Contra Costa ART Appendix A

GIS Exposure Analysis

The aim of this appendix is to familiarize the reader with the data and methodology used to conduct an analysis of shoreline and community asset exposure to sea level rise and storm events for the Contra Costa County Adapting to Rising Tides (ART) project. This analysis was conducted using a Geographic Information System (GIS). GIS is an ideal tool to support sea level rise adaptation planning because it can both perform spatial analyses and produce maps to visualize results. Of notable importance is that access to technology, data availability, scenario selection and the number and type of asset influence the analysis design and the type of data results produced. The methodology described below was developed to understand the current and future risk of a wide variety of assets, including roadways, residences, industrial properties, public facilities and community members. In addition, the analysis investigated the exposure to both current flooding and six future flooding scenarios. Because areas at risk from current flooding may also be at progressive risk from future flooding, the analysis method was specifically developed to understand the combined and separate exposure to the flood scenarios. For a contrasting methodology can refer to the *ART Pilot Project - ART Vulnerability and Risk Assessment Report Appendix C. ART GIS Exposure Analysis - September 2012* (**http://www.adaptingtorisingtides.org/wp-content/uploads/2014/12/ART_GIS_ExposureAnalysis.pdf**)

Sea Level Rise Inundation Data

To inform an understanding of exposure in the Contra Costa County ART project sea level rise inundation scenarios developed by NOAA's Coastal Services Center[1] for six water levels were selected. ART project staff used the maps and underlying data to examine the vulnerability and risk of various assets to the following six water levels:

- 12" sea level rise + daily high tide (mean high higher water, MHHW)
- 24" sea level rise + daily high tide (mean high higher water, MHHW)
- 36" sea level rise + daily high tide (mean high higher water, MHHW)
- 48" sea level rise + daily high tide (mean high higher water, MHHW)
- 60" sea level rise + daily high tide (mean high higher water, MHHW)
- 72" sea level rise + daily high tide (mean high higher water, MHHW)

[1] https://coast.noaa.gov/dataregistry/search/dataset/info/slr

The data for these six maps was further merged by Association of Bay Area Government (ABAG) GIS staff to produce a single layer[2] that was used in this exposure analysis. ABAG used the NOAA layers to create a geospatial resource wherein each sea level rise scenario extent was separated from the other five scenarios, creating a layer where the inundation for each amount of sea level rise is uniquely identified, for example areas exposed to 5 feet of sea level rise are not also shown as exposed to 4 feet of sea level rise, and so on. This new layer simplifies the determination of exposure to the different water levels and reduces the processing and data handling necessary.

In addition, the analysis methodology identified assets located in a "disconnected low-lying area" adjacent to each of the six sea level rise inundation scenarios. Disconnected low-lying areas are at an elevation below the sea level rise water level but are not currently hydraulically connected to the inundated areas due to protection by levees or other topographic features. While these areas are at lower risk of flooding due to shoreline overtopping or overland flow, which is closely linked to the condition of the adjacent topographic protection, they are at risk of flooding from back ups and lost capacity of the stormwater infrastructure that serves them. Therefore, it is important to map these areas and calculate exposure separately because the risks that are reflected are different, and therefore the solutions may also be different.

FEMA National Flood Hazard Layer Flood Risk Data

In addition to the six NOAA sea level rise inundation scenarios, FEMA's preliminary Flood Insurance Rate Maps (FIRMs) dated January 2016[3] were used to identify assets within a Special Flood Hazard Area (SFHA). SFHAs are defined as the areas that will be inundated by a flood event having a 1-percent chance of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the base flood or 100-year flood. Assets were analyzed against this layer to determine the potential exposure to current flooding as a complement to the analysis of future flooding.

Shoreline and Community Asset Data

Exposure to current and future flooding was completed for the majority of the asset categories assessed. Asset categories that lacked geospatial data or where visual inspection was an adequate approach due to the limited number of assets were not included in the GIS exposure analysis (see Table 1).

TABLE 1. ASSET CATEGORIES, DATA FORMAT AND SOURCES USED IN THE ART GIS EXPOSURE ANALYSIS.

Sector	Asset Category	Data Source	Format
Business &	Commercial	Contra Costa County Assessors Data	Polygons

[2] http://resilience.abag.ca.gov/open-data/

[3] The preliminary FIRMs became effective in September 2016 with only minor revisions that did not significantly change the exposure analysis findings.

