Figure 4. Digitized points of the flooded area using a severity scale attribute of 1 (min) – 3 (max).

Figure 5. Interpolation (Kriging) of digitized points with a value greater than two (2).

Figure 6. Selection of flooded areas with cell values that are greater than two (2) from the interpolation of the digitized points.

Comparing Flood Assessment by Photos to FEMA Map

For the second aspect of the study, I used the most recent version of the FEMA flood maps of the area. This FEMA flood map layer contains attributes that express the severity of the different flood zones. Although there are several FEMA flood zones (table 1), I only selected zones AE and AH located in the "High Risk Areas" for this project because we are only interested in the high-risk zones that are not directly related to the lake and river flooding.

AREA	ZONE	DESCRIPTION
Moderate – to Low-Risk Areas	**B and X** (shaded)	Area of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floods. B Zones are also used to designate base floodplains of lesser hazards, such as areas protected by levees from 100-year flood, or shallow flooding areas with average depths of less than one foot or drainage areas less than 1 square mile.
	C and X (unshaded)	Area of minimal flood hazard, usually depicted on Flood Insurance Rate Maps (FIRMs) as above the 500-year flood level. Zone C may have ponding and local drainage problems that don't warrant a detailed study or designation as base floodplain. Zone X is the area determined to be outside the 500-year flood and protected by levee from 100-year flood.
High-Risk Areas	**A**	Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas, no depths or base flood elevations are shown within these zones.
	AE	The base floodplain where base flood elevations are provided. AE Zones are now used on new format FIRMs instead of A1-A30 Zones.
	A1-30	These are known as numbered A Zones (e.g., A7 or A14). This is the base floodplain where the FIRM shows a BFE (old format).
	AH	Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
	AO	River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones.
	AR	Areas with a temporarily increased flood risk due to the building or restoration of a flood control system (such as a levee or a dam). Mandatory flood insurance purchase requirements will apply, but rates will not exceed the rates for unnumbered A Zones if the structure is built or restored in compliance with Zone AR floodplain management regulations.
	A99	Areas with a 1% annual chance of flooding that will be protected by a Federal flood control system where construction has reached specified legal requirements. No depths or base flood elevations are shown within these zones.
High-Risk – Coastal Areas	**V**	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. No base flood elevations are shown within these zones.
	VE, V1 – 30	Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.
Undetermined - Risk Areas	**D**	Areas with possible but undetermined flood hazards. No flood hazard analysis has been conducted. Flood insurance rates are commensurate with the uncertainty of the flood risk.

Table 1. FEMA flood areas and zones.

I selected only the zones that were designated as "hazardous flooding areas" from the FEMA layer (using the Structured Query Language selection FLD_ZONE='AE' OR FLD_ZONE='AH') and then converted that selection to a new layer (fig. 7). With the newly created layer of FEMA's "hazardous flooding areas" flood zones and the vector layer of flooded areas derived from the photos in part A, I was able to run two sets of alternative combination of GIS operations (union-intersect and symmetrical difference overlay analysis) to select only the areas that were flooded and not accounted for by the FEMA layer. The union operation served to combine both of the layers and their attributes into a new union layer. From the union layer, I selected only the features where the FEMA flood zones and the zones I generated did not overlap. The last selection shows the areas of FEMA flood zones that I did not map and the flood zones that I generated but that FEMA did not take into account (fig. 8).

Figure 7. FEMA hazard zones AE and AH located in the selected "High-Risk Areas."

Figure 8. Flooded area not accounted for by FEMA. It results from an overlay analysis using FEMA High risk flood layers and the digitizing and interpolation derived layer of the 2008 flood event.

