usRAP
UNITED STATES ROAD ASSESSMENT PROGRAM
A program of the AAA Foundation for Traffic Safety

Pilot Program Phase II

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DISCLAIMER

The conclusions and recommendations presented in this report are those of AAAFTS and its contractors and do not represent the official positions and policies of the participating highway agencies. The maps prepared in the pilot studies and presented in this report are illustrative examples that provide useful information concerning the safety performance of the roadway system and are presented here solely to demonstrate the potential utility of usRAP. The specific maps presented in this report do not, by themselves, provide sufficient information to determine which roadways should receive priority for improvement. In determining improvement priorities, highway agencies consider many factors beyond those depicted on the maps in this report. Decisions regarding any improvements are based on detailed engineering studies that consider the improvement types most appropriate for specific road sections and the cost and anticipated effectiveness of those improvements. In response to recently established Federal legislation contained in Section 1410 of SAFETEA-LU, each state highway agency will be establishing its own criteria and procedures necessary to satisfy the identification of 5 percent of their public road locations exhibiting the most severe safety needs. This report does not constitute a standard, specification, or regulation.

The information contained in this report has been compiled for the purpose of identifying, evaluating, or planning safety enhancements. The report identifies information used for the purpose of developing highway safety construction improvement projects which may be implemented, using federal-aid highway funds. Any document displaying this notice shall be used only for those purposes deemed appropriate by the participating state departments of transportation. See Title 23, United States Code, Section 409.

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Section 1.
Introduction

1.1 Background

The level of safety for motorists on U.S. roads varies widely. Controlled-access freeways, with no at-grade intersections or driveways, provide the highest level of safety among road types. Other safety enhancing features of roadways include medians, roadside clear zones, guardrails, median barriers, and intersection turn lanes. Highway agencies have limited funds for improving the safety features of roadways, so it is important that their investment decisions are made in a way that provides maximum benefits to motorists and to the public at large.

Roadway and roadside improvements will have a key role in improving the overall safety performance of the highway system. However, a key to understanding the nature of safety on the highway system is to recognize that, while every crash occurs on some road segment, this does *not* imply that the design or operational characteristics of that road segment are necessarily the *cause* of those crashes. While driver and vehicle factors contribute to the causation of many more crashes than road factors, risk maps of the road system can help to identify roadways where there are opportunities to improve safety.

Currently, there is no systematic road assessment program in North America to inform motorists of the level of safety on the roads they travel or to help auto clubs and others provide informed advice to highway agencies on needs for safety improvement. Systematic road assessment programs have begun in Europe and Australia. The European Road Assessment Program (EuroRAP) was started in 2000 and the Australian Road Assessment Program (AusRAP) was started in 2003 to develop and implement systematic road assessment protocols.

The AAA Foundation for Traffic Safety (AAAFTS) has initiated a pilot program to test the technological and political feasibility of instituting a U.S. Road Assessment Program (usRAP). This work has been funded by AAAFTS and the FIA Foundation for the Automobile and Society. The pilot program is examining the various technological barriers—are appropriate data available and how should those data be aggregated? The pilot test is also examining political barriers—will highway agencies cooperate with such a program and can liability concerns be overcome? This pilot program is focusing attention on the need for highway safety improvement and starting a national dialogue on the issue. There is concern that crash investigations and existing road safety data in many jurisdictions are not adequate to support comprehensive analyses of road safety features. The national dialogue should help create public support for higher funding to upgrade data systems and make road safety improvements.

The usRAP pilot program began in 2004 and a report on the first phase of the work was published by AAAFTS in 2006. The Phase I work included pilot studies of usRAP concepts in two states: Iowa and Michigan. Two safety mapping protocols were tested:

risk maps that present a synthesis of available crash statistics summarized by crash location and star rating maps that present an assessment of safety-related design features of specific roadway sections.

A second phase of the usRAP pilot program has further developed the risk mapping concepts tested in Phase I with pilot studies in two additional states: Florida and New Jersey. Phase II explored the development of supplementary risk maps that address safety issues of interest to the participating states, such as unbelted occupant, speed-related, alcohol-involved, lane departure, commercial-vehicle-involved, older-driver, and young driver crashes. Phase II has also developed a new road assessment protocol: performance tracking to monitor the changes in safety over time for specific roadway sections.

The usRAP pilot program is very timely given recent Federal highway safety program requirements in Section 1401 of the Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). A provision in Section 1401 requires that states, as a condition for obtaining Federal funds from the Highway Safety Improvement Program (HSIP), must submit an annual report to the U.S. Secretary of Transportation describing at least 5 percent of locations with the most severe safety needs, and an assessment of remedies, costs, and other impediments to solving the problems at each location. The Secretary is required to make these reports available to the public on the U.S. Department of Transportation web site and through other means. The risk maps prepared in the usRAP pilot program represent an effective tool that could be used to identify 5 percent of the roadway system with the greatest safety needs. usRAP maps may also be an effective tool for identifying roadway sections eligible for improvement as part of the SAFETEA-LU high-risk rural roads program.

An International Road Assessment Program (iRAP) has been created to coordinate the results of usRAP, EuroRAP, and AusRAP. iRAP has also launched a pilot program to apply the RAP concepts to improving highway safety in low- and middle-income countries throughout the world.

Midwest Research Institute (MRI) has managed the pilot program for AAAFTS with assistance from the Center for Transportation Research and Education (CTRE) at Iowa State University (ISU) and the participation of an advisory panel of key stakeholders. This report supplements the Phase I report published in 2006 and presents the results of Phase II of the usRAP pilot program, including the results of further work with Iowa and Michigan and the results of pilot studies conducted in Florida and New Jersey.

1.2 Objectives

The primary objectives of the potential usRAP program are to:

- reduce death and serious injury on U.S. roads rapidly through a program of systematic assessment of risk that identifies major safety shortcomings, which can be addressed by practical road improvement measures.

- ensure that assessment of risk lies at the heart of strategic decisions on route improvements, crash protection, and standards of route management.

The objectives are identical to the objectives of the ongoing EuroRAP and AusRAP programs.

As envisioned, usRAP would be implemented as a cooperative effort by highway agencies and auto clubs to accomplish the important objectives presented above. At the heart of the usRAP concept is that highway agencies need the support of auto clubs and the general public to make the case for investments to bring about a substantial reduction in highway crashes. Better information on the safety performance of the roads the motoring public travels should create additional dialogue and public debate on road safety, something that is sorely needed, which in turn can create support for greater investment in highway safety and can help to target those investments to the locations with the greatest need.

1.3 usRAP Advisory Panel

This pilot program has been conducted under the guidance of an advisory panel of key stakeholders representing highway agencies, auto clubs, and other interested organizations. The members of the advisory panel are:

- Kevin Bakewell, Auto Club South, Tampa, Florida
- Patrick Brady, Florida Department of Transportation, Tallahassee, Florida
- Gregory Cohen, American Highway Users, Washington, DC
- John Daly, Genesee County Road Commission, Flint, Michigan (representing the National Association of County Engineers)
- Michael Trentacoste, Federal Highway Administration, McLean, Virginia
- Michael Halladay, Federal Highway Administration, Washington, DC
- Dale Lighthizer, Michigan Department of Transportation, Lansing, Michigan
- Patricia Ott, New Jersey Department of Transportation, Trenton, New Jersey (representing the AASHTO Standing Committee on Highway Traffic Safety)
- Jack Peet, Auto Club Group/AAA Michigan, Dearborn, Michigan
- Keith Sinclair, American Association of State Highway and Transportation Officials (AASHTO), Washington, DC
- Ed Stoloff, Institute of Transportation Engineers, Washington, DC
- Thomas Welch, Iowa Department of Transportation, Ames, Iowa (representing the AASHTO Standing Committee on Highway Traffic Safety)
- Roger Wentz, American Traffic Safety Services Association, Fredericksburg, Virginia

1.4 Organization of This Report

The remainder of this report is organized as follows. Section 2 presents the results of the Phase II usRAP pilot studies conducted in Florida and New Jersey. Section 3 presents the results of further work conducted as part of Phase II with the Phase I pilot study states, Iowa and Michigan. Section 4 presents recommendations on further development of the usRAP protocols and recommendations for Phase III of the pilot program.

Section 2.
usRAP Phase II Pilot Studies

This section of the report presents an overview of the pilot studies conducted in Florida and New Jersey as part of Phase II of the usRAP pilot program.

2.1 Objective

The objective of the pilot studies was to further demonstrate and test potential usRAP concepts by application to roads in two additional states. In Phase I, initial usRAP concepts were derived from EuroRAP and from the discussions of the usRAP technical advisory panel and were applied in pilot studies in Iowa and Michigan. Additional pilot studies have been conducted in Phase II in Florida and New Jersey. The initial usRAP concepts are likely to continue to evolve through this series of pilot studies that is expected to continue into Phase III.

2.2 usRAP Protocols Tested

The usRAP concept involves three protocols for safety assessment and mapping of roadway systems. These are:

- *risk mapping* to document the risk of death and serious injury crashes and show where risk is high and low
- *star ratings* based on inspection of roads to examine how well they protect users from crashes and from deaths and serious injuries when crashes occur
- *performance tracking* to monitor changes in the safety performance of the road system over time and relate those changes to ongoing safety improvement programs

This section of the report focuses on risk mapping for the Phase II pilot studies in Florida and New Jersey. Supplementary mapping and performance tracking for the states that participated in the Phase I pilot studies, Iowa and Michigan, is addressed in Section 3 of this report. In accordance with the recommendations in the Phase I report, further work on the star rating protocol has been deferred pending completion of additional research on the Road Protection Score (RPS) concept on which the star ratings are based. Plans for research on the RPS concept are addressed in Section 4 of this report.

usRAP risk maps use four risk measures based on observed crash history. Each measure is computed for the road sections of appropriate length for each type of road that makes up the road network under consideration. Each measure is classified into five categories and displayed on maps using color coding for the five categories. The four maps and their corresponding risk measures are:

- Map 1—fatal and serious injury crashes per mile of road
- Map 2—fatal and serious injury crashes per hundred million vehicle-miles of travel
- Map 3—ratio of fatal and serious injury crash rate per hundred million vehicle-miles of travel to the average crash rate for similar roads
- Map 4—potential number of fatal and serious injury crashes saved per mile in a specified time period if crash rate per hundred million vehicle-miles were reduced to the average crash rate for similar roads

All four maps can be prepared from a database that contains just four pieces of information about each road section:

- number of fatal and serious injury crashes that occurred on the road section in a specified time period
- road design type
- section length
- traffic volume (ADT)

Map 1 is considered useful because it presents the actual observed number of crashes per unit-length (crash density).

