Assessing and Mitigating the Exposure of Coastal Communities to Hurricane Flood Damage

Final Report to the
Florida Department of Community Affairs
Division of Emergency Management

By the
Florida Planning and Development Lab
Department of Urban and Regional Planning
Florida State University

Robert E. Deyle and Timothy S. Chapin
Department of Urban and Regional Planning
Principal Investigators

Earl Jay Baker
Department of Geography
Associate Investigator

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Executive Summary

Florida's growth management legislation requires coastal communities to include policies in their comprehensive plans that limit development in and direct populations away from "coastal high hazard areas" (CHHAs). Local governments also are required to adopt policies to maintain or reduce evacuation clearance times within larger areas designated as "hurricane vulnerability zones" (HVZs). State law also requires local governments to enact land development regulations and take other initiatives to implement these policies.

This report presents final results from our analysis of the impacts of implementing those policies between the time that local comprehensive plans were approved by the State Department of Community Affairs (DCA), circa 1989-1991 and the year 2002. Specifically we analyzed the following in a sample of 88 coastal communities in 15 counties: (1) residential development that occurred within and outside of CHHAs and HVZs during comparable time periods prior to and following state approval of local comprehensive plans, (2) the effects of those land use changes on the exposure of people and private residential property to hurricane flooding, (3) the effects of those land use changes on evacuation clearance times and emergency shelter demand, and (4) the extent to which those land use changes can be explained by the actual content of the coastal elements of local comprehensive plans.

Our analyses show that residential development following state approval of local comprehensive plans has been slower and at lower densities within CHHAs than in areas outside CHHAs, a finding that is consistent with the state's mandate to limit development within CHHAs and direct population concentrations away from such areas. Nonetheless, fully a third of the coastal communities in our sample do not show evidence of such trends, and the aggregate residential development within CHHAs and HVZs since plan approval has still been substantial.

We estimate that a total of approximately 152,000 new residential units were built within the two hurricane hazard zones combined during the period between plan approval and 2002 within the 88 communities in our sample. The associated increase in total population (permanent plus seasonal) for the two hazard zones is in excess of 340,000 people, while the sum of the increase in 2002 just value of residential property improvements is nearly $30 billion. Rough extrapolations for the entire 35 coastal counties of the state yield estimates of 420,000 new residential units within the total HVZ and associated increases of approximately 954,000 new residents and $81 billion in new residential structures.

The associated impacts on evacuation clearance times and public shelter demand are also substantial. Our analyses of the impacts of post-plan growth on estimated 2002 hurricane evacuation clearance times in 5 counties show mean increments in clearance times for the most constrained critical roadway segments in these 5 counties of 1.5 hours for a Category 1 hurricane, 2.2 hours for a Category 3, and 3.0 hours for a Category 4/5 hurricane. These impacts suggest that the aggregate effects of numerous small increases may be undermining the state's goal of protecting and enhancing public safety. In 4 of the 5 counties, the majority of the post-plan increases in evacuation clearance times are attributable to growth within the CHHA and the HVZ. Post-plan-approval growth within the HVZs in the 5 counties we analyzed has resulted in an estimated increase in public shelter demand of over 20,000 persons for a Category 4/5 storm.

Our analysis of the quality of the coastal elements of the comprehensive plans of the communities in our sample revealed that local plans were more nearly compliant with the state's

mandates concerning development within CHHAs and HVZs in 2002 than they were when the plans were first approved by DCA circa 1990. Nevertheless, it is evident from our analyses of plan content, and from our case studies, that a number of communities have failed to revise their CHHA definitions to be consistent with state legislation adopted in 1994, despite having completed one evaluation and appraisal report (EAR) cycle. Furthermore, between 8 and 16 percent of the communities in our sample of 76 coastal jurisdictions lacked one or more the mandated policies governing development within the CHHA as of 2002.

Our bivariate statistical analyses provide some evidence that post-plan growth densities are lower in communities with coastal elements in their original comprehensive plans that conformed with the state's mandates concerning development within CHHAs. We find, however, that plan amendments between the year of plan approval and 2002 have had relatively little significant impact on growth patterns during that same time period. Our preliminary multivariate analyses indicate that the best predictor of post-plan growth density is the growth density in a community prior to plan approval, a finding that is borne out by our case studies. In most of our 12 case study communities, the residential densities permitted in the CHHA as stipulated in the future land use element of local comprehensive plans reflected allowable densities already established in communities' existing plans and/or zoning ordinances. Only a couple of the communities we studied took initiatives that appear to have significantly affected post-plan residential densities in the form of down-zoning vacant land within the CHHA and engaging in aggressive public acquisition of wetlands for conservation purposes.

The preliminary multivariate results as well as our case studies suggest that communities with lower pre-plan densities were more likely to adopt plans that limit densities within CHHAs and, therefore, that lower post-plan densities in many communities reflect good planning and growth management practices that predate the comprehensive plans adopted pursuant to the 1985 state mandate. It is likely, however, as noted by several of the local planning officials we interviewed, that densities within CHHAs would be higher yet if communities did not have policies in place that discourage zoning amendments to increase allowable densities.

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Introduction

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This report presents final results from our analysis of the impacts of implementing those policies between the time that local comprehensive plans were approved by the State Department of Community Affairs (DCA), circa 1988-1991 and the year 2002. Specifically we analyzed the following: (1) residential development that occurred within and outside of CHHAs and HVZs during comparable time periods prior to and following state approval of local comprehensive plans, (2) the effects of those land use changes on the exposure of people and private residential property to hurricane flooding, (3) the effects of those land use changes on evacuation clearance times and emergency shelter demand, and (4) the extent to which those land use changes can be explained by the actual content of the coastal elements of local comprehensive plans. In the following sections we present a summary of our findings from these analyses.

Residential Development Patterns within and outside of Hurricane Hazard Zones

The first comprehensive plans developed under Florida's 1985 local planning mandate were adopted by local governments and approved by DCA between 1988 and 1991. Land development regulations and other growth management strategies implementing these policies were adopted by local governments to varying degrees in the years following approval of the plans.

Florida has 35 coastal counties and an additional 158 municipalities that are required to include coastal management elements in their comprehensive plans. We were unable to analyze all of these jurisdictions because of various data constraints.[1] Nonetheless, our ultimate sample of 88 jurisdictions (15 counties and 73 municipalities) provides good coverage of the range of geographic and socio-economic variation among Florida's coastal jurisdictions and thus can be viewed as a reasonable sample of the likely variation in both hazard exposure and planning responses (see Figure 1).

Table 1 summarizes key characteristics of the 15 counties from which our sample is drawn. Total 1990 populations range from a low of 11,504 in Gulf, a rural Panhandle county with substantial amounts of undeveloped coastal land at that time, to Palm Beach County, one of the densely-populated counties of southeast Florida. Our sample constitutes 36 percent of the

[1] Sample selection criteria include the following:
(1) coastal jurisdictions required to include a coastal element in the local comprehensive plan;
(2) comprehensive plan approved between 1988 and 1991;
(3) 2002 property appraiser tax roll data and parcel geometry available;
(4) parcel geometry in useable format, e.g. shapefile or ArcInfo coverage; not un-projected CAD files;
(5) reliable land use coding data - suspect data field checked;
(6) some vacant land in Cat 1 or Cat 3 zone in 1995; and
(7) no exceptional circumstances.

total 2002 population of all 35 coastal counties in Florida and 41 percent of the area. The decadal average growth rate for our sample of 15 counties (26 percent) is nearly identical to the average for all 35 coastal counties (27 percent). Values for individual counties in our sample range from lows of 12 to 20 percent in some of the more built-out coastal areas in northeast Florida (Brevard and Volusia counties) and the central west coast (Sarasota County) and some of the slower-growing Panhandle counties (Bay, Escambia, and Okaloosa) to very fast growing areas in which populations increased in excess of 40 percent (Santa Rosa and St. Johns counties). The densities of these population increases average 65 people per square mile, with a range from a low of 6 people per square mile in Gulf County to highs of 132 and 136 in Lee and Palm Beach counties.

Table 1. Characteristics of Coastal Counties.

County	Population Change 1980-1990	U.S. Census Population 1990	U.S. Census Population 2000	Population Change 1990-2000	Area in Square Miles	Population Increase per Sq Mi
Bay	30%	126,994	148,217	17%	764	28
Brevard	46%	398,978	476,230	19%	1,018	76
Escambia	12%	262,798	294,410	12%	662	48
Gulf	8%	11,504	14,560	27%	555	6
Hernando	127%	101,115	130,802	29%	478	62
Indian River	51%	90,208	112,947	25%	503	45
Lee	63%	335,113	440,888	32%	804	132
Okaloosa	31%	143,776	170,498	19%	936	29
Palm Beach	50%	863,518	1,131,184	31%	1,974	136
Pasco	45%	281,131	344,765	23%	745	85
Santa Rosa	46%	81,608	117,743	44%	1,017	36
Sarasota	37%	277,776	325,957	17%	572	84
St. Johns	63%	83,829	123,135	47%	609	66
St. Lucie	72%	150,171	192,695	28%	572	74
Volusia	43%	370,712	443,343	20%	1,103	66
Totals:	45%	3,579,231	4,467,374	25%	12,312	72
Averages:	48%			26%		65

Our objective for this segment of the project was to determine how residential land use changed subsequent to the approval of local comprehensive plans within CHHAs and to contrast those patterns with land use changes outside the designated CHHAs. To do this we had to answer two questions:

(1) How did residential land use change subsequent to approval of local comprehensive plans?

(2) To what extent did land use changes differ within and outside of hurricane hazard zones?

Changes in Residential Land Use Patterns Over Time

To answer the first question, we made the following determinations for each coastal jurisdiction:

- Where did residential development exist at the time the local comprehensive plan was approved by DCA and how much vacant residential land was available at that time?
- Where did residential development exist at the end of the "post-plan" time period in 2002?
- Where did residential development exist, and how much vacant residential land was available, in the base year at the start of the "pre-plan" time period?

To make these determinations we used 2002 county property appraiser tax roll data and property parcel geometry obtained through the Florida Department of Revenue. We deduced the development status of each parcel in years prior to 2002 from "actual year built" data that we obtained directly from the counties.

Communities are required to adopt land development regulations to implement the policies in their comprehensive plans within one year of plan approval by DCA. We therefore identified property records as having been developed "pre-plan" where the "actual year built" for improvements on the parcel was the year of plan approval or earlier. This approach accounts for the expected lag in plan implementation after the adoption and approval of the local plan. We designated property parcels with an actual year built after the year of plan approval as having been developed "post-plan."

We defined the base year of the pre-plan time period for each community so that the lengths of the post-plan and pre-plan time periods were the same. Thus, for example, if a community's comprehensive plan was approved in 1990, the length of the post-plan period would be 12 years (1990 to 2002). The base year for the corresponding pre-plan period would, therefore, be 1978.

We defined the 2002 developed land use status of each parcel based on the land use codes contained in the 2002 tax roll data. We assumed that the parcel was undeveloped prior to the year built date. To estimate the supply of vacant residential land at the start of the pre-plan and post-plan time periods, we defined land as vacant residential land if it was categorized as vacant residential or unimproved agricultural land by the county property appraiser in the base year of the time period or if it was categorized as improved residential land use subsequent to the base year.

Comparison of Development Patterns within and outside of Hurricane Hazard Zones

To answer the second question we had to determine whether or not a given property parcel lay within or outside of the CHHA or the HVZ. We did so by overlaying the CHHA and HVZ boundaries with the property parcel polygons.

