Economic Impact of Sea level Rise to the City of Los Angeles

by

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Final Report

January 27, 2013

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Executive Summary

Sea level rise is among the most profound effects of global climate change. It can be caused by the melting of glacier and massive ice sheets around the world and the thermal expansion of the ocean when the average global temperature increases. According to the IPCC Fourth Assessment Report, there is strong evidence showing that the sea level has been gradually rising in the past century. Many studies predict that sea level rise will be accelerating over the coming decades. Moreover, sea level rise is also expected to increase the intensity and severity of extreme coastal disasters, such as high tides, strong storms, and coastal flooding (IPCC, 2007). A recent study by National Research Council (NRC) projects that sea level rise for California coast can reach 0.12 to 0.61 m by 2050 and 0.42 to 1.67 m by 2100 (NRC, 2012).

Given its long shoreline and increasing exposure to risk and potential damage from sea level rise, California has been putting great efforts in incorporating sea level rise considerations into regional and local coastal development planning. California Executive Order S-13-08, which was signed by Governor Schwarzenegger in 2008, requires the California Natural Resources Agency to coordinate with public agencies at different levels and with private entities to develop a climate adaptation plan for the state.

This study is part of a larger effort to evaluate the vulnerability of City of Los Angeles to sea level rise caused by climate change. The focus of this study is the potential economic losses from coastal flooding events, which can be amplified by sea level rises. Together with the physical and social vulnerability assessments that are performed in parallel to this study, these coordinated research efforts aim to help the policymakers and planners of the City better plan and address sea level rise issues for the coastal communities.

The analysis in the study is performed based on the application of two modeling tools. HAZUS MH 2.1, FEMA's standardized modeling tool for estimating potential losses from hazards, is used to evaluate the property damage to building stocks (including both buildings and their contents) and the direct business interruption losses in the flooding affected region. The Input-Output (I-O) model, one of the most widely used tool of regional impact analysis, is then applied to calculate the total business interruption losses based on the direct loss estimates from the HAZUS model.

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In this study, we model two scenarios of sea level rise: 1) 0.5 meters by 2050; and 2) 1.4 meters by 2100. For each of these scenarios, we evaluate the economic impacts of two coastal flood events: a) a 10-year coastal flood; and b) a 100-year coastal flood.

The simulation results indicate that building exposure values (values of building at risk) of a 10-yr flood event increases from $2.5 billion in the Base Case to $2.7 billion in the 0.5 m sea level rise scenario, and increases further to $3.3 billion in the 1.4 m sea level rise scenario. For a 100-yr flood event, the building exposure values are $3.1, $3.4, and $4.5 billion for the Base Case, 0.5 m sea level rise, and 1.4 m sea level rise scenarios, respectively.

Building exposure values of a 10-yr flood event increases from $2.5 billion in the Base Case to $2.7 billion in the 0.5 m sea level rise scenario, and increases further to $3.3 billion in the 1.4 m sea level rise scenario. For a 100-yr flood event, the building exposure values are $3.1, $3.4, and $4.5 billion for the Base Case, 0.5 m sea level rise, and 1.4 m sea level rise scenarios

Table ES-1 presents the summary results of building stock losses for the scenarios analyzed. For a 10-yr flood event, the direct building losses are expected to be $410.3 million with 0.5 m sea level rise, and nearly doubled with 1.4 m sea level rise. For a 100-yr flood event, the building losses increase from $820.2 million to $1,441 million when sea level rises from 0.5 m to 1.4 m. Losses to residential buildings comprise about 50% of the total losses. The other 50% losses are split evenly between the commercial buildings and industrial buildings in most simulated scenarios.

Table ES-1. Summary Results of General Building Losses (millions of 2010$)

	Base Case		**0.5 m Sea Level Rise**		**1.4 m Sea Level Rise**	
Category	**10-Yr Flood**	**100-Yr Flood**	**10-Yr Flood**	**100-Yr Flood**	**10-Yr Flood**	**100-Yr Flood**
Building Losses	103.3	260.9	179.4	364.4	315.0	649.9
Content Losses	132.6	312.1	219.6	435.5	380.2	759.9
Inventory Losses	6.8	15.5	11.3	20.3	19.7	31.5
Total Building Losses	**242.7**	**588.6**	**410.3**	**820.2**	**714.9**	**1,441.3**

Table ES-2 presents the summary results of building-related business interruption losses for the study scenarios. The business interruption losses are relatively small compared with the building stock losses. For a 10-yr flood event, the total output losses in the City are expected to be $5.8 million to $9.1 million under the two simulated sea level rise scenarios. For a 100-yr flood event, the total output losses are expected to be $10.5 to $21.9 million. The major reason of the relatively low business interruption losses caused by the coastal flood events is that over 95% of the damaged buildings are residential buildings, rather than the buildings of producing sectors. Another important reason is that the HAZUS direct output loss estimation has taken into consideration the production recapture factor, which refers to the ability of businesses to recapture lost production by working overtime or extra shifts once their operational capability is restored. This is the most effective resilience measure that has been widely documented in the literature that can help reduce the potential business interruption losses in the aftermath of natural disasters.

Table ES-2. Summary of Business Interruption Losses

Category	Base Case		0.5 m Sea Level Rise		1.4 m Sea Level Rise	
	10-Yr Flood	100-Yr Flood	10-Yr Flood	100-Yr Flood	10-Yr Flood	100-Yr Flood
Output Losses (M 2010$)	$3.4	$7.4	$5.8	$10.5	$9.1	$21.9
Income Losses (M 2010$)	$2.3	$4.9	$3.8	$6.6	$5.9	$13.6
Employment Losses (Jobs)	24	52	41	74	64	158

Our simulation shows that the transportation system and the utility system in the City would suffer very limited damages from the flooding in the scenarios evaluated in this study.

Our estimates on the potential economic impacts of sea level rise to the City should be considered on the conservative side. The analysis only focuses on the potential impacts from the temporary flooding in the coastal area due to extreme coastal storms, and how those impacts can be amplified by sea level rise. Any impacts caused by long-term and permanent coastal erosion and beach area losses of sea level rise are not covered in this study.

I. Introduction

Sea level rise is among the most profound effects of global climate change. It can be caused by the melting of glacier and massive ice sheets around the world and the thermal expansion of the ocean when the average global temperature increases. According to the IPCC Fourth Assessment Report, there is strong evidence showing that the sea level has been gradually rising in the past century. With the availability of satellite technology in the past twenty years, more accurate rates of sea level rise have been recorded. Satellite observation data indicate that since early 1990s, the average rate of global sea level rise was about 3 mm per year (IPCC, 2007). Various forecasts of sea level rise for the future have been undertaken by various studies based on alternative scenarios of Greenhouse Gas (GHG) emission projections. For example, with respect to the IPCC SRES A1B scenario, the projected global sea level rise by mid 2090s can reach 0.22 to 0.44 m relative to the 1990 sea level (IPCC, 2007). In addition, sea level rises vary across different regions. A recent study by National Research Council (NRC) projects that sea level rise for California coast can reach 0.12 to 0.61 m by 2050 and 0.42 to 1.67 m by 2100 (NRC, 2012).

Sea level rise is also expected to increase the intensity and severity of extreme coastal disasters, such as high tides, strong storms, and coastal flooding (IPCC, 2007). Studies focusing on the eastern coast of the U.S. and Canada have found that in the past century, there was a trend of reducing return periods of extreme coastal disasters due to sea level rise (Zhang et al., 2000; William et al., 2009).

Given its long shoreline and increasing exposure to risk and potential damage from sea level rise, California has been putting great efforts in incorporating sea level rise considerations into regional and local coastal development planning. California Executive Order S-13-08 was signed by Governor Schwarzenegger in 2008, which requires the California Natural Resources Agency to coordinate with public agencies at different levels and with private entities to develop a climate adaptation plan for the state. In particular, the Executive Order requires that an independent panel convened by the National Academy of Sciences to develop the first Sea Level Rise Assessment Report for California.

This study is part of a larger effort to evaluate the vulnerability of City of Los Angeles to sea level rise. The focus of this study is the potential economic losses of coastal flooding events, which can be amplified by sea level rises. Together with the physical and social vulnerability assessments that are performed in parallel to this one, these studies aim to help the policymakers and planners of the City better plan and address sea level rise issues for the coastal communities. The economic impacts analyzed in this study include both property damage losses, and direct and indirect business interruption losses. The two sea level rise scenarios evaluated in this study are 0.5 meters by 2050 and 1.4 meters by 2100. They are consistent with the climate change and sea level rise scenarios evaluated for the California Energy Commission's Public Interest Energy Research (PIER) Climate Change Research Program by the California Climate Change Center (Cayan et al., 2009). The same scenarios are also used in a recent USGS study, which models the impact of severe winter storms, especially due to sea level rise, to the Southern California Coastal Region.

The analysis in the study is performed based on the application of two modeling tools. HAZUS MH 2.1, FEMA's standardized modeling tool for estimating potential losses from hazards, is used to evaluate the property damage to building stocks (including both buildings and their contents) and the direct business interruption losses in the flooding affected region. The Input-Output (I-O) model, one of the most widely used tool of regional impact analysis, is then applied to calculate the total business interruption losses based on the direct loss estimates from the HAZUS model.

This report is divided into eight sections. In the next section, we first provide a brief summary of studies on socioeconomic impact analysis of sea level rise. In Section III, we present an overview of basic concepts related to economic impacts of disasters. The two modeling tools used in this study are then introduced in Section IV. Section V presents the sea level rise and coastal flood scenarios evaluated. Section VI gives a brief introduction to the study region. The analysis results are presented in Section VII. The report concludes with Section VIII.

II. Socioeconomic Impact Analysis on Sea Level Rise

Since the early 1990s, there has been an increasing number of studies that examined the socioeconomic cost of sea level rise. Many of the early studies estimated the economic losses of sea level rise in terms of values of property that would be vulnerable under alternative sea-level rise scenarios as well as the potential cost of protection (IPCC, 2001). Several early studies (e.g., EPA, 1989 and Nordhaus, 1991) estimated that with a doubling of GHG concentration towards the second half of the 21th century, the expected cost to the U.S. economy in 2065 can reach $7 to $9 billion (in 1990 dollars) in terms of property damages and cost of protection. The cumulative losses can exceed $100 billion. Several following studies, including Yohe et al. (1996) and Yohe and Schlesinger (1998) presented much lower loss estimates, at about $0.2 to $0.4 billion (also in 1990 dollars) annually, or a cumulative of over $30 billion by 2065, after taking cost-reducing effects such as natural, regulative, and market-based adaptation potentials into consideration. In most of these early studies, cost-benefit approach was widely used. Sea level rise can also increase the frequency and severity of extreme coastal storms, which can cause even higher damages to the coastal and low-lying properties. West et al. (2001) indicated that extreme coastal storms can increase total losses from sea level rise by 20%.

More recent studies have expanded the scope of sea level rise economic impact analysis to include impacts on coastal businesses, erosion impacts, values of lost wetland, consumer surplus losses from reduced beach visits, etc. The Heinz Center (2000) study found that the accelerating coastal erosion caused by sea level rise can result in losses to property owners to more than $500 million per year. Michael et al. (2004) evaluated the economic cost of sea level rise to three communities (Shady Side, Piney Point, and Hooper Island) in the Chesapeake Bay area. The total economic impacts, including property damages to residential properties, damages to roads and bridges, and wetland losses resulted from inundation in a two-foot sea level rise scenario by 2100, as well as damages caused by increasing number of episodic flood events, were estimated to be $27 million of the three communities.

Since 2009, several studies were undertaken to evaluate the economic impacts of sea level rise for California. Heberger et al. (2009) analyzed the impacts of sea level rise along the 1,100 miles coast of California and the 1,000 miles of shoreline around the San Francisco Bay. Inundation and erosion geospatial data, under the assumption of three sea level rise scenarios (0.5m, 1.0m, and 1.4m), are integrated with the HAZUS software to estimate the consequences of a coastal flooding event with a 100-year return period. This study estimated that nearly 500 thousand people and $100 billion worth of property in the state will be at risk; much of the critical infrastructure, including hospitals, power plants, wastewater treatment plants, schools will be at risk of damage; building new or enhancing existing coastal protection structures would cost $14 billion, with an additional annual maintenance cost of $1.4 billion (in 2000 dollars).

With an integration of a beach attendance model and a beach sediment model, and based on the analysis of 51 public beaches in Los Angeles County and Orange County, Pendleton et al. (2011) evaluated the economic impacts of permanent beach loss caused by sea level rise and temporary beach inundation by extreme coastal storms. The study indicated that a 1 m sea level rise by 2100 can reduce more than 500 thousand beach visits by Southern California local residents in each year. This can be translated into an economic welfare loss of $40 to $63 million annually. In addition, severe wind storms can also result in substantial reductions in beach attendance and related spending. An extremely stormy year is expected to reduce beach visits by more than 300 thousand, and the economic welfare loss can reach $37 million.

King et al. (2011) conducted a comprehensive economic impact analysis of sea level rise of five representative California coastal communities. Three sea level rise scenarios by 2100 are evaluated in terms of three categories of coastal region impacts: 1) temporary flooding from coastal storms with a 100-year return period; 2) long-term beach erosion; and 3) long-term upland erosion. Using Venice Beach as an example, the economic impacts of structure and content damages stemming from a 100-year coastal flooding with 1.4 m sea level rise by 2100 are estimated to be over $50 million. In addition, annual losses in beach benefits (including recreational value, habitat value, beach-related spending, and tax revenue), which is caused by slow and steady beach width decrease from a 1.4 m sea level rise by 2100 can reach nearly $500 million.

In this study, we analyze the economic impact of sea level rise to the City of Los Angeles. Our analysis is focused on temporary flooding in the coastal area caused by extreme coastal storms. Economic impacts evaluated in this study will include property losses (building and content losses), as well as direct and indirect business interruption losses due to extreme coastal flooding events. Potential impacts to transportation system and utility system will also be evaluated. Any impacts caused by long-term and permanent beach area losses from sea level rise are not covered in this study. There are three areas of the City that are located along the Pacific Coast: Pacific Palisades, Venice/Playa del Rey, and San Pedro/Wilmington. When we compute the property losses and the direct business interruption losses, we focus on the coastal regions within the City that are directly affected by the coastal flooding events. As for the indirect business interruption losses, they include not only the multiplier (ripple) effects of the direct business interruption losses taking place within the City, but also the indirect effects to the City stemming from the losses to the coastal regions that are outside of the City but within the boundary of the LA County.

III. Basic Concepts

For many years, the main focus of disaster loss estimation has been focusing on property damage to structures. All other types of impacts (economic, sociological, psychological, etc.) were classified into a category termed "indirect" or "secondary" losses. By the mid-1990s, there was a growing appreciation of the role of business interruption losses, which refer to the reduction in the flow of goods and services produced by property (capital stock). This stock vs. flow distinction is a basic concept in economics, and both the losses on capital stock and goods flow have direct and indirect versions. *Direct property damage* relates to the effects of natural phenomena, such as fault rupture, ground shaking, landslides, tsunami, wave surge, etc., while *collateral*, or *indirect*, *property damage* is exemplified by ancillary fire caused by ruptured pipelines, or loss of fresh water supply due to sea water intrusion, etc. *Direct Business Interruption* refers to the immediate reduction or cessation of economic production in a damaged factory or in a factory, though not experienced through property damage, but is suffered from service disruptions for at least one of its utility lifelines, or curtailed in one of its key production inputs. *Indirect Business Interruption* (referred to as contingent BI by the insurance industry) stems from the “ripple,” or “multiplier," effects associated with the supply chain or customer chain of the directly affected business (see, e.g., European Union, 2003; Rose, 2004; National Research Council, 2005; Rose et al., 2007).

An important consideration to emphasize is that nearly all direct property damage takes place at a given point in time, and that ancillary (or indirect) property damage takes place during a fairly short time span. Business interruption, on the other hand, being a flow variable, is time-dependent. It begins when the ground shaking starts or the building structures are hit by flooding and continues until the built environment is repaired and reconstructed to some desired or feasible level (not necessarily pre-disaster status) and a healthy business environment is restored. As such, business interruption is complicated because it is highly influenced by the choices of private and public decision makers about the pattern of recovery, including repair and reconstruction.

IV. Analytical Models

A. FEMA HAZUS Model

HAZUS-MH 2.1, the FEMA modeling tool for estimating potential losses from hazards, is used in this study to analyze the potential physical damages and some social impacts of the flood disasters. Specifically, the HAZUS-MH 2.1 Flood Model is applied. This is a large expert system that contains census block data on the built environment, a set of damage functions, and GIS capability. The HAZUS-MH Flood Model is widely used by planners and policy analysts to perform flood impact analyses. The methodology used by HAZUS to estimate flood losses includes two modules: Flood Hazard Analysis and Flood Loss Estimation Analysis. The former uses inputs, such as frequency, ground elevation, and other ground characteristics, to estimate the depth and velocity of the flood hazard. The results are then used by the Flood Loss Estimation Module to calculate resulting physical damage and direct business interruption, which are in turn translated into direct dollar values of building replacement costs and business downtime costs, respectively (FEMA, 2011b).