Industry	Industrial		
	Hazardous material facilities	Contra Costa County Health Services	Points
Contaminated Lands	Landfills	*No spatial data used*	
	Brownfields	State Water Resources Control Board's Geotracker	Points
Energy	Power generation	California Energy Commission	Points
	Power distribution		
	Refineries	Contra Costa County Assessors Data and ESRI World Imagery (2012)	Polygons
	Pipelines	California Energy Commission	Lines
Ground Transportation	Roadways	Metropolitan Transportation Commission 2011TeleAtlas	Lines
	Rail lines		
Housing	Single	Contra Costa County Assessors Data	Polygons
	Multifamily		
	Mobile homes		
Natural Areas	Tidal wetlands	San Francisco Estuary Institute's EcoAtlas and ESRI World Imagery (2012)	Polygons
Parks and Recreation	Regional parks	California Protected Areas Database and ESRI World Imagery (2012)	Polygons
	City parks		Points
	Marinas	*No spatial data used*	
	Bay Trail	Association of Bay Area Governments	Line
People	Population	U.S. Census Bureau Decennial Census 2010	Polygons
	Households	U.S. Census Bureau Decennial Census 2010	Polygons
	Community Indicators	U. S. Census Bureau American Community Survey 2010-2014; Center for Neighborhood Technology	Polygons
Public Services	Police Stations	Homeland Security Infrastructure Program (HSIP) database	Points
	Fire Stations	Contra Costa County Health Services and Department of Conservation and Development	
	K-12 Schools		
	Public Healthcare Facilities		
	Waste Collection	*No spatial data used*	

Seaport and Marine Oil Terminals	Port of Richmond	*No spatial data used*	
	Marine oil terminals	*No spatial data used*	
Water Management	Water supply	*No spatial data used*	
	Wastewater services	Contra Costa County Assessors Data and ESRI World Imagery (2012)	Polygons
	Flood Control	*No spatial data used*	
	Stormwater	City of Richmond Public Works	Lines

Analysis Methods

Inundation vector files were used to analyze the exposure of selected assets represented as vectors in point, line, or polygon format (see Table 1) to current and future flooding using ESRI's ArcMap Version 10.1 with the Spatial Analyst extension. The primary geoprocess used in the analysis was the Spatial Join function. By using this geoprocess the asset could be joined to the flood scenario layer and maintain all the data within the original asset data set as well as hazard layer for further processing while also being able to document which *combination* of current and future flooding the asset was exposed to. If particular assets were not exposed to certain scenarios the Spatial Join geoprocess would return a "Null" value for the exposure.

The goal of the analysis was to identify assets that were either totally or partially within areas that could be flooded either today and/or with sea level rise, and to determine the scenario at which the asset would be subjected to potential flooding. Below is an overview of the three data formats and how the data was configured.

Points – A 25-meter (82-feet) buffer using the ArcToolbox Buffer tool was created around the point locations to approximate the footprint of the asset and to account for any potential spatial error in its exact location. Example asset categories with point data included schools, police stations and hazardous material sites. Using ArcToolbox -> Analysis Tools -> Overlay -> Spatial Join tool (Figure 1), assets (target features) were spatially joined to a current (NFHL) or future flood (SLR) layer. The resulting file (output feature class) from this process contained asset point data for each current and future flood scenario evaluated.

