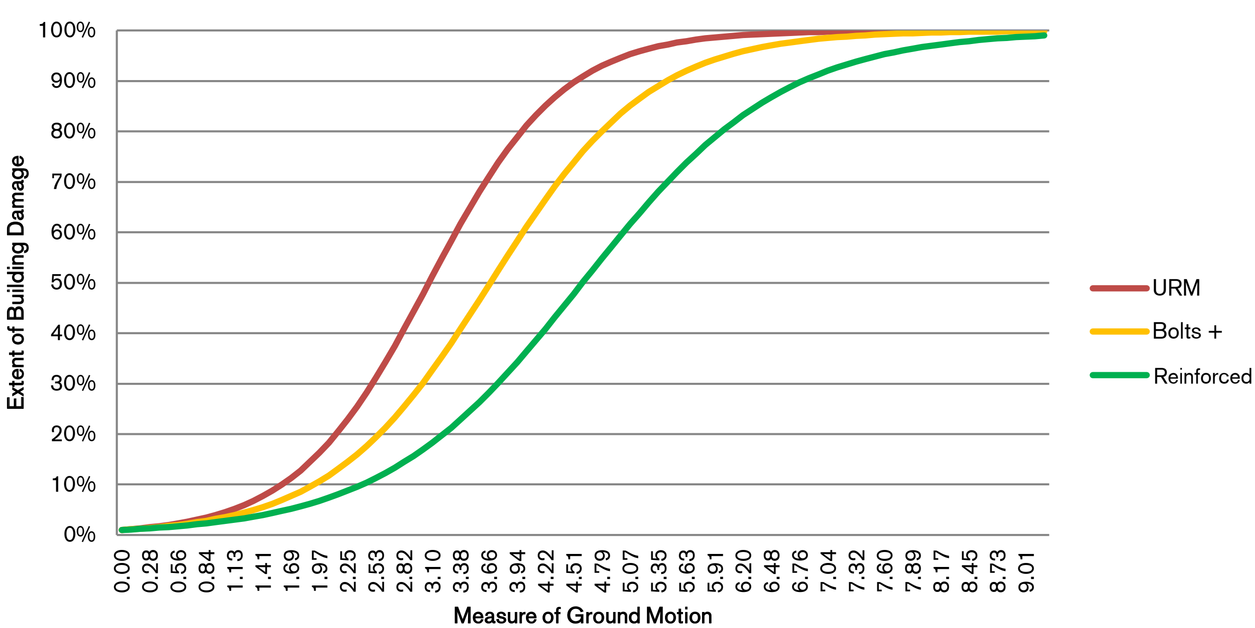
A. Fragility of Building Types: "Fragility Curves"

"Fragility curves" describe the degree of damage to buildings of a given construction type for a range of earthquakes. [1] They typically show an s-shaped curve of damage as a function of earthquake severity. The earthquake severity (x-axis) is generally a measure of ground motion, such as acceleration, and the y-axis is generally the percentage of building damaged or percentage of building value lost.

Figure 1 shows an illustrative set of fragility curves for a class of URM buildings with three levels of retrofit: i) no retrofit, ii) retrofits to the "Bolts-Plus" standards, and iii) further enhanced retrofits. As the curves illustrate, higher levels of reinforcing retrofits i) reduce the damage for a given level of earthquake ground motion, or alternatively, ii) increase the level of earthquake ground motion a building can survive with a given level of damage.

The fragility curves provide an indication of the expected level of building damage in various types of quakes, and the potential reduction in that damage that can be achieved through building retrofits. These are key building blocks for calculating the benefit of preserving buildings' value, one of the two primary benefits of building retrofits.

Figure 1. Fragility Curves: Damage from Ground Motion, for Various URM Retrofits



1 The fragility curves also assume buildings in average condition for their type (e.g., un-retrofitted URMs). In practice, some otherwise similarly constructed buildings will have been well-maintained, and others maintained little if at all. These would be expected to perform differently as individual buildings in the event of an earthquake. This consideration makes HAZUS results more representative and useful when applied to a large cohort of buildings, as they are here, rather than to a single building or a small cohort of a given type of buildings

Improving the life safety for residents and tenants of URMs is the primary objective of the City's proposal for retrofits. Buildings that partially or totally fail during earthquakes can cause significant human injuries and even deaths. The data that produce the damage curves also provide the basis for estimating life safety impacts of buildings at varying levels of retrofit during earthquakes of any specified level of severity.

The damage estimates used in this study were generated by HAZUS (Hazards US), a computerized loss-estimation model developed by the Federal Emergency Management Agency (FEMA) and the National Institute of Building Sciences. The HAZUS model employs fragility curves, which can be tailored to specific building parameters, as one of its major analytical building blocks. Chris Poland, David Gonzalez, and Seth Thomas from Degenkolb Engineers volunteered to develop specifically-designed "Bolts-Plus" fragility curves for URMs in Seattle, with different curves for two-story and four-story buildings (used to represent 1-2 story buildings and 3+ story buildings, respectively). These curves have been combined with existing HAZUS fragility curves for unreinforced masonry and reinforced masonry buildings, again with different curves for 1-2 story buildings and 3+ story buildings.

B. Earthquake Events

1. Range of events. In order to assess the overall risk associated with earthquakes and the economic impacts of reducing the damage they cause, it is important to look at a range of earthquakes to which URMs may be exposed. That risk exposure actually consists of exposure to a continuum of events of varying severity originating on various faults. A full set of site-specific potential events defines a "hazard curve."

In order to calculate modeled impacts to a large number of subsets of the 929 Seattle URM buildings, however, it was deemed more practical to define a more limited set of representative earthquakes. This study elected to define three earthquakes that may be considered medium, large and extremely large in impact. These have each then been combined with associated probability-of-occurrence estimates that are intended to allow these three events to capture the combined, overall risk from Seattle-area earthquakes (see section B.2.) - that is, the area under the hazard curve in the relevant range where damage would be expected.[1]

These three specific events were selected by the team in consultation with Art Frankel of the USGS Earthquake Science Center at the University of Washington, who is recognized as a leading national seismologist, and who is expert in Pacific Northwest seismic conditions and mapping. The three earthquakes are the following:

1. Medium Earthquake: Nisqually Intraplate, magnitude 6.8
2. Large Earthquake: Cascadia Subduction Zone, magnitude 9.0
3. Extremely Earthquake: Seattle Fault, magnitude 6.7

Smaller and Larger Events: While both smaller and larger earthquakes are possible and the actual impact in any other events would be unique, the set of three events chosen were selected to cover the expected long-term exposure to URM building damage. The medium sized earthquake selected for this analysis represents quakes at the least magnitude that would produce significant damage impacts.[2]

2. Probabilities of events. Probabilities of various earthquakes and their associated damages are a critical component of the benefit-cost analysis of potential URM retrofits. The less likely an event is to occur, the less weight it is assigned by building owners in terms of risk to their investment. Conversely, the more likely an event, the more weight it is assigned.

Selection of the set of earthquake probabilities for the three representative earthquakes involved: i) identifying the "recurrence intervals" by which earthquakes are often characterized, ii) calculating the corresponding annual likelihoods of their occurrence, and iii) selecting judgmental confidence intervals around these baseline likelihoods that explicitly acknowledge the uncertainty of these parameter values. (As noted, this produces imprecise estimates, which supports the use of sensitivity analyses that assume much higher probabilities. These sensitivities are included in Task Memo 5.1, below.)

- **Recurrence interval estimates.** Recurrence intervals are frequently expressed in terms of the probability of an event or range of events recurring within a 50-year interval. For the three specific earthquakes listed above, the estimated recurrence interval likelihoods (provided by USGS scientist Art Frankel) are:
    - Nisqually Intraplate M6.8: 84% in 50 years
    - Cascadia Subduction Zone M9.0: 14% in 50 years
    - Seattle Fault M6.7: 5% in 50 years

1 Some earthquake hazard analyses (e.g., those prepared for individual building grant applications to FEMA) define a larger number of earthquakes, which then can be associated with smaller individual annual probabilities of occurrence, to cover the same range of hazards and cumulative probabilities.

2 The peak ground accelerations of these three events correspond to the three intervals that generate the large majority of impacts in FEMA hazard analyses performed for Seattle projects.

- **Probabilities.** These recurrence intervals can be translated into annual probabilities. The resulting average annual probabilities of occurrence[1] are:
  - Nisqually Interplate M6.8: 3.67% per year
  - Cascadia Subduction Zone M9.0: 0.30% per year
  - Seattle Fault M6.7: 0.10% per year
- **Uncertainty regarding event probabilities.** It is recognized that recurrence intervals, and thus annual probabilities of occurrence are quite imprecise, since for such infrequent events there is not an extensive empirical data base from which to estimate. This is particularly true for major events such as the Cascadia Subduction Zone M9.0 and Seattle Fault M6.7 quakes used as representative of large and extremely large Seattle-area earthquakes.

  Thus, while the values above reflect professional judgment, they are recognized to have fairly wide +/- intervals. As a consequence the annual probability value parameters are a highlighted assumption addressed in the sensitivity analysis section of the study.

C. Economic Parameters for Analysis

The two key economic analysis parameters that help summarize ongoing - and potentially reduced - future risks to URM buildings from earthquakes are the time horizon for the analysis and the discount rate used to compare or aggregate multiple years' probable benefits or costs.

1. Time horizon. While the annual likelihood of an earthquake continues indefinitely into the future, the benefits of URM building retrofit are limited by the projected remaining life of the building. That parameter is uncertain and varies from one building to another. As a baseline, however, the primary locus for building impact analysis in this field - those performed by FEMA or using the FEMA model - assumes a time horizon of 30 years. That is the baseline assumption used in this benefit-cost analysis. Because of the significant level of uncertainty, this parameter is one of the variables for which sensitivity analyses are included in the benefit-cost calculations. The baseline, and the low and high sensitivity analysis assumptions are:

- Low: 20 years,
- **Baseline: 30 years,**
- High: 50 years.

2. Discount rate. With the benefits of URM building seismic retrofits extending into the future (e.g., 30 years), it is also crucial to select a discount rate that reflects the fact that people tend to discount benefits that happen further off in the future. This discounting, though, differs between entities and it is useful to compare these differences when evaluating benefits and costs. For example, developers in real estate typically prefer that benefits accrue within a few years of an investment. This is represented by a higher discount rate. On the other hand, a governmental utility might be satisfied with a longer period for investments to return benefits which would be a lower discount rate. For example, Seattle Public Utilities currently applies 3%, 5% and 7% real discount rates in its asset management business case analyses to test alternatives before making a capital improvement.

Therefore discount rates are another parameter for which sensitivity analyses are included in this study's benefit cost calculations. We used a baseline for this analysis of 7% real discount rate because FEMA uses this rate in analyses of the economic impacts of seismic retrofits. The baseline, and the low and high sensitivity analysis assumptions for real (i.e., inflation-adjusted) discount rate are:

- Low: 3%,
- **Baseline: 7%,**
- High: 10%

Conclusion

The parameters in this task memo form the basis for the quantitative portion of the analysis in the following sections where the physical, economic and life-safety losses from earthquakes are estimated. To draw valid benefit-cost implications from that analysis, it is crucial to define the appropriate range of representative earthquakes, their appropriate probabilities of occurrence, and the damage susceptibility of the URM buildings they could damage.

Those choices, described above, are the primary analytical parameters for this benefit-cost analysis. A secondary set of still-important parameters involves the time horizon and discount rate for which the earthquake damages will be evaluated. Those are also listed above, and it is important to note that the later analysis will consider whether changing those assumptions materially affects the results.

1 These probabilities are calculated and applied at this level of detail not because of precise knowledge of their values but in order to focus benefit calculations that are proportional to the probabilities.

TASK 4 MEMO: Calculation of Earthquake & Seismic Retrofit Impacts

The purpose of this memo is to report on the comparative impacts of the three earthquakes described in Task Memo 3. The primary emphasis is on impacts assuming no retrofits and impacts assuming retrofits consistent with the Bolts-Plus standards. Detailed impact calculations were also developed assuming the same set of buildings were reinforced masonry structures, to provide a point of comparison and to help assess the potential outcomes if a mandatory seismic retrofit program were adopted. Three components of the earthquake impact comparison are covered in this memo:

1. Seattle URM Buildings. A multi-perspective description of the set of Seattle buildings selected for the study, the distributions of their key physical characteristics and their locations.
2. Earthquake Impact Calculation Model. Overview of HAZUS, the federal disaster impact estimation model used in this study to estimate comparative quantitative impacts of retrofit alternatives in a variety of earthquake scenarios.
3. Major Model-Estimated Impacts. A summary of the major HAZUS modeled impacts, highlighting the relative performance of URM buildings versus Bolts-Plus seismically retrofitted buildings in specific earthquake events.

Comparative non-quantitative impacts such as those listed in Task Memo 2 are also vital to a benefit-cost analysis. These other policy, social and environmental impacts are addressed in Task Memo 5.

A. Affected Buildings: Seattle Inventory of URMs

The study is based on data for 929 potential URMs provided by the City of Seattle Department of Planning and Development (DPD). This data set does not include single-family buildings, which may account for many more. In addition, the selected 929 buildings may have missed some URMs and may also include some non-URM buildings (e.g., wood frame buildings with brick cladding). Further more, some potential URMs have received retrofits of different standards. These differences are due in large part to the necessary reliance on available data sources as the high cost of building-by-building inspection would be prohibitive for this type of analysis. The impact of using this existing data on the findings are discussed below.

1. DPD Potential URM Data Base. The initial potential URM data base for this study was assembled for the Seattle's Department of Planning and Development (DPD). The DPD data combined information available from the King County Assessor's on-line files augmented with "windshield survey" information on the same buildings. Several aspects of the building are important for seismic performance such as number of stories and occupancy type. Other aspects such as square footage and assessed value of improvements are important data to measure the scale of potential losses and costs of retrofits..

Based on the detailed scope developed for this study, several other variables were determined to be important either to the estimation of impacts or to differentiation of impacts for desired scenarios. As a consequence, the study team added building-by-building information on other variables, including underlying soil type, historic district, value of contents, number of occupants, longitude and latitude, and (alternative) building retrofit condition assumed for any individual run.

The team considered questions about the completeness and detailed accuracy of the specific set of buildings included in the initial DPD data set. However, it was recognized that the average benefits versus costs and their variability were the critical features of the information being analyzed for the study, not necessarily the total scale of impacts. As a result, the analysis proceeded on that basis.

2. URM Categorization for Analysis. To tease out the differences in economic impacts from Seattle's range of earthquakes (reported below), the data base of potential URMs buildings has been disaggregated into sub-groups, depending on whether they are low-rise or taller and whether they are in a soil liquefaction zone or built on more stable soil. Potential URM buildings in historic districts have also been identified separately.

Building height versus soil type distribution of the URM buildings in the DPD data base is shown in **Table 1** below.

How URM buildings perform during earthquakes can be influenced by the height of the building and location particularly if on liquefaction soils. Either characteristic will worsen a building's expected performance and increase the extent of its damage. This outcome will be seen for earthquakes of any severity even if the earthquake source is at a distance from the city. In earthquakes from shallow faults within or very near the city the frequency of shaking will increase the risk for shorter buildings, although unstable soils remain a risk factor. A building with both risk characteristics will be likely to be damaged the most.

3. Location of URMs. The geographic distribution within Seattle of the 929 potential URMs provides information which is valuable to both the impact calculation and other associated policy considerations. **Map 1** shows the geographic distribution of all 929 URMs within Seattle.

Table 1. Distribution of Seattle URM Buildings, By Height and Underlying Soil (Culled Data)

Building Height	Stable Soil	Liquefaction Zone	Totals
1-2 Stories	516 (55.5%)	73 (7.9%)	589 (63.4%)
3+ Stories	281 (30.2%)	59 (6.4%)	340 (36.6%)
Totals	797 (85.7%)	132 (14.3%)	929 (100%)

One crucial influence of location concerns the performance of otherwise-similar buildings that are differing distances from one or more of the design earthquakes defined for this analysis. This is most important in the case of the Seattle Fault M6.7 earthquake on a fault running through Seattle near downtown. The sources of the other two earthquakes (Nisqually-type and Cascadia) are further from Seattle, and their relative impacts throughout the city would vary less substantially.

- As pointed out in the discussion of **Table 1** above, both building height and type of underlying soil contribute to the performance of URMs - and Bolts-Plus retrofitted URMs - in the event of an earthquake. In addition, location within a designated historic district affects the choices available to a building owner considering seismic retrofits, whether voluntary or mandatory.
- **Maps 1-4** portray the geographic distributions of potential URMs for each combination of building height (1, 2 and 3+) and liquefaction zone (Y/N). These distinctions are also presented in two “roll-up” summaries.
- **Maps 2 and 3** show the geographic distributions of lower (1-2 stories) and higher (3+ story) URMs. These differences are relevant not only because the lower and higher buildings perform differently in earthquakes, but because the building occupancy of the two groups of buildings differs, with 1-2 story buildings being primarily commercial and industrial, and 3+ story buildings including a much greater component of residential apartments, some with street-level commercial space.
- To present summary information on just soil type, **Map 4** overlays a map of liquefaction zones on the map of all 929 URMs.

In addition, the location of potential URMs have been mapped against race and social justice measures for various neighborhoods within Seattle. This information can help to assess whether, or to what extent, earthquakes or policies to minimize their impacts would have disproportionate impacts on different racial or income groups within the city.

- **Map 5** overlays the map of the 929 potential URMs on a map showing differing racial composition of various sub-areas within Seattle.
- **Map 6** overlays the map of the 929 potential URMs on a map showing differing levels of household income in various sub-areas within Seattle.

It appears that at an aggregate level the potential URMs are found across a wide spectrum of neighborhoods regardless of racial composition or income. On Map 5, there are numerous potential URM buildings in both primarily white and primarily non-white areas of the City. Based on group means, the average non-white population for neighborhoods housing URMs is about 24-25%, which is slightly lower than the City-wide average of 30%.

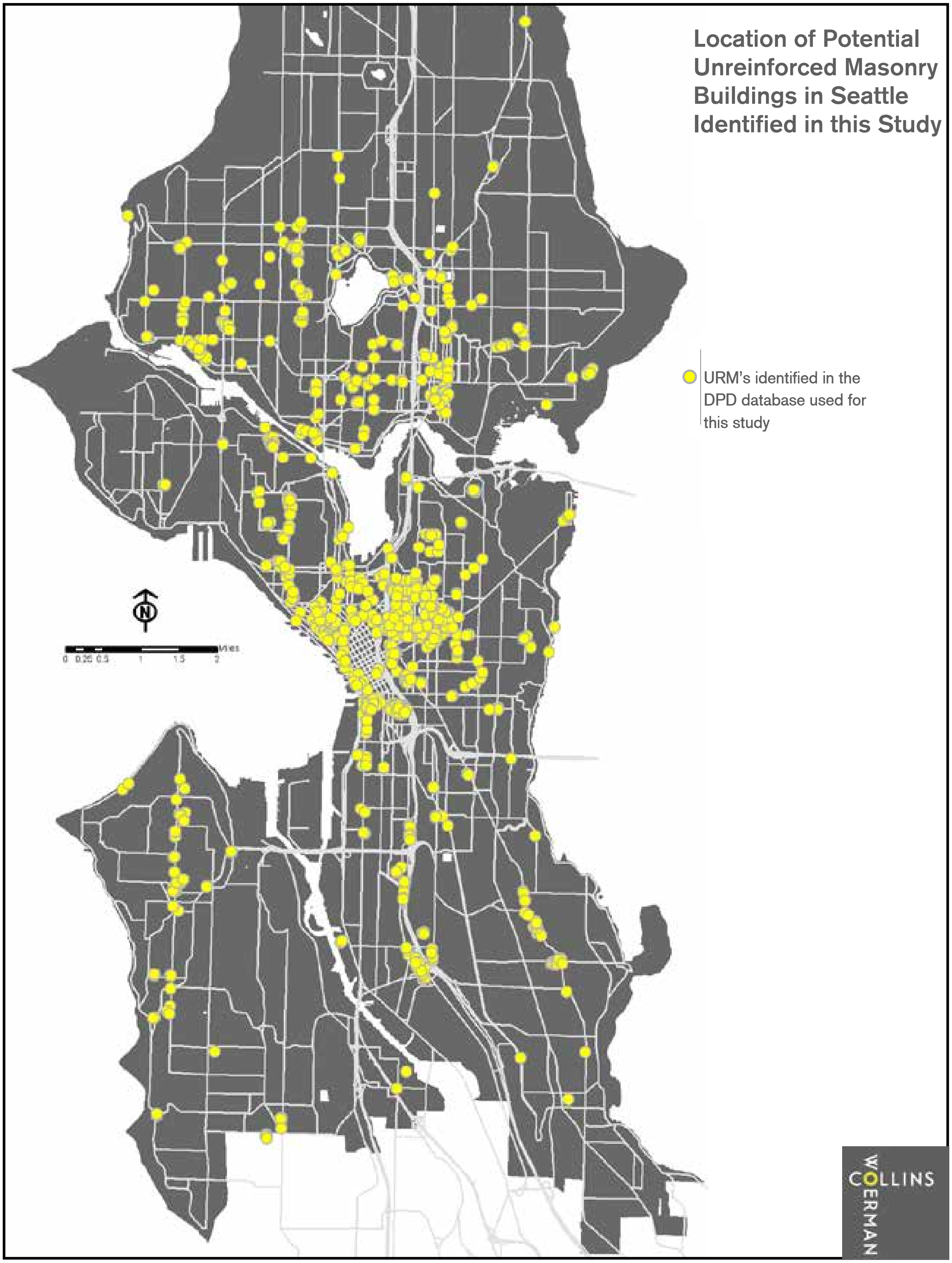
Map 6 illustrates that the same is true with respect to household incomes. There are numerous URMs in both above- and below-average income neighborhoods. Again based on group means, the average household income for neighborhoods housing URMs is about 93-94% of the City-wide average.

This suggests that there would not be disproportionate anticipated impacts on groups based on race or income in the event of earthquakes, nor would there be disproportionate anticipated impacts on groups based on race or income if Seattle were to adopt a new URM retrofit policy.

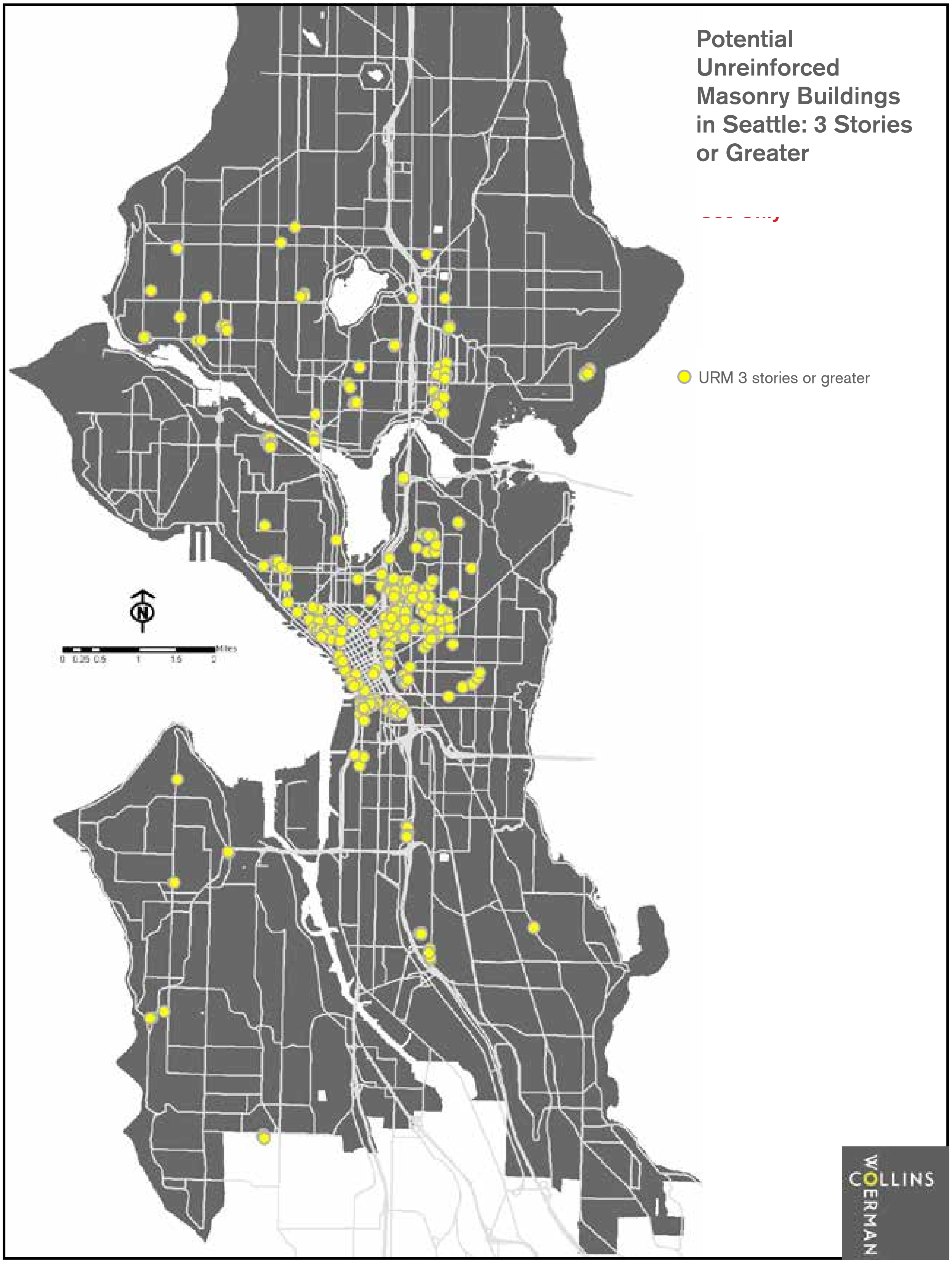
There may, however, be disproportionate impacts on smaller start-up businesses, which tend to be strongly represented in certain neighborhoods of URM buildings, due to lower rents. Furthermore, while on an expected basis there may not be higher likelihoods of earthquake impacts on neighborhoods with certain racial composition or income levels, an actual earthquake may have localized impacts that would be disproportionately borne by certain groups.

4. Variability of URMs. An important feature of the potential URM data set - which would remain true if the size of the data set were to increase or decrease upon further review - is that it reflects URMs in a wide variety of buildings, with diverse sizes, uses and current conditions. The **URM Photos** illustrate this, showing both low-rise and taller URMs varying widely in assessed value per square foot, with some in better and some in worse condition, and some located in historic districts and some not. This variability tends to be averaged out in results because of the large inventory of 929 buildings. It also illustrates the reality of the diverse set of URM buildings to which any new retrofit policy proposal would apply.

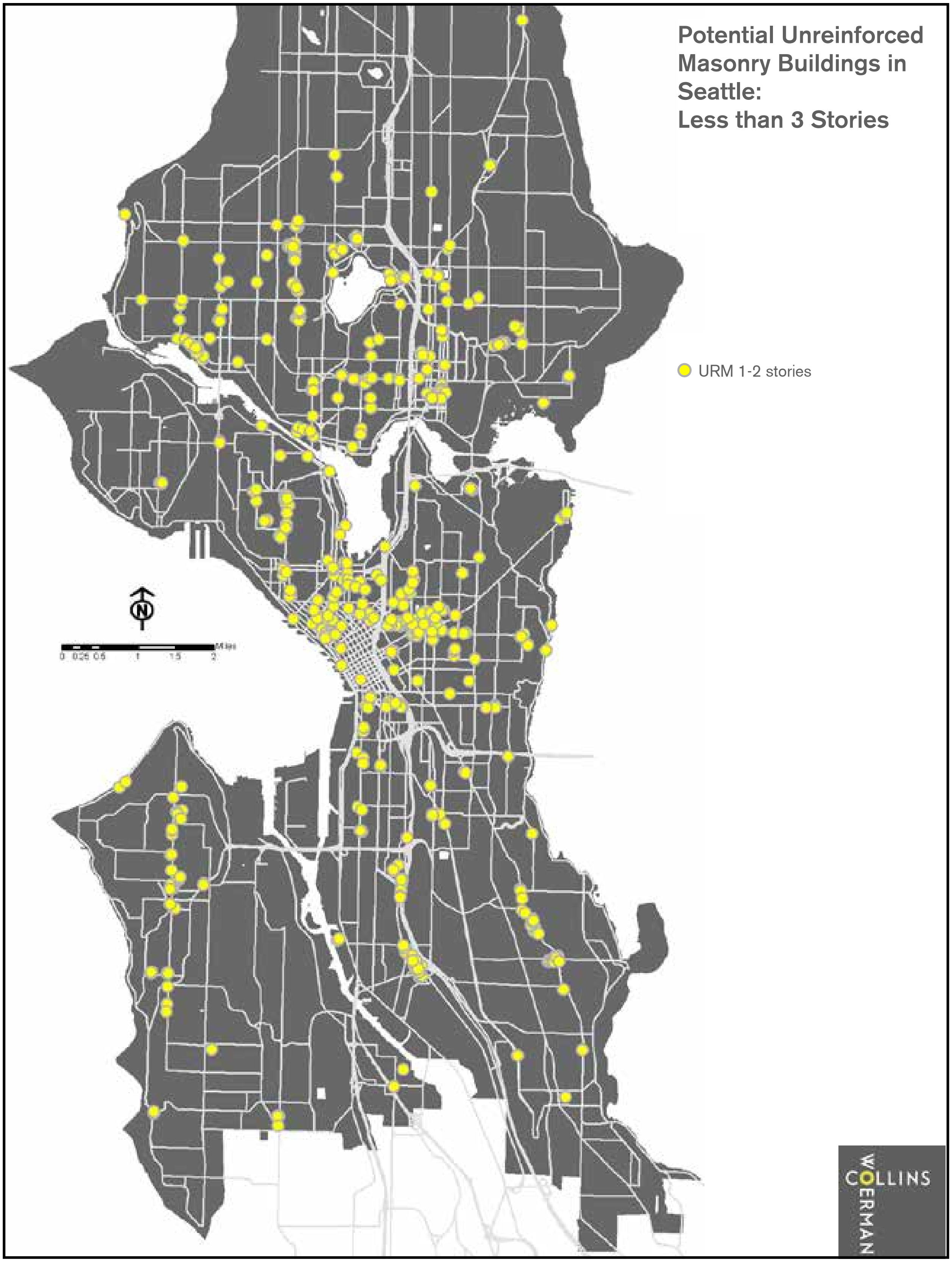
Map 1


Location of Potential
Unreinforced Masonry
Buildings in Seattle
Identified in this Study
URM's identified in the
DPD database used for
this study
COLLINS WOERMAN

Map 2

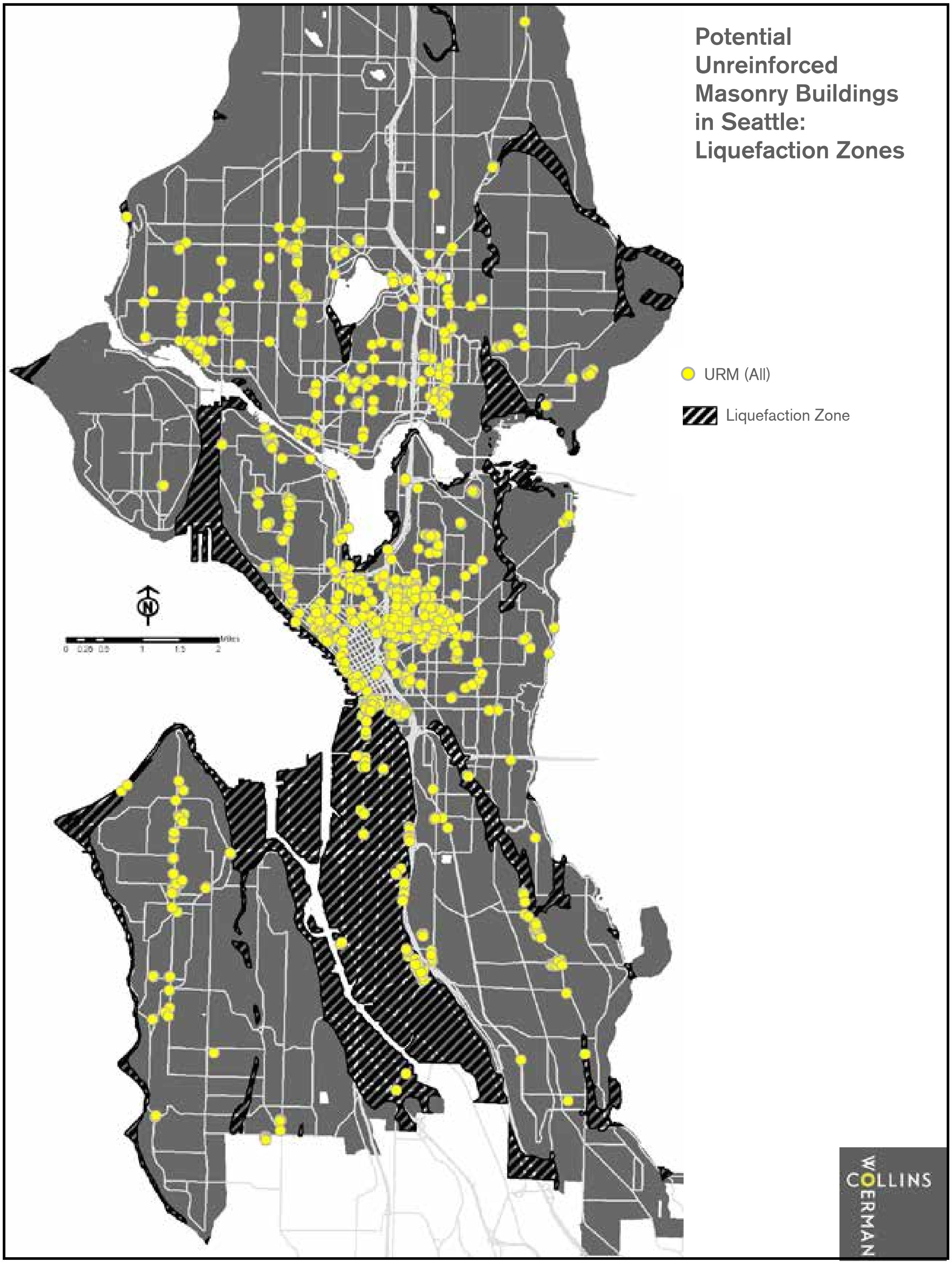

Potential Unreinforced Masonry Buildings in Seattle: 3 Stories or Greater
URM 3 stories or greater
N
Miles
0 0.25 0.5 1 1.5 2

Map 3

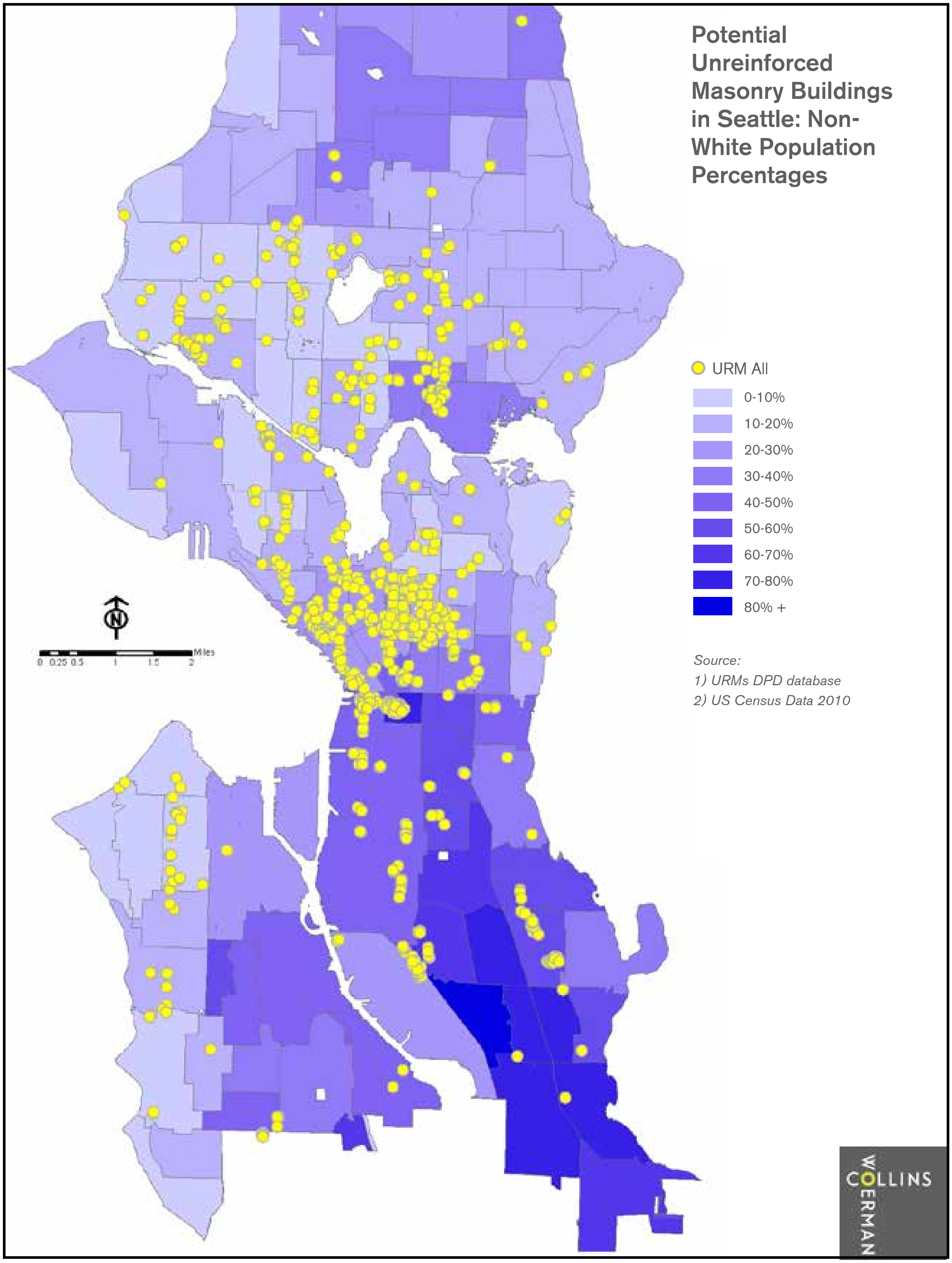


Potential Unreinforced Masonry Buildings in Seattle:
Less than 3 Stories
URM 1-2 stories
N
0 0.25 0.5 1 1.5 2
Miles
COLLINS
WOERMAN