Prior to 1994, coastal jurisdictions were allowed some latitude in how they defined the CHHA. Most defined it in terms of the National Flood Insurance Program (NFIP) V-zone, the state's Coastal Construction Control Line (CCCL), and/or some determination of coastal areas susceptible to repetitive flood damage. In 1994, amendments to Chapter 163 of the *Florida Statutes*, changed the definition of the CHHA to the Category 1 hurricane evacuation zone. It is this definition that we applied in these analyses on the assumption that over the ensuing years local governments would be required to modify their CHHA definitions in accord with the statute. Rule amendments in 1994 also added a definition for the HVZ as the area requiring

evacuation in the event of a 100-year storm or a Category 3 hurricane. We defined it simply as the Category 3 evacuation zone because that is the basis upon which evacuations are conducted in the state.

Evacuation zones are typically defined for each county by the county emergency management staff based on models that predict the areas likely to be inundated by storm surge from hurricanes of different intensities. Unlike surge zones, however, which model storm surge flooding based on topography, evacuation zones are more generalized boundaries that utilize recognizable features such as major roads to define boundaries that are more readily understood by the public at large when an evacuation order is given. In some counties, separate evacuation zones are not mapped in the hurricane evacuation study for each hurricane intensity level. Thus, for example, in Volusia County, only two hurricane evacuation zones are mapped: Zone A and Zone B. Zone A is evacuated for both a Category 1 hurricane and a Category 2 hurricane, while Zone B is evacuated for a Category 3, 4, or 5 hurricane. In cases such as Volusia County, we defined the CHHA as coincident with Zone A.

The extent to which individual communities are included within these hurricane hazard zones varies substantially from one part of Florida to another. At one extreme are counties along the northeast Atlantic coast of Florida, such as Volusia, that have high dune ridges along narrow barrier islands and narrow hurricane hazard zones. In these areas, the area encompassed by the CHHA is largely limited to a narrow strip along the ocean with a narrow fringe of HVZ along the sounds behind the barrier islands (see Figure 2). It is for this reason that the hurricane evacuation zones are aggregated in Volusia. In some cases, however, there are communities located on the barrier islands that have no land outside the HVZ. In the eastern Florida Panhandle, in counties such as Bay, relatively high bluffs along the Gulf of Mexico limit the extent of the CHHA along the open Gulf to a fairly narrow strip, but the CHHA and HVZ are more extensive along the margins of the interior bays (see Figure 3). Due to steeper coastal margins along some portions of these bays, there are some communities that do not have a CHHA, but do have an HVZ, i.e. they are not flooded by a Category 1 storm but would be flooded by a Category 3. At the other extreme are counties such as Lee, along the southwest coast of Florida, where, because of low topographic relief, the CHHA and HVZ cover extensive areas (see Figure 4). In some cases virtually the entire community lies within the CHHA.

Findings for Residential Development

To assess residential development patterns within and outside of CHHAs, we estimated the number of residential units on each property parcel based on the land use codes in the county tax roll data for single family, mobile home, condominium, and cooperative land uses. For multi-family residential structures and hotels and motels, we obtained data on the number of units per structure from the Florida Department of Business and Professional Regulation, which licenses all multi-family residential properties in the state. We then calculated growth rates within and outside of the two hurricane hazard zones prior to and following state approval of a jurisdiction's comprehensive plan.

A total of 76 communities within our sample have land within the CHHA defined as the Category 1 hurricane evacuation zone. Increases in the absolute numbers of residential units within the CHHA after plan approval within our sample range from a low of 3 new residential units in Port Orange (Volusia County) to 18,732 new units in unincorporated Lee County, with a median of 354. Figure 5 depicts these post-plan-approval changes. Labels are included for those

communities in the top three classes of the distribution, i.e. those with increases in excess of 1,441 residential units.[2] It is not surprising that all eight of the jurisdictions with increases of this magnitude are unincorporated coastal counties. These are the areas likely to have had the largest areas of undeveloped land within their hurricane hazard zones at the time their comprehensive plans were approved by DCA in the late 1980s and early 1990s. An examination of the growth rates for individual jurisdictions also reveals substantial variation but shows that rates are relatively comparable within and outside of CHHAs (see Table 2).

In an effort to ascertain whether or not comprehensive plan policy implementation may have influenced these observed development patterns, we conducted a two-dimensional analysis as shown in Table 3 for those communities that have land both within and outside the CHHA. *A priori*, successful implementation of the state mandate to direct population and development away from CHHAs would be evidenced by lower growth rates within the CHHA after plan approval than before and by lower growth rates within the CHHA than outside the CHHA after plan approval.

Table 2. Comparison of Growth Rates for Numbers of Residential Units Within and Outside of CHHAs.

Number of Residential Units	Range	Mean	Median
within CHHA (n = 76)	1-86%	22%	15%
outside CHHA (n = 73)	1-217%	32%	26%

Table 3. Summary of the Hazard Zone Location and Development Timing Dimensions.

Hazard Zone Location Dimension	Development Timing Dimension	
	Developed Pre-Plan	*Developed Post-Plan*
Within CHHA	Development inside of hazard zone, but developed prior to comp plan policy implementation	Development inside of hazard zone one or more years after comp plan approval
Outside of CHHA	Development outside of hazard zone, but developed prior to comp plan policy implementation	Development outside of hazard zone one or more years after comp plan approval

Table 4 presents a two-dimensional comparison of median growth rates for numbers of residential units within and outside of CHHAs both before and after comprehensive plan approval as well as ratios for the growth rates after and prior to plan approval. All else being equal, we would expect slower residential growth rates within CHHAs after plan approval than before if coastal communities were effectively implementing policies to limit growth within CHHAs. Table 4 shows this to be the case (a drop from 67 percent to 14 percent). A Mann-

[2] The distribution of values for the numbers of new residential units were classified by natural breaks into five classes using ArcGIS 9.0 software. Figure 5 depicts those jurisdictions with increases in the three top classes.

Whitney-Wilcoxon test of the difference in medians reveals the difference to be statistically significant at better than the 99.98 percent confidence level. Further examination of Table 4 shows, however, a similar, statistically significant decline in the median growth rate for numbers of residential units built outside of CHHAs (77 percent versus 28 percent).

Table 4. Median Growth Rates for Numbers of Residential Units Before and After Comprehensive Plan Approval Within and Outside of CHHAs.

Location	Prior to Plan Approval	After Plan Approval	After/Prior Ratio	Mann-Whitney-Wilcoxon p-value
Within CHHA	67%	14%	0.23	<0.0002
Outside CHHA	77%	28%	0.35	<0.0002
Mann-Whitney-Wilcox p-value	0.1867	0.0003	0.0014	

This parallel trend both within and outside of CHHAs may be evidence that the post-plan approval decline within CHHAs was due to broader phenomena such as the overall impacts of comprehensive plan implementation, independent of policies directed specifically at CHHAs, or other phenomena such as limited supplies of vacant land, reduced rates of population growth, or slower economic growth. It is very likely that the supply of vacant residential land declined over this time period. In addition, reference to Table 1 shows that population growth in these 15 counties was significantly greater between 1980 and 1990 (45 percent increase) than between 1990 and 2000 (25 percent). Thus the observed declines in numbers of new residential units after plan approval may not reflect any direct impacts of plan implementation.

Table 4 also shows that the median growth rates within and outside of the CHHA were not significantly different prior to the approval of local comprehensive plans (67 percent versus 77 percent). However, the median post-plan growth rate within CHHAs after plan approval was significantly lower than that outside CHHAs (14 percent versus 28 percent). Thus it appears that some factors above and beyond those affecting the whole jurisdiction may have been at work during the post-plan-approval period. Such an assumption is further supported by comparing the ratios of median growth rates after plan approval versus before plan approval. This ratio also is lower within the CHHA than outside (0.23 versus 0.35) and the difference is significant at the 99.86 percent level. This difference offers another signal that differential comprehensive plan policies might have had an effect, all else being equal. It is possible, however, that there were greater constraints to the vacant land supply within the CHHAs than outside, or that other factors may have contributed to these observed differences.

To control for the possible effects of land supply, we also calculated residential "growth densities." These represent the total numbers of new residential units built within a given time period, normalized for the amount of vacant residential land present at the start of that time period.[3] In Table 5 we display median residential "growth densities" before and after comprehensive plan approval within and outside of CHHAs in our sample jurisdictions. Not

[3] We coded the land use of a property parcel as vacant residential if it was designated as vacant residential land or unimproved agricultural land with no primary residence in the property appraiser tax roll. We also assumed that parcels coded as residential in 2002 were vacant residential land prior to the year in which the current residential structure was built.

surprisingly, Table 5 shows that growth densities were higher within the CHHA, immediately adjacent to the coast, than in more inland areas, both before and after plan approval. Beyond this distinction, however, we again find evidence of growth patterns consistent with the state's mandate to direct populations away from CHHAs: there was a statistically significant (at the 98.34 percent confidence level) decrease in median growth density within the CHHA following plan approval, whereas there was no significant change in residential growth density outside that hazard zone. In fact, the median after/prior growth density ratio for areas outside the CHHA is greater than 1.0.

Table 5. Median Residential Growth Densities Before and After Comprehensive Plan Approval Within and Outside of CHHAs.

Location	Prior to Plan Approval	After Plan Approval	After/Prior Ratio	Mann-Whitney-Wilcoxon p-value
Within CHHA (units/acre)	2.72	2.31	0.91	0.0166
Outside CHHA (units/acre)	1.37	1.23	1.07	0.2005
Mann-Whitney-Wilcox p-value	<0.0002	<0.0002	0.0359	

The overall patterns, therefore, are consistent with the hypothesis that implementation of comprehensive plan policies may have reduced residential growth within CHHAs relative to areas outside CHHAs. Nevertheless, residential growth has not been curtailed within CHHAs by any means. While only 8 percent of the 61 coastal communities with land both within and outside a CHHA had higher rates of residential growth within the CHHA after comprehensive plan approval than before, a third (33 percent) had higher rates of growth in the numbers of residential units within their CHHAs than outside after plan approval. It is important, therefore, to examine the overall effects of population growth within CHHAs. In the following section we present an overview of the increases in residential exposure to hurricane flooding that occurred within CHHAs between the time local plans were approved by DCA and 2002.

Aggregate Exposure Impacts

We estimated aggregate changes in residential exposure to hurricane flooding for five parameters: 1) number of residential units, 2) total number of seasonal residents, 3) total number of permanent residents, 4) total population, and 5) total 2002 just value of residential property improvements. We calculated the number of permanent residents for each residential parcel by multiplying each residential unit by the average household size and the proportion of occupied housing units for the census tract in which it was located. We used 1990 census figures for our pre-plan estimates and 2000 census figures for our 2002 estimates. To estimate the number of seasonal residents we used separate multipliers for tourist units and seasonal residential units. The first we obtained from the regional hurricane evacuation studies prepared for each county by or for Florida's regional planning councils. The second we obtained from the U.S. Census. We estimated the market value of residential property improvements by subtracting the Land Value for each parcel from its Total Just Value as assessed by each county property appraiser. The

Total Just Value field is typically 85 percent of the assessor's determination of the true market value of a property prior to the consideration of any exemptions.

Table 6 presents sums for each of the five exposure measures for all of the 88 coastal communities we analyzed. Our estimates reveal substantial increases in the numbers of residential structures both within the CHHAs of these communities and within the HVZ increments (the area in addition to that within the CHHA that is evacuated for a Category 3 hurricane) totaling approximately 153,000 for the two hurricane hazard zones combined. Given the comparable average 1990-2000 population growth rates for our sample (26 percent) and for all 35 coastal counties in the state (27 percent), a rough approximation for the state is 420,000 new residential units within the total HVZ.[4] The associated increase in total population (permanent plus seasonal) for the two hazard zones within our sample is in excess of 345,000 people, while the sum of the increase in 2002 just value of residential property improvements is nearly $30 billion. Applying a similar extrapolation approach yields rough estimates of total increases within the hurricane hazard zones of the state's 35 coastal counties of approximately 954,000 new residents and $81 billion in new residential structures subsequent to state approval of local comprehensive plans between 1988 and 1991.

These figures present a sobering context within which to consider the evidence that the state's mandate to limit development within and direct population concentrations away from CHHAs may have constrained growth within CHHAs to some degree.