In HAZUS, loss estimation from floods is calculated based on the inventory data of the building stock, infrastructure, and population within the study region that are exposed to the simulated flood event. For this initial economic impact study, we largely use the inventory data for the City of Los Angeles contained in the HAZUS database. For residential structures, census data are used as the main data source, while for the non-residential structures, Dun & Bradstreet (D&B) data are used (FEMA, 2011a).

Appendix A presents a detailed summary of the analytical steps undertaken in our HAZUS modeling.

In this study, losses that will be estimated through the HAZUS modeling tool include:

- Physical damage to building stocks (residential and non-residential), essential facilities, transportation system and utility system.
- Debris generation.
- Social impacts such as estimates of shelter requirements.

B. Input-Output Model

Input-Output (I-O) analysis, developed by Nobel laureate Wassily Leontief, is the most widely used tool of regional impact analysis in the U.S. and throughout the world. Moreover, it has been used extensively to analyze the economic impacts of natural hazards (see, e.g., ATC, 1991; Rose and Lim, 2002; Rose et al., 2011). It is especially adept at estimating ripple, or multiplier, effects. I-O can be defined as a static, linear model of all purchases and sales between sectors of an economy, based on the technological relationships of production. In an I-O analysis, it is important to distinguish two types of second-order effects. The first is "indirect" effects, which represent the interaction between producing sectors. The second is "induced" effects, which represent the interaction between households and producing sectors; production generates income paid to households, who in turn spend a major portion of this income on produced goods and services, thereby generating additional multiplier effects.

For this study, we use the most widely used source of regional I-O tables, the Impact Analysis for Planning (IMPLAN) System (MIG, 2012). This source consists of three components: 1) a study region (can be state, county, sub-county) data base, 2) a set of algorithms capable of generating I-O tables for any state, county or sub-county group, and 3) a computational capability for calculating multipliers and performing impact analyses. The IMPLAN sectoring scheme is currently based on the North American Industrial Classification System (NAICS), and includes the details of 440 sectors. When performing the analysis, the user has the flexibility to aggregate the IMPLAN sectors according to the study needs.

I-O model has both demand-side and supply-side versions. The demand-side I-O model is the standard version, where a change in final demand affects the economy by causing product supply to respond through a multiplier process. The supply-side I-O model is a variant of the standard model in which the impacts to the economy takes place through the production side of the economy. This can be a change in primary factors (e.g., labor) of individual sector economic activity that ripples throughout the economy through marketing patterns of sales of one sector to another (Rose and Wei, 2011). In this study, both demand-side and supply-side I-O models will be applied to provide a more comprehensive evaluation of the potential economic losses stemming from a flood event to the City.

I-O has been used successfully in conjunction with HAZUS (see, e.g., Rose et al., 2007; Rose et al., 2011; FEMA, 2012). In fact, the Indirect Economic Loss Module (IELM) of HAZUS is based on an I-O methodology. However, in this study, we use the IMPLAN I-O model, rather than the HAZUS IELM for two main reasons. First, using IMPLAN I-O data enables us to construct a model at a finer level of sectoral detail than is available in HAZUS. Second, through our previous experience, we conclude that the IELM involves some assumptions regarding interregional trade that would exaggerate the ability of the economy to adjust to the hazards and would thus underestimate the impacts.

Outputs from I-O analysis include business interruption impacts in terms of:

- Gross Output
- Personal Income
- Employment

The business interruption impacts are analyzed at both the economy-wide level and the sectoral level.

Figure 1 presents the overall framework of the modeling system used in this study.

In the figure, the blue shaded section represents the analysis performed in HAZUS and the outputs obtained from the HAZUS simulations. After providing the characteristics of the coastal flooding event, such as the return period of the flood and the still water level associated with alternative sea level rise scenarios, the Flood Hazard Analysis Module is run to model the depth and velocity of the flood. Then based on the coastal inundation results and building exposure in the affected region, the Flood Loss Estimation Module estimates the direct structure and economic damage through the use of vulnerability curves (FEMA, 2011a). The direct property damages estimated from HAZUS include general building stock damage, essential facility damage, and the impacts on the functionality of the lifeline and transportation systems. The building-related direct business interruption losses will also be estimated. These losses are calculated based on the results of building damages and business loss of function time, and the default sectoral output per square feet per day data provided in the HAZUS model. In the HAZUS Flood model, induced damage from a flood event includes debris generation.

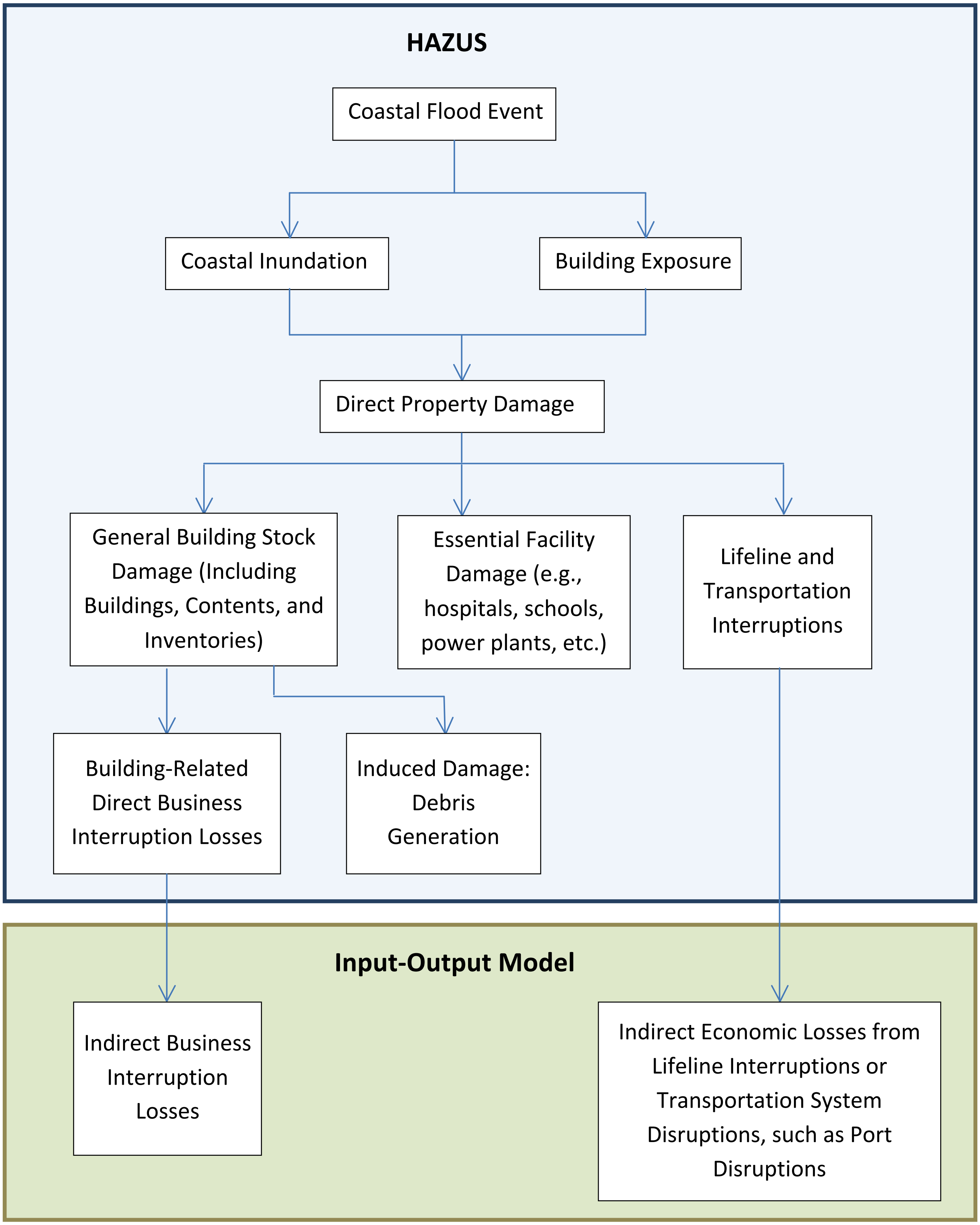
HAZUS
Coastal Flood Event
Coastal Inundation
Building Exposure
Direct Property Damage
General Building Stock Damage (Including Buildings, Contents, and Inventories)
Essential Facility Damage (e.g., hospitals, schools, power plants, etc.)
Lifeline and Transportation Interruptions
Building-Related Direct Business Interruption Losses
Induced Damage: Debris Generation
Input-Output Model
Indirect Business Interruption Losses
Indirect Economic Losses from Lifeline Interruptions or Transportation System Disruptions, such as Port Disruptions

Figure 1. Schematic Diagram of the Modeling Framework

The green shaded section in the figure represents the analysis performed in the Input-Output Model. Both the demand-side and supply-side I-O approaches are applied to the building-related direct business interruption losses obtained from HAZUS to compute the total (including direct, indirect, and induced) business interruption losses. Interruptions to lifeline and transportation systems can also generate direct and indirect economic impacts. For example, if the extreme storm event and the subsequent flooding would cause any disruptions to the port operation, disruptions to the movement of both imports and exports through the port will affect not only the direct import using sectors and export producing sectors, but also sectors along the supply and demand chains of those directly affected sectors (Rose and Wei, 2011). However, since as will be presented below that the HAZUS results indicate that the impacts from the coastal flooding events simulated in this study would result in only very small impacts to the lifeline and transportation systems, we did not perform their indirect economic impact analysis using the I-O model.

V. Analysis Scenarios

Sea level rise will increase the occurrence of extreme events such as storm surge, high tides, coastal flood. For example, in January 2010 a severe winter storm, equivalent of a hundred-year storm or worse (NBC news, 2010), hit San Pedro and Long Beach region, which led to street flooding in this area. According to recent studies, with sea level rise, storm and flood events similar to the January 2010 Southern Los Angeles flood (which represented a 10-year flood) are likely to occur more often (Bromirski et al., 2012). The likelihood of the City of L.A. experiencing more severe flood hazards, such as a 100-year flood would also be expected to increase with sea level rise.

In this study, we analyze the physical damage and economic impacts from sea level rise based on two temporary coastal flood scenarios: 1) A 10-year coastal flood (10% chance of happening in any single year); and 2) A 100-year coastal flood (1% chance of happening in any single year).

For each flood scenario, we also analyze the effects of two sea level rise scenarios: 0.5-meter sea level rise by 2050 and 1.4-meter sea level rise by 2010. In order to obtain an assessment on the incremental impacts on building stock and business operation from flooding due to sea level rises, we also run the simulations assuming no sea level rise (which is referred to as the Base Case scenario).

Thus, six scenarios are analyzed in this study, namely:

1. 10-yr coastal flood without sea level rise
2. 100-yr coastal flood without sea level rise

3. 10-yr coastal flood with 0.5 meter sea-level rise
4. 100-yr coastal flood with 0.5 meter sea-level rise
5. 10-yr coastal flood with 1.4 meter sea-level rise, and
6. 100-yr coastal flood with 1.4 meter sea-level rise

VI. Study Region

A. Economy of City of Los Angeles

In order to analyze the economic impact of sea level rise to the City, we have constructed the Input-Output model for the City based on the zip code level economic data gathered from IMPLAN. The sectoring scheme used in the I-O table is presented in Appendix B. The constructed LA City I-O table is shown in Appendix C. In the I-O table each row represents the dollar value of sales of the sector listed at the left (row labels) to the sectors of the economy listed at the top (column labels). The total sales of a sector include not only the delivery of intermediate inputs to other production sectors of the economy, but also final goods and services consumed by government, households, and the production of goods for capital formation. Each column represents the dollar value of purchases of inputs from other sectors of the economy used to produce the output of the sector listed at the top. The column also includes the dollar value inputs of the primary factors, such as labor and capital, in the production. The row and columns labels are identically labeled and ordered, and the total uses of each good and service equals the total production of each in the economy, with the designation "Total Gross Output."

According to the LA City I-O table, in 2010, the total gross output of the city is $438 billion and total value-added is $269 billion.[2] Total employment in Year 2010 is about 2.7 million. In terms of gross output, the top five sectors are Professional and Technical Services, Entertainment and Recreation, Banks and Financial Institutions, Government Services, and Real Estate. These five sectors combined account for more than 50 percent of the total gross output of the City.

B. Building Stock

The geographical size of the City is about 470 square miles. It contains 838 census tracts and 29,426 census blocks. According to the 2010 Census, the City has over 1.2 million households and has a total population of nearly 3.8 million.

Tables 1 and 2 present the HAZUS default data on values of building stocks in the City. It shows that there are in total 831,612 buildings within the region, which have a total replacement value of $283

[2] Gross output measures the total revenue received from the sale of a good from a given sector. It includes all costs of production--both returns to primary factors of production (including a normal rate of return on investment) and payments for intermediate goods. Value-added pertains to the returns to primary factors of production (labor, capital, and natural resources), which provide the basis for a net measure of economic activity. Essentially value-added is equivalent to Gross Domestic Product (GDP), or Gross Regional Product (GRP).

billion. Among various occupancy classes, residential buildings account for over 75% of the total replacement values of buildings in the City. In terms of building type, wood structures account for more than 70% of the total.

Table 1. Building Exposure by Occupancy Type for City of Los Angeles

Occupancy	Exposure (million 2010$)	Percent of Total
Residential	213,028	75.30%
Commercial	51,249	18.10%
Industrial	9,641	3.40%
Agricultural	281	0.10%
Religion	3,563	1.30%
Government	1,236	0.40%
Education	3,975	1.40%
Total	**282,972**	**100.00%**

Table 2. Building Exposure by Building Type for City of Los Angeles

Building Type	Exposure (million 2010$)	Percent of Total
Concrete	32,530	11.50%
ManufHousing	445	0.16%
Masonry	28,419	10.04%
Steel	18,238	6.45%
Wood	203,341	71.86%
Total	**282,973**	**100.00%**

C. Transportation System and Utility System

Tables 3 and 4 present the HAZUS inventory data on transportation system and utility system dollar exposure in the entire study region. The dollar exposure values are computed based on the replacement cost of the infrastructures and facilities. The transportation system includes highway, railway, light rail, bus facility, ports, ferries, and airport. Highway system comprises the majority of the total transportation system dollar exposure. Utility system includes potable water, wastewater, oil, natural gas, electricity, and communication. Electric power facilities comprise about 60% of the total value exposure of the utility system. Wastewater treatment facilities account for another 28%.

Table 3. Transportation System Dollar Exposure (in million 2010$)

	Highway	Railway	Light Rail	Bus Facility	Ports	Ferries	Airport	Total

Segments	14,725.3	342.6	178.6	0.0	0.0	0.0	285.7	15,532.1
Bridges	4,764.0	7.5	1.6	0.0	0.0	0.0	0.0	4,773.2
Tunnels	9.1	0.0	0.0	0.0	0.0	0.0	0.0	9.1
Facilities	0.0	34.4	117.4	18.0	199.7	2.9	34.4	406.6
Total	19,498.4	384.5	297.6	18.0	199.7	2.9	320.1	20,721.1

Table 4. Utility System Dollar Exposure (in million 2010$)

	Potable Water	Waste Water	Oil Systems	Natural Gas	Electric Power	Communication	Total
Facilities	211.2	507.0	1.4	1.4	1,116.5	2.7	1,840.2

VII. Analysis Results

A. Replacement Value of Property at Risk

Increasing number and values of property will be at risk from flooding (for both 10-yr and 100-yr flood events) as a result of sea level rise. Table 5 presents the building exposure (in terms of replacement values) for various sea level rise and flood event scenarios. Building exposure values of a 10-yr flood event increases from $2.5 billion in the Base Case to $2.7 billion in the 0.5 m sea level rise scenario, and increases further to $3.3 billion in the 1.4 m sea level rise scenario. For a 100-yr flood event, the building exposure values are $3.1, $3.4, and $4.5 billion for the Base Case, 0.5 m sea level rise, and 1.4 m sea level rise scenarios, respectively. Residential buildings account for more than 60% of the total exposure values.

