Comparison of the New Digital Flood Insurance Rate Map (DFIRM) with the Existing FIRM, Wilson, North Carolina

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The 100-yr floodplain on new Digital Flood Insurance Rate Maps (DFIRMs) for the city of Wilson, North Carolina, were compared with the floodplain defined by the existing Flood Insurance Rate Maps (FIRMs) and validated against two recent flood events. Of the 16,776 ha in the study area, 16% and 79% were delineated as areas within and outside of the 100-yr floodplain on both flood maps, respectively. In the remaining 5% of the study area, areas located within the 100-yr floodplain (based on the DFIRMs) increased by 2.8%. The 100-yr floodplain on both flood maps was also compared to the September 1999 and August 2002 flood events. For the 1999 flood, only 67% and 62% of the flooded parcels were within the 100-yr floodplain on the DFIRMs and FIRMs, respectively. Of the 29 street intersections flooded during the 2002 flood, 52% were identified by the DFIRMs, and 38% by the FIRMs. Although the 100-yr floodplain on the DFIRMs performed a better overall job of delineating the flooded parcels and intersections, it did miss a portion of the flooded areas.

Key words: DFIRM, FIRM, floodplain, North Carolina.

INTRODUCTION

After the massive 1999 flood caused by Hurricane Floyd in eastern North Carolina, rescue, recovery, and mitigation lessons were learned that should help reduce the risk of similar damages in the future (e.g., Batchelor et al. 2000; FEMA 2000; USACE and FEMA 2000; Maiolo et al. 2001; Manuel 2001). Nevertheless, another storm like Hurricane Floyd could produce similar property damage because so many structures remain in flood-prone areas (Manuel 2001). In 1999, flood hazard data and maps were of limited utility because they were out-of-date. Approximately 75% of North Carolina Flood Insurance Rate Maps (FIRMs) were at least five years old. Although there are 100 counties in the state, North Carolina receives only one updated flood study per county each year from the Federal Emergency Management Agency (FEMA). Many counties and communities do not have the resources to assume the responsibility of maintaining their own FIRMs (NCFMP 2001).

In October 2000, North Carolina was designated as the first Cooperating Technical State through FEMA’s Cooperating
Technical Community Partnership initiative. In 2001, a multi-year/phase and multi-million dollar statewide floodplain-mapping program was initiated to create Digital Flood Insurance Rate Maps (DFIRMs) (Fig. 1) for all counties in the state (NCFMP 2001). Houses/properties shown within the 100-yr flood zone require the owner to purchase flood insurance. Each flood zone is regulated by different agencies at the federal, state, and local levels, and has provisions for possible development (e.g., development in the floodway is prohibited). The new DFIRMs are currently in a review process that gives local governmental agencies, the private sector, and citizens the opportunity to make appeals before the maps go into effect. When the review process is complete, the DFIRMs will replace the existing FIRMs as the official regulatory documents for the city of Wilson, which serves as the basis of this study.

DFIRMs and FIRMs are created by mathematical models that input the calculated water surface height and discharge at a particular location along a river channel, along with topography and land surface conditions that influence the direction and velocity of flood flows. Errors are anticipated in both sets of maps due to uncertainties or errors associated with the input parameters, as well as inadequacies of the models themselves. The goal of this
study, therefore, was to quantify the differences between the old and new maps for Wilson and to use records of past flooding to determine which maps more accurately predicted actual flood events. In particular, we (1) extracted and compared flood zones from the DFIRMs and FIRMs, and (2) extracted and compared flooded parcels from the 1999 flood (Hurricane Floyd) and flooded street intersections from a localized heavy storm in 2002 with flood zones from the DFIRMs and FIRMs.

STUDY AREA AND DATA

This study was conducted in the city of Wilson (population of 50,000), located on the Coastal Plain of North Carolina approximately 65 km east of Raleigh and 65 km west of Greenville. The city is located in the northwest center of Wilson County in portions of three sub-basins (Contentnea Creek, Hominy Swamp, and Toisnot Swamp basins). Wilson has experienced two major flood events during the past several years, the 1999 flood that followed Hurricane Floyd, and the flood of 2002. These floods caused extensive damage in the city and heightened public awareness of flooding issues. Wilson also regularly deals with nuisance flooding during moderate rainstorms. Due to these circumstances, the new DFIRMs are of great interest to the city and its citizens.