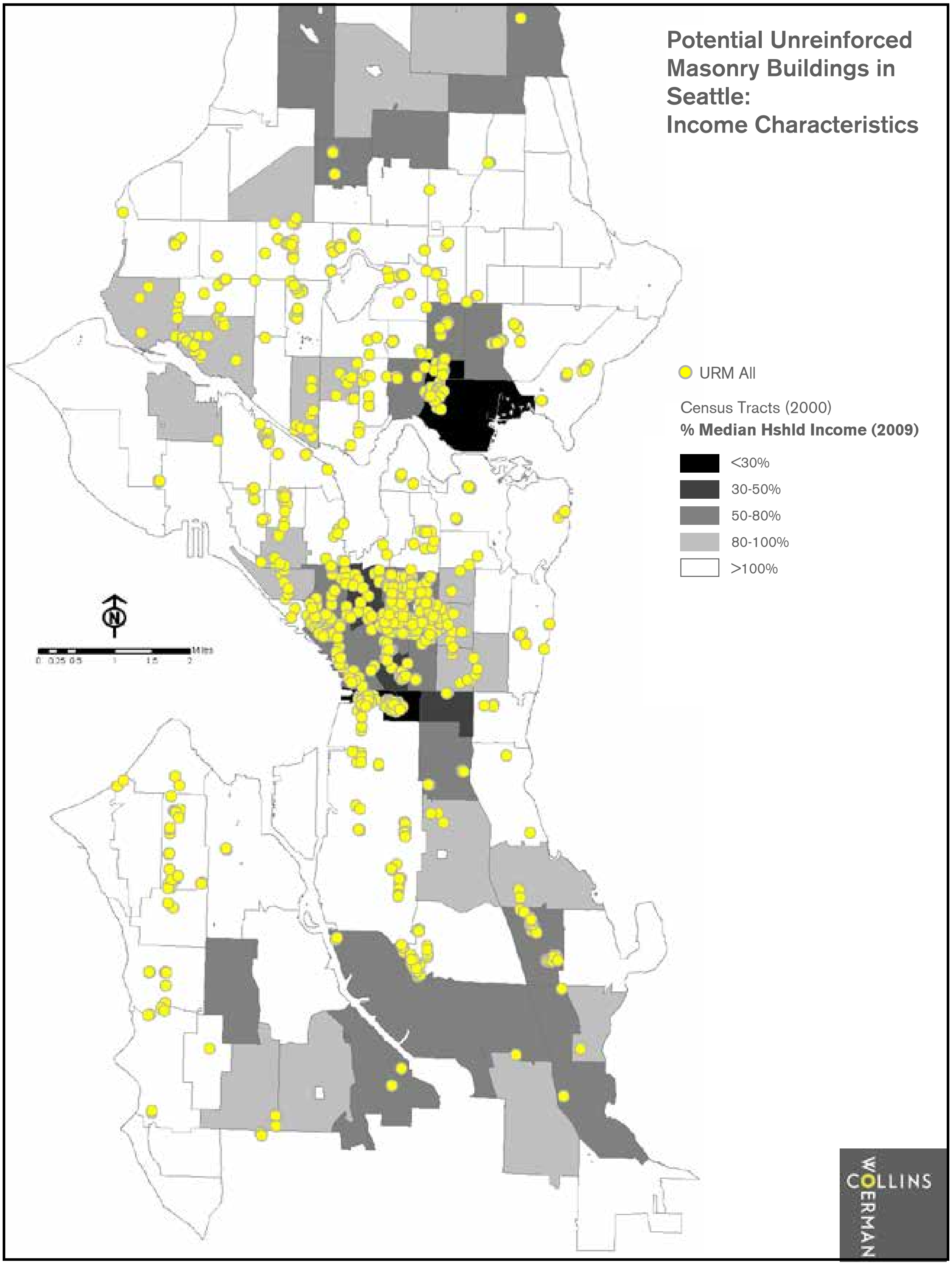
Map 4


Potential
Unreinforced
Masonry Buildings
in Seattle:
Liquefaction Zones
URM (All)
Liquefaction Zone
N
COLLINS
WOERMAN

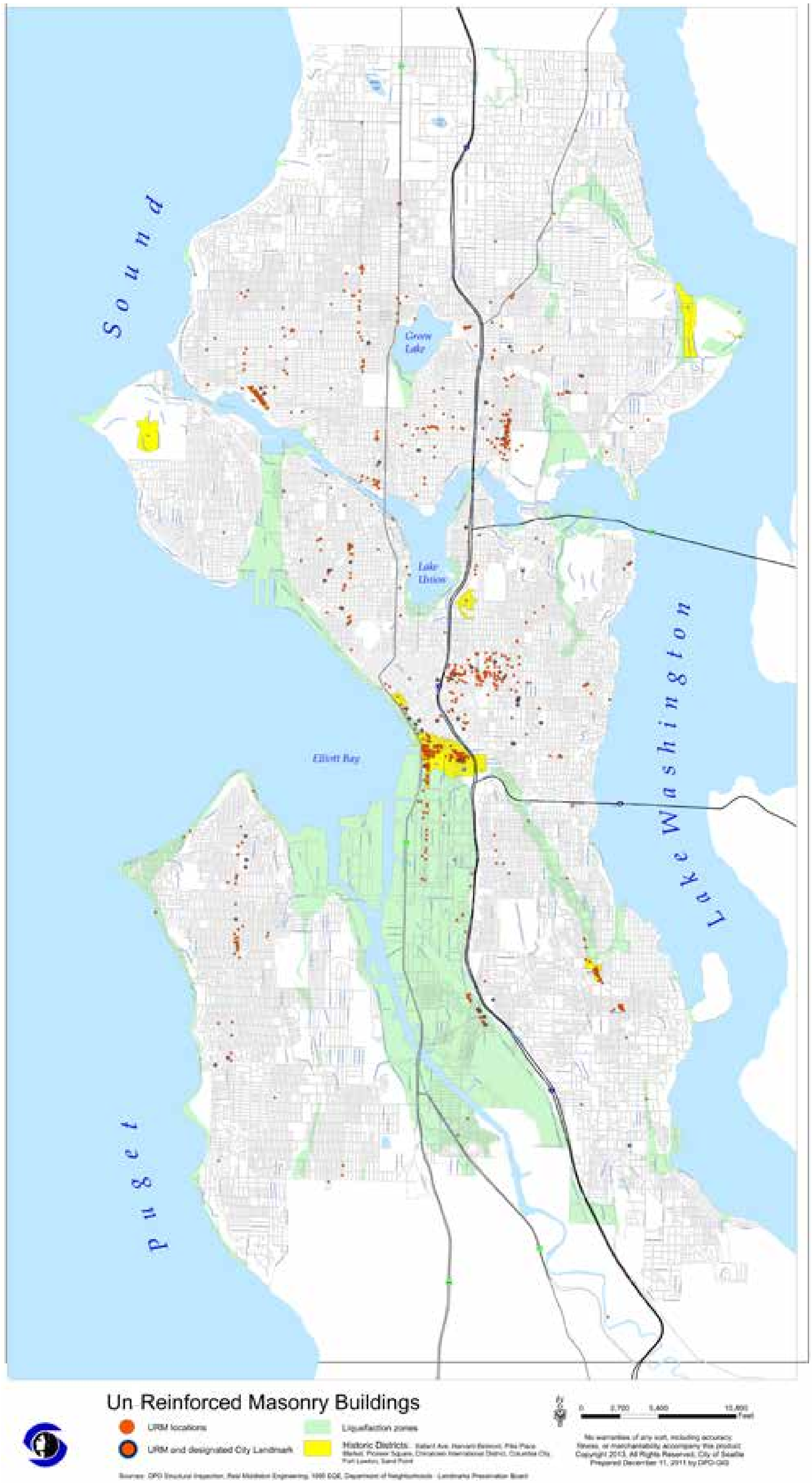
Map 5


Potential Unreinforced Masonry Buildings in Seattle: Non-White Population Percentages
URM All
0-10%
10-20%
20-30%
30-40%
40-50%
50-60%
60-70%
70-80%
80% +
Source:
1) URMs DPD database
2) US Census Data 2010
N
Miles
0 0.25 0.5 1 1.5 2
COLLINS WOERMAN

Map 6



Potential Unreinforced Masonry Buildings in Seattle:
Income Characteristics
URM All
Census Tracts (2000)
% Median Hshld Income (2009)
<30%
30-50%
50-80%
80-100%
>100%
Miles
COLLINS WOERMAN



Potential Unreinforced Masonry Buildings and Historic Districts

URM Photos


LOW SQUARE FOOTAGE


HISTORIC DISTRICT


HISTORIC DISTRICT


COMMERCIAL


COMMERCIAL


HISTORIC DISTRICT


COMMERCIAL


HISTORIC DISTRICT

LOW SQUARE FOOTAGE


MULTIFAMILY


HISTORIC DISTRICT


MULTIFAMILY


MIXED USE


HIGH SQUARE FOOTAGE

COMMERCIAL

B. Impact Calculation Tool: HAZUS Risk Assessment Model

1. Development, Design and Selective Use of HAZUS tool. HAZUS was developed by FEMA for analyzing the diverse impacts of a variety of major disasters. It includes capabilities for earthquakes, floods and tornados. Intended as a complete event impact estimation tool, it provides capabilities for estimating impacts to a variety of services and infrastructure as well as impacts on an area's building stock. While HAZUS is extremely large and versatile, its main application for the Seattle URM Retrofit Benefit-Cost Analysis Study lies in its ability to calculate estimates of comparative impacts of different earthquakes for different levels of masonry building retrofit. Only those modules have been used for this study.

2. Seattle-specific refinements and enhancements. HAZUS provides "resident" options for virtually all key features of buildings that may be affected by earthquakes. Some of these have been retained for the benefit-cost analysis, while others have been replaced by specifically developed inputs tailored to the requirements of HAZUS.

- **Building Set.** The underlying purpose of this study concerns Seattle URMs, while HAZUS is generally used to analyze impacts across an area's entire inventory of buildings. In this case, instead of relying on HAZUS' overall Seattle information, the study compiled information on all HAZUS-required variables for the 929 buildings in the DPD data set. Some variables were already present in the DPD data set, and only needed to be formatted to HAZUS specifications. Other variables - such as building longitude and latitude and estimated building occupancy numbers - were assembled separately as part of the study, and combined with the DPD data.
- **Building Types.** HAZUS provides default parameter values for building types that include unreinforced masonry (URM) and reinforced masonry buildings, with both low-rise and taller buildings modeled separately. As noted in Task 3, Seattle-specific building information was developed for Seattle URMs retrofitted to the Bolts-Plus standard.
- **Earthquake Events.** HAZUS also allows for specification of the earthquake event for which impacts are modeled and calculated. This requires "shake maps," which indicate the nature of horizontal acceleration associated with an event. As noted above, this analysis included HAZUS impact modeling for three events, Nisqually 6.8, Cascadia Subduction Zone 9.0 and Seattle Fault 6.7 earthquakes. For each of these, an existing shake map was available, and these maps were input to the HAZUS model for the appropriate runs.
- **Separate HAZUS Runs.** In order to capture group-specific information from the versatile HAZUS model, this study defined 135 separate HAZUS runs, covering various combinations of earthquakes, building retrofit condition, building height, underlying soil and historic district location.

3. Limitations on Results. HAZUS documentation is careful to point out that the tool provides approximate estimates, not precise impacts. Thus, while the results presented here are numerical and expressed as "point estimates," it should be borne in mind that the actual results could be either larger or smaller than reported, given the many variables that affect the impacts of any specific event[1]. In addition, sensitivity analyses warrant examination, since they can help clarify the impact of various particularly uncertain assumptions on the "bottom line."

It is also important to recognize that the HAZUS results reflect the aggregate estimated impact across a substantial sample of buildings, rather than predictable impacts for an individual building. For example, HAZUS' building damage results are expressed as percentages of buildings experiencing varying percentage levels of damage to their structural and non-structural elements. This type of information is most valuable in assessing impacts to a large inventory, rather than in predicting outcomes for an individual building.

4. Key output capabilities. HAZUS provides numerous options for impact "outputs." Some are general and high-level, such as casualties and building damage. Even these require tailored input information on the numbers of people exposed at the time of a quake and the value of the building.

Other outputs (impacts) are more specialized, such as loss of inventory or earnings, and can provide meaningful results only if there is accurate information on the baseline conditions that are exposed to loss. These other outputs are discussed later in this chapter.

For information on HAZUS Modeling, see the end of this section.

1 Reviewers note that HAZUS does not take into account the cumulative impact on URMs after multiple earthquakes. Experience in Christ Church shows that URMs weaken after each quake.

C. Modeled Earthquake Impacts

1. Physical Damage to Buildings. HAZUS presents a range of building damage estimates with separate estimates provided for structural and non-structural elements. In addition, for the non-structural elements, there are separate impact estimates for drift-sensitive (magnitude of horizontal movement) elements and acceleration-sensitive (speed of movement) elements. For each of these three building components, HAZUS estimates the percentage of buildings that will experience the following degrees of damage:

- None
- Slight
- Moderate
- Extensive, and
- Total

The information provided for these measures is useful in a variety of ways. First, it allows the reader to understand and visualize the extent of major damage or destruction versus minor damage that involves cost but does not damage the building beyond repair. Second, and indirectly, this information is used by HAZUS to develop estimates of the economic damage to the value of buildings.

- Tables listing the full results of the HAZUS building damage analysis are presented in **Appendix 4.A**. Those tables cover impact estimates for the three study earthquakes, with separate tables for completely unreinforced masonry buildings, Bolts-Plus retrofitted buildings, and reinforced masonry buildings. As noted earlier, we used reinforced masonry data as bookend on the HAZUS analysis. The Bolts Plus information was specifically developed for this analysis. In addition, each of the tables provides individual line-item results for the building subsets differentiated by building height, underlying soil and location (or not) in a historical district.
- In a Nisqually-type M6.8quake, 10% of the entire inventory of un-retrofitted URMs are projected to be either extensively damaged or totally destroyed. In a Cascadia M9.0 quake, the corresponding fraction of extensively damaged or destroyed buildings is 15%, and in a Seattle M6.7 quake, the fraction rises to 44% of the City-wide inventory of buildings.
- In any of the three representative earthquakes, the subsets of buildings with above average probabilities of destruction are projected to be i) those three or more stories high, ii) those in liquefaction zones, and iii) those in historic districts. These differences are noticeable, but not dramatic.
- Bolts-Plus seismic retrofits are estimated to lower the probabilities of extensive damage or destruction in the three representative earthquakes to 1%, 1% and 10%, respectively.

2. Economic Loss to Buildings. The economic loss estimates presented by the HAZUS model cover both losses to the building structure and to the building contents. HAZUS calculates percentage loss values for each building in its specific location, and for its corresponding contents. These are multiplied by the building and content values provided as an input to HAZUS.

The initial building values input to HAZUS were obtained from the King County Assessor's Office "value of improvements" data. These are generally considered to underestimate actual building value to some degree, and in this analysis the building values - and thus the HAZUS building damage estimates - have been increased by 10 percent.

The contents values are not available on a building-by-building basis. Instead, they have been assumed to be equal to 50 percent of the building value, an average default value used in HAZUS studies[2].

- **Tables 1A and 1B** and **1C** on the following page report the total exposed value of potential URM buildings, together with their HAZUS-estimated earthquake damage if unretrofitted, retrofitted to the Bolts-Plus standard, or fully reinforced. The combined (building plus contents) value shown in **Tables 1A, 1B and 1C** are for the 929 potential URMs in the DPD data set. It is estimated that $2.853 billion of value is at risk in the event of an earthquake.

As shown in **Table 1A,** the predicted damages from these three types of earthquakes to unreinforced masonry buildings for all 929 buildings range from $128.3 million for the Nisqually 6.8 earthquake to $634.1 million for the Seattle Fault 6.7 earthquake. These are 4.5% and 22.2% of the total exposed value, respectively. The damage in a Cascadia 9.0 earthquake would be intermediate, but closer to the Nisqually 6.8 value. For any of the three earthquakes, the percentage of value lost to buildings is substantially greater than the percentage of contents value lost.

It should be noted that the HAZUS model runs suggest that the majority of the value of URMs in Seattle survive even the largest earthquakes. This runs counter to a common belief that all URMs would collapse. Some do, but many do not. Which particular buildings survive is not predicted by the model.

1 This is somewhat higher than the relative value of building contents used in FEMA building analyses, but not to a degree that would influence overall benefit-cost ratio results.

Table 1B shows the estimated damage from the same three earthquakes if the 929 buildings were seismically retrofitted to the Bolts-Plus standard. The earthquake damage estimates are considerably lower with buildings at the Bolts-Plus standard. This is what you would expect as Bolts-Plus is designed to reduce damage from quakes and these results support that contention. The extent of the HAZUS-estimated dollar damage would then range from $88.4 million for the Nisqually 6.8 earthquake to $334.8 million for the Seattle Fault 6.7 earthquake. Those damages represent just 3.1% and 11.7% of the exposed value, respectively, which are reductions of nearly a third (31%) to almost half (47%) relative to the total damages the buildings were predicted to sustain before Bolts-Plus.

The estimated dollar savings in this scenario range from $40 million to $300 million, relative to a base case where no URMs have been seismically retrofitted.

Earthquake	**Reduction in Loss**
Nisqually M6.8:	$ 39.9 m savings
Cascadia M9.0:	$ 41.7 m savings
Seattle M6.7:	$299.3 m savings

Table 1A: Economic Impacts for Un-Reinforced Masonry Buildings

Measure	**Exposed Value**	**Estimated Damage**		
		Nisqually	*Cascadia*	*Seattle*
Building ($m)	$1,902.0	$100.7	$154.8	$512.0
Contents ($m)	$ 951.0	$ 27.6	$ 42.9	$122.2
Combined ($m)	$2,852.9	$128.3	$197.7	$634.1
Percentage of Combined Value Lost:		4.5%	6.9%	22.2%

Table 1B: Economic Impacts for Bolts-Plus Retrofitted Masonry Buildings

Measure	**Exposed Value**	**Estimated Damage**		
		Nisqually	*Cascadia*	*Seattle*
Building ($m)	$1,902.0	$58.1	$101.7	$238.8
Contents ($m)	$ 951.0	$30.3	$ 54.3	$ 96.0
Combined ($m)	$2,852.9	$88.4	$156.0	$334.8
Percentage of Combined Value Lost:		3.1%	5.5%	11.7%
Bolts-Plus Damage Reduction - $		**$39.9**	**$41.7**	**$299.3**
- %		**31%**	**21%**	**47%**

Table 1C: Economic Impacts for Reinforced Masonry Buildings

Measure	**Exposed Value**	**Estimated Damage**		
		Nisqually	*Cascadia*	*Seattle*
Building ($m)	$1,902.0	$ 7.5	$20.3	$52.4
Contents ($m)	$ 951.0	$ 3.7	$10.0	$23.1
Combined ($m)	$2,852.9	$11.2	$30.3	$75.6
Percentage of Combined Value Lost:		0.4%	1.1%	2.6%
RM Damage Reduction - $		**$117.1**	**$167.4**	**$558.5**
- %		**91%**	**85%**	**88%**

Table 1C shows the estimated damage from the same three earthquakes if the 929 buildings were the equivalent of reinforced masonry buildings. The earthquake damage estimates associated with the occurrence of the three design quakes are even lower. The extent of the HAZUS-estimated dollar damage would then range from $11.2 million for the Nisqually Fault 6.8 earthquake to $75.6 million for the Seattle Fault 6.7 earthquake. Those damages represent just 0.4% and 2.6% of the exposed value, respectively, which are reductions of roughly 90% relative to the damages the buildings are predicted to sustain in the aggregate if maintained in an unreinforced state.

The estimated dollar savings in this scenario range from $117 million to $558 million, relative to a base case where no URMs have been seismically retrofitted.

Earthquake	Reduction in Loss
Nisqually:	$117.1 m savings
Cascadia:	$167.4 m savings
Seattle:	$558.5 m savings

More detailed HAZUS economic loss estimate results are shown in Appendix 4.B economic loss tables. These tables cover impact estimates for the three study earthquakes, separated by type: completely unreinforced masonry buildings, Bolts-Plus retrofitted buildings, and reinforced masonry buildings. Each of the tables also provides individual line-item results for the building subsets differentiated by building height, underlying soil and location (or not) in a historical district.

3. Building-Related Casualty Impacts. HAZUS reports casualty estimates for four categories of injury. These categories cover injured persons who are:

i. treated and released,
ii. hospitalized with minor injury,
iii. hospitalized with life-threatening injuries and survive, and
iv. killed by the event.

HAZUS further provides differentiated casualty impacts between an event occurring during the daytime versus the same event occurring during night-time hours. Most buildings have different levels of occupancy - and thus exposure to casualty - during the day versus at night, and thus differing exposure to casualties.

The estimated casualty impacts for the Study's three design earthquakes - shown separately for daytime and nighttime events - are shown in **Tables 2A, 2B and 2C**.

Table 2A presents the casualty estimates for Seattle's 929 represented URM buildings on the assumption that none of them is seismically retrofitted to any degree[3]. As would be expected, the casualty rates for all degrees of injury are lowest for the Nisqually earthquake and highest for the Seattle Fault quake. Averaging the daytime and nighttime estimates, there are estimated to be 8 deaths from a Nisqually 6.8 quake, ranging up to 12 deaths for a Cascadia Subduction Zone quake and 60 deaths from a Seattle 6.7 quake. There would also be proportionally more of the other categories of casualties as the quakes become more severe. [Note: there was only one death reported from the 2001 Nisqually quake. This is below the number of deaths predicted by the HAZUS model. There are earthquakes with a similar geologic mechanism to Nisqually such as the magnitude 6.5 quake in the Kent Valley in 1965 that resulted in 7 deaths and the magnitude 7.1 Olympia earthquake in 1949 that resulted in 8 deaths that support the HAZUS results.]

Following a Bolts-Plus retrofit, the results improve dramatically as shown in Table 2B. It is estimated that buildings retrofitted to that level would have zero deaths from either a Nisqually 6.8 or Cascadia 9.0 event. The model predicts that Bolts-Plus retrofits would still allow a limited number of deaths from a Seattle Fault quake, but that number would be reduced by more than 90% from the estimate for completely unreinforced masonry buildings.

The results for reinforced masonry buildings shown in **Table 2C** are also striking. If all potential URMs in the Seattle data set were replaced with comparably sized reinforced masonry buildings with comparable occupancy, building-related casualties of all degrees of severity would be virtually eliminated for each of the three earthquakes. There would be only a handful of people requiring any treatment, and none are projected to require hospitalization.

Indeed, this result is why URMs were beginning to fall out of favor in seismically active regions as early as the mid-1930's. Structural engineers and architects realized that unreinforced masonry buildings were susceptible to the accelerations and movement that occurs in earthquake impacted regions.

Appendix 4.C contains a series of tables similar to those for Appendices 4.A and 4.B, these covering the range of casualty impacts for alternative earthquakes, degrees of seismic retrofit, and subsets of the 929 potential URM buildings.

Conclusion

With key earthquake and retrofit impacts identified in the Task 2 Memo and the representative earthquakes identified in the Task 3 Memo, the HAZUS earthquake impact model from FEMA allowed us to estimate the impacts of those earthquakes under alternative assumptions about URM buildings' retrofits.

2 This analysis is designed to compare the benefits and costs before and after a retrofit and is not indicative of the actual injuries and deaths from any particular earthquake. Some small portion of the buildings in the database may have already been retrofitted to a Bolt-Plus standard, which should lower the actual amount of injuries and deaths.

Table 2A: Estimated Casualties for Un-Reinforced Masonry Buildings

Daytime Occupants	Daytime Event: Nature of Casualty	Estimated Casualties		
		Nisqually	*Cascadia*	*Seattle*
27,761	Treated & Released	141	231	940
	Hospitalized	34	59	275
	Life-Threatening Injury	4	8	43
	Death	10	17	86
Nighttime Occupants	**Nighttime Event:** Nature of Casualty	**Estimated Casualties**		
		Nisqually	*Cascadia*	*Seattle*
12,926	Treated & Released	80	120	386
	Hospitalized	19	30	110
	Life-Threatening Injury	2	4	16
	Death	6	8	33

Table 2B: Estimated Casualties for Bolts-Plus Retrofited Masonry Buildings

Daytime Occupants	Daytime Event: Nature of Casualty	Estimated Casualties		
		Nisqually	*Cascadia*	*Seattle*
27,761	Treated & Released	10	18	114
	Hospitalized	0	1	23
	Life-Threatening Injury	0	0	1
	Death	0	0	6
Nighttime Occupants	**Nighttime Event:** Nature of Casualty	**Estimated Casualties**		
		Nisqually	*Cascadia*	*Seattle*
12,926	Treated & Released	6	11	51
	Hospitalized	1	1	9
	Life-Threatening Injury	0	0	1
	Death	0	0	2

Table 2C: Estimated Casualties for Reinforced Masonry Buildings

Daytime Occupants	Daytime Event: Nature of Casualty	Estimated Casualties		
		Nisqually	*Cascadia*	*Seattle*
27,761	Treated & Released	0	1	6
	Hospitalized	0	0	0
	Life-Threatening Injury	0	0	0
	Death	0	0	0
Nighttime Occupants	**Nighttime Event:** Nature of Casualty	**Estimated Casualties**		
		Nisqually	*Cascadia*	*Seattle*
12,926	Treated & Released	0	1	3
	Hospitalized	0	0	0
	Life-Threatening Injury	0	0	0
	Death	0	0	0

HAZUS Modeling

The unreinforced masonry earthquake modeling was done using HAZUS-MH (version 2.1) software. HAZUS-MH is a risk assessment mapping tool used for analyzing potential damage and losses from hurricanes, floods, and earthquakes. It uses scientific and engineering methods in a GIS (ArcGIS 10.0) to estimate hazard related damage to the built environment as well as injuries and casualties.

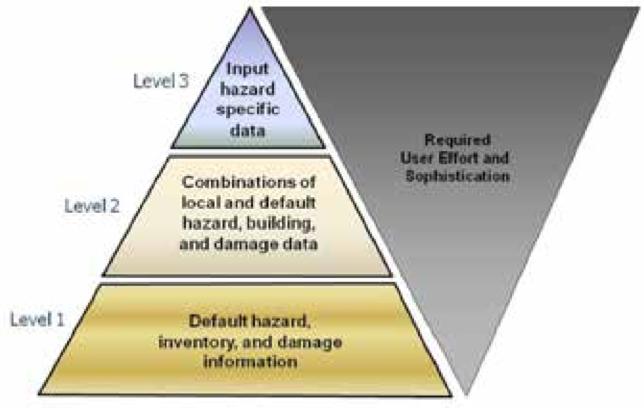
In HAZUS-MH there are three levels of modeling (see Figure 1). The first level is the most basic and least accurate, although still considered a reliable predictor of earthquake effects for large groups of buildings. It uses default (built-in) data from national and regional databases, in the absence of user-supplied data and generic building types provided in the HAZUS software. The second level called "User-Defined" is more accurate and requires additional data and information that must be input into the program. Some examples include census and specific building data. Lastly, the third level of HAZUS modeling called "Advanced Engineering Building Model (AEBM)" is the most time consuming and information intensive, and consequently the most accurate. It allows users to create building-specific damage and loss functions for assessing losses for an individual building (or group of similar buildings) both in their existing condition and after seismic retro-fitting. Building-specific damage and loss functions are based on the properties of a particular building. The particular building of interest could be either an individual building or a typical building representing a group of buildings of an archetype. This is the method we used.[1]

The Advanced Engineering Building Model (AEBM) process has six complex steps that include many sub-steps (see Figure 2) that require advanced knowledge of not only the HAZUS software, but also building engineering. The first step is creating a study region. The second step is defining and inputting the earthquake hazard data (shakemap and liquefaction data). The third step is creating and inputting the AEBM profiles (unique building types with user created fragility curves). The fourth step is creating and inputting the AEBM inventory (includes building data, type and design level; and occupancy type). The fifth step is running the analysis. The sixth and final step is creating the report.[2]

1: Creating the Study Region

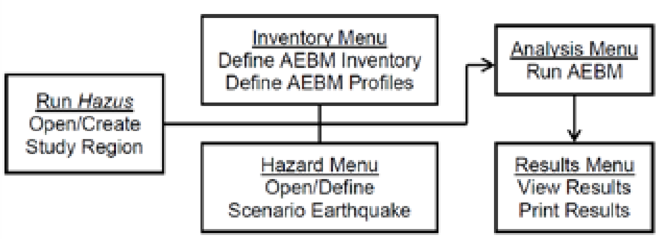
The study region is the area being modeled. The region is created based on Census Tract, Census Block, county, or state. For this study the region was the city of Seattle, WA at the Census Tract level. Once you create a region it cannot be modified. Consequently we had to create a different region for each modeling run (a total of 135 regions, 108 for the first phase and 27 for the second phase).

Figure 1: Levels of Analysis



Source: The Federal Emergency Management Agency (FEMA)

Figure 2. Flowchart of AEBM process



Source: The Federal Emergency Management Agency (FEMA)

1 Federal Emergency Management Agency. 2012. HAZUS-MH 2.1: Advanced Engineering Building Module (AEBM): Technical and User's Manual. www.fema.gov/plan/prevent/hazus

2 Federal Emergency Management Agency. 2012. HAZUS-MH 2.1: Earthquake Model: User Manual. www.fema.gov/plan/prevent/hazus.

Step 2: Defining and Inputting the Earthquake Hazard Data

In order to do a modeling run you must define and input a hazard scenario. This includes shakemaps and liquefaction maps. In this study we defined three earthquakes: the Cascadia Subduction Zone 9.0 magnitude earthquake; the Seattle Fault 6.7 magnitude earthquake; and the Nisqually 6.8 magnitude earthquake. We used the appropriate USGS shakemaps, converted the shapefiles to a geodatabase using the Shakemap Utility and imported the data along with the liquefaction maps for each earthquake scenario. This was done for each study region and every modeling run.

Step 3: Creating and Inputting AEBM Profiles

AEBM profiles describe a large set of building performance characteristics, including fragility curves. Fragility curves describe the probability of being in a specific damage state (slight, moderate, extensive and complete) as a function of the size of an earthquake. For this project 68 profiles were created using two building types, three seismic code levels (Existing, Bolts Plus, and ASCE 41 Retrofit), and eleven occupancy types (commercial, residential, education etc.).[3]

Each new profile must be entered into an access database and then imported into HAZUS via a complex process. HAZUS is quite demanding. Everything has to be exactly correct (the processes, formatting and data) or the profiles and modeling will not work. Every building being analyzed and input into the AEBM Inventory must be linked to one of these AEBM Profiles. This was done for each of the 135 study regions.

Step 4: Creating and Inputting AEBM Inventory

Each building being analyzed must be input into an access database and then imported into HAZUS using specific formatting for each of the 135 study regions. The following data is required for every building:

- Building type
- Occupancy type
- Building design level (seismic code)
- Building area (square footage)
- Building value
- Content value
- Latitude
- Longitude
- Day time and night time occupancy

Step 5 and 6: Running the Analysis and Creating the Report

Now that the study region(s) have been created; all the necessary and correct hazard data, profiles and building inventory have been input properly, it's time to run the analyses. We ran 135 of them and created an equal number of reports.

This level of analysis would not have been possible without a few experts who contributed during key phases. Kelly Stone, a Risk Analyst for FEMA Region 10, provided much needed guidance on setting up and performing the complex AEBM process. Seth Thomas, a Designer at Degenkolb Engineers created the unique building profiles, which include the fragility curves. And Dr. Arthur Frankel, a Senior Scientist with the USGS, provided guidance on which shake maps we should use.

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3 Federal Emergency Management Agency. 2012. HAZUS-MH 2.1: Advanced Engineering Building Module (AEBM): Technical and User's Manual. www.fema.gov/plan/prevent/hazus.

An unreinforced masonry building anchors a key intersection in a Seattle neighborhood.

TASK 5.1 MEMO: Benefit-Cost Analysis

This task combines analysis of the impacts listed in Task 2 with the seismic retrofit policy alternatives defined in Task 1. It presents the results of benefit-cost analysis of those impacts in two task memos:

1. **Comparing 100% unreinforced buildings versus 100% Bolts-Plus retrofitted buildings.** In this section the costs of earthquake impacts to unreinforced masonry buildings are compared with the costs of impacts to those same buildings if they were assumed to meet the Bolts-Plus standard. (Note that while impact calculations are included in Appendices 4a, 4b and 4c for reinforced masonry buildings, these do not match a seismic retrofit option, and are included more for illustrative purposes, to provide a "bookend" on major earthquake impacts.)
2. **Current URM Code and Building Mix versus post-Retrofit Code and Building Mix.** This section presents information on the kinds of economic considerations building owners take into account when deciding whether or not to retrofit their URMs. The range of likely responses from URM building owners facing new mandatory seismic retrofit requirements are described in this section, along with information on the range of benefit-cost consequences associated with these new code-driven responses.

A. Benefit-Cost Analysis - URM to Bolts-Plus Comparisons

If it is assumed that all URM buildings are retrofitted with the types of Bolts-Plus interior structural strengthening measures described in Task 1, the historic value of the buildings and the aesthetic character of their neighborhoods would be preserved in the absence of earthquakes. Differences in these two key qualitative factors would arise primarily in the event of earthquakes strong enough to destroy or seriously damage an unreinforced building, but not a retrofitted building. Accordingly, the majority of the benefit of Bolts-Plus seismic retrofits accrues from a combination of life safety improvements and reduction in the economic damage to surviving buildings. These benefits are highlighted in this section.

To check if the variability in the quantified portion of the analysis makes a difference in the outcomes, a substantial number of sensitivity analyses were conducted. These scenarios illustrate how much the baseline benefit-cost results would be affected by the choice of alternative assumptions within identified reasonable ranges.

While the economic and life safety impacts described in Task 4 constitute a major portion of this benefit-cost analysis of retrofits, there are other non-quantified impacts which become important in the benefit-cost comparisons when comparing policy alternatives for seismic retrofits.

1. HAZUS Modeled Impact Comparisons. The HAZUS impact comparisons are based on conversion of all buildings from an unreinforced condition to Bolts-Plus retrofit condition. This estimate of aggregate impacts is thus an upper-bound for the set of buildings in question, because i) some of them are already retrofitted, and ii) faced with new Code requirements some of them will be demolished instead of retrofitted.

That upper-bound caveat applies to the aggregate estimates of benefits and costs, but not to the benefit-cost ratio estimates. That is because the impact results per square foot are similar among the various subsets of the 929 buildings that were analyzed separately, so the benefit-cost ratio results that were calculated for all buildings are also reasonable estimates for virtually any subset of the 929 buildings that may actually be retrofitted.

The same logic would apply if it were discovered that some URM buildings have been omitted from the DPD data set underlying this analysis, and the cohort of retrofitting buildings were to increase as a result.

2. Quantified Benefits and Costs of Retrofits. The quantified elements of these benefit-cost analyses are summarized in Table 1 below. The pattern of relative costs is clear - all earthquake-damage costs would be greater for un-retrofitted unreinforced masonry buildings than for Bolts Plus URMs. This cost saving is offset by the cost of installing the seismic retrofits in those buildings. The question addressed by the benefit-cost analysis is whether the damage cost saving is greater than or less than the cost associated with performing seismic retrofits.

The impacts provided by the HAZUS model provide parallel building and contents damage costs, as well as casualty estimates for both pre- and post-retrofit buildings. The casualty impacts have been monetized. These have been augmented with estimated economic losses of displacement and business losses for building occupants. The reduction of these combined sources of loss represents the quantified economic "benefit" of retrofits, while the seismic retrofit cost itself is the "cost."

3. Probability Weights for Earthquake Costs or Cost Reductions. As described in Task 3, the earthquake risk for Seattle URM buildings is represented by three representative earthquakes together with their respective annual probabilities of occurrence. Thus, while an earthquake may happen only at infrequent intervals, for any given year there is an "expected" cost associated with its probability of occurring in that year.

Table 1. Comparative Quantified Earthquake Damage Costs - Pre-Retrofit versus Post-Retrofit URMs

Benefit-Cost Element	Pre-Retrofit	Post-Retrofit
Retrofit Costs	None	Average or building-specific seismic retrofit cost
Building loss impacts	Higher damage to unreinforced buildings	Lower damage to partially reinforced buildings
Building contents loss	Higher damage due to more heavily damaged buildings	Lower damage due to less heavily damaged buildings
Other economic loss	Longer and more extensive occupant displacement and business closures	Shorter and less extensive occupant displacement and business closures
Casualty impacts	More extensive due to occupants in or near more heavily damaged buildings	Less extensive due to occupants in or near less heavily damaged buildings

Accordingly, the earthquake-related costs listed in **Table 1** can be expressed as recurrent expected costs, comprised of the earthquakes' annual probabilities multiplied by the costs estimated to result when the earthquakes actually occur.

4. Baseline Quantitative Benefit Cost Analysis. Defining the stream of future expected annual cost savings from Bolts-Plus seismic retrofits sets the stage for benefit-cost analysis calculations. The formula below lays out the calculation steps leading to a "benefit-cost ratio" - a standard measure of the benefits of an investment or policy relative to its costs.

Benefit-Cost Ratio = (Present Value of Expected Annual Cost Savings) / (Seismic Retrofit Costs),

where,

Expected Annual Cost = (Nisqually Cost Savings x Nisqually Quake Annual Probability)
\+ (Cascadia Cost Savings x Cascadia Quake Annual Probability)
\+ (Seattle Cost Savings x Seattle Quake Annual Probability)

The ideal minimum target value for this ratio is 1.00, although if it is based on only the quantified subset of a policy's impacts, a "triple bottom line" assessment is necessary to array the economic results side-by-side with the non-quantified social and environmental benefits and costs.

