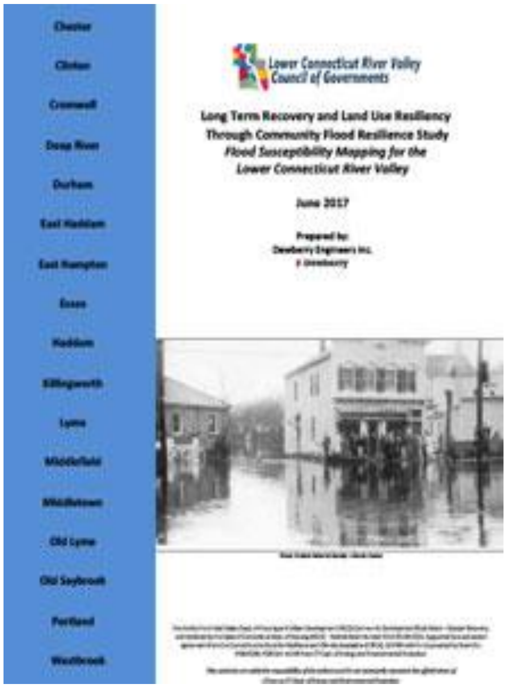
Long Term Recovery and Land Use Resiliency through Community Flood Resilience Study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Lower Connecticut River Valley Council of Governments

Long Term Recovery and Land Use Resiliency
Through Community Flood Resilience Study
Flood Susceptibility Mapping for the
Lower Connecticut River Valley

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Flooding is one of the most severe and potentially devastating natural disasters that can occur. Floods can come in many forms, including river, coastal, and flash flooding. Whenever any of these types of flooding occur, long-term planning and adaptation, preparedness and response time are all critical factors in reducing the overall impacts. Awareness of areas that are currently prone and will be more prone to flooding in the future is essential to consider in short-term, as well as long-term, planning. The majority of planning activity related to resilience and climate adaptation, both in the region and the State, has focused on coastal flooding and sea level rise. This study focuses on inland flooding, which was identified as an area of limited research, and concerns all communities. The study will also provide an example of work in which other communities can engage. Such awareness comes from an understanding of a combination of not only regional climatic factors, but also of non-climate factors that relate to natural, physical, and developed characteristics.

The current study estimates flood susceptibility in the Lower Connecticut River Valley Region (LCRVR) not due to climate change, while also looking at the climatic mechanisms that correlate with rainfall throughout the region and at projected trends in rainfall in the future. Several quantitative and qualitative methods were considered to estimate flood susceptibility; the final selected method involves performing a logistic regression, which is a statistical method for analyzing a dataset in which there are one or more independent variables that determine a binary (yes or no) outcome, using several flood risk factors that could potentially affect the region and for which sufficient data were available. Flood risk factors considered include elevation, slope, land curvature (concave, convex, or flat), distance to water body, land cover, vegetative density, surficial materials, soil drainage class, and percent impervious surface. The objective was to link each of the flood risk factors to the occurrence of flooding for a flood event having a recurrence interval of at least 100 years. Satellite images of spatial flood inundation over the region were obtained for a significant flood event that occurred in April of 2011; areas inundated by this event were observed outside of the FEMA 100-year floodplain. Due to the fact that the overall quality of these satellite images was not sufficient for the flood risk factor analysis, it was alternatively decided to use the 100-year FEMA floodplain.

The LCRVR was divided into three regions (urban, rural, and coastal) to determine the differences in the contributions of each flood risk factor to flood susceptibility between an urban and a rural area and between inland vs. coastal areas; for each region 4,000 points were randomly chosen from which to extract data for each flood risk factor (refer to Table A-1 for data source information). An equal number of these points were selected in locations that were within and outside of the 100-year floodplain for each region. The data for each flood risk factor were selected from all locations using ArcGIS and associated with a '1' if the location was within the floodplain and a '0' otherwise. The resulting relationships between each factor and flood occurrence were ingested into a logistic regression from which regression coefficients were obtained. The magnitude of the coefficients indicates the relative strength of each flood risk factor's influence on flooding in a sub-region. It was found that 'elevation' and 'distance to water' have the most influence on flood susceptibility in the urban and coastal sub-regions, while ‘distance to water’ and ‘surficial materials’ dominate in the rural sub-region. The final logistic regression equation obtained for each sub-region was then used to assign probabilities of flooding to all locations within that sub-region. The results for each sub-region were combined to create an overall probability map of the LCRVR. Probabilities were classified within one of five classes: 0 – 20% (“very low risk”); 20 – 40% (“low risk”); 40 – 60% (“medium risk”); 60 – 80% (“high risk”); and 80 – 100% (“very high risk”). It was observed that several areas classified as “very high risk” and “high risk” were located outside of the FEMA 100-year flood area. Several types of critical infrastructure were overlaid on the flood susceptibility map to identify those assets that are most vulnerable to the 100-year flood.