Table 6. Aggregate Changes in Residential Hurricane Exposure Between Plan Approval Year and 2002.

Exposure Parameter	CHHA (n = 76)	HVZ Increment (n = 76)	Total HVZ
Number of residential units	75,177	76,551	151,692
Seasonal population	46,683	19,078	65,761
Permanent population	121,981	155,633	277,614
Total population	168,610	174,661	343,271
2002 just value of residential structures	$18.9 billion	$10.4 billion	$29.3 billion

Impacts on Evacuation Clearance Times and Emergency Shelter Demand

Under Florida's 1985 growth management legislation, coastal communities are required to include policies in their comprehensive plans that reduce or maintain hurricane evacuation clearance times within HVZs. Having previously estimated the growth that occurred between approval of comprehensive plans and 2002, we then estimated the effect of that growth on hurricane evacuation clearance times in selected counties. In addition, we assessed the effect of that growth on public shelter demand that would occur during hurricane evacuations. We completed such analyses for jurisdictions in 5 of the 15 counties in our larger sample (Bay,

[4] This estimate is based on the proportion of total 2000 population in the 35 coastal counties that is accounted for by the 15 counties in our sample (36 percent). This extrapolation implicitly assumes that our sample is also proportionately representative of the spatial extent of CHHAs and HVZs throughout the state.

Indian River, Pasco, St. Johns, and Volusia) to provide an overview of the different impacts likely to be associated with post-plan approval growth patterns.

Method

Using the methods described earlier in this report, we calculated changes in both permanent and seasonal residential units subsequent to approval of local government comprehensive plans through 2002. Separate computations were made for mobile homes and other types of residences. As part of the Hurricane Evacuation Study (HES) updates for the respective regions of the state, Post, Buckley, Schuh, and Jernigan (PBS&J) had performed the most recent clearance time and shelter demand analyses for the counties selected for our examination. In conjunction with those studies, PBS&J prepared Abbreviated Transportation Models (ATMs), consisting of a set of spreadsheets that allow users to vary certain inputs and assumptions and generate new outputs, including clearance times and shelter demand estimates.

We replaced PBS&J's data on numbers of residential units with our calculations of numbers of residential units in the ATMs for the counties in our analysis. We used our data for the year of comprehensive plan approval to create a base year condition and then inserted our data for 2002 to estimate the impact of post-plan-approval growth.

The ATMs divide counties into Transportation Evacuation Zones (TEZs). The area that would be evacuated in a Category 1 hurricane, for example, is divided into a number of TEZs which are wholly included within the Category 1 evacuation zone. We overlaid the TEZs for each county with property parcel boundaries to allocate residential units to the TEZs and entered those figures into the "Socioeconomic Data" worksheets from the ATMs. These worksheets contain multipliers for numbers of people in each residential unit and numbers of vehicles in each unit. They are linked to another worksheet containing assumptions about how the populations will behave during a hurricane threat. We did not modify any of the original multipliers or behavioral assumptions in our analysis. For each county, we used the ATM to compute evacuation clearance times for a number of critical roadway segments in the county for hurricanes of various intensities, and we computed the number of people who would seek shelter in public facilities in each of the hurricane scenarios. The differences in clearance times and shelter demand that we generated are attributable to increases in the numbers of residential units that had occurred subsequent to plan approval.

Clearance Time Impacts

Table 7 displays the aggregate effects of post-plan-approval growth within the HVZs of individual coastal jurisdictions on the maximum 2002 evacuation clearance times of the five counties we analyzed. The increments reported are for the most constrained critical roadway segment in each county for a given hurricane intensity. Mean increments due to growth within HVZs range from 1.5 hours for a Category 1 hurricane to 2.2 hours for a Category 3 and 3.0 hours for a Category 4/5. Such increases are clearly not in concert with the intent of the state's planning mandate to maintain or reduce hurricane evacuation clearance times within HVZs in particular or within counties as a whole.

Increases in permanent and seasonal populations within HVZs between plan approval and 2002 account for an average of between 15 and 18 percent of estimated 2002 evacuation clearance times for all three hurricane categories. Estimated 2002 evacuation clearance times for

Bay and St. Johns Counties equal or exceed the state's recommended maximum of 16 hours for both Category 3 and Category 4/5 hurricanes. In St. Johns County, the post-plan increments within the HVZ account for all of the margins that exceed the state guideline. In Bay County, the post-plan increments within the HVZ account for about half of the margins that exceed the state guidelines. For both the Category 3 and the Category 4/5 storms, the pre-plan base evacuation clearance times that we calculated already exceeded the state guideline of 16 hours.

Table 7. Contributions to 2002 Evacuation Clearance Times from Residential Growth within Hurricane Vulnerability Zones Between Plan-Approval Year and 2002*

	Increase in Clearance Time (hours)								
	Category 1			Category 3			Category 4/5		
County	2002 Time	Post-Plan Increment	Post-Plan Share	2002 Time	Post-Plan Increment	Post-Plan Share	2002 Time	Post-Plan Increment	Post-Plan Share
Bay	14.3	1.8	13%	22.0	3.1	14%	24.5	4.1	17%
Pasco	4.0	0.7	18%	8.7	1.5	18%	14.3	2.7	19%
Indian River	7.3	1.8	25%	8.0	1.9	14%	8.0	1.9	14%
Volusia	7.7	0.4	5%	10.0	0.6	6%	13.8	2.2	16%
St. Johns	11.0	2.6	24%	17.0	3.9	23%	16.9	4.0	23%
Mean:	8.9	1.5	17%	13.1	2.2	15%	15.5	3.0	18%

*Shaded values exceed the state guideline of 16 hours for maximum evacuation clearance time.

Table 8 shows the changes in clearance times for the critical roadway segment in each county that experienced the greatest increase between plan approval year and 2002. Separate estimates are presented for the largest increase in clearance time attributable to any single municipality in each county, along with the increase attributable to growth in the county's unincorporated area and the total increase for the county.

For Category 1 storms, the increases for the most highly impacted critical roadway segment ranged from almost half an hour in Volusia County to more than 2.5 hours in St. Johns. For Category 4/5 hurricanes, increases ranged from nearly 2 hours in Indian River County to more than 4 hours in Bay. In the majority of instances, the largest increase in clearance time in a county occurred at the critical roadway segment having the longest clearance time at the time of plan adoption. There were, however, important spatial variations in contributions to the clearance time increases within each county. From among the jurisdictions in our sample, the largest single municipal contribution to a county's total clearance time increase was 24 percent.

One important finding is that even when growth in individual communities did not result in significant increases in clearance times, collectively the increases were sometimes substantial for anyone in the county needing to pass through a critical roadway segment. This is demonstrated by Figures 6-9 which illustrate the almost negligible impacts of post-plan growth in the small city of South Daytona Beach (Figure 6), the more substantial impacts of growth in the City of Edgewater (Figure 7), the intermediate impacts of growth in unincorporated Volusia County (Figure 8), and the aggregate impacts of growth throughout the county (Figure 9).

Table 8. Contributions to Increases in Clearance Time Since Plan Approval at Critical Roadway Segments Experiencing Largest Increase

	Increase in Clearance Time (hours)		
County	**Category 1**	**Category 3**	**Category 4/5**
Bay			
Single municipality	0.8	0.9	1.6
Unincorporated area	1.3	2.1	2.5
County total	2.1	3.1	4.1
Pasco			
Single municipality	0.01	0.02	0.06
Unincorporated area	0.6	1.2	2.2
County total	0.7	1.5	2.7
Indian River			
Single municipality	0.5	0.5	0.5
Unincorporated area	1.0	1.0	1.0
County total	1.9	1.9	1.9
Volusia			
Single municipality	0.1	0.3	1.3
Unincorporated area	0.3	0.3	0.7
County total	0.4	0.6	2.2
St. Johns			
Single municipality	0.4	0.5	0.5
Unincorporated area	1.9	3.2	3.2
County total	2.6	3.9	3.9

There was a great deal of variation among our five counties with respect to the hurricane hazard zone within the county where growth has had the greatest impact on clearance times. Table 9 shows the amount (in hours) and percent of the increase at the critical roadway segments with the largest increases, that are attributable to growth within the CHHA, the portion of the HVZ inland of the CHHA (HVZ increment), and the area inland of the HVZ in each county plus mobile homes (Other). In most counties, mobile homes throughout the county are evacuated regardless of the hurricane intensity because of wind vulnerability. The PBS&J ATMs also assume different amounts of "shadow evacuation" for each hurricane category. This refers to evacuation by people who live landward of the zone told to evacuate for a given storm intensity.

In Indian River County, growth within the CHHA was the source of almost all (94-98 percent) of the clearance time increase. In Bay County, the CHHA contribution decreased with storm intensity: 63 percent in Category 1 storms, 42 percent in Category 3 storms, and 24 percent in Category 4/5 storms. In Pasco County, more than 80 percent of the clearance time increase came from growth in areas *inland* of the HVZ plus mobile homes for all three storm categories. It is evident from the results shown in Tables 8 and 9 that serious efforts to prevent increases in clearance times in coastal counties must recognize the spatial variability of the effects of growth.

Table 9. Contributions of Different Hazard Zones to Increases in Clearance Time Since Plan Approval at Critical Roadway Segments Experiencing Largest Increase

	Increase in Clearance Time (hours)		
County	**Category 1**	**Category 3**	**Category 4-5**
Bay			
Plan year base	11.71	17.19	18.96
2002 increase	2.09	3.13	4.07
CHHA increase	1.31	1.31	0.99
HVZ increment increase	0.13	1.14	0.94
CHHA %	63%	42%	24%
HVZ increment %	6%	36%	23%
Other %	31%	22%	53%
Pasco			
Plan year base	3.29	7.16	11.59
2002 increase	0.74	1.54	2.66
CHHA increase	0.07	0.12	0.17
HVZ increment increase	0.10	0.27	0.36
CHHA %	10%	8%	7%
HVZ increment %	3%	9%	7%
Other %	87%	83%	87%
Indian River			
Plan year base	5.41	6.06	6.06
2002 increase	1.84	1.92	1.92
CHHA increase	1.80	1.8	1.8
HVZ increment increase	1.84	1.92	1.92
CHHA %	98%	94%	94%
HVZ increment %	2%	6%	6%
Other %	0%	0%	0%
Volusia			
Plan year base	7.32	7.20	11.58
2002 increase	0.42	0.67	2.20
CHHA increase	0.22	0.00	0.00
HVZ increment increase	0.26	0.52	0.52
CHHA %	52%	0%	0%
HVZ increment %	9%	78%	24%
Other %	38%	22%	76%
St. Johns			
Plan year base	8.41	12.87	12.92
2002 increase	2.59	3.92	3.96
CHHA increase	0.96	2.05	2.05
HVZ increment increase	1.08	3.58	1.47
CHHA %	89%	52%	65%
HVZ increment %	11%	39%	35%
Other %	0%	9%	0%

Public Shelter Demand

Table 10 shows that for the five counties analyzed the median increases in shelter demand due to post-plan approval growth ranged from approximately 1,000 people for a Category 1 hurricane, to 2,000 for a Category 3 storm and 3,000 for a Category 4/5. As shown in the table, post-plan-approval growth has resulted in an increased demand of over 20,000 persons in these five counties combined for a Category 4/5 storm. Based on a standard of 20 square feet of shelter space per person, these deficits translate into nearly 1.5 million square feet of needed shelter capacity. Growth that occurred between approval of local comprehensive plans and 2002 was responsible for between 14 and 104 percent of the individual county shelter deficits reported by the DCA in 2004 (Florida Department of Community Affairs, 2004) and for 28 percent of the aggregate deficit for these five counties.