Table 5. Building Exposure by Occupancy Type by Scenario (million 2010$)

Occupancy	Base Case		0.5 m Sea Level Rise		1.4 m Sea Level Rise	
	10-Yr Flood	100-Yr Flood	10-Yr Flood	100-Yr Flood	10-Yr Flood	100-Yr Flood
Residential	1,527	1,968	1,727	2,209	2,101	2,922
Commercial	607	736	672	848	804	1,114
Industrial	273	281	276	300	292	366
Other	52	68	62	73	71	86
Total Building Exposure	**2,458**	**3,052**	**2,738**	**3,430**	**3,268**	**4,488**

B. General Building Stock Losses

HAZUS estimates the direct physical damage (in terms of repair costs) to the general building stock in the study region for each flood and sea level rise scenario. We used the default general building inventory for the study region and the damage functions provided by the HAZUS Flood Model in our analysis. General building inventory data provided in HAZUS include information on the foundation type, first floor elevation, presence of basements, and number of stories of the buildings. For every census block, the water depth results computed by the Flood Analysis Module are used together with the damage function for specific occupancy class to determine the percentage damage of the buildings and contents (FEMA, 2011b). Tables 6-9 present the expected building damages by general occupancy type and by building type for the two sea level rise scenarios. In HAZUS, three "damage states" are defined based on the percent damage of the building: damages ranging between 1% and 10% are considered slight; damages of 11% to 50% are considered moderate; damages exceeding 50% are considered substantial.

The results in Tables 6-9 indicate that for a 10-year flood event, the total number of damaged buildings increases from around 1,000 buildings to nearly 1,700 buildings when the sea level rises from 0.5 m to 1.4 m. For a 100-year flood event, the building damage number increases from nearly 1,900 for the 0.5 m scenario to nearly 3,500 for the 1.4 m scenario. In all scenarios, most of the buildings are moderately damaged. In terms of occupancy class, residential buildings account for more than 95% of the total damaged buildings. In terms of building type, majority (over 95%) of the damaged buildings are wood structures.

Table 6. Expected Building Damage by Occupancy and by Building Type, 10-Yr Flood for 0.5 m Sea Level Rise Scenario

	Slight Damage		Moderate Damage		Substantial Damage		Total
	Count	%	Count	%	Count	%	Count
by Occupancy							
Residential	1	0	994	99	6	0	1,001
Commercial	0	0	7	100	0	0	7
Industrial	0	0	6	100	0	0	6
Other	0	0	0	0	0	0	0
by Building Type							
Concrete	0	0	4	100	0	0	4
ManufHousing	0	0	0	0	5	100	5
Masonry	0	0	8	100	0	0	8
Steel	0	0	4	100	0	0	4
Wood	1	0	978	100	1	0	980

Table 7. Expected Building Damage by Occupancy and by Building Type, 100-Yr Flood for 0.5 m Sea Level Rise Scenario

	Slight Damage		Moderate Damage		Substantial Damage		Total
	Count	%	Count	%	Count	%	Count
by Occupancy							
Residential	0	0	1,803	97	55	3	1,858
Commercial	3	13	20	87	0	0	23
Industrial	0	0	9	100	0	0	9
Other	0	0	0	0	0	0	0
by Building Type							
Concrete	1	7	14	93	0	0	15

ManufHousing	0	0	0	0	5	100	5
Masonry	0	0	23	100	0	0	23
Steel	0	0	7	100	0	0	7
Wood	0	0	1,763	97	49	3	1,812

Table 8. Expected Building Damage by Occupancy and by Building Type, 10-Yr Flood for 1.4 m Sea Level Rise Scenario

	Slight Damage		**Moderate Damage**		**Substantial Damage**		**Total**
	Count	**%**	**Count**	**%**	**Count**	**%**	**Count**
by Occupancy							
Residential	0	0	1,597	97	47	3	1,644
Commercial	0	0	16	94	1	6	17
Industrial	0	0	11	100	0	0	11
Other	0	0	0	0	0	0	0
by Building Type							
Concrete	0	0	11	100	0	0	11
ManufHousing	0	0	0	0	6	100	6
Masonry	0	0	17	100	0	0	17
Steel	0	0	7	100	0	0	7
Wood	0	0	1,564	98	40	2	1,604

Table 9. Expected Building Damage by Occupancy and by Building Type, 100-Yr Flood for 1.4 m Sea Level Rise Scenario

	Slight Damage		**Moderate Damage**		**Substantial Damage**		**Total**
	Count	**%**	**Count**	**%**	**Count**	**%**	**Count**
by Occupancy							
Residential	3	0	3,275	97	83	2	3,361
Commercial	4	4	80	89	6	7	90
Industrial	0	0	25	100	1	4	26
Other	1	0	5	0	0	0	6
by Building Type							
Concrete	2	4	46	96	0	0	48
ManufHousing	0	0	0	0	8	100	8
Masonry	1	2	48	96	1	2	50
Steel	0	0	22	100	0	0	22
Wood	3	0	3,203	98	74	2	3,280

The expected building damages in dollar values are estimated in HAZUS for each occupancy class. This is calculated by multiplying the percent damage of the buildings by the full replacement value of the buildings of the specific occupancy class. In addition, the losses caused by the damage of building contents and business inventory are also estimated. Table 10 presents the summary results of building losses for the study scenarios. Direct property losses with respect to buildings include: 1) building repair and replacement costs (including both structural and non-structural damage); 2) building contents losses; and 3) building inventory losses. In order to obtain a better assessment on the potential incremental building damages caused by flood events due to sea level rises, we also run the simulations assuming no sea level rise (which is referred to as the Base Case scenario in the table). Tables 11-16 present the building losses by general occupancy class for each individual scenario.

The direct building-related losses can be substantial. The results indicate that the expected general building losses increase with the increase in sea level and the severity of the flooding. For a 10-year flood event, the total building losses are $242.7 million in the Base Case. The losses increase to $410.3 million in the 0.5 m sea level rise scenario, and to $714.9 million in the 1.4 m sea level rise scenario. For a 100-yr flood event, the building losses increases from $588.6 million in the Base Case to $820.2 million and $1,441.3 million in the 0.5 m and 1.4 m sea level rise scenarios, respectively. Losses to residential buildings account for about 50% of the total losses. The other 50% losses are split evenly between the commercial buildings and the industrial buildings in all the scenarios except for the scenario of a 100-yr flood with 1.5 m sea level rise. For this scenario, the losses to the commercial buildings are over 60% higher than the losses to the industrial buildings.

Table 10. Summary Results of General Building Losses (millions of 2010$)

	Base Case		0.5 m Sea Level Rise		1.4 m Sea Level Rise	
Category	**10-Yr Flood**	**100-Yr Flood**	**10-Yr Flood**	**100-Yr Flood**	**10-Yr Flood**	**100-Yr Flood**
Building Losses	103.3	260.9	179.4	364.4	315.0	649.9
Content Losses	132.6	312.1	219.6	435.5	380.2	759.9
Inventory Losses	6.8	15.5	11.3	20.3	19.7	31.5
Total Building Losses	**242.7**	**588.6**	**410.3**	**820.2**	**714.9**	**1,441.3**

Table 11. General Building Losses, 10-Yr Flood for the Base Case (millions of 2010$)

Category	Residential	Commercial	Industrial	Others	Total
Building Losses	72.7	17.9	11.4	1.2	**103.3**
Content Losses	50.2	37.9	38.8	5.7	**132.6**
Inventory Losses	0.0	0.7	6.0	0.0	**6.8**
Total Building Losses	**122.9**	**56.5**	**56.3**	**6.9**	**242.7**

Table 12. General Building Losses, 100-Yr Flood for the Base Case (millions of 2010$)

Category	Residential	Commercial	Industrial	Others	Total
Building Losses	189.5	40.4	28.4	2.6	**260.9**
Content Losses	126.3	85.2	90.1	10.6	**312.1**
Inventory Losses	0.0	1.9	13.5	0.1	**15.5**
Total Building Losses	**315.8**	**127.5**	**132.0**	**13.3**	**588.6**

Table 13. General Building Losses, 10-Yr Flood for the 0.5 m Sea Level Rise Scenario (millions of 2010$)

Category	Residential	Commercial	Industrial	Others	Total
Building Losses	129.9	27.8	19.9	1.8	**179.4**

Content Losses	87.5	58.6	65.5	8.1	**219.6**
Inventory Losses	0.0	1.2	10.0	0.1	**11.3**
Total Building Losses	**217.4**	**87.6**	**95.4**	**10.0**	**410.3**

Table 14. General Building Losses, 100-Yr Flood for the 0.5 m Sea Level Rise Scenario (millions of 2010$)

Category	Residential	Commercial	Industrial	Others	Total
Building Losses	266.1	58.5	35.7	4.1	**364.4**
Content Losses	179.4	126.1	114.0	16.0	**435.5**
Inventory Losses	0.0	2.8	17.4	0.2	**20.3**
Total Building Losses	**445.5**	**187.4**	**167.0**	**20.2**	**820.2**

Table 15. General Building Losses, 10-Yr Flood for the 1.4 m Sea Level Rise Scenario (millions of 2010$)

Category	Residential	Commercial	Industrial	Others	Total
Building Losses	230.0	49.6	32.1	3.2	**315.0**
Content Losses	154.7	104.7	107.8	13.0	**380.2**
Inventory Losses	0.0	2.4	17.2	0.1	**19.7**
Total Building Losses	**384.8**	**156.7**	**157.2**	**16.3**	**714.9**

Table 16. General Building Losses, 100-Yr Flood for the 1.4 m Sea Level Rise Scenario (millions of 2010$)

Category	Residential	Commercial	Industrial	Others	Total
Building Losses	461.8	123.9	56.0	8.3	**649.9**
Content Losses	305.7	263.2	160.8	30.1	**759.9**
Inventory Losses	0.0	6.5	24.7	0.3	**31.5**
Total Building Losses	**767.5**	**393.7**	**241.5**	**38.7**	**1441.3**

Figures 2 to 5 present total building-related (including building, contents, and inventory) loss maps for the County and City of Los Angeles for the different scenarios in this study.

C. Business Interruption Losses

In addition to the building stock losses, immediate reduction or cessation of economic production will occur in a damaged factory building. If a firm has to stop or cut back its production because of the building damages from flooding, it will demand fewer inputs for their production. This in turn reduces the production of all of its suppliers, who in turn reduce their orders through a successive round of upstream demands. The direct business interruption losses also magnify themselves downstream along successive supply chains in a similar manner. The sum total of all these chain reactions is referred to as multiplier effects in the I-O analysis. When we compute the multiplier effects of the direct business interruption, we include not only the multiplier (ripple) effects of the direct losses taking place within the City, but also the indirect effects to the City stemming from the direct business losses to the coastal regions outside of the City but within the boundary of the LA County.

Table 17 presents the direct building-related output damages (direct business interruption losses) for each scenario simulated in this study. It presents the losses to both the City and Rest of County. The Rest of County results are needed to compute their indirect impacts to the City economy.

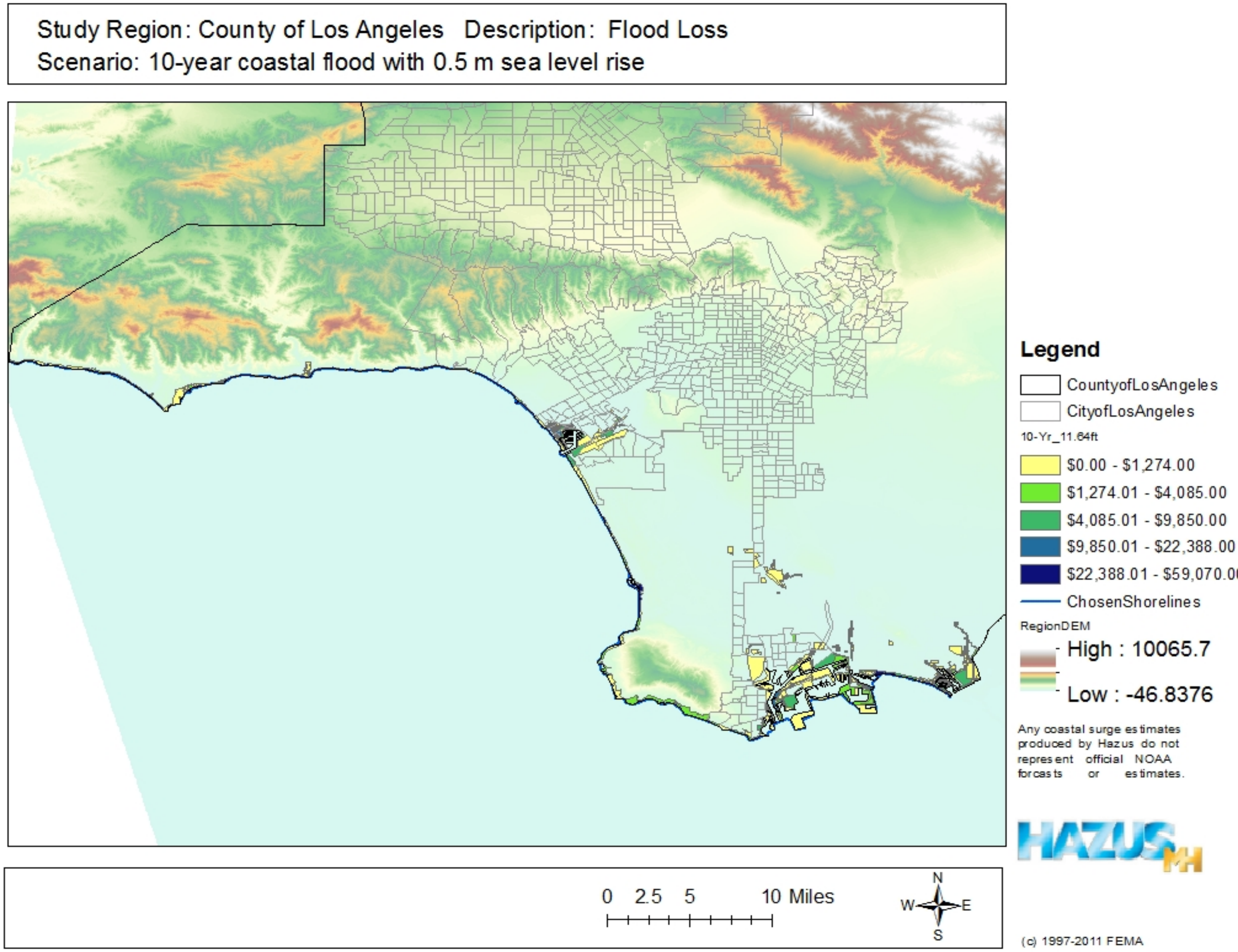

Figure 2. Building Losses for 10-year Coastal Flood with 0.5 Meter Sea Level Rise

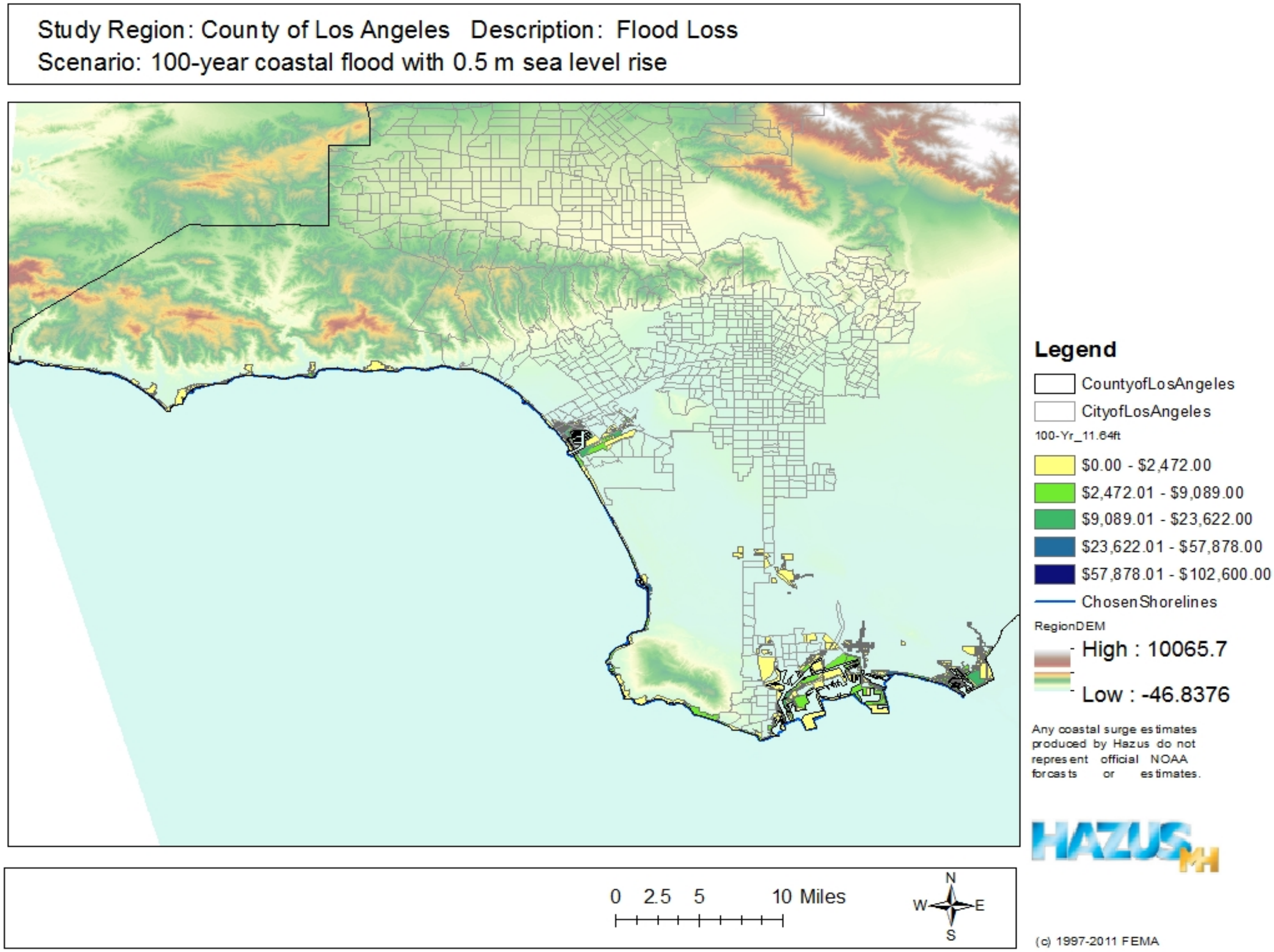

Figure 3. Building Losses for 100-year Coastal Flood with 0.5 Meter Sea Level Rise