Map 2 is considered the basic risk map because fatal and serious injury crashes per hundred million vehicle-miles of travel are proportional to the risk of a fatal or serious injury to an individual motorist traveling through the section in question.

Maps 3 and 4 are useful because they compare the crash experience for particular road segments to their group average. Map 4, in particular, is intended as indicative of the safety benefit that could be achieved if a road section were improved.

Additional map types are also being considered for use in usRAP because they are appropriate for North American conditions or because they address specific concerns of participating highway agencies. In Phase I, these supplementary maps types included intersection risk maps and maps that express risk in terms of the economic losses due to crashes. In Phase II, supplementary maps types have addressed specific crash types of interest to highway agencies, including crash types associated with emphasis areas in the state strategic highway safety plans.

2.3 Pilot Study Activities

The following activities have been conducted as part of the Phase II pilot studies:

- The research team met with the participating highway agencies to identify existing data files, and data elements within those files, that were available for testing of usRAP concepts and to discuss the quality of those data.
- Using the available data, and in consultation with the participating highway agencies, the research team developed procedures for preparing risk maps. The following issues were considered:
  - how should the highway system be divided into analysis sections considering road design types, traffic volumes, logical termini, desirable minimum section lengths, and desirable minimum average crash frequencies?
  - what crash severity levels should be addressed in risk maps?
  - what safety-related measures are most appropriate as the basis for specific maps?
  - how should those measures be divided into levels that are appropriate for color coding of highway sections on the maps?
- The research team prepared risk maps for the highway systems of interest selected in each state. The risk maps included Maps 1 through 4, as well as other map types identified by the research team and the participating highway agencies as potentially relevant.

2.4 Results of the Florida Pilot Study

The Florida pilot study was conducted in cooperation with the Florida Department of Transportation. This section presents the results of the Florida pilot study. The section first discusses general issues concerning the roadway network included in the pilot study, the manner in which that road network was divided into road segments for analysis, and the data that were assembled for analysis. The results of risk mapping are then presented.

A decision was reached in consultation with the Florida Department of Transportation to focus the pilot study on rural state highways.

2.4.1 Roads Selected for Inclusion in Mapping

Florida has over 120,500 mi of publicly owned and operated roads. Only state-owned (primary) roads were selected for the Florida pilot study. These roads include Interstate, US, toll, and state numbered routes.

State highways were included in the study scope except for:

- Conventional highways within cities with populations of 5,000 or more

- Freeways within metropolitan area boundaries for metropolitan areas with populations of 50,000 or more

For the sake of continuity, freeway sections within smaller cities that were not part of larger metropolitan areas were included in the pilot study. The final “rural” designation was based on visual inspection. As a result, the rural/urban designation on a few sections was changed to provide continuity.

2.4.2 Road Classification

Roads were classified into four road design types: freeway, multilane divided, multilane undivided, and two-lane roads. Road type definition was based on access control, median type, and number of lanes. Unique combinations of access control, median type, and number of lanes were assigned to one of the road-type categories. In some cases, particularly where this combination was atypical, sections were assessed based on the design type and extent of adjacent road sections. The appropriate category was then assigned based on this assessment.

2.4.3 Scope of Analysis and Mapping

Risk maps were developed for the entire state (all roads shown in Figure 1).

2.4.4 Segmentation

Roadway data used for analysis and display purposes was obtained from the Florida DOT’s Roadway Characteristics Inventory (RCI). The RCI is a database consisting of physical and administrative roadway data maintained by, or of interest to, the Florida DOT (Transportation Statistics RCI Office Handbook, Florida DOT, July 2005). Initial road segmentation was based on homogeneity among the 30 most requested RCI attributes. Therefore, a change in any of the roadway attributes resulted in a new road segment.

As many of the RCI sections are quite short, the project team joined together adjacent sections with similar characteristics into “analysis sections.” Rules were developed to allow aggregation of sections:

- with same county, route number, and road type
- of speed limits within 5 mph
- with ADTs within 20 percent, or within 2,000 veh/day
- with similar ADT, same road type, and speed limits less than or equal to 50 mph in towns with population under 5,000

Figure 1. Roads Covered by Florida Risk Maps (Statewide)

- with very short sections with speed limits greater than or equal to 55 mph, with same road type and similar ADT
- of extremely short length
- with speed limits less than or equal to 50 mph just outside a town with similar sections within the town

In some cases, particularly where extremely short sections were not aggregated, these rules were modified to eliminate unrealistically short analysis sections. Rule modifications included:

- with ADTs within 40 percent, or within 4,000 veh/day
- with very short sections with speed limits greater than 50 mph, with same road type and similar ADT (per above) and speed limits within 10 mph

2.4.5 Crash Type, Selection, and Assignment

For all maps prepared in the Florida pilot study, only fatal and serious injury crashes were analyzed. For the remainder of this section, presentation and discussion of crashes, and crash-based data, are limited to fatal and serious injury crashes on rural state roads.

In Florida, crashes are located with respect to the Florida basemap (linear referencing system). Crash locations were defined, and geocoded, based on a mileage along a unique road segment. Once a crash was geocoded, the corresponding geographic coordinates (longitude, latitude) were derived.

2.4.6 Study Period and Data Summary

Five years of data (2001-2005) were selected for analysis and presentation. EuroRAP uses three years of data, but the traffic volumes and crash densities on Florida rural highways are much lower than for typical European rural highways. Table 1 presents crash totals for 6,012 centerline miles of rural state highways for each year of the study period.

Table 1. Crash Data for Florida Pilot Study

Year	Fatal crashes	Serious injury crashes	Total fatal and serious injury crashes
2001	421	1,895	2,316
2002	485	1,881	2,366
2003	481	1,929	2,410
2004	505	1,963	2,468
2005	525	1,917	2,442
Total	2,417	9,585	12,002

2.4.7 Risk Maps

Following is a summary of the data used for risk mapping in the Florida pilot study:

- Statewide totals for rural state highways
  - 1,584 segments
  - 6,000 mi of road
  - 25 billion annual veh-mi of travel (VMT)
  - 12,002 fatal and serious injury crashes
- Statewide averages for analysis sections on rural state highways
  - Average length = 3.8 mi
  - AADT = 11,500 veh/day
  - Fatal and serious injury crashes = 1.52 crashes/section/year
  - Fatal and serious injury crash density = 0.40 crashes/mi/year
  - Average crash rate = 9.50 per 100M VMT

Table 2 presents summary information by road type.

Table 2. Summary Risk Mapping Data for Florida Pilot Study

Road type	Number of sections	Total length (mi)	Average length (mi)	AADT	Annual VMT (billion)	Fatal & serious injury crashes: Total frequency	Annual frequency	Annual density (per mi)	Average rate (per 100M VMT)
Freeway	89	949	10.7	35,913	12.4	3,709	8.33	0.78	5.96
Multilane divided	423	1,009	2.4	13,515	5.0	2,834	1.34	0.56	11.39
Multilane undivided	31	28	0.9	10,311	0.1	56	0.36	0.39	10.44
Two-lane roads	1,041	4,026	3.9	5,278	7.8	5,403	1.04	0.27	13.93
Total	**1,584**	**6,012**	**3.8**	**11,519**	**25.3**	**12,002**	**1.52**	**0.40**	**9.50**

2.4.7.1 Selection of Risk Categories for Use on Risk Maps

A sequence of color codes was used to define categories on each map in ascending order of risk:

- dark green (lowest risk)
- light green
- yellow
- red
- black (highest risk)

Risk categories are defined so that each category in increasing order of risk contains a progressively smaller portion of the roadway system and so that the highest risk category on each map includes 5 percent of roadway length. The selected risk categories and their associated colors are as follows:

- dark green (lowest risk) — 40 percent of roadway length
- light green — 25 percent of roadway length
- yellow — 20 percent of roadway length
- red — 10 percent of roadway length
- black (highest risk) — 5 percent of roadway length

This approach should serve to focus attention on the roadway sections with the greatest potential for safety improvement. The highest risk category (shown in black on the various maps) should assist in meeting the new Federal mandate that states identify 5 percent of locations with the most severe safety needs (see Section 4.2 of the usRAP Phase I report). The roads in the highest risk category vary among the various types of maps, indicating that there are multiple considerations in deciding which road sections have the most severe safety needs. Each state has established its own criteria for generating its 5-percent reports; usRAP risk mapping could provide one method for accomplishing this in the future, but the final choice of approaches will be determined by individual state highway agencies.

Examples of maps for the Florida pilot study are presented below. Maps have been developed using five years of data.

Because shorter section lengths were used in the Florida pilot study than would be suggested by EuroRAP criteria (see discussion of segmentation above), some road sections in the Florida pilot study experienced only a few fatal and major injury crashes in five years but were classified in a high risk category. It did not appear appropriate to classify sections with limited crash experience as high risk, since they generally had short lengths or very low traffic volumes, so a criterion was adopted that no road section would be considered for classification in the two highest risk categories (red and black on the various maps) unless it experienced more than two fatal or major injury crashes in five years; such low-crash-count segments with higher risk measures generally appear in the medium risk (yellow) category on the maps presented. The segmentation issues for low-crash-count sections will be considered in future research.

2.4.7.2 Road Section Crash Density Maps (Map 1)

The first type of risk map developed was the annual crash density map (Map 1). Figure 2 presents a crash density map for Florida using categories with risk category boundaries using the criteria discussed above. The lowest risk category (dark green) on this map includes 40 percent of the total length of the Florida state highway system; the highest risk category includes 5 percent of the total length. Because Map 1 is based on crashes per mile, some higher volume roads, including freeways, appear in the higher risk categories; on subsequent maps taking traffic volumes into account, freeways generally appear in the lower risk categories.