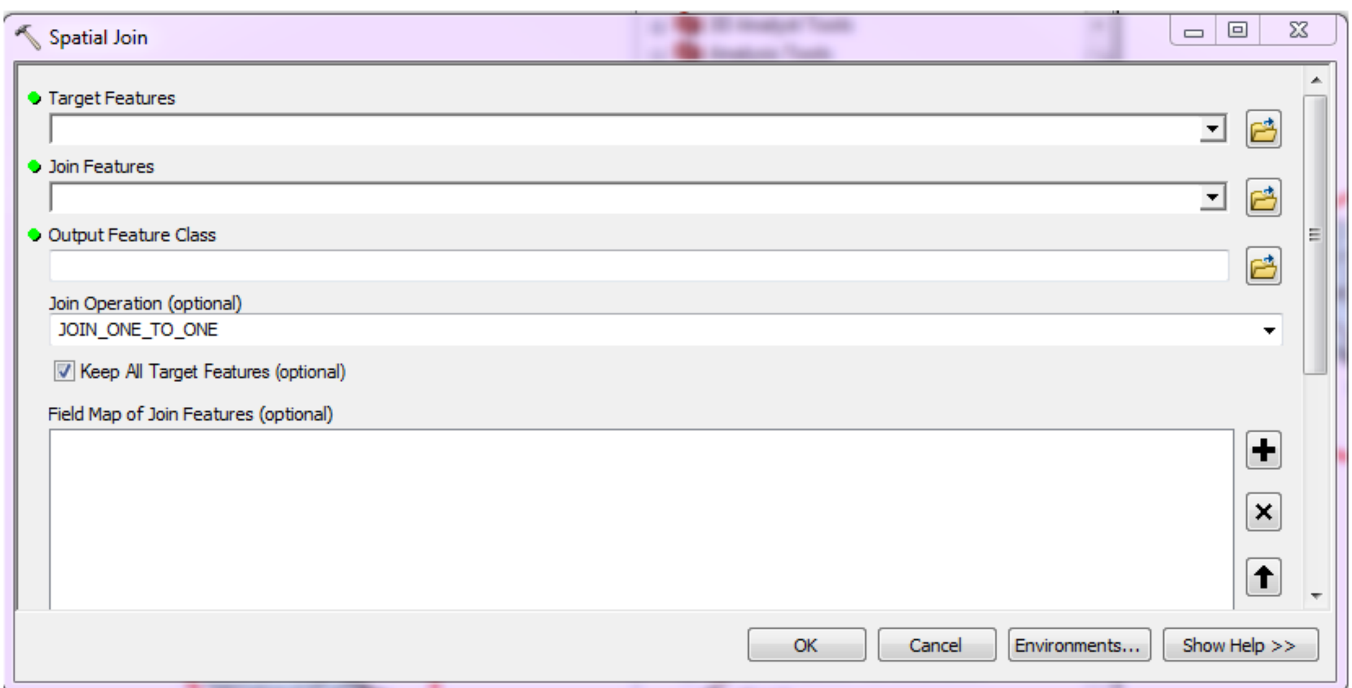
Lines – A 5-meter (16-feet) buffer was created to more accurately depict the footprint of linear assets including roadways and rail lines. The analysis was conducted in two phases because in creating the buffer the data was converted to a polygon, and it was not possible to calculate the length of the resulting polygon using the Calculate Geometry function. Therefore, the initial analysis used ArcToolbox Intersect tool (Figure 2) to analyze the overlay between the buffered line data and the current and future flooding data. This analysis determined the length of asset exposed (e.g., road miles) to each of the current and future flood scenarios separately, therefore it was not possible to discern which linear asset segments were exposed to current flooding only, future flooding only, or a combination of current and future flooding.

Polygon – Polygons were used to analyze assets with larger footprints such as land use parcels, wastewater facilities, and refineries. ArcToolbox – Spatial Join tool (Figure 1) was used to determine if the asset footprint was exposed. Inundation depth was not determined using this method, nor was proportion of polygon exposed in contrast to previous ART project approaches. This method was selected to make better use of the data layer produced by ABAG and it allowed for a quicker determination of which assets were exposed to each water level and also allowed for the analysis to include exposure to both current and future flooding.

Polygons were also used to analyze population and household exposure, using data from the 2010 U.S. Census at the block level[4]. The block is the smallest available geography for Census data, and provides for a more accurate estimate of exposure. Using the ArcToolbox Intersect tool (Figure 2), census blocks were intersected with the SLR, NFHL, and low-lying polygons. The area of the census block that was contained with each hazard was calculated using the Calculate Geometry function, and then the total area of the census block was used to generate a percent of the block exposed. This percent was applied to the population and household counts contained in the 2010 census blocks, and then totaled by Census Designated Place.