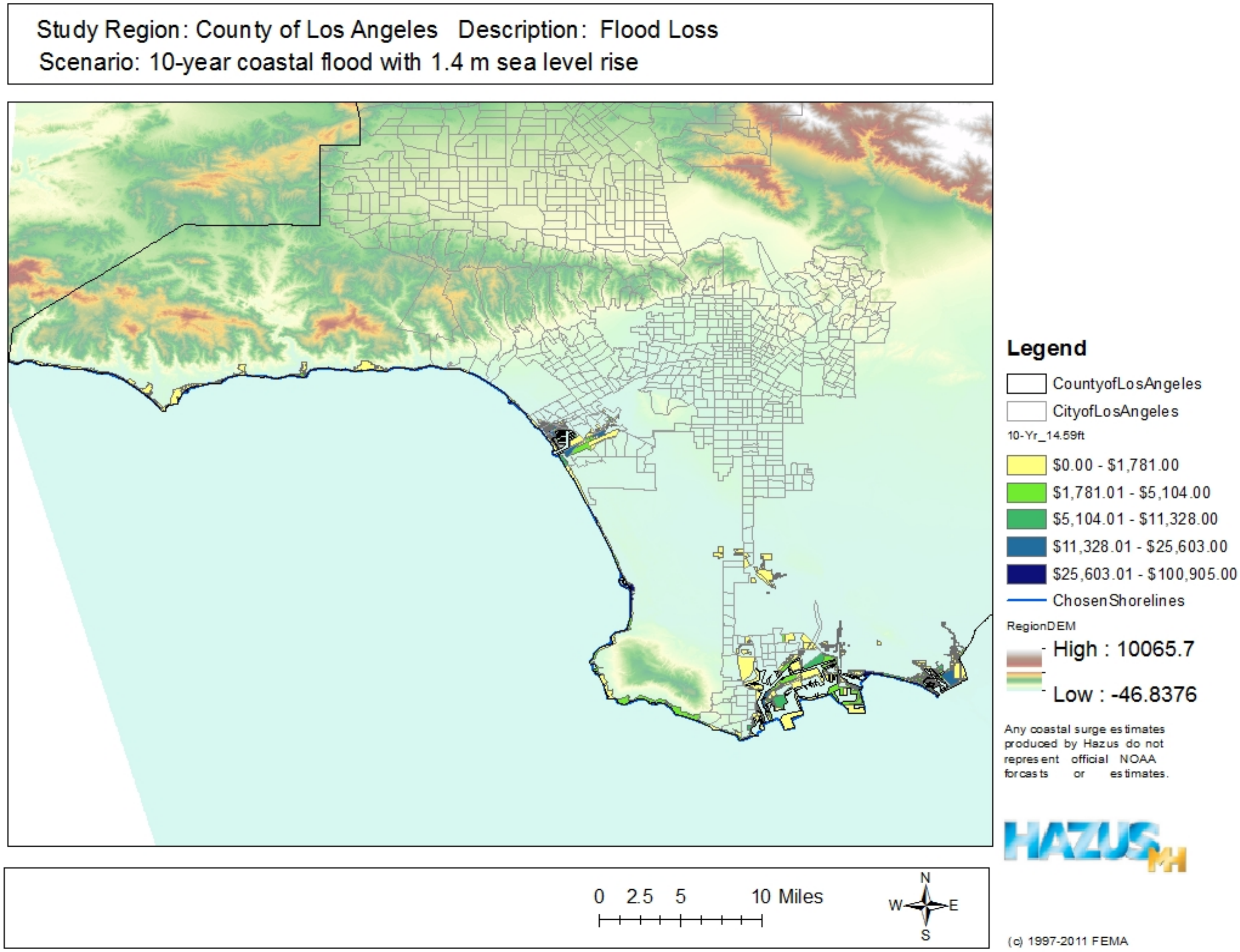

Figure 4. Building Losses for 10-year Coastal Flood with 1.4 Meter Sea Level Rise

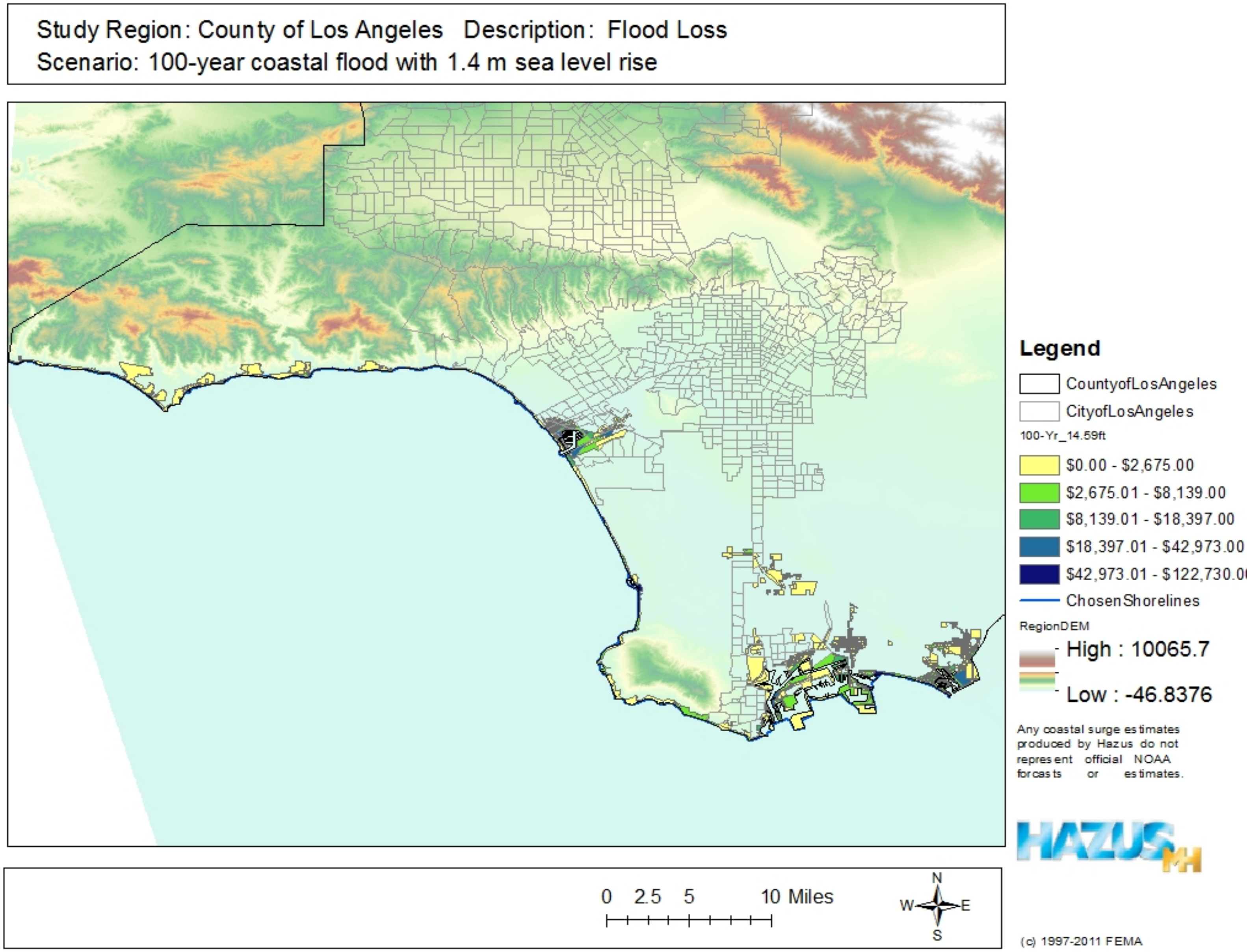

Figure 5. Building Losses for 100-year Coastal Flood with 1.4 Meter Sea Level Rise

Table 17. Direct Output Losses for Study Scenarios

Occupancy Class*	City of Los Angeles (thousand 2010$)						Rest of County of Los Angeles (thousand 2010$)					
	10-yr-Base Case	100-yr-Base Case	10yr-0.5m	100yr-0.5m	10yr-1.4m	100yr-1.4m	10-yr-Base Case	100-yr-Base Case	10yr-0.5m	100yr-0.5m	10yr-1.4m	100yr-1.4m
RES1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RES2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RES3A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RES3B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RES3C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RES3D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RES3E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RES3F	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RES4	38.7	65.6	50.5	84.9	80.6	128.0	410.7	583.4	531.2	724.7	623.6	1,515.0
RES5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RES6	0.0	0.0	0.0	0.0	0.0	1.1	5.4	6.5	6.5	7.5	6.5	10.8
COM1	7.5	32.3	26.9	49.5	40.9	129.0	63.4	175.5	94.6	184.9	182.8	282.8
COM2	60.2	155.9	103.2	232.2	191.4	501.1	44.1	176.7	115.0	315.0	249.4	538.7
COM3	74.2	146.2	129.0	262.4	194.6	663.4	111.8	290.7	195.7	459.1	346.2	782.8
COM4	123.6	254.8	209.7	395.7	311.8	819.3	365.6	666.5	509.7	839.7	791.4	1,304.2
COM5	4.3	8.6	5.4	15.1	8.6	31.2	15.1	39.8	20.4	53.8	40.9	101.1
COM6	3.2	10.8	10.8	22.6	12.9	226.9	0.0	0.0	0.0	0.0	0.0	8.6
COM7	45.2	134.4	102.1	171.0	175.3	396.8	173.1	345.6	261.3	473.1	402.1	861.2
COM8	131.2	284.9	240.8	468.8	367.7	938.7	793.5	1,485.6	1,076.3	1,823.6	1,640.8	2,467.6
COM9	0.0	0.0	0.0	0.0	0.0	0.0	23.7	85.0	52.7	98.9	82.8	121.5
COM10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IND1	2.2	3.2	2.2	4.3	4.3	14.0	0.0	5.4	3.2	21.5	11.8	35.5
IND2	1.1	2.2	2.2	3.2	3.2	8.6	0.0	0.0	0.0	0.0	0.0	5.4
IND3	61.3	138.7	101.1	182.8	196.8	230.1	0.0	2.3	0.0	8.6	2.2	10.8
IND4	0.0	0.0	0.0	1.1	0.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0
IND5	0.0	0.0	0.0	1.1	1.1	2.2	0.0	0.0	0.0	0.0	0.0	0.0
IND6	2.2	3.2	2.2	4.3	4.3	7.5	3.2	4.3	4.3	5.4	5.4	9.7
AGR1	1.1	3.2	2.2	4.3	3.2	5.4	0.0	1.1	0.0	5.4	3.2	7.5
REL1	65.6	162.4	150.5	258.1	202.1	479.5	300.0	612.6	520.4	851.6	752.7	1,516.1
GOV1	16.1	25.8	22.6	45.2	30.1	69.9	15.1	31.2	22.6	41.9	34.4	102.1
GOV2	22.6	39.8	32.3	47.3	44.1	119.3	43.0	90.4	75.3	124.7	107.5	207.5
EDU1	49.5	128.0	107.5	309.7	227.9	643.0	107.5	328.4	181.7	318.3	293.5	973.1
EDU2	19.4	31.2	29.0	45.2	35.5	87.1	1.1	16.2	18.3	35.5	17.2	406.4

* Please refer to Appendix Table B2 for the description of the occupancy classes.

The detailed steps adopted to compute the total business interruption losses are presented in Appendix D.

Table 18 presents the summary results of the total business interruption losses. Compared with the general building stock losses, losses caused by building-related business interruption are much smaller, only at the scale of about 1.3-1.5% of the building stock losses. One major reason is that over 95% of the damaged buildings are residential buildings, rather than buildings of producing sectors. Another important reason is that the HAZUS direct output loss estimation has taken into consideration the production recapture factor. Production recapture or rescheduling refers to the ability of businesses to recapture lost production by working overtime or extra shifts once their operational capability is restored. This is the most effective resilience measure that has been widely reported in the literature that can help reduce the potential business interruption losses in the aftermath of natural disasters. The third reason is that the flood events with the two sea level rise scenarios simulated in this study would only cause very limited impacts to the utility systems. According to our simulation, for the worst case scenario (the 100-yr flood event under the 1.5 m sea level rise scenario), there are only moderate damages to two wastewater treatment facilities and three oil refineries. As for the other critical lifeline facilities, including water, natural gas, and electricity, the simulations indicate no damages in all the scenarios.

The results in Table 18 indicates that for a 10-year flood event, the total output losses increases from $3.4 million in the Base Case to $5.8 million in the 0.5 m sea level rise scenario, and to $9.1 million in the 1.4 m sea level rise scenario. For a 100-yr flood event, the output losses increases from $7.4 million in the Base Case to $10.5 million in the 0.5 m and $21.9 million in the 1.4 m sea level rise scenarios. The impacts to income and employment have similar patterns across the scenarios.

Tables E1-E6 in Appendix E presents the business interruption losses by sector for each individual scenario.

Table 18. Summary of Business Interruption Losses

	Base Case		0.5 m Sea Level Rise		1.4 m Sea Level Rise	
Category	10-Yr Flood	100-Yr Flood	10-Yr Flood	100-Yr Flood	10-Yr Flood	100-Yr Flood
Output Losses (M 2010$)	$3.4	$7.4	$5.8	$10.5	$9.1	$21.9
Income Losses (M 2010$)	$2.3	$4.9	$3.8	$6.6	$5.9	$13.6
Employment Losses (Jobs)	24	52	41	74	64	158

D. Damages to Essential Facilities

The HAZUS model contains the dataset for essential facilities in the study area. These data, together with other inventory data, such as demographics, transportation systems, and lifeline systems, are used in the estimation of damages and direct economic losses related to general building stock. In addition, HAZUS also reports on the impact to the functionality of the essential facilities caused by the flood event.

Essential facilities, whose operation is essential to the daily life of the community, include hospitals, police stations, fire stations, and schools. The HAZUS Flood model determines the damage to the essential facilities based on the location of the facility and the depth of flooding (FEMA, 2011b).

Table 19 presents the expected damage to the essential facilities in the City for the two flood events under the two sea level rise scenarios. The numbers in the table represent the number of essential facilities being damaged at two different levels: moderately damaged or substantially damage. The results also show whether or not the facility loses functionality because of the damage. The results indicate that only a limited number of essential facilities would suffer damages from flooding in our simulated scenarios. For example, it estimated that only one fire station will experience at least moderate damage under the two simulated flood events. It will not be functional in the 100-yr flood event or in the 10-yr flood event under the 1.4 m sea level rise scenario.

Table 19. Expected Damage to Essential Facilities

	10-Yr Flood with 0.5 m Sea Level Rise			**100-Yr Flood with 0.5 m Sea Level Rise**		
	At Least Moderate	**At Least Substantial**	**Loss of Use**	**At Least Moderate**	**At Least Substantial**	**Loss of Use**
Fire Stations	1	0	0	1	0	1
Hospitals	1	0	1	1	0	1
Police Stations	0	0	0	0	0	0
Schools	0	0	0	1	0	1
	10-Yr Flood with 1.4 m Sea Level Rise			**100-Yr Flood with 1.4 m Sea Level Rise**		
	At Least Moderate	**At Least Substantial**	**Loss of Use**	**At Least Moderate**	**At Least Substantial**	**Loss of Use**
Fire Stations	1	0	1	1	0	1
Hospitals	1	0	1	2	0	1
Police Stations	0	0	0	1	0	1
Schools	1	0	0	4	0	4

E. Transportation System

The simulation results indicated that there are minimal impacts to the transportation system in the city. Therefore, we did not perform further economic impact analysis on the potential damages to the transportation system. A more in-depth analysis of the economic consequences of the potential damages to the transportation systems should be undertaken in future studies.