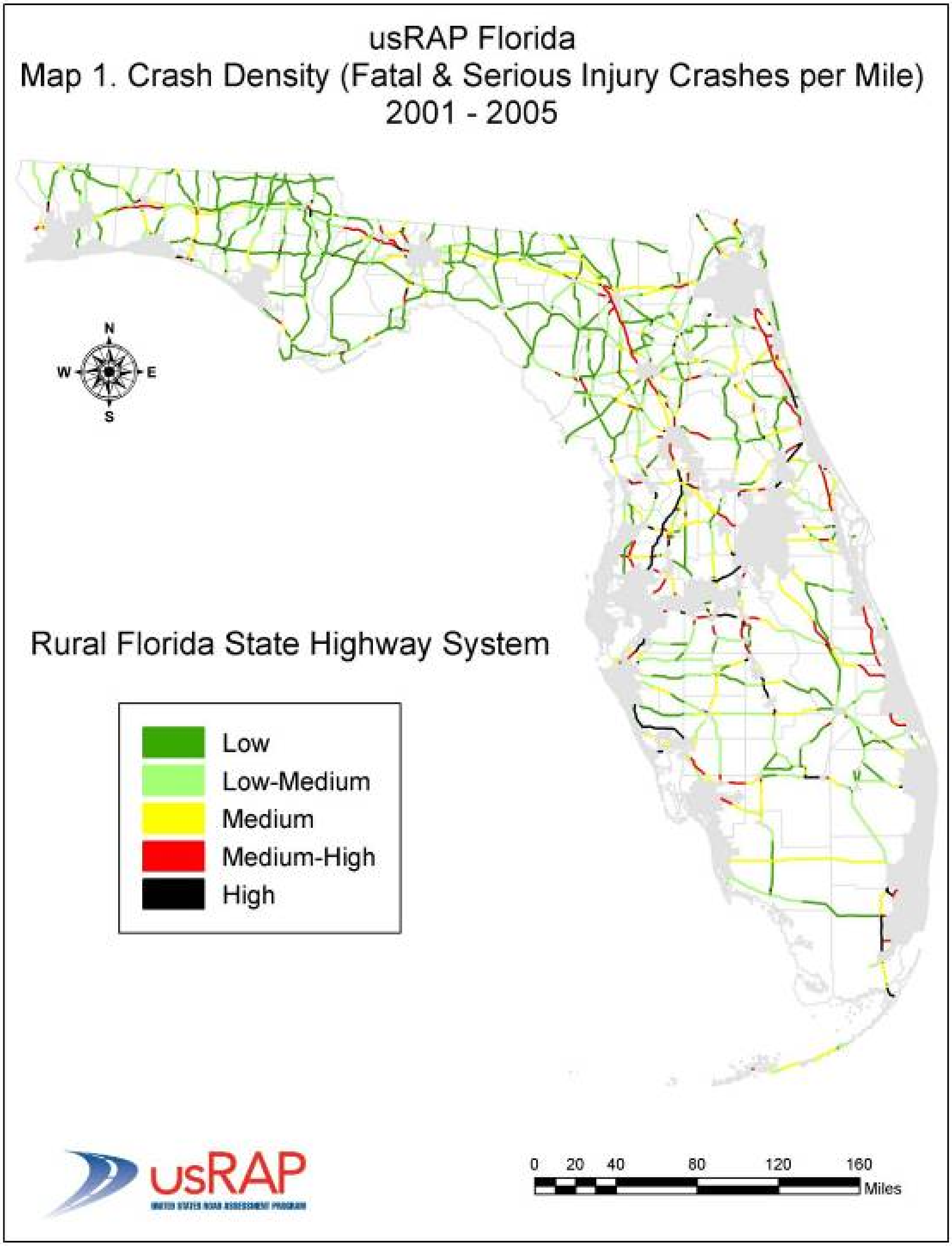

Figure 2. Example of Map 1 for Florida

2.4.7.3 Road Section Crash Rate Maps (Map 2)

Risk maps based on crash rate were also developed for Florida roads. While five years of crash data were used, a single AADT value, provided in the RCI, was used to compute exposure. Figure 3 presents a typical crash rate map for Florida roads.

2.4.7.4 Ratio of Crash Rate Relative to Similar Road Types (Map 3)

Figure 4 presents a map based on the ratio of fatal- and serious-injury crash rate for each road section to the average rate based on similar roads (Map 3).

2.4.7.5 Potential Crash Savings (Map 4)

Map 4 indicates the potential for reducing fatal- and serious-injury crashes if road sections with above-average crash rates could be brought to the average crash rate for roads of similar type. Figure 5 presents a typical map of this type for rural state highways in Florida.

2.4.7.6 Supplementary Maps

usRAP pilot studies typically involve the development of supplementary maps, in addition to the basic Maps 1 through 4, that address issues of interest to the participating highway agencies. Additional map types were created for the Florida pilot study to address seven specific crash types of interest, including:

- unbelted-occupant crashes
- speed-related crashes
- alcohol- or drug-involved crashes
- lane-departure crashes
- commercial-vehicle-involved crashes
- older-driver crashes
- younger-driver crashes

Maps analogous to Maps 1 through 4 were prepared for crashes involving unbelted vehicle occupants (see Figures 6 through 9). Unbelted occupant crashes are defined as crashes in which an unbelted vehicle occupant (driver or passenger) was killed or seriously injured. For each of these maps, a minimum of three fatal or serious injury unbelted occupant crashes in five years were required for a section to be considered medium-high or high risk.