Assessment of Potential Damage

After obtaining a block population point layer (a layer that contains data on the number of houses and people in a selected area) from U.S. Census data, I clipped/removed some of the data from the population layer to fit the size of the selected Fond du Lac study area layer (fig. 9). Using the clipped block population layer and the union layer of flooded areas (generated by FEMA and by photos), I ran an intersection overlay analysis to obtain only the block population layer's point features of the flooded area (fig. 10). That operation also attached to each block point the attribute (information/description) of the corresponding flood features (from the union layer). By computing some of the attribute data attached to the previously created flood-block intersection layer, I was able to determine the number of houses in the selected damage zone, the number of occupied houses, and the number of people who live within the area that are not accounted for by FEMA. The area has a population of 821, 311 occupied households and 322 housing units (fig. 11).
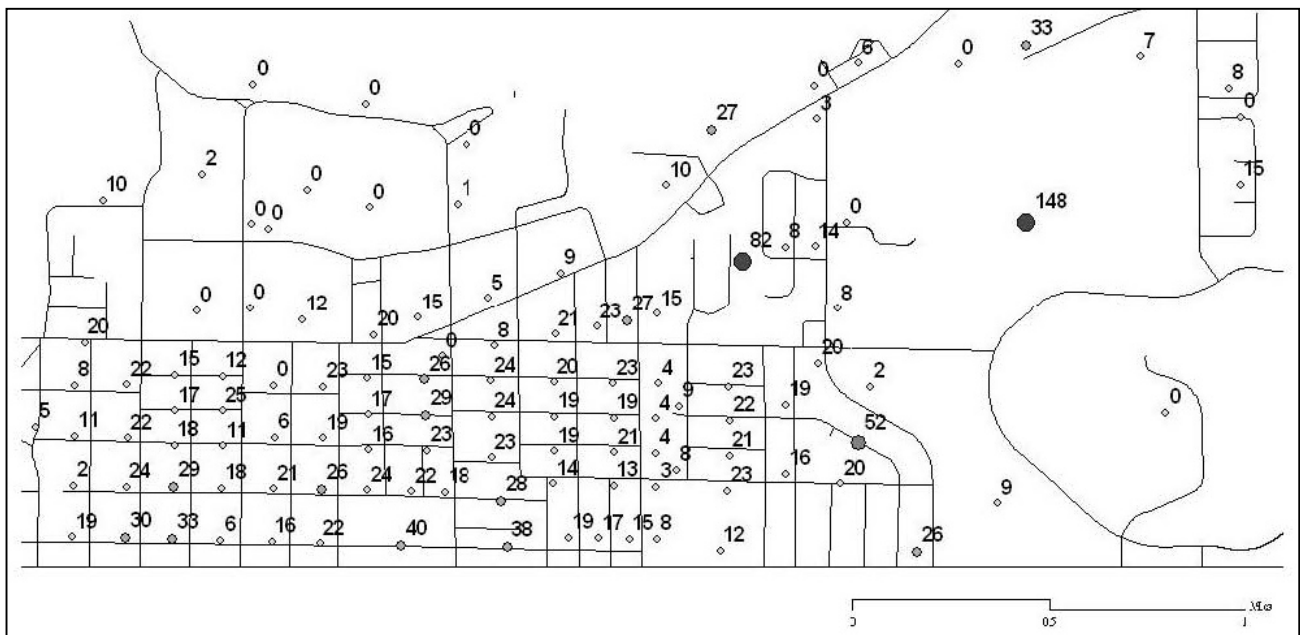
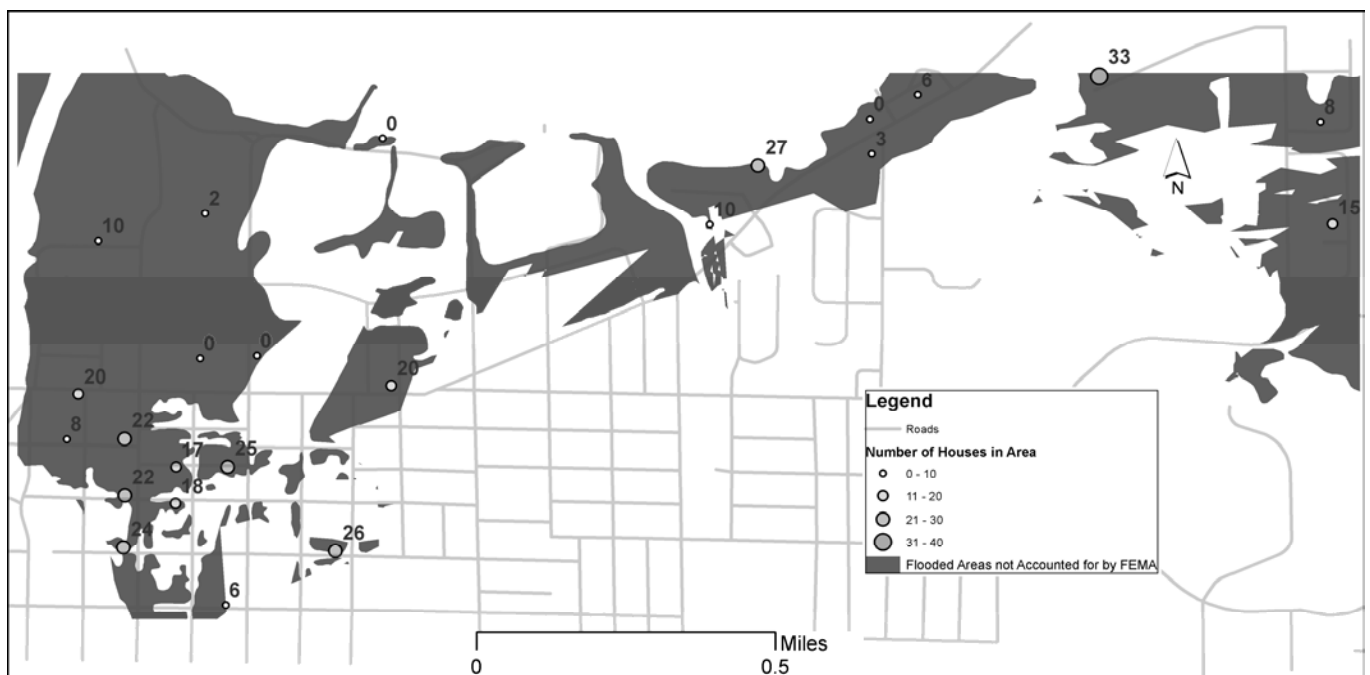**Figure 9**. Block population layer for Fond du Lac area.

Figure 10. Result of intersection overlay analysis using union layer and block population. The dots express the number of houses for the census block they represent.