F. Debris Generation

HAZUS estimates induced damages from the flooding in terms of the generation of building-related debris. Major forms of estimates include flood-damaged building finishes (e.g., dry wall, insulation, carpet, etc.), structure components (e.g., wood, brick, etc.), and foundation materials (e.g., concrete slab, concrete block, etc.). The distinction among the three categories is made in the HAZUS model because different types of materials would require different handling equipment to clean up. HAZUS estimates the debris generation for each census block within the study region. The results are presented as the weight of debris in tons. Note that different from the HAZUS Earthquake Model, HAZUS Flood Model does not estimate debris generated from building contents or damage to non-building facilities (such as bridges or lifelines) (FEMA, 2011b). Table 20 summarizes the results of debris generation for different scenarios.

Table 20. Debris Generation

Category	Base Case		0.5 m Sea Level Rise		1.4 m Sea Level Rise	
	10-Yr Flood	100-Yr Flood	10-Yr Flood	100-Yr Flood	10-Yr Flood	100-Yr Flood
Finishes	68%	49%	53%	47%	48%	40%
Structure	20%	32%	29%	34%	33%	36%
Foundations	12%	19%	18%	19%	19%	24%
Total (tons)	19,575	62,725	40,549	96,007	78,420	204,579

E. Shelter Requirements

HAZUS also estimates the number of households that are expected to be displaced due to the flood (based on the location of the inundation areas and the demographic data) and the number of individuals that would seek public shelters in the short-term. Adjustment factors such as income and age are used as well to determine the need for government-provided shelters. For example, lower income people are more likely to use shelter. In addition, younger and less established families as well as elderly families are more likely to use shelter (FEMA, 2011b). The shelter requirement results are shown in Table 21.

Table 21. Shelter Requirements

Category	Base Case		0.5 m Sea Level Rise		1.4 m Sea Level Rise	
	10-Yr Flood	100-Yr Flood	10-Yr Flood	100-Yr Flood	10-Yr Flood	100-Yr Flood
Households Displaced	1,796	3,162	2,680	3,997	3,556	6,868
People Seeking Temporary Shelter	4,114	8,080	6,695	10,399	9,241	18,296

VIII. Conclusion

Sea level rise is among the most profound impacts of climate change. It can be caused by the melting of glacier and massive ice sheets around the world and the thermal expansion of the ocean when the average global temperature goes up. Since early 1990s, the annual average rate of global sea level rise was about 3 mm. Most modeling work has indicated that we will be experiencing more expedited sea level rise in the coming decades. A recent study by National Research Council (NRC) estimated that sea level rise for California coast can reach 0.12 to 0.61 m by 2050 and 0.42 to 1.67 m by 2100 (NRC, 2012).

This study analyzes the potential economic impacts of coastal floods, whose impacts can be greatly amplified by sea level rises. Two sea level rise scenarios are evaluated: 1) 0.5 meters sea level rise by 2050; and 2) 1.4 meter sea level rise by 2100. These two scenarios are consistent with those used in the California Energy Commission's Public Interest Energy Research (PIER) Climate Change Research Program and the ones used in a recent USGS study focusing on the sea level rise impacts to the Southern California coast.

Two advanced modeling tools are applied in this study. Hazards-United States Multihazard (HAZUS-MH) 2.1, the FEMA standardized modeling tool for estimating potential losses from hazards, is used to evaluate the direct losses to building stock and the direct output (business interruption) losses in the flooding affected region. Other impacts such as damage to essential facilities, transportation system, and utility system are also evaluated by HAZUS. The Input-Output (I-O) model, one of the most widely used tool of regional impact analysis, is then applied to calculate the total business interruption losses based on the direct building-related output loss estimates from the HAZUS model.

The results show that with a 0.5 m sea level rise, $2.7 to $3.4 billion of building stock in the City will be at risk to coastal flood events. With a 1.4 m sea level rise, $3.3 billion to $4.5 billion of building stock will be at risk. For a 10-yr flood event, the direct building losses are expected to be $410.3 million with 0.5 m sea level rise, and nearly doubled with 1.4 m sea level rise. For a 100-yr flood event, the building losses increase from $820.2 million to $1,441 million when sea level rises from 0.5 m to 1.4 m. Losses to residential buildings comprise about 50% of the total losses. The other 50% losses are split evenly between the commercial buildings and industrial buildings in most simulated scenarios.

The business interruption losses are relatively small compared with the building stock losses. For a 10-yr flood event, the total output losses in the City are expected to be $5.8 million to $9.1 million under the two simulated sea level rise scenarios. For a 100-yr flood event, the total output losses are expected to be $10.5 to $21.9 million. The major reason of the relatively low business interruption losses caused by the coastal flood events is that over 95% of the damaged buildings are residential buildings, rather than the buildings of producing sectors.

Our simulation shows that the transportation system and the utility system in the City would suffer very limited damages from the flooding in the scenarios evaluated in this study.

Our estimates on the potential economic impacts of sea level rise to the City should be considered on the conservative side. The analysis only focuses on the potential impacts from the temporary flooding in the coastal area due to extreme coastal storms, and how those impacts can be amplified by sea level rise. Any impacts caused by long-term and permanent coastal erosion and beach area losses of sea level rise are not covered in this study.

References:

Applied Technology Council (ATC). 1991. Seismic Vulnerability and Impacts of Disruptions of Utility Lifelines in the Coterminous United States, report ATC-25. Redwood, CA: Applied Technology Council.

Bromirski, P. D., Cayan, D. R., Graham, N., Tyree, M., and Flick, R. E. 2012. *Coastal Flooding-Potential Projections: 2000–2100*. Report prepared for California Energy Commission by Scripps Institution of Oceanography. Publication number: CEC-500-2012-011.

Cayan, D., Tyree, M., Dettinger, M., Hidalgo, H., Das, T., Maurer, E., Bromirski, P., Graham, N., and Flick, R. 2009. *Climate Change Scenarios and Sea Level Rise Estimates for California 2008 Climate Change Scenarios Assessment*. California Climate Change Center. CEC ‐ 500 ‐ 2009 ‐ 014 ‐ F.

Environmental Protection Agency (EPA). 1989. *The Potential Effects of Global Climate Change on the United States.* Report to Congress. Appendix B: Sea Level Rise. Washington, D.C.: U.S. Environmental Protection Agency. EPA 230-05-89-052.

European Union. 2003. *Proceedings of the Joint NEDEIS and University of Twente Workshop: In Search of a Common Methodology for Damage Estimation*, Bruxelles: Office for Official Publications of the European Communities.

FEMA. 2011a. HAZUS-MH Flood Model User Manual. Available at: http://www.fema.gov/library/viewRecord.do?id=5120.

FEMA. 2011b. HAZUS-MH Flood Model Technical Manual. Available at: http://www.fema.gov/library/viewRecord.do?id=5120.

FEMA. 2012. *Introduction of HAZUS-MH Software*. Available at: http://www.fema.gov/protecting-our-communities/hazus#3Rose, A., Wei, D. and A. Wein. 2011. "Economic Impacts of the ShakeOut Scenario," *Earthquake Spectra* 27(2): 539-57.

Heinz Center. 2000. *Evaluation of Erosion Hazards*. Report prepared for the Federal Emergency Management Agency. Washington, D.C.

Intergovernmental Panel on Climate Change (IPCC). 2001. *Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Third Assessment Report of the IPCC. http://www.grida.no/publications/other/ipcc_tar/.

Intergovernmental Panel on Climate Change (IPCC). 2007. *Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the IPCC. http://www.ipcc.ch/publications_and_data/ar4/wg2/en/contents.html.

Matthew Heberger, Heather Cooley, Pablo Herrera, Peter H. Gleick, and Eli Moore of the Pacific Institute. *The Impacts of Sea-Level Rise on the California Coast*. California Climate Change Center. CEC-500-2009-024-F.

Michael, J.A., Sides, D.A., and Sullivan, T.E. 2003. *The Economic Cost of Sea Level Rise to Three Chesapeake Bay Communities*. Towson University, Maryland.

Minnesota IMPLAN Group (MIG). 2012. *Impact Analysis for Planning (IMPLAN) System*, Hudson, WI.

National Research Council (NRC). 2005. *Improved Seismic Monitoring--Improved Decision-Making: Assessing the Value of Reduced Uncertainty*, Washington, DC: National Academy Press.

National Research Council (NRC). 2012. *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*. The National Academies Press, Washington, D.C.

NBA News. 2010. *San Pedro, Long Beach Hit Hard by Storm*. http://www.nbclosangeles.com/news/local/San-Pedro-Long-Beach-Hit-Hard-by-Storm-82198537.html.

Nordhaus, W.D. 1991. "To Slow or Not To Slow," *Economic* 5: 920-927.

Pendleton, L, King, P. , Mohn, C., Webster, D.G. , Vaughn, R. and Adams, P.N. 2011. "Estimating the Potential Economic Impacts of Climate Change on Southern California Beaches," *Climatic Change* 109(1): 277-298.

Rose, A. 2004. Economic Principles, Issues, and Research Priorities of Natural Hazard Loss Estimation, in Y. Okuyama and S. Chang (eds.) Modeling of Spatial Economic Impacts of Natural Hazards, Heidelberg: Springer.

Rose, A. and D. Lim. 2002. "Business Interruption Losses from Natural Hazards: Conceptual and Methodology Issues in the Case of the Northridge Earthquake," *Environmental Hazards: Human and Social Dimensions* 4: 1-14.

Rose, A. and Wei, D. 2011. *Measuring Economic Risk Benefits of USCG Marine Safety Programs*. Final Report to U.S. Coast Guard.

Rose, A. et al. 2007. "Benefit-Cost Analysis of FEMA Hazard Mitigation Grants," *Natural Hazards Review* 8(4): 97-111.

Rose, A., Wei, D. and A. Wein. 2011. "Economic Impacts of the ShakeOut Scenario," *Earthquake Spectra* 27(2): 539-57.

West, J.J., Small, M.J., and Dowlatabadi, H. 2001. "Storms, Investor Decisions, and the Economic Impacts of Sea-Level Rise," *Climatic Change* 48: 317-342.

William, S.V. and Zervas, C. 2011. "Cool-Season Sea Level Anomalies and Storm Surges along the U.S. East Coast: Climatology and Comparison with the 2009/10 El Niño," *Monthly Weather Review* 139(7): 2290–2299.

Yohe, G .W. and Schlesinger, M.E. 1998. "Sea Level Change: the Expected Economic Cost of Protection or Abandonment in the United States," *Climatic Change* 38: 447–472.

Yohe, G.W., Neumann, J., Marshall, P., and Ameden, H. 1996. "The Economic Cost of Greenhouse-Induced Sea-Level Rise for Developed Property in the United States," *Climatic Change* 32: 387–410.

Zhang, K.Q., Douglas, B.C., and Leatherman, S.P. 2000. "Twentieth-Century Stormactivity along the US East Coast," *Journal of Climate* 13(10): 1748-1761.

Appendix A. Coastal Flood Modeling using HAZUS-MH Flood Tool

Hazards-United States Multihazard (HAZUS-MH) is a Geographic Information Systems (GIS)-based modeling platform to estimate physical, economic, and social impacts of natural disasters. HAZUS-MH Flood 2.1, Federal Emergency Management Agency (FEMA)'s standardized methodology and modeling tool for estimating potential losses from floods, is utilized to estimate potential building stock damages in the event of 10- and 100-yr coastal flood scenarios impacting the County and City of Los Angeles. The modeling tool is also useful for analyzing the effects of sea-level rise (0.5 and 1.4 meter) to the County and City of Los Angeles communities.

The first step in the modeling process is the creation of the study region, the County of Los Angeles, using the aggregation level of census block. The entire County results are needed because when we calculate the indirect business interruption losses, we not only take into account the multiplier (ripple) effects of the direct business interruption losses taking place within the City, but also the indirect effects to the City stemming from the losses to the coastal communities that are outside of the City but within the boundary of the LA County. Flood hazard is chosen as the hazard of concern. In this step, HAZUS-MH assembles data about the chosen built environment. The default inventory using HAZUS-MH default data was utilized in this study. The study region is opened thereafter in an ArcGIS Editor that contains the HAZUS-MH tool set including inventory, hazard, analysis, and results tabs.

A coastal flood hazard type is chosen next within the hazard tab. The terrain is created using a Digital Elevation Model (DEM) which is a 3D representation of a terrain's surface. The geographical extent of the DEM is computed using the extent calculator tool within HAZUS-MH. The default National Elevation Dataset (NED) with spatial resolution of 1 arc-second or 30 meters from the United States Geological Survey (USGS) was used for this analysis. HAZUS then creates the DEM grid and the hillshade from the user data.

A new scenario is created thereafter, where shoreline extent selection and still water elevation data were needed. The default shoreline for the County region was used. FEMA's 2008 Flood Insurance Study (FIS) for Los Angeles County was used to identify the 100-year (or 1-percent annual chance) still water elevation of 10 feet, without wave setup information, for flooding from the Pacific Ocean at the San Pedro Bay. 100-year still water elevations of 11.64 feet and 14.59 feet were used to represent the 0.5 and 1.4 meter sea-level rise scenarios. The still water levels for floods with other return periods (10-, 50-, and 500-year) are computed by HAZUS based on the 100-year still water level.

The next step in the analysis is to delineate the floodplain. Return period of 10 and 100 year floods were chosen for raster processing. The result of this step is a delineated flood plain boundary and a raster grid of the flood elevation.

The analysis tab allows the user to select potential loss modules including building stock, essential facilities, and transportation and utility systems. For building-related losses, the results tab contains information pertaining to the building stock losses and direct output losses by specific occupancy classes.

These direct output losses, from the six user-defined scenarios, for 33 different occupancy classes were extracted from HAZUS-MH and utilized further within the Input-Output (I-O) analysis.

Appendix B. I-O Model Sectors and Correspondence to HAZUS Occupancy Classes

Table B1. I-O Model Sectoring Scheme

	Sea Level Rise I-O Model Sector	IMPLAN Sector	HAZUS Occupancy Class
1	Agriculture, Forestry and Fishing	1-19	AGR1
2	Mining, Quarrying, and Oil and Gas Extraction	20-30	IND4
3	Electric Utilities	31; 428; 431	COM4
4	Gas Utilities	32	COM4
5	Water and Wastewater Utilities	33	COM4
6	Construction	34-40	IND6
7	Food Manufacturing	41-69	IND3
8	Beverage and Tobacco Product Manufacturing	70-74	IND3
9	Chemical Manufacturing	115-141	IND3
10	Nonmetallic Mineral/Metals Processing & Manufacturing	153-180	IND4
11	High Technology	192; 209; 211; 234-256; 284-288; 305-308; 345; 350; 352-353	IND5
12	Other Heavy Industry	181-191; 193-208; 210; 212-215; 217-233; 276-283; 289-294	IND1
13	Other Light Industry	75-114; 142-152; 216; 257-275; 295-304; 309-318; 341-344	IND2
14	Air Transportation	332	COM4
15	Rail Transportation	333	COM4
16	Water Transportation	334	COM4
17	Truck Transportation	335	COM4
18	Transit and ground passenger transportation	336	COM4
19	Other Transportation and Warehousing	337-340	COM4
20	Wholesale Trade	319	COM2
21	Retail Trade	320-331	COM1
22	Banks & Financial Institutions	354-359	COM5
23	Telecommunications	351	IND2
24	Professional & Technical Services	362-390	COM4
25	Education Services	391-393	EDU1 & EDU2
26	Medical Office/Clinic	394-396	COM7
27	Hospitals	397	COM6
28	Nursing and Residential Care Facilities	398	RES6
29	Hotels	411-412	RES4
30	Entertainment & Recreation	346-349; 402-410; 413	COM8 & COM9
31	Other Services	399-401; 414-426	COM3, COM10, REL1
32	Gov't & Non-NAICS	427; 429-430; 432-440	GOV1 & GOV2
33	Real Estate	360	RES3
34	Owner-occupied dwellings	361	RES1, RES2, RES5

Table B2. Description of HAZUS Occupancy Classes

No.	Label	Occupancy Class	Description
		Residential	
1	RES1	Single Family Dwelling	Detached House
2	RES2	Mobile Home	Mobile Home
3-8	RES3a-f	Multi Family Dwelling	Apartment/Condominium
9	RES4	Temporary Lodging	Hotel/Motel
10	RES5	Institutional Dormitory	Group Housing (military, college), Jails
11	RES6	Nursing Home	
		Commercial	
12	COM1	Retail Trade	Store
13	COM2	Wholesale Trade	Warehouse
14	COM3	Personal and Repair Services	Service Station/Shop
15	COM4	Professional/Technical Services	Offices
16	COM5	Banks/Financial Institutions	
17	COM6	Hospital	
18	COM7	Medical Office/Clinic	Offices
19	COM8	Entertainment & Recreation	Restaurants/Bars
20	COM9	Theaters	Theaters
21	COM10	Parking	Garages
		Industrial	
22	IND1	Heavy	Factory
23	IND2	Light	Factory
24	IND3	Food/Drugs/Chemicals	Factory
25	IND4	Metals/Minerals Processing	Factory
26	IND5	High Technology	Factory
27	IND6	Construction	Office
		Agriculture	
28	AGR1	Agriculture	
		Religion/Non-Profit	
29	REL1	Church	
		Government	
30	GOV1	General Services	Office
31	GOV2	Emergency Response	Police/Fire Station
		Education	
32	EDU1	Schools	
33	EDU2	Colleges/Universities	Does not include group housing