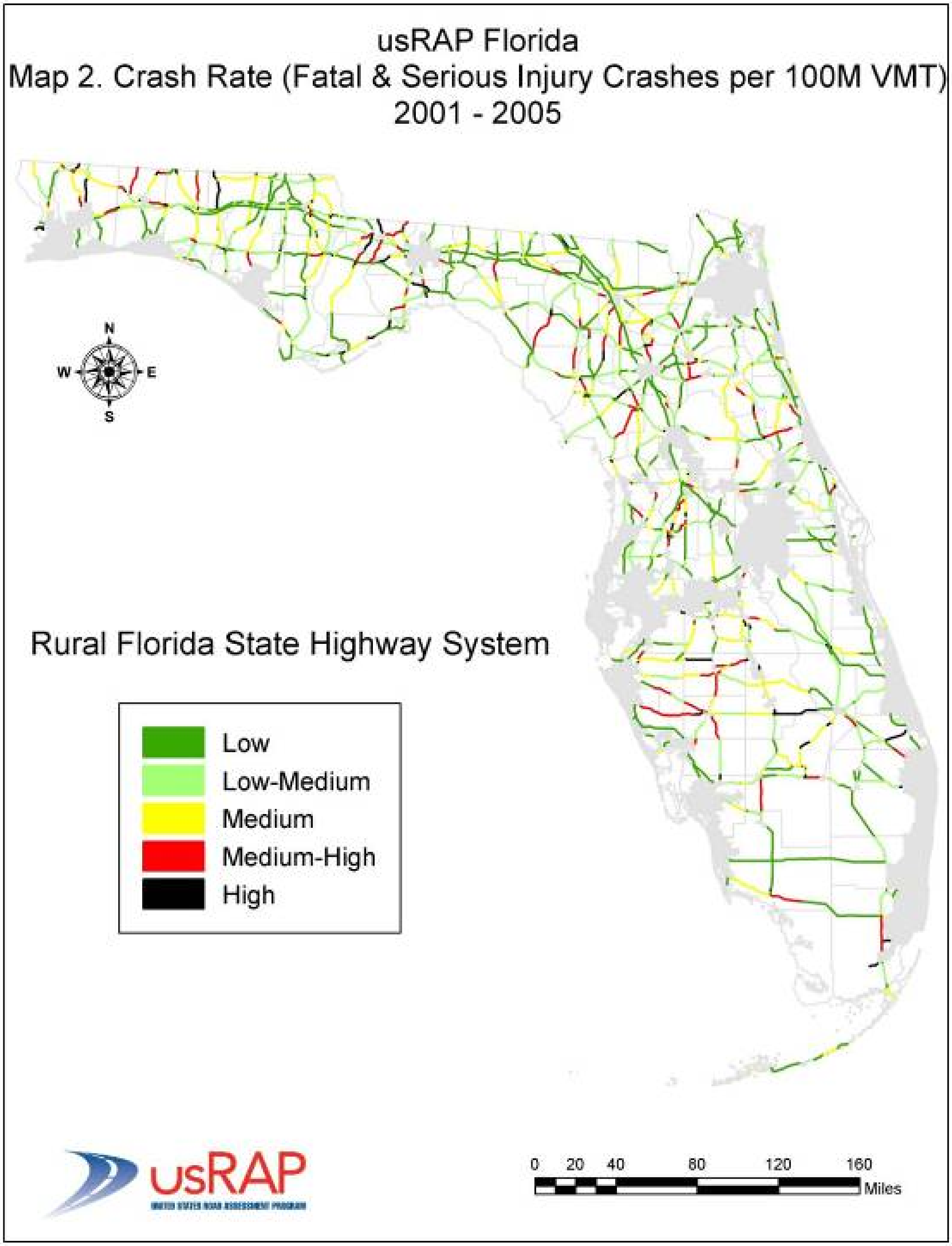

Figure 3. Example of Map 2 for Florida

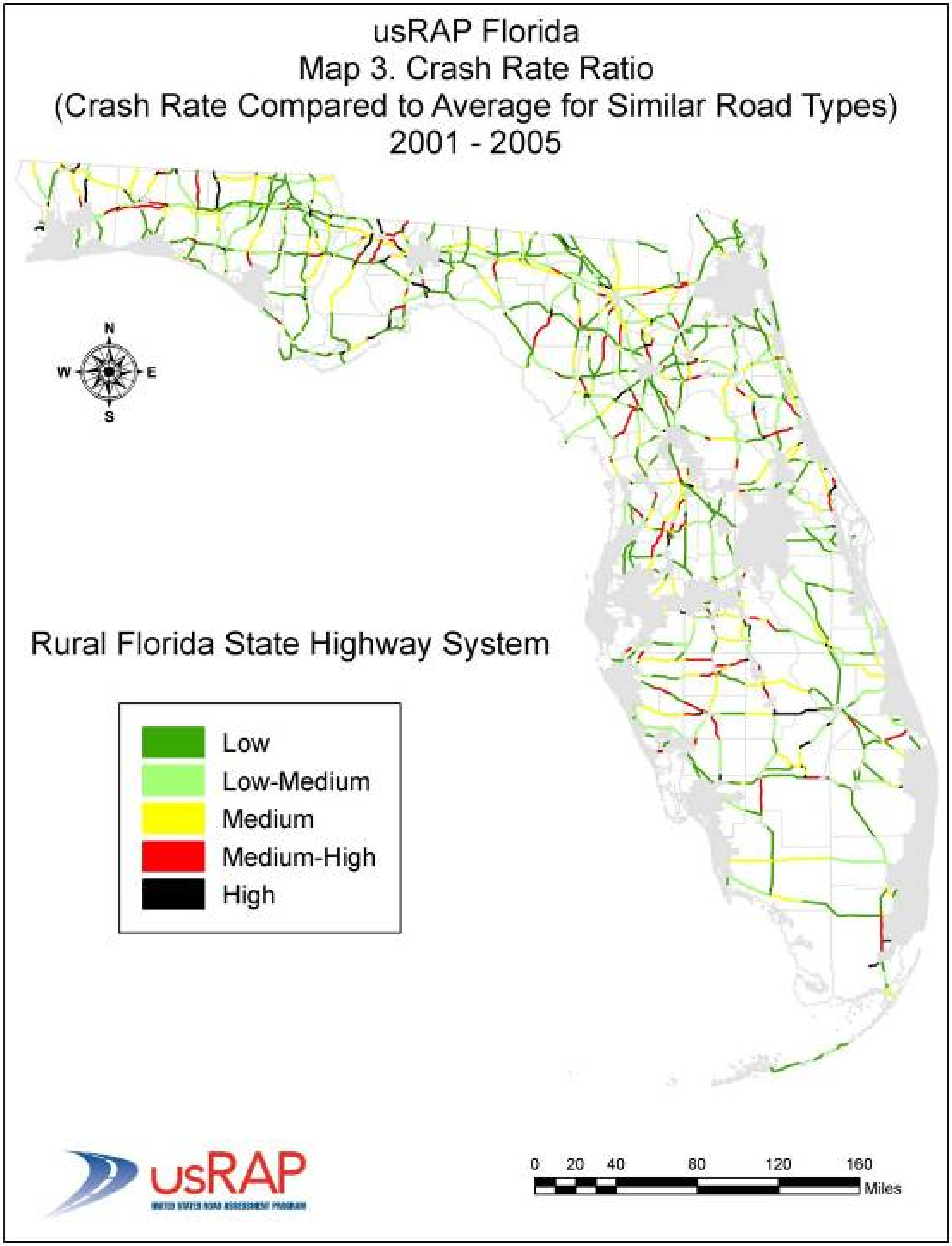

Figure 4. Example of Map 3 for Florida

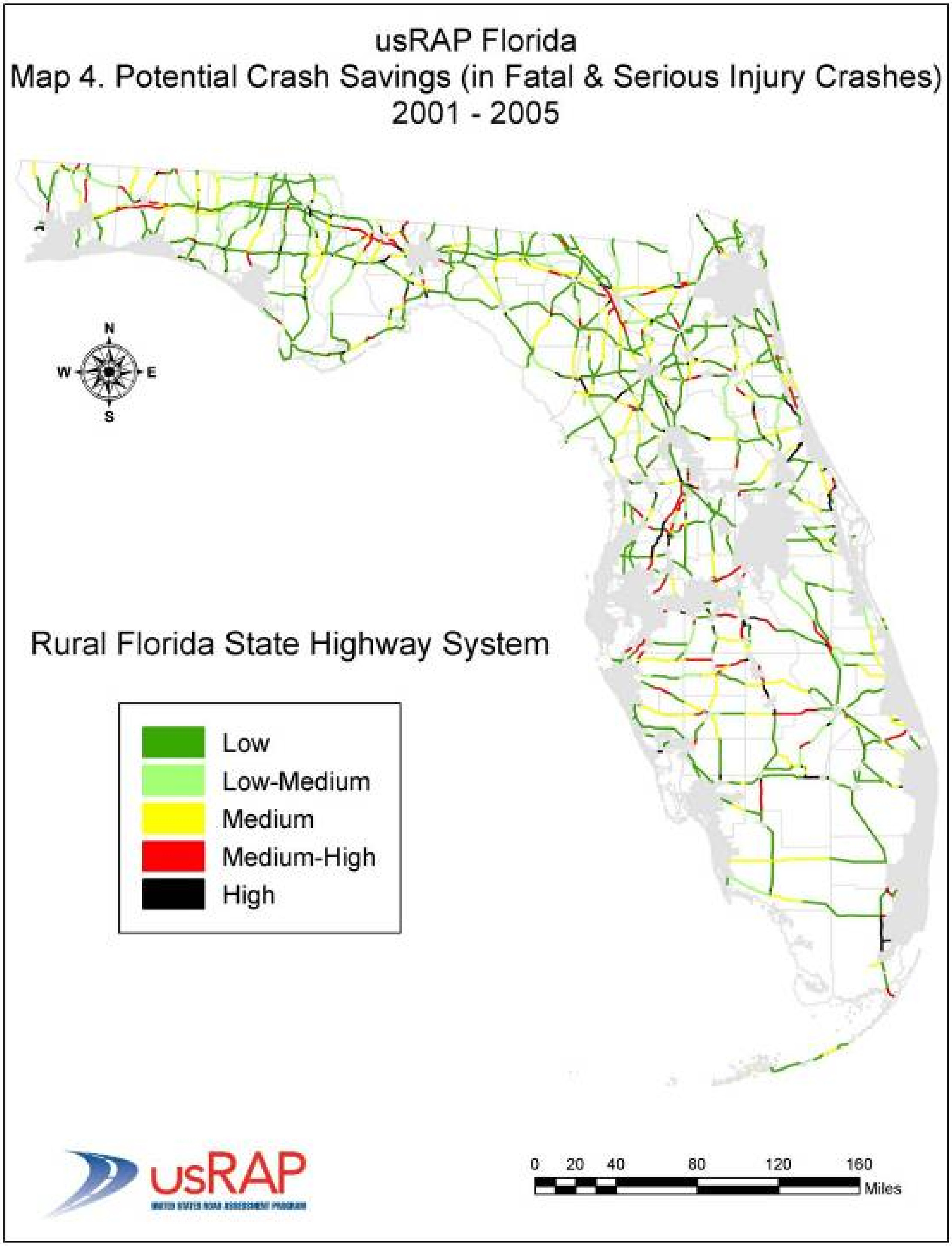

Figure 5. Example of Map 4 for Florida

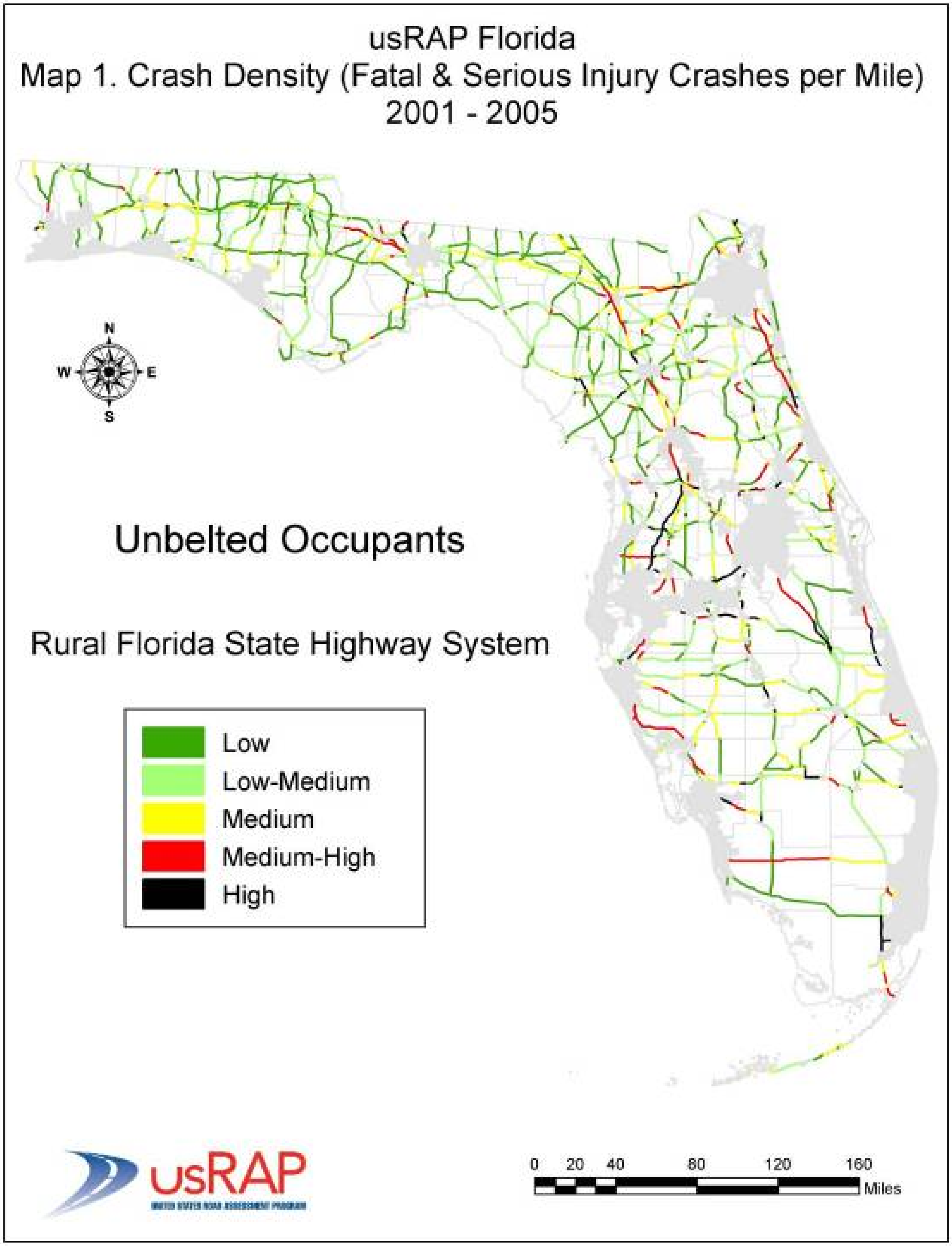

Figure 6. Florida Map 1 for Unbelted Occupants

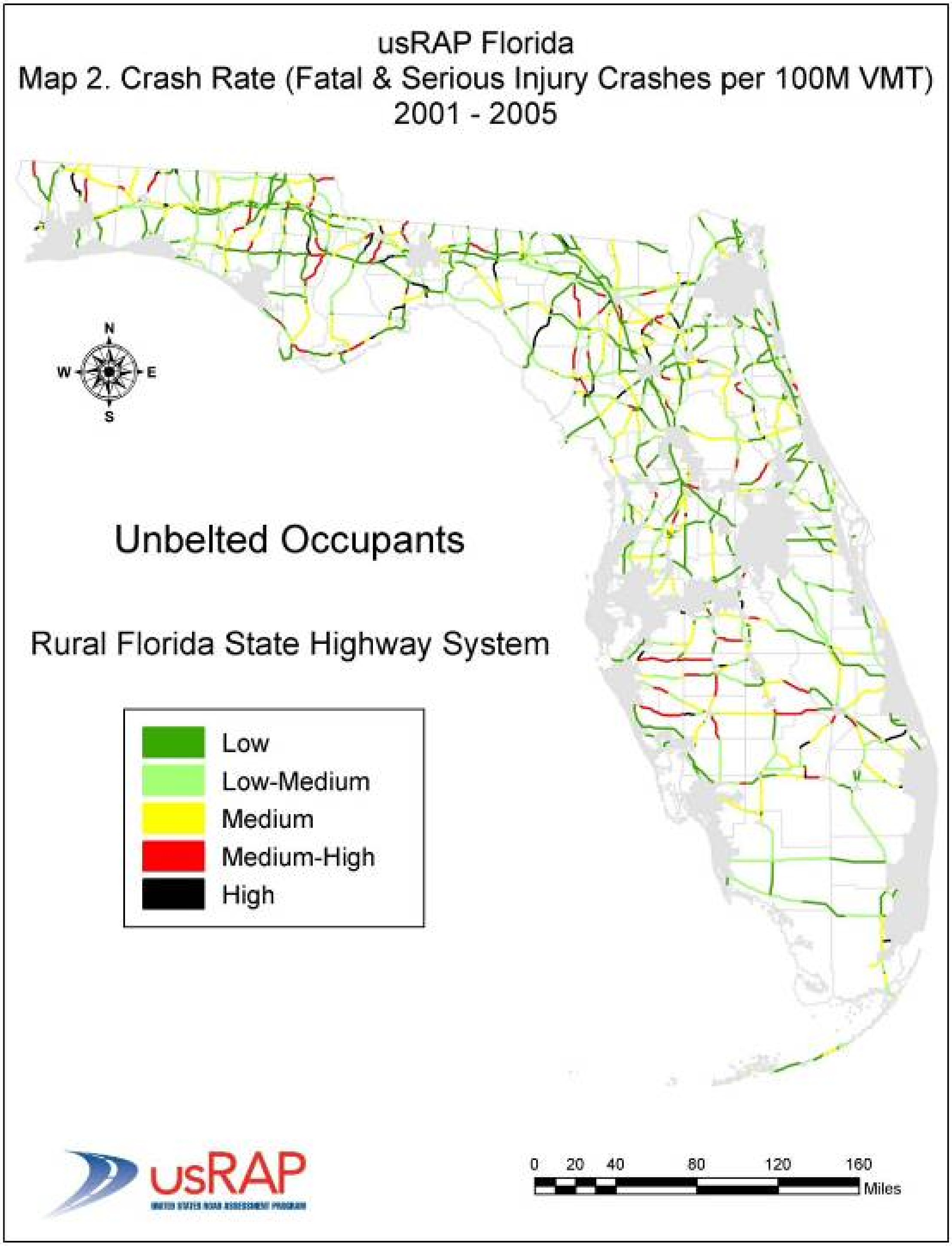

Figure 7. Florida Map 2 for Unbelted Occupants

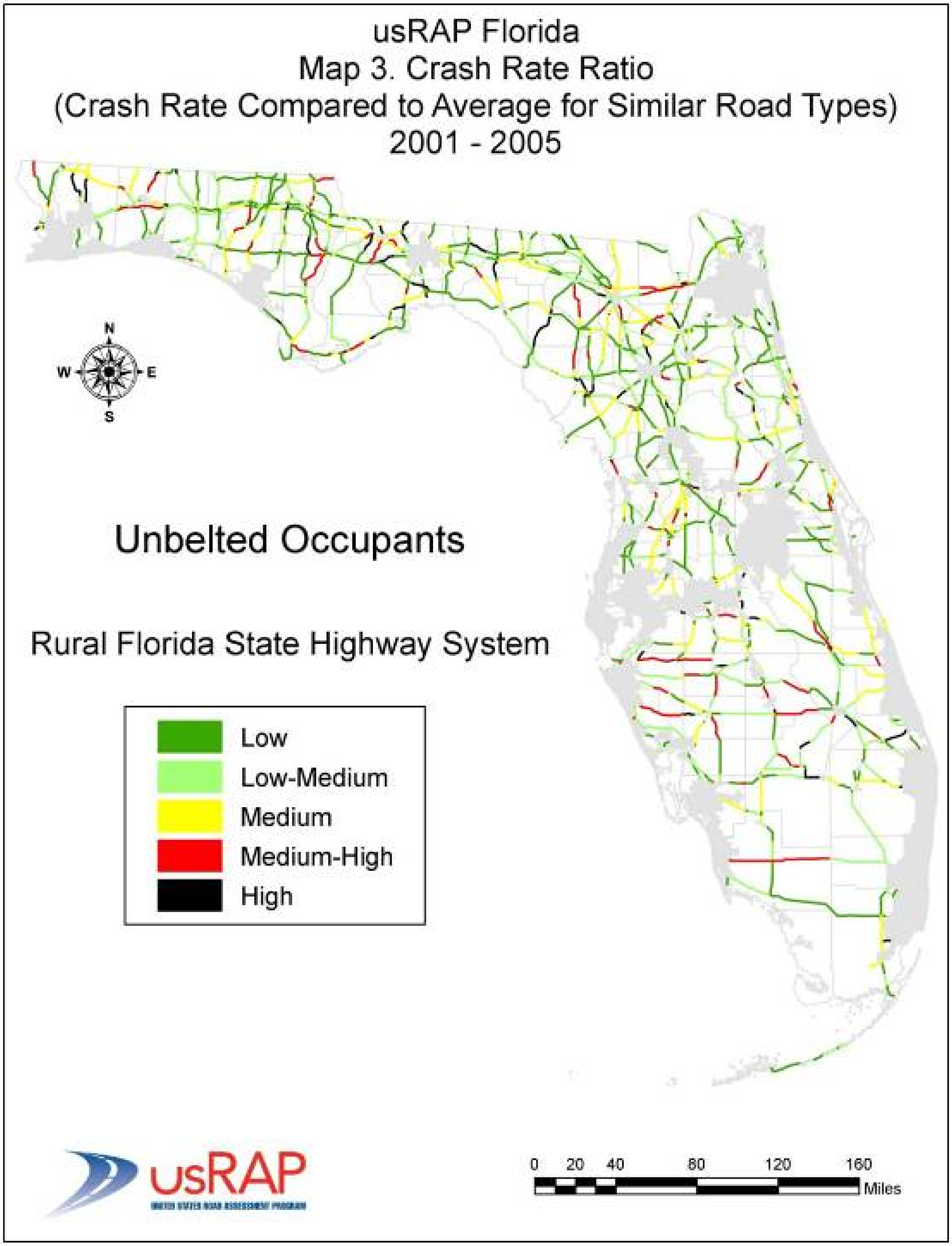

Figure 8. Florida Map 3 for Unbelted Occupants