The FEMA 100-year flood maps are limited to the sub-watersheds of greater than one square mile that FEMA chose to study with limited resources. Other limiting factors are the age of the underlying studies illustrated by the FEMA maps (often more than two decades old) and their focus on only areas where development existed or was imminently anticipated. FEMA’s flood mapping is developed using physical models to perform hydrologic and hydraulic analysis of a statistical rainfall event with a one percent chance of being equaled or exceeded in any given year (referred to as the 100-year flood). In general terms, hydrologic analysis is the study of transforming rainfall amount into quantity of runoff. Hydraulic analysis takes that quantity of water and uses a physical model to route it through existing terrain, while considering such factors as topography and vegetative density. This modeling is referred to as “detailed analysis.” Some areas are studied by “approximate methods.” In general, areas studied by approximate methods use a simplified hydrologic analysis methodology and route runoff quantity along best available topography alone.

The susceptibility maps from this study provide a less expensive method of covering all land area within the region. By using the statistical modeling methodology described in this report it was possible to identify the contribution of flood factors within the physically modeled FEMA 100-year floodplain and apply them to the entire study region to identify areas thought to be vulnerable to flooding. As part of this study an ArcGIS map document file is available here for the region's municipalities' future planning analysis containing the flood susceptibility, land use, and critical infrastructure datasets and also please contact the Lower Connecticut River Valley Council of Governments to obtain this data. One important disclaimer about the flood susceptibility map is that it was created for present-day conditions and is only to be used for planning purposes. It is not intended to replace the FEMA mapping for regulatory or flood insurance decisions.

Regarding climatic factors affecting the LCRVR, an analysis looking at the major climatic mechanisms linked to rainfall in the region was performed through a simple correlation analysis between long-term total precipitation and long-term averages of nearly 40 climate indices. It was found that by incorporating a time difference, or lag time, between the period over which rainfall is totaled and the corresponding period over which climate indices are averaged, 12 and 48 months maximized the predictive skill of the correlation. The reason for incorporating a lag time is based on the assumption that the effects of a particular climate mechanism on rainfall do not occur immediately; there is some delay before the corresponding impact on rainfall manifests itself. The 12-month lag time revealed a strong and significant correlation with El Niño, while the 48-month lag time revealed a strong and significant correlation with the Caribbean SST (sea-surface temperature) index. The correlations at the 48-month lag time were used to create a statistical model to predict future 48-month rainfall totals; predictions were shown to be relatively accurate when compared to historic observations. This model provides a long-term window into the future and can be used to predict the future onset and persistence of extended periods of high rainfall and drought.

Local- and regional-scale statistical analyses were performed for the city of Hartford and for a region encompassing several Mid-Atlantic and Northeastern states to detect changes in historical rainfall statistics over and near the LCRVR. Tests were performed on trends (i) in the Annual Maximum Series (AMS) of 24-hour rainfall and (ii)

Peaks-Over-Threshold (POT). Slight linear trends were found at Hartford but were not significant at the 95% and 90% confidence levels. On a regional level, 20% of rain gauges, including gauges in northwestern Connecticut, experienced statistically significant increases in AMS over the period of record, while 32% showed statistically positive trends in POT, which indicates significant increase in heavy rainfall outside of the LCRVR. The change in the 70th and 98th percentiles of rainy day rainfall was also investigated to determine if the change in light/moderate rainfall is consistent with changes in heavier rainfall. Comparing two periods (1955 – 1985 and 1986 – 2016) revealed that even though there are significant increases in heavy rainfall on a regional basis, there are very few locations that experienced a significant change in light/moderate rainfall, suggesting a disproportionate effect of climate change on heavier events as opposed to an overall wetter climate. In contrast, as the local-scale analysis revealed no significant increase in heavy rainfall intensity and frequency, it is likely that the LCRVR has "beat the odds" by not experiencing an increase in heavy rainfall activity. It is also possible that there may be some other effect, perhaps from Long Island Sound, that has caused differences in rainfall trends in the region. This cannot be said for sure without additional analysis.