Source: FEMA (2011b)

Appendix C. Los Angeles City 2010 Input-Output Table

(in million 2010$)

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21
01. Agriculture, Forestry and Fishing	0.3	0.0	0.0	0.0	0.0	0.2	14.0	0.9	0.2	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
02. Mining, Quarrying, and Oil and Gas Extraction	0.1	4.0	20.2	164.6	0.0	11.7	1.3	0.2	582.4	10.5	2.4	1.4	6.9	1.4	0.1	0.0	0.4	0.0	3.4	0.5	0.4
03. Electric Utilities	0.5	1.2	0.2	0.2	0.0	9.7	20.9	3.9	52.8	10.6	18.8	7.9	40.3	0.5	0.0	0.4	0.8	0.3	7.4	14.4	44.4
04. Gas Utilities	0.7	3.7	0.4	4.3	0.0	13.7	81.7	8.5	317.9	33.4	22.0	17.5	102.4	0.2	0.0	0.7	1.3	0.1	12.1	18.6	23.5
05. Water and Wastewater Utilities	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
06. Construction	1.0	14.1	35.0	3.4	1.0	14.3	34.3	5.0	108.8	16.1	45.3	20.1	78.5	1.3	20.6		2.0	0.3	45.0	26.4	73.6
07. Food Manufacturing	6.3	0.0	0.5	0.0	0.0	2.2	878.2	235.3	47.9	1.0	1.8	0.4	29.1	2.2	0.1	0.2	0.5	0.0	0.6	5.3	3.7
08. Beverage and Tobacco Product Mft	0.0	0.0	0.0	0.0	0.0	0.0	3.4	7.9	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
09. Chemical Manufacturing	15.2	9.4	19.7	6.4	0.1	556.9	94.8	25.2	5,420.4	37.9	316.9	97.2	1,593.4	465.0	16.0	0.1	138.8	11.8	150.5	105.5	49.2
10. Nonmetallic Mineral/Metals Processing & Mft	0.0	0.6	0.1	1.3	0.0	50.1	1.8	17.5	10.2	41.4	37.5	55.8	44.9	0.3	0.4	0.0	0.1	0.0	0.3	1.8	1.3
11. High Technology	0.1	0.8	1.3	3.7	0.0	61.2	10.6	38.8	127.2	24.2	3,003.6	116.9	252.2	68.5	0.6	0.6	3.3	0.5	16.7	71.6	51.0
12. Other Heavy Industry	0.7	7.4	4.0	17.3	0.0	327.0	39.5	50.3	73.8	21.4	173.5	568.2	159.2	9.6	6.1	16.7	24.6	9.3	21.9	36.7	53.4
13. Other Light Industry	0.8	3.1	1.8	11.6	0.0	465.6	158.9	85.3	201.4	19.8	263.8	139.3	1,081.9	7.7	3.4	1.3	12.4	1.4	24.2	118.4	120.6
14. Air Transportation	0.1	0.2	0.4	1.1	0.0	8.1	7.6	1.2	11.6	1.7	20.8	5.0	18.6	0.1	0.1	0.4	2.6	0.0	3.0	12.3	3.8
15. Rail Transportation	0.5	1.2	14.2	1.7	0.0	12.2	49.9	6.3	51.8	17.4	7.8	7.6	50.5	1.0	1.0	0.1	12.9	0.1	0.6	1.7	1.5
16. Water Transportation	0.1	0.1	0.3	0.0	0.0	2.5	10.7	0.6	4.8	1.2	0.6	0.4	1.0	1.6	0.1	0.0	0.4	0.0	0.6	0.3	0.1
17. Truck Transportation	1.4	2.0	2.2	2.6	0.0	95.3	122.7	22.9	104.3	32.0	57.1	31.6	122.3	5.2	1.2	1.5	53.1	0.8	11.1	29.3	64.4
18. Transit and Ground Passenger Transportation	0.0	0.0	0.1	0.7	0.0	2.1	1.3	0.2	1.7	0.4	6.2	1.4	4.7	0.0	1.3	0.0	0.0		0.1	1.7	0.8
19. Other Transportation and Warehousing	0.6	1.1	14.9	234.0	0.0	15.6	30.8	5.8	134.0	10.0	58.2	14.4	103.7	228.1	3.1	40.8	103.9	1.4	168.9	296.2	267.2
20. Wholesale Trade	3.8	3.6	3.1	7.2	0.0	258.9	330.0	75.9	644.7	71.3	606.3	200.5	527.9	23.9	3.4	1.0	19.9	1.8	22.1	333.1	135.3
21. Retail Trade	0.1	0.5	0.1	0.2	0.0	338.0	3.4	6.5	51.0	0.3	14.4	14.0	13.9	0.2	0.1		9.0	0.4	4.9	10.2	30.3
22. Banks & Financial Institutions	4.2	7.0	12.3	48.7	0.1	144.9	47.7	7.0	75.3	16.7	177.4	49.9	148.8	60.3	25.7	13.8	70.0	10.0	56.8	286.1	447.0
23. Telecommunications	0.1	0.7	1.6	1.9	0.0	71.3	15.3	3.8	28.7	5.5	149.7	19.2	67.9	27.9	0.4	1.2	9.6	1.2	16.2	79.1	98.2
24. Professional & Technical Services	2.2	47.9	33.7	59.3	0.7	1,031.5	447.4	127.6	1,695.6	96.8	1,927.0	313.5	1,031.8	197.8	32.2	21.2	110.7	16.2	224.0	1,189.4	1,136.3
25. Education Services	0.6	0.0	0.5	2.5		0.4	0.0	0.0	0.2	0.0	0.1	0.0	0.7	0.3	0.2				0.2	6.3	30.4
26. Medical Office/Clinic																					
27. Hospitals																					
28. Nursing and Residential Care Facilities																					
29. Hotels	0.0	0.2	0.7	1.8	0.0	11.1	6.6	0.9	8.4	1.9	31.1	6.8	23.8	0.2	0.1	0.1	0.1	0.2	2.9	7.6	3.6
30. Entertainment & Recreation	0.2	3.2	10.6	8.1	0.0	84.0	44.6	9.6	126.5	10.9	193.8	33.8	117.6	104.2	3.6	1.4	8.0	1.3	20.4	122.8	144.4
31. Other Services	0.4	0.7	1.4	7.7	0.1	159.8	29.1	4.1	72.0	13.1	49.9	18.5	76.3	2.6	1.1	0.2	13.6	2.9	27.2	86.0	91.9
32. Gov't & Non-NAICS	0.8	2.4	3.8	15.6	0.0	16.0	35.2	10.2	270.8	110.3	113.1	32.0	156.6	255.6	1.8	51.3	44.9	1.8	70.8	201.7	106.3
33. Real Estate	7.3	1.5	3.3	8.4	0.1	56.1	33.1	6.8	33.4	5.0	107.4	21.5	99.6	41.4	0.6	12.2	16.2	0.1	66.9	181.3	592.4
34. Owner-occupied Dwellings																					
Employee Compensation	50.5	312.1	343.1	456.2	2.2	3,308.0	935.8	236.5	1,225.1	300.6	5,426.0	1,600.9	4,319.8	1,157.6	144.0	66.8	520.2	214.4	2,251.0	6,862.3	6,285.4
Proprietary Income	64.5	140.9	3.5	90.8	1.0	1,510.0	117.9	62.8	228.4	20.3	281.3	20.6	151.9	-6.8	-0.1	2.2	437.2	74.2	360.3	1,230.5	970.5
Other Property Income	3.8	216.0	295.6	962.9	5.2	1,103.2	639.6	151.5	3,413.3	156.9	3,831.9	808.5	1,685.9	422.8	73.4	95.8	157.4	93.7	602.7	3,524.8	767.6
Indirect Business Taxes	3.4	57.0	16.6	372.3	0.9	85.2	25.4	177.6	88.5	15.8	207.4	48.7	159.7	387.9	6.3	14.8	25.0	15.9	147.7	3,130.2	2,421.7
Other	0.2	0.6	0.5	2.8	0.0	25.7	16.2	7.2	58.0	16.4	68.7	19.2	69.5	37.0	0.5	7.1	6.9	0.3	10.6	33.4	21.4
Foreign Trade	6.7	27.1	111.3	900.0	0.0	528.9	429.8	148.5	3,249.8	173.8	643.7	446.4	765.7	23.1	5.0	8.5	18.5	4.6	40.1	80.9	86.9
Domestic Trade	47.0	56.6	130.1	889.0	0.4	2,019.5	2,877.5	841.3	4,452.6	525.0	3,214.9	1,580.5	3,065.3	380.6	38.9	66.4	218.6	27.5	328.6	990.7	1,354.7
Gross Output	**223.8**	**927.0**	**1,087.3**	**4,288.7**	**12.0**	**12,400.7**	**7,597.1**	**2,393.6**	**22,973.8**	**1,819.8**	**21,080.5**	**6,319.6**	**16,174.4**	**3,909.3**	**390.8**	**426.9**	**2,042.9**	**492.6**	**4,719.7**	**19,097.3**	**15,483.5**

Los Angeles City 2010 Input-Output Table (continued)

	22	23	24	25	26	27	28	29	30
01. Agriculture, Forestry and Fishing	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	2.1
02. Mining, Quarrying, and Oil and Gas Extraction	0.2	0.4	4.4	0.3	2.0	0.8	0.2	0.2	4.5
03. Electric Utilities	12.9	5.6	50.9	22.3	9.4	16.2	5.0	13.9	160.5
04. Gas Utilities	12.2	23.2	51.8	83.0	7.3	5.0	6.2	13.8	149.0
05. Water and Wastewater Utilities	0.1	0.1	0.2	0.7	0.0	0.1	0.0	0.1	0.5
06. Construction	284.3	115.2	195.9	8.8	27.9	16.6	8.8	29.4	193.9
07. Food Manufacturing	0.2	0.1	19.3	64.3	1.8	76.3	24.7	10.1	1,568.4
08. Beverage and Tobacco Product Mft	0.0	0.0	0.1	0.6	0.0	0.8	0.2	0.1	26.2
09. Chemical Manufacturing	40.9	27.5	602.9	23.6	467.8	262.0	21.9	12.5	224.7
10. Nonmetallic Mineral/Metals Processing & Mft	0.3	1.6	6.1	0.4	2.4	0.8	0.2	0.1	17.0
11. High Technology	138.6	151.9	378.1	65.7	148.4	67.3	8.8	6.6	154.0
12. Other Heavy Industry	5.3	23.5	100.4	11.7	5.5	2.3	0.4	2.7	147.3
13. Other Light Industry	140.0	55.5	350.6	39.0	90.3	56.5	13.1	26.4	580.0
14. Air Transportation	60.6	8.3	82.5	5.0	10.7	1.2	0.7	1.6	45.4
15. Rail Transportation	0.7	2.3	9.4	0.6	2.4	2.2	0.2	0.2	20.9
16. Water Transportation	0.1	0.1	28.6	0.0	0.1	0.2	0.0	0.0	1.3
17. Truck Transportation	8.3	6.4	56.7	7.2	22.0	13.9	2.6	2.3	146.4
18. Transit and Ground Passenger Transportation	30.8	4.3	42.0	3.0	5.9	1.5	1.1	1.0	41.3
19. Other Transportation and Warehousing	72.4	15.5	184.9	10.6	27.6	14.1	2.3	4.7	123.7
20. Wholesale Trade	38.5	32.4	245.7	40.2	137.5	78.3	15.3	6.0	695.8
21. Retail Trade	13.5	0.7	18.6	0.4	15.3	14.1	1.3	0.7	89.3
22. Banks & Financial Institutions	8,158.2	103.7	1,376.5	53.2	394.2	157.9	49.4	47.9	974.6
23. Telecommunications	549.1	735.7	679.8	33.4	87.8	30.9	7.9	15.1	259.7
24. Professional & Technical Services	3,166.7	738.8	5,533.7	284.2	1,009.4	421.9	113.0	254.1	3,936.4
25. Education Services	1.9	6.5	4.6	14.2	0.8	1.6			14.3
26. Medical Office/Clinic			4.1		219.7	118.4	0.2		3.4
27. Hospitals			0.0		1.3	6.5	0.0		0.0
28. Nursing and Residential Care Facilities									
29. Hotels	151.8	19.9	167.8	9.7	21.5	2.7	1.2	3.4	86.0
30. Entertainment & Recreation	614.4	500.8	1,038.6	69.8	171.1	53.0	32.6	62.3	3,668.3
31. Other Services	398.6	73.0	455.8	39.7	90.4	60.4	9.8	24.1	386.1
32. Gov't & Non-NAICS	910.1	141.0	387.3	102.2	54.3	37.7	7.5	31.7	450.2
33. Real Estate	652.9	94.8	1,038.7	322.3	327.5	478.9	65.2	24.9	1,377.1
34. Owner-occupied Dwellings									
Employee Compensation	10,659.0	1,558.5	24,837.3	2,811.6	5,583.9	3,766.5	1,023.3	621.2	20,156.7
Proprietary Income	719.2	37.5	8,172.3	116.8	1,697.2	73.9	72.3	50.6	2,120.8
Other Property Income	6,812.0	3,216.5	13,357.0	-277.4	462.9	264.4	78.9	371.1	13,641.4
Indirect Business Taxes	739.5	598.3	1,714.6	123.4	146.7	109.2	85.1	174.3	2,122.2
Other	133.1	23.9	72.5	7.7	16.7	10.5	1.4	4.7	89.4
Foreign Trade	118.9	56.8	263.4	36.0	70.5	40.8	9.1	15.0	531.8
Domestic Trade	5,628.4	1,144.8	4,212.0	535.8	981.1	696.9	152.2	210.7	6,567.2
Gross Output	**40,273.6**	**9,525.1**	**65,745.3**	**4,670.0**	**12,321.5**	**6,962.4**	**1,821.7**	**2,043.4**	**60,777.7**