Table 2 presents the earthquake event costs for un-retrofitted URM buildings in Nisqually, Cascadia and Seattle Fault earthquakes, together with the expected annual earthquake risk cost for that set of buildings. Building damage, contents damage, other economic activity losses and monetized casualty costs are listed separately, along with the total. The expected annual cost is $9.65 million.

Table 3 presents the corresponding earthquake event costs for URM buildings retrofitted to the Bolts-Plus standards, for the same set of earthquakes, and also shows the expected annual earthquake risk cost for buildings so retrofitted. The same cost components are listed, along with the total. And the bottom row of **Table 3** reports the net cost savings from Bolts-Plus retrofits, relative to the risk costs for un-retrofitted URM buildings. The expected annual cost with Bolts-Plus drops to $4.69 million per year.

Table 2. Earthquake Event and Corresponding Expected Annual Damage Costs - Un-retrofitted Unreinforced Masonry (URM) Buildings

	Nisqually	Cascadia	Seattle	Expected Annual
Annual Probability	0.0367	0.0030	0.0010	
Building Damage, $m	$100.7	$154.8	$512.0	$4.67
Contents Damage, $m	$27.6	$42.9	$122.2	$1.26
Other Economic Loss, $m	$19.2	$29.6	$95.1	$0.89
Casualties, $m	$57.7	$92.0	$434.8	$2.83
Total Cost, $m	**$205.2**	**$319.3**	**$1,164.0**	**$9.65**

Table 3. Earthquake Event and Corresponding Expected Annual Damage Costs - Bolts-Plus Retrofitted URM Buildings

	Nisqually	Cascadia	Seattle	Expected Annual
Annual Probability	0.0367	0.0030	0.0010	
Building Damage, $m	$58.1	$101.7	$238.8	$2.68
Contents Damage, $m	$30.2	$54.3	$96.0	$1.37
Other Economic, $m	$13.3	$23.4	$50.2	$0.61
Casualties, $m	**$0.2**	**$0.3**	**$28.9**	**$0.04**
Total Cost, $m	$101.8	$179.6	$413.9	$4.69
URM Savings, $m	**$103.4**	**$139.7**	**$750.1**	**$4.96**

Table 4. Baseline Benefit-Cost Ratios - Bolts-Plus Retrofits to Seattle URMs

B-C Ratio Element	Annual Cost or Benefit ($m)	Present Value of Cost or Benefit ($m)	Benefit-Cost Ratio
Retrofit Cost		$808.8	
Economic Savings	**$2.17**	$27.0	**0.033**
Casualty Savings	$2.79	$34.6	0.043
Total Savings	**$4.96**	$61.6	**0.076**

Thus, the total annual expected retrofit cost savings shown in the bottom row of Table 3, amounts to $4.96 million ($9.65 million minus $4.69 million), of which $2.14 million is based on building, content and other economic activity cost savings, and the remaining $2.79 million is based on the estimated monetized reduction in casualty costs.

These annual savings are a key building block for the quantified benefit-cost analysis of seismic retrofits. The retrofits would have a significant upfront cost, but would produce a stream of the future annual benefits estimated in Table 3. Each of these life-cycle benefit cost elements depends on key assumptions.

- **Seismic Retrofit Costs -** Local structural engineers, building owners and others were consulted regarding the most reasonable assumption for the average cost of Bolts-Plus seismic retrofits. While the range of values discussed was wide ($20 - $60 per square foot) for a number of reasons, they translated to an average or representative value of about $40 per SF for a set of buildings of varying sizes and in varying conditions.
- **Life Cycle Benefit Calculation -** To convert the stream of annual benefits from seismic retrofits to an equivalent "present value," the two key assumptions are i) the number of future years to include, and ii) the discount rate to apply to future years' potential savings. As noted in Task Memo 3, the values selected for the baseline analysis are 30 years and a 7% real discount rate.

Table 4 incorporates these key assumptions and calculates the resulting benefit-cost ratios.

Two separate benefit-cost ratios are shown in **Table 4**. One incorporates only the direct economic benefits of seismic retrofits - reductions in damage to buildings and contents and reductions in earthquake-related business activity disruption. This is labeled "Economic Savings," and has a value of **0.033**, shown in a shaded cell in the right -hand column. This Economic Savings benefit-cost ratio reflects the benefits that would accrue directly or indirectly to building owners. The other benefit-cost ratio includes the economic savings and also incorporates monetized values of casualty reductions. These were calculated using FEMA's estimates of the average cost associated with casualties of various severities, including deaths from earthquakes. Adding these estimated savings, the resulting "Total Savings" benefit-cost ratio is **0.076**, also shown in a shaded cell in the right-hand column. This Total Savings benefit-cost ratio reflects both the "internal" benefits accruing to building owners and the "external," or public benefits associated with life safety improvements for others who would be at risk in earthquakes.

These baseline benefit-cost ratios are quite low. They mean that for each $100 of retrofit cost, there would be $3.30 or $7.60 of life-cycle savings associated with the reduced earthquake damage.

<u>5. Sensitivity Analyses of Key Assumptions.</u> The baseline benefit-cost ratio calculations depend on many assumptions, some of which are either inherently uncertain, variable from building to building, or judgmental in nature. That raises the question of how sensitive the overall result is to these various types of variability.

To address this question, seven different key assumptions have been selected and evaluated below, to determine how influential changes in them would be on the overall benefit-cost result.

While these sensitivity analyses help to identify the assumptions most important in estimating a baseline average benefit-cost ratio for the inventory of URM buildings in Seattle, they are perhaps even more valuable in helping to illustrate the building-to-building variability in the benefits versus costs of seismic retrofits.

- **Retrofit Cost -** Information from structural engineers, building owners and past experience with individual buildings consistently recognizes that the costs of seismic retrofits can vary widely from building to building. Moreover, it is not clear without individual inspections how many of the 929 Seattle URM buildings would require retrofits in the low end of the potential cost range and how many would require retrofits in the high end of that range.

  To address this expected variability from building to building as well as the uncertainty regarding average retrofit cost for the entire building cohort, this first sensitivity analysis focuses on the wide range of Bolts-Plus seismic retrofit cost estimates suggested by participants in a building owners and managers charrette convened by Collins-Woerman, which was reviewed and accepted by the project's Technical Review Group structural engineers.

  These groups suggested that costs could be as low as $20 per square foot and as high as $60 per square foot for the performance standards and measures that would be required in a Bolts-Plus program. **Table 5a** shows the benefit-cost results for retrofits within that possible cost range.

  The retrofit costs are the denominator for the benefit-cost ratios, so halving the cost - from $40 per SF to $20 per SF - doubles the benefit cost ratios. Similarly, increasing the cost by half - from $40 per SF to $60 per SF - lowers the benefit cost ratios by one-third. These patterns are shown in Table 5a.

Table 5a. Alternative Retrofit Cost per Square Foot

Alternative Assumption Values	Benefit-Cost Ratio	
	Economic Savings	*Economic and Casualty Savings*
$20 per sf	0.067	0.152
$40 per sf	0.033	0.076
$60 per sf	0.022	0.051

  While the overall average for the full set of URM buildings may lie closer to the middle of the range assumed in Table 5a, there would be many buildings nearer the lower and upper ends of that cost range, for which the retrofit economics could be significantly better or worse than the average. However, it is worth noting that even in the best case shown in Table 5a, when casualty costs are quantified and retrofit costs are at the low end of the range, the benefit cost ratio is still just 0.152, meaning that the present value of quantified benefits would be 15.2% of the costs.

- **Building Value -** The source data for the 929 URM buildings' values is from the King County Assessor's Office real property files. Each property has separate land and improvements value estimates, and the improvements values were extracted for each of the buildings in the DPD data set.

  It is generally recognized that these improvements values tend to understate actual market values somewhat, so the initial source data was increased by 10% to better approximate market value. However, the 10% adjustment factor is judgmental, and this sensitivity analysis considered the impacts of applying upward adjustment factors of 5% and 20%.

  Note that the value of improvements has been estimated as a percentage of the building values. As a result, increasing the building adjustment factor also increases the value of contents by the same percentage. The results are shown in Table 5b below.

  Due to the multiplicative nature of this sensitivity analysis, the economic savings are decreased by about 5% in the low case, and they are increased by about 10% in the high case. This is seen in Table 5b, where the Economic Savings benefit-cost ratios change by those percentage amounts. The casualty savings are not affected by this case, so the Economic and Casualty Savings benefit-cost ratios do not rise proportionately. As shown by the range of benefit-cost ratios in Table 5b, none of these cases changes the overall result appreciably; the estimated benefits are still a small fraction of the costs of seismic retrofits in each case.

Table 5b. Alternative Building Value Premium Above Assessed Value

Alternative Assumption Values	Benefit-Cost Ratio	
	Economic Savings	*Economic and Casualty Savings*
AV + 5%	0.032	0.075
AV + 10%	0.033	0.076
AV + 20%	0.036	0.079

- **Contents Value -** The baseline benefit-cost analysis assumes that the value of contents in URM buildings is equal to 50% of the value of the building. This is consistent with other previous HAZUS analyses and exceeds the FEMA default assumption. However, the actual contents value is highly variable from building to building, and the assumption is fairly uncertain in the aggregate as well.

  In recognition of these facts, this set of sensitivity analyses considers both substantially lower and substantially higher contents value assumptions. As with several other assumptions, this can inform the building to building variability in this factor and its effect on the economics of seismic retrofits. It also helps to determine to what degree the overall assessment of retrofits is influenced by this factor. Table 5c reports the benefit-cost ratios for assumptions regarding contents value that range from a low of 30% to a high of 70% of building value.

  Table 5c shows that assuming either substantially lower or higher levels of building contents value changes the benefit-cost ratio results surprisingly little. While the assumptions are +/-40% of the baseline assumption, the benefit-cost ratios are essentially unchanged.

  This reflects the mixed value of retrofits to contents preservation from one earthquake event to the other. For both Nisqually Fault and Cascadia Subduction Zone design earthquakes, contents values are preserved to a significantly greater degree in seismically retrofitted URMs, but for the Seattle Fault event, the reverse is estimated to be true. These results largely cancel one another out, after adjusting for the probabilities of the various earthquakes.

- **Displacement and Business Disruption Loss -** The cost of displacement and loss of business due to physical damage and required closures has been estimated in the baseline benefit-cost analysis to amount to an additional 15% beyond the economic loss to the buildings and their contents. This is a very imprecise estimate, but it is based on the proportional losses for these impacts that have been estimated in prior HAZUS earthquake analyses, including the evaluation of the Seattle Fault quake prepared in 2005 (Earthquake Engineering Research Institute and Washington Military Department Emergency Management Division).

Table 5c. Alternative Loss of Building Contents Multiplier Value

Alternative Assumption Values	Benefit-Cost Ratio	
	Economic Savings	*Economic and Casualty Savings*
30% * Building	0.034	0.077
50% * Building	0.033	0.076
70% * Building	0.033	0.075

Table 5d. Alternative Loss Adjustment to Reflect Business Disruption

Alternative Assumption Values	Benefit-Cost Ratio	
	Economic Savings	*Economic and Casualty Savings*
10% of Building	0.032	0.075
15% of Building	0.033	0.076
30% of Building	0.038	0.080

Recognizing the wide range of impacts possible from building to building - and even in the aggregate for the 929 building data set - this sensitivity analysis examines the effects on the overall benefit-cost ratios of changing that high-level assumption for business activity loss.

The results shown in **Table 5d** indicate that increases or decreases the level of assumed business disruption loss make very little difference in the overall benefit-cost ratio calculations. That is because this component of savings from reduced economic loss represents less than 15% of the total savings, so a change in that portion changes the overall result by less than 15%.

With the casualty reduction component of total savings unaffected by this change in assumption, the aggregate benefit-cost calculations for economic and casualty loss would experience an even lower proportional change.

- **Discount Rate -** The impacts associated with an earthquake are projected as a future series of annual impacts based on small annual probabilities. The series of annual impacts are converted into present value calculations using a discount rate, which accounts for the diminishing value of events that are projected to occur in increasingly distant future years.

  The baseline benefit-cost calculation discounts future annual impacts at an inflation-adjusted rate of 7% per year.

This is the rate assumed by FEMA for similar earthquake-related benefit-cost calculations. However, many public agencies, including several capital-intensive City of Seattle departments, assume lower inflation-adjusted annual discount rates, in the range of 3%-5%. Conversely, the inflation-adjusted discount rates used for major private investment analyses frequently range upward from 7%.

Table 5e shows the sensitivity of the overall benefit-cost ratios to lower and higher discount rate assumptions. One potential use of this information is to consider reasonable ranges for different groups of individual buildings. For example, the lower end of the discount rate range may be more reasonable for public buildings, and the higher end of the range for privately owned buildings.

As shown in Table 5e, the relatively wide range of alternative discount rate assumptions changes the benefit-cost results substantially in percentage terms. However, since the baseline result is so far below the "cost effectiveness" threshold of 1.0, these sensitivity analysis results still fall far below that threshold as well.

Table 5e. Alternative Discount Rate for Future Cost Savings

Alternative Assumption Values	Benefit-Cost Ratio	
	Economic Savings	*Economic and Casualty Savings*
3% Real	0.053	0.120
7% Real	0.033	0.076
10% Real	0.025	0.058

Table 5f. Alternative Time Horizon of Analysis

Alternative Assumption Values	Benefit-Cost Ratio	
	Economic Savings	*Economic and Casualty Savings*
20 Years	0.028	0.065
30 Years	0.033	0.076
50 Years	0.037	0.085

- **Time Horizon -** The appropriate length of the future series of annual impacts to include depends in each individual URM building's case on the expected life of the building. For private owners in particular, it also depends on their planning horizon for financial planning, which may be shorter than the physical life expectancy of the building.

  In evaluating the benefit-cost prospects of the large cohort of 929 URMs in the DPD data base, the baseline analysis uses a planning horizon of 30 years. This is the period assumed by FEMA for similar earthquake-related benefit-cost calculations. However, due to the variability in URM buildings' conditions and probable remaining life, as well as the variability in owners' planning horizons, this sensitivity analysis explores the impacts on the overall benefit-cost ratio calculations of both shorter and longer planning horizons.

  Table 5f presents the results for benefit-cost analyses extending over 20, 30 and 50 years. While the 30 year horizon assumption may be reasonable on average for the entire cohort of buildings, the shorter period may be more appropriate for individual buildings that are in poorer condition, while the longer period may be more appropriate for buildings that are in better condition or that are publicly owned and projected for longer-term use.

  Table 5f indicates that the baseline benefit-cost calculation results are not particularly sensitive - neither in percentage change or absolute ratio change - to this assumption. This is true even for a period twenty years longer than in the baseline. That is because the added years are also the ones most heavily discounted. Similarly, shortening the time horizon from 30 to 20 years eliminates the ten most heavily discounted years of the baseline, resulting in proportionally less reduction in the present value of benefits.

- **Earthquake Events' Likelihood -** The last of the key assumptions addressed in these sensitivity analyses is the set of probabilities of the three design earthquakes occurring in a given year. The probabilities assumed in the baseline benefit-cost calculations reflect the accepted earthquake recurrence intervals selected by Northwest seismologists through a combination of empirical and theoretical techniques. While these are accepted baseline values, they are also recognized as being inherently uncertain. To address this uncertainty, a plus-and-minus range of +100% / - 50% was suggested by seismologist Art Frankel, who was the primary expert source for the baseline values (see Task Memo 3).

  Table 5g includes those cases as sensitivity analysis lower-bound and upper-bound values and shows the impacts on benefit-cost ratios of that range of earthquake probabilities. These alternative assumptions do not affect the estimated degree of economic damage or estimated numbers of casualties in the event of the three design earthquakes; they simply affect the annual probability multipliers that are applied to those impacts. Thus, the annual damages before and after retrofits are multiplied by the same factor, which means the savings from retrofits are also multiplied by that factor.

  As shown in Table 5g, the benefit cost ratios in the low and high earthquake probability sensitivity analysis cases are equal to 50% and 200% of their baseline values. As

Table 5g. Alternative Annual Probabilities of Earthquakes' Occurrence

Alternative Assumption Values	Benefit-Cost Ratio *Economic Savings*	Benefit-Cost Ratio *Economic and Casualty Savings*
50% * Baseline	0.017	0.038
Baseline [1]	0.033	0.076
200% * Baseline	0.067	0.152

[1] Baseline annual probabilities are 3.677% for Nisqually, 0.30% for Cascadia and 0.10% for Seattle earthquakes.

Table 5h. All "Best Case" Sensitivity Values

Alternative Assumption Values	Benefit-Cost Ratio *Economic Savings*	Benefit-Cost Ratio *Economic and Casualty Savings*
All "Best Case"	0.333	0.688
Baseline	**0.033**	**0.076**
All "Worst Case"	0.007	0.017

with each of the preceding sensitivity analysis cases, the low baseline benefit-cost ratio results mean that these fairly wide percentage adjustments still result in a range of benefit-cost ratio calculations that are all far below the cost-effectiveness threshold.

- **Composite Sensitivity Analysis -** The preceding sensitivity analyses considered individually show that the baseline benefit-cost ratio result is very insensitive to alternative assumptions within a reasonable range. The highest ratio calculated is 0.152, meaning a return of $15.20 for each $100 spent on seismic retrofits.

  It is possible that more than one variable could assume a value consistent with greater benefit from retrofits. It is of course highly unlikely that all seven variables considered would deviate from the baseline in the same direction, and even less likely that they would vary to the maximum extent of the ranges considered above. Nevertheless, it is illustrative to examine what the impact would be for the benefit-cost ratio if that did occur. The results are shown in **Table 5h**, for both an All Best Case and an All Worst Case set of assumptions.

  Table 5h indicates that even assuming extreme positive values for all seven sensitivity analysis variables, the composite benefit-cost ratio would still only reach 0.688, while in the extreme negative case, the benefit-cost ratio would only be 0.017. In short, the baseline conclusion is unaffected by any combination of sensitivity analysis values.

6. Non-Quantified Impacts. The preceding baseline and sensitivity analyses reflect the two primary considerations in a "triple bottom line" analysis of seismic retrofits' benefits and costs. The financial elements are well represented, through the inclusion of building, contents, and business/tenant displacement reduction benefits. And the monetized life safety benefits that are estimated represent the largest, most significant of the social benefits - through cost reductions - associated with retrofits.

In addition, there are four other benefits often recognized as accompanying seismic retrofits of URM buildings, in particular. These are the following:

- **Increases in buildings' market value -** It is possible that seismic retrofits would increase either the lease rates or the market sales value of URMs. Retrofits in the absence of building remodels or upgrades would raise lease rates if potential tenants recognized the value of improved life safety or reduced probability of business disruption. Similarly, the market sales value of URM buildings could rise if potential new owners recognized the value of the reduction in investment risk.

  If these market values were adjusted, however, the extent of the adjustment (to lease rates or sales price) would be similar to the estimated benefits in the preceding quantified benefit-cost analysis. Such adjustments would not represent additional benefits. They are rather the market mechanisms by which the owners could recoup the relatively small expected benefits estimated above from their investment in seismic retrofits. [1]

- **Reductions in buildings' insurance costs** - Reductions in buildings' seismic insurance costs have been identified as a potential benefit of seismic retrofits. This relates to an assumed reduction in seismic risk cost.

  The benefits calculated in the preceding sections are based on reductions in risk costs. That risk cost could either be borne by the building owner directly or transferred to an insurance carrier for a price. The expected cost to the owner - and the reduction in that cost due to retrofits - is similar in either case. The insurance consists of trading a very small chance of a large cost into a 100% chance of a small cost, the insurance payment.

  For URM building owners who currently have seismic insurance, it is possible that they would be able to insure the lowered post-retrofit risk at a lower premium, continuing to bear the risk cost through insurance. Some URM owners who do not currently have seismic insurance, they may after a retrofit be able to insure the lowered risk cost. In that case, while the reduction in risk cost may be the same, they would then

1 DPD consulted with local real estate brokers, who were of the opinion that there would be little impact on buildings' market value from performing seismic retrofits without other building improvements.

be bearing it through insurance payments, rather than through accepting the low probability of a major loss. In either case, the acquisition of insurance and its cost does not represent an additional benefit or cost. It is more accurately an alternative form of the risk cost, which would be reduced by seismic retrofits, as previously estimated.

- **Greater Historic Preservation** - Many URM buildings in Seattle have historic value. Some of these buildings are officially recognized and others may be at some time in the future. Further, while a substantial number of these buildings have been seismically retrofitted, there are others that have not. Those that have not been retrofitted face a greater probability of damage or destruction in the event of large earthquakes. While their retrofit would not guarantee their preservation, it would significantly increase the likelihood of their preservation in the event of most of the range of earthquakes that could occur in or near Seattle.

  The direct economic value to the historic buildings owners of that more-likely preservation was estimated and is reflected in the earlier sections of this task memo. However, historically relevant buildings also have value to the community and the City. While not quantified, increasing the probability of retaining that value represents an additional social/environmental benefit of URM retrofits.

- **Maintaining Community Visual Character** - In a number of neighborhoods throughout Seattle, URM buildings create a significant portion of a positive neighborhood aesthetic character. While these buildings may not be considered historically significant, in other regards they are similar, in that they are of value to their community in general, not just to their owners and occupants.

  Some Seattle neighborhoods are visually identified by the broader community in a positive way because of their extended streetscapes of side-by-side URMs. As with historically significant URMs, these "neighborhood character URMs" have value to more than their owners, and their seismic retrofit would increase the probability of retaining that environmental/social value in the event of large earthquakes.

7. Perspectives. Several different parties are involved either in sharing the costs of adopting retrofits or in realizing benefits they provide, so it would be possible for retrofits to have net benefits in the aggregate but not for a party whose participation is necessary. For the Seismic Retrofit Benefit Cost Analysis, the key parties identified at the outset were:

- Building owners,
- Public policy officials,
- Tenant/occupants, and
- The general public.

The primary economic and social benefits from building preservation and life safety improvements would accrue to building owners and building tenants and occupants. From the preceding analysis, they amount to only a small percentage of the costs involved in seismic retrofits. Further, while there would be some additional environmental/social benefits from historic preservation and community aesthetic appeal perspectives, these do not appear to be nearly sufficient to balance the substantial net cost from retrofits.

As a result, there is no way to shuffle the benefit shares through financial or other mechanisms to produce a "win-win" outcome for all key parties or groups. Recognizing that limitation, this report does not include further examination of means by which the total benefits and costs could be realigned to elicit support from, and provide net benefit to, all affected parties.

Conclusion

Savings in the event of a quake are significant. However, while they represent significant percentage reductions, those reductions are relative to an already small base. Further, the probability of an earthquake for which the savings would be realized is very small in any given year. Thus, even when looking over an extended 30-year planning horizon for the URMs in Seattle, the cumulative present value of benefits - reduced earthquake losses - is quite small, and would amount to only about 8% of the costs of the retrofits, on average, across the City-wide inventory of URMs.

Numerous assumptions are required to arrive at those estimated results, and each warrants careful consideration. However, when a wide but feasible range of alternative assumption values is tested, even the most conservative assumptions make very little positive difference in the ratio of benefits to costs from seismic retrofits. They remain uneconomical, relative to their costs.

From a triple bottom line perspective, social and environmental benefits must also be considered. Key among these, in the case of URMs, are historic preservation and maintenance of neighborhood character where that is defined by signature URMs. There would be further benefits in both of these areas. However, these do not appear to account for a significant portion of the negative net cost of retrofits. This is in part because the HAZUS model results indicate that most URMs would survive even the most severe of the representative earthquakes studied even without seismic retrofits, and 80-90% would survive the medium-large earthquake. Further, while the extent of damage would be reduced by retrofits, Bolts-Plus would not save all of the remaining at-risk buildings.

TASK 5.2 MEMO: Benefits-Cost Analysis of Mandatory Seismic Upgrade

The analysis in Task Memo 5.1 focused on the benefits and costs of seismic retrofits alone, in the absence of other factors. It was based on an identified inventory of 929 URM buildings, and its estimates assumed that all buildings were in an unreinforced condition and that all would then be retrofitted. However, reality is more complicated. Specifically:

i. The existing URM building inventory compiled by DPD may include some buildings with partial or full seismic retrofits, and may not include other URMs, and

ii. Owner actions following a mandatory retrofit code would include a mix of responses that would span a wide range from demolition to retrofits. These responses could afford some owners the ability to offset at least a part of the substantial seismic retrofit cost.

Task Memo 5.2 addresses these two complications. First it describes some of the uncertainties surrounding the 929 building set of URM buildings. Second, it evaluates the benefits and costs of adopting a mandatory seismic retrofit code, by identifying the range of likely choices building owners would make with a mandatory retrofit policy and the impacts associated with each.

A. Adjustments for voluntary retrofits in baseline URM data set

A portion of the masonry buildings in the potential URM data base are already seismically retrofitted, some only partially, some to Bolts-Plus standards, and some to levels even higher than Bolts-Plus. As a result, relative to the estimates in the HAZUS runs for URM buildings, these buildings would:

- Be safer and have fewer casualties in any earthquake;
- Sustain less earthquake damage to building and contents, and
- Cost less to seismically upgrade to Bolts-Plus standards.

The aggregate cost to upgrade the inventory of 929 buildings to the Bolts-Plus standards would be somewhat less as a result of the retrofit work that has already been done, and the aggregate exposure and corresponding loss for these buildings in earthquakes would also be less. Conversely, adding URMs that had not been included in the initial data set would increase aggregate upgrade costs and potential seismic losses.

DPD conducted a limited sample survey of Seattle URMs to assess the extent of past retrofits. Based on that survey DPD estimated that approximately 15% of the existing

URMs have been seismically upgraded to some degree[1]. This would not necessarily affect the benefit-cost ratio estimates of **Task Memo 5.1**, because the ratio of benefits to costs was quite similar among all building sub-types and locations examined. Nevertheless, if the total actual URM inventory is less, it would indicate that the aggregate City-wide cost of retrofits and the potential financial and life safety losses from earthquakes would be smaller than shown in Task Memos 4 and 5.1.

B. Range of building owner responses to new codes

Just as not all 929 existing URMs are in a completely un-retrofitted state, not all un-retrofitted buildings would end up being seismically retrofitted if a mandatory seismic retrofit code were adopted. Building owners would have several choices if faced with such a code requirement:

- Seismically upgrade their building to the Bolts-Plus standards
- Demolish their building and rebuild to current seismic code
- Demolish their building and leave the parcel undeveloped for now
- Leave their building in URM condition as long as allowed and then possibly risk penalties

1 2012 URM Survey Report, City of Seattle Department of Planning and Development prepared for URM Pollciy Committee 3/21/2012

Table 6. Building Owner Response Options to Mandatory Seismic Retrofit Code - What Would Make Each A "Second Best" Option

Owner Response	Economic Characteristics of Buildings
Retrofit the URM	▪ Building's retrofit cost is greater than its incremental income-generating value from retrofitting (i.e., why it's still an un-retrofitted URM)) ▪ Building's retrofit cost is less than its total income-generating value as a retrofitted URM (i.e., why it would be retrofitted rather than razed) ▪ Building's retrofit cost is less than its net loss in incremental income-generating value as a new replacement building (i.e., why it would be retrofitted rather than razed and replaced) ▶ ***Typical Attributes:*** *Attractive building; attractive location; limited potential for increasing FAR within current location and zoning*
Demolish and Rebuild	▪ Building's remodel-plus-retrofit cost is greater than its total income-generating value as a retrofitted URM (i.e., why it's still an un-retrofitted URM now but would not be retrofitted) ▪ Building's retrofit cost is greater than its net loss in incremental income-generating value as a new replacement building (i.e., why it would be replaced) ▶ ***Typical Attributes:*** *Unexceptional building; attractive location; significant potential for increasing FAR within current location and zoning*
Demolish and Vacate	▪ Building's retrofit cost is greater than its total income-generating value as a retrofitted URM (i.e., why it would be razed rather than retrofitted) ▪ New building income generating potential is less than new building cost ▶ ***Typical Attributes:*** *Building in poor condition; unexceptional location; limited potential for increasing FAR within current location and zoning, due to either zoning or market*
Defer Action and Disregard Code	▪ If a new code allows for deferred compliance, owners of any of the three preceding categories of buildings would defer retrofits at least as long as permitted by the new code. ▪ Some owners may also evaluate the cost of potential penalties compared to the cost of shifting from a URM to their second-best option, and accept penalties for non-compliance if that is deemed the less costly option. ▶ ***Typical Attributes:*** *Code-approved deferral response probable for all categories; continuing to disregard the code after the compliance date will most likely happen where difference between URM and second-best choice is greatest*

These same options exist currently, with the exception that no penalties are associated with leaving buildings as URMs. For the buildings that have been left in an unreinforced condition, that represents the owner's preferred option. If a mandatory seismic code eliminates or prohibits that option, owners would move to their second choice among those listed above.

Table 6 lists key economic or market characteristics of buildings that would fall within each of the options. The assumption is that the building owners choosing each option would do so based on their economic self-interest. In other words, each row describes conditions in which it is owners' current second-best option. ((Note: These characteristics are also illustrated in Figures 1 - 6 below.)

C. Benefits and Costs for Alternative Responses to A Mandatory Retrofit Code

Building and Life Safety Impacts. The alternative owner responses listed above would result in very different outcomes for the parcels choosing each. One would result in no building, at least in the immediate future, one would result in the status quo URMs, and two would result in different strengths of remodeled or new buildings. These distinctions would translate into differences in earthquake impacts, as well as differences in economic impacts for the buildings' owners. And finally, given the widely ranging physical outcomes, the community impacts on historic preservation and neighborhood character would also differ.

Table 7. Seismic Retrofit Levels of Benefits and Costs for Buildings with Differing Owner Responses to Mandatory Retrofit Code

Owner Choice	Retrofit Cost	Damage in Earthquakes	Casualties in Earthquakes	Other Economic Impacts to Owner
Retrofit to Bolts-Plus	Equal to Bolts-Plus Estimate	HAZUS Estimate for Bolts-Plus	HAZUS Estimate for Bolts-Plus	Increased lease revenues provide partial offset to retrofit cost
Demolish/Rebuild	Greater than Retrofit	HAZUS Estimate for RM ("Reinforced")	HAZUS Estimate for RM ("Reinforced")	Net loss to owner less than with retrofit alone
Demolish/Vacate	None, but cost of demolition	None	None	Loss of entire building value, but net cost less than if retrofitted
Disregard Code	None	HAZUS Estimate for URMs	HAZUS Estimate for URMs	Net cost to owner less than if retrofitted

Table 7 above summarizes the implications for retrofit costs, economic impacts and casualty impacts of the four primary potential responses by building owners to adoption of a mandatory retrofit code. In some cases these are described in Table 7 relative to the impacts estimated in the **Section A** where all buildings were assumed to be URMs currently and all were assumed to retrofit to Bolts-Plus standards. Owners' net benefit-cost outcomes would still be negative, but the impacts in the right-hand column represent a partial revenue offset not reflected in the "retrofit-only" evaluation of Section A.

Other Building Preservation Values: URM building preservation is inherently desirable in many instances, such as when a building is of historic significance or when an individual building or a streetscape of URMs creates a desirable neighborhood character.

The benefit-cost analysis of a mandatory seismic retrofit code requires a complex comparison to address this pair of values.

- In the absence of a new retrofit code, there is a small possibility each year that a building will be lost in an earthquake, due either to building collapse or to structural damage so extensive it would be uneconomic to repair.
- If a mandatory seismic retrofit code is adopted, the possibility of building loss is reduced, *but only for buildings that are retrofitted*. Some URM buildings would be demolished in response to the mandatory code, so the probable prevalence of demolitions must be taken into account.

The implications of the baseline probability assumptions for these alternative code outcomes is summarized in **Table 8.** The building loss implications under current conditions were estimated in previous Task Memos, relying on HAZUS model analysis. That analysis estimates an annual probability of 0.45% that a URM building will be lost due to earthquakes, which translates to a 12.75% probability over a 30-year planning horizon.

Table 8. Estimated Loss of URM Buildings -Alternative Code and Owner Response Scenarios [1]

Alternative	Annual Probability of Loss of URM Building	30-Year Probability of Loss of Building
Current Conditions	0.45%	12.75%
Mandatory Seismic Retrofit Code - Owner Responses		
Owner Retrofits	0.03%	1.00%
Owner Demolishes and Rebuilds	n/a	100%
Owner Demolishes and Leaves Vacant	n/a	100%
Owner Disregards Code	0.45%	12.75%

[1] The estimates of building losses through earthquakes are based on the earthquake probabilities described in Task 3, combined with the estimates of buildings with either extensive or total damage, which are presented in the tables of Task 4, Appendix A

The building loss implications of a mandatory code would be the average of the implications for each of the four owner responses, each weighted by the percentage of buildings whose owners would choose that response. For those choosing retrofits the probability of building loss would be reduced, for those delaying compliance it would be unchanged, and for those demolishing the probability would be 100%.

Interpreting the 30-year building loss estimates in the right column, the 100% loss in the two demolition cases means that if 12% or more of building owners respond to adoption of a mandatory code by demolishing their buildings, the combined loss of URMs over the 30-year planning horizon used in the benefit-cost analysis would be greater than the probable loss of un-retrofitted URMs over that horizon. (Note that similar logic applies to calculations of economic loss and casualties, as indicated in Table 7. To the extent that URMs were demolished, there would be diminished casualties and reduced exposure to further economic loss.)

Note, however, that these estimates are based on aggregate impacts for all 929 buildings in the DPD data set. The buildings lost in each case - earthquake versus mandatory code - would likely be different.

- Those destroyed, either physically or economically, by earthquakes would be fairly random, although there is a slightly higher likelihood of loss for buildings in historic districts than elsewhere (13.57% likelihood over 30 years, versus 12.57% for the non-Historic District URMs).
- Those demolished by owners, on the other hand, would tend to be those with either significant redevelopment possibilities, which would rebuild, or those on sites with lower than average development value, which would simply demolish.

Those distinctions may, however, be minor issues if the percentage of buildings demolished is on the scale of the Los Angeles mandatory seismic retrofit policy. In that case, the percentage of URMs demolished was in excess of 15%[2].

D. Benefit-Cost Analyses: Alternative Code Responses.

The benefit-cost of retrofitting URM buildings is addressed in Section 5.1, and it indicates that seismic retrofits are not economically cost effective. However, that analysis focuses only on the cost of retrofits and the benefits they provide in terms of building preservation and life safety improvements.

Imposing a seismic retrofit requirement that precludes the status quo would force building owners to re-evaluate the economics of their remaining choices. There may be no superior “second-best” options (or they would already have been chosen), but in many cases owners may have options that while less economic than the status quo are superior to simply performing seismic retrofits and absorbing the high retrofit costs with only small offsetting benefits.

This section describes the range of potential owner responses, and the range of net benefit-cost results to owners that may occur when they are able to offset at least some of the net costs of seismic retrofits by redesigning or replacing their building.

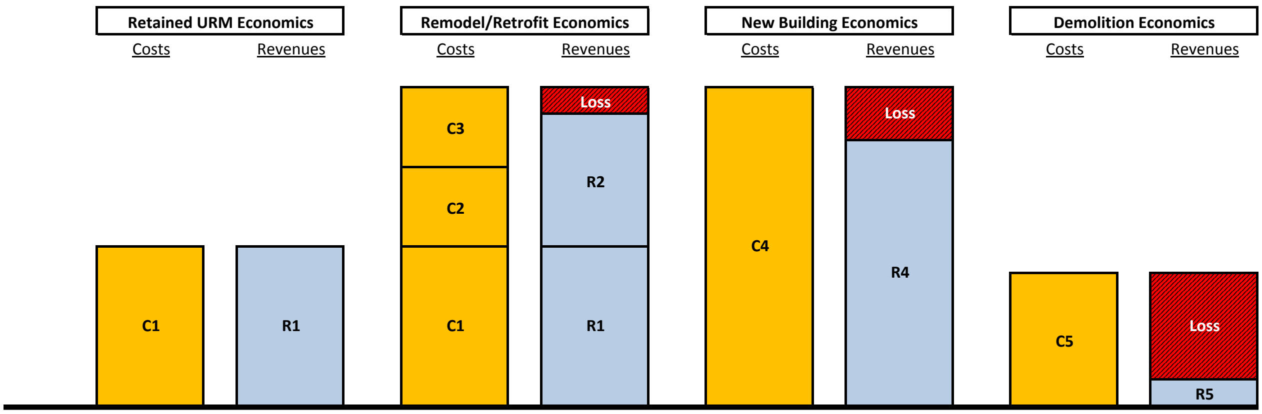
It is important to note that each of these cases assumes that the building owners are behaving rationally, choosing the most economical available option, and successfully financing sound retrofit options. In practice, there are owners who do not currently behave that way, for a variety of reasons. Among these are poor market information, challenging ownership structures or limited access to credit.

- **Poor information:** The market for real estate and the zoning regulations that help to define opportunities both change over time, and both are complex. In some cases the current information on a URM building’s potential is not fully appreciated, and it may remain as a URM even though other alternative uses are available and economically superior.
- **Challenging ownership structures:** Some buildings carry on as they are in part because of inertia. Closely held buildings may have been inherited, or may be a one-off investment of individuals or couples with no other real estate interest or expertise. Other buildings may be owned by relatively large, unwieldy consortiums that also proceed by inertia rather than according to clear management principles.
- **Limited access to credit:** Some building owners may be “land rich” and resource poor. Perhaps a building was inherited, collects modest rents and pays modest taxes or the owners may have limited access to capital because of limited access to credit.

With those caveats in mind, the following subsections address the still-wide range of rational responses that could be expected for various subsets of the existing Seattle URM buildings.

2 Summary Report of URM Retrofit Laws, Seattle Department of Planning and Development, 2012

Figure 1. High Potential for Market Recovery of Mandatory Code Cost - URM with Significant Market Opportunities Through Remodel/Retrofit, Less with New Building



Net Income:

Owner Option	Rev - Cost	Net Income/Loss	
Retain URM	(R1 - C1)	$0 m.	
Remodel/Retrofit	(R1+R2-C1-C2-C3)	($1) m.	<= Second best choice
New Building	(R4 - C4)	($2) m.	
Demolish	(R5 - C5)	($4) m.	