An analysis of future rainfall projections was then conducted to determine how heavy rainfall will change over the LCRVR in the mid- and long-term future using data from the Intergovernmental Panel on Climate Change's (IPCC's) CMIP5 modeling experiments. The high emission Representative Concentration Pathway (RCP) 8.5 (W/m2) scenario was used to provide an upper bound on expected changes. All raw model data used for future projections were bias-corrected by comparing model results from a historical period (1950 – 2005) to observations at the National Oceanographic and Atmospheric Administration (NOAA) Global Historical Climatology Network (GHCN) rain gauge (ID# GHCND:USW00014740), at Hartford Bradley International Airport.

Projections in the future Precipitation-Frequency (P-F) curve at Hartford were then investigated. It was found that projected mid-term (2045) and long-term (2075) P-F curves show increases across the full range of frequencies, with higher percentage changes occurring for the more frequent events. Results indicate that today’s 100-year 24-hour rainfall event will become a ~53-year event in 2045 and a ~45-year event in 2075, whereas more drastic changes are seen for more frequent events. These and prior results demonstrate the importance of determining which present-day recurrence intervals (e.g. 100-year) are important for land use and recovery planning, hazard mitigation, design standards and/or flood warning plans and then building socioeconomic models to show how a more frequent occurrence of such events will impact response and/or recovery costs. This analysis is also useful for informing the possible changes in the shorter-duration flash flood risk, which is more driven by precipitation compared to riverine flooding (especially on the Connecticut River). Although the latter is also driven by rain and snow, it is also driven strongly by additional factors such as upstream flow, land cover, impervious area and ice jams and dam releases.

A series of three outreach workshops for community officials, an online survey of stakeholders, and a review of planning and regulatory documents throughout the region were conducted. The workshops were used to review methodology and present results, and most importantly, to discuss the practical applications of the susceptibility mapping for community planning and operations, with a focus on resiliency. Practical applications range from quantitative analysis of at risk property and infrastructure, for planning, to modifications of design standards for new development and post disaster recovery.

ArcGIS Map Package
(for those who have ArcGIS Software)

Arc Map Viewer
(when the map opens,click "About",
then click "More details... in the upper left hand corner)

Help for Map Viewer
(if you have trouble printing the map, use your keyboard print controls)

This map is a utilitarian version of the the more technical map package that is also available for this project. It is meant to be used by those who do not have access to ArcGIS. The project, prepared by Dewberry Engineers Inc. and the Lower Connecticut River Valley Council of Governments (RiverCOG) and funded by the United States Dept. of Housing and Urban Development (HUD) Community Development Block Grant – Disaster Recovery, administered by the State of Connecticut Dept. of Housing #6202. Federal Grant Number B-13-DS-09-0001 and supported by a sub-award agreement from the Connecticut Institute for Resilience and Climate Adaptation (CIRCA), UCONN with funds provided by Grant No. PO#43280, PS#2014-14249 from CT Dept. of Energy and Environmental Protection was developed to enhance RiverCOG's communities ability to plan, prepare, recover, and adapt from the consequences of climate change. Climate and research indications are that severe storm events leading to an increase chance of inland flooding are becoming more prevalent in the Northeast United States. The map is meant to go hand and hand with the project report entitled Long Term Recovery and Land Use Resiliency Through Community Flood Resilience Study, Flood Susceptibility Mapping for the Lower Connecticut River Valley, June 2017 available here and at www.rivercog.org. Produced for regional planning purposes only, it is the first in the State of Connecticut, and perhaps the nation to research less costly Geographic Information Systems (GIS) alternatives to more fully determine areas of flood susceptibility within the Federal Emergency Management Agency (FEMA) Special Flood Hazard Area (SFHA) x zone, beyond the areas designated by the 100 year flood zone where detailed flood analysis may not have been performed, using the indicators of the existing 100 year flood zone through logistic regression analysis within the 17 member communities of the RiverCOG region. Although current data sets are only applicable for analysis at the regional scale, it is hoped, by determining the usefulness of the modeling techniques, through ground truthing at the local level, that when appropriate scale data becomes available at the local, regional, State, and national level that this modeling technique will provide a less costly alternative to traditional flood modeling. Even though the scale of the data is most appropriately used at the regional scale it should be useful for determining areas of concern as it relates to critical infrastructure, both private and public at the municipal scale. To enhance and help with the land use planning process, data sets have been included for critical infrastructure locations, as well as existing land use, land cover, and zoning.