DFIRMs were provided to Wilson in shapefile format by the NCFMP (NCFMP 2001). The existing FIRMs (also in shapefile format) were created by FEMA and manually digitized in-house by GIS personnel in Wilson. The paper source maps from which the FIRMs were digitized were originally in North American Datum of 1927 (NAD 27). After digitization, the data were converted to the North American Datum of 1983 (NAD 83). (The DFIRMs also use NAD 83 as its vertical datum.) City personnel surveyed no new cross sections on the FIRMs and DFIRMs. Details of the actual modeling techniques utilized to create the flood boundaries on the DFIRMs and FIRMs were unknown to the authors. One major known difference between the two map sets, however, was the source elevation data used. The FIRMs utilized elevation data based on USGS 1:24,000 topographic quadrangles, while the DFIRMs used newly collected light detection and ranging (LIDAR) digital elevation model (DEM) data from the NCFMP. The maps were also created at different times; therefore, the locations of the cross sections along the rivers used in the models could have differed. The 1999 and 2002 flood data were compiled by city GIS staff, and were obtained from Wilson police and fire department reports and/or data collected by the Wilson Development Services Department in the recovery efforts after each flood event. These flood data were collected at the level of individual parcels, and because they were listings created by city staff, may contain errors. Although every effort was made to identify as many flooded properties as possible, the 544 parcels listed as flooded may not be a complete inventory of all parcels that were flooded.

The 1999 flood that followed Hurricane Floyd has been categorized as a 100- to 500-yr flood event (Lecce 2000). The 2002 flood event was caused by a severe localized storm that dumped more than 20 cm of rain on the northern portions of the city in a matter of hours. Additional ancillary datasets such as current street centerlines, municipal boundaries, and aerial photography were obtained from the city's
existing GIS database and used as background information in the creation of overlays of flood maps (from the DFIRMs or FIRMs). DEM data available through the NCFMP were also utilized to determine whether flooded parcels were located in low elevation environments. All datasets utilized either were in the Lambert Conformal Conic Projection using State Plane Coordinates (SPC), NAD 83, and Zone 3200, or were projected into this geo-referencing system.

METHODS

Comparison of 100-yr Floodplains

The first step in the analysis was to extract and compare the 100-yr flood zones from the DFIRMs and FIRMs. The 100-yr floodplain on the FIRMs and DFIRMs was also divided into the floodway fringe (AE) and the floodway (AEFW). Thus, there were seven possible changes of flood zone designations based on the two datasets, and each of these fell into one of three categories: agreement, partial agreement, or disagreement. Agreement meant that there was no change in zone designation. Partial agreement meant that there was a change between the floodway and floodway fringe designations, but with the area still falling within the 100-yr floodplain. Disagreement meant that there was an exchange between the floodway and floodway fringe and the area outside of the 100-yr floodplain.

Comparison with Flood Data

The second part of the analysis compared the parcels that flooded in 1999 and the street intersections that flooded in 2002 with the 100-yr flood zones on the FIRMs and DFIRMs. Flooded parcels or street intersections were defined as either being within or outside the 100-yr floodplain on the DFIRMs or FIRMs. Parcels and street intersections inundated in the 1999 and 2002 flood events were also compared to the 500-yr flood zone on the DFIRMs. This analysis, however, was not possible on the FIRMs because they did not contain a digital version of the 500-yr flood zone. It should be noted that the 500-yr flood zone is currently not a regulated zone in Wilson. It also would have been useful to analyze areas inside the 100-yr floodplain that did not flood during either event, but the data were lacking for such an analysis.