Code	Cost (C) or Revenue (R) Component
C1	Cost of existing URM
R1	Lease revenues from existing URM
C2	Cost to seismically retrofit URM
C3	Cost beyond retrofit to perform substantial alterations
R2	Increased lease revenues from substantial alterations
C4	Cost of a new replacement building
R4	Lease revenues from a new replacement building
C5	Investment cost of retaining parcel without building
R5	Revenues from surface use (e.g., parking)

D.1. Owner Response: Seismically Retrofit Building to Bolts-Plus

Owners who choose to seismically retrofit their URMs to Bolts-Plus is the option assumed in the retrofit benefit cost analysis of **Task Memo 5.1**. It is a response that has been chosen by many owners in the past, where building economics supported it. As noted in **Table 6**, owners selecting this response to a mandatory code would be those for whom the economic value of preserving the building with a seismic retrofit is worse than maintaining the status quo, but better than the economics of demolishing the building, with or without a replacement.

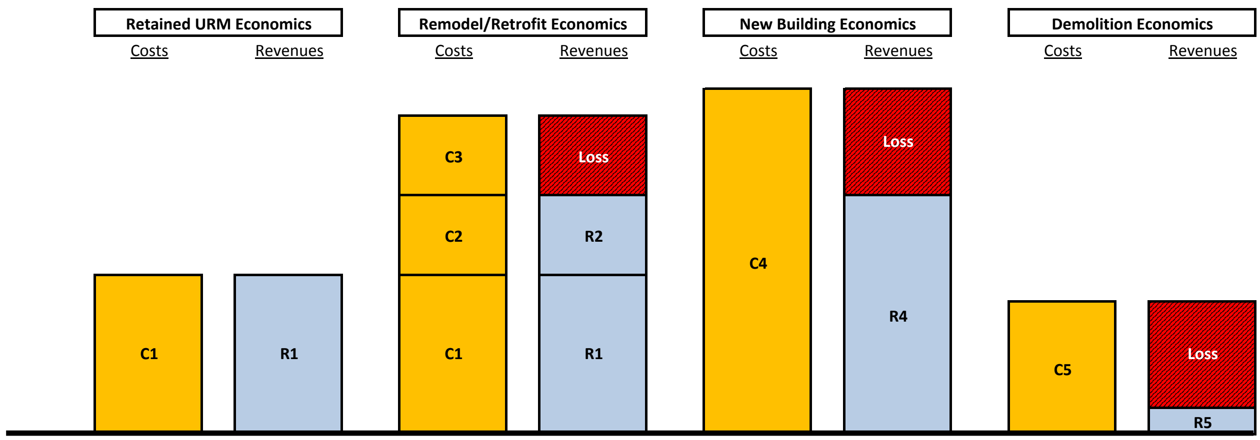
Individual owners choosing this response would experience a wide range of net added costs, as illustrated by the two scenarios in **Figures 1 and 2**. Each is consistent with Bolts Plus retrofitting, but with very different economic implications for the owner. The definitions of the individual cost and revenue elements shown in these figures as well as in **Figures 3-6** are as follows:

Figure 1 above portrays the economics of cases where the retrofit option is nearly as economical as the status quo. Buildings in these circumstances would be similar to those that have voluntarily retrofitted in the past to allow them to obtain greater income potential. For such buildings, while the direct seismic impact benefit of retrofits would only cover about 3% of the cost of the retrofit, being required to retrofit would prompt building owners to undertake substantial alterations that would both secure life safety benefits and produce additional net income. That income would offset a substantial portion of the remaining 97% of the retrofit cost. Note that in the example shown, replacing the URM with a new building would also offset a portion of the mandatory seismic retrofit cost, although not as much as with a remodel. And simply razing the building and using the parcel for a surface use (parking) would also be an inferior investment relative to remodeling and retrofitting the URM.

Figure 2 shows the other extreme of cases where remodeling and retrofitting would be the best economic option for owners facing a mandatory seismic retrofit code. In these cases, remodeling and retrofitting is still the economically best option, as there is little or no opportunity to reduce losses relative to simply absorbing the cost of the retrofit. In other words, the owner losses resulting from a mandatory code would be substantial in any case, but they would be less for the remodel and retrofit option.

For such cases where the retrofit option is not nearly as economical as the status quo, it is because there is little untapped market potential for the building and site. The net economic loss to owners of such buildings would be

Figure 2. Low Potential for Market Recovery of Mandatory Code Cost - URM with Little or No Market Opportunities Through Remodel/Retrofit, Less with New Building



Net Income:

Owner Option	Rev - Cost	Net Income/Loss	
Retain URM	(R1 - C1)	$0 m.	
Remodel/Retrofit	(R1+R2-C1-C2-C3)	($3) m.	<= Second best choice
New Building	(R4 - C4)	($4) m.	
Demolish	(R5 - C5)	($4) m.	

Code	Cost (C) or Revenue (R) Component
C1	Cost of existing URM
R1	Lease revenues from existing URM
C2	Cost to seismically retrofit URM
C3	Cost beyond retrofit to perform substantial alterations
R2	Increased lease revenues from substantial alterations
C4	Cost of a new replacement building
R4	Lease revenues from a new replacement building
C5	Investment cost of retaining parcel without building
R5	Revenues from surface use (e.g., parking)

more substantial, and in some cases it would be similar to the benefit-cost outcome reported in **Section A.** Note that there could be even worse outcomes associated with constructing a new building or demolishing the URM without any replacement.

Table 9 summarizes the benefit-cost analysis components for this subset of the current URMs.

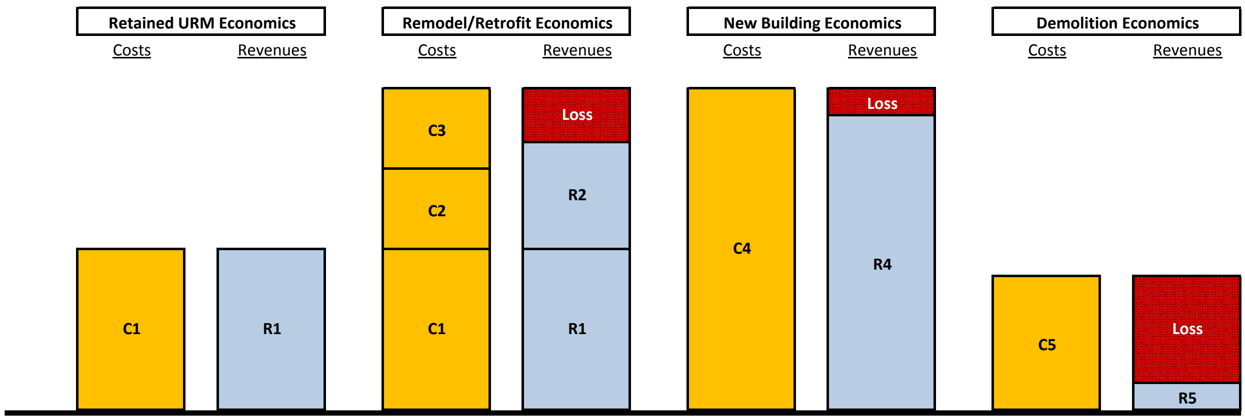
Net Benefit-Cost Assessment: For these current URM buildings, the financial and casualty elements of the benefit-cost ratio upon adoption of a mandatory seismic retrofit code could vary widely, from a low of 0.076 for some buildings, to a high close to 1.00 for those with the highest untapped market potential for attractive remodeled URMs.

In addition, these buildings would produce positive net social benefits in the form of preserved neighborhood character and historic preservation. They would retain the attractive visual amenity of URMs in normal times, and be more likely to survive future earthquakes with their URM appeal intact.

Table 9. Benefit-Cost Assessment for Buildings That Would Choose to Retrofit with A Mandatory Seismic Code

Impact Element	Mandatory Retrofit
Building & Casualty Benefit-Cost	B-C Ratio = 0.076
Increased Net Benefit from Remodeled Building Market Value	Ranging from zero to just below the combined cost of seismic retrofits plus other building upgrade investments.
Neighborhood Character	Visual amenity and neighborhood brand would be, i) maintained with preserved building look in the absence of earthquake conditions, and ii) enhanced due to improved survival probability in the event of an earthquake.
Historic Preservation	Historic character of the building would also be either, i) maintained in the absence of earthquakes (for most seismic retrofit additions), and ii) enhanced due to improved survival probability in the event of an earthquake.

Figure 3. High Potential for Market Recovery of Mandatory Code Cost - URM with Significant Market Opportunities Through New Building, Less with Remodel/Retrofit



Net Income:

Owner Option	Rev - Cost	Net Income/Loss	
Retain URM	(R1 - C1)	$0 m.	
Remodel/Retrofit	(R1+R2-C1-C2-C3)	($2) m.	
New Building	(R4 - C4)	($1) m.	<= Second best choice
Demolish	(R5 - C5)	($4) m.	

Code	Cost (C) or Revenue (R) Component
C1	Cost of existing URM
R1	Lease revenues from existing URM
C2	Cost to seismically retrofit URM
C3	Cost beyond retrofit to perform substantial alterations
R2	Increased lease revenues from substantial alterations
C4	Cost of a new replacement building
R4	Lease revenues from a new replacement building
C5	Investment cost of retaining parcel without building
R5	Revenues from surface use (e.g., parking)

D.2. Owner Response: Demolish and Rebuild

This owner response option differs fundamentally from the one assumed in the retrofit benefit cost analysis of **Section A**. The seismic cost impacts in this case are essentially the same as those associated with the "reinforced masonry" building case of the HAZUS runs, but the costs would not be based on seismic retrofits, but rather on building demolition and replacement.

This is also an owner response that has been chosen for many Seattle buildings in the past, where building economics supported it. As noted in **Table 6,** owners selecting this response to a mandatory code would be those for whom the economic value of demolishing the building and replacing it is worse than maintaining the status quo (or they would have done so already), but better than the economics of preserving the building with a seismic retrofit.

Individual owners choosing this response would also experience a wide range of net added costs, as illustrated by the two scenarios shown in **Figures 3 and 4.** Each is consistent with post-Code demolition and rebuild, but again with very different economic implications for the owner.

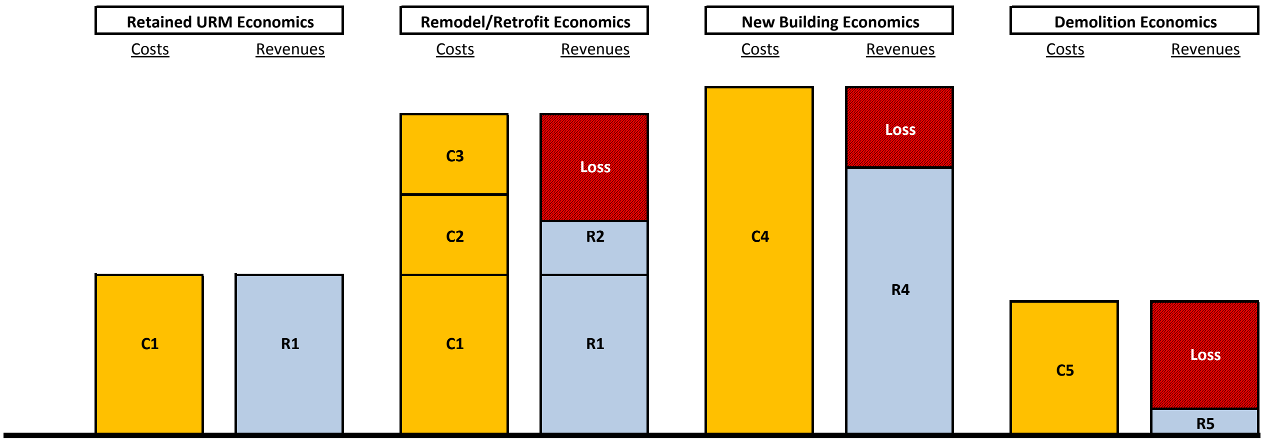
As with the preceding case where retrofitting was the second-best economic option for an owner, there would be a range of circumstances where demolishing and rebuilding would be second-best. **Figure 3** above portrays the economics of cases where the rebuild option is nearly as economical as the status quo. Buildings in these circumstances would be similar to URM buildings that have been replaced in the past to access greater income-earning potential.

For such buildings, the choice is not to augment a seismic retrofit, but rather to construct an entire new building to current standards. Note that in the **Figure 3** example, replacing the URM with a new building would offset a larger portion of the mandatory seismic retrofit cost than would performing a URM retrofit with a remodel. And simply razing the building and using the parcel for a surface use (parking) would again be an inferior investment relative to demolishing the URM and rebuilding.

Building owners in this case would not recover the full cost of their investment in a new building, but they would minimize their losses, and their benefit-cost outcome would be better than available through a seismic retrofit of the URM.

Figure 4 shows the negative extreme of cases where demolishing and rebuilding would be the best economic option for owners facing a mandatory seismic retrofit code. In these cases, rebuilding is still the economically best option, as there is little or no opportunity to reduce losses relative to simply absorbing the cost of the retrofit. In other words, the owner losses resulting from a mandatory code would be substantial in any case, but they would be less for the demolish and rebuild option.

Figure 4. Low Potential for Market Recovery of Mandatory Code Cost - URM with Moderate Market Opportunities Through New Construction, Less with Remodel/Retrofit



Net Income:

Owner Option	Rev - Cost	Net Income/Loss	
Retain URM	(R1 - C1)	$0 m.	
Remodel/Retrofit	(R1+R2-C1-C2-C3)	($4) m.	
New Building	(R4 - C4)	($3) m.	<= Second best choice
Demolish	(R5 - C5)	($4) m.	

Code	Cost (C) or Revenue (R) Component
C1	Cost of existing URM
R1	Lease revenues from existing URM
C2	Cost to seismically retrofit URM
C3	Cost beyond retrofit to perform substantial alterations
R2	Increased lease revenues from substantial alterations
C4	Cost of a new replacement building
R4	Lease revenues from a new replacement building
C5	Investment cost of retaining parcel without building
R5	Revenues from surface use (e.g., parking)

For such cases where the demolish and rebuild option is not nearly as economical as the status quo, it is again because there is little untapped market potential for the building and site. The rebuild option may be the second-best choice because it allows the owner to realize unused FAR capacity on the parcel that is not achieved with the existing URM, or because the existing URM is in worse than average condition. The net economic loss to owners of such buildings would be substantial, and in some cases it would be similar to the benefit-cost outcome reported in **Section A.** Note that there could be even worse outcomes associated with demolishing the URM without any replacement.

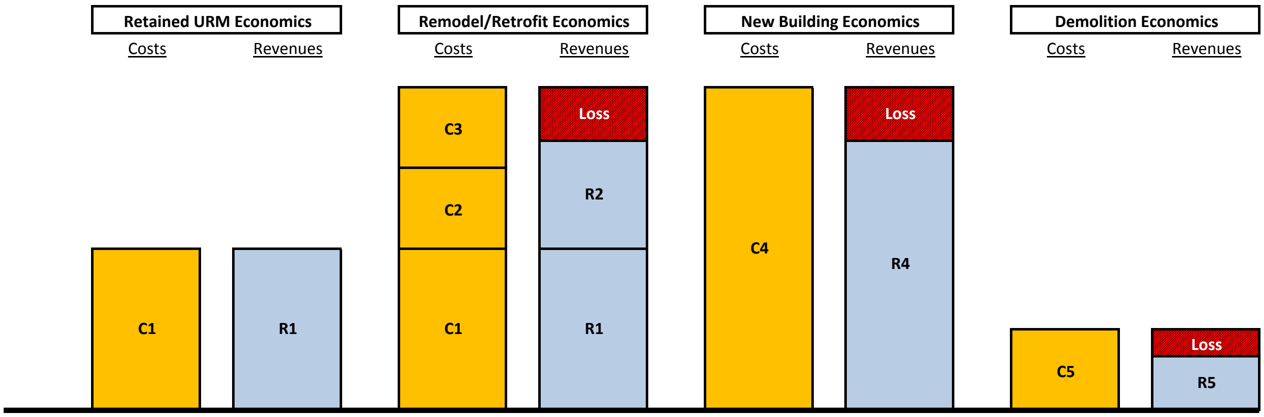
Net Benefit-Cost Assessment: For these current URM buildings, the financial and casualty elements of the benefit-cost ratio upon adoption of a mandatory seismic retrofit code could vary widely, from a low of 0.076 for buildings in locations without untapped market potential to a high close to 1.00 for those with the highest untapped high-end market potential.

However, the demolition of these buildings would sacrifice the current positive social benefits that accrue from URMs in the form of distinctive neighborhood character and historic preservation.

Table 10. Benefit-Cost Assessment for Buildings That Would Choose to Demolish and Rebuild with A Mandatory Seismic Code

Impact Element	Mandatory Retrofit
Modeled Benefit-Cost	B-C Ratio > 0.076 Election to rebuild indicates that the economics would be superior to those of retrofitting existing building; The degree of the difference would vary from building to building.
Increased Net Benefit from Remodeled Building Market Value	Market value would increase by more than the cost of retrofit, but less than the full cost to rebuild.
Neighborhood Character	Replacement buildings built to current code and for maximum profitability are unlikely to retain the character of URMs; The interruption of consistent URM street fronts would diminish neighborhood URM character.
Historic Preservation	This owner response option is not available for designated historic buildings; For others, the historic preservation potential would be lost.

Figure 5. High Potential for Market Recovery of Mandatory Code Cost - URM on High Traffic Site but Limited Opportunities Through Retrofit or New Building



Net Income:

Owner Option	Rev - Cost	Net Income/Loss	
Retain URM	(R1 - C1)	$0 m.	
Remodel/Retrofit	(R1+R2-C1-C2-C3)	($2) m.	
New Building	(R4 - C4)	($2) m.	
Demolish	(R5 - C5)	($1) m.	<= Second best choice

Code	Cost (C) or Revenue (R) Component
C1	Cost of existing URM
R1	Lease revenues from existing URM
C2	Cost to seismically retrofit URM
C3	Cost beyond retrofit to perform substantial alterations
R2	Increased lease revenues from substantial alterations
C4	Cost of a new replacement building
R4	Lease revenues from a new replacement building
C5	Investment cost of retaining parcel without building
R5	Revenues from surface use (e.g., parking)

D.3. Owner Response: Demolish Building

A third owner response option includes a subset of current URMs that would simply be demolished instead of retrofitting or rebuilding.

This is another owner response that has been chosen for some Seattle URM buildings in the past, where building economics supported it. As noted in **Table 6**, owners selecting this response to a mandatory code would be those for whom the economic value of demolishing the building now is worse than maintaining the status quo, due to the demolition cost and possibly modest loss of operating revenue involved, but where absorbing the cost of demolition and lost revenues is still better than the economics of either preserving the building with a seismic retrofit or replacing it with a new building.

These conditions would be most likely in locations with limited lease market potential, irrespective of the building involved. Specific buildings may include vacant or limited-use structures, as well as some in below average condition with very limited FAR build-out potential. **Figures 5 and 6** present illustrations of cases where demolishing owners could experience relatively modest net losses and more substantial net losses.

Figure 5 illustrates the most economically attractive of buildings that would be demolished and not replaced. It represents buildings in which the choice to demolish is predicated partly on access to significant parking or other non-building income.

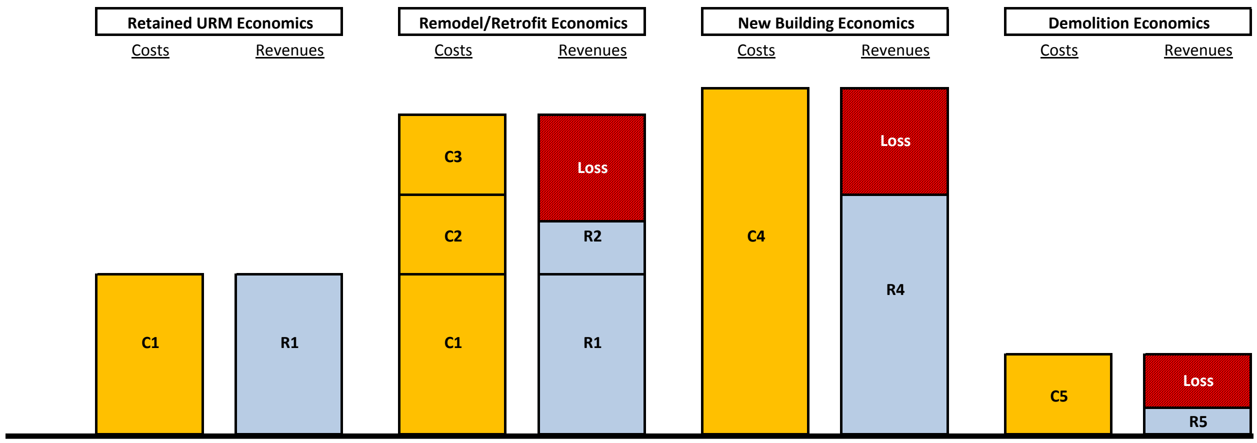
In addition to having relatively high income potential from parking or other surface use, these URMs would also be those for which either remodel/retrofit or new building options are not as promising. This could be due to location disadvantages, poor character or condition of the existing URM, or possibly both.

Figure 6 illustrates the least economical of cases where the owner response would be demolition without rebuilding. In this case demolishing the building would produce a substantial net loss for the owner, but remodeling and retrofitting or constructing a replacement building would result in even greater losses.

Net Benefit-Cost Assessment: For these current URM buildings, the financial element of the benefit-cost ratio upon adoption of a mandatory seismic retrofit code could vary widely, from a low of 0.076 for buildings in locations without potential as surface uses, to a high close to 1.00 for those with the highest untapped market potential, as in high parking demand areas.

However, the demolition of these buildings would sacrifice the current positive social benefits that accrue from URMs in the form of distinctive neighborhood character and historic preservation.

Figure 6. Low Potential for Market Recovery of Mandatory Code Cost - Tear-Down Less Costly than Either Retrofit or New Building



Net Income:

Owner Option	Rev - Cost	Net Income/Loss	
Retain URM	(R1 - C1)	$0 m.	
Remodel/Retrofit	(R1+R2-C1-C2-C3)	($4) m.	
New Building	(R4 - C4)	($4) m.	
Demolish	(R5 - C5)	($2) m.	<= Second best choice

Code	Cost (C) or Revenue (R) Component
C1	Cost of existing URM
R1	Lease revenues from existing URM
C2	Cost to seismically retrofit URM
C3	Cost beyond retrofit to perform substantial alterations
R2	Increased lease revenues from substantial alterations
C4	Cost of a new replacement building
R4	Lease revenues from a new replacement building
C5	Investment cost of retaining parcel without building
R5	Revenues from surface use (e.g., parking)

D.4. Owner Response: Disregard or Delay Compliance with New Mandatory Seismic Code

It has been noted that since each of the preceding cases is inferior from the owner's perspective to simply retaining the URM in un-reinforced condition, it is likely that at least some owners would elect to delay their response to a mandatory code as long as possible. That could mean waiting until the latest date specified in the new code, or delaying even longer if the risk cost of penalties specified in the code is less onerous than the cost of installing retrofits to come into compliance.

This choice amounts in effect to a temporary option that is superior to any of the "second best" options described in the preceding sections. It would prolong the period in which owners could continue under their "first best" option of retaining their URM in un-retrofitted condition.

At such time as the compliance deadline approached, some owners would convert from this path to whichever of the preceding three choices represents their second best option. Others may continue to disregard the new code until the penalty cost of non-compliance became sufficiently high to force them to pick their second-best option.

Table 11. Benefit-Cost Assessment for Buildings That Would Choose to Demolish and Leave Parcel Vacant with A Mandatory Seismic Code

Impact Element	Mandatory Retrofit
Modeled Benefit-Cost	Net cost of this option would be less than for retrofit Avoided retrofit cost would exceed loss of current building's income stream
Increased Net Benefit from Remodeled Building Market Value	n/a

Table 12. Benefit-Cost Assessment for Buildings That Would Choose to Disregard A New Mandatory Seismic Retrofit Code

Impact Element	Mandatory Retrofit
Modeled Benefit-Cost	Retain current economic conditions
Neighborhood Character	Retain current neighborhood amenity value
Historic Preservation	Retain current historic value

Net Benefit-Cost Assessment: For these current URM buildings, current financial conditions would be preserved for however long the owners defer retrofitting their buildings. Depending on the penalty provisions of the mandatory program, there could be risk of penalty costs if the owners do not meet specified retrofit deadlines. However, for this to be a reasonable choice, the expected cost of those penalties would be less than the loss involved in selecting one of the other code response options.

The net building preservation impacts of this intermediate step by owners would be superior to the cases where owners go directly to their second best option and that option involves demolition. The building preservation impacts would, however, be inferior to a remodel/retrofit scenario, because there would be a higher probability of URMs lost to earthquakes each year.

Conclusion

A potential mandatory code requirement that URMs perform seismic retrofits would produce a range of responses, each with its own set of impacts. The response for an individual building owner who has not voluntarily retrofitted his/her URM would depend on what is the current second-best economic option after retaining the building in its current state. If performing retrofits is the second-best option the benefit-cost calculus is essentially the same as in the preceding section, except that some owners would be able to offset a part of that substantial net cost by simultaneously remodeling and upgrading their buildings.

Other URM building owners would demolish their buildings instead of retrofitting to comply with a new mandatory code. Again, that would occur when it represented the best remaining economic option for them. In those cases, there might be even better life safety improvements on the parcel - there would either be no building or a new, stronger building built to current code. However, in those cases the current URMs would be lost, and in the aggregate there would likely be greater loss of neighborhood aesthetic character, as well as the potential for greater loss of historically valuable buildings that have not officially been designated, and thus are eligible for demolition.

Triple Bottom Line Analyses

In evaluating public policies it is important to consider not only measureable economic impact of a particular policy, but also community and environmental values. Sometimes these non-economic values can be measured, but when that is difficult, qualitative measures are used to inform decision-makers on potential impacts of particular policy choices.

URMs have many non-quantified values. URMs are prized for their human scale, attractive color, and design articulation and detailing. Most if not all are over 50 years old which lends an air of stability and comfort for citizens and visitors. Because of their longevity, URMs are fixtures in many Seattle neighborhoods and have often played a decades-long role in shaping both the identify and character of the neighborhood.

Because they were designed and built for an earlier economy and earlier technologies, URMs offer a diversity and range of floor sizes and shapes, façades and street openings, and ceiling heights. These legacy dimensions lend themselves to a broad diversity of users such as small businesses, start-up entrepreneurs, and small locally-owned shops who may not prefer nor require current corporate designs and dimensions.

URMs represent an environmental benefit, too, in that the energy to create them has already been expended. They were often made with locally sourced materials. If demolished, that embodied energy is lost as any new building to replace the URM will require additional energy and emissions for construction.

These embodied energy values are somewhat offset operationally in that URMs may not be the most energy efficient structures in terms of air leaks, out-of-date heating systems, and low density given their high square-footage to employee or high square-footage to sales ratios.

URMs are also valued for how they contribute to neighborhood character when many share the same street. URMs dominate the experience in some neighborhoods such as Ballard Avenue and Columbia City, parts of Capitol Hill and West Seattle, and pretty much all of Chinatown International District and Pioneer Square neighborhoods. While some are protected as historic buildings or districts, others simply continue to play a large role in their neighborhoods.

These non-quantified benefits are listed in Tables 3 and 4 of the Task 2 Memo, described further in subsection 6 of the Task 5.1 Memo, and summarized in Tables 9 and 10 of the Task 5.2 Memo. These last two tables highlight the different outcomes of these non-quantitative factors both in cases where URM buildings are retrofitted and in cases where they are demolished and replaced by new buildings.

TASK 6 MEMO: Seismic Retrofit Program Financing Options Analysis

Introduction

Unreinforced masonry buildings (URMs) in Seattle can pose a public safety risk during earthquakes -- not only to building occupants, but also the general public (e.g., pedestrians, vehicular traffic). Yet not all buildings are upgraded. The earlier Task Memos in this document demonstrated that the economics of a retrofit for safety reasons is not cost effective given the relatively low benefit to cost ratio.

It was also pointed out that some URM owners have fairly attractive "second-best" alternatives to retaining their buildings in unreinforced condition. Some portion of these owners with unreinforced buildings might contemplate a retrofit and upgrade if there were incentives or public participation in helping to cover the cost of reinforcing these fragile buildings.

Creating such an incentive program faces substantial challenges. Some tools available to provide public support in other states are more limited in Washington State given our state constitution's limitation on the use of public resources for private gain.[1] Even so, there are a few strategies that should be considered as the City of Seattle investigates the options for encouraging retrofits of unreinforced masonry buildings.

Depending upon whether a URM retrofit program is voluntary or mandatory, incentives and assistance may take different forms. Under a voluntary retrofit program, a suite of incentives will likely be important in order to encourage building owners to act. In a mandatory program, there may be more emphasis on direct funding assistance, for example, by way of some form of levy or grant.

A. Why provide incentives or funding for seismic retrofits?

While URM buildings may present hazards in a major seismic event, they can also provide other private and public benefits that are lost if the buildings are demolished. Such benefits vary among types and locations of URM buildings. And while the economic risk to the owner may inform retrofit decisions, in cases where the benefits from improved public safety and historic preservation are significant, these benefits may not be fully reflected in owners' retrofit decisions.

Suitably designed financial incentives can provide a means of incorporating these public values in retrofit decisions. The scale of incentives can be tailored to the amount of benefit that would otherwise be overlooked. Task Memo 5.1 and 5.2 demonstrate that the public safety benefit is small relative to the cost. However, there are preservation benefits that should be considered as well.

- For example, many URM buildings are representative of a neighborhood's character and identity. These buildings can provide affordable housing or lower lease rates for business that may not be able to afford lease rates in newly constructed buildings. Many of these URMs are low rise in scale and have a pleasant human scale to their windows, doors, and facades.
- Conversely, some URM buildings may be falling into disrepair or abandonment and this lack of care impacts the value of neighboring properties. Where rehabilitation is not desirable, replacement with new structures might better fit the needs of the community and its specific real estate market.

An ideal approach to URM building retrofits would provide building owners with a combination of information and carefully selected incentives to encourage preservation of the most promising URM buildings, as opposed to a passive alternative course that could lead to permanent loss of important or valuable structures.

The values to be captured by such an incentive program are those that would not accrue directly or at least not entirely to building owners, and thus may not adequately influence their seismic retrofit decisions. These values would include the following:

- Improved safety for building inhabitants, occupants, and from the general public;
- Preservation of the character of neighborhoods that is lent by URM buildings;
- Preservation of URM buildings with historic significance;
- Preservation of affordable housing frequently provided by URMs;
- Avoidance of disproportionate displacement after an earthquake of vulnerable populations who may live or work in URM buildings;
- Preservation of the small business "incubation" role often performed by URM buildings; and
- Reducing the degree of under-investment in seismic retrofits due to lenders' hesitancy to provide financing.

A mix of several incentives programs may provide the best means of accounting for these diverse value considerations. Some incentive options focus narrowly on certain types of buildings or uses. Others are small by themselves, but in combination could provide appropriately sized "market correction" for the values above. After being considered individually for reasonableness, it will be important to also assess which might provide a pragmatic combined solution.

1 Article 8, Section 7 of the Washington State Constitution prohibits the lending of public credit for private purposes.

Financing Strategies: Alternatives Considered for Seattle

While there are numerous forms of public financing assistance, and many could theoretically be structured to apply to the costs of URM seismic retrofits, there are two broad groups of financing options:

- the proceeds of various sorts of levies, and
- incentive programs offering tax forgiveness, expanded development rights, etc.

Section B covers a range of alternative levies, with additional descriptive detail provided in Appendix A. Sections C, D and E all address the diverse - and more flexible - range of financial incentive tools other than levies. **Section C** provides a broad overview, with sufficient examination to narrow the initial list down to those most promising as sources of URM seismic retrofit financing assistance. **Section D** expands the description of the "short list" of URM financing assistance candidates. And **Section E** provides quantitative information on the scale of assistance potentially available from each "short list" source, comparing it to the baseline estimated cost of retrofits and the size of public benefits that may not accrue to the owner who must make the decision on a building retrofit.

Finally, **Section F** summarizes the findings of the URM retrofit financing analysis, and describes how the available tools could be accessed and used most efficiently in a City of Seattle retrofit support and assistance program.

B. Levies

Background

Use of levy funds could theoretically provide a financing opportunity for URM seismic retrofits. Levies are designed to provide the capital necessary to secure bond financing, which can then be used to pay for improvements - such as seismic retrofits.

A number of levy types exist in the State of Washington and they are used for a wide range of public purposes. Most types of levies are reserved for specific purposes, such as schools, libraries, or affordable housing. **Appendix A** contains summary descriptions of the main types of levies available in Washington State.

The range of levies includes some that are assessed on a broad municipal tax base as well as some that are assessed within special assessment districts, such as a local improvement district. Each has different implications for how (and which) properties are taxed. They all yield similar outcomes in terms of creating a source of capital funding. A brief synopsis of each major type of levy is provided in the table to the right.

Summary of Levy Options' Potential Financing Value

Based on the legal limitations and levy application restrictions noted in the table above, it is unlikely that additional funding for URM seismic retrofits could be obtained from most regular levy sources. The City-wide general levy options do not appear to be feasible, due to either legal limits on their allowable purposes or procedural requirements that make them unlikely to succeed. The limited area levies are also likely to be either infeasible or impractical. Some are restricted to purposes that do not include seismic retrofits, while others would be confined to the affected property owners, effectively taking money out of one pocket and putting it in another without providing net new incentives for retrofits.

Summary of Levy-Type Funding Options

Type of Levy	Extent of Levy	Desirable or Appropriate for URM?	Legal?
Regular property tax levy (e.g., to secure general obligation bonds)	City-Wide	No - Regular levies are limited to certain public purposes, which do not presently include URM retrofits for private buildings; also subject to overall limits that cannot be exceeded by statute.	No - Probably not feasible without a change to state law
Excess / Special Levy	City-Wide	No - requires a supermajority for approval; subject to strict time limits	Not determined
Benefit assessment district	Only within the district (i.e., those receiving the benefit)	No - presently limited to certain types of taxing districts only. URMs not included.	No - Use of benefit assessment districts is limited to certain types of taxing districts
Local improvement district	Specified by the boundaries of the district	**Possibly** - Community Renewal Law authorizes activities to remedy areas such as those that are "injurious to public safety" though a community renewal district If confined to just URM owners, there would be no incremental incentive value	**Not determined** - It is unclear whether a levy could be applied to the City as a whole, or only to the owners of URM buildings
Earmarked funds	The Seattle City Council can earmark general funds for governmental purposes	Possibly – City Council needs to determine that URM retrofit funding is a priority over other City priorities that rely on general funds	Yes - presumably legal as long as state constitutional limitations are honored.
Tax increment financing	N/A	No - Not legal for this purpose	No

C. Financial Incentive Options

General Considerations

Financial incentives would be an appropriate form of retrofit assistance in the case of a voluntary URM retrofit program, where participation would be optional. Incentives could encourage participation either by lessening the overall up-front cost burden for a retrofit or by creating new development opportunities, which could create more income earning potential over time to help pay for debt incurred for retrofit costs.

It is important to note that different types of incentives are sometimes applicable to only certain types of properties or zones. For example, only certain zones or property types are eligible to send or receive credits for transfers of development rights that can be exchanged for bonus floor area. Some tax credits are only available to owners of historic properties. After accounting for a range of incentive options, some URM owners will still have few incentives available to them and may opt to not retrofit, absent penalties for non-compliance.

However, as described in Task Memo 5.2 Figures 1-6, for some buildings seismic retrofits are closer to being cost effective than they are for others, and it is these that are most likely to be motivated by an incentive program.

From a feasibility perspective, some otherwise attractive potential incentives would require a change in State law. Property tax abatements for existing buildings under rehabilitation are not currently legal under State law, even though similar abatements for certain new construction projects (such as affordable housing under the Multifamily Housing Tax Exemption program) are legal and do exist.

With those considerations in mind, this section explores a wide range of theoretically possible incentive types to assess which might be applied effectively to seismic retrofit financing assistance. The list below represents an initial inventory. The purpose of the accompanying summary assessments is to identify any fatal flaws or practical limitations for specific incentive candidates and winnow the list to identify the most promising options.

Types of Incentives to Encourage Seismic Retrofits

The following table includes incentives that could be theoretically used to encourage seismic retrofits to URM buildings in Seattle. Some of these incentives are currently in use for other purposes; others would require further study or changes to state law, as noted in the table.

Incentive	How it is applied	Theoretical maximum value	Comments	Promise as a retro-fit incentive?
Transfer of Development Rights (TDR)	A URM could act as a TDR sending property: A given URM property (or collection of properties) could act as a TDR sending area, selling additional unused FAR at a market price ($/SF) to offset retrofit costs.	$10/SF	▪ Currently, there is an over-supply of TDRs, which has led to depreciation in their value. ▪ TDRs are currently used for landmark / historic properties (sending areas) and designated receiving areas, primarily in downtown zones	No - Unlikely. Expect concern from affordable housing entities that TDRs would lose value from over-supply.
Community Development Block Grants	Annual HUD grants to the City of Seattle of $9 million to $10 million annually are directed to help low and moderate-income Seattle individuals, families, and communities. Roughly one third supports emergency shelters, another third is economic development, and the final third builds and preserves affordable housing.	Not quantified.	Competition for CDBG grants is high and any redirection of these funds towards URMs would reduce funding to other key city priorities dollar for dollar. URM owners might benefit but at a direct cost to others who benefit from existing programs.	Possible – but with a dollar-for-dollar reduction to other city priorities.
Historic and Rehabilitation Federal Income Tax Credits	i) Tax credit of 10% of construction costs for non-residential buildings, built before 1936; ii) 20% tax credit for certified historic structures	$4 - $8/SF, depending upon building	▪ Currently available to qualified buildings. ▪ Building owners may opt to sell the tax credit instead	Yes - for historic or old buildings that meet the program criteria
Property Tax Special Valuation for Historic Properties	Deduction of qualified rehabilitation expenses from assessed value for designated landmarks or buildings in registered historic districts	$0.40- $0.50/SF per year for ten years; $4 - $5/SF total	▪ Currently available to qualified buildings. ▪ Rehabilitation cost must be at least 25% of the current assessed value. ▪ Deduction can be taken for 10 years.	Yes - for landmarks and historic district buildings that qualify for the program
Multi-Family Tax Exemption	Current multi-family tax exemption (MFTE) program applies to both new and existing multifamily residential properties and exempts property taxes on eligible projects for up to 12 years.	Not quantified	A small number of URM buildings may qualify for the current program; however, in order to be eligible, the residential portion of such existing buildings must have been vacant for the preceding 12 months.	An expanded version applying to all URMs is discussed below.