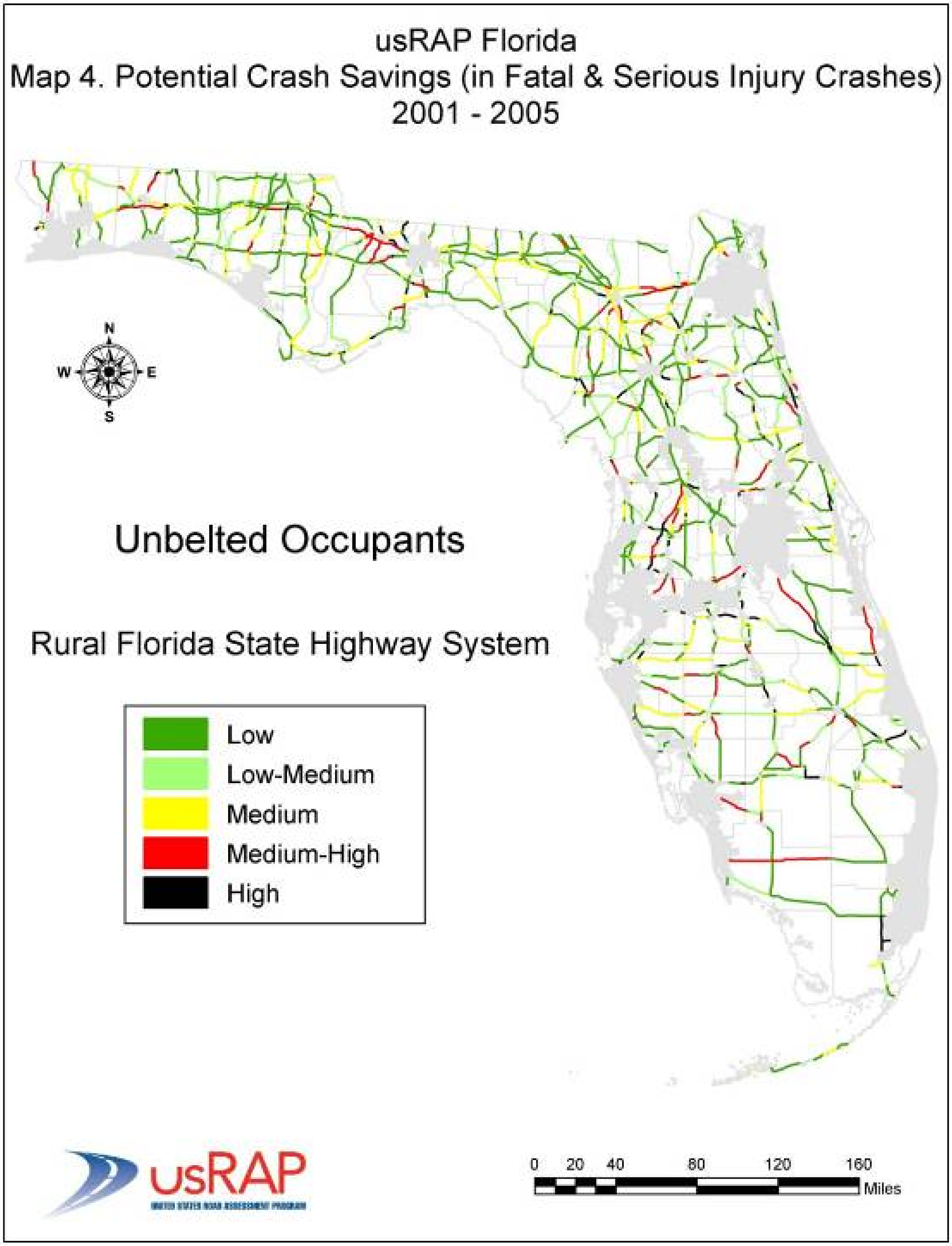

Figure 9. Florida Map 4 for Unbelted Occupants

Maps analogous to Maps 1 through 4 were prepared for speed-related crashes (see Figures 10 through 13). Speed-related crashes are defined as crashes in which any reported driver contributing cause is "exceeded safe speed limit" or "exceeded stated speed limit." For each of these maps, a minimum of three fatal or serious injury speed-related crashes were required for a section to be considered medium-high or high risk.