RESULTS AND DISCUSSION

Comparison of Areas Within and Outside the 100-yr Floodplain

Of the 16,776 ha in the city, the areas mapped within and outside of the 100-yr floodplain were 3,317 ha and 13,459 ha on the DFIRMs, whereas the areas mapped within and outside of the 100-yr floodplain were 2,840 ha and 13,936 ha on the FIRMs (Table 1). On a location-by-location basis, both flood maps identified 2,653 ha within the 100-yr floodplain and 13,272 ha of land outside the 100-yr floodplain. The total area in agreement on the two maps was 15,925 ha, or 94.9% of the entire study area. In addition, 187 ha of land within the 100-yr floodplain on the FIRMs are now mapped on the DFIRMs as outside of the 100-yr floodplain. A larger area (664 ha) originally mapped on the FIRMs as outside the 100-yr floodplain is now
Comparison of the Floodway, Floodway Fringe and the Zone Outside the 100-yr Floodplain

The floodway and the floodway fringe are managed differently in Wilson. For example, development in the floodway fringe is possible with some provisions, but it is completely prohibited in the floodway. Changes in zone designation, therefore, have significant implications for land management. Both maps are in close agreement, with 15,512 ha of land identified in the floodway, floodway fringe, or outside the 100-yr floodplain. This represents 92.5% of the entire study area. Figure 2, for example, shows a small portion of the city where there is a high degree of agreement between both maps. Using ancillary datasets, most of the areas in agreement are either near the center of the existing floodway and floodway fringe, or else far from existing flood boundaries. In other words, most of the changes took place near existing boundaries. As illustrated in Figure 3, however, there are areas of disagreement located away from the boundaries where both maps can differ greatly.

Further analysis details the exchanges in each flood zone designation (Table 2). A total of 152 ha changed from floodway to floodway fringe, whereas 261 ha changed from floodway fringe to floodway. Another 664 ha changed from being located outside the 100-yr floodplain to inside the 100-yr floodplain, of which 41 ha were added.

Table 1. Spatial comparison of areas within and outside of the 100-yr floodplains (in ha).

<table>
<thead>
<tr>
<th>FIRMs</th>
<th>Inside the floodplain</th>
<th>Outside the floodplain</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFIRMs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside the floodplain</td>
<td>2,653</td>
<td>664</td>
<td>3,317</td>
</tr>
<tr>
<td>Outside the floodplain</td>
<td>187</td>
<td>13,272</td>
<td>13,459</td>
</tr>
<tr>
<td>Total</td>
<td>2,840</td>
<td>13,936</td>
<td>16,776</td>
</tr>
</tbody>
</table>
Table 2. Spatial comparison of the floodway, the floodway fringe, and the area outside the 100-yr floodplain (in ha).

<table>
<thead>
<tr>
<th></th>
<th>Floodway</th>
<th>Floodway fringe</th>
<th>Area outside the 100-yr floodplain</th>
<th>$\chi^2$</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFIRMs Floodway</td>
<td>998</td>
<td>261</td>
<td>41</td>
<td>17.99</td>
<td>.00</td>
</tr>
<tr>
<td>Floodway fringe</td>
<td>152</td>
<td>1,242</td>
<td>623</td>
<td>78.29</td>
<td>.00</td>
</tr>
<tr>
<td>Area outside the 100-yr floodplain</td>
<td>15</td>
<td>172</td>
<td>13,271</td>
<td>20.43</td>
<td>.00</td>
</tr>
</tbody>
</table>

Figure 2. Comparison between the DFIRMs and FIRMs showing strong overall agreement. Agreement – no change in zone designation. Partial agreement – changes between the AEFW and AE designations. Disagreement – exchanges between areas inside and outside of the 100-yr floodplain.
to the floodway and 623 ha were added to the floodway fringe. A total of 187 ha were removed from the 100-yr floodplain, of which 15 ha came from the floodway and 172 ha came from the floodway fringe. LIDAR DEMs showed that the switch from floodway to floodway fringe occurred mainly in steep areas along the existing floodway/floodway fringe boundary. The slope in these areas was close to 2–3 standard deviations (SD = 4.35°) above the mean (10.63°) for the study area. The areas that switched from floodway fringe to floodway were also generally in areas of greater than average slope and, as expected, were of slightly higher elevation than the area in the new floodway. Another interesting trend that was particularly evident in the Hominy Basin was that areas added to the floodway tended to be located on the eastern portion of the floodway, while areas that became the floodway fringe tended to be located along the western portion of the floodway. The areas that were in the floodway and floodway fringe zones on the existing FIRMs, but outside the 100-yr floodplain on the new DFIRMs had an average elevation of 33 m above mean sea level. Of the areas removed from the 100-yr floodplain, 80 ha were in the Toisnot Basin, 36 ha in the Hominy Basin, and 72 ha in the Contentnea Basin.
Table 3. The number of flooded parcels during the 1999 flood.