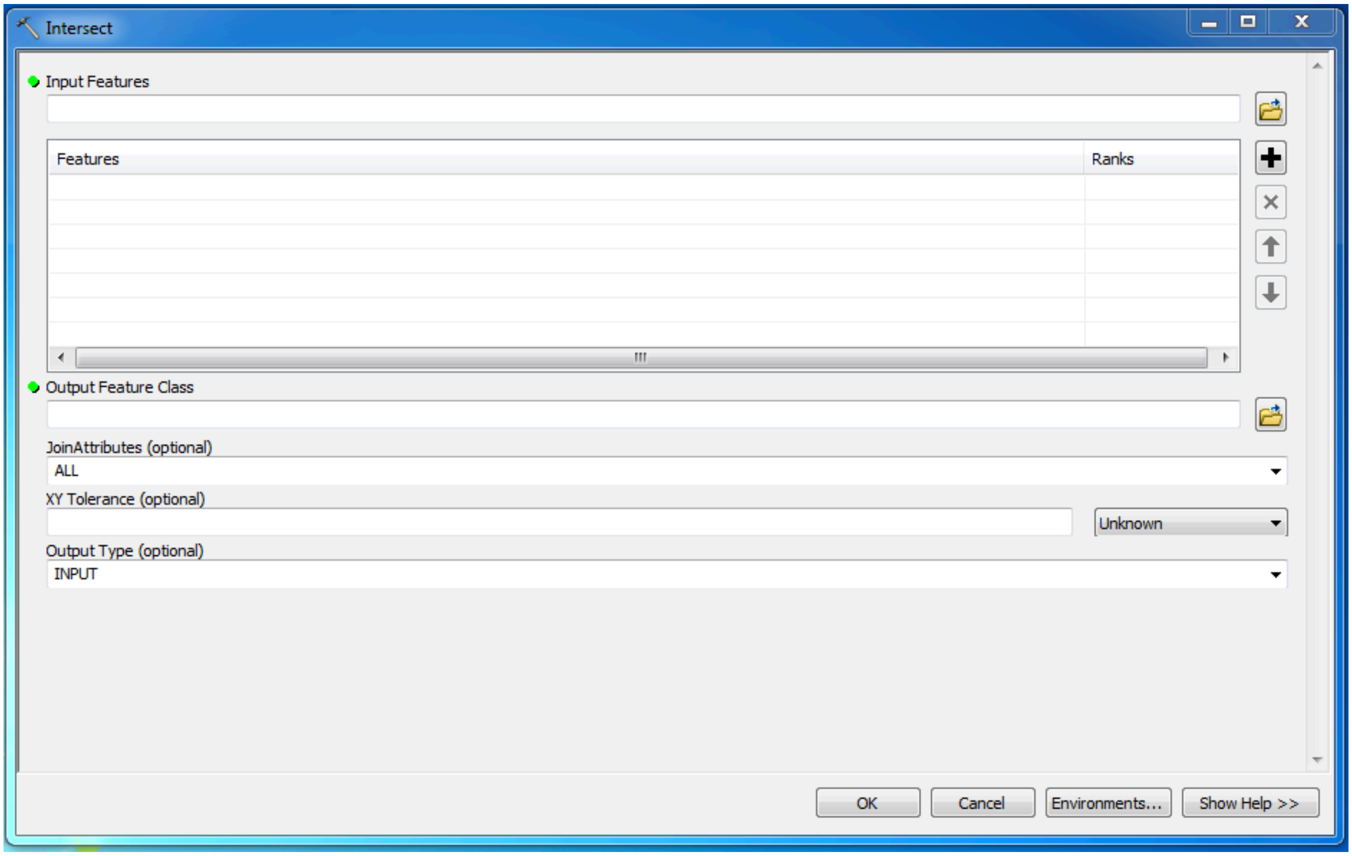
A more detailed diagram of the process used in analyzing exposure for points and polygons is described in Figure 3.