Incentive	How it is applied	Theoretical maximum value	Comments	Promise as a retrofit incentive?
Seismic Retrofit Property Tax Exemption	Provide a full property tax break for a given period to all URMs in the state that retrofit to the Bolts+Plus standard. This is modeled after affordable housing tax exemption program, which can provide tax relief for up to 12 years	Varies by property. ~1% of taxable property value. Average tax @ 1% for all URMs is $36,630*12 years = $439,560 (max)	A property tax exemption for rehabilitation of existing structures would require a new state law. Currently allowed for new construction of residential structures that provide affordable housing (<80% median income)	Yes, potential significant value to offset retrofit costs if authorized by the legislature. URMs are common across the state, so this should not be considered Seattle-centric.
Transferable FAR bonus	Allow increased Floor Area Ratio (FAR) for certain "sending" zones; FAR could be sold in a TDR-like arrangement.	Similar to TDR value, ~$10/SF	TDR programs already provide for additional FAR to be transferred from one property to another; unclear whether a viable market for additional FAR could exist.	No - Not likely because of deflated value due to over-supply of TDRs already on the market
"On-Site +1 FAR Bonus	Owners are given a +1 FAR bonus upon completion of a retrofit to the BoltsPlus standard.	The value could vary widely, depending on program rules and site configuration of individual buildings	▪ FAR bonuses commonly used by the city to achieve public benefit. ▪ Would result in preservation of URMs while allowing for new construction adjacent or sometimes above the preserved building. ▪ Additions above URM buildings may require costly additional support. ▪ Some appreciate diverse building types, others do not.	Yes.
Parking Requirement Waivers	Waive or reduce parking requirements to allow for additional leasable / usable area on a given parcel	Market rate for leasable space	Many zones already do not require parking; therefore, this incentive may be of little benefit	No - Most zones already have low/no minimum parking requirements
Expanded Allowable Uses	Expand uses allowed by right in certain zones	Increase in value depends upon use / market rate of leasable area	Would require a thorough review of what uses to allow / incentivize in certain zones	Potential benefit.
Early Adopter Incentive	Offer incentives on a time-limited basis, so that early adopters receive the most benefit	Value of incentive set to decrease over time -- can theoretically be applied to any incentive	Incentives could be offered on a sliding scale and combined with a mandatory retrofit clause at the end of a given period, e.g., 15 years.	Most likely to have value if combined with a penalty for noncompliance

Incentive Options - Summary of Initial Feasibility Screening

Based on the options presented above, the four incentives that appear most likely to encourage seismic retrofits in a voluntary program are:

i. Federal Historic Preservation Tax Incentive (federal tax credit),

ii. Property Tax Special Valuation (property tax deduction),

iii. Property Tax Exemption (12 year fixed period), and

iv. On-Site +1 bonus.

These are described more extensively and the scale of their potential assistance and range of their application among Seattle URMs is estimated in sections D & E.

Several other incentive options are potentially feasible, although they face even greater hurdles than the three listed above. A TDR program could be of value if a market demand exists for development credits. However, the current supply of TDRs already exceeds demand and it is unlikely that most buildings would be able to benefit from an expanded TDR program for URMs. Also, a time-based incentive program could have value in terms of encouraging owners to retrofit earlier rather than later. However, it does not represent a source of assistance, but rather a design feature that could accelerate the use of financing made available through other incentive programs.

D. URM Retrofit Financing Incentives - Overview of Promising Options for Seattle

D.1. Primary Incentive Options

Four incentive options offer the most promising potential to encourage and provide significant funding for the seismic retrofit of URM buildings.
They are:

1. Federal Historic Preservation Tax Incentive (federal tax credit);
2. Property Tax Special Valuation (property tax deduction),
3. Property Tax Exemption (12 year fixed period); and
4. On-Site +1 FAR bonus.

For these incentive options, estimates of their potential target group and aggregate financial assistance potential are described below.

Among the four, the Federal Historic Preservation Tax Incentive and the Property Tax Special Valuation are existing programs, administered through the National Parks Service and the Seattle Landmark Preservation Board, respectively. Thus, the key issue in their implementation is connecting the programs with eligible buildings in Seattle that have not yet taken advantage of them.

The other two programs listed above -- the property tax exemption and On-Site +1 FAR bonus -- are not currently available explicitly for the purpose of URM building retrofits. However, these are incentives currently available and deployed by the City for other purposes. The key issues in their potential implementation are weighing their advantages against the costs involved in either eliminating or shifting responsibility for some current property tax revenues, or promoting development above current Building Code allowances.

D.2. Secondary Potential Incentive Options

Three other types of incentives are potentially useful, but have not been explored further and quantified for one of three main reasons: 1) sufficient data was not available to quantify to a reasonable extent the usefulness or potential value of the incentive, 2) the estimated value of the incentive was likely too small to be of sufficient use, or 3) any revenue would represent a diversion from other priority City uses of the same funding source.

These incentives include:

1. Transfer of Development Rights (TDR) -- eligible for trade or sale;
2. Community Development Block Grants -- existing grants used for building and restoring affordable housing; and
3. Multifamily Tax Exemption (MFTE) program -- available to qualified rehabilitation projects for residential properties (or properties converted to residential use) that provide a certain level of affordable housing for the duration of the tax exemption.

These incentives are discussed in more detail later in this section.

D.3. Primary Incentive Options - How They Work

Federal Historic Preservation Tax Incentive

The Federal Historic Preservation Tax Incentive is an existing two-part program -- eligible grantees need only apply for the grant and follow the guidelines to receive the tax credit. Successful grantees receive either a 10% or 20% federal tax credit for a substantial rehabilitation of a qualified property. A number of requirements apply. Some of the more critical requirements include:

- Buildings eligible for the 10% tax credit must have been built before 1936 and be in a non-residential use.
- Buildings eligible for the 20% tax credit must be certified historic structures in commercial, industrial, or residential use.
- The cost of the rehabilitation must exceed the pre-rehabilitation adjusted basis of the building. The adjusted basis is calculated by the purchase price, minus the cost of land, plus improvements already made, minus depreciation. This threshold requirement could be difficult to meet in some cases, but more attainable in others.

The tax credit is not specifically intended for seismic retrofits, but because of the "substantial rehabilitation" required under the program, any building undertaking such a renovation would be required to upgrade to the City's current seismic standards or the potential future Bolts Plus standard.

A full overview of the program and associated requirements, including information on key limitations on potential use, is available at http://www.nps.gov/tps/tax-incentives.htm[2]

There are procedural guidelines that must be followed in order to receive the tax credits. These procedures require coordinating and filing forms with the National Park Service (NPS), the State Historic Presentation Office (SHPO), and the Internal Revenue Service.

- For the 20% rehabilitation credit, the building must be listed on the National Register and the owners must request written approval from the National Park Service.
- For both the 20% and 10% credit, the applicant starts with the SHPO who will provide all the application forms, regulations and program information. There are multiple forms.
- Those that only seek the 10% Rehabilitation Tax Credit need only file IRS form 3468 for the tax year in which the building is placed back in service.
- There are also IRS provisions governing what amount of credit may be taken and for how long the owner must retain ownership and the initially specified use of the qualifying building, each of which involves record-keeping requirements.

Successful applicants report that while there is a learning curve, it is easier the second time through.

Property Tax Special Valuation

The Property Tax Special Valuation is also an existing program, providing special tax valuation relief for historic properties. Owners of qualifying buildings who perform a certain level of rehabilitation need only apply to the appropriate administrative agency to receive the assessed value deduction. These owners can offset a major portion of the added tax burden they would otherwise bear for rehabilitating and thus increasing the assessed value of historic properties. A number of requirements apply:

- Buildings must either be designated landmarks with ordinance controls or be in a contributing building in a local historic district, "National Register District."
- The cost of the rehabilitation must be at least 25% of the pre-rehabilitation assessed value of the improvement. This threshold requirement could again sometimes be difficult to meet, but in fewer cases than the federal tax credit programs.

The property tax special valuation program is available up to 10 years. It is not specifically intended for seismic retrofits, but many buildings performing seismic retrofits alone would qualify, and even more would qualify if they performed a combination of remodeling and seismic retrofitting.

Property Tax Exemption

A property tax exemption program does not currently exist for the explicit purpose of retrofitting URM buildings. However, the current multi-family tax exemption (MFTE) program applies to both new and existing multifamily residential properties and exempts property taxes on eligible projects for up to 12 years. A small number of URM buildings may qualify for the current program; however, in order to be eligible, the residential portion of such existing buildings must have been vacant for the preceding 12 months.

2 As noted by the NPS: "A number of provisions in the Internal Revenue Code affect the way in which real estate investments are treated generally. These provisions include the "at-risk" rules, the passive activity limitation, and the alternative minimum tax. What these provisions mean, in practice, is that many taxpayers may not be able to use tax credits earned in a certified rehabilitation project."

The potential property tax incentive quantified in this report considers an expanded property tax exemption program that would apply to all taxable URM properties that undergo a seismic retrofit to the Bolts Plus standard. Such a program could be applied in a similar manner to the existing MFTE, whereby improvements would be required to be completed within a certain time frame (e.g., three years) and eligible for a tax exemption upon issuance of a certificate of occupancy. Similar to the MFTE, the time period of the exemption assumed in the descriptions and incentive estimation for this option is 12 years.

On-Site +1 Floor Area Ratio Bonus

Floor Area Ratio (FAR) bonuses are the result of multiplying the area of the parcel times the ratio selected. FAR bonuses are commonly used as an incentive for property owners and developers to provide a number of different types of public benefits, such as affordable housing or public open space.

This concept is to give an on-site FAR bonus for property owners who retrofit a URM to the Bolts Plus standard. This would allow property owners to put increased density on other parts of the parcel. This becomes a way to preserve URMs where development pressure is high while allowing property owners additional value to offset those costs if they have additional site area to accommodate a new building.

A FAR bonus of 1 would provide an increase of buildable area on a parcel equal to the size of the parcel. Thus a 10,000 square foot lot with a FAR bonus of +1 would be allowed to have an additional 10,000 sf of built area on the site.

This built area could not be stacked above the URM, typically because construction above a URM would trigger higher standards than Bolts Plus. Ssome worry too, about the impacts on neighborhood scale and character of new construction next to retrofitted URMs, although other research shows building diversity creates value. Designated historic properties would be subject to the same regulations and guidelines that govern, among other things, modifications to the existing structure.

D.4. Other Potential Incentives - How They Work

While the secondary set of existing incentives were deemed to be less likely to provide a substantial incentive to retrofit, they still may be of some use to the City or URM owners. The potential application of each of these incentives is described briefly below.

Transfer of Development Rights Credits

TDR credits are available as a tool to help encourage preservation of certain buildings in the City, such as landmark buildings and affordable housing. Credits are typically either sold directly to a developer of an eligible property at a market-determined rate in order to increase its development potential, or put in a TDR "bank" to be sold at a later time. This tool is not currently applied for URM seismic retrofits. However, expanding TDRs' to include this purpose could incentivize URM owners to retrofit by designating URM properties as TDR sending sites. URM owners could opt to sell or trade the development rights to their properties in order to provide the necessary capital for retrofitting.

Presently, the market for TDR credits is relatively oversupplied, with a value of around $10/SF.[3] The addition of several hundred URM buildings would most certainly drive the supply of TDRs upward and the market price downward, reducing the value of the incentive. Given this scenario, TDRs would likely provide only a very limited amount of funding for retrofits. Moreover, that funding may displace funding for other TDR-eligible City policy purposes.

Community Development Block Grants

Community Development Block Grants (CDBG) provide funding for a number of programs in the City of Seattle, primarily for low-income individuals and neighborhoods. Currently CDBG provides between $9 million -$10 million annually, approximately one-third of which is allocated toward building and preserving affordable housing. Some of this funding could theoretically be used to help cover soft costs for URM retrofits if that did not violate the state prohibition on the lending of credit. However, given the scope of the URM retrofit program, the amount of funding from CDBG would likely to be too small to provide a sufficient incentive for building owners to complete retrofits. And again, any funding that is provided may represent a shift from other City policy purposes that would otherwise by financed by the CDBG funds. Nonetheless, CDBG and other similar grants are worthy of further consideration.

Multifamily Tax Exemption Program

The current multi-family tax exemption (MFTE) program could provide some incentive for owners of URM buildings

3 Information based on an interview with Rick Hooper, City of Seattle Director of Housing, on 10/30/2013

to retrofit; however, it is likely that only a small subset of URMs would be eligible. Eligible properties are exempted from property taxes for a maximum of 12 years, provided that buildings remain in compliance with the program requirements.

In order to be eligible for the program, a number of initial requirements[4] must be met, including (but not limited to):

- The residential portion of an existing building must have been vacant for the preceding 12 months;
- The Multifamily Housing must be located in a Residential Targeted Area;
- The Multifamily Housing must be part of a residential or mixed-use project;
- The buildings must fail to comply with one or more standards of the applicable building and construction code;
- Upon completion of rehabilitation or conversion the building must achieve a condition of Substantial Compliance with current building code;
- There shall be no displacement of existing residential tenants; and
- A minimum of four (4) additional dwelling units must be added.

It is likely that some URM buildings will qualify for the MFTE; however, the current dataset does not provide information on whether or not, and how long, buildings have been vacant, which is an important element of the eligibility requirements. Therefore, it is not possible with current data to quantify the potential scope of the MFTE for URMs.

E. Size of Primary Retrofit Financial Incentive Options

The set of URMs in Seattle is very diverse, as is the short list of primary retrofit financial incentive options. This section provides estimates of the size of financial incentives available from each of these incentive programs, highlighting factors that contribute to variability of the incentive size from building to building. In addition, rough estimates are provided on maximum numbers and percentages of URMs that could be eligible for each program, where possible. Again, there are factors that would limit building owners' participation, and these are described as well.

E.1. Federal Historic Preservation Tax Incentive (federal tax credit)

The federal tax credit incentive is based upon the cost of the building's rehabilitation. The model used for the purpose of this report assumes a $40/square foot mean cost to retrofit a building to the Bolts Plus standard. One of the requirements of the tax credit is that the cost of the rehabilitation must exceed either $5,000 or the pre-rehabilitation adjusted cost basis of the building, whichever is greater.[5] Therefore, the cost of the retrofit alone may be less than the amount required for the building rehabilitation. However, for this model, the value of the incentive was calculated relative to the estimated cost of a Bolts Plus retrofit alone, not the potential cost of a more comprehensive rehabilitation. This isolates how much the incentive is actually worth toward the cost of the retrofit alone, but does not consider the potential cost required to be spent toward a qualifying rehabilitation.

E.1.1. 10% federal tax credit for all taxable non-residential buildings constructed before 1936

Per-Building Incentive Amount

1. Determine the median gross square footage, by use and number of stories, for taxable buildings in the model identified as being in commercial, industrial, or office use
   » Square footage of taxable buildings 1-2 stories, commercial, industrial, or office use
   » Square footage of taxable buildings 3+ stories, commercial, industrial, or office use
2. Determine the median retrofit cost, by use and number of stories, by multiplying the median square footage of taxable buildings in each category by retrofit cost per square foot. Assume $40/square foot for retrofit cost.
3. Sum the median retrofit cost for each use, classified by 1-2 stories and 3+ stories.
4. Multiply the total median retrofit cost for each class by 10% to determine the estimated per-building tax credit applicable to the retrofit cost.
5. ***Resulting tax credit: up to $4/sf, or 10% of the cost of the building seismic retrofit.***

   Note that the direct saving to building owners estimated in Task Memo 5.1 was approximately 2% of the cost of the retrofit, with the public benefit from life safety adding another 2% of the retrofit cost. This incentive program would compensate owners for the life safety benefit, as well as providing an allowance for other public benefits such as historic preservation and helping to maintain important neighborhood character.

4 Seattle Municipal Code, Chapter 5.73 - 2004 Multifamily Housing Property Tax Exemption Program

5 Tax Incentives for Preserving Historic Properties. National Parks Service. http://www.nps.gov/tps/tax-incentives.htm

Number of Potentially Eligible Buildings. Not all URMs identified in the initial 929 building DPD dataset would be eligible for these federal tax credits, so several adjustments were made. Omitted from the initial set were buildings identified as being in religious, government, or school use. Buildings in these uses were considered likely to be non-taxable. Second, residential buildings were removed, since they are excluded from credit eligibility. Remaining in the dataset after this refinement were buildings identified as commercial, office, and industrial use. However, some non-taxable parcels remained in this dataset, so a correction factor was applied to building counts to mitigate this issue. [The correction factor was based upon a sampling of the dataset; details on the methodology used for the sample can be found in **Appendix B**.]

After these adjustments, a subset of **406, or 44%** of Seattle's potential URM buildings were identified as <u>possibly</u> eligible for the 10% federal tax credits.

Since these tax credits are currently available but not widely used, it is important to recognize the factors limiting their use. One factor is the set of IRS tax code provisions noted above. These are unlikely to change to support wider use of the credits. A second factor is the requirement that the renovation cost exceed the depreciated value of the building. This is a significant limitation, because many otherwise-eligible buildings have relatively high "improvements" values. And a third key factor limiting use is the set of procedural hurdles that make it difficult for individual building owners to apply for, obtain, and retain the tax credits. This last factor may be mitigated to some extent by a well-designed City program providing assistance to otherwise-eligible building owners considering seismic retrofits to their URM buildings.

E.1.2. 20% federal tax credit for all taxable designated historical structures

Per-Building Incentive Amount

1. Determine the median gross square footage, by use and number of stories, for taxable buildings in the model identified as being in commercial, industrial, office, or residential use
   » Square footage of taxable buildings 1-2 stories, commercial, industrial, office, or residential use
   » Square footage of taxable buildings 3+ stories, commercial, industrial, office, or residential use
2. Same as for the 10% tax credit
3. Same as for the 10% tax credit
4. Multiply the total median retrofit cost for each class by 20% to determine the estimated per-building tax credit applicable to the retrofit cost.
5. ***Resulting tax credit: up to $8/sf, or 20% of the cost of the building seismic retrofit.***

   Note again that the direct saving to building owners estimated in Task Memo 5.1 was approximately 2% of the cost of the retrofit, with the public benefit from life safety adding another 2% of the retrofit cost. This incentive program would compensate owners for the life safety benefit, as well as providing a significant allowance for other public benefits such as historic preservation and helping to maintain important neighborhood character.

Number of Potentially Eligible Buildings.

Not all URMs identified in the initial 929 building DPD dataset would be eligible for the 20% federal tax credits for historical buildings. First, the list was trimmed to only designated historic buildings or buildings in designated historic neighborhoods. Then, buildings identified as being in religious, government, or school use were removed, since buildings in these uses were considered likely to be non-taxable. Once again, however, some non-taxable parcels remained in this dataset, so a correction factor was applied to building counts to mitigate this issue.

After these adjustments, a subset of 93, or 10% of Seattle's URM buildings were identified as <u>potentially</u> eligible for the 20% federal tax credits.

As with the 10% federal tax credit, these tax credits are currently available but not widely used. The same set of factors limit their use: i) the set of IRS tax code provisions noted above, ii) the minimum renovation cost condition, and iii) the set of procedural hurdles that make it difficult for individual building owners to apply for, obtain, and retain the tax credits. As noted previously, the third of these factors may be mitigated to some extent by a well-designed City program providing assistance to otherwise-eligible building owners considering seismic retrofits to their URM buildings.

E.2. Property Tax Special Valuation Incentive

The property tax special valuation incentive is straightforward. Focusing on the seismic retrofit cost that would be covered, the value of the benefit is determined by the tax rate saved on the qualifying rehabilitation (i.e., seismic retrofit) amount. The applicable rate changes over time, and a conservative value is used below to provide an order of magnitude estimate of the overall potential value of this incentive. Its greater limitation may lie in the narrowly targeted subset of historic URM buildings to which it would apply. These, however, are among the most desirable URM buildings to preserve in the event of earthquakes.

The property tax special valuation incentive was calculated as follows:

Per-Building Incentive Amount

1. Determine the average cost of seismic retrofit rehabilitation qualifying for the deduction, assumed to be $40/sf.
2. Determine the estimated annual property tax saving per building, using the average deduction value and an approximate annual tax rate of .01.
3. Determine the estimated incentive per building by multiplying the estimated property tax deduction value by 10 years.
4. ***Resulting tax exemption value: The value of the property tax deduction would vary widely from URM building to building, based on the actual cost of retrofits. Based on the baseline seismic retrofit cost, the average value of a 10-year tax deduction would be approximately $4/sf, which represents 10% of the baseline cost of retrofits.***

   This amount is still in excess of the estimated direct benefits of seismic retrofits, but may match up well with the combination of direct owner benefits and other community values cited earlier.

Number of Potentially Eligible Buildings. A minority of the URM buildings in the initial 929 building DPD dataset are eligible for the property tax deduction program, because it is limited to designated historical buildings or those in historic districts.

Initial categorization of that inventory identified approximately 150, or 16% of Seattle's potential URM buildings were identified as eligible for the property tax deduction program.

E.3. Property Tax Exemption Incentive

The property tax exemption incentive is assumed here to cover all taxable URMs. While the property tax rate will change over time, a rate equal to 1% of a parcel's building + improvement value is used to approximate the estimated tax. 1% of building + improvement value represents a fair approximation of the amount of tax assessed to each parcel in the model, based on recent history.

<u>All non-historic, taxable buildings pre-1936</u>

Per-Building Incentive Amount

1. Determine the median parcel value by number of stories identified for the improvement for all taxable buildings in the model identified as being in commercial, industrial, office, or residential use
2. Determine the median property tax per building by number of stories, for taxable buildings in the model identified as being in commercial, industrial, office, or residential use: Median parcel value * .01
   - Buildings 1-2 stories, commercial, industrial, office, or residential use
   - Buildings 3+ stories, commercial, industrial, office, or residential use
3. Determine the estimated incentive per building by multiplying the estimated median property tax by 12 years. Classify by 1-2 stories and 3+ stories.
4. ***Resulting tax exemption value: The value of the property tax exemption would vary widely from URM building to building, while the cost of retrofits would vary less. Based on averages for the dataset of buildings, the average value of a 12-year tax exemption would be approximately $20-$22/sf, which represents just over 50% of the baseline cost of retrofits.***

   This amount is well in excess of the estimated benefits of seismic retrofits, but could be scaled back by reducing the number of years for which the tax exemption would apply.

Number of Potentially Eligible Buildings. A high percentage of the potential URMs identified in the initial 929 building DPD dataset could be eligible for a possible property tax exemption program. However, buildings identified as being in religious, government, or school use were still removed, since buildings in these uses were considered likely to be non-taxable. And because some non-taxable parcels remained in this dataset, the correction factor was applied to building counts for this possible program.

After these adjustments, a subset of 700, or 75% of Seattle's URM buildings were identified as <u>potentially</u> eligible for a property tax exemption program. The critical factor limiting this program option is its feasibility, since it would require a change in state law.

E.4. FAR Bonus Incentive

The FAR Bonus was too speculative to calculate because it is highly variable from building to building so there are no estimates included in this report. Nevertheless, this incentive may provide significant value and opportunity for certain types of buildings with unused FAR values and available building footprints for new construction. Consideration of a FAR bonus should be included in development of a composite package of incentives.

Potential Tax Incentive	Estimated Number of total URMs potentially eligible for incentives	Estimated Percentage of total URMs potentially eligible for incentive
10% Tax credit on older buildings	406	44%
20% Tax Credits for Historic Re-hab	93	10%
Special Valuation	150	16%
Tax Exemption	700	75%

Conclusion

This investigation of potential seismic retrofit financing options has focused on those available through public policy choices. The overall findings include the following:

- There are likely to be some gaps in information about benefits, costs, and options for URM retrofit and remodeling that are preventing some URM building owners from performing seismic retrofits, even when it is in their economic interest to do so. These gaps could be closed for many owners if the City adopted a more proactive role in assembling and distributing information to the community of URM building owners.
- There are existing programs designed to provide incentives for rehabilitation of certain URMs, primarily those of established historical significance or subsidized housing. These tend to be under-used, in part due to URM owners' unfamiliarity with the programs, and in part due to the substantial procedural requirements prior to obtaining the program benefits. Again, the City could improve the market penetration of these programs by providing a central point of information and application support for URM owners.
- There are some potential new financing incentive tools, such as property tax abatements and FAR allowance bonuses for URM seismic retrofits, that the City could consider further. These could potentially be designed to apply to a broader spectrum of URMs than can be reached with existing programs.

A URM retrofit financing policy that incorporated some or all of these options has the potential for increasing the fraction of URMs that are retrofitted to Bolts-Plus levels, without imposing heavy net financial on URM owners. Such a program has the potential for targeting and reaching those URM owners for whom seismic retrofits of their buildings - with or without substantial remodels - are a reasonably close "second-best" financial option to simply maintaining the status quo. This could produce an economic break-even or net gain for these building owners, and simultaneously advance other positive public policy outcomes, including improved life safety, historic preservation and maintenance of neighborhood aesthetic appeal.

APPENDICES

KEY TO DETAILED HAZUS OUTPUT TABLES

The individual rows of the detailed tables in the following Appendices 4.A, 4.B and 4.C refer to different subsets of the 929 buildings in the DPD URM data set. The three-digit codes for these building categories include a first digit for building height, a second digit for underlying soil, and a third digit for historic district location. The complete list is as follows:

Code	Height (stories)	Liquefaction Soil (Yes, No)	Historic District (Yes, No)
100	1	No	No
101	1	No	Yes
110	1	Yes	No
111	1	Yes	Yes
200	2	No	No
201	2	No	Yes
210	2	Yes	No
211	2	Yes	Yes
300	3+	No	No
301	3+	No	Yes
310	3+	Yes	No
311	3+	Yes	Yes

The detailed tables also include sub-totals by building height, underlying soil and historic district location. These are provided for each combination of earthquake (3) and building retrofit status (3).

Appendix 4.A. Building Damage

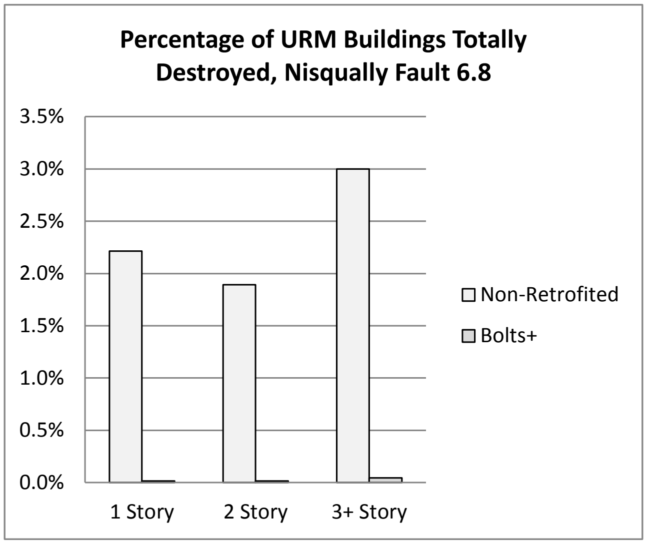
		Nisqually Fault Earthquake, Magnitude 6.8														
		Structural Elements					*Non-Structural, Drift-Sensitive*					*Non-Structural, Acceleration-Sensitive*				
URM Subset		**None**	**Slight**	**Mod**	**Exten**	**Total**	**None**	**Slight**	**Mod**	**Exten**	**Total**	**None**	**Slight**	**Mod**	**Exten**	**Total**
Non-Retrofited																
100	E	0.65	0.22	0.06	0.05	0.02	0.84	0.10	0.03	0.01	0.02	0.48	0.35	0.14	0.02	0.01
101	E	0.73	0.18	0.05	0.03	0.01	0.90	0.07	0.02	0.00	0.01	0.58	0.30	0.10	0.01	0.01
110	E	0.40	0.29	0.12	0.13	0.06	0.61	0.19	0.10	0.04	0.06	0.32	0.38	0.20	0.05	0.05
111	E	0.57	0.25	0.08	0.07	0.02	0.79	0.13	0.05	0.01	0.02	0.38	0.39	0.18	0.03	0.02
200	E	0.66	0.22	0.06	0.05	0.01	0.85	0.09	0.03	0.01	0.01	0.49	0.35	0.13	0.02	0.01
201	E	0.71	0.19	0.05	0.04	0.01	0.89	0.07	0.02	0.01	0.01	0.58	0.30	0.10	0.01	0.01
210	E	0.50	0.28	0.10	0.09	0.03	0.72	0.16	0.07	0.02	0.03	0.35	0.39	0.19	0.04	0.03
211	E	0.57	0.26	0.08	0.07	0.02	0.79	0.13	0.05	0.01	0.02	0.42	0.38	0.16	0.02	0.02
300	E	0.56	0.25	0.08	0.07	0.03	0.71	0.20	0.05	0.02	0.03	0.43	0.37	0.16	0.03	0.02
301	E	0.49	0.28	0.10	0.10	0.04	0.65	0.22	0.07	0.02	0.04	0.36	0.39	0.19	0.04	0.03
310	E	0.49	0.28	0.10	0.09	0.04	0.65	0.22	0.07	0.02	0.04	0.36	0.39	0.19	0.03	0.03
311	E	0.52	0.27	0.09	0.08	0.03	0.68	0.22	0.06	0.02	0.03	0.37	0.39	0.18	0.03	0.02
Total	**E**	**0.57**	**0.25**	**0.08**	**0.07**	**0.03**	**0.74**	**0.17**	**0.05**	**0.01**	**0.03**	**0.43**	**0.37**	**0.16**	**0.03**	**0.02**
1 Story	**E**	**0.62**	**0.23**	**0.07**	**0.06**	**0.02**	**0.82**	**0.11**	**0.04**	**0.01**	**0.02**	**0.47**	**0.35**	**0.14**	**0.02**	**0.02**
2 Story	**E**	**0.62**	**0.23**	**0.07**	**0.06**	**0.02**	**0.83**	**0.11**	**0.04**	**0.01**	**0.02**	**0.47**	**0.35**	**0.14**	**0.02**	**0.02**
3+ Story	**E**	**0.54**	**0.26**	**0.09**	**0.08**	**0.03**	**0.69**	**0.21**	**0.06**	**0.02**	**0.03**	**0.40**	**0.37**	**0.17**	**0.03**	**0.02**
Liq Zone	**E**	**0.50**	**0.27**	**0.10**	**0.09**	**0.03**	**0.68**	**0.20**	**0.06**	**0.02**	**0.03**	**0.37**	**0.39**	**0.19**	**0.03**	**0.03**
Non-Liq Zone	**E**	**0.60**	**0.24**	**0.08**	**0.07**	**0.02**	**0.76**	**0.16**	**0.04**	**0.01**	**0.02**	**0.45**	**0.36**	**0.15**	**0.02**	**0.02**
Hist District	**E**	**0.58**	**0.27**	**0.09**	**0.08**	**0.03**	**0.75**	**0.20**	**0.06**	**0.02**	**0.03**	**0.40**	**0.37**	**0.17**	**0.03**	**0.02**
Non-Hist Dist	**E**	**0.58**	**0.24**	**0.08**	**0.07**	**0.02**	**0.74**	**0.16**	**0.05**	**0.01**	**0.02**	**0.43**	**0.36**	**0.16**	**0.03**	**0.02**
Bolts+																
100	B	0.88	0.09	0.03	0.00	0.00	0.91	0.07	0.02	0.00	0.00	0.42	0.36	0.18	0.03	0.01
101	B	0.92	0.06	0.02	0.00	0.00	0.94	0.05	0.01	0.00	0.00	0.54	0.32	0.13	0.02	0.00
110	B	0.78	0.15	0.06	0.01	0.00	0.83	0.11	0.04	0.01	0.00	0.23	0.39	0.29	0.06	0.02
111	B	0.83	0.12	0.04	0.00	0.00	0.87	0.09	0.03	0.01	0.00	0.26	0.40	0.26	0.05	0.02
200	B	0.88	0.09	0.03	0.00	0.00	0.91	0.06	0.02	0.00	0.00	0.44	0.37	0.17	0.02	0.01
201	B	0.91	0.07	0.02	0.00	0.00	0.93	0.05	0.01	0.00	0.00	0.53	0.32	0.13	0.02	0.01
210	B	0.81	0.14	0.05	0.00	0.00	0.86	0.10	0.03	0.01	0.00	0.25	0.40	0.28	0.06	0.02
211	B	0.83	0.12	0.04	0.00	0.00	0.87	0.09	0.03	0.01	0.00	0.29	0.41	0.25	0.04	0.01
300	B	0.81	0.13	0.05	0.01	0.00	0.85	0.10	0.03	0.01	0.00	0.36	0.38	0.21	0.04	0.01
301	B	0.75	0.17	0.07	0.01	0.00	0.81	0.13	0.05	0.01	0.00	0.24	0.40	0.28	0.06	0.02
310	B	0.75	0.17	0.07	0.01	0.00	0.81	0.13	0.04	0.01	0.00	0.24	0.40	0.28	0.06	0.02
311	B	0.76	0.16	0.07	0.01	0.00	0.82	0.12	0.04	0.01	0.00	0.25	0.40	0.27	0.05	0.02
Total	**B**	**0.82**	**0.13**	**0.05**	**0.01**	**0.00**	**0.86**	**0.10**	**0.03**	**0.01**	**0.00**	**0.35**	**0.38**	**0.22**	**0.04**	**0.01**
1 Story	**B**	**0.87**	**0.10**	**0.03**	**0.00**	**0.00**	**0.90**	**0.07**	**0.02**	**0.00**	**0.00**	**0.40**	**0.36**	**0.19**	**0.03**	**0.01**
2 Story	**B**	**0.87**	**0.10**	**0.03**	**0.00**	**0.00**	**0.90**	**0.07**	**0.02**	**0.00**	**0.00**	**0.40**	**0.37**	**0.19**	**0.03**	**0.01**
3+ Story	**B**	**0.79**	**0.15**	**0.06**	**0.01**	**0.00**	**0.84**	**0.11**	**0.04**	**0.01**	**0.00**	**0.32**	**0.39**	**0.24**	**0.04**	**0.02**
Liq Zone	**B**	**0.77**	**0.16**	**0.06**	**0.01**	**0.00**	**0.83**	**0.12**	**0.04**	**0.01**	**0.00**	**0.25**	**0.40**	**0.28**	**0.06**	**0.02**
Non-Liq Zone	**B**	**0.83**	**0.12**	**0.04**	**0.00**	**0.00**	**0.87**	**0.09**	**0.03**	**0.01**	**0.00**	**0.38**	**0.37**	**0.20**	**0.04**	**0.01**
Hist District	**B**	**0.83**	**0.16**	**0.06**	**0.01**	**0.00**	**0.89**	**0.12**	**0.04**	**0.01**	**0.00**	**0.29**	**0.39**	**0.26**	**0.05**	**0.02**
Non-Hist Dist	**B**	**0.82**	**0.12**	**0.04**	**0.00**	**0.00**	**0.86**	**0.09**	**0.03**	**0.01**	**0.00**	**0.36**	**0.38**	**0.21**	**0.04**	**0.01**
Reinforced Masonry																
100	H	0.98	0.01	0.00	0.00	0.00	0.98	0.02	0.00	0.00	0.00	0.76	0.23	0.01	0.00	0.00
101	H	0.99	0.01	0.00	0.00	0.00	0.99	0.01	0.00	0.00	0.00	0.88	0.11	0.00	0.00	0.00
110	H	0.95	0.05	0.01	0.00	0.00	0.94	0.06	0.01	0.00	0.00	0.42	0.53	0.05	0.00	0.00
111	H	0.98	0.02	0.00	0.00	0.00	0.97	0.03	0.00	0.00	0.00	0.61	0.38	0.01	0.00	0.00
200	H	0.99	0.01	0.00	0.00	0.00	0.98	0.02	0.00	0.00	0.00	0.82	0.17	0.00	0.00	0.00
201	H	0.99	0.01	0.00	0.00	0.00	0.99	0.01	0.00	0.00	0.00	0.87	0.13	0.00	0.00	0.00
210	H	0.97	0.03	0.00	0.00	0.00	0.95	0.04	0.00	0.00	0.00	0.51	0.47	0.02	0.00	0.00
211	H	0.98	0.02	0.00	0.00	0.00	0.97	0.03	0.00	0.00	0.00	0.67	0.32	0.01	0.00	0.00
300	H	0.96	0.04	0.01	0.00	0.00	0.94	0.05	0.00	0.00	0.00	0.69	0.29	0.02	0.00	0.00
301	H	0.94	0.06	0.01	0.00	0.00	0.92	0.07	0.01	0.00	0.00	0.53	0.45	0.02	0.00	0.00
310	H	0.94	0.06	0.01	0.00	0.00	0.92	0.07	0.01	0.00	0.00	0.54	0.44	0.02	0.00	0.00
311	H	0.95	0.05	0.01	0.00	0.00	0.93	0.06	0.01	0.00	0.00	0.58	0.40	0.02	0.00	0.00
Total	**H**	**0.96**	**0.03**	**0.00**	**0.00**	**0.00**	**0.95**	**0.04**	**0.00**	**0.00**	**0.00**	**0.68**	**0.30**	**0.02**	**0.00**	**0.00**
1 Story	**H**	**0.98**	**0.02**	**0.00**	**0.00**	**0.00**	**0.97**	**0.03**	**0.00**	**0.00**	**0.00**	**0.73**	**0.26**	**0.01**	**0.00**	**0.00**
2 Story	**H**	**0.98**	**0.02**	**0.00**	**0.00**	**0.00**	**0.98**	**0.02**	**0.00**	**0.00**	**0.00**	**0.75**	**0.24**	**0.01**	**0.00**	**0.00**
3+ Story	**H**	**0.95**	**0.04**	**0.01**	**0.00**	**0.00**	**0.94**	**0.06**	**0.01**	**0.00**	**0.00**	**0.64**	**0.34**	**0.02**	**0.00**	**0.00**
Liq Zone	**H**	**0.95**	**0.05**	**0.01**	**0.00**	**0.00**	**0.93**	**0.06**	**0.01**	**0.00**	**0.00**	**0.55**	**0.43**	**0.02**	**0.00**	**0.00**
Non-Liq Zone	**H**	**0.97**	**0.03**	**0.00**	**0.00**	**0.00**	**0.96**	**0.04**	**0.00**	**0.00**	**0.00**	**0.73**	**0.26**	**0.01**	**0.00**	**0.00**
Hist District	**H**	**1.01**	**0.05**	**0.01**	**0.00**	**0.00**	**1.00**	**0.06**	**0.01**	**0.00**	**0.00**	**0.61**	**0.37**	**0.02**	**0.00**	**0.00**
Non-Hist Dist	**H**	**0.95**	**0.03**	**0.00**	**0.00**	**0.00**	**0.94**	**0.04**	**0.00**	**0.00**	**0.00**	**0.70**	**0.29**	**0.02**	**0.00**	**0.00**