<table>
<thead>
<tr>
<th>Flooded parcels</th>
<th>DFIRMs</th>
<th>FIRMs</th>
<th>Difference</th>
<th>$\chi^2$</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>In floodway</td>
<td>156</td>
<td>125</td>
<td>31</td>
<td>3.42</td>
<td>.06</td>
</tr>
<tr>
<td>In floodway fringe</td>
<td>209</td>
<td>212</td>
<td>-3</td>
<td>0.02</td>
<td>.88</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>365</strong></td>
<td><strong>337</strong></td>
<td><strong>28</strong></td>
<td><strong>1.12</strong></td>
<td><strong>.29</strong></td>
</tr>
<tr>
<td>Outside the 100-yr floodplain</td>
<td>179</td>
<td>207</td>
<td>-28</td>
<td>2.03</td>
<td>.15</td>
</tr>
</tbody>
</table>

Changes in zone designations within the floodway and floodway fringe should have a minimal effect on property values because both of these zones are typically regulated by local governmental agencies. However, areas that were redesignated from being outside the 100-yr floodplain to being within the 100-yr floodplain, or vice versa, have the potential produce more significant impacts. For example, if a property originally located within the 100-yr floodplain was redesignated as outside the 100-yr floodplain, this may encourage owners to develop the property or sell it to others for development. These owners may also face a higher tax bill due to the increase in property value. On the other hand, properties that become part of the new 100-yr floodplain may be subject to lower property taxes due to a decrease in property value, but may also face greater regulation.

*Evaluation of the Flood Maps using the Parcels Flooded during the 1999 and 2002 Flood Events*

There were 544 parcels inundated in Wilson during the 1999 flood that followed Hurricane Floyd. Based upon the FIRMs, 125 parcels were within the floodway and 212 within the floodway fringe. Based on the DFIRMs, there were 156 parcels in the floodway and 209 in the floodway fringe. This is consistent with the overall increase in the areas designated as being within the floodway on the DFIRMs (Table 2). The total number of parcels correctly identified by the DFIRMs was 365 (67.1% of the total parcels) and by the FIRMs was 337 (61.9%) (Table 3). The difference in the number of parcels correctly identified by the two maps would initially seem to indicate that the DFIRMs identified 28 flooded parcels that the FIRMs did not identify. Upon further investigation on a parcel-by-parcel basis, however, it was found that the DFIRMs actually identified 35 flooded parcels that the FIRMs did not identify, and the FIRMs identified seven parcels that the DFIRMs did not identify.

A similar analysis was conducted using the flooded street intersections during a localized flooding event that occurred in August 2002. Citywide, 29 intersections were flooded, with 51.7% correctly identified by the DFIRMs as being in the floodway or floodway fringe, whereas 37.9% were correctly identified by the FIRMs (Table 4). It should be noted that in this...
comparison the DFIRMs did not fail to identify any flooded intersections identified as flooded on the FIRMs. In addition, both sets of maps identified three intersections as being in the floodway; two of the intersections were the same on both maps, while the third one differed.

The final analysis used the 500-yr floodplain (Zone X) on the DFIRMs to map the flooded parcels in 1999 and the flooded street intersections in 2002. Of the 179 flooded parcels that were outside the 100-yr floodplain (on the DFIRMs, Table 3), 17 were within the 500-yr floodplain. Of the 14 flooded intersections that were outside the 100-yr floodplain (Table 4), three were within the 500-yr floodplain. Also, in several of the areas where flooded parcels were outside the 100-yr floodplain but within the 500-yr floodplain, these newly identified parcels were contiguous to additional parcels that were flooded but were outside Zone X. In other words, if we were to move the Zone X boundary slightly, the map would identify more flooded parcels. The remainder of the parcels and intersections were scattered throughout the city and in many cases were distant from any flood zones. In summary, there is a slight but limited improvement in delineating flooded areas when Zone X is used.