	31	32	33	34	Household	Government	Other	Foreign Trade	Domestic Trade	Gross Output
01. Agriculture, Forestry and Fishing	0.0	0.0	0.1	0.0	7.6	0.1	0.0	34.9	161.2	**223.8**
02. Mining, Quarrying, and Oil and Gas Extraction	1.7	16.8	0.5	0.6	21.2	1.6	24.6	33.8	1.1	**927.0**
03. Electric Utilities	26.3	12.7	51.1	0.0	429.3	14.3	0.0	0.2	21.3	**1,087.3**
04. Gas Utilities	29.2	85.1	22.1	0.0	741.8	46.2	0.0	2.4	2,347.8	**4,288.7**
05. Water and Wastewater Utilities	0.2	0.5	0.2		7.3	1.4	0.0	0.1	0.0	**12.0**
06. Construction	110.4	371.6	169.3	281.9	0.0	1,403.4	8,331.8	0.7	304.8	**12,400.7**
07. Food Manufacturing	37.1	19.2	0.1	0.1	3,451.2	36.7	22.2	404.9	645.2	**7,597.1**
08. Beverage and Tobacco Product Mft	0.3	0.2	0.0		104.2	0.2	0.3	59.2	2,189.6	**2,393.6**
09. Chemical Manufacturing	130.6	211.6	15.6	23.6	7,164.5	329.4	1,709.4	2,514.1	60.7	**22,973.8**
10. Nonmetallic Mineral/Metals Processing & Mft	4.3	7.6	0.5	1.7	19.6	3.8	3.4	224.7	1,259.8	**1,819.8**
11. High Technology	118.8	31.8	16.5	4.9	2,191.6	464.8	4,034.5	2,295.3	6,949.1	**21,080.5**
12. Other Heavy Industry	177.9	69.7	2.4	11.4	1,010.8	118.9	594.4	863.3	1,551.1	**6,319.6**
13. Other Light Industry	223.0	109.4	26.0	55.9	2,402.0	163.1	528.9	1,596.4	6,995.5	**16,174.4**
14. Air Transportation	18.5	8.6	4.8	0.1	647.4	20.7	7.9	987.6	1,898.9	**3,909.3**
15. Rail Transportation	3.2	7.2	0.8	1.0	38.2	5.9	3.9	52.0	0.0	**390.8**
16. Water Transportation	0.1	1.7	0.0	0.1	48.7	6.9	0.3	297.2	16.2	**426.9**
17. Truck Transportation	45.8	29.9	1.8	8.1	536.3	28.0	137.7	226.4	0.0	**2,042.9**
18. Transit and Ground Passenger Transportation	7.5	4.8	3.8		207.3	7.0	0.0	0.0	108.7	**492.6**
19. Other Transportation and Warehousing	94.4	38.0	1.7	0.9	149.8	26.8	13.7	874.5	1,331.5	**4,719.7**
20. Wholesale Trade	136.1	70.3	5.8	18.0	5,404.7	194.5	2,009.6	3,056.1	3,638.9	**19,097.3**
21. Retail Trade	49.9	0.6	2.3	33.0	14,394.3	0.5	351.6	0.0	0.0	**15,483.5**
22. Banks & Financial Institutions	1,119.0	227.0	458.6	1,382.9	10,516.3	130.6	51.1	1,325.8	12,037.1	**40,273.6**
23. Telecommunications	141.0	38.2	36.2	0.4	1,077.0	127.6	103.9	207.9	4,794.0	**9,525.1**
24. Professional & Technical Services	1,148.6	473.1	664.9	236.3	3,016.6	1,349.7	2,185.3	4,504.7	26,965.3	**65,745.3**
25. Education Services	40.9	0.4	0.0		3,975.3	108.8	0.0	16.3	441.9	**4,670.0**
26. Medical Office/Clinic	2.3				11,883.7	11.8	0.0	0.0	77.9	**12,321.5**
27. Hospitals	0.0				6,948.1	4.1	0.0	1.9	0.5	**6,962.4**
28. Nursing and Residential Care Facilities					1,817.5	4.2	0.0	0.0	0.0	**1,821.7**
29. Hotels	33.8	7.7	14.0	1.6	938.4	30.9	0.0	0.2	444.6	**2,043.4**
30. Entertainment & Recreation	281.3	59.3	89.6	14.0	8,685.9	196.0	127.3	5,291.5	38,772.9	**60,777.7**
31. Other Services	162.5	34.8	22.8	135.7	8,588.3	135.7	0.0	3.6	4,485.5	**15,765.4**
32. Gov't & Non-NAICS	135.0	159.5	31.2	5.5	3,473.8	18,217.6	25.4	2,123.4	582.1	**28,376.4**
33. Real Estate	588.5	129.4	518.2	354.8	3,962.1	137.5	0.0	33.7	15,733.6	**27,134.5**
34. Owner-occupied Dwellings					18,948.3	0.0	0.0	0.0	0.0	**18,948.3**
Employee Compensation	5,659.6	22,421.4	1,899.4	0.0						
Proprietary Income	2,387.9	0.0	1,262.0	0.0						
Other Property Income	148.3	3,283.3	18,206.9	13,489.6						
Indirect Business Taxes	457.7	-568.5	2,746.2	1,896.2						
Other	32.2	20.9	2.6	2.6						
Foreign Trade	211.1	190.5	19.3	42.7						
Domestic Trade	2,000.5	802.2	837.4	944.6						
Gross Output	**15,765.4**	**28,376.4**	**27,134.5**	**18,948.3**						**438,226.8**

Appendix D. Calculation Steps in Input-Output Analysis

In this study, we use Input-Output model to analyze the total business interruption losses of two flood events, 10-year and 100-year floods, for two sea level rise scenarios -- 0.5 m by 2050 and 1.4 m by 2100. The following calculation steps are undertaken to perform the analysis for each scenario:

1. The direct output losses (direct business interruption loss) of the City for each of the 33 occupancy classes are obtained from the HAZUS simulation. These results are then translated to sectoral direct output loss for each of the 34 sectors in the I-O Model using the occupancy to sector mapping scheme shown in Table B2 in Appendix B.

2. The sectoral direct output losses are converted to final demand losses and value added losses using the diagonal element of the corresponding sector in the Leontief inverse matrix and Ghoshian inverse matrix, respectively.

3. The multiplier (total) impacts on both demand-side and supply-side stemming from the direct business interruption (BI) loss are computed by applying the demand-side I-O Model and supply-side I-O Model of the City to the final demand losses and value added losses, respectively.

4. The total multiplier impacts for the City stemming from the direct BI losses incurred in the City are calculated as the sum of the demand-side and supply-side impacts calculated in Step 3, net the double-counting of the direct impacts (the direct impacts are included in both the demand-side total losses and supply-side total losses calculations).

5. The direct BI losses in Rest of the County would also generate indirect impacts to the City. The total impacts (including both demand-side and supply-side) of the direct BI losses in Rest of the County are first computed using the I-O Model of the County.

6. The direct BI losses for Rest of the County are subtracted from the total impacts to get the indirect impacts stemming from the direct BI losses for Rest of the County.

7. The indirect impacts (calculated in Step 6) on the City economy stemming from the direct BI losses for Rest of the County are computed by multiplying the total indirect impacts to the County as a whole by the percentage economy size of the City with respect to the County.

The total BI losses for the City is the sum of the total multiplier impacts for the City stemming from the direct BI losses incurred in the City (Step 4) and the indirect impacts to the City stemming from the direct BI losses incurred in Rest of the County (Step 7).

Appendix E. Sectoral Business Interruption Losses

Table E1. Total Business Interruption Losses by Sector for City of Los Angeles, 10-Year Flood Event for the Base Case

Sector		City Direct BI Losses			City Total Impacts from City Direct BI Losses			Indirect Impacts to the City from Direct BI Losses in Rest of County			City Total BI Losses		
		Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)
1	Agriculture, Forestry and Fishing	0.001	0.001	0	0.001	0.001	0	0.001	0.001	0	0.002	0.001	0
2	Mining, Quarrying, and Oil and Gas Extraction	0.000	0.000	0	0.004	0.002	0	0.003	0.003	0	0.007	0.005	0
3	Electric Utilities	0.002	0.001	0	0.006	0.002	0	0.006	0.007	0	0.012	0.009	0
4	Gas Utilities	0.006	0.001	0	0.015	0.002	0	0.010	0.010	0	0.024	0.011	0
5	Water and Wastewater Utilities	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0
6	Construction	0.002	0.001	0	0.026	0.010	0	0.036	0.036	0	0.062	0.046	0
7	Food Manufacturing	0.014	0.002	0	0.038	0.005	0	0.025	0.025	0	0.063	0.030	0
8	Beverage and Tobacco Product Manufacturing	0.004	0.001	0	0.007	0.001	0	0.008	0.008	0	0.015	0.009	0
9	Chemical Manufacturing	0.043	0.003	0	0.100	0.006	0	0.053	0.052	0	0.152	0.058	0
10	Nonmetallic Mineral/Metals Processing & Mfg	0.000	0.000	0	0.003	0.000	0	0.004	0.004	0	0.007	0.004	0
11	High Technology	0.000	0.000	0	0.038	0.010	0	0.040	0.044	0	0.078	0.054	0
12	Other Heavy Industry	0.002	0.001	0	0.016	0.004	0	0.012	0.012	0	0.028	0.016	0
13	Other Light Industry	0.001	0.000	0	0.039	0.011	0	0.044	0.047	0	0.083	0.058	0
14	Air Transportation	0.006	0.002	0	0.014	0.004	0	0.018	0.018	0	0.031	0.022	0
15	Rail Transportation	0.001	0.000	0	0.002	0.001	0	0.002	0.002	0	0.004	0.002	0
16	Water Transportation	0.001	0.000	0	0.001	0.000	0	0.001	0.001	0	0.002	0.001	0
17	Truck Transportation	0.003	0.001	0	0.010	0.005	0	0.010	0.010	0	0.021	0.015	0
18	Transit and Ground Passenger Transportation	0.001	0.000	0	0.002	0.001	0	0.003	0.003	0	0.005	0.004	0
19	Other Transportation and Warehousing	0.007	0.004	0	0.021	0.011	0	0.022	0.022	0	0.043	0.033	0
20	Wholesale Trade	0.060	0.026	0	0.102	0.043	1	0.055	0.055	0	0.157	0.098	1
21	Retail Trade	0.008	0.004	0	0.060	0.028	1	0.079	0.079	1	0.139	0.107	2
22	Banks & Financial Institutions	0.004	0.001	0	0.121	0.034	1	0.250	0.235	1	0.371	0.269	2
23	Telecommunications	0.000	0.000	0	0.021	0.003	0	0.060	0.060	0	0.081	0.064	0
24	Professional & Technical Services	0.098	0.049	1	0.249	0.125	2	0.303	0.301	2	0.553	0.426	4
25	Education Services	0.069	0.043	1	0.083	0.052	1	0.026	0.026	0	0.109	0.078	1
26	Medical Office/Clinic	0.045	0.027	0	0.088	0.052	1	0.066	0.066	1	0.153	0.117	1
27	Hospitals	0.003	0.002	0	0.029	0.016	0	0.041	0.041	0	0.070	0.057	0
28	Nursing and Residential Care Facilities	0.000	0.000	0	0.007	0.004	0	0.011	0.011	0	0.017	0.015	0
29	Hotels	0.039	0.013	0	0.045	0.015	0	0.005	0.005	0	0.050	0.020	0
30	Entertainment & Recreation	0.131	0.048	1	0.227	0.083	1	0.159	0.161	1	0.386	0.244	2
31	Other Services	0.140	0.071	2	0.179	0.091	3	0.071	0.069	1	0.250	0.160	4
32	Gov't & Non-NAICS	0.039	0.031	0	0.095	0.075	1	0.092	0.092	1	0.187	0.167	2
33	Real Estate	0.000	0.000	0	0.045	0.005	0	0.118	0.118	1	0.163	0.123	1
34	Owner-occupied Dwellings	0.000	0.000	0	0.047	0.000	0	0.077	0.000	0	0.123	0.000	0
Total		**0.729**	**0.330**	**6**	**1.739**	**0.705**	**13**	**1.710**	**1.621**	**11**	**3.449**	**2.325**	**24**

Table E2. Total Business Interruption Losses by Sector for City of Los Angeles, 100-Year Flood Event for Base Case

Sector		City Direct BI Losses			City Total Impacts from City Direct BI Losses			Indirect Impacts to the City from Direct BI Losses in Rest of County			City Total BI Losses		
		Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)
1	Agriculture, Forestry and Fishing	0.003	0.002	0	0.004	0.002	0	0.001	0.001	0	0.005	0.003	0
2	Mining, Quarrying, and Oil and Gas Extraction	0.000	0.000	0	0.009	0.004	0	0.006	0.006	0	0.015	0.010	0
3	Electric Utilities	0.003	0.001	0	0.013	0.004	0	0.011	0.014	0	0.024	0.018	0
4	Gas Utilities	0.013	0.002	0	0.032	0.004	0	0.020	0.020	0	0.052	0.024	0
5	Water and Wastewater Utilities	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0
6	Construction	0.003	0.001	0	0.057	0.022	0	0.074	0.074	0	0.131	0.096	1
7	Food Manufacturing	0.032	0.004	0	0.085	0.012	0	0.051	0.051	0	0.136	0.062	0
8	Beverage and Tobacco Product Manufacturing	0.010	0.001	0	0.016	0.002	0	0.017	0.017	0	0.033	0.019	0
9	Chemical Manufacturing	0.097	0.006	0	0.225	0.014	0	0.107	0.106	0	0.333	0.121	0
10	Nonmetallic Mineral/Metals Processing & Mfg	0.000	0.000	0	0.006	0.001	0	0.008	0.008	0	0.014	0.009	0
11	High Technology	0.000	0.000	0	0.087	0.023	0	0.084	0.091	0	0.170	0.114	0
12	Other Heavy Industry	0.003	0.001	0	0.034	0.009	0	0.025	0.025	0	0.060	0.034	0
13	Other Light Industry	0.001	0.000	0	0.089	0.024	0	0.091	0.096	0	0.179	0.121	1
14	Air Transportation	0.012	0.004	0	0.030	0.009	0	0.036	0.036	0	0.066	0.045	0
15	Rail Transportation	0.001	0.000	0	0.004	0.002	0	0.004	0.004	0	0.008	0.005	0
16	Water Transportation	0.001	0.000	0	0.003	0.000	0	0.002	0.002	0	0.005	0.002	0
17	Truck Transportation	0.006	0.003	0	0.023	0.011	0	0.021	0.021	0	0.044	0.032	0
18	Transit and Ground Passenger Transportation	0.002	0.001	0	0.005	0.003	0	0.006	0.006	0	0.011	0.009	0
19	Other Transportation and Warehousing	0.014	0.008	0	0.046	0.025	0	0.046	0.046	0	0.092	0.071	1
20	Wholesale Trade	0.156	0.066	1	0.250	0.106	1	0.113	0.113	1	0.362	0.218	2
21	Retail Trade	0.032	0.015	0	0.149	0.070	2	0.162	0.161	2	0.311	0.231	4
22	Banks & Financial Institutions	0.009	0.002	0	0.270	0.076	1	0.511	0.480	2	0.781	0.556	4
23	Telecommunications	0.001	0.000	0	0.046	0.008	0	0.122	0.122	0	0.168	0.129	0
24	Professional & Technical Services	0.202	0.101	1	0.548	0.275	4	0.620	0.615	5	1.168	0.890	9
25	Education Services	0.159	0.100	2	0.192	0.120	3	0.051	0.052	1	0.243	0.173	3
26	Medical Office/Clinic	0.134	0.079	1	0.227	0.134	2	0.136	0.136	1	0.364	0.271	3
27	Hospitals	0.011	0.006	0	0.069	0.038	0	0.085	0.085	1	0.154	0.123	1
28	Nursing and Residential Care Facilities	0.000	0.000	0	0.015	0.009	0	0.022	0.022	0	0.037	0.031	1
29	Hotels	0.066	0.022	1	0.080	0.026	1	0.011	0.011	0	0.091	0.037	1
30	Entertainment & Recreation	0.285	0.104	2	0.502	0.184	3	0.333	0.336	2	0.835	0.520	5
31	Other Services	0.309	0.158	5	0.397	0.203	6	0.144	0.139	2	0.540	0.341	8
32	Gov't & Non-NAICS	0.066	0.052	1	0.196	0.155	2	0.195	0.194	2	0.391	0.349	4
33	Real Estate	0.000	0.000	0	0.103	0.012	1	0.246	0.246	1	0.349	0.258	2
34	Owner-occupied Dwellings	0.000	0.000	0	0.105	0.000	0	0.156	0.000	0	0.261	0.000	0
Total		**1.631**	**0.740**	**15**	**3.915**	**1.588**	**29**	**3.518**	**3.336**	**23**	**7.434**	**4.925**	**52**

Table E3. Total Business Interruption Losses by Sector for City of Los Angeles, 10-Year Flood Event for the 0.5 M Sea Level Rise Scenario