Appendix 4.A. Building Damage

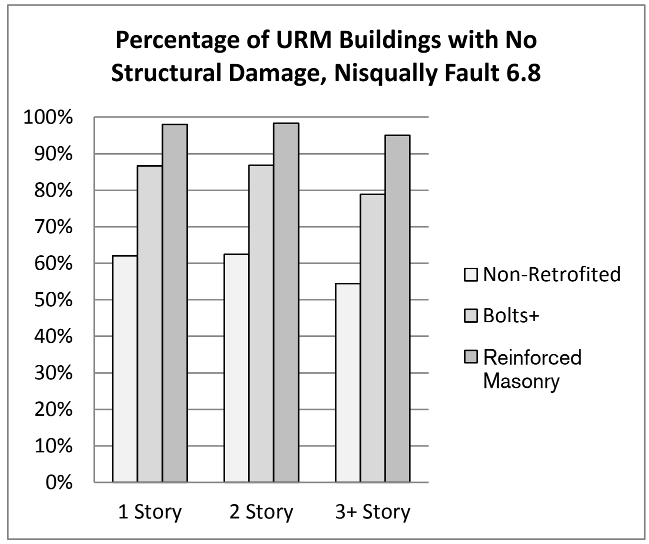
		Cascadia Subduction Zone Earthquake, Magnitude 9.0														
		Structural Elements					*Non-Structural, Drift-Sensitive*					*Non-Structural, Acceleration-Sensitive*				
URM Subset		**None**	**Slight**	**Mod**	**Exten**	**Total**	**None**	**Slight**	**Mod**	**Exten**	**Total**	**None**	**Slight**	**Mod**	**Exten**	**Total**
Non-Retrofited																
100	E	0.50	0.28	0.10	0.09	0.03	0.73	0.16	0.06	0.02	0.03	0.30	0.40	0.23	0.04	0.03
101	E	0.50	0.28	0.10	0.09	0.03	0.72	0.16	0.07	0.02	0.03	0.30	0.40	0.23	0.04	0.03
110	E	0.47	0.28	0.11	0.10	0.04	0.69	0.17	0.07	0.02	0.04	0.29	0.39	0.23	0.05	0.03
111	E	0.50	0.28	0.10	0.09	0.03	0.72	0.16	0.07	0.02	0.03	0.30	0.40	0.23	0.04	0.03
200	E	0.51	0.28	0.10	0.09	0.03	0.73	0.15	0.06	0.02	0.03	0.30	0.40	0.23	0.04	0.03
201	E	0.50	0.28	0.10	0.09	0.03	0.72	0.16	0.07	0.02	0.03	0.30	0.40	0.23	0.04	0.03
210	E	0.48	0.28	0.10	0.10	0.04	0.71	0.16	0.07	0.02	0.04	0.30	0.40	0.23	0.05	0.03
211	E	0.50	0.28	0.10	0.09	0.03	0.72	0.16	0.07	0.02	0.03	0.30	0.40	0.23	0.04	0.03
300	E	0.45	0.29	0.11	0.11	0.05	0.62	0.23	0.08	0.03	0.05	0.29	0.39	0.23	0.05	0.04
301	E	0.43	0.29	0.11	0.11	0.05	0.61	0.23	0.08	0.03	0.05	0.29	0.39	0.23	0.05	0.04
310	E	0.42	0.29	0.12	0.12	0.05	0.60	0.23	0.09	0.03	0.05	0.29	0.39	0.23	0.05	0.04
311	E	0.43	0.29	0.11	0.11	0.05	0.61	0.23	0.08	0.03	0.05	0.29	0.39	0.23	0.05	0.04
Total	**E**	**0.46**	**0.28**	**0.11**	**0.10**	**0.04**	**0.65**	**0.20**	**0.08**	**0.02**	**0.04**	**0.29**	**0.39**	**0.23**	**0.05**	**0.03**
1 Story	**E**	**0.50**	**0.28**	**0.10**	**0.09**	**0.03**	**0.72**	**0.16**	**0.07**	**0.02**	**0.03**	**0.30**	**0.40**	**0.23**	**0.04**	**0.03**
2 Story	**E**	**0.50**	**0.28**	**0.10**	**0.09**	**0.03**	**0.73**	**0.16**	**0.06**	**0.02**	**0.03**	**0.30**	**0.40**	**0.23**	**0.04**	**0.03**
3+ Story	**E**	**0.44**	**0.29**	**0.11**	**0.11**	**0.05**	**0.61**	**0.23**	**0.08**	**0.03**	**0.05**	**0.29**	**0.39**	**0.23**	**0.05**	**0.04**
Liq Zone	**E**	**0.45**	**0.29**	**0.11**	**0.11**	**0.05**	**0.64**	**0.21**	**0.08**	**0.03**	**0.05**	**0.29**	**0.39**	**0.23**	**0.05**	**0.04**
Non-Liq Zone	**E**	**0.47**	**0.28**	**0.11**	**0.10**	**0.04**	**0.66**	**0.20**	**0.07**	**0.02**	**0.04**	**0.29**	**0.39**	**0.23**	**0.05**	**0.03**
Hist District	**E**	**0.47**	**0.31**	**0.12**	**0.12**	**0.05**	**0.67**	**0.23**	**0.09**	**0.03**	**0.05**	**0.29**	**0.39**	**0.23**	**0.05**	**0.04**
Non-Hist Dist	**E**	**0.46**	**0.28**	**0.10**	**0.10**	**0.04**	**0.65**	**0.20**	**0.07**	**0.02**	**0.04**	**0.29**	**0.39**	**0.23**	**0.05**	**0.03**
Bolts+																
100	B	0.79	0.14	0.05	0.01	0.00	0.85	0.11	0.04	0.01	0.00	0.20	0.39	0.31	0.07	0.03
101	B	0.79	0.15	0.05	0.01	0.00	0.84	0.11	0.04	0.01	0.00	0.20	0.39	0.31	0.07	0.03
110	B	0.78	0.15	0.06	0.01	0.00	0.84	0.11	0.04	0.01	0.00	0.20	0.39	0.31	0.07	0.03
111	B	0.79	0.15	0.05	0.01	0.00	0.84	0.11	0.04	0.01	0.00	0.20	0.39	0.31	0.07	0.03
200	B	0.80	0.14	0.05	0.01	0.00	0.85	0.11	0.03	0.01	0.00	0.20	0.39	0.31	0.07	0.03
201	B	0.79	0.15	0.05	0.01	0.00	0.84	0.11	0.04	0.01	0.00	0.20	0.39	0.31	0.07	0.03
210	B	0.79	0.15	0.06	0.01	0.00	0.84	0.11	0.04	0.01	0.00	0.20	0.39	0.31	0.07	0.03
211	B	0.79	0.15	0.05	0.01	0.00	0.84	0.11	0.04	0.01	0.00	0.20	0.39	0.31	0.07	0.03
300	B	0.69	0.20	0.09	0.01	0.00	0.77	0.15	0.06	0.02	0.01	0.17	0.37	0.34	0.08	0.04
301	B	0.69	0.20	0.10	0.01	0.00	0.77	0.15	0.06	0.02	0.01	0.17	0.37	0.34	0.08	0.04
310	B	0.69	0.20	0.10	0.01	0.00	0.77	0.15	0.06	0.02	0.01	0.17	0.37	0.34	0.08	0.04
311	B	0.69	0.20	0.10	0.01	0.00	0.77	0.15	0.06	0.02	0.01	0.17	0.37	0.34	0.08	0.04
Total	**B**	**0.73**	**0.18**	**0.08**	**0.01**	**0.00**	**0.80**	**0.14**	**0.05**	**0.01**	**0.01**	**0.18**	**0.38**	**0.33**	**0.08**	**0.03**
1 Story	**B**	**0.79**	**0.15**	**0.05**	**0.01**	**0.00**	**0.84**	**0.11**	**0.04**	**0.01**	**0.00**	**0.20**	**0.39**	**0.31**	**0.07**	**0.03**
2 Story	**B**	**0.79**	**0.14**	**0.05**	**0.01**	**0.00**	**0.85**	**0.11**	**0.04**	**0.01**	**0.00**	**0.20**	**0.39**	**0.31**	**0.07**	**0.03**
3+ Story	**B**	**0.69**	**0.20**	**0.09**	**0.01**	**0.00**	**0.77**	**0.15**	**0.06**	**0.02**	**0.01**	**0.17**	**0.37**	**0.34**	**0.08**	**0.04**
Liq Zone	**B**	**0.72**	**0.18**	**0.08**	**0.01**	**0.00**	**0.79**	**0.14**	**0.05**	**0.01**	**0.01**	**0.18**	**0.38**	**0.33**	**0.08**	**0.03**
Non-Liq Zone	**B**	**0.73**	**0.18**	**0.08**	**0.01**	**0.00**	**0.80**	**0.13**	**0.05**	**0.01**	**0.01**	**0.18**	**0.38**	**0.33**	**0.08**	**0.03**
Hist District	**B**	**0.75**	**0.20**	**0.09**	**0.01**	**0.00**	**0.83**	**0.15**	**0.06**	**0.02**	**0.01**	**0.18**	**0.38**	**0.33**	**0.08**	**0.03**
Non-Hist Dist	**B**	**0.72**	**0.17**	**0.08**	**0.01**	**0.00**	**0.79**	**0.13**	**0.05**	**0.01**	**0.00**	**0.18**	**0.38**	**0.33**	**0.08**	**0.03**
Reinforced Masonry																
100	H	0.95	0.04	0.00	0.00	0.00	0.94	0.06	0.00	0.00	0.00	0.35	0.59	0.05	0.00	0.00
101	H	0.95	0.04	0.00	0.00	0.00	0.94	0.06	0.00	0.00	0.00	0.35	0.59	0.06	0.00	0.00
110	H	0.95	0.05	0.01	0.00	0.00	0.93	0.06	0.01	0.00	0.00	0.33	0.61	0.06	0.00	0.00
111	H	0.95	0.04	0.00	0.00	0.00	0.94	0.06	0.00	0.00	0.00	0.35	0.59	0.06	0.00	0.00
200	H	0.96	0.04	0.00	0.00	0.00	0.94	0.05	0.00	0.00	0.00	0.36	0.59	0.05	0.00	0.00
201	H	0.95	0.04	0.00	0.00	0.00	0.94	0.06	0.00	0.00	0.00	0.35	0.59	0.06	0.00	0.00
210	H	0.95	0.04	0.01	0.00	0.00	0.94	0.06	0.00	0.00	0.00	0.34	0.60	0.06	0.00	0.00
211	H	0.95	0.04	0.00	0.00	0.00	0.94	0.06	0.00	0.00	0.00	0.35	0.59	0.06	0.00	0.00
300	H	0.88	0.10	0.02	0.00	0.00	0.86	0.12	0.02	0.00	0.00	0.26	0.65	0.09	0.00	0.00
301	H	0.88	0.10	0.02	0.00	0.00	0.86	0.12	0.02	0.00	0.00	0.25	0.65	0.09	0.00	0.00
310	H	0.88	0.10	0.02	0.00	0.00	0.86	0.12	0.02	0.00	0.00	0.25	0.65	0.09	0.00	0.00
311	H	0.88	0.10	0.02	0.00	0.00	0.86	0.12	0.02	0.00	0.00	0.25	0.65	0.09	0.00	0.00
Total	**H**	**0.91**	**0.08**	**0.01**	**0.00**	**0.00**	**0.89**	**0.10**	**0.01**	**0.00**	**0.00**	**0.29**	**0.63**	**0.08**	**0.00**	**0.00**
1 Story	**H**	**0.95**	**0.04**	**0.00**	**0.00**	**0.00**	**0.94**	**0.06**	**0.00**	**0.00**	**0.00**	**0.35**	**0.59**	**0.06**	**0.00**	**0.00**
2 Story	**H**	**0.95**	**0.04**	**0.00**	**0.00**	**0.00**	**0.94**	**0.06**	**0.00**	**0.00**	**0.00**	**0.36**	**0.59**	**0.05**	**0.00**	**0.00**
3+ Story	**H**	**0.88**	**0.10**	**0.02**	**0.00**	**0.00**	**0.86**	**0.12**	**0.02**	**0.00**	**0.00**	**0.26**	**0.65**	**0.09**	**0.00**	**0.00**
Liq Zone	**H**	**0.90**	**0.09**	**0.01**	**0.00**	**0.00**	**0.88**	**0.10**	**0.01**	**0.00**	**0.00**	**0.28**	**0.64**	**0.08**	**0.00**	**0.00**
Non-Liq Zone	**H**	**0.91**	**0.08**	**0.01**	**0.00**	**0.00**	**0.89**	**0.10**	**0.01**	**0.00**	**0.00**	**0.30**	**0.63**	**0.08**	**0.00**	**0.00**
Hist District	**H**	**0.95**	**0.10**	**0.02**	**0.00**	**0.00**	**0.93**	**0.12**	**0.01**	**0.00**	**0.00**	**0.27**	**0.64**	**0.09**	**0.00**	**0.00**
Non-Hist Dist	**H**	**0.90**	**0.07**	**0.01**	**0.00**	**0.00**	**0.88**	**0.09**	**0.01**	**0.00**	**0.00**	**0.30**	**0.63**	**0.08**	**0.00**	**0.00**

Appendix 4.A. Building Damage

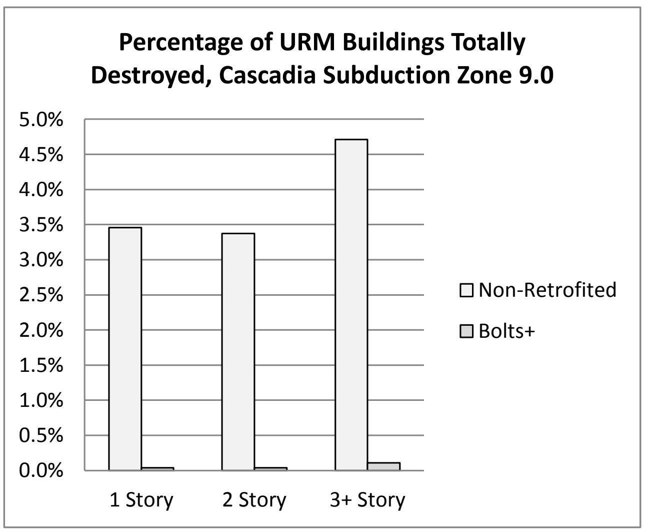
		Seattle Fault Earthquake, Magnitude 6.7														
		Structural Elements					*Non-Structural, Drift-Sensitive*					*Non-Structural, Acceleration-Sensitive*				
URM Subset		**None**	**Slight**	**Mod**	**Exten**	**Total**	**None**	**Slight**	**Mod**	**Exten**	**Total**	**None**	**Slight**	**Mod**	**Exten**	**Total**
Non-Retrofited																
100	E	0.17	0.21	0.13	0.22	0.27	0.27	0.19	0.17	0.11	0.27	0.13	0.28	0.26	0.12	0.21
101	E	0.19	0.21	0.12	0.20	0.28	0.32	0.17	0.14	0.10	0.28	0.14	0.27	0.24	0.12	0.22
110	E	0.05	0.13	0.12	0.25	0.45	0.08	0.13	0.18	0.15	0.45	0.06	0.18	0.23	0.17	0.36
111	E	0.05	0.14	0.12	0.26	0.42	0.10	0.15	0.19	0.15	0.42	0.06	0.19	0.25	0.17	0.33
200	E	0.15	0.21	0.14	0.23	0.27	0.25	0.19	0.18	0.11	0.27	0.12	0.27	0.27	0.13	0.21
201	E	0.21	0.23	0.13	0.20	0.22	0.34	0.19	0.15	0.09	0.22	0.16	0.30	0.25	0.11	0.18
210	E	0.05	0.13	0.12	0.26	0.44	0.09	0.14	0.18	0.15	0.44	0.06	0.19	0.23	0.17	0.35
211	E	0.06	0.16	0.13	0.26	0.38	0.12	0.16	0.19	0.15	0.38	0.08	0.22	0.25	0.16	0.30
300	E	0.23	0.26	0.15	0.20	0.16	0.40	0.20	0.16	0.08	0.16	0.16	0.33	0.28	0.10	0.13
301	E	0.16	0.24	0.15	0.24	0.21	0.32	0.18	0.19	0.10	0.21	0.13	0.30	0.28	0.11	0.17
310	E	0.16	0.24	0.15	0.24	0.21	0.32	0.18	0.19	0.10	0.21	0.13	0.30	0.29	0.12	0.17
311	E	0.15	0.24	0.15	0.24	0.22	0.31	0.17	0.19	0.11	0.22	0.13	0.30	0.28	0.12	0.17
Total	**E**	**0.18**	**0.23**	**0.14**	**0.22**	**0.22**	**0.32**	**0.19**	**0.17**	**0.10**	**0.22**	**0.14**	**0.30**	**0.27**	**0.12**	**0.18**
1 Story	**E**	**0.15**	**0.20**	**0.13**	**0.22**	**0.30**	**0.25**	**0.18**	**0.17**	**0.11**	**0.30**	**0.12**	**0.26**	**0.25**	**0.13**	**0.24**
2 Story	**E**	**0.13**	**0.20**	**0.13**	**0.24**	**0.30**	**0.22**	**0.18**	**0.18**	**0.12**	**0.30**	**0.11**	**0.26**	**0.26**	**0.14**	**0.24**
3+ Story	**E**	**0.20**	**0.26**	**0.15**	**0.21**	**0.18**	**0.37**	**0.19**	**0.17**	**0.09**	**0.18**	**0.15**	**0.32**	**0.28**	**0.11**	**0.14**
Liq Zone	**E**	**0.12**	**0.21**	**0.14**	**0.24**	**0.28**	**0.25**	**0.16**	**0.19**	**0.12**	**0.28**	**0.11**	**0.27**	**0.27**	**0.13**	**0.23**
Non-Liq Zone	**E**	**0.20**	**0.24**	**0.14**	**0.21**	**0.20**	**0.35**	**0.19**	**0.16**	**0.09**	**0.20**	**0.15**	**0.31**	**0.28**	**0.11**	**0.16**
Hist District	**E**	**0.16**	**0.25**	**0.16**	**0.25**	**0.24**	**0.32**	**0.18**	**0.20**	**0.11**	**0.24**	**0.13**	**0.29**	**0.28**	**0.12**	**0.18**
Non-Hist Dist	**E**	**0.19**	**0.23**	**0.14**	**0.21**	**0.22**	**0.32**	**0.19**	**0.16**	**0.10**	**0.22**	**0.14**	**0.30**	**0.27**	**0.12**	**0.18**
Bolts+																
100	B	0.47	0.24	0.20	0.07	0.02	0.57	0.20	0.12	0.06	0.05	0.10	0.30	0.38	0.14	0.09
101	B	0.44	0.19	0.21	0.11	0.04	0.52	0.18	0.13	0.08	0.09	0.10	0.29	0.37	0.14	0.10
110	B	0.25	0.25	0.31	0.14	0.04	0.36	0.25	0.19	0.10	0.10	0.05	0.24	0.40	0.18	0.13
111	B	0.26	0.26	0.31	0.14	0.04	0.37	0.24	0.19	0.10	0.10	0.05	0.23	0.40	0.18	0.13
200	B	0.48	0.25	0.20	0.06	0.01	0.58	0.21	0.12	0.05	0.03	0.09	0.29	0.39	0.14	0.09
201	B	0.55	0.22	0.17	0.06	0.02	0.63	0.18	0.10	0.05	0.04	0.12	0.32	0.37	0.12	0.07
210	B	0.28	0.26	0.30	0.12	0.03	0.40	0.25	0.18	0.09	0.08	0.06	0.24	0.40	0.17	0.12
211	B	0.37	0.28	0.26	0.07	0.01	0.49	0.25	0.15	0.07	0.04	0.07	0.27	0.40	0.16	0.10
300	B	0.43	0.27	0.23	0.06	0.01	0.54	0.23	0.14	0.06	0.04	0.09	0.30	0.39	0.14	0.08
301	B	0.33	0.28	0.28	0.09	0.02	0.45	0.25	0.17	0.08	0.05	0.08	0.29	0.40	0.15	0.09
310	B	0.33	0.28	0.28	0.09	0.02	0.45	0.25	0.17	0.08	0.05	0.08	0.28	0.40	0.15	0.09
311	B	0.32	0.28	0.29	0.09	0.02	0.44	0.25	0.17	0.08	0.06	0.08	0.28	0.40	0.15	0.09
Total	**B**	**0.41**	**0.26**	**0.24**	**0.07**	**0.02**	**0.52**	**0.23**	**0.14**	**0.06**	**0.05**	**0.09**	**0.29**	**0.39**	**0.14**	**0.09**
1 Story	**B**	**0.43**	**0.24**	**0.22**	**0.09**	**0.02**	**0.53**	**0.21**	**0.14**	**0.07**	**0.06**	**0.09**	**0.28**	**0.38**	**0.14**	**0.10**
2 Story	**B**	**0.44**	**0.25**	**0.22**	**0.07**	**0.02**	**0.54**	**0.22**	**0.13**	**0.06**	**0.05**	**0.08**	**0.28**	**0.39**	**0.15**	**0.09**
3+ Story	**B**	**0.39**	**0.27**	**0.25**	**0.07**	**0.01**	**0.51**	**0.24**	**0.15**	**0.06**	**0.04**	**0.09**	**0.29**	**0.39**	**0.14**	**0.08**
Liq Zone	**B**	**0.31**	**0.28**	**0.29**	**0.10**	**0.02**	**0.43**	**0.25**	**0.17**	**0.08**	**0.06**	**0.07**	**0.27**	**0.40**	**0.16**	**0.10**
Non-Liq Zone	**B**	**0.44**	**0.26**	**0.22**	**0.07**	**0.01**	**0.55**	**0.22**	**0.13**	**0.06**	**0.04**	**0.09**	**0.30**	**0.39**	**0.14**	**0.08**
Hist District	**B**	**0.37**	**0.29**	**0.29**	**0.10**	**0.02**	**0.49**	**0.26**	**0.17**	**0.08**	**0.06**	**0.08**	**0.28**	**0.40**	**0.15**	**0.09**
Non-Hist Dist	**B**	**0.42**	**0.25**	**0.22**	**0.07**	**0.01**	**0.53**	**0.22**	**0.13**	**0.06**	**0.04**	**0.09**	**0.29**	**0.39**	**0.14**	**0.09**
Reinforced Masonry																
100	H	0.80	0.16	0.05	0.00	0.00	0.78	0.18	0.04	0.00	0.00	0.11	0.60	0.28	0.01	0.00
101	H	0.74	0.18	0.08	0.00	0.00	0.73	0.20	0.07	0.00	0.00	0.13	0.53	0.31	0.02	0.00
110	H	0.69	0.23	0.08	0.00	0.00	0.68	0.26	0.06	0.00	0.00	0.04	0.52	0.43	0.02	0.00
111	H	0.68	0.23	0.08	0.00	0.00	0.67	0.26	0.07	0.00	0.00	0.03	0.51	0.44	0.02	0.00
200	H	0.81	0.15	0.04	0.00	0.00	0.79	0.17	0.03	0.00	0.00	0.10	0.61	0.28	0.01	0.00
201	H	0.83	0.13	0.04	0.00	0.00	0.81	0.15	0.03	0.00	0.00	0.15	0.61	0.23	0.01	0.00
210	H	0.71	0.22	0.07	0.00	0.00	0.70	0.24	0.06	0.00	0.00	0.04	0.54	0.41	0.02	0.00
211	H	0.77	0.18	0.05	0.00	0.00	0.75	0.21	0.04	0.00	0.00	0.05	0.58	0.35	0.01	0.00
300	H	0.66	0.24	0.10	0.00	0.00	0.65	0.27	0.08	0.00	0.00	0.08	0.60	0.31	0.01	0.00
301	H	0.60	0.28	0.12	0.00	0.00	0.59	0.31	0.10	0.00	0.00	0.06	0.59	0.35	0.01	0.00
310	H	0.59	0.28	0.12	0.00	0.00	0.59	0.31	0.10	0.00	0.00	0.05	0.58	0.36	0.01	0.00
311	H	0.59	0.29	0.12	0.00	0.00	0.58	0.32	0.10	0.00	0.00	0.05	0.58	0.36	0.01	0.00
Total	**H**	**0.69**	**0.23**	**0.08**	**0.00**	**0.00**	**0.68**	**0.25**	**0.07**	**0.00**	**0.00**	**0.08**	**0.59**	**0.32**	**0.01**	**0.00**
1 Story	**H**	**0.77**	**0.17**	**0.06**	**0.00**	**0.00**	**0.76**	**0.19**	**0.05**	**0.00**	**0.00**	**0.10**	**0.58**	**0.31**	**0.01**	**0.00**
2 Story	**H**	**0.79**	**0.16**	**0.05**	**0.00**	**0.00**	**0.77**	**0.19**	**0.04**	**0.00**	**0.00**	**0.09**	**0.60**	**0.31**	**0.01**	**0.00**
3+ Story	**H**	**0.64**	**0.26**	**0.10**	**0.00**	**0.00**	**0.63**	**0.29**	**0.09**	**0.00**	**0.00**	**0.07**	**0.60**	**0.32**	**0.01**	**0.00**
Liq Zone	**H**	**0.63**	**0.26**	**0.11**	**0.00**	**0.00**	**0.62**	**0.29**	**0.09**	**0.00**	**0.00**	**0.05**	**0.57**	**0.38**	**0.01**	**0.00**
Non-Liq Zone	**H**	**0.71**	**0.21**	**0.08**	**0.00**	**0.00**	**0.70**	**0.24**	**0.06**	**0.00**	**0.00**	**0.09**	**0.60**	**0.30**	**0.01**	**0.00**
Hist District	**H**	**0.67**	**0.28**	**0.11**	**0.00**	**0.00**	**0.66**	**0.31**	**0.09**	**0.00**	**0.00**	**0.06**	**0.58**	**0.34**	**0.01**	**0.00**
Non-Hist Dist	**H**	**0.70**	**0.21**	**0.07**	**0.00**	**0.00**	**0.69**	**0.23**	**0.06**	**0.00**	**0.00**	**0.08**	**0.60**	**0.31**	**0.01**	**0.00**



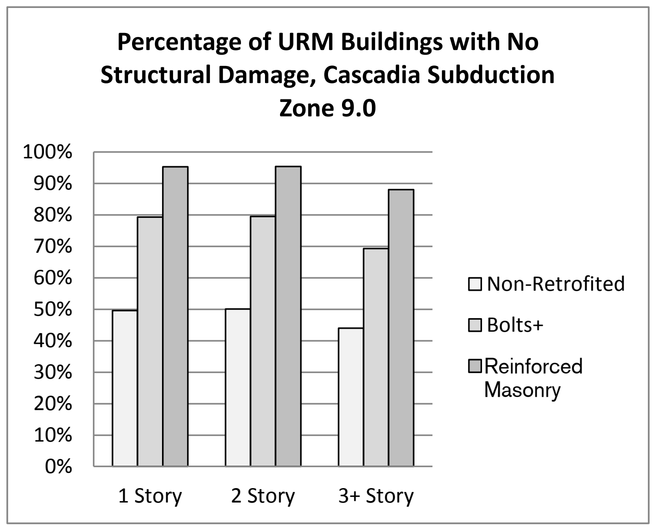
Percentage of URM Buildings Totally Destroyed, Nisqually Fault 6.8
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
1 Story
2 Story
3+ Story
Non-Retrofited
Bolts+



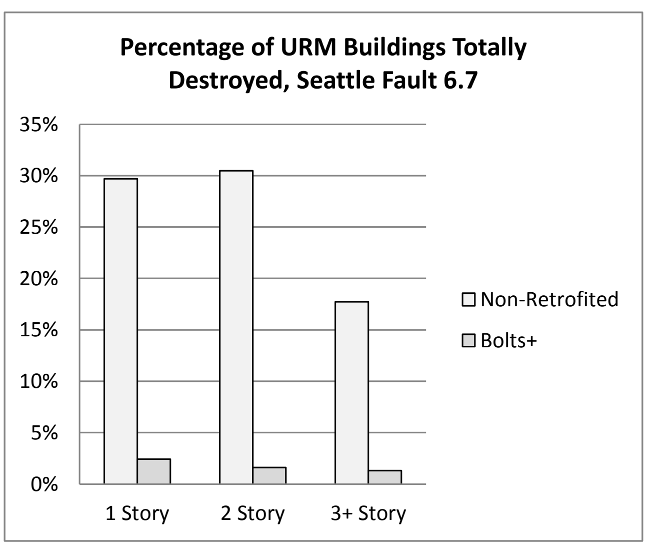
Percentage of URM Buildings with No Structural Damage, Nisqually Fault 6.8
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1 Story
2 Story
3+ Story
Non-Retrofited
Bolts+
Reinforced Masonry



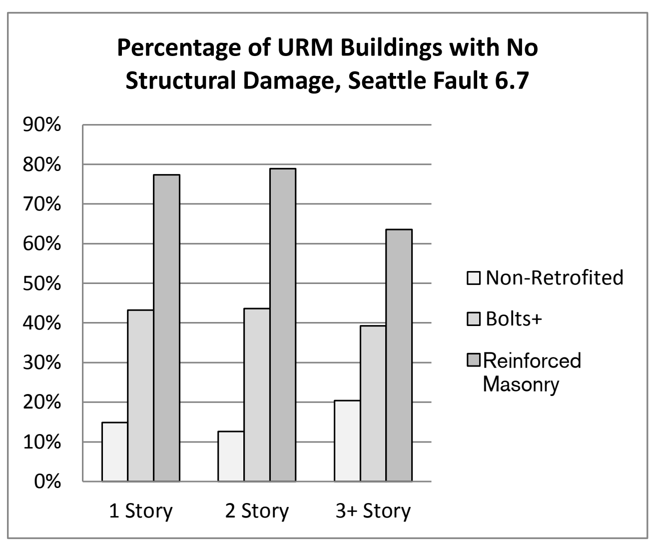
Percentage of URM Buildings Totally Destroyed, Cascadia Subduction Zone 9.0
5.0%
4.5%
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
1 Story
2 Story
3+ Story
Non-Retrofited
Bolts+



Percentage of URM Buildings with No Structural Damage, Cascadia Subduction Zone 9.0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1 Story
2 Story
3+ Story
Non-Retrofited
Bolts+
Reinforced Masonry



Percentage of URM Buildings Totally Destroyed, Seattle Fault 6.7
35%
30%
25%
20%
15%
10%
5%
0%
1 Story
2 Story
3+ Story
Non-Retrofited
Bolts+



Percentage of URM Buildings with No Structural Damage, Seattle Fault 6.7
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1 Story
2 Story
3+ Story
Non-Retrofited
Bolts+
Reinforced Masonry

Appendix 4.B. Economic Loss

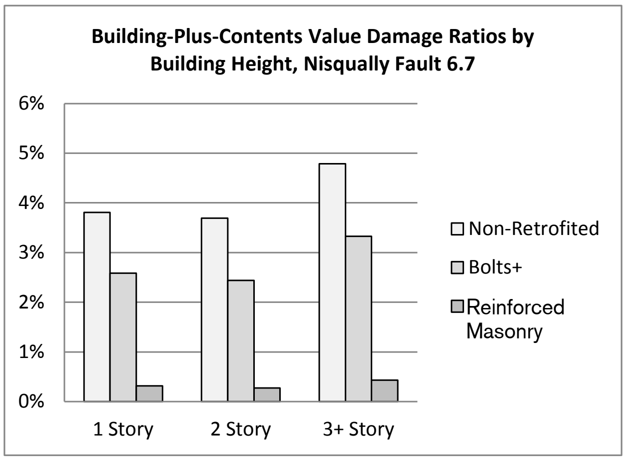
		Nisqually Fault Earthquake, Magnitude 6.8									
		Building ($000)				*Contents ($000)*			*Total ($000)*		
URM Subset		**Exposure**	**Damage-S**	**Damage-N**	**Ratio**	**Exposure**	**Damage-S**	**Ratio**	**Exposure**	**Damage**	**Ratio**
Non-Retrofited											
100	E	$89,327	$977	$2,408	3.79%	$44,663	$988	2.21%	$133,990	$4,373	3.26%
101	E	$7,246	$71	$114	2.55%	$3,623	$53	1.46%	$10,869	$238	2.19%
110	E	$11,166	$411	$780	10.67%	$5,583	$282	5.05%	$16,749	$1,473	8.79%
111	E	$9,777	$128	$360	4.99%	$4,888	$144	2.95%	$14,665	$632	4.31%
200	E	$227,650	$2,680	$5,210	3.47%	$113,825	$2,277	2.00%	$341,475	$10,167	2.98%
201	E	$31,935	$290	$582	2.73%	$15,967	$249	1.56%	$47,902	$1,121	2.34%
210	E	$88,774	$2,476	$3,873	7.15%	$44,387	$1,622	3.65%	$133,161	$7,971	5.99%
211	E	$2,628	$55	$82	5.21%	$1,314	$36	2.74%	$3,942	$173	4.39%
300	E	$923,176	$11,159	$38,353	5.36%	$461,588	$13,622	2.95%	$1,384,764	$63,134	4.56%
301	E	$48,365	$812	$2,569	6.99%	$24,182	$900	3.72%	$72,547	$4,281	5.90%
310	E	$74,813	$1,408	$3,823	6.99%	$37,406	$1,369	3.66%	$112,219	$6,600	5.88%
311	E	$214,189	$3,419	$9,531	6.05%	$107,095	$3,522	3.29%	$321,284	$16,472	5.13%
Total	**E**	**$1,729,046**	**$23,886**	**$67,685**	**5.30%**	**$864,521**	**$25,064**	**2.90%**	**$2,593,567**	**$116,635**	**4.50%**
Total, Adj	**E**	**$1,902,000**	**$26,300**	**$74,500**	**5.30%**	**$951,000**	**$27,600**	**2.90%**	**$2,852,900**	**$128,300**	**4.50%**
1 Story	**E**	**$117,516**	**$1,587**	**$3,662**	**4.47%**	**$58,757**	**$1,467**	**2.50%**	**$176,273**	**$6,716**	**3.81%**
2 Story	**E**	**$350,987**	**$5,501**	**$9,747**	**4.34%**	**$175,493**	**$4,184**	**2.38%**	**$526,480**	**$19,432**	**3.69%**
3+ Story	**E**	**$1,260,543**	**$16,798**	**$54,276**	**5.64%**	**$630,271**	**$19,413**	**3.08%**	**$1,890,814**	**$90,487**	**4.79%**
Liq Zone	**E**	**$401,347**	**$7,897**	**$18,449**	**6.56%**	**$200,673**	**$6,975**	**3.48%**	**$602,020**	**$33,321**	**5.53%**
Non-Liq Zone	**E**	**$1,327,699**	**$15,989**	**$49,236**	**4.91%**	**$663,848**	**$18,089**	**2.72%**	**$1,991,547**	**$83,314**	**4.18%**
Hist District	**E**	**$314,140**	**$4,775**	**$13,238**	**5.73%**	**$157,069**	**$4,904**	**3.12%**	**$471,209**	**$22,917**	**4.86%**
Non-Hist Dist	**E**	**$1,414,906**	**$19,111**	**$54,447**	**5.20%**	**$707,452**	**$20,160**	**2.85%**	**$2,122,358**	**$93,718**	**4.42%**
Bolts+											
100	B	$89,327	$109	$1,857	2.20%	$44,663	$1,107	2.48%	$133,990	$3,073	2.29%
101	B	$7,246	$8	$99	1.48%	$3,623	$58	1.60%	$10,869	$165	1.52%
110	B	$11,166	$37	$483	4.66%	$5,583	$255	4.57%	$16,749	$775	4.63%
111	B	$9,777	$15	$342	3.65%	$4,888	$187	3.83%	$14,665	$544	3.71%
200	B	$227,650	$301	$4,011	1.89%	$113,825	$2,478	2.18%	$341,475	$6,790	1.99%
201	B	$31,935	$32	$470	1.57%	$15,967	$274	1.72%	$47,902	$776	1.62%
210	B	$88,774	$264	$3,050	3.73%	$44,387	$1,847	4.16%	$133,161	$5,161	3.88%
211	B	$2,628	$7	$74	3.08%	$1,314	$45	3.42%	$3,942	$126	3.20%
300	B	$923,176	$1,618	$25,849	2.98%	$461,588	$14,247	3.09%	$1,384,764	$41,714	3.01%
301	B	$48,365	$125	$1,978	4.35%	$24,182	$1,055	4.36%	$72,547	$3,158	4.35%
310	B	$74,813	$215	$3,058	4.37%	$37,406	$1,601	4.28%	$112,219	$4,874	4.34%
311	B	$214,189	$566	$8,277	4.13%	$107,095	$4,332	4.05%	$321,284	$13,175	4.10%
Total	**B**	**$1,729,046**	**$3,297**	**$49,548**	**3.06%**	**$864,521**	**$27,486**	**3.18%**	**$2,593,567**	**$80,331**	**3.10%**
Total, Adj	**B**	**$1,902,000**	**$3,600**	**$54,500**	**3.05%**	**$951,000**	**$30,200**	**3.18%**	**$2,852,900**	**$88,400**	**3.10%**
1 Story	**B**	**$117,516**	**$169**	**$2,781**	**2.51%**	**$58,757**	**$1,607**	**2.73%**	**$176,273**	**$4,557**	**2.59%**
2 Story	**B**	**$350,987**	**$604**	**$7,605**	**2.34%**	**$175,493**	**$4,644**	**2.65%**	**$526,480**	**$12,853**	**2.44%**
3+ Story	**B**	**$1,260,543**	**$2,524**	**$39,162**	**3.31%**	**$630,271**	**$21,235**	**3.37%**	**$1,890,814**	**$62,921**	**3.33%**
Liq Zone	**B**	**$401,347**	**$1,104**	**$15,284**	**4.08%**	**$200,673**	**$8,267**	**4.12%**	**$602,020**	**$24,655**	**4.10%**
Non-Liq Zone	**B**	**$1,327,699**	**$2,193**	**$34,264**	**2.75%**	**$663,848**	**$19,219**	**2.90%**	**$1,991,547**	**$55,676**	**2.80%**
Hist District	**B**	**$314,140**	**$753**	**$11,240**	**3.82%**	**$157,069**	**$5,951**	**3.79%**	**$471,209**	**$17,944**	**3.81%**
Non-Hist Dist	**B**	**$1,414,906**	**$2,544**	**$38,308**	**2.89%**	**$707,452**	**$21,535**	**3.04%**	**$2,122,358**	**$62,387**	**2.94%**
Reinforced Masonry											
100	H	$89,327	$7	$214	0.25%	$44,663	$122	0.27%	$133,990	$343	0.26%
101	H	$7,246	$0	$8	0.11%	$3,623	$5	0.14%	$10,869	$13	0.12%
110	H	$11,166	$4	$88	0.82%	$5,583	$43	0.77%	$16,749	$135	0.81%
111	H	$9,777	$1	$42	0.44%	$4,888	$21	0.43%	$14,665	$64	0.44%
200	H	$227,650	$17	$374	0.17%	$113,825	$218	0.19%	$341,475	$609	0.18%
201	H	$31,935	$2	$42	0.14%	$15,967	$23	0.14%	$47,902	$67	0.14%
210	H	$88,774	$24	$460	0.55%	$44,387	$263	0.59%	$133,161	$747	0.56%
211	H	$2,628	$0	$8	0.30%	$1,314	$5	0.38%	$3,942	$13	0.33%
300	H	$923,176	$188	$3,482	0.40%	$461,588	$1,772	0.38%	$1,384,764	$5,442	0.39%
301	H	$48,365	$16	$281	0.61%	$24,182	$139	0.57%	$72,547	$436	0.60%
310	H	$74,813	$26	$429	0.61%	$37,406	$206	0.55%	$112,219	$661	0.59%
311	H	$214,189	$63	$1,067	0.53%	$107,095	$514	0.48%	$321,284	$1,644	0.51%
Total	**H**	**$1,729,046**	**$348**	**$6,495**	**0.40%**	**$864,521**	**$3,331**	**0.39%**	**$2,593,567**	**$10,174**	**0.39%**
Total, Adj	**H**	**$1,902,000**	**$400**	**$7,100**	**0.39%**	**$951,000**	**$3,700**	**0.39%**	**$2,852,900**	**$11,200**	**0.39%**
1 Story	**H**	**$117,516**	**$12**	**$352**	**0.31%**	**$58,757**	**$191**	**0.33%**	**$176,273**	**$555**	**0.31%**
2 Story	**H**	**$350,987**	**$43**	**$884**	**0.26%**	**$175,493**	**$509**	**0.29%**	**$526,480**	**$1,436**	**0.27%**
3+ Story	**H**	**$1,260,543**	**$293**	**$5,259**	**0.44%**	**$630,271**	**$2,631**	**0.42%**	**$1,890,814**	**$8,183**	**0.43%**
Liq Zone	**H**	**$401,347**	**$118**	**$2,094**	**0.55%**	**$200,673**	**$1,052**	**0.52%**	**$602,020**	**$3,264**	**0.54%**
Non-Liq Zone	**H**	**$1,327,699**	**$230**	**$4,401**	**0.35%**	**$663,848**	**$2,279**	**0.34%**	**$1,991,547**	**$6,910**	**0.35%**
Hist District	**H**	**$314,140**	**$82**	**$1,448**	**0.49%**	**$157,069**	**$707**	**0.45%**	**$471,209**	**$2,237**	**0.47%**
Non-Hist Dist	**H**	**$1,414,906**	**$266**	**$5,047**	**0.38%**	**$707,452**	**$2,624**	**0.37%**	**$2,122,358**	**$7,937**	**0.37%**