Table 10. Contributions to Public Shelter Deficits from Residential Growth Between Plan-Approval Year and 2002

	Increments in Shelter Demand by Category (persons)			2004 Deficit	Percent Deficit
County	Category 1	Category 3	Category 4/5	Category 4/5	Due to Growth
Bay	1,480	2,212	3,394	7,445	46%
Pasco	3,199	6,643	10,269	40,454	25%
Indian River	465	751	751	721	104%
Volusia	432	909	3,085	21,368	14%
St. Johns	1,017	2,421	2,598	2,509	104%
Sum:	6,593	12,936	20,097	72,497	28%
Median:	1,017	2,212	3,085	7,445	46%

Evidence on the Impacts of Comprehensive Plan Quality on Coastal Residential Land Use

The final question we have examined is whether or not there is evidence that the quality of the coastal elements of communities' comprehensive plans can be credited with residential development patterns that appear to be in concert with the state's mandates. To make this assessment, we reviewed the coastal elements of the originally-approved comprehensive plans of each of the jurisdictions in our sample and compared specific objectives and policies with those in effect in 2002. We conducted a series of bivariate and multivariate statistical tests to determine whether or not better coastal element policies have, in fact, been associated with residential development patterns in CHHAs that are consistent with the state's policy mandates. In addition, we have conducted interviews with planning officials in a representative sub-sample of communities to get more information about why residential development within the CHHAs of those communities looked as it did in 2002 compared to conditions at the time the local comprehensive plan was approved by DCA circa 1990.

Plan Quality Analysis

We focused on the following required plan components in assessing the approved and 2002 coastal elements of each community's comprehensive plan:

(1) define the CHHA as the evacuation zone for a Category 1 hurricane as established in the regional hurricane evacuation study applicable to the local government (*Fla. Admin. Code* § 9J-5.003(17) (2006));

(2) designate coastal high hazard areas and limit development within them (*Fla. Admin. Code* § 9J-5.012(3)(c)(7) (2006));

(3) include an objective to limit public expenditures that subsidize development permitted in coastal high-hazard areas subsequent to the element's adoption except for restoration or enhancement of natural resources (*Fla. Admin. Code* § 9J-5.012(3)(b)(5) (2006));

(4) include an objective to direct population concentrations away from known or predicted CHHAs (*Fla. Admin. Code* § 9J-5.012(3)(b)(6) (2006)); and

(5) include an objective to maintain or reduce evacuation clearance times within larger areas designated as "hurricane vulnerability zones" (HVZs) (*Fla. Admin. Code* §§ 9J-5.003(18) and 9J-5.012(3)(b)(7) (2006)).

We also determined whether or not the CHHA was depicted on a map in the community's comprehensive plan and, more particularly, whether or not the CHHA was depicted on the community's future land use map (FLUM).

The original plan elements were obtained primarily from the DCA's comprehensive plan library and their archives. Plan content in 2002 was ascertained by comparing current comprehensive plan content with the original plans. Where the current plans contained different language, we used the DCA library of comprehensive plan amendments to determine when relevant plan content was amended. We have, therefore, a parallel set of variables representing plan quality at the time the plan was approved by DCA and plan quality in 2002.

Table 11 presents an overview of the quality of the CHHA definitions and mapping in the coastal elements of the 76 communities in our sample that have land within the CHHA defined as the Category 1 evacuation zone. While it is clear that there has been a marked decrease in the number of communities whose coastal elements lacked a CHHA definition or map, it is noteworthy that as of 2002 there remained a number of communities who had failed to define and designate a CHHA and that nearly a third of the communities included no graphic representation of the CHHA within their plans.

The absence of CHHA definitions and corresponding maps in some of the original plans may be attributable to the latitude provided in the original statute and regulatory language for defining the CHHA. Communities which do not face the open ocean or Gulf often do not have designated NFIP V-zones. Communities without sand beaches on the Atlantic or Gulf are not covered by the state's Coastal Construction Control Line (CCCL) permitting program and, therefore, would not have had a designated CCCL. However, all of these jurisdictions should have amended their CHHA definitions to reflect the 1994 statutory amendments that redefined the CHHA as the Category 1 evacuation zone. Some clearly had not done so as late as 2002.

Table 11. Quality of Comprehensive Plan CHHA Definitions and Mapping as Approved by DCA and in 2002

Plan Variables	Approved Plans	2002 Plans
CHHA definition (N=76)		
None	14%	4%
Smaller than Cat 1 evac zone = 1	75%	33%
Equal to Cat 1 evac zone = 2	3%	58%
Larger than Cat 1 evac zone = 3	8%	5%
Existence of CHHA map (N=76)		
No map depicting CHHA = 0	54%	30%
Displayed on map other than FLUM = 2	41%	54%
Displayed on FLUM = 3	5%	16%
CHHA mapped on FLUM (N=76)		
CHHA not depicted on FLUM = 0	95%	84%
CHHA depicted on FLUM = 1	5%	16%

Table 12 presents the plan quality scores for the three mandated objectives and policies that we examined. The sample size is larger for the evacuation time variable because all of the communities in our sample include an HVZ, while only 76 include a CHHA. Here again there is a general pattern of improvement when original plan content is compared with that in effect in 2002. However, it also is noteworthy that between 8 and 16 percent of the communities lacked one or more of the required objectives or policies in their plans as of 2002.

We assessed the relationship between plan quality and post-plan residential development by conducting bivariate analyses of the comprehensive plan variables described in Tables 11 and 12 with our two measures of post-plan-approval residential development: (1) residential growth rate and (2) residential growth density. We also tested a variety of multivariate regression models for these two dependent variables with the plan quality variables and a suite of control variables that may also promote or hinder development within CHHAs. The controls include the following:

- *Hurricane history variables*, such as the timing, number, and intensity of storms in both the pre- and post-plan period;
- *Land supply variables*, such as the percentage of the jurisdiction within the CHHA and the total vacant residential acreage within the CHHA covered by wetlands in the plan approval year;
- *Demand variables*, such as the county population growth rate;
- *Implementation variables*, such as the average annual spending per capita on comprehensive planning related activities during the post-plan period;

- *Political commitment*, measured as the proportion of city/county commissioner years represented by commissioners in office in the year of comprehensive plan adoption; and
- *Existing conditions variables,* including estimates of the growth rates and growth densities in the pre-plan period.

Table 12. Quality of Comprehensive Plan Hazard Zone Objectives and Policies as Approved by DCA and in 2002

Plan Variables	Approved Plans	2002 Plans
Limit public expenditures within CHHA (N=76)		
No policy = 0	16%	8%
A single policy that mirrors 9J-5 mandate but is no more explicit or restrictive = 1	28%	25%
A single policy that is more explicit or restrictive than 9J-5 mandate = 2	38%	43%
Two or more policies that are more explicit or restrictive than 9J-5 mandate = 3	18%	24%
Direct population concentrations away from the CHHA (N=76)		
No policy = 0	33%	16%
A single policy that mirrors 9J-5 mandate but is no more explicit or restrictive = 1	12%	16%
A single policy that is more explicit or restrictive than 9J-5 mandate = 2	34%	39%
Two or more policies that are more explicit or restrictive than 9J-5 mandate = 3	21%	29%
Maintain or reduce evacuation clearance times within HVZ (N=88)		
No policy = 0	20%	10%
A single policy that mirrors 9J-5 mandate but is no more explicit or restrictive = 1	19%	20%
A single policy that is more explicit or restrictive than 9J-5 mandate = 2	32%	40%
Two or more policies that are more explicit or restrictive than 9J-5 mandate = 3	28%	30%

Bivariate Correlation Results

We completed two different correlation analyses for each dependent variable (growth rate and growth density):

(1) Correlations with the approved comprehensive plan quality variables; and

(2) Correlations with the 2002 comprehensive plan quality variables.

Correlation Results for the Approved Comprehensive Plan Quality Variables

Table 13 presents correlations between the growth rate and growth density variables and measures of the quality of the policies in communities' plans at the time they were originally approved by DCA. The results for the growth density variable are consistent with a hypothesis that better plan quality should be associated with lower post-plan growth densities within the CHHA. Communities with definitions of the CHHA that equal or exceed the Category 1 evacuation zone, and communities with more stringent policies to limit public expenditures that subsidize development within the CHHA and to direct population concentrations away from the CHHA, were more likely to have lower growth densities within their CHHAs between the year of plan approval and 2002. The results for the growth rate dependent variable are not consistent with our expectations, however. The only variable that is significantly correlated with post-plan growth rates within the CHHA is that for the quality of the policy directing population concentrations away from the CHHA. The coefficient is positive, however, indicating that communities with better policies had higher post-plan growth rates.

Table 13. Pearson Correlations Between Approved Plan Quality Variables and Post-Plan Growth Density and Growth Rate

Variable	Growth Rate	Growth Density
CHHA definition	.077 (.255)	-.164 * (.080)
Existence of CHHA map	-.026 (.412)	-.132 (.130)
CHHA map on the FLUM	-.166 (.076)	-.059 (.308)
Limit public expenditures	-.072 (.042)	-.175 * (.066)
Direct population concentrations away from CHHA	.275 *** (.008)	-.150 * (.100)
Maintain or reduce evacuation clearance times	.082 (.240)	.074 (.265)

Note: Top value reports the Pearson's Correlation Coefficient and the bottom value reports the probability value for the null hypothesis.
*** Significant at the 99% level; ** Significant at the 95% level;
* Significant at the 90% level

Correlation Results for the 2002 Comprehensive Plan Quality Variables

Table 14 presents correlations between the growth rate and growth density variables and measures of the quality of the policies in communities' plans as of 2002. These results point to the importance of a map within the comprehensive plan that depicts the location of the CHHA, but otherwise suggest that post-plan residential growth patterns are better explained by policies in place at the outset of the post-plan-approval period than by policy amendments that occurred subsequently. As was the case with the approved plan quality variables, the results for the effect on post-plan growth rate of the policy directing populations concentrations away from the CHHA is counterintuitive. The differences between our findings for raw growth rates and growth densities may reflect the importance of controlling for the supply of vacant residential land as is done with the growth density variable.

Table 14. Pearson Correlations Between 2002 Comprehensive Plan Quality Variables and Post-Plan Growth Density and Growth Rate

Variable	Growth Rate	Growth Density
CHHA definition	.117 (.158)	-.119 (.154)
Existence of CHHA map	-.212 ** (.033)	-.183 * (.058)
CHHA map on the FLUM	-.031 (.394)	-.038 (.372)
Limit public expenditures	.037 (.375)	.033 (.391)
Direct population concentrations away from CHHA	.223 ** (.026)	.046 (.348)
Maintain or reduce evacuation clearance times	.115 (.160)	-.094 (.211)

Note: Top value reports the Pearson's Correlation Coefficient and the bottom value reports the probability value for the null hypothesis.
*** Significant at the 99% level; ** Significant at the 95% level;
* Significant at the 90% level

Multivariate Regression Results

Multivariate regression improves upon simple bivariate correlations by measuring the statistical relationship between variables of interest, while controlling for other potential explanatory variables. This approach allows the analyst to better estimate the root causes of variation in a dependent variable. To date, we have run a number of multiple regression models in an effort to determine those factors that explain variation in the growth rates and growth densities for our sample of communities. While this multiple regression work remains ongoing, several preliminary findings of interest to this project have been generated:

(1) *Several comprehensive plan quality variables have been found to be significant explanatory variables for both growth rate and growth density*. In particular, the CHHA definition in the approved comprehensive plan and the quality of the three

policy variables in the approved plan (Limit Public Expenditures within the CHHA, Direct Population Concentrations Away from the CHHA, and Maintain or Reduce Evacuation Clearance Times) are useful predictors for the dependent variables. These findings provide further evidence that comprehensive plan quality is associated with less post-plan development within the CHHA.

(2) *The comprehensive plan quality variables (especially the policy variables) remain statistically significant even when control variables are entered into the model, with one key exception (See point #3 below)*. This suggests that comprehensive plan quality is a better predictor for desirable development outcomes than such factors as hurricane history, market demand, implementation, and political variables.