Maps analogous to Maps 1 through 4 were prepared for alcohol- or drug-involved crashes in Florida. Alcohol- or drug-involved crashes are defined as those in which an officer reported alcohol/drug involvement in at least one of two areas of the crash report, including driver/pedestrian contributing causes or the explicit alcohol/drug use report element. If any of the conditions in Table 3 were satisfied, the crash was identified as alcohol- or drug-involved. Figures 14 through 17 present Maps 1 through 4, respectively, for alcohol- and drug-involved crashes in Florida. For each of these maps, a minimum of three fatal or serious injury alcohol- or drug-involved crashes were required for a section to be considered medium-high or high risk.

Table 3. Alcohol- or Drug-Involved Crash Criteria for Florida Supplementary Maps

Alcohol/drug use	Contributing causes—driver/pedestrian	Alcohol involved (crash-level, derived)
Alcohol—Under Influence	Alcohol—Under Influence	Alcohol Was Involved
Drugs—Under Influence	Drugs—Under Influence	Drugs Were Involved
Alcohol & Drugs—Under Influence	Alcohol & Drugs—Under Influence	Both Alcohol and Drugs Were Involved
Had Been Drinking		

Maps analogous to Maps 1 through 4 (Figures 18 through 21) were prepared for lane-departure crashes in Florida. Lane-departure crashes are defined by the first harmful event of the crash and the first driver contributing cause, as specified by the Florida DOT. Qualifying first harmful events and driver contributing causes are presented in Table 4. For each of these maps, a minimum of three fatal or serious injury lane-departure crashes was required for a section to be considered medium-high or high risk.

Table 4. Lane Departure Crash Criteria for Florida Supplementary Maps

First harmful event		Contributing causes—driver
Collision With MV in Transport (Head on)	Collision With Construction Barricade Sign	Improper Lane Change
Collision With MV in Transport (Sideswipe)	Collision With Crash Attenuators	Improper Passing
MV Hit Sign/Sign Post	MV Hit Other Fixed Object	Drove Left of Center
MV Hit Utility Pole/Light Pole	MV Ran Into Ditch/Culvert	Driving Wrong Side/Way
MV Hit Guardrail	Ran Off Road Into Water	
MV Hit Fence	Overturned	
MV Hit Concrete Barrier Wall	Downhill Runaway	
MV Hit Bridge/Pier/Abutment/Rail	Median Crossover	
MV Hit Tree/Shrubbery		