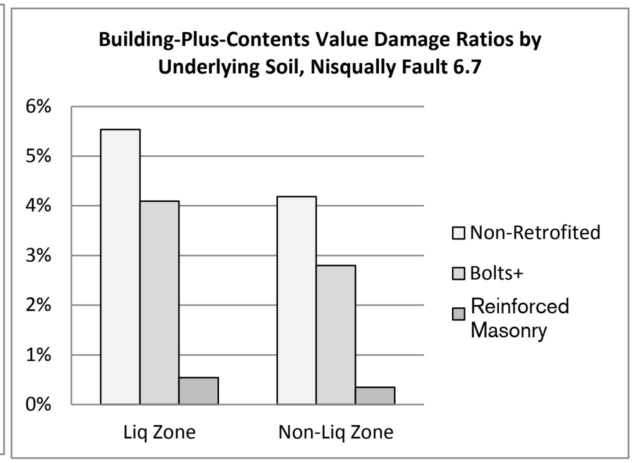
Appendix 4.B. Economic Loss

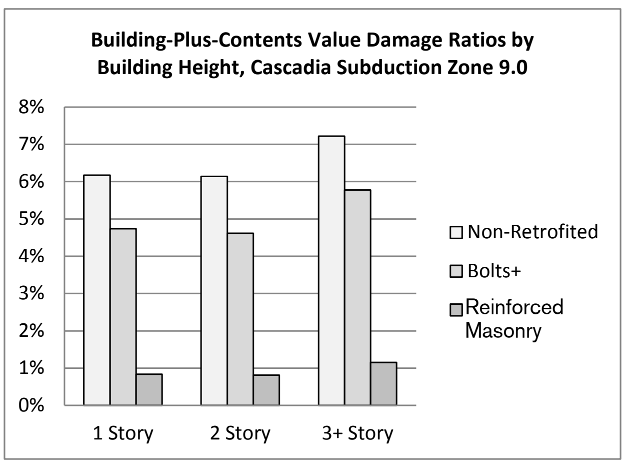
		Cascadia Subduction Zone Earthquake, Magnitude 9.0									
		Building ($000)				*Contents ($000)*			*Total ($000)*		
URM Subset		**Exposure**	**Damage-S**	**Damage-N**	**Ratio**	**Exposure**	**Damage-S**	**Ratio**	**Exposure**	**Damage**	**Ratio**
Non-Retrofited											
100	E	$89,327	$1,940	$4,382	7.08%	$44,663	$1,824	4.08%	$133,990	$8,146	6.08%
101	E	$7,246	$197	$339	7.40%	$3,623	$149	4.11%	$10,869	$685	6.30%
110	E	$11,166	$307	$609	8.20%	$5,583	$246	4.41%	$16,749	$1,162	6.94%
111	E	$9,777	$177	$515	7.08%	$4,888	$201	4.11%	$14,665	$893	6.09%
200	E	$227,650	$4,973	$10,764	6.91%	$113,825	$4,595	4.04%	$341,475	$20,332	5.95%
201	E	$31,935	$707	$1,585	7.18%	$15,967	$656	4.11%	$47,902	$2,948	6.15%
210	E	$88,774	$2,586	$4,321	7.78%	$44,387	$1,878	4.23%	$133,161	$8,785	6.60%
211	E	$2,628	$74	$122	7.46%	$1,314	$54	4.11%	$3,942	$250	6.34%
300	E	$923,176	$17,067	$60,057	8.35%	$461,588	$21,353	4.63%	$1,384,764	$98,477	7.11%
301	E	$48,365	$992	$3,226	8.72%	$24,182	$1,142	4.72%	$72,547	$5,360	7.39%
310	E	$74,813	$1,785	$5,077	9.17%	$37,406	$1,812	4.84%	$112,219	$8,674	7.73%
311	E	$214,189	$4,848	$14,074	8.83%	$107,095	$5,060	4.72%	$321,284	$23,982	7.46%
Total	**E**	**$1,729,046**	**$35,653**	**$105,071**	**8.14%**	**$864,521**	**$38,970**	**4.51%**	**$2,593,567**	**$179,694**	**6.93%**
Total, Adj	**E**	**$1,902,000**	**$39,200**	**$115,600**	**8.14%**	**$951,000**	**$42,900**	**4.51%**	**$2,852,900**	**$197,700**	**6.93%**
1 Story	**E**	**$117,516**	**$2,621**	**$5,845**	**7.20%**	**$58,757**	**$2,420**	**4.12%**	**$176,273**	**$10,886**	**6.18%**
2 Story	**E**	**$350,987**	**$8,340**	**$16,792**	**7.16%**	**$175,493**	**$7,183**	**4.09%**	**$526,480**	**$32,315**	**6.14%**
3+ Story	**E**	**$1,260,543**	**$24,692**	**$82,434**	**8.50%**	**$630,271**	**$29,367**	**4.66%**	**$1,890,814**	**$136,493**	**7.22%**
Liq Zone	**E**	**$401,347**	**$9,777**	**$24,718**	**8.59%**	**$200,673**	**$9,251**	**4.61%**	**$602,020**	**$43,746**	**7.27%**
Non-Liq Zone	**E**	**$1,327,699**	**$25,876**	**$80,353**	**8.00%**	**$663,848**	**$29,719**	**4.48%**	**$1,991,547**	**$135,948**	**6.83%**
Hist District	**E**	**$314,140**	**$6,995**	**$19,861**	**8.55%**	**$157,069**	**$7,262**	**4.62%**	**$471,209**	**$34,118**	**7.24%**
Non-Hist Dist	**E**	**$1,414,906**	**$28,658**	**$85,210**	**8.05%**	**$707,452**	**$31,708**	**4.48%**	**$2,122,358**	**$145,576**	**6.86%**
Bolts+											
100	B	$89,327	$237	$3,743	4.46%	$44,663	$2,274	5.09%	$133,990	$6,254	4.67%
101	B	$7,246	$24	$304	4.53%	$3,623	$185	5.11%	$10,869	$513	4.72%
110	B	$11,166	$36	$532	5.09%	$5,583	$288	5.16%	$16,749	$856	5.11%
111	B	$9,777	$21	$453	4.85%	$4,888	$249	5.09%	$14,665	$723	4.93%
200	B	$227,650	$609	$9,143	4.28%	$113,825	$5,780	5.08%	$341,475	$15,532	4.55%
201	B	$31,935	$86	$1,364	4.54%	$15,967	$815	5.10%	$47,902	$2,265	4.73%
210	B	$88,774	$307	$3,720	4.54%	$44,387	$2,273	5.12%	$133,161	$6,300	4.73%
211	B	$2,628	$9	$109	4.49%	$1,314	$67	5.10%	$3,942	$185	4.69%
300	B	$923,176	$3,073	$48,300	5.56%	$461,588	$27,379	5.93%	$1,384,764	$78,752	5.69%
301	B	$48,365	$173	$2,696	5.93%	$24,182	$1,437	5.94%	$72,547	$4,306	5.94%
310	B	$74,813	$297	$4,233	6.06%	$37,406	$2,223	5.94%	$112,219	$6,753	6.02%
311	B	$214,189	$841	$12,132	6.06%	$107,095	$6,365	5.94%	$321,284	$19,338	6.02%
Total	**B**	**$1,729,046**	**$5,713**	**$86,729**	**5.35%**	**$864,521**	**$49,335**	**5.71%**	**$2,593,567**	**$141,777**	**5.47%**
Total, Adj	**B**	**$1,902,000**	**$6,300**	**$95,400**	**5.35%**	**$951,000**	**$54,300**	**5.71%**	**$2,852,900**	**$156,000**	**5.47%**
1 Story	**B**	**$117,516**	**$318**	**$5,032**	**4.55%**	**$58,757**	**$2,996**	**5.10%**	**$176,273**	**$8,346**	**4.73%**
2 Story	**B**	**$350,987**	**$1,011**	**$14,336**	**4.37%**	**$175,493**	**$8,935**	**5.09%**	**$526,480**	**$24,282**	**4.61%**
3+ Story	**B**	**$1,260,543**	**$4,384**	**$67,361**	**5.69%**	**$630,271**	**$37,404**	**5.93%**	**$1,890,814**	**$109,149**	**5.77%**
Liq Zone	**B**	**$401,347**	**$1,511**	**$21,179**	**5.65%**	**$200,673**	**$11,465**	**5.71%**	**$602,020**	**$34,155**	**5.67%**
Non-Liq Zone	**B**	**$1,327,699**	**$4,202**	**$65,550**	**5.25%**	**$663,848**	**$37,870**	**5.70%**	**$1,991,547**	**$107,622**	**5.40%**
Hist District	**B**	**$314,140**	**$1,154**	**$17,058**	**5.80%**	**$157,069**	**$9,118**	**5.81%**	**$471,209**	**$27,330**	**5.80%**
Non-Hist Dist	**B**	**$1,414,906**	**$4,559**	**$69,671**	**5.25%**	**$707,452**	**$40,217**	**5.68%**	**$2,122,358**	**$114,447**	**5.39%**
Reinforced Masonry											
100	H	$89,327	$26	$685	0.80%	$44,663	$387	0.87%	$133,990	$1,098	0.82%
101	H	$7,246	$3	$56	0.81%	$3,623	$32	0.88%	$10,869	$91	0.84%
110	H	$11,166	$4	$104	0.97%	$5,583	$51	0.91%	$16,749	$159	0.95%
111	H	$9,777	$2	$86	0.90%	$4,888	$43	0.88%	$14,665	$131	0.89%
200	H	$227,650	$67	$1,672	0.76%	$113,825	$968	0.85%	$341,475	$2,707	0.79%
201	H	$31,935	$10	$251	0.82%	$15,967	$140	0.88%	$47,902	$401	0.84%
210	H	$88,774	$36	$698	0.83%	$44,387	$396	0.89%	$133,161	$1,130	0.85%
211	H	$2,628	$1	$20	0.80%	$1,314	$12	0.91%	$3,942	$33	0.84%
300	H	$923,176	$571	$9,910	1.14%	$461,588	$5,181	1.12%	$1,384,764	$15,662	1.13%
301	H	$48,365	$33	$561	1.23%	$24,182	$276	1.14%	$72,547	$870	1.20%
310	H	$74,813	$56	$887	1.26%	$37,406	$427	1.14%	$112,219	$1,370	1.22%
311	H	$214,189	$158	$2,542	1.26%	$107,095	$1,222	1.14%	$321,284	$3,922	1.22%
Total	**H**	**$1,729,046**	**$967**	**$17,472**	**1.07%**	**$864,521**	**$9,135**	**1.06%**	**$2,593,567**	**$27,574**	**1.06%**
Total, Adj	**H**	**$1,902,000**	**$1,100**	**$19,200**	**1.07%**	**$951,000**	**$10,000**	**1.05%**	**$2,852,900**	**$30,300**	**1.06%**
1 Story	**H**	**$117,516**	**$35**	**$931**	**0.82%**	**$58,757**	**$513**	**0.87%**	**$176,273**	**$1,479**	**0.84%**
2 Story	**H**	**$350,987**	**$114**	**$2,641**	**0.78%**	**$175,493**	**$1,516**	**0.86%**	**$526,480**	**$4,271**	**0.81%**
3+ Story	**H**	**$1,260,543**	**$818**	**$13,900**	**1.17%**	**$630,271**	**$7,106**	**1.13%**	**$1,890,814**	**$21,824**	**1.15%**
Liq Zone	**H**	**$401,347**	**$257**	**$4,337**	**1.14%**	**$200,673**	**$2,151**	**1.07%**	**$602,020**	**$6,745**	**1.12%**
Non-Liq Zone	**H**	**$1,327,699**	**$710**	**$13,135**	**1.04%**	**$663,848**	**$6,984**	**1.05%**	**$1,991,547**	**$20,829**	**1.05%**
Hist District	**H**	**$314,140**	**$207**	**$3,516**	**1.19%**	**$157,069**	**$1,725**	**1.10%**	**$471,209**	**$5,448**	**1.16%**
Non-Hist Dist	**H**	**$1,414,906**	**$760**	**$13,956**	**1.04%**	**$707,452**	**$7,410**	**1.05%**	**$2,122,358**	**$22,126**	**1.04%**

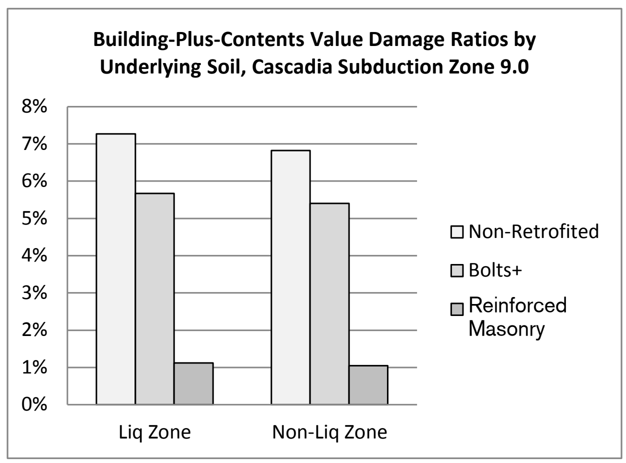
Appendix 4.B. Economic Loss

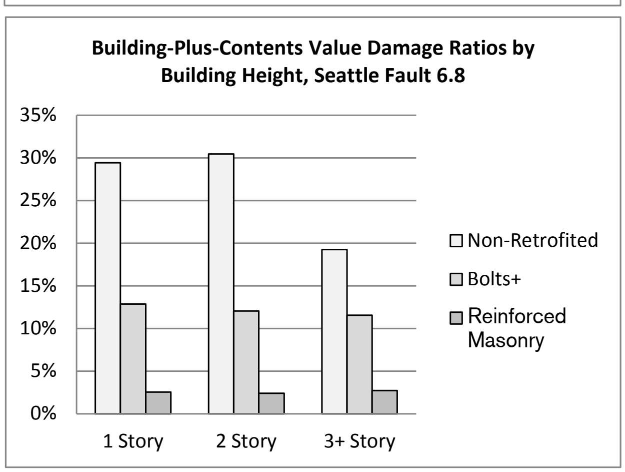
		Seattle Fault Earthquake, Magnitude 6.7									
		Building ($000)				*Contents ($000)*			*Total ($000)*		
URM Subset		**Exposure**	**Damage-S**	**Damage-N**	**Ratio**	**Exposure**	**Damage-S**	**Ratio**	**Exposure**	**Damage**	**Ratio**
Non-Retrofited											
100	E	$89,327	$7,498	$21,842	32.85%	$44,663	$6,846	15.33%	$133,990	$36,186	27.01%
101	E	$7,246	$806	$1,604	33.26%	$3,623	$568	15.68%	$10,869	$2,978	27.40%
110	E	$11,166	$1,692	$3,953	50.56%	$5,583	$1,320	23.64%	$16,749	$6,965	41.58%
111	E	$9,777	$1,055	$3,593	47.54%	$4,888	$1,093	22.36%	$14,665	$5,741	39.15%
200	E	$227,650	$21,749	$53,892	33.23%	$113,825	$17,494	15.37%	$341,475	$93,135	27.27%
201	E	$31,935	$2,590	$6,264	27.73%	$15,967	$2,079	13.02%	$47,902	$10,933	22.82%
210	E	$88,774	$15,045	$29,649	50.35%	$44,387	$10,223	23.03%	$133,161	$54,917	41.24%
211	E	$2,628	$407	$767	44.67%	$1,314	$267	20.32%	$3,942	$1,441	36.56%
300	E	$923,176	$39,601	$159,050	21.52%	$461,588	$48,798	10.57%	$1,384,764	$247,449	17.87%
301	E	$48,365	$2,839	$10,278	27.12%	$24,182	$3,114	12.88%	$72,547	$16,231	22.37%
310	E	$74,813	$4,893	$15,670	27.49%	$37,406	$4,903	13.11%	$112,219	$25,466	22.69%
311	E	$214,189	$14,284	$46,389	28.33%	$107,095	$14,343	13.39%	$321,284	$75,016	23.35%
Total	**E**	**$1,729,046**	**$112,459**	**$352,951**	**26.92%**	**$864,521**	**$111,048**	**12.85%**	**$2,593,567**	**$576,458**	**22.23%**
Total, Adj	**E**	**$1,902,000**	**$123,700**	**$388,200**	**26.91%**	**$951,000**	**$122,200**	**12.85%**	**$2,852,900**	**$634,100**	**22.23%**
1 Story	**E**	**$117,516**	**$11,051**	**$30,992**	**35.78%**	**$58,757**	**$9,827**	**16.72%**	**$176,273**	**$51,870**	**29.43%**
2 Story	**E**	**$350,987**	**$39,791**	**$90,572**	**37.14%**	**$175,493**	**$30,063**	**17.13%**	**$526,480**	**$160,426**	**30.47%**
3+ Story	**E**	**$1,260,543**	**$61,617**	**$231,387**	**23.24%**	**$630,271**	**$71,158**	**11.29%**	**$1,890,814**	**$364,162**	**19.26%**
Liq Zone	**E**	**$401,347**	**$37,376**	**$100,021**	**34.23%**	**$200,673**	**$32,149**	**16.02%**	**$602,020**	**$169,546**	**28.16%**
Non-Liq Zone	**E**	**$1,327,699**	**$75,083**	**$252,930**	**24.71%**	**$663,848**	**$78,899**	**11.89%**	**$1,991,547**	**$406,912**	**20.43%**
Hist District	**E**	**$314,140**	**$21,981**	**$68,895**	**28.93%**	**$157,069**	**$21,464**	**13.67%**	**$471,209**	**$112,340**	**23.84%**
Non-Hist Dist	**E**	**$1,414,906**	**$90,478**	**$284,056**	**26.47%**	**$707,452**	**$89,584**	**12.66%**	**$2,122,358**	**$464,118**	**21.87%**
Bolts+											
100	B	$89,327	$1,477	$9,751	12.57%	$44,663	$4,493	10.06%	$133,990	$15,721	11.73%
101	B	$7,246	$259	$889	15.84%	$3,623	$389	10.74%	$10,869	$1,537	14.14%
110	B	$11,166	$391	$1,738	19.07%	$5,583	$737	13.20%	$16,749	$2,866	17.11%
111	B	$9,777	$266	$1,642	19.52%	$4,888	$653	13.36%	$14,665	$2,561	17.46%
200	B	$227,650	$3,487	$22,169	11.27%	$113,825	$11,430	10.04%	$341,475	$37,086	10.86%
201	B	$31,935	$532	$2,899	10.74%	$15,967	$1,424	8.92%	$47,902	$4,855	10.14%
210	B	$88,774	$3,264	$12,170	17.39%	$44,387	$5,630	12.68%	$133,161	$21,064	15.82%
211	B	$2,628	$62	$294	13.55%	$1,314	$151	11.49%	$3,942	$507	12.86%
300	B	$923,176	$10,282	$97,070	11.63%	$461,588	$44,538	9.65%	$1,384,764	$151,890	10.97%
301	B	$48,365	$773	$5,958	13.92%	$24,182	$2,507	10.37%	$72,547	$9,238	12.73%
310	B	$74,813	$1,329	$9,401	14.34%	$37,406	$4,007	10.71%	$112,219	$14,737	13.13%
311	B	$214,189	$3,913	$27,091	14.48%	$107,095	$11,339	10.59%	$321,284	$42,343	13.18%
Total	**B**	**$1,729,046**	**$26,035**	**$191,072**	**12.56%**	**$864,521**	**$87,298**	**10.10%**	**$2,593,567**	**$304,405**	**11.74%**
Total, Adj	**B**	**$1,902,000**	**$28,600**	**$210,200**	**12.56%**	**$951,000**	**$96,000**	**10.09%**	**$2,852,900**	**$334,800**	**11.74%**
1 Story	**B**	**$117,516**	**$2,393**	**$14,020**	**13.97%**	**$58,757**	**$6,272**	**10.67%**	**$176,273**	**$22,685**	**12.87%**
2 Story	**B**	**$350,987**	**$7,345**	**$37,532**	**12.79%**	**$175,493**	**$18,635**	**10.62%**	**$526,480**	**$63,512**	**12.06%**
3+ Story	**B**	**$1,260,543**	**$16,297**	**$139,520**	**12.36%**	**$630,271**	**$62,391**	**9.90%**	**$1,890,814**	**$218,208**	**11.54%**
Liq Zone	**B**	**$401,347**	**$9,225**	**$52,336**	**15.34%**	**$200,673**	**$22,517**	**11.22%**	**$602,020**	**$84,078**	**13.97%**
Non-Liq Zone	**B**	**$1,327,699**	**$16,810**	**$138,736**	**11.72%**	**$663,848**	**$64,781**	**9.76%**	**$1,991,547**	**$220,327**	**11.06%**
Hist District	**B**	**$314,140**	**$5,805**	**$38,773**	**14.19%**	**$157,069**	**$16,463**	**10.48%**	**$471,209**	**$61,041**	**12.95%**
Non-Hist Dist	**B**	**$1,414,906**	**$20,230**	**$152,299**	**12.19%**	**$707,452**	**$70,835**	**10.01%**	**$2,122,358**	**$243,364**	**11.47%**
Reinforced Masonry											
100	H	$89,327	$157	$1,880	2.28%	$44,663	$1,020	2.28%	$133,990	$3,057	2.28%
101	H	$7,246	$25	$177	2.79%	$3,623	$96	2.65%	$10,869	$298	2.74%
110	H	$11,166	$36	$379	3.72%	$5,583	$177	3.17%	$16,749	$592	3.53%
111	H	$9,777	$24	$327	3.59%	$4,888	$160	3.27%	$14,665	$511	3.48%
200	H	$227,650	$389	$4,537	2.16%	$113,825	$2,548	2.24%	$341,475	$7,474	2.19%
201	H	$31,935	$56	$590	2.02%	$15,967	$317	1.99%	$47,902	$963	2.01%
210	H	$88,774	$301	$2,461	3.11%	$44,387	$1,332	3.00%	$133,161	$4,094	3.07%
211	H	$2,628	$7	$63	2.66%	$1,314	$34	2.59%	$3,942	$104	2.64%
300	H	$923,176	$2,276	$22,814	2.72%	$461,588	$10,899	2.36%	$1,384,764	$35,989	2.60%
301	H	$48,365	$154	$1,383	3.18%	$24,182	$622	2.57%	$72,547	$2,159	2.98%
310	H	$74,813	$270	$2,245	3.36%	$37,406	$1,003	2.68%	$112,219	$3,518	3.13%
311	H	$214,189	$761	$6,355	3.32%	$107,095	$2,820	2.63%	$321,284	$9,936	3.09%
Total	**H**	**$1,729,046**	**$4,456**	**$43,211**	**2.76%**	**$864,521**	**$21,028**	**2.43%**	**$2,593,567**	**$68,695**	**2.65%**
Total, Adj	**H**	**$1,902,000**	**$4,900**	**$47,500**	**2.75%**	**$951,000**	**$23,100**	**2.43%**	**$2,852,900**	**$75,600**	**2.65%**
1 Story	**H**	**$117,516**	**$242**	**$2,763**	**2.56%**	**$58,757**	**$1,453**	**2.47%**	**$176,273**	**$4,458**	**2.53%**
2 Story	**H**	**$350,987**	**$753**	**$7,651**	**2.39%**	**$175,493**	**$4,231**	**2.41%**	**$526,480**	**$12,635**	**2.40%**
3+ Story	**H**	**$1,260,543**	**$3,461**	**$32,797**	**2.88%**	**$630,271**	**$15,344**	**2.43%**	**$1,890,814**	**$51,602**	**2.73%**
Liq Zone	**H**	**$401,347**	**$1,399**	**$11,830**	**3.30%**	**$200,673**	**$5,526**	**2.75%**	**$602,020**	**$18,755**	**3.12%**
Non-Liq Zone	**H**	**$1,327,699**	**$3,057**	**$31,381**	**2.59%**	**$663,848**	**$15,502**	**2.34%**	**$1,991,547**	**$49,940**	**2.51%**
Hist District	**H**	**$314,140**	**$1,027**	**$8,895**	**3.16%**	**$157,069**	**$4,049**	**2.58%**	**$471,209**	**$13,971**	**2.96%**
Non-Hist Dist	**H**	**$1,414,906**	**$3,429**	**$34,316**	**2.67%**	**$707,452**	**$16,979**	**2.40%**	**$2,122,358**	**$54,724**	**2.58%**

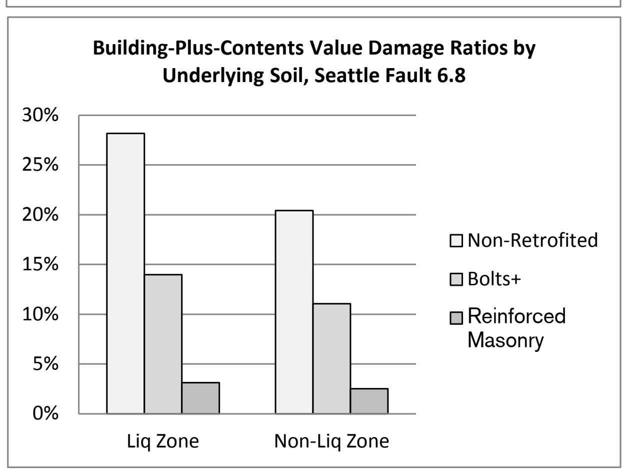

Building-Plus-Contents Value Damage Ratios by Building Height, Nisqually Fault 6.7
6%
5%
4%
3%
2%
1%
0%
1 Story
2 Story
3+ Story
Non-Retrofited
Bolts+
Reinforced Masonry


Building-Plus-Contents Value Damage Ratios by Underlying Soil, Nisqually Fault 6.7
6%
5%
4%
3%
2%
1%
0%
Liq Zone
Non-Liq Zone
Non-Retrofited
Bolts+
Reinforced Masonry


Building-Plus-Contents Value Damage Ratios by Building Height, Cascadia Subduction Zone 9.0
8%
7%
6%
5%
4%
3%
2%
1%
0%
1 Story
2 Story
3+ Story
Non-Retrofited
Bolts+
Reinforced Masonry


Building-Plus-Contents Value Damage Ratios by Underlying Soil, Cascadia Subduction Zone 9.0
8%
7%
6%
5%
4%
3%
2%
1%
0%
Liq Zone
Non-Liq Zone
Non-Retrofited
Bolts+
Reinforced Masonry


Building-Plus-Contents Value Damage Ratios by Building Height, Seattle Fault 6.8
35%
30%
25%
20%
15%
10%
5%
0%
1 Story
2 Story
3+ Story
Non-Retrofited
Bolts+
Reinforced Masonry


Building-Plus-Contents Value Damage Ratios by Underlying Soil, Seattle Fault 6.8
30%
25%
20%
15%
10%
5%
0%
Liq Zone
Non-Liq Zone
Non-Retrofited
Bolts+
Reinforced Masonry

		Nisqually Fault Earthquake, Magnitude 6.8											
		Day Time Scenario						*Night Time Scenario*					
URM Subset		**Exposed**	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Deaths/000**	**Exposed**	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Deaths/000**
Non-Retrofited													
100	E	2592	9	2	0	1	**0.39**	125	1	0	0	0	**0.00**
101	E	182	0	0	0	0	**0.00**	11	0	0	0	0	**0.00**
110	E	292	4	1	0	0	**0.00**	83	1	0	0	0	**0.00**
111	E	207	1	0	0	0	**0.00**	0	0	0	0	0	**0.00**
200	E	5715	19	5	1	1	**0.17**	572	1	0	0	0	**0.00**
201	E	226	1	0	0	0	**0.00**	148	0	0	0	0	**0.00**
210	E	875	7	2	0	0	**0.00**	73	0	0	0	0	**0.00**
211	E	106	1	0	0	0	**0.00**	0	0	0	0	0	**0.00**
300	E	12279	55	13	2	4	**0.33**	10297	64	16	2	5	**0.49**
301	E	2291	23	6	1	2	**0.87**	857	8	2	0	1	**1.17**
310	E	1098	8	2	0	1	**0.91**	122	1	0	0	0	**0.00**
311	E	1898	13	3	0	1	**0.53**	638	4	1	0	0	**0.00**
Total	**E**	**27761**	**141**	**34**	**4**	**10**	**0.36**	**12926**	**80**	**19**	**2**	**6**	**0.46**
1 Story	**E**	**3273**	**14**	**3**	**0**	**1**	**0.31**	**219**	**2**	**0**	**0**	**0**	**0.00**
2 Story	**E**	**6922**	**28**	**7**	**1**	**1**	**0.14**	**793**	**1**	**0**	**0**	**0**	**0.00**
3+ Story	**E**	**17566**	**99**	**24**	**3**	**8**	**0.46**	**11914**	**77**	**19**	**2**	**6**	**0.50**
Liq Zone	**E**	**4476**	**34**	**8**	**0**	**2**	**0.45**	**916**	**6**	**1**	**0**	**0**	**0.00**
Non-Liq Zone	**E**	**23285**	**107**	**26**	**4**	**8**	**0.34**	**12010**	**74**	**18**	**2**	**6**	**0.50**
Hist District	**E**	**4910**	**39**	**9**	**1**	**3**	**0.61**	**1654**	**12**	**3**	**0**	**1**	**0.60**
Non-Hist Dist	**E**	**22851**	**102**	**25**	**3**	**7**	**0.31**	**11272**	**68**	**16**	**2**	**5**	**0.44**
Bolts+													
100	B	2592	1	0	0	0	**0.00**	125	0	0	0	0	**0.00**
101	B	182	0	0	0	0	**0.00**	11	0	0	0	0	**0.00**
110	B	292	0	0	0	0	**0.00**	83	0	0	0	0	**0.00**
111	B	207	0	0	0	0	**0.00**	0	0	0	0	0	**0.00**
200	B	5715	1	0	0	0	**0.00**	572	0	0	0	0	**0.00**
201	B	226	0	0	0	0	**0.00**	148	0	0	0	0	**0.00**
210	B	875	0	0	0	0	**0.00**	73	0	0	0	0	**0.00**
211	B	106	0	0	0	0	**0.00**	0	0	0	0	0	**0.00**
300	B	12279	4	0	0	0	**0.00**	10297	5	1	0	0	**0.00**
301	B	2291	2	0	0	0	**0.00**	857	1	0	0	0	**0.00**
310	B	1098	1	0	0	0	**0.00**	122	0	0	0	0	**0.00**
311	B	1898	1	0	0	0	**0.00**	638	0	0	0	0	**0.00**
Total	**B**	**27761**	**10**	**0**	**0**	**0**	**0.00**	**12926**	**6**	**1**	**0**	**0**	**0.00**
1 Story	**B**	**3273**	**1**	**0**	**0**	**0**	**0.00**	**219**	**0**	**0**	**0**	**0**	**0.00**
2 Story	**B**	**6922**	**1**	**0**	**0**	**0**	**0.00**	**793**	**0**	**0**	**0**	**0**	**0.00**
3+ Story	**B**	**17566**	**8**	**0**	**0**	**0**	**0.00**	**11914**	**6**	**1**	**0**	**0**	**0.00**
Liq Zone	**B**	**4476**	**2**	**0**	**0**	**0**	**0.00**	**916**	**0**	**0**	**0**	**0**	**0.00**
Non-Liq Zone	**B**	**23285**	**8**	**0**	**0**	**0**	**0.00**	**12010**	**6**	**1**	**0**	**0**	**0.00**
Hist District	**B**	**4910**	**3**	**0**	**0**	**0**	**0.00**	**1654**	**1**	**0**	**0**	**0**	**0.00**
Non-Hist Dist	**B**	**22851**	**7**	**0**	**0**	**0**	**0.00**	**11272**	**5**	**1**	**0**	**0**	**0.00**
Reinforced Masonry													
100	H	2592	0	0	0	0	**0.00**	125	0	0	0	0	**0.00**
101	H	182	0	0	0	0	**0.00**	11	0	0	0	0	**0.00**
110	H	292	0	0	0	0	**0.00**	83	0	0	0	0	**0.00**
111	H	207	0	0	0	0	**0.00**	0	0	0	0	0	**0.00**
200	H	5715	0	0	0	0	**0.00**	572	0	0	0	0	**0.00**
201	H	226	0	0	0	0	**0.00**	148	0	0	0	0	**0.00**
210	H	875	0	0	0	0	**0.00**	73	0	0	0	0	**0.00**
211	H	106	0	0	0	0	**0.00**	0	0	0	0	0	**0.00**
300	H	12279	0	0	0	0	**0.00**	10297	0	0	0	0	**0.00**
301	H	2291	0	0	0	0	**0.00**	857	0	0	0	0	**0.00**
310	H	1098	0	0	0	0	**0.00**	122	0	0	0	0	**0.00**
311	H	1898	0	0	0	0	**0.00**	638	0	0	0	0	**0.00**
Total	**H**	**27761**	**0**	**0**	**0**	**0**	**0.00**	**12926**	**0**	**0**	**0**	**0**	**0.00**
1 Story	**H**	**3273**	**0**	**0**	**0**	**0**	**0.00**	**219**	**0**	**0**	**0**	**0**	**0.00**
2 Story	**H**	**6922**	**0**	**0**	**0**	**0**	**0.00**	**793**	**0**	**0**	**0**	**0**	**0.00**
3+ Story	**H**	**17566**	**0**	**0**	**0**	**0**	**0.00**	**11914**	**0**	**0**	**0**	**0**	**0.00**
Liq Zone	**H**	**4476**	**0**	**0**	**0**	**0**	**0.00**	**916**	**0**	**0**	**0**	**0**	**0.00**
Non-Liq Zone	**H**	**23285**	**0**	**0**	**0**	**0**	**0.00**	**12010**	**0**	**0**	**0**	**0**	**0.00**
Hist District	**H**	**4910**	**0**	**0**	**0**	**0**	**0.00**	**1654**	**0**	**0**	**0**	**0**	**0.00**
Non-Hist Dist	**H**	**22851**	**0**	**0**	**0**	**0**	**0.00**	**11272**	**0**	**0**	**0**	**0**	**0.00**