(3) *For the growth density dependent variable, when a measure of pre-plan growth density is included in the model as a control, the impact of the comprehensive plan quality variables is substantially muted*. This finding indicates that the growth densities experienced by our sample of communities in the post-plan period are best explained by the densities established prior to this period. Communities with lower growth densities in their CHHAs prior to adopting comprehensive plans circa 1990 were also more likely to have lower growth densities following plan adoption. These findings imply that communities with lower pre-plan densities were more likely to adopt plans that limit densities within CHHAs.

Taken as a whole, the regression results suggest that comprehensive plan quality can be a factor in development outcomes, but, in the case of growth densities, it may be secondary to conditions that were established prior to the approval and implementation of these plans. Our preliminary findings suggest that to some extent better plan policies may have been adopted by communities who were already practicing good planning and growth management and that they simply continued to practice good planning after adopting their new plans.

Case Studies

We have interviewed planning officials in a sub-sample of 12 communities that span a range of composite plan quality scores (map and policy scores for the approved plan and 2002) and post-plan-approval growth densities (see Table 15) in an effort to understand the underlying reasons for the post-plan-approval residential development in each community. Several general patterns are evident from these case studies, as well as some insights into reasons behind the patterns observed in some of the best and worst apparent performances.

Table 15. Case Study Communities

Composite Quality Score	Post-Plan-Approval Growth Density		
	0 - 1.5	**1.51 - 3.0**	**> 3.1**
0 - 4.5	Palm Beach Shores	St. Johns County	Cape Canaveral, Panama City Beach, Venice
4.6 - 7.5	Gulf County		Okaloosa County
7.6 - 12.0	Brevard County, Pasco County	Hernando County, Melbourne	Vero Beach

Brevard and Pasco Counties are the two jurisdictions in our sample with the lowest post-plan growth densities coupled with high composite plan quality scores. Their stories are very different. Brevard County had low growth densities both before (0.73 unit/acre) and after (0.78 unit/acre) plan approval. Although the county's initial definition of the CHHA was based on the NFIP V-zone and the state CCCL, the Category 1 evacuation zone is narrow because of high coastal topography so there is not a great deal of difference between the original CHHA definition and that which was in place by 2002. As was the case in many Florida jurisdictions, the allowable densities incorporated in the original comprehensive plan, which was approved in 1988, reflected the existing zoning at that time. However, unlike most of the coastal communities in our case study sample, Brevard County down-zoned a significant portion of its CHHA subsequent to adoption of its plan. The South Beach area on the barrier island south of the City of Melbourne Beach was down-zoned from 4 units/acre to 1 unit/acre in the early 1990s. The down-zoning within the CHHA was undertaken as part of a county-wide "right-sizing" initiative to bring allowable densities into conformity with actual built densities. The low densities for the South Beach area in particular were also based on limited hurricane evacuation capacity. Thus Brevard County is a prime example of a community where post-plan densities reflect pre-plan densities. However, in this case, that pattern was enhanced by intentionally reducing maximum densities within the CHHA both to reflect actual densities at the time the plan was adopted in 1988 and to address evacuation concerns.

Pasco County experienced a significant decrease in growth densities within the CHHA. The pre-plan density was 2.09 units/acre while the post-plan density was only 0.64 unit/acre. In Pasco County, unlike Brevard, the difference between the original CHHA area, based on the NFIP V-zone, and that encompassed by the Category 1 evacuation zone, is substantial. Much of this area, however is covered in salt marsh. There are no barrier islands along the Pasco County coast and very few areas with sandy beaches. According to the planning official with whom we spoke, development in Pasco County has historically been centered primarily on inland areas associated with transportation infrastructure and easy access to economic opportunities in the greater Tampa Bay area. Development pressure within the CHHA has been low. Most of the development in the early 1990s within the CHHA was associated with two dredge-and-fill projects within salt marshes that were permitted in the 1970s and, therefore, vested under the comprehensive plan when it was adopted in 1989. More recently there has been an emphasis on public acquisition within the CHHA to reduce the market for development. It appears, therefore, that the pattern in Pasco County can be explained by vesting of two 1970s developments with high densities, an overall low market demand because of less attractive coastal land cover, and deliberate efforts to protect coastal wetlands and remove them from the market.

At the other extreme in Table 15 are three communities with low composite plan quality scores and high growth densities. These communities have somewhat similar stories. Venice and Cape Canaveral had relatively high pre-plan densities, ranging from 3.25 units/acre in Venice to 5.00 units/acre in Cape Canaveral (no data available for Panama City Beach). Both also had higher growth densities within the CHHA after plan adoption than before ranging from 5.53 units/acre in Venice to 6.11 units/acre in Cape Canaveral. Panama City Beach had no definition of the CHHA in their original comprehensive plan. They had adopted the Category 1 evacuation zone definition in 2001. Cape Canaveral and Venice both had CHHA definitions limited to areas smaller than the Category 1 evacuation zone. Neither community had amended their definition as

of 2002. All of these communities were scheduled to complete EARs prior to 2002. In the cases of Cape Canaveral and Venice, it appears that the CHHA definition was not revised as part of the EAR despite the fact that revision of the definition is explicitly listed in DCA's list of 9J-5 amendments that should be addressed.

In all three communities, the comprehensive plans adopted between 1989 and 1991 incorporated allowable densities that already were in place in the existing comprehensive plan and/or zoning ordinance. The City of Panama City Beach, however, made a significant subsequent change to the future land use category within its CHHA. The city designated most of its CHHA for "seasonal resort" development in its future land use element, an approach that also has been taken in Bay County. Within this land use category, condominiums are permitted that are licensed by the state as non-residential, "public lodging" properties. We have not made this distinction in our analyses because the property appraiser use codes that we employed to assign land use categories treat all condominiums as residential.

Palm Beach Shores appears in the upper left cell of Table 15 with a low composite plan quality score but a low post-plan growth density as well. It appears, therefore, that low post-plan density must be due to factors other than the implementation of policies in the community's comprehensive plan. All of Palm Beach Shores lies within the Category 1 evacuation zone, but the city has not revised its much narrower CHHA definition to conform to the current requirements. Because of its small size, Palm Beach Shores has not been required to complete an EAR to date. The city was largely built out at the time the current plan was approved in 1989. The zoning ordinance was adopted in 1973 and has been largely unchanged since. It includes four zoning districts with maximum allowable densities ranging from 3 to 42 units/acre. The comprehensive plan adopted the densities permitted in the zoning ordinance. Only 8 new residential structures have been built since the plan was approved in 1989. Based on our estimate of 9.5 acres of vacant residential land present at the time the plan was approved, this yields a post-plan growth density of 0.84 unit/acre in contrast to a pre-plan growth density of 12.70. There is no evidence that CHHA development policies are in any way responsible for these patterns.

Vero Beach, in the bottom right corner of Table 15, represents the other counter-intuitive extreme - a high composite plan quality score but high post-plan growth density. The story here is simple. Densities were established prior to approval of the comprehensive plan in 1990 and were not changed when the plan was adopted. In addition, the community was largely built-out at the time the plan was approved. Thus the pre-plan and post-plan growth densities are virtually identical: 3.15 versus 3.14 units/ac. In addition, the CHHA definition was not revised following completion of the city's first EAR in 1999, although they are now on notice from DCA that the definition should be amended.

Gulf and Okaloosa Counties are at either end of the growth density spectrum with medium composite plan quality scores. Their stories are very different. Gulf County's plan quality is largely the result of a stipulation agreement imposed by DCA in 1992. Its very low growth densities appear, however, to be a function of factors other than the implementation of those policies. Relatively little development pressure was present prior to 2002. Only 540 new residential units were built after plan approval within the county's CHHA versus 468 during a comparable time period before. In addition, extensive areas of the county's Category 1 evacuation zone are covered by riverine wetland and are unattractive for development. A total of 90% of the county's vacant residential land within the CHHA lies within wetlands. Nonetheless,

if the amount of vacant residential land present at the time the comprehensive plan was approved is adjusted downward to exclude these wetlands, the county's post-plan growth density would still be only 0.14 unit/acre.

Okaloosa County's story is complicated by other special factors. Growth densities increased substantially between the pre-plan period (1.72 units/acre) and the post-plan period ending in 2002 (4.22 units/acre). Much of the county's CHHA lies along the eastern end of Santa Rosa Island, an area referred to locally as "Okaloosa Island." The federal government deeded portions of Santa Rosa Island to Escambia, Santa Rosa, and Okaloosa counties in the 1940s with the stipulation that the land be used for public purposes. As a result, until recently, all development in the Oklaoosa Island area has been done through long-term leases governed by a set of covenants. These covenants pre-date the county's comprehensive plan and have been reflected in the maximum allowable densities contained in the plan. These range from 5.4 to 40 units/acre. The remaining portion of the county's CHHA lies east of the City of Destin. In this area, maximum allowable densities range from 4 to 25 units/acre. These are largely consistent with zoning that was in place at the time the plan was adopted, although the county did down-zone some areas in 2000 following a NFIP flood zone restudy after Hurricane Opal, which struck the area in 1995. Overall, however, the maximum allowable densities are high in Okaloosa County, despite the presence of policies in the comprehensive plan that exceed the minima dictated by the 9J-5 regulations.

Three of our case study communities have mid-range post-plan growth densities - St. Johns County, Hernando County, and the City of Melbourne. St. Johns County has a low composite plan quality score, while the other three communities have plan quality scores at the higher end. St. Johns is a county that started with a relatively weak coastal element and has made significant changes. Its 1990 comprehensive plan did not include a definition of the CHHA, but this was remedied by amendments made in 2000. The original plan lacked a policy explicitly directing population concentrations away from the CHHA, but the 2000 amendments adopted a policy that exceeded the 9J-5 minimum. In addition, the 2000 amendments strengthened the policies concerning the maintenance and enhancement of evacuation times. Allowable densities within the CHHA were as high as 15 units/acre prior to the 1990 plan. The plan reduced those densities to 10 units/acre and these were further reduced to 8 units/acre with the 2000 amendments. However, it is only within the last few years that the county has begun to revise its zoning ordinance to reflect the densities stipulated in the future land use element. There have been two successful lawsuits under Chapter 170 *Florida Statutes* that resulted in the county being directed to permit development to the previously allowed densities. The lower post-plan densities appear to be largely a function of much lower maximum densities in three of the four zoning districts within the CHHA which range from 1 to 4 units/acre.

Hernando County and the City of Melbourne have high composite plan quality scores and moderate post-plan growth densities. Although Hernando County's original CHHA definition was restricted to the NFIP V-zone, it has consistently limited development to densities of 1 unit/acre within the CHHA. These restrictive policies, coupled with extensive public land acquisition for conservation purposes, in cooperation with the federal and state governments, that began prior to the 1989 comprehensive plan, appear to account for the relatively low pre- and post-plan growth densities in Hernando County (0.98 and 1.17 units/acre respectively). Most of the development that was permitted within the V-zone was vested. In the case of the City of Melbourne, very high plan quality scores are coupled with relatively high maximum allowable

densities. While the 1988 comprehensive plan reportedly reduced the maximum allowable densities to some degree, they remain relatively high at 10 units/acre. Nevertheless, the post-plan growth density of 2.57 units/acre represents an improvement over the pre-plan growth density of 5.13.

Discussion

The results of our analyses of residential growth patterns within and outside of CHHAs before and after approval of comprehensive plans circa 1990 are consistent with the hypothesis that implementation of comprehensive plan policies may have reduced residential growth within CHHAs relative to areas outside CHHAs. Both growth rates and growth densities within CHHAs are significantly lower after plan approval than before, and post-plan growth rates and growth densities within CHHAs are significantly lower than those outside of CHHAs. Nonetheless, residential growth has not been curtailed within CHHAs by any means. Fully one third of the 61 coastal communities with land both within and outside a CHHA had higher rates of growth in the numbers of residential units within their CHHAs than outside after plan approval.