FIGURE 1. SPATIAL JOIN



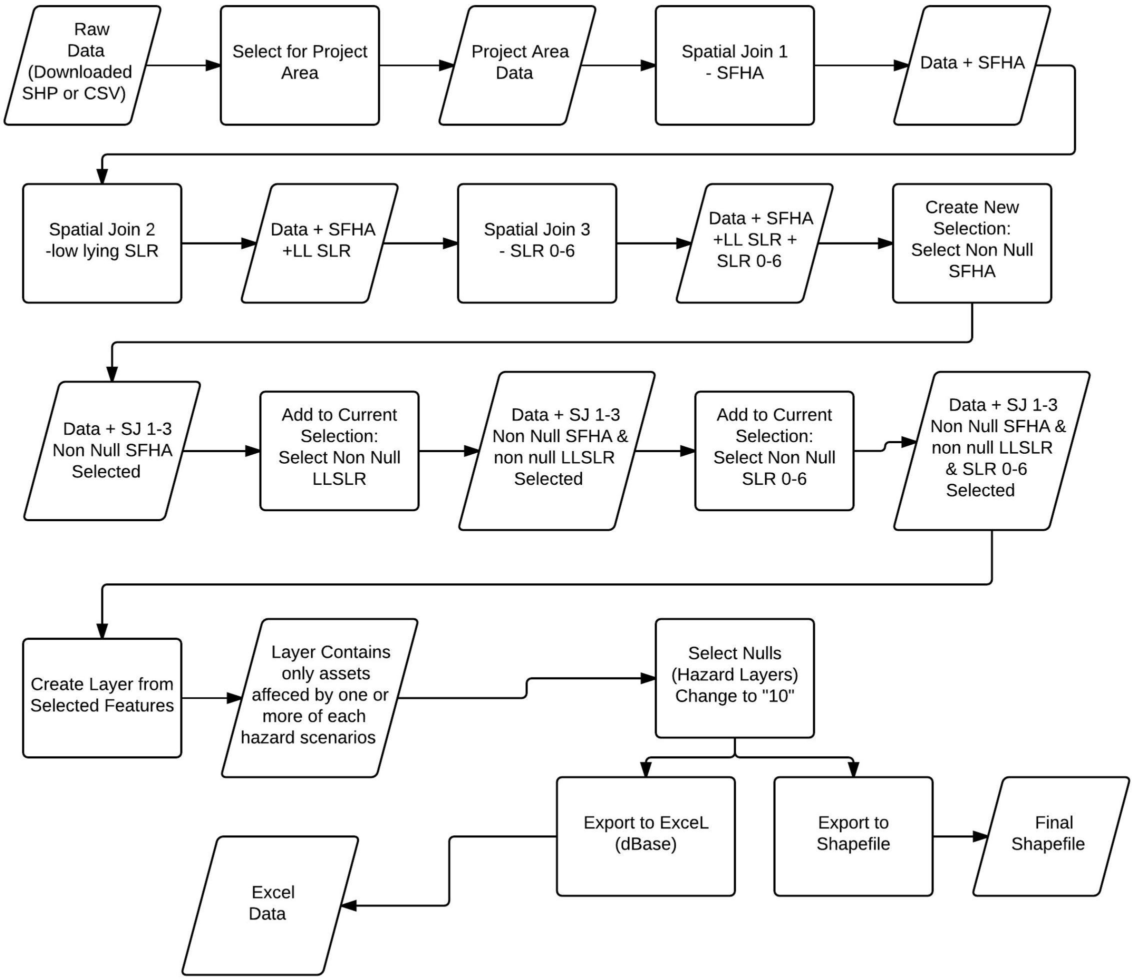
[4] The data used in the exposure analysis is from the 2010 Census, and represents a "point in time" count. Data that are more recent, and have more detailed information, have been collected since 2010 through the American Community Survey (ACS).

FIGURE 2: INTERSECT TOOL



A more detailed diagram of the process used in analyzing exposure for points and polygons is described in Figure 3 below.

FIGURE 3. DETAILED SPATIAL JOIN PROCESS FOR VARIOUS SCENARIOS



Recommendations and Considerations

When conducting a multi-scenario / multi-asset GIS-based exposure analysis there are a few issues to consider.

- Acquiring, creating and managing geospatial data is extremely time consuming. Allow adequate time to acquire, create and manage GIS data.
- It is important to test a few analytical approaches to find one that is appropriate for the data and is consistent with the project goals. Reach out to peers and GIS experts to troubleshoot problems. As data (both hazard and asset) formats and accuracy changes the procedures and geo-processes used in the analysis change considerably as well.
- Structure the data and data output so it can easily be exported into other formats include spreadsheets or databases for use in assessing vulnerability. This Contra Costa exposure analysis required substantial use of Microsoft Excel for post processing data. Not only were the combinations of current and future flooding distinct from earlier analysis, but also the assets studied (e.g. Land Use -> Industrial-> Heavy Industrial, Light Industrial, Research Park, Vacant) required a substantial amount of data manipulation.

In each of the steps required for desktop analysis, from data acquisition through desktop analysis to spreadsheet post processing is an opportunity for error and therefore it is important to have a standardized QA/QC workflow established to avoid mistakes or oversights given the quantities and multiple formats of data.