<table>
<thead>
<tr>
<th>Flooded street intersections</th>
<th>DFIRMs</th>
<th>FIRMs</th>
<th>Difference</th>
<th>$\chi^2$</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>In floodway</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>In floodway fringe</td>
<td>12</td>
<td>8</td>
<td>4</td>
<td>0.80</td>
<td>0.37</td>
</tr>
<tr>
<td>Not in the 100-yr floodplain</td>
<td>14</td>
<td>18</td>
<td>-4</td>
<td>0.50</td>
<td>0.48</td>
</tr>
</tbody>
</table>

**SUMMARY AND CONCLUSIONS**

The 100-yr floodplains on the new Digital Flood Insurance Rate Maps (DFIRMs) and existing Flood Insurance Rate Maps (FIRMs) were extracted and compared in Wilson, North Carolina. Of the 16,776 ha in the study area, 2,653 ha were identified as within the 100-yr floodplain, and 13,272 ha were delineated as outside the 100-yr floodplains on both flood maps. This represents about 95% of the total study area. For the remaining 5% of the study area, there was an exchange of the 100-yr floodplain designation. Some areas mapped as within the 100-yr floodplain on the FIRMs are now mapped as outside of the 100-yr floodplain on the DFIRMs, and vice versa. An additional 477 ha of land were mapped as within the 100-yr floodplains on the DFIRMs. These areas are mostly long narrow strips running parallel to the existing floodplain, new channels extending out from the existing floodplain, and large expanses of area adjacent to the existing floodplain, but extending over a broader area.

The 100-yr floodplain delineation on both maps was also compared to the September 1999 flood event caused by Hurricane Floyd and the August 2002 flood
event created by a localized heavy storm. For the 1999 flood, only 67% and 62% of the flooded parcels (with a total of 544 parcels) were within the 100-yr floodplain on the DFIRMs and FIRMs, respectively. For the 29 flooded street intersections during the 2002 flood event, only 52% were identified by the DFIRMs, and 38% by the FIRMs.

Although the new DFIRMs did a better job overall of flood delineations in 1999 and 2002, both sets of maps failed to identify a portion of flooded areas. An additional analysis was conducted to try to ascertain why these areas were not identified by either map. Initially it was suspected that the flooded areas not identified by the DFIRMs and FIRMs were localized low lying areas that were not near a stream channel, and flooding (or flash flooding) in these areas could come from the inward flow of water into the areas during a heavy storm with a rapid rainfall rate. Upon investigation, however, it was realized that this was not generally the case. The majority of areas that suffered flooding, but were not identified by either set of maps is best described as being very near the mean elevation for the study area and between zero and one standard deviations below the mean slope of the area based on the downloaded DEMs (NCFMP 2000). Furthermore, 68% of the parcels that the DFIRMs failed to identify were at least 300 m from the floodway and 42% of parcels were at least 600 m from the floodway. In other words, most of the flooded areas that were not identified were extremely flat, of average elevation, and distant from drainage channels as identified by the floodway as well as floodway fringe of the flood maps, and they are outside the 100-yr floodplain.

Because the 500-yr floodplain contains areas that have clearly flooded in the past, it may seem logical to promote the use of the 500-yr floodplain as a regulatory tool for future flood mitigation and flood prevention activities. However, two major questions remain. First, the 500-yr floodplain has never been regulated. Will local governments be willing to do so? Second, what should be done about areas that have been flooded, but are located outside the 500-yr floodplain? Because regulation in the floodway fringe is extremely controversial in Wilson, it appears doubtful that the city will regulate the 500-yr floodplain. In addition, the large number of flooded parcels and street intersections located outside of any flood hazard area suggests that future flood prevention and mitigation efforts may need to focus on storm sewer design, implementation, and maintenance, instead of simply moving the flood zone boundaries around. Furthermore, perhaps a closer look at how flood hazard areas are delineated is in order if other communities experience similar flooding issues in non-delineated flood areas.

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LITERATURE CITED


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