Our estimates of aggregate changes in residential exposure to hurricane flooding in the period between plan approval and 2002 reveal substantial increases both within the CHHAs of these communities and within the HVZ increments. A total of approximately 152,000 new residential units were built within the two hurricane hazard zones combined. The associated increase in total population (permanent plus seasonal) for the two hazard zones within our sample is in excess of 340,000 people, while the sum of the increase in 2002 just value of residential property improvements is nearly $30 billion. Rough extrapolations for the entire 35 coastal counties of the state yield estimates of 420,000 new residential units within the total HVZ and associated increases of approximately 954,000 new residents and $81 billion in new residential structures.

Our analyses of the impacts of post-plan growth on estimated 2002 hurricane evacuation clearance times in 5 counties also revealed impacts that are not consistent with the state's mandate that local governments maintain or reduce hurricane evacuation times within their HVZs. We found mean increments in clearance times for the most constrained critical roadway segments in these five counties of 1.5 hours for a Category 1 hurricane, 2.2 hours for a Category 3, and 3.0 hours for a Category 4/5 hurricane. These impacts suggest that the aggregate effects of numerous small increases may be undermining the state's goal of protecting and enhancing public safety. On average, post-plan development within HVZs accounted for 15 to 18 percent of the estimated 2002 evacuation clearance times for all three hurricane categories. In 4 of the 5 counties, the majority of the post-plan increases in evacuation clearance times are attributable to growth within the CHHA and the HVZ. The remaining increases are due to increases in predicted "shadow evacuation" from growth in other areas of the counties and/or increases in the numbers of mobile homes, which are typically evacuated for all hurricane categories regardless of location.

Post-plan-approval growth within HVZs in the 5 counties we analyzed has resulted in an estimated increase in public shelter demand of over 20,000 persons for a Category 4/5 storm, which translates into nearly 1.5 million square feet of needed shelter capacity. Growth that occurred between approval of local comprehensive plans and 2002 was responsible for between

14 and 104 percent of the individual county shelter deficits reported by the DCA in 2004 for these 5 counties.

Our analysis of the quality of the coastal elements of the comprehensive plans of the communities in our sample revealed that local plans were more nearly compliant with the state's mandates concerning development within CHHAs and HVZs in 2002 than they were when the plans were first approved by DCA circa 1990. Nevertheless, it is evident from our analyses of plan content, and from our case studies, that a number of communities have failed to revise their CHHA definitions to be consistent with state legislation adopted in 1994, despite having completed one evaluation and appraisal report (EAR) cycle. Furthermore, between 8 and 16 percent of the communities in our sample of 76 coastal jurisdictions lacked one or more the mandated policies governing development within the CHHA as of 2002.

Our bivariate statistical analyses provide some evidence that post-plan growth densities are lower in communities with coastal elements in their original comprehensive plans that conform with the state's mandates concerning development within CHHAs. We find, however, that plan amendments between the year of plan approval and 2002 have had relatively little significant impact on growth patterns during that same time period. Our preliminary multivariate analyses indicate that the best predictor of post-plan growth density is the growth density in a community prior to plan approval, a finding that is borne out by our case studies. In most of our 12 case study communities, the residential densities permitted in the CHHA as stipulated in the future land use element of local comprehensive plans reflected allowable densities already established in communities' existing plans and/or zoning ordinances. Only a couple of the communities we studied took initiatives that appear to have significantly affected post-plan residential densities in the form of down-zoning vacant land within the CHHA and engaging in aggressive public acquisition of wetlands for conservation purposes.

The preliminary multivariate results as well as our case studies suggest that communities with lower pre-plan densities were more likely to adopt plans that limit densities within CHHAs and, therefore, that lower post-plan densities in many communities reflect good planning and growth management practices that predate the comprehensive plans adopted pursuant to the 1985 state mandate. It is likely, however, as noted by several of the local planning officials we interviewed, that densities within CHHAs would be higher yet if communities did not have policies in place that discourage zoning amendments to increase allowable densities.

References Cited

Florida Department of Community Affairs, Division of Emergency Management. 2004. *Statewide emergency shelter plan*. Tallahassee, FL: The Department.

Acknowledgements

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Figure 1. Florida Coastal County Sample