Level 1: Medical Care **Level 2:** Hospitalization **Level 3:** Life-Threatening **Level 4:** Death

Cascadia Subduction Zone Earthquake, Magnitude 9.0

Appendix 4.C. Casualties

URM Subset		*Day Time Scenario* Exposed	Level 1	Level 2	Level 3	Level 4	Deaths/000	*Night Time Scenario* Exposed	Level 1	Level 2	Level 3	Level 4	Deaths/000
Non-Retrofited													
100	E	2592	18	5	1	1	**0.39**	125	1	0	0	0	**0.00**
101	E	182	1	0	0	0	**0.00**	11	0	0	0	0	**0.00**
110	E	292	2	1	0	0	**0.00**	83	1	0	0	0	**0.00**
111	E	207	2	0	0	0	**0.00**	0	0	0	0	0	**0.00**
200	E	5715	39	10	1	3	**0.52**	572	4	1	0	0	**0.00**
201	E	226	2	0	0	0	**0.00**	148	1	0	0	0	**0.00**
210	E	875	7	2	0	1	**1.14**	73	1	0	0	0	**0.00**
211	E	106	1	0	0	0	**0.00**	0	0	0	0	0	**0.00**
300	E	12279	107	27	4	8	**0.65**	10297	97	25	4	7	**0.68**
301	E	2291	22	6	1	2	**0.87**	857	8	2	0	1	**1.17**
310	E	1098	11	3	0	1	**0.91**	122	1	0	0	0	**0.00**
311	E	1898	19	5	1	1	**0.53**	638	6	2	0	0	**0.00**
Total	**E**	**27761**	**231**	**59**	**8**	**17**	**0.61**	**12926**	**120**	**30**	**4**	**8**	**0.62**
1 Story	**E**	**3273**	**23**	**6**	**1**	**1**	**0.31**	**219**	**2**	**0**	**0**	**0**	**0.00**
2 Story	**E**	**6922**	**49**	**12**	**1**	**4**	**0.58**	**793**	**6**	**1**	**0**	**0**	**0.00**
3+ Story	**E**	**17566**	**159**	**41**	**6**	**12**	**0.68**	**11914**	**112**	**29**	**4**	**8**	**0.67**
Liq Zone	**E**	**4476**	**42**	**11**	**1**	**3**	**0.67**	**916**	**9**	**2**	**0**	**0**	**0.00**
Non-Liq Zone	**E**	**23285**	**189**	**48**	**7**	**14**	**0.60**	**12010**	**111**	**28**	**4**	**8**	**0.67**
Hist District	**E**	**4910**	**47**	**11**	**2**	**3**	**0.61**	**1654**	**15**	**4**	**0**	**1**	**0.60**
Non-Hist Dist	**E**	**22851**	**184**	**48**	**6**	**14**	**0.61**	**11272**	**105**	**26**	**4**	**7**	**0.62**
Bolts+													
100	B	2592	1	0	0	0	**0.00**	125	0	0	0	0	**0.00**
101	B	182	0	0	0	0	**0.00**	11	0	0	0	0	**0.00**
110	B	292	0	0	0	0	**0.00**	83	0	0	0	0	**0.00**
111	B	207	0	0	0	0	**0.00**	0	0	0	0	0	**0.00**
200	B	5715	2	0	0	0	**0.00**	572	0	0	0	0	**0.00**
201	B	226	0	0	0	0	**0.00**	148	0	0	0	0	**0.00**
210	B	875	0	0	0	0	**0.00**	73	0	0	0	0	**0.00**
211	B	106	0	0	0	0	**0.00**	0	0	0	0	0	**0.00**
300	B	12279	10	1	0	0	**0.00**	10297	9	1	0	0	**0.00**
301	B	2291	2	0	0	0	**0.00**	857	1	0	0	0	**0.00**
310	B	1098	1	0	0	0	**0.00**	122	0	0	0	0	**0.00**
311	B	1898	2	0	0	0	**0.00**	638	1	0	0	0	**0.00**
Total	**B**	**27761**	**18**	**1**	**0**	**0**	**0.00**	**12926**	**11**	**1**	**0**	**0**	**0.00**
1 Story	**B**	**3273**	**1**	**0**	**0**	**0**	**0.00**	**219**	**0**	**0**	**0**	**0**	**0.00**
2 Story	**B**	**6922**	**2**	**0**	**0**	**0**	**0.00**	**793**	**0**	**0**	**0**	**0**	**0.00**
3+ Story	**B**	**17566**	**15**	**1**	**0**	**0**	**0.00**	**11914**	**11**	**1**	**0**	**0**	**0.00**
Liq Zone	**B**	**4476**	**3**	**0**	**0**	**0**	**0.00**	**916**	**1**	**0**	**0**	**0**	**0.00**
Non-Liq Zone	**B**	**23285**	**15**	**1**	**0**	**0**	**0.00**	**12010**	**10**	**1**	**0**	**0**	**0.00**
Hist District	**B**	**4910**	**4**	**0**	**0**	**0**	**0.00**	**1654**	**2**	**0**	**0**	**0**	**0.00**
Non-Hist Dist	**B**	**22851**	**14**	**1**	**0**	**0**	**0.00**	**11272**	**9**	**1**	**0**	**0**	**0.00**
Reinforced Masonry													
100	H	2592	0	0	0	0	**0.00**	125	0	0	0	0	**0.00**
101	H	182	0	0	0	0	**0.00**	11	0	0	0	0	**0.00**
110	H	292	0	0	0	0	**0.00**	83	0	0	0	0	**0.00**
111	H	207	0	0	0	0	**0.00**	0	0	0	0	0	**0.00**
200	H	5715	0	0	0	0	**0.00**	572	0	0	0	0	**0.00**
201	H	226	0	0	0	0	**0.00**	148	0	0	0	0	**0.00**
210	H	875	0	0	0	0	**0.00**	73	0	0	0	0	**0.00**
211	H	106	0	0	0	0	**0.00**	0	0	0	0	0	**0.00**
300	H	12279	1	0	0	0	**0.00**	10297	1	0	0	0	**0.00**
301	H	2291	0	0	0	0	**0.00**	857	0	0	0	0	**0.00**
310	H	1098	0	0	0	0	**0.00**	122	0	0	0	0	**0.00**
311	H	1898	0	0	0	0	**0.00**	638	0	0	0	0	**0.00**
Total	**H**	**27761**	**1**	**0**	**0**	**0**	**0.00**	**12926**	**1**	**0**	**0**	**0**	**0.00**
1 Story	**H**	**3273**	**0**	**0**	**0**	**0**	**0.00**	**219**	**0**	**0**	**0**	**0**	**0.00**
2 Story	**H**	**6922**	**0**	**0**	**0**	**0**	**0.00**	**793**	**0**	**0**	**0**	**0**	**0.00**
3+ Story	**H**	**17566**	**1**	**0**	**0**	**0**	**0.00**	**11914**	**1**	**0**	**0**	**0**	**0.00**
Liq Zone	**H**	**4476**	**0**	**0**	**0**	**0**	**0.00**	**916**	**0**	**0**	**0**	**0**	**0.00**
Non-Liq Zone	**H**	**23285**	**1**	**0**	**0**	**0**	**0.00**	**12010**	**1**	**0**	**0**	**0**	**0.00**
Hist District	**H**	**4910**	**0**	**0**	**0**	**0**	**0.00**	**1654**	**0**	**0**	**0**	**0**	**0.00**
Non-Hist Dist	**H**	**22851**	**1**	**0**	**0**	**0**	**0.00**	**11272**	**1**	**0**	**0**	**0**	**0.00**

Level 1: Medical Care **Level 2:** Hospitalization **Level 3:** Life-Threatening **Level 4:** Death

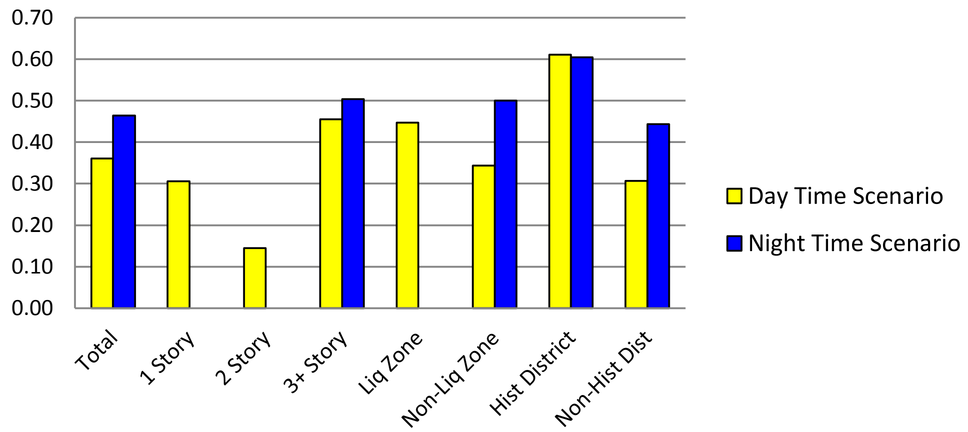
Seattle Fault Earthquake, Magnitude 6.7	
Day Time Scenario	*Night Time Scenario*

Appendix 4.C. Casualties

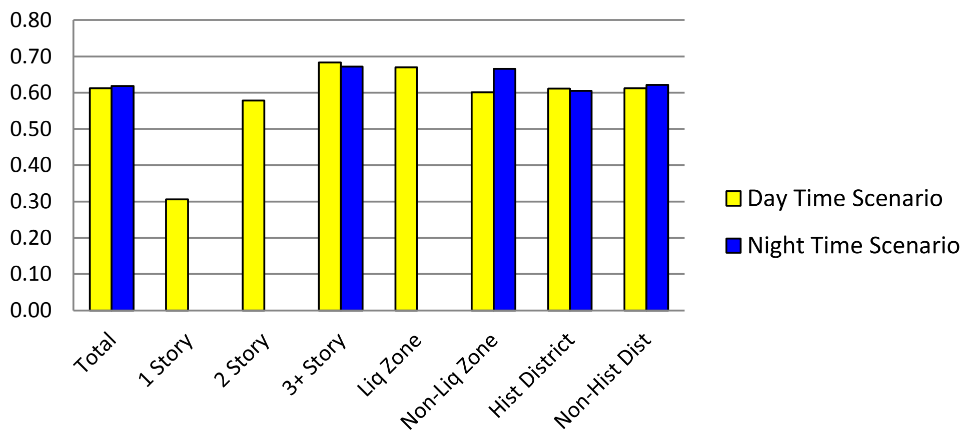
URM Subset		Exposed	Level 1	Level 2	Level 3	Level 4	Deaths/000	Exposed	Level 1	Level 2	Level 3	Level 4	Deaths/000
Non-Retrofited													
100	E	2592	112	33	6	10	**3.86**	125	7	2	0	1	**8.00**
101	E	182	7	2	0	1	**5.49**	11	1	0	0	0	**0.00**
110	E	292	20	6	1	2	**6.85**	83	6	2	0	1	**12.05**
111	E	207	16	5	1	2	**9.66**	0	0	0	0	0	**0.00**
200	E	5715	252	75	12	23	**4.02**	572	20	6	1	2	**3.50**
201	E	226	9	3	0	1	**4.42**	148	4	1	0	0	**0.00**
210	E	875	63	19	3	6	**6.86**	73	4	1	0	0	**0.00**
211	E	106	6	2	0	1	**9.43**	0	0	0	0	0	**0.00**
300	E	12279	269	76	12	23	**1.87**	10297	287	82	13	25	**2.43**
301	E	2291	76	22	3	7	**3.06**	857	28	8	1	2	**2.33**
310	E	1098	39	11	2	4	**3.64**	122	5	1	0	0	**0.00**
311	E	1898	71	21	3	6	**3.16**	638	24	7	1	2	**3.13**
Total	**E**	**27761**	**940**	**275**	**43**	**86**	**3.10**	**12926**	**386**	**110**	**16**	**33**	**2.55**
1 Story	**E**	**3273**	**155**	**46**	**8**	**15**	**4.58**	**219**	**14**	**4**	**0**	**2**	**9.13**
2 Story	**E**	**6922**	**330**	**99**	**15**	**31**	**4.48**	**793**	**28**	**8**	**1**	**2**	**2.52**
3+ Story	**E**	**17566**	**455**	**130**	**20**	**40**	**2.28**	**11914**	**344**	**98**	**15**	**29**	**2.43**
Liq Zone	**E**	**4476**	**215**	**64**	**10**	**21**	**4.69**	**916**	**39**	**11**	**1**	**3**	**3.28**
Non-Liq Zone	**E**	**23285**	**725**	**211**	**33**	**65**	**2.79**	**12010**	**347**	**99**	**15**	**30**	**2.50**
Hist District	**E**	**4910**	**185**	**55**	**7**	**18**	**3.67**	**1654**	**57**	**16**	**2**	**4**	**2.42**
Non-Hist Dist	**E**	**22851**	**755**	**220**	**36**	**68**	**2.98**	**11272**	**329**	**94**	**14**	**29**	**2.57**
Bolts+													
100	B	2592	11	3	0	1	**0.39**	125	0	0	0	0	**0.00**
101	B	182	1	0	0	0	**0.00**	11	0	0	0	0	**0.00**
110	B	292	4	1	0	0	**0.00**	83	1	0	0	0	**0.00**
111	B	207	4	1	0	0	**0.00**	0	0	0	0	0	**0.00**
200	B	5715	20	4	0	1	**0.17**	572	1	0	0	0	**0.00**
201	B	226	1	0	0	0	**0.00**	148	0	0	0	0	**0.00**
210	B	875	9	2	0	1	**1.14**	73	1	0	0	0	**0.00**
211	B	106	0	0	0	0	**0.00**	0	0	0	0	0	**0.00**
300	B	12279	36	7	1	2	**0.16**	10297	39	7	1	2	**0.19**
301	B	2291	11	2	0	0	**0.00**	857	4	1	0	0	**0.00**
310	B	1098	6	1	0	0	**0.00**	122	1	0	0	0	**0.00**
311	B	1898	11	2	0	1	**0.53**	638	4	1	0	0	**0.00**
Total	**B**	**27761**	**114**	**23**	**1**	**6**	**0.22**	**12926**	**51**	**9**	**1**	**2**	**0.15**
1 Story	**B**	**3273**	**20**	**5**	**0**	**1**	**0.31**	**219**	**1**	**0**	**0**	**0**	**0.00**
2 Story	**B**	**6922**	**30**	**6**	**0**	**2**	**0.29**	**793**	**2**	**0**	**0**	**0**	**0.00**
3+ Story	**B**	**17566**	**64**	**12**	**1**	**3**	**0.17**	**11914**	**48**	**9**	**1**	**2**	**0.17**
Liq Zone	**B**	**4476**	**34**	**7**	**0**	**2**	**0.45**	**916**	**7**	**1**	**0**	**0**	**0.00**
Non-Liq Zone	**B**	**23285**	**80**	**16**	**1**	**4**	**0.17**	**12010**	**44**	**8**	**1**	**2**	**0.17**
Hist District	**B**	**4910**	**28**	**5**	**0**	**1**	**0.20**	**1654**	**8**	**2**	**0**	**0**	**0.00**
Non-Hist Dist	**B**	**22851**	**86**	**18**	**1**	**5**	**0.22**	**11272**	**43**	**7**	**1**	**2**	**0.18**
Reinforced Masonry													
100	H	2592	0	0	0	0	**0.00**	125	0	0	0	0	**0.00**
101	H	182	0	0	0	0	**0.00**	11	0	0	0	0	**0.00**
110	H	292	0	0	0	0	**0.00**	83	0	0	0	0	**0.00**
111	H	207	0	0	0	0	**0.00**	0	0	0	0	0	**0.00**
200	H	5715	1	0	0	0	**0.00**	572	0	0	0	0	**0.00**
201	H	226	0	0	0	0	**0.00**	148	0	0	0	0	**0.00**
210	H	875	0	0	0	0	**0.00**	73	0	0	0	0	**0.00**
211	H	106	0	0	0	0	**0.00**	0	0	0	0	0	**0.00**
300	H	12279	3	0	0	0	**0.00**	10297	3	0	0	0	**0.00**
301	H	2291	1	0	0	0	**0.00**	857	0	0	0	0	**0.00**
310	H	1098	0	0	0	0	**0.00**	122	0	0	0	0	**0.00**
311	H	1898	1	0	0	0	**0.00**	638	0	0	0	0	**0.00**
Total	**H**	**27761**	**6**	**0**	**0**	**0**	**0.00**	**12926**	**3**	**0**	**0**	**0**	**0.00**
1 Story	**H**	**3273**	**0**	**0**	**0**	**0**	**0.00**	**219**	**0**	**0**	**0**	**0**	**0.00**
2 Story	**H**	**6922**	**1**	**0**	**0**	**0**	**0.00**	**793**	**0**	**0**	**0**	**0**	**0.00**
3+ Story	**H**	**17566**	**5**	**0**	**0**	**0**	**0.00**	**11914**	**3**	**0**	**0**	**0**	**0.00**
Liq Zone	**H**	**4476**	**1**	**0**	**0**	**0**	**0.00**	**916**	**0**	**0**	**0**	**0**	**0.00**
Non-Liq Zone	**H**	**23285**	**5**	**0**	**0**	**0**	**0.00**	**12010**	**3**	**0**	**0**	**0**	**0.00**
Hist District	**H**	**4910**	**2**	**0**	**0**	**0**	**0.00**	**1654**	**0**	**0**	**0**	**0**	**0.00**
Non-Hist Dist	**H**	**22851**	**4**	**0**	**0**	**0**	**0.00**	**11272**	**3**	**0**	**0**	**0**	**0.00**

Level 1: Medical Care **Level 2:** Hospitalization **Level 3:** Life-Threatening **Level 4:** Death

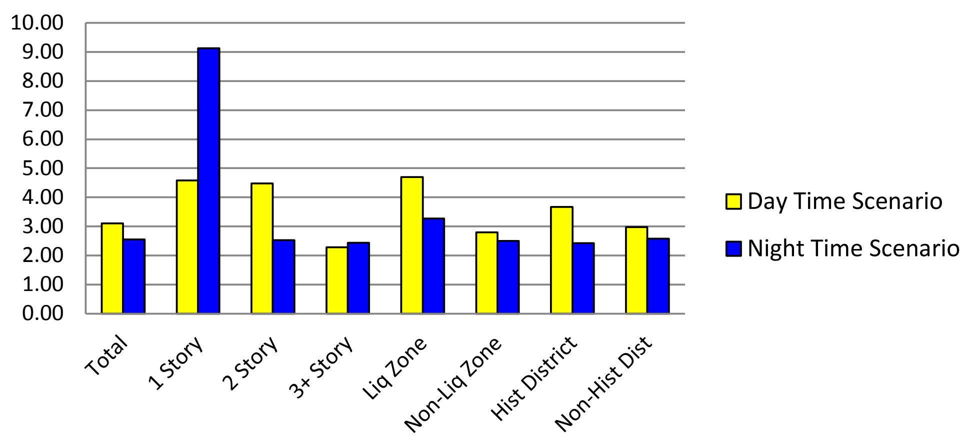
Death Rate per 1,000 Exposed Population, Unretrofited Buildings
Nisqually 6.8 Magnitude Quake



Death Rate per 1,000 Exposed Population, Unretrofited Buildings
Cascadia Subduction Zone 9.0 Magnitude Quake



Death Rate per 1,000 Exposed Population, Unretrofited Buildings
Seattle Fault Magnitude 6.7 Quake



APPENDIX 6.A

Types of Levies

A number of levy types exist in the State of Washington that are used for a wide range of public purposes. It is unlikely that funding for URM retrofits could be obtained from most regular levy sources.

The summary descriptions below were adapted from the Washington Department of Revenue Property Tax Levies Operations Manual, 2013.

Regular Property Tax Levies:

Regular property tax levies are generally considered to be those levies that are subject to the statutory limitations described in RCW 84.52.043. As long as the levy amounts remain within the rate limits specified by law and do not exceed the limitations that have been imposed on levy growth, the taxing district officials make the budget decisions and determine the size of the property tax levy. Most "regular" property tax levies do not require approval of the voters. All together, certain local regular levies cannot exceed $5.90/$1000 of assessed valuation in aggregate. Levies not subject to this limit include the following: State, Ports, Public Utility Districts, Emergency Medical Services, Affordable Housing, Conservation Futures, County Ferry Districts, Criminal Justice, and County Transit.

The aggregate of all tax levies upon real and personal property by the state and all taxing districts, now existing or hereafter created, shall not in any year exceed one percent of the true and fair value of such property. (RCW 84.52.050)

Excess or Special Levies:

Excess levies are those that impose property taxes over and above regular property tax levies. They are in "excess" of the many limits we put on regular levies. Excess levies require not only voter approval; but most also require a 60 percent "super" majority to be approved. The following statutes are relevant to most excess levies, but each type of excess levy also has other important statutes that must be considered. These levies are generally for only one year but can be for two to six years with respect to school districts and fire protection districts.

The districts allowed an excess levy are: metropolitan park district, park and recreation service area, park and recreation district, water-sewer district, solid waste disposal district, public facilities district, flood control zone district, county rail district, service district, public hospital district, road district, certain library districts, cemetery district, city, town, transportation benefit district, emergency medical service district with a population density of less than one thousand per square mile, cultural arts, stadium, and convention district, ferry district, city transportation authority, or regional fire protection service authority.(RCW 84.52.052)

Benefit Assessment Districts:

Benefit assessments, or special assessments, are not really property taxes. They are special charges created to recover monies to pay for services or improvements that have a particular, direct benefit to lands and their owners. Rather than basing the charge on assessed value like property taxes, benefit assessments are determined by an assessment plan that is meant to charge amounts to a parcel of property that reflect the actual benefit that property will receive. These assessments are usually based on a flat-fee per parcel, an amount per acre, or a combination of characteristics like these; rarely are they based on assessed value. Properties can be charged in different amounts if the district authorities find that different classes of property benefit in different ways.

Districts that that can levy a benefit assessment include the following: diking and drainage districts, horticultural districts, irrigation districts, mosquito districts, river and harbor improvement districts, and weed districts. Fire districts may use benefit assessments in return for giving up some of their taxing authority.

Local Improvement Districts:

Local improvement district (LID) assessments are those that are set up for a specific length of time with an annual due date, a specified penalty interest rate, delinquent interest rate, and bond interest rate. For instance, these districts can be for the establishment of sewer improvement, water systems, roads, lighting, etc. The laws covering the specific type of district dictate the details of collecting the assessment. For example, there is a provision for using an LID for "community renewal", under the Community Renewal Law (Chapter 35.81 RCW). This law allows for the definition of certain community renewal areas, for which an LID can be used to make assessments and secure tax-exempt bonds for an essential public purpose (such as public safety).

LIDs can be approved by either a petition from a majority of property owners within a given area or ordinance approved by the local governing body, such as a city council.[4]

4 RCW 35.43.070 Ordinance – Action on petition or resolution, and RCW 35.43.120 Petition – Requirements.

Earmarked funds

Earmarked funds are generally levies created for very specific purposes or services. They may be from within a district's regular levy or they may be a small, stand-alone levy. In general, the funds raised would be devoted to the specific purpose to which the funds are dedicated, not for the day-to-day operation of districts.

Tax Increment Financing

Tax increment financing (TIF) in Washington State is legal, but is reserved for financing certain types of infrastructure projects. Two notable examples of TIF in Washington include the Local Infrastructure Financing Tool (LIFT) Program created in 2006 and the Local Revitalization Financing (LRF) Program, created by Second Substitute Senate Bill 5045 (2SSB 5045) in 2009. Both programs were created to help certain local governments finance local public infrastructure improvement projects within a certain area using local sales and/or property tax revenues to pay for improvements.

APPENDIX 6.B

The calculation of incentives involved two incentive options based on tax benefits: 1) the federal historic tax credit and 2) a property tax exemption program. In order to more accurately calculate the potential value of the incentives, non-taxable properties had to be removed from the dataset. This involved an initial removal of over 130 parcels assumed to be tax-exempt: schools, governmental, and religious organizations. However, non-taxable parcels in other uses remained in the dataset, with no field to indicate that they were tax-exempt. Therefore, a representative sample of the remaining parcels was taken in order to produce a correction factor that could be used to create an approximate number of taxable parcels.

Additional caveats:

- Some taxable properties have a lower tax value than the appraised value because of historic designation (e.g., a portion of the property was not taxable)
- If either the land or improvement was not taxable on a given parcel, the parcel was considered to be non-taxable

Sampling Methodology:

- Removed properties built 1936 and after
- Removed properties presumed to be tax-exempt: Schools, governmental, religious
- As a result of the above, obtained a population size of 795 parcels
- Assigned parcels a random number from 1-100,000
- Ordered list lowest to highest based on random number assignment
- Determined sample size required (86)
- Sampled properties from top of list down, 1-86.

Result:

77 Taxable

9 Non-Taxable (including two properties where land was taxable but improvements were not)

90% Taxable / .9 correction factor

Confidence Level: 95%

Confidence interval: 10

Sample size required determined by the following formula:

$$\text{Sample Size (SS)} = \frac{Z^2 * (p * (1-p))}{c^2}$$

Where:

Z = Z value (e.g. 1.96 for 95% confidence level)
p = percentage picking a choice, expressed as decimal (.5 used for sample size needed)
c = confidence interval, expressed as decimal (e.g., .1 = ±10)

After calculating the sample size, a correction was made for the finite population sampled:

Corrected Sample Size = SS/(1+(SS-1)/Pop))

APPENDIX 6.C

Alternative Courses of Action: Policy Precedents from URM Programs in California

California provides the most robust set of case studies relating to policies that have been established for the purpose of either mandating or encouraging the seismic retrofit of URM buildings. A number of these policies were enacted around the time of the Loma Prieta earthquake in 1989, though several notable examples (such as Long Beach and Los Angeles) have had established URM policies based on building codes that have been in place for several decades.

The relevant legal frameworks in place in California contain some notable differences to those in Washington State. One example is the Mello-Roos Community Facilities District Act of 1982, similar to a special assessment financing arrangement. Mello-Roos allows jurisdictions to provide market rate loans to private property owners to finance seismic retrofits. Bonds issued by a jurisdiction are secured by a special tax on the properties included in the Community Facilities District. Because of this, jurisdiction are legally liable for the debt. One advantage cited for this type of financing strategy is that Mello-Roos style financing may be easier to qualify for than traditional financing.[1] Another example of legislation, the Mills Act, has been used to retrofit and preserve historic URM buildings by allowing cities to enter into contracts with owners of such buildings. The contracts provided that property taxes can be abated for an initial period of 10 years for qualified historic properties if the subject property continued to be actively preserved / restored by the property owner.

Types of Programs: Mandatory v. Voluntary Retrofits

Most retrofit programs in California that were reviewed for the purpose of this report were mandatory by way of ordinance - i.e., affected URM building owners were required, within a specified timeframe, to retrofit buildings to a certain seismic standard. Such ordinances also specified penalties for not complying with retrofit requirements. Therefore, the main incentive for compliance was the threat of legal action if compliance was not achieved. Among the programs reviewed, mandatory programs were reportedly successful at achieving the end goal of compliance with the ordinance, resulting either in a seismic retrofit of the affected structures or in demolition. According to a recent (undated) report authored by Seattle DPD, mandatory programs were also reported to be much more successful at achieving compliance -- 87% v. 13 - 31% -- than voluntary retrofit programs[2] *(note: this figure appears to ignore the reported success rate of the voluntary Palo Alto URM program, which had achieved a compliance rate of 65% as of 2004 -- buildings either retrofitted or demolished).* Voluntary programs in California included those with incentives to encourage retrofits as well as those without incentives.

The City of Palo Alto's URM retrofit program appears to be somewhat of an exception to the trend of mandatory programs being more successful than voluntary programs. Palo Alto's URM ordinance, which mandated engineering reports for URM buildings, resulted in the retrofit of nearly half of all buildings identified as such (as of 2004). URM building inspection reports were required to be made public (including building tenants), which may have helped to encourage some building owners to take action more quickly than otherwise. The program also included incentives for URM buildings located in the downtown district, such as FAR bonuses and exemptions from certain zoning requirements if seismic upgrades were completed. More detail on this program is provided below.

Funding and Financing Alternatives

A number of case studies of URM programs undertaken in California were reviewed with the goal of analyzing their approaches to funding and financing seismic retrofits for URM buildings. Some jurisdictions chose not to provide funding for retrofits, either placing the cost burden on the owner or instead providing incentives to help defray the costs.

Summary of California URM retrofit funding strategies

Funding strategies for programs reviewed in California included:

‡ No outside funding (entire retrofit funding burden placed on the owner)

‡ Limited funding (e.g., funding for engineering studies, permit fee waivers)

‡ Tax increment financing administered by a redevelopment agency

‡ Levy w/ special assessment bond issue (only eligible URM properties within assessment district levied)

‡ City-wide bond issue to provide low-interest financing for retrofits

‡ General fund (to subsidize soft costs such as engineering studies)

‡ Community Development Block Grants (CDBG)

1 1 California Office of Emergency Services. Seismic Retrofit Incentive Programs: A Handbook for Local Governments. (1992). Retrieved from http://www.abag.ca.gov/bayarea/eqmaps/incentives/Incentives.pdf

2 2 Seattle DPD. Summary Report of URM Retrofit Laws. (Date Unknown)

Notable Program Examples

The two programs summarized below highlight the different approaches and strategies applied in a voluntary program versus those used in a mandatory program. As mentioned above, Palo Alto's program is notable for its relative success as a voluntary program in effecting retrofits, and in some cases, demolition of URM buildings. The program included some incentives that may have also played a role in encouraging building owners to act. The Long Beach URM program, which required retrofits, was notable for its use of a special assessment district to secure funding for seismic upgrades to URM buildings.

The following information was summarized from the California Office of Emergency Services document "Seismic Retrofit Incentive Programs: A Handbook for Local Governments", and Seattle DPD document " Summary Report of URM Retrofit Laws: Selected California Jurisdictions with URM Building Best Practices in Earthquake Risk Reduction", which included detailed case studies of the Palo Alto Program.

Voluntary Retrofits with Incentives -- City of Palo Alto

Program Summary

The City of Palo Alto's URM program is notable for being a voluntary retrofit program. However, building engineering reports for URM buildings were required by passage of Ordinance #3666 (1986). As a result of this ordinance, 65% of URM buildings identified were either retrofitted or demolished as of 2004.

Key Highlights

ǂ Voluntary retrofit program -- unlike most others in CA, which required retrofits as part of a mandatory program

ǂ URM engineering reports were mandatory by ordinance

ǂ Minimal City staff time required (one employee); City absorbed these admin costs

ǂ Incentives (e.g., a 25% FAR bonus) were provided for retrofits within a year of the ordinance passage

ǂ Engineer reports identifying buildings as URMs were made available to the public -- including building tenants -- in order to give building owners an incentive to upgrade

ǂ Owners must submit a statement to the City building inspector within one year of the report detailing their intentions for addressing any deficiencies

ǂ The voluntary nature of the program gave owners flexibility to complete retrofits when they were able to do so (e.g., at expiration of leases, sale of building, etc.)

ǂ Final outcome: Of the 46 URM buildings identified, 20 were retrofitted and were 10 demolished; 12 buildings had no action taken.

Background:

Palo Alto initially attempted to establish a mandatory URM retrofit program in 1982, but faced opposition from building owners and the general public. The City Council subsequently rejected the proposal and the law was tabled. Part of the reason for the law's rejection was the lack of inclusion of the business community and other affected citizens. As a result the Council directed that a citizen's committee be established for the purpose of recommending "an economical, practical and cost-effective method of reducing seismic hazards in Palo Alto". The committee included representatives from the City's business community, planning professionals, architects, engineers, realtors, and other similar individuals.

After four years of work, including the development of a classification system for URM buildings and development of an incentive program, a new ordinance was passed four years later by the City Council. The ordinance requires that engineering reports be completed and made available to the public (including building tenants). Subsequent seismic retrofitting under the ordinance is voluntary.

Outcome:

In terms of achieving the program goal of retrofitting buildings identified in the engineering study, the program was a modest success. By 2004, 18 years after the ordinance had passed, 20 (43%) of the of the 46 URM buildings identified had been retrofitted. Another 10 (22%) had been demolished and 12 (26%) had no action taken on them. The remaining four buildings fell into some other category.

As of 2004, eight properties had taken advantage of the zoning incentive allowing an additional 25% FAR (or 2,500 SF, whichever greater) to buildings undergoing retrofits.

Palo Alto URM Buildings -- Outcome of Voluntary URM Ordinance as of 2004 [3]

Action	Number	Percent
Retrofitted	20	43%
Demolished	10	22%
No action	12	26%
URM Removed	2	4%
Vacated	1	2%
Exempt	1	2%
Total	46	100%

Additional Notes:

‡ Engineering reports for a number of buildings not identified as URMs but identified as potentially hazardous were completed, which resulted in many of these buildings undertaking retrofits.

‡ The 1992 report by the California Office of Emergency Services identified factors that contributed to the relative success of the Palo Alto URM program. These included:

- ‡ An active community that was not only a part of the process for crafting the ordinance, but also responsive to the URM reports being made public
- ‡ The community's relative wealth and a thriving downtown, which generally enabled URM owners to find financing for retrofits, given enough time and flexibility on the part of the City
- ‡ To a limited extent, zoning incentives; however, as noted in the table above, the incentives were not especially widely used. It is also not clear whether retrofits were completed as a result of the incentives being available, or whether retrofits would have been completed anyway.

Special Assessment Bond Financing (Mandatory Retrofit Program) -- City of Long Beach

Program Summary

The City of Long Beach URM program is notable for its use of public bond financing for retrofits to privately-owned buildings. This represented the largest use of assessment bonds publicly issued for this purpose in California; the City of Torrance, CA had pioneered the tool in 1987. The program was mandatory; however, participation in the special assessment district for the purpose of obtaining long-term financing was voluntary.

Key Highlights

‡ The City included 506 (mostly commercial) URMs at the time the bond financing was issued; of those, only about one-quarter (137) were included in the assessment district

‡ A 1970's ordinance requiring seismic retrofits classified buildings into three types, based on level of hazard; buildings in the two most hazardous categories had mostly been brought up to code or demolished.

‡ The remainder of the buildings classified as "least dangerous" were those offered special financing as part of retrofit district

‡ Retrofitting was required, though membership in the assessment district was **voluntary** - - the main incentive was the long-term financing available, targeted toward building owners who could not otherwise get such long-term financing from other sources.

‡ The City was not directly liable for bond repayment; responsibility was assigned to the property owner via a lien on the assessment to be used for the retrofit.

‡ City administrative costs were reimbursed by the bond issue

Background:

The City of Long Beach had been addressing seismic safety through building codes and other regulatory measures since the 1930's. The portion of their seismic upgrade program here focuses on the buildings classified as "least hazardous" from a 1970's ordinance requiring buildings to be either retrofitted or torn down, on a timeline determined by their classification. Owners of buildings classified as "least hazardous" were required to either develop a plan for seismic retrofits by early 1991 or take action to demolish

3 City of Palo Alto. (2004). Unreinforced Masonry Building Report to City Council. Fred Herman, (Preparer). Retrieved from http://www.cityofpaloalto.org/cityagenda/publish/cmrs/4045.pdf

their building. As an incentive to owners of these buildings to undertake retrofits, the City formed a voluntary special assessment district. Owners were offered the then-market-rate of 11.3% for long-term (30-year) loans to finance the retrofits. The loans were secured as follows:

‡ URM Owner elects to participate in assessment district

‡ Engineering study determines extent of retrofit needed and estimated cost. All retrofits require that the roof and floors to be bolted to the adjoining walls, for the interior and exterior walls to be reinforced, and for provisions allowing existing usage and occupancy to be maintained/restored.

‡ The owners' parcels were then examined to determine their estimated and/or appraised values and associated "value to lien" ratio. Property value to assessment lien (the value of the improvement) ratios of 2.5:1 or above were considered sufficient to be included in the district.

‡ Tax rolls were checked to ensure that none of the owners was delinquent in property tax payment.

‡ After amending its code to allow for the creation of the district and assessments, the City took legislative action through council to approve the Assessment Engineer's estimate, and obtained the bond funding. Building owners were given approximately two years to complete the retrofits; payments for the retrofits could either be made directly to the contractor during construction, or as a reimbursement to the owner after work was completed. Any cost overruns (outside of the original estimate) were the responsibility of the owner. Bond payments were made by each owner in the district in the form of an annual assessment lien. The annual payment represented a pro-rata share of the total bond issue, which included the value of the retrofits as well as a percentage of the administrative costs. A failure to pay the assessment in excess of two years could result in the City taking action to foreclose the property.

Outcome:

The City ultimately issued bonds in the amount of $17.4 million to cover the seismic improvements of the 137 buildings included in the district. $14.9 million was deposited into the improvement fund to cover project costs; the rest of the proceeds covered required reserves, interest payments, fees, and administrative costs. The program was considered to be generally successful. One primary advantage identified was the City's ability to provide building owners with private financing while retaining to repayment liability; this liability lay with the owners, who were required to pay the assessments through the liens placed on their property. Other advantages identified were the relatively large project area size (i.e., the number of building owners participating in the program), the ability of the City to fully educate URM owners on the nature of the program and the commitment required, and the willingness on the part of the City to develop a previously-untried method of special assessment financing.

Additional Notes:

‡ It was very important for the City to frame the URM program as one being developed for public safety, rather than providing a public benefit to private building owners.

‡ A second assessment district, consisting of approximately 40 property owners, was formed for those owners who had failed to sign up for the first district but desired to be included in the program

‡ The City of Torrance, CA implemented a very similar program, though on a much smaller scale, in 1987. One key difference was that Torrance offered a 50% subsidy for engineering studies prior to the assessment, which was also bond-financed.

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