	Sector	City Direct BI Losses			City Total Impacts from City Direct BI Losses			Indirect Impacts to the City from Direct BI Losses in Rest of County			City Total BI Losses		
		Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)
1	Agriculture, Forestry and Fishing	0.002	0.001	0	0.003	0.001	0	0.001	0.001	0	0.004	0.002	0
2	Mining, Quarrying, and Oil and Gas Extraction	0.000	0.000	0	0.007	0.003	0	0.005	0.004	0	0.011	0.008	0
3	Electric Utilities	0.003	0.001	0	0.010	0.003	0	0.009	0.011	0	0.019	0.014	0
4	Gas Utilities	0.011	0.001	0	0.026	0.003	0	0.015	0.015	0	0.041	0.018	0
5	Water and Wastewater Utilities	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0
6	Construction	0.002	0.001	0	0.046	0.018	0	0.055	0.055	0	0.101	0.073	1
7	Food Manufacturing	0.023	0.003	0	0.067	0.009	0	0.037	0.037	0	0.104	0.046	0
8	Beverage and Tobacco Product Manufacturing	0.007	0.001	0	0.012	0.002	0	0.012	0.012	0	0.024	0.014	0
9	Chemical Manufacturing	0.070	0.004	0	0.175	0.011	0	0.080	0.079	0	0.255	0.090	0
10	Nonmetallic Mineral/Metals Processing & Mfg	0.000	0.000	0	0.005	0.001	0	0.006	0.006	0	0.011	0.007	0
11	High Technology	0.000	0.000	0	0.070	0.019	0	0.061	0.067	0	0.131	0.086	0
12	Other Heavy Industry	0.002	0.001	0	0.028	0.007	0	0.019	0.019	0	0.046	0.026	0
13	Other Light Industry	0.001	0.000	0	0.072	0.020	0	0.067	0.071	0	0.139	0.091	1
14	Air Transportation	0.010	0.003	0	0.024	0.007	0	0.027	0.027	0	0.051	0.034	0
15	Rail Transportation	0.001	0.000	0	0.003	0.001	0	0.003	0.003	0	0.006	0.004	0
16	Water Transportation	0.001	0.000	0	0.002	0.000	0	0.001	0.001	0	0.004	0.002	0
17	Truck Transportation	0.005	0.002	0	0.019	0.009	0	0.016	0.016	0	0.035	0.025	0
18	Transit and Ground Passenger Transportation	0.001	0.001	0	0.004	0.002	0	0.005	0.005	0	0.009	0.007	0
19	Other Transportation and Warehousing	0.012	0.007	0	0.037	0.021	0	0.034	0.034	0	0.071	0.054	1
20	Wholesale Trade	0.103	0.044	1	0.181	0.077	1	0.083	0.083	0	0.264	0.160	2
21	Retail Trade	0.027	0.013	0	0.123	0.058	2	0.121	0.120	2	0.244	0.178	3
22	Banks & Financial Institutions	0.005	0.002	0	0.222	0.063	1	0.383	0.360	2	0.605	0.422	3
23	Telecommunications	0.001	0.000	0	0.038	0.006	0	0.091	0.091	0	0.129	0.097	0
24	Professional & Technical Services	0.166	0.083	1	0.450	0.226	3	0.461	0.457	3	0.911	0.683	7
25	Education Services	0.137	0.086	2	0.163	0.103	2	0.039	0.039	1	0.202	0.142	3
26	Medical Office/Clinic	0.102	0.060	1	0.179	0.106	2	0.101	0.100	1	0.280	0.206	2
27	Hospitals	0.011	0.006	0	0.058	0.032	0	0.063	0.063	0	0.121	0.095	1
28	Nursing and Residential Care Facilities	0.000	0.000	0	0.012	0.007	0	0.016	0.016	0	0.029	0.024	0
29	Hotels	0.051	0.017	0	0.062	0.020	1	0.008	0.008	0	0.070	0.028	1
30	Entertainment & Recreation	0.241	0.088	2	0.417	0.153	3	0.249	0.252	2	0.667	0.405	4
31	Other Services	0.280	0.143	4	0.350	0.179	5	0.104	0.100	2	0.454	0.279	7
32	Gov't & Non-NAICS	0.055	0.043	1	0.162	0.128	2	0.142	0.142	1	0.304	0.270	3
33	Real Estate	0.000	0.000	0	0.086	0.010	0	0.180	0.180	1	0.266	0.190	1
34	Owner-occupied Dwellings	0.000	0.000	0	0.087	0.000	0	0.116	0.000	0	0.203	0.000	0
Total		**1.330**	**0.611**	**12**	**3.202**	**1.306**	**24**	**2.608**	**2.473**	**17**	**5.811**	**3.778**	**41**

Table E4. Total Business Interruption Losses by Sector for City of Los Angeles, 100-Year Flood Event for the 0.5 M Sea Level Rise Scenario

	Sector	City Direct BI Losses			City Total Impacts from City Direct BI Losses			Indirect Impacts to the City from Direct BI Losses in Rest of County			City Total BI Losses		
		Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)
1	Agriculture, Forestry and Fishing	0.004	0.002	0	0.006	0.003	0	0.002	0.001	0	0.007	0.004	0
2	Mining, Quarrying, and Oil and Gas Extraction	0.000	0.000	0	0.012	0.006	0	0.007	0.007	0	0.020	0.013	0
3	Electric Utilities	0.003	0.001	0	0.018	0.006	0	0.014	0.018	0	0.033	0.024	0
4	Gas Utilities	0.014	0.002	0	0.044	0.006	0	0.024	0.024	0	0.068	0.030	0
5	Water and Wastewater Utilities	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0
6	Construction	0.004	0.002	0	0.084	0.033	1	0.094	0.094	1	0.177	0.126	1
7	Food Manufacturing	0.042	0.006	0	0.124	0.017	0	0.064	0.063	0	0.188	0.080	0
8	Beverage and Tobacco Product Manufacturing	0.013	0.002	0	0.021	0.003	0	0.021	0.021	0	0.042	0.023	0
9	Chemical Manufacturing	0.127	0.008	0	0.300	0.019	0	0.122	0.121	0	0.422	0.140	0
10	Nonmetallic Mineral/Metals Processing & Mfg	0.001	0.000	0	0.008	0.001	0	0.010	0.010	0	0.019	0.011	0
11	High Technology	0.001	0.000	0	0.121	0.033	0	0.100	0.109	0	0.221	0.141	1
12	Other Heavy Industry	0.004	0.001	0	0.049	0.012	0	0.031	0.031	0	0.079	0.043	0
13	Other Light Industry	0.002	0.001	0	0.125	0.035	1	0.111	0.118	1	0.236	0.152	1
14	Air Transportation	0.012	0.004	0	0.039	0.011	0	0.046	0.046	0	0.085	0.057	0
15	Rail Transportation	0.001	0.000	0	0.006	0.002	0	0.005	0.005	0	0.010	0.007	0
16	Water Transportation	0.001	0.000	0	0.004	0.001	0	0.002	0.002	0	0.006	0.003	0
17	Truck Transportation	0.006	0.003	0	0.031	0.015	0	0.027	0.027	0	0.059	0.042	0
18	Transit and Ground Passenger Transportation	0.002	0.001	0	0.007	0.004	0	0.008	0.008	0	0.016	0.013	0
19	Other Transportation and Warehousing	0.015	0.008	0	0.058	0.032	1	0.055	0.054	0	0.113	0.087	1
20	Wholesale Trade	0.000	0.000	0	0.152	0.065	1	0.144	0.144	1	0.296	0.208	2
21	Retail Trade	0.049	0.023	1	0.227	0.107	3	0.203	0.202	3	0.431	0.309	6
22	Banks & Financial Institutions	0.396	0.112	2	0.749	0.212	4	0.573	0.538	3	1.322	0.750	6
23	Telecommunications	0.001	0.000	0	0.074	0.012	0	0.159	0.159	0	0.234	0.172	0
24	Professional & Technical Services	0.208	0.104	2	0.769	0.386	6	0.835	0.828	6	1.604	1.214	12
25	Education Services	0.355	0.222	5	0.401	0.251	5	0.065	0.066	1	0.465	0.317	6
26	Medical Office/Clinic	0.023	0.013	0	0.179	0.106	2	0.190	0.190	2	0.369	0.295	3
27	Hospitals	0.015	0.008	0	0.101	0.056	1	0.102	0.102	1	0.204	0.158	1
28	Nursing and Residential Care Facilities	0.000	0.000	0	0.023	0.014	0	0.028	0.028	0	0.050	0.041	1
29	Hotels	0.085	0.028	1	0.108	0.035	1	0.015	0.014	0	0.122	0.050	1
30	Entertainment & Recreation	0.640	0.234	4	0.948	0.347	6	0.399	0.403	2	1.346	0.750	8
31	Other Services	0.490	0.250	8	0.632	0.323	10	0.184	0.177	3	0.816	0.500	13
32	Gov't & Non-NAICS	0.092	0.073	1	0.296	0.234	3	0.249	0.248	3	0.545	0.482	6
33	Real Estate	0.000	0.000	0	0.171	0.020	1	0.311	0.311	2	0.482	0.331	3
34	Owner-occupied Dwellings	0.000	0.000	0	0.172	0.000	0	0.208	0.000	0	0.380	0.000	0
Total		**2.608**	**1.110**	**23**	**6.060**	**2.406**	**45**	**4.406**	**4.168**	**29**	**10.466**	**6.573**	**74**

Table E5. Total Business Interruption Losses by Sector for City of Los Angeles, 10-Year Flood Event for the 1.4 M Sea Level Rise Scenario

Sector		City Direct BI Losses			City Total Impacts from City Direct BI Losses			Indirect Impacts to the City from Direct BI Losses in Rest of County			City Total BI Losses		
		Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)
1	Agriculture, Forestry and Fishing	0.003	0.002	0	0.004	0.002	0	0.001	0.001	0	0.006	0.004	0
2	Mining, Quarrying, and Oil and Gas Extraction	0.000	0.000	0	0.011	0.006	0	0.007	0.007	0	0.019	0.012	0
3	Electric Utilities	0.004	0.001	0	0.017	0.005	0	0.013	0.016	0	0.029	0.021	0
4	Gas Utilities	0.016	0.002	0	0.042	0.005	0	0.022	0.022	0	0.064	0.027	0
5	Water and Wastewater Utilities	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0
6	Construction	0.004	0.002	0	0.075	0.029	1	0.084	0.084	1	0.160	0.114	1
7	Food Manufacturing	0.045	0.006	0	0.115	0.016	0	0.057	0.057	0	0.173	0.073	0
8	Beverage and Tobacco Product Manufacturing	0.014	0.002	0	0.022	0.003	0	0.019	0.019	0	0.041	0.022	0
9	Chemical Manufacturing	0.137	0.009	0	0.304	0.019	0	0.123	0.122	0	0.427	0.141	0
10	Nonmetallic Mineral/Metals Processing & Mfg	0.000	0.000	0	0.008	0.001	0	0.010	0.009	0	0.017	0.010	0
11	High Technology	0.001	0.000	0	0.115	0.031	0	0.095	0.104	0	0.211	0.135	1
12	Other Heavy Industry	0.004	0.001	0	0.045	0.012	0	0.029	0.029	0	0.074	0.040	0
13	Other Light Industry	0.002	0.001	0	0.117	0.032	1	0.103	0.110	1	0.220	0.142	1
14	Air Transportation	0.015	0.004	0	0.038	0.011	0	0.041	0.041	0	0.079	0.052	0
15	Rail Transportation	0.001	0.001	0	0.006	0.002	0	0.004	0.004	0	0.010	0.006	0
16	Water Transportation	0.002	0.000	0	0.004	0.001	0	0.002	0.002	0	0.006	0.003	0
17	Truck Transportation	0.008	0.004	0	0.030	0.014	0	0.024	0.024	0	0.054	0.038	0
18	Transit and Ground Passenger Transportation	0.002	0.001	0	0.007	0.004	0	0.007	0.007	0	0.014	0.011	0
19	Other Transportation and Warehousing	0.018	0.010	0	0.059	0.033	1	0.053	0.053	0	0.112	0.085	1
20	Wholesale Trade	0.191	0.081	1	0.316	0.134	2	0.127	0.127	1	0.443	0.261	3
21	Retail Trade	0.041	0.019	1	0.195	0.091	3	0.184	0.183	2	0.379	0.274	5
22	Banks & Financial Institutions	0.009	0.002	0	0.350	0.099	2	0.582	0.547	3	0.933	0.646	4
23	Telecommunications	0.001	0.000	0	0.060	0.010	0	0.138	0.138	0	0.198	0.148	0
24	Professional & Technical Services	0.247	0.124	2	0.708	0.356	5	0.697	0.690	5	1.405	1.046	10
25	Education Services	0.263	0.165	3	0.305	0.191	4	0.059	0.060	1	0.365	0.252	5
26	Medical Office/Clinic	0.175	0.104	1	0.298	0.176	3	0.154	0.154	1	0.452	0.330	4
27	Hospitals	0.013	0.007	0	0.090	0.050	1	0.096	0.096	1	0.186	0.146	1
28	Nursing and Residential Care Facilities	0.000	0.000	0	0.020	0.012	0	0.025	0.025	0	0.045	0.037	1
29	Hotels	0.081	0.027	1	0.099	0.033	1	0.013	0.013	0	0.112	0.045	1
30	Entertainment & Recreation	0.368	0.135	2	0.655	0.240	4	0.380	0.384	2	1.035	0.624	6
31	Other Services	0.397	0.203	6	0.514	0.262	8	0.158	0.153	2	0.672	0.415	11
32	Gov't & Non-NAICS	0.074	0.059	1	0.250	0.197	3	0.219	0.218	2	0.469	0.416	5
33	Real Estate	0.000	0.000	0	0.138	0.016	1	0.275	0.275	1	0.413	0.291	2
34	Owner-occupied Dwellings	0.000	0.000	0	0.138	0.000	0	0.177	0.000	0	0.314	0.000	0
Total		**2.136**	**0.970**	**19**	**5.157**	**2.094**	**38**	**3.980**	**3.773**	**26**	**9.137**	**5.868**	**64**

Table E6. Total Business Interruption Losses by Sector for City of Los Angeles, 100-Year Flood Event for the 1.4 M Sea Level Rise Scenario

Sector		City Direct BI Losses			City Total Impacts from City Direct BI Losses			Indirect Impacts to the City from Direct BI Losses in Rest of County			City Total BI Losses		
		Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)	Output ($M)	Income ($M)	Employment (Jobs)
1	Agriculture, Forestry and Fishing	0.005	0.003	0	0.008	0.004	0	0.003	0.003	0	0.011	0.007	0
2	Mining, Quarrying, and Oil and Gas Extraction	0.001	0.001	0	0.027	0.013	0	0.015	0.014	0	0.042	0.027	0
3	Electric Utilities	0.011	0.003	0	0.043	0.014	0	0.027	0.034	0	0.071	0.048	0
4	Gas Utilities	0.042	0.005	0	0.108	0.014	0	0.049	0.049	0	0.158	0.063	0
5	Water and Wastewater Utilities	0.000	0.000	0	0.001	0.000	0	0.000	0.000	0	0.001	0.001	0
6	Construction	0.008	0.003	0	0.191	0.074	1	0.175	0.175	1	0.367	0.249	2
7	Food Manufacturing	0.053	0.007	0	0.237	0.033	1	0.115	0.114	0	0.352	0.147	1
8	Beverage and Tobacco Product Manufacturing	0.017	0.002	0	0.036	0.004	0	0.038	0.038	0	0.073	0.042	0
9	Chemical Manufacturing	0.160	0.010	0	0.617	0.039	0	0.251	0.248	0	0.867	0.287	0
10	Nonmetallic Mineral/Metals Processing & Mfg	0.003	0.001	0	0.022	0.004	0	0.020	0.019	0	0.042	0.023	0
11	High Technology	0.002	0.001	0	0.302	0.082	1	0.197	0.214	0	0.499	0.295	1
12	Other Heavy Industry	0.014	0.004	0	0.121	0.031	0	0.060	0.060	0	0.181	0.091	1
13	Other Light Industry	0.005	0.001	0	0.293	0.081	2	0.213	0.227	1	0.507	0.308	3
14	Air Transportation	0.039	0.011	0	0.097	0.029	0	0.084	0.084	0	0.181	0.113	1
15	Rail Transportation	0.004	0.001	0	0.014	0.005	0	0.008	0.008	0	0.022	0.013	0
16	Water Transportation	0.004	0.001	0	0.010	0.002	0	0.005	0.005	0	0.014	0.006	0
17	Truck Transportation	0.020	0.009	0	0.076	0.036	1	0.050	0.050	0	0.126	0.086	1
18	Transit and Ground Passenger Transportation	0.005	0.003	0	0.017	0.010	0	0.015	0.015	0	0.032	0.025	1
19	Other Transportation and Warehousing	0.047	0.026	0	0.154	0.085	1	0.109	0.108	1	0.263	0.194	2
20	Wholesale Trade	0.501	0.212	3	0.827	0.351	5	0.264	0.264	2	1.092	0.615	6
21	Retail Trade	0.129	0.060	2	0.540	0.253	7	0.390	0.388	5	0.930	0.641	12
22	Banks & Financial Institutions	0.031	0.009	0	0.943	0.267	5	1.202	1.129	6	2.145	1.395	10
23	Telecommunications	0.003	0.001	0	0.159	0.027	0	0.280	0.280	1	0.440	0.307	1
24	Professional & Technical Services	0.648	0.325	5	1.853	0.930	14	1.483	1.470	11	3.336	2.400	24
25	Education Services	0.730	0.458	10	0.841	0.527	11	0.113	0.115	1	0.953	0.642	12
26	Medical Office/Clinic	0.397	0.234	3	0.732	0.433	6	0.322	0.321	3	1.054	0.754	9
27	Hospitals	0.227	0.125	2	0.421	0.232	3	0.202	0.202	1	0.623	0.434	4
28	Nursing and Residential Care Facilities	0.001	0.001	0	0.054	0.032	1	0.052	0.052	1	0.106	0.084	2
29	Hotels	0.128	0.042	1	0.178	0.059	2	0.026	0.025	0	0.204	0.084	2
30	Entertainment & Recreation	0.939	0.344	6	1.689	0.619	11	0.859	0.868	5	2.548	1.487	16
31	Other Services	1.143	0.583	18	1.449	0.740	23	0.333	0.322	5	1.782	1.061	28
32	Gov't & Non-NAICS	0.189	0.150	2	0.657	0.519	7	0.475	0.473	5	1.132	0.992	12
33	Real Estate	0.000	0.000	0	0.384	0.045	2	0.593	0.593	3	0.977	0.638	5
34	Owner-occupied Dwellings	0.000	0.000	0	0.370	0.000	0	0.369	0.000	0	0.739	0.000	0
Total		**5.506**	**2.637**	**52**	**13.472**	**5.593**	**103**	**8.397**	**7.967**	**55**	**21.869**	**13.559**	**158**