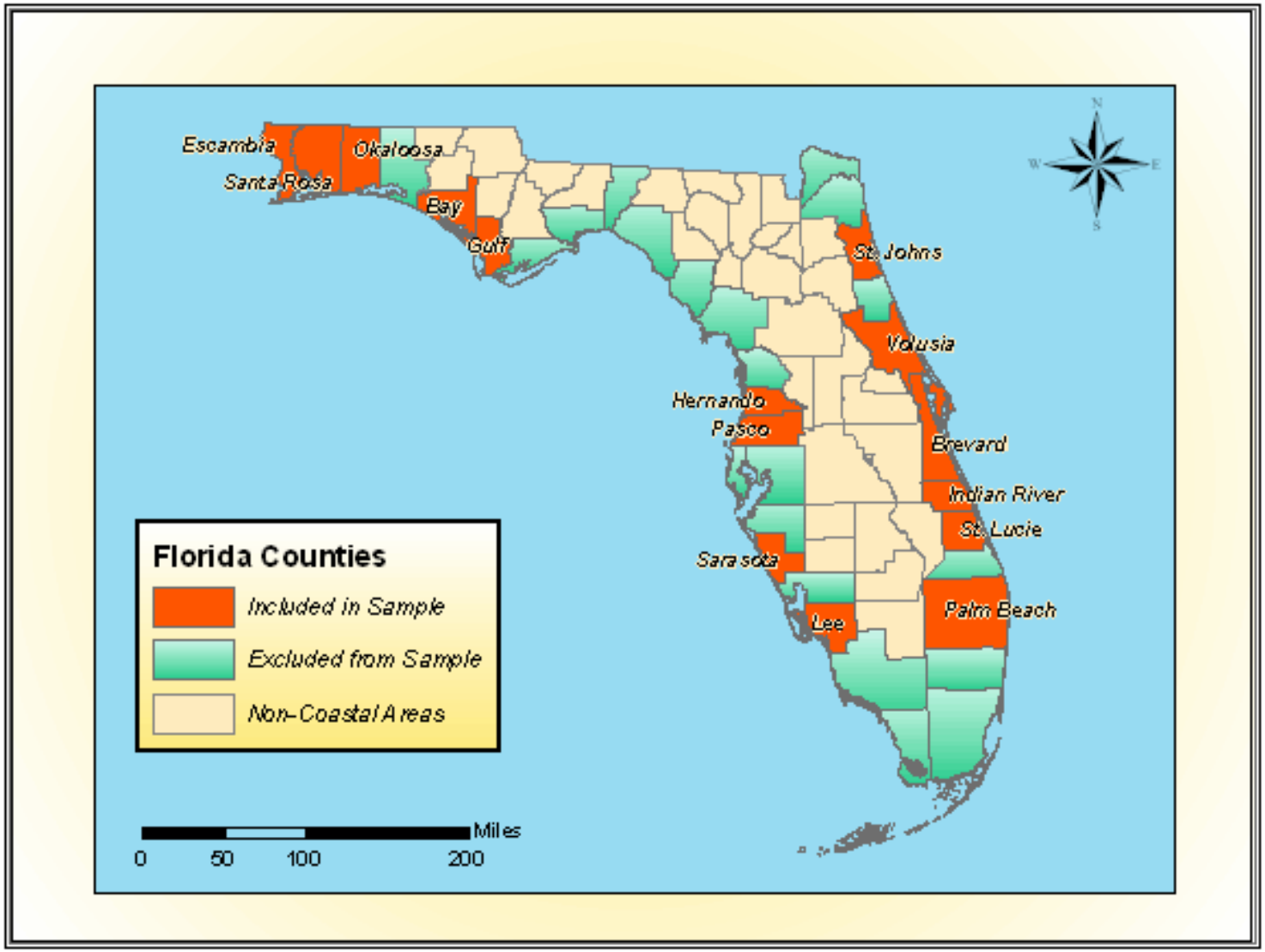

Figure 2. Volusia County Hazard Zones

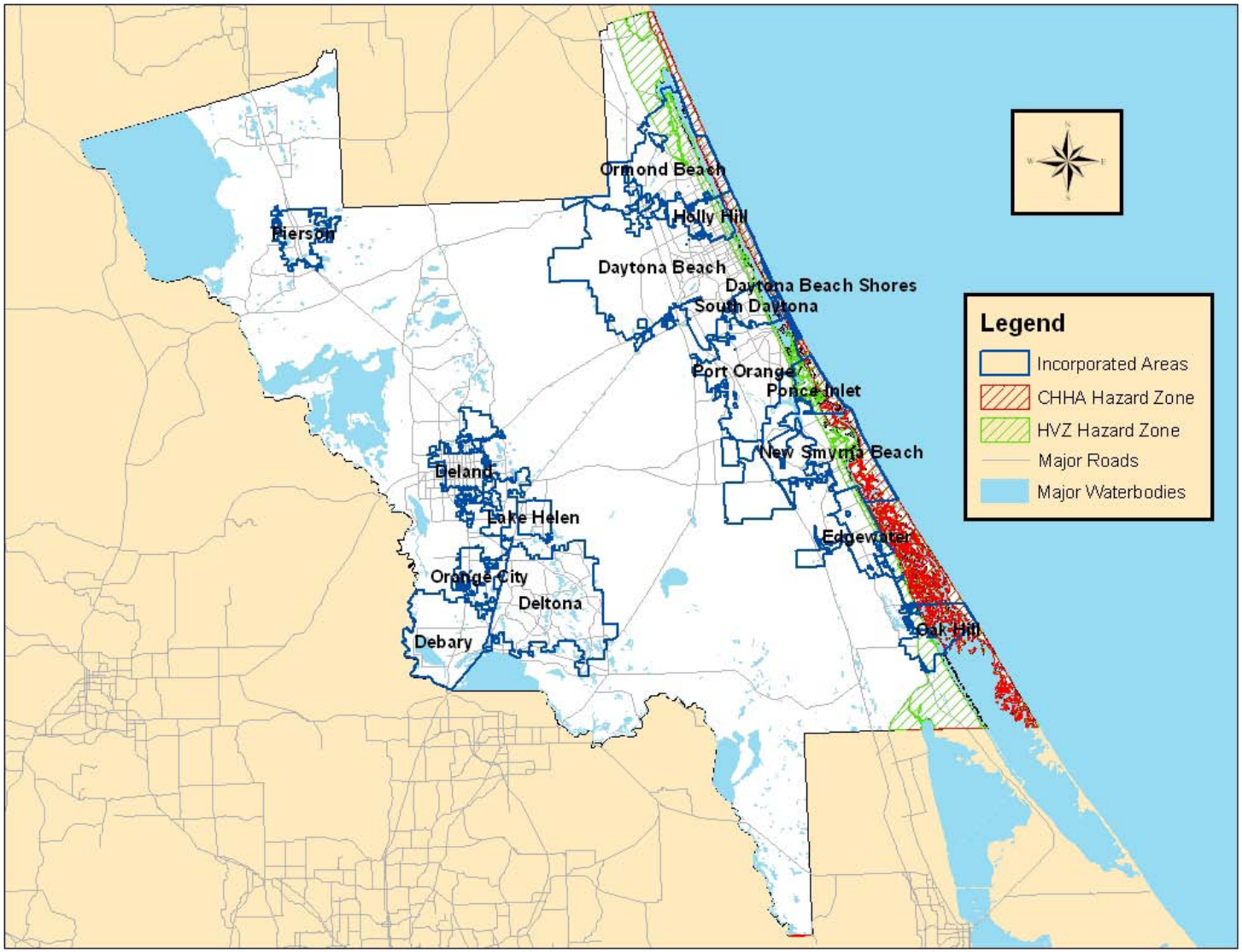

Figure 3. Bay County Hazard Zones

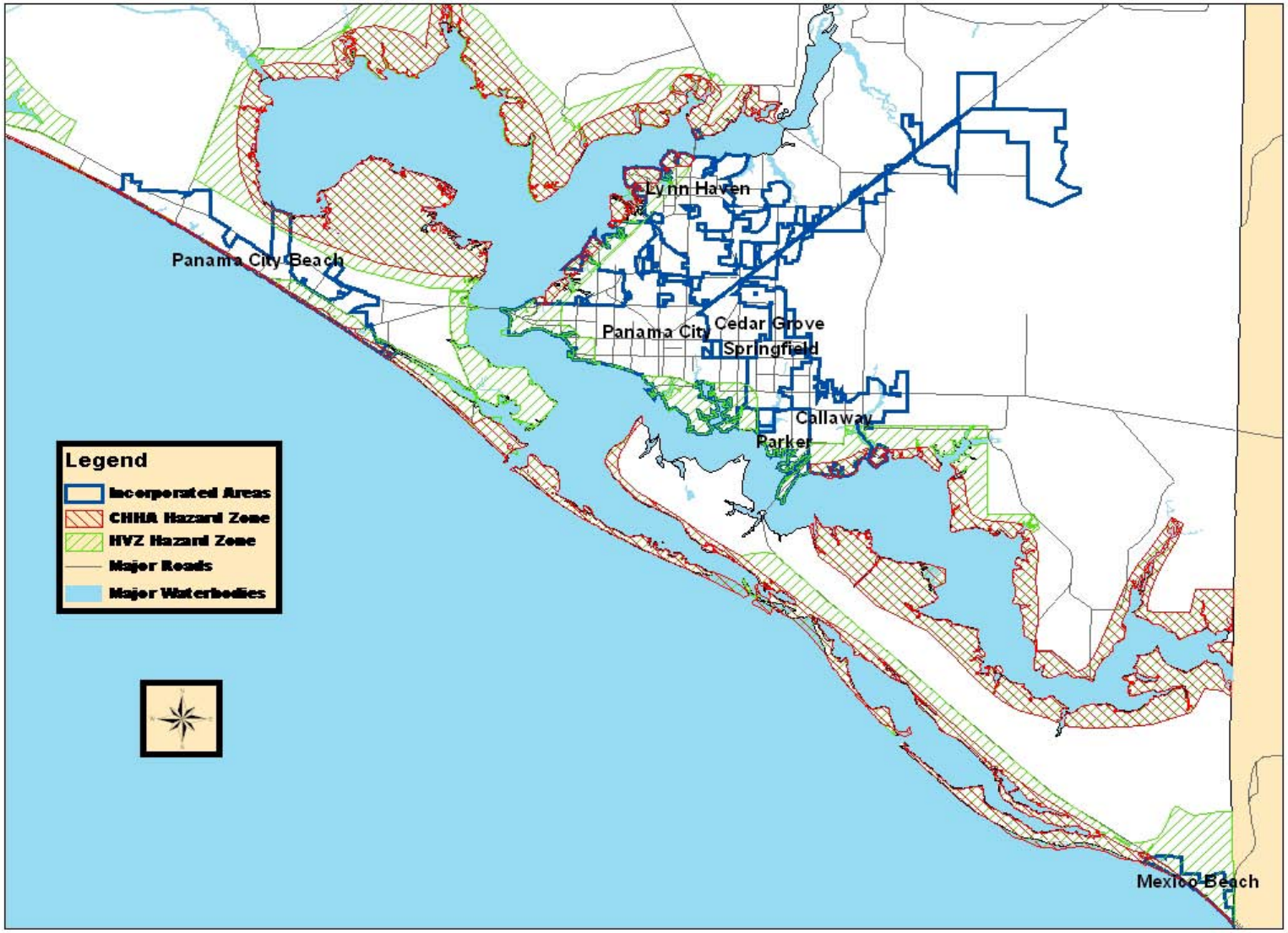

Figure 4. Lee County Hazard Zones

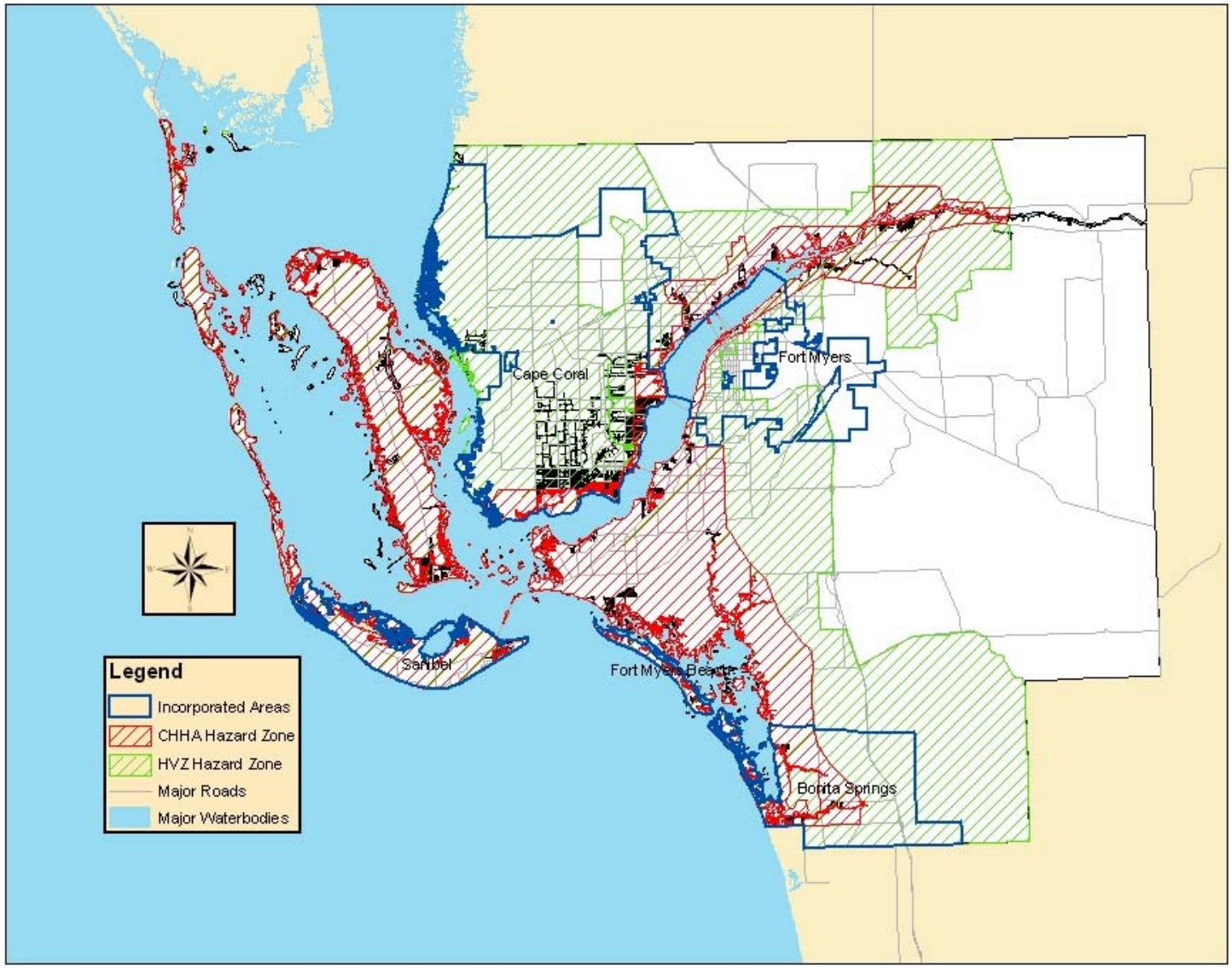

Figure 5. Numbers of residential units built within CHHAs after comprehensive plan approval

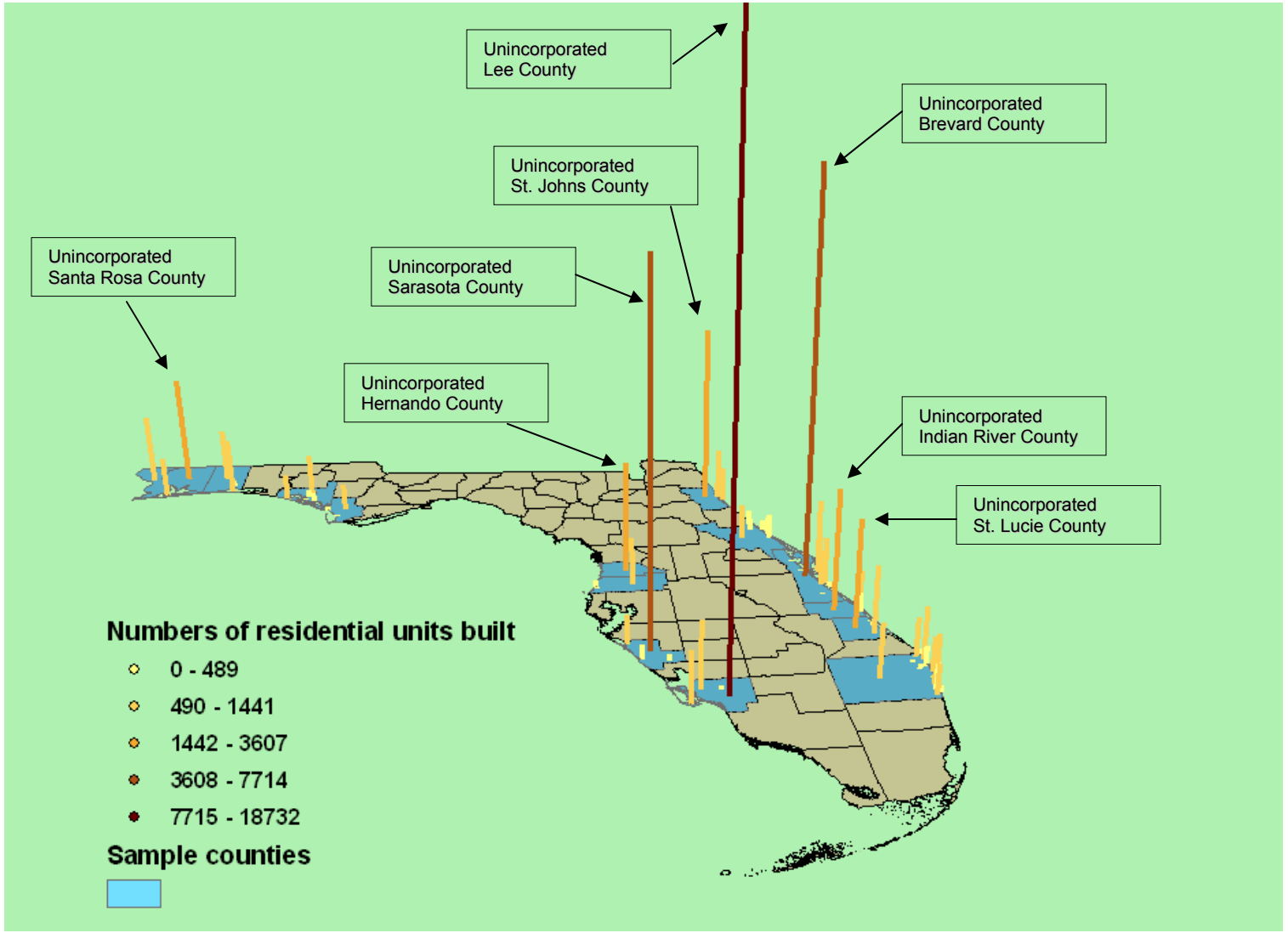

Figure 6. Impacts of 1990-2002 Land Use Change in Daytona Beach Shores on Evacuation for Category 4/5 Hurricane in Volusia County