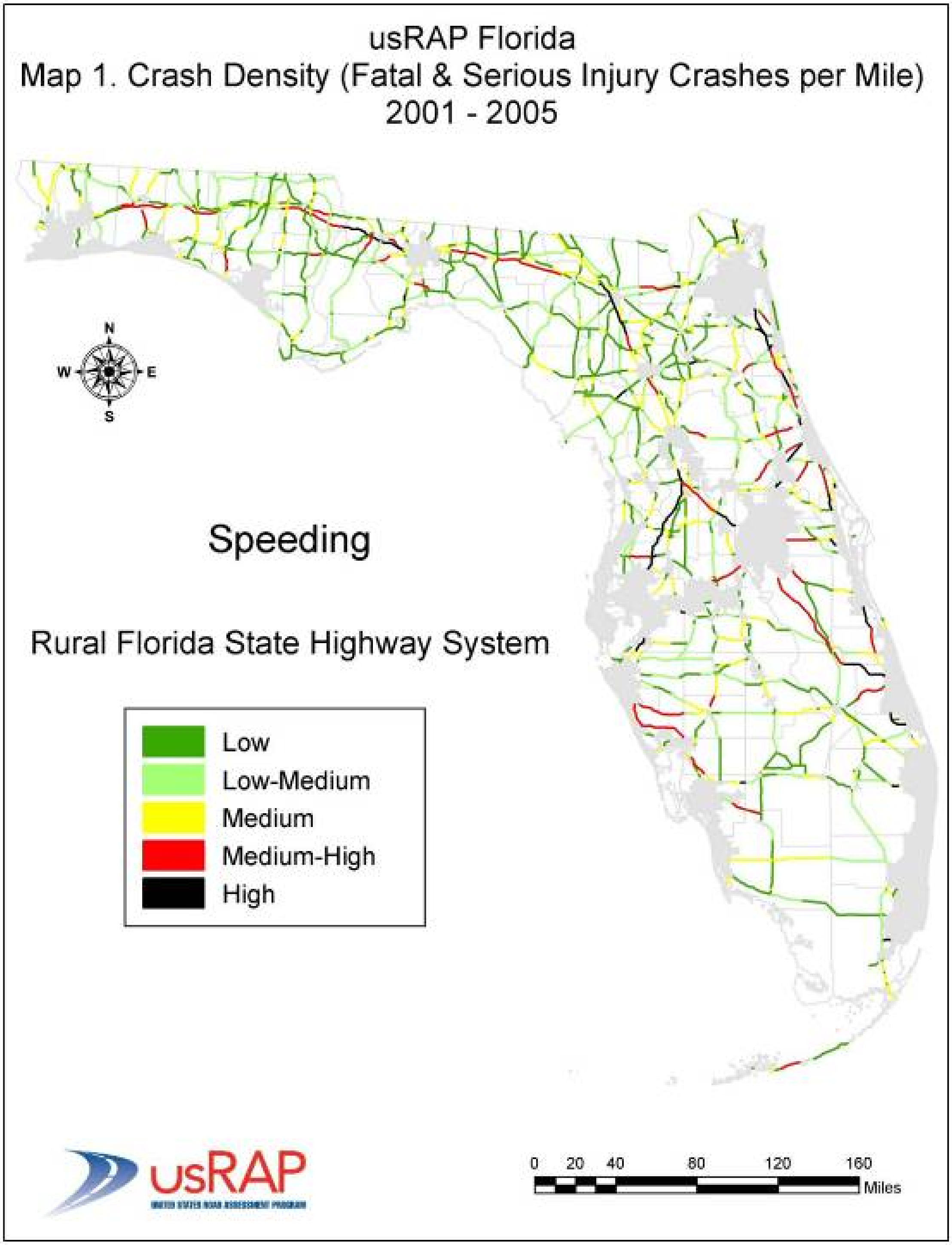

Figure 10. Florida Map 1 for Speed-Related Crashes

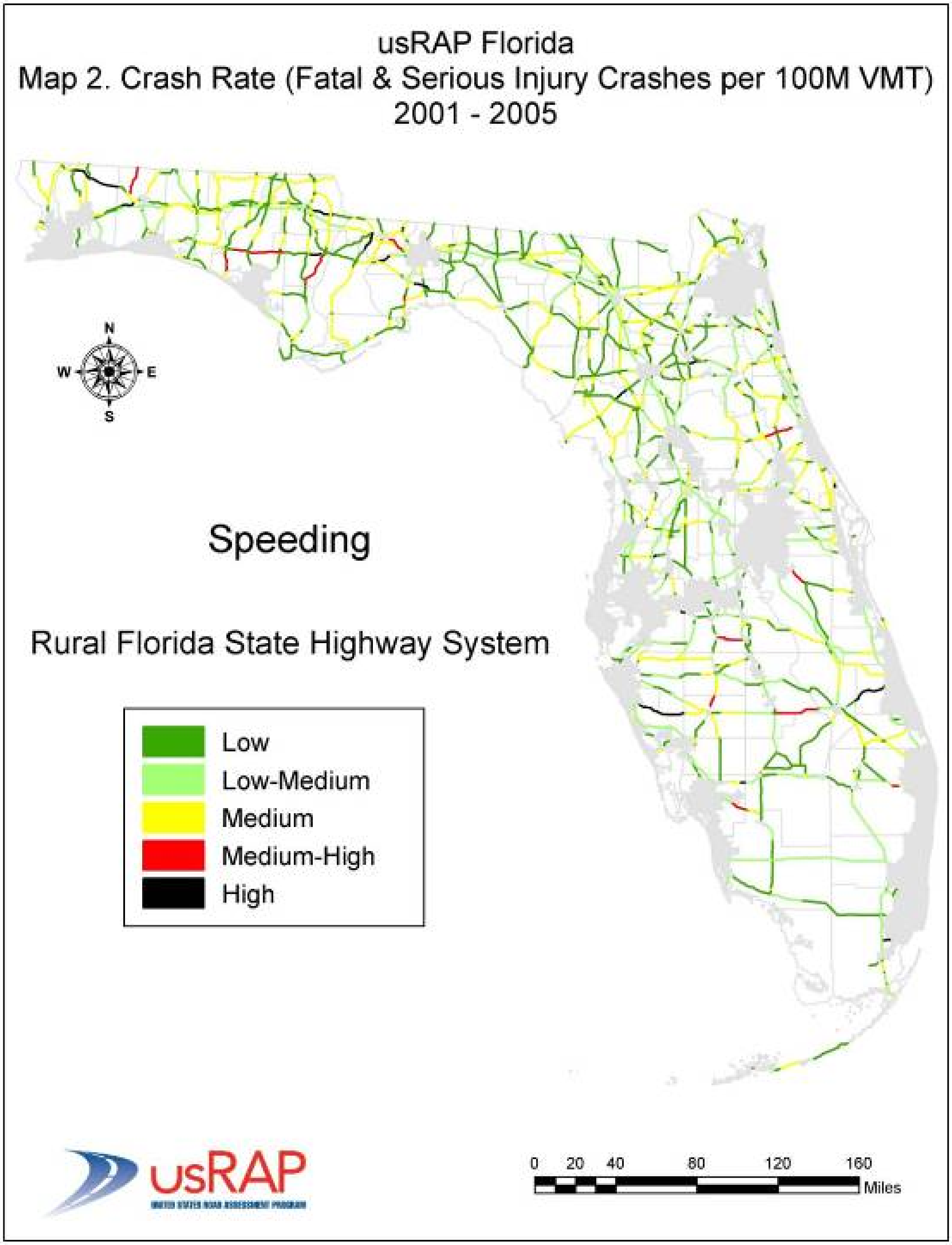

Figure 11. Florida Map 2 for Speed-Related Crashes

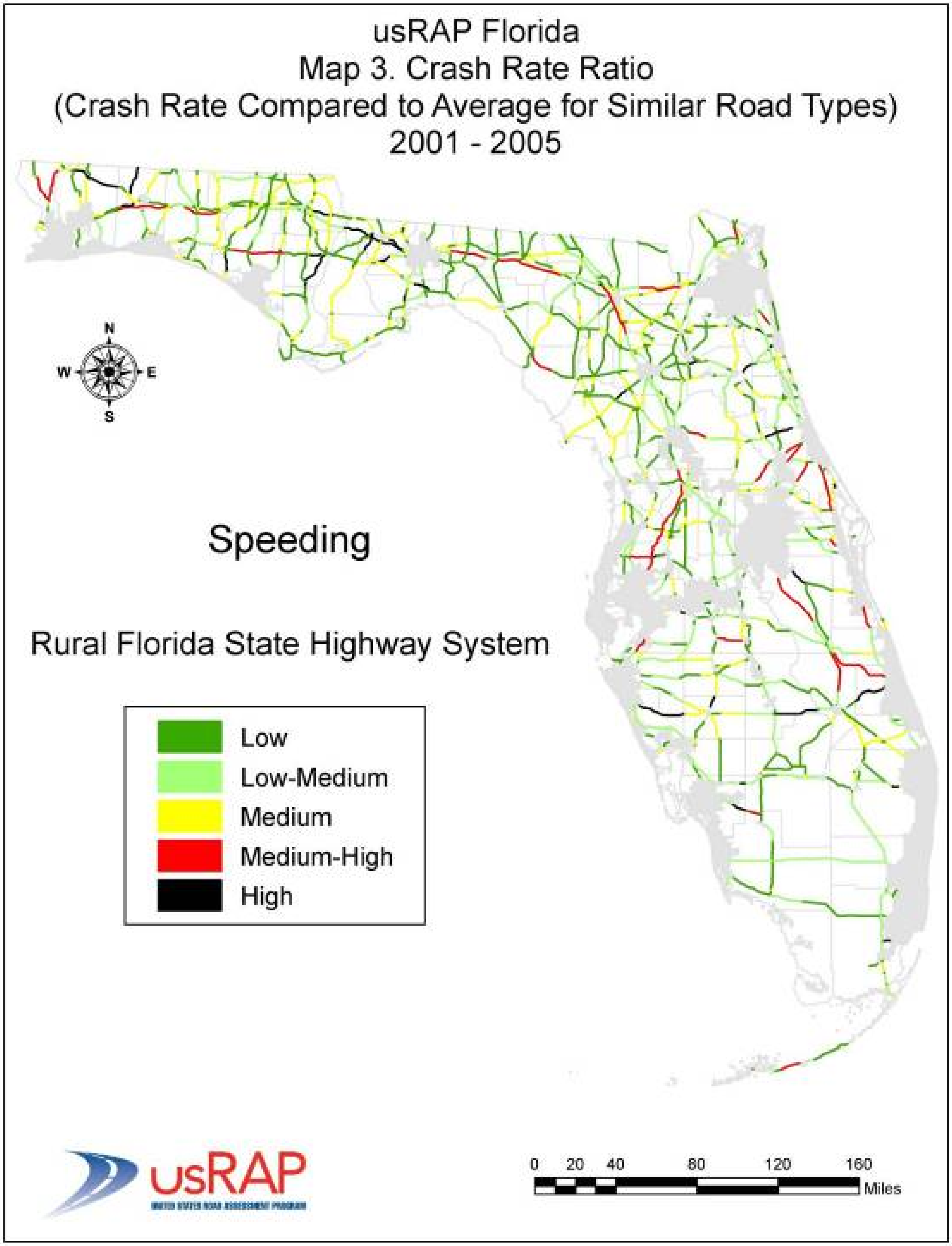

Figure 12. Florida Map 3 for Speed-Related Crashes

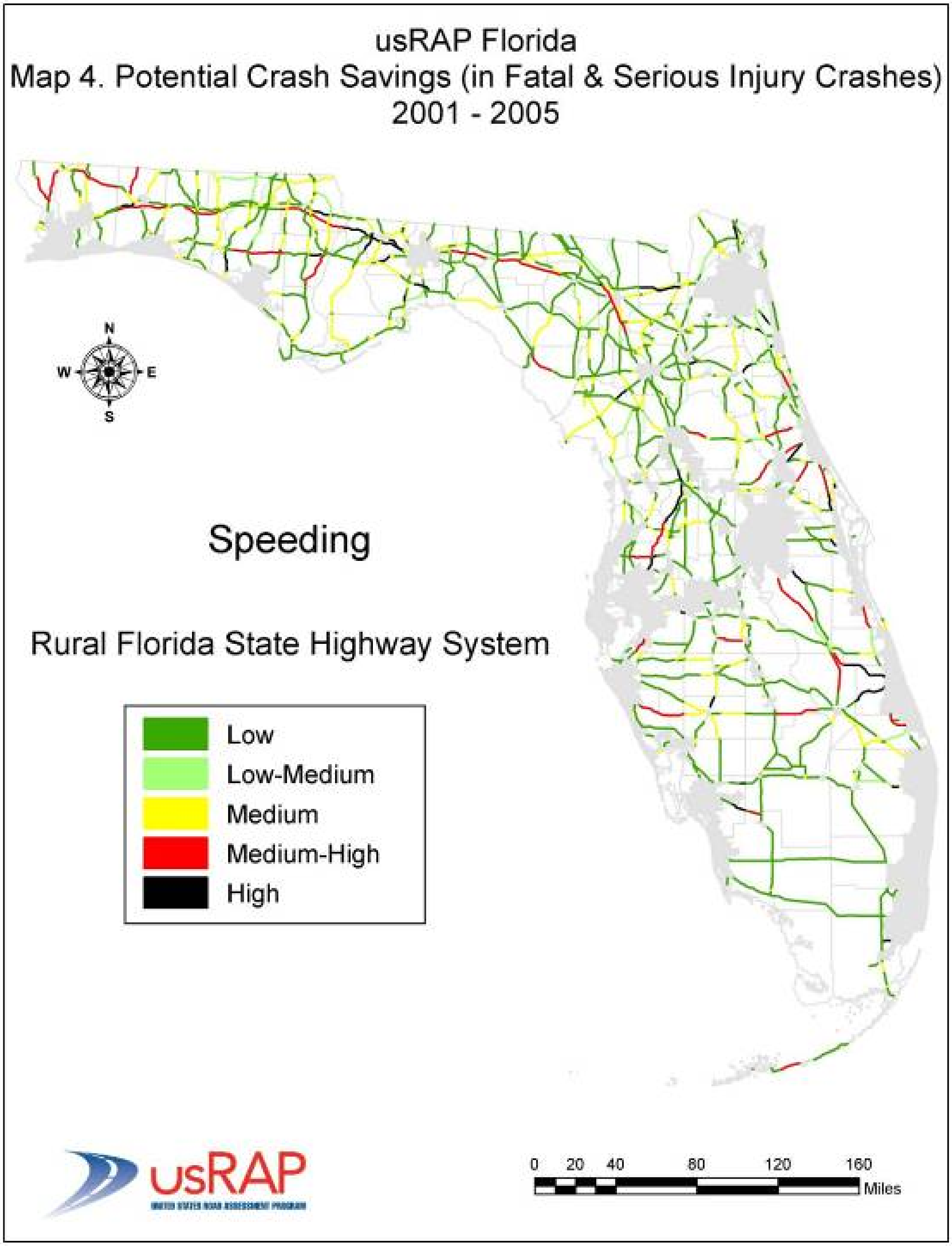

Figure 13. Florida Map 4 for Speed-Related Crashes

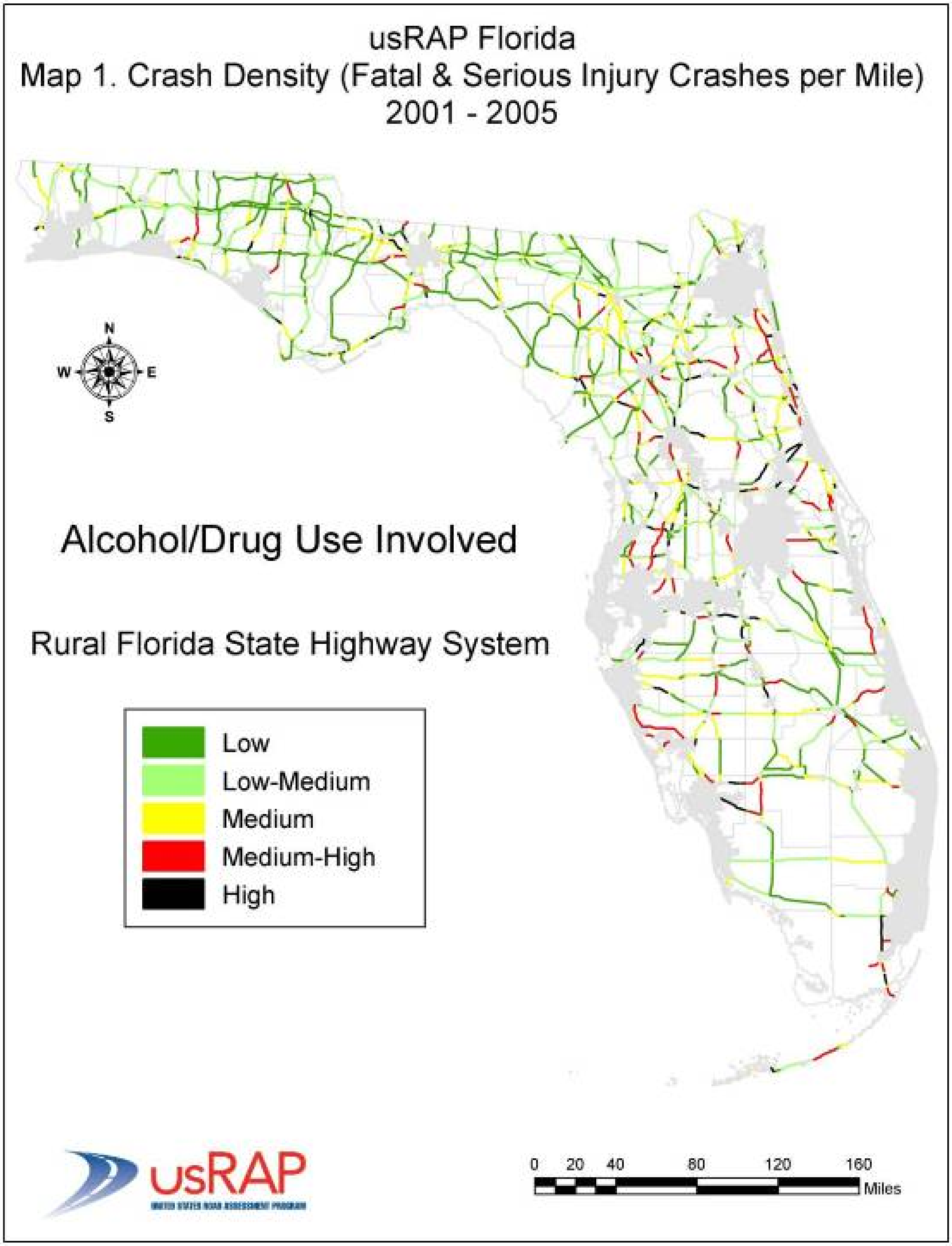

Figure 14. Florida Map 1 for Alcohol- or Drug-Involved Crashes

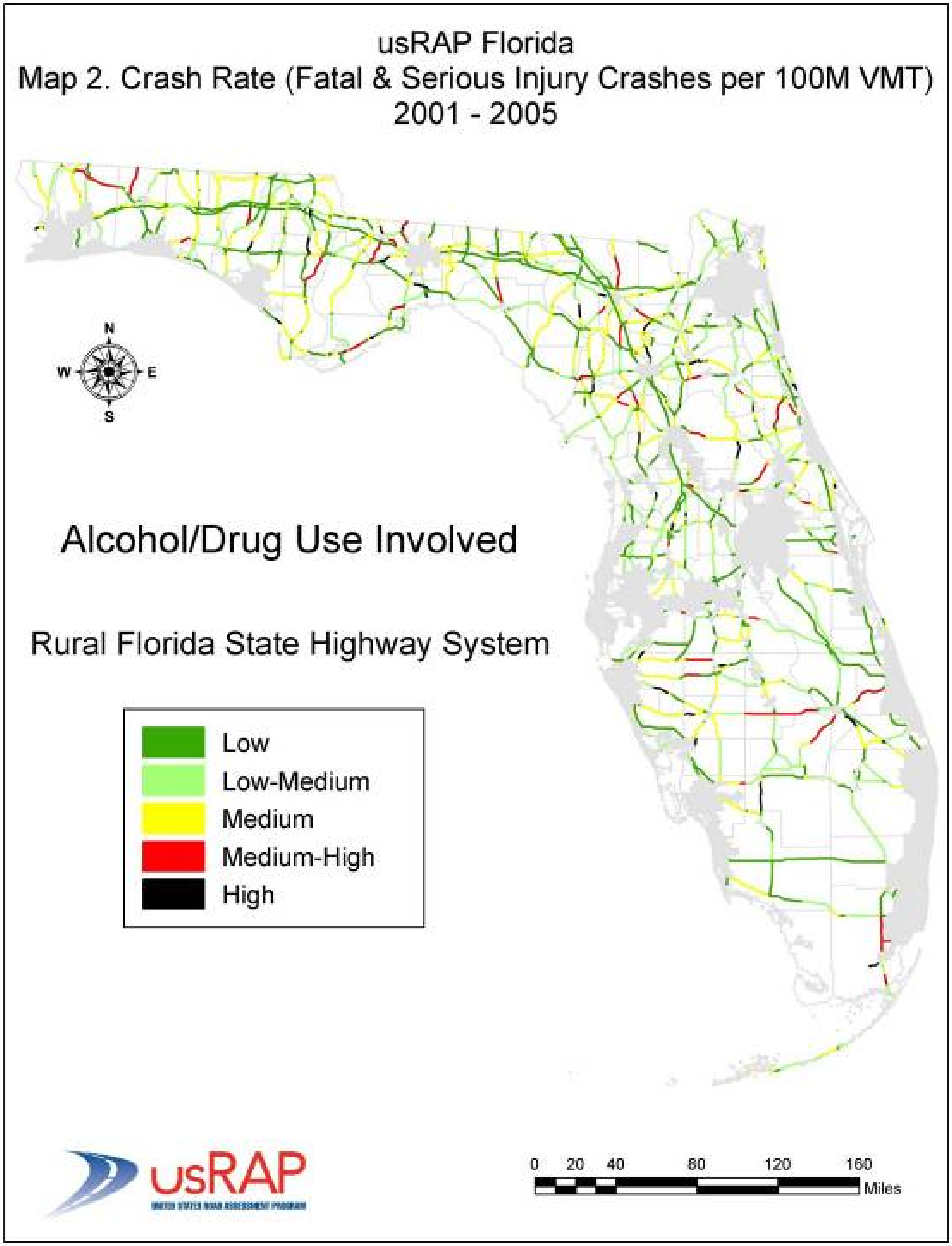

Figure 15. Florida Map 2 for Alcohol- or Drug-Involved Crashes

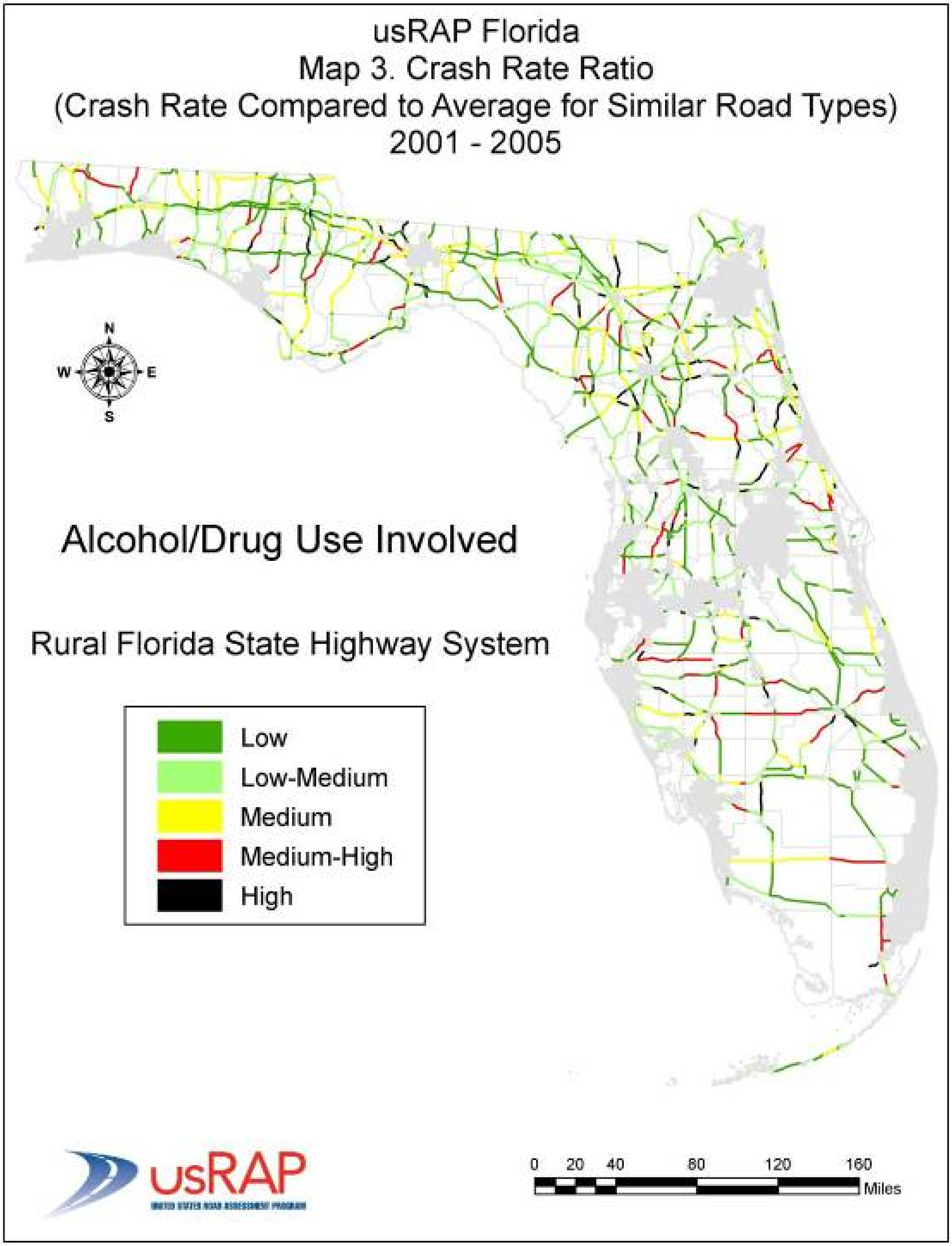

Figure 16. Florida Map 3 for Alcohol-or Drug-Involved Crashes