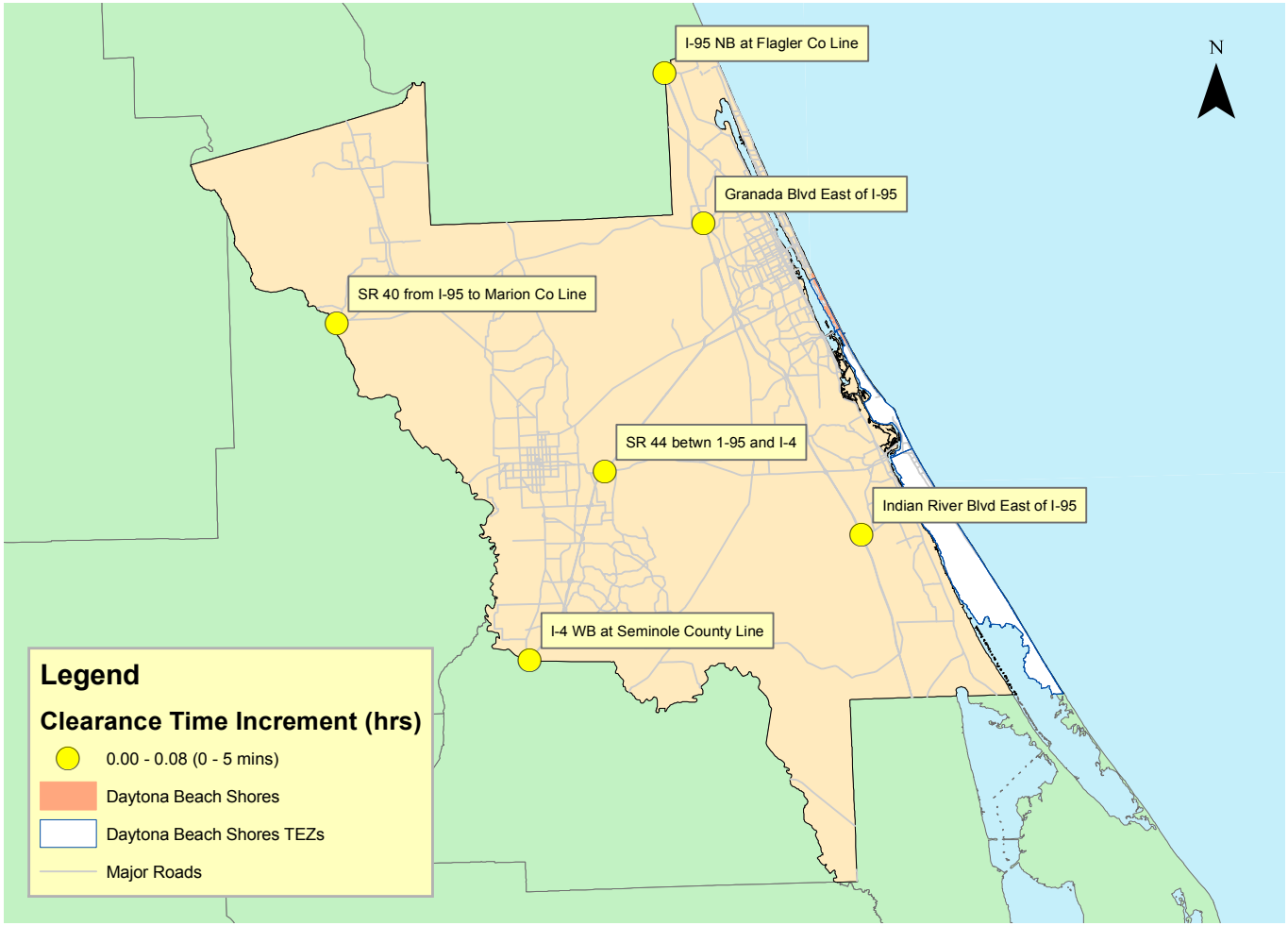

Figure 7. Impacts of 1990-2002 Land Use Change in Edgewater on Evacuation for Category 4/5 Hurricane in Volusia County

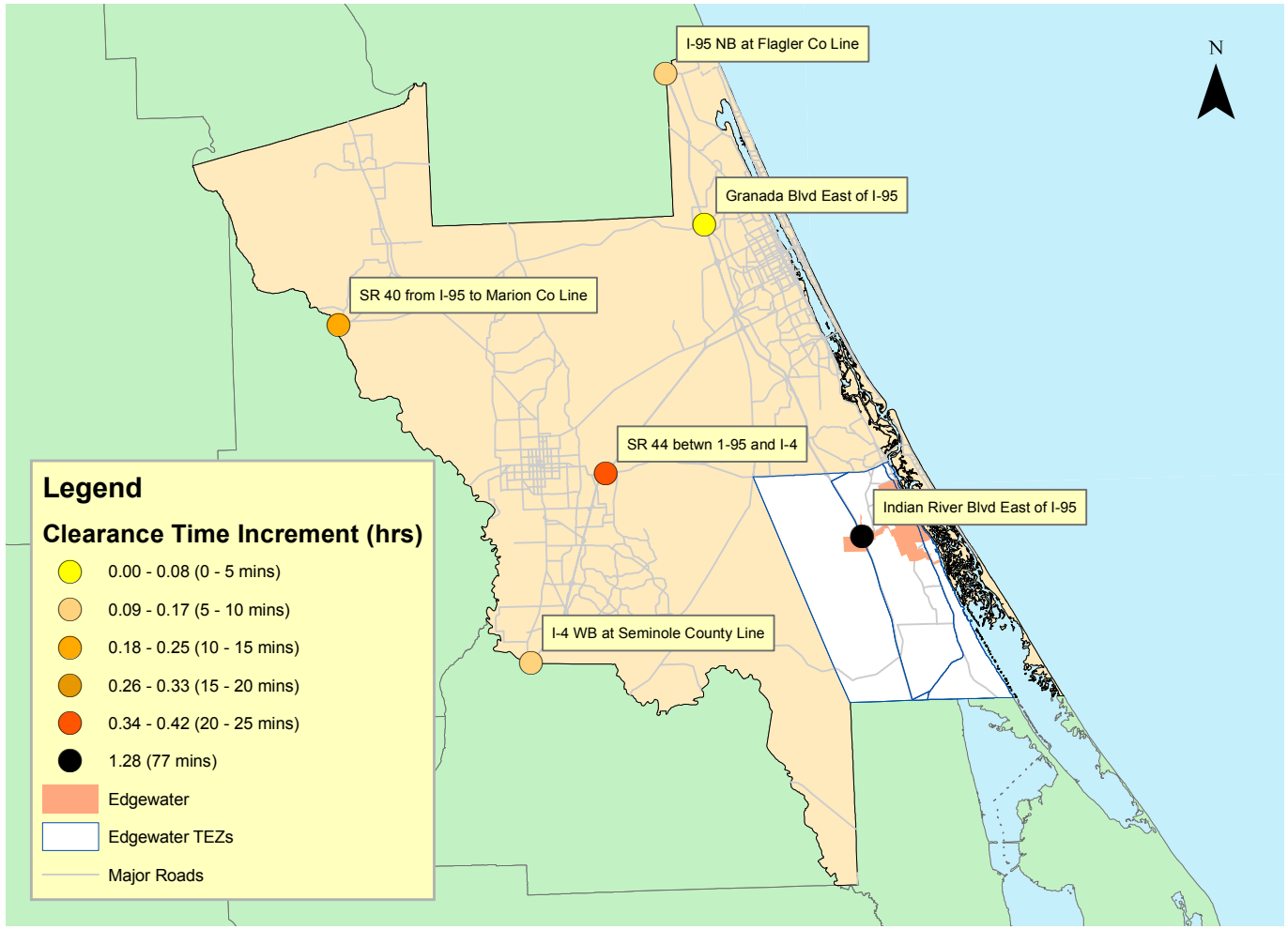

Figure 8. Impacts of 1990-2002 Land Use Change in Unincorporated Volusia County on Evacuation for Category 4/5 Hurricane in Volusia County

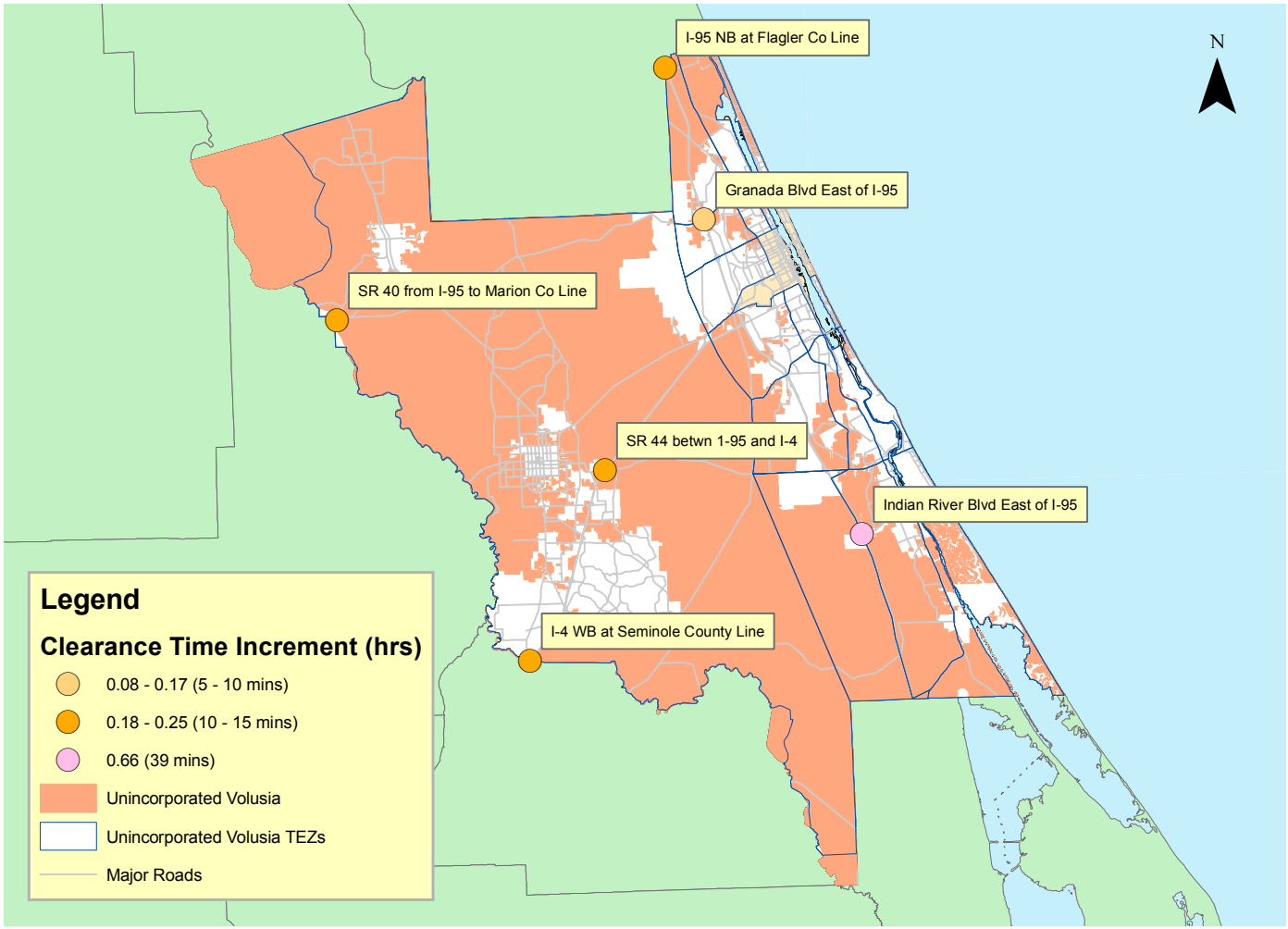

Figure 9. Impacts of 1990-2002 Aggregate Land Use Change in Coastal Communities on Evacuation for Category 4/5 Hurricane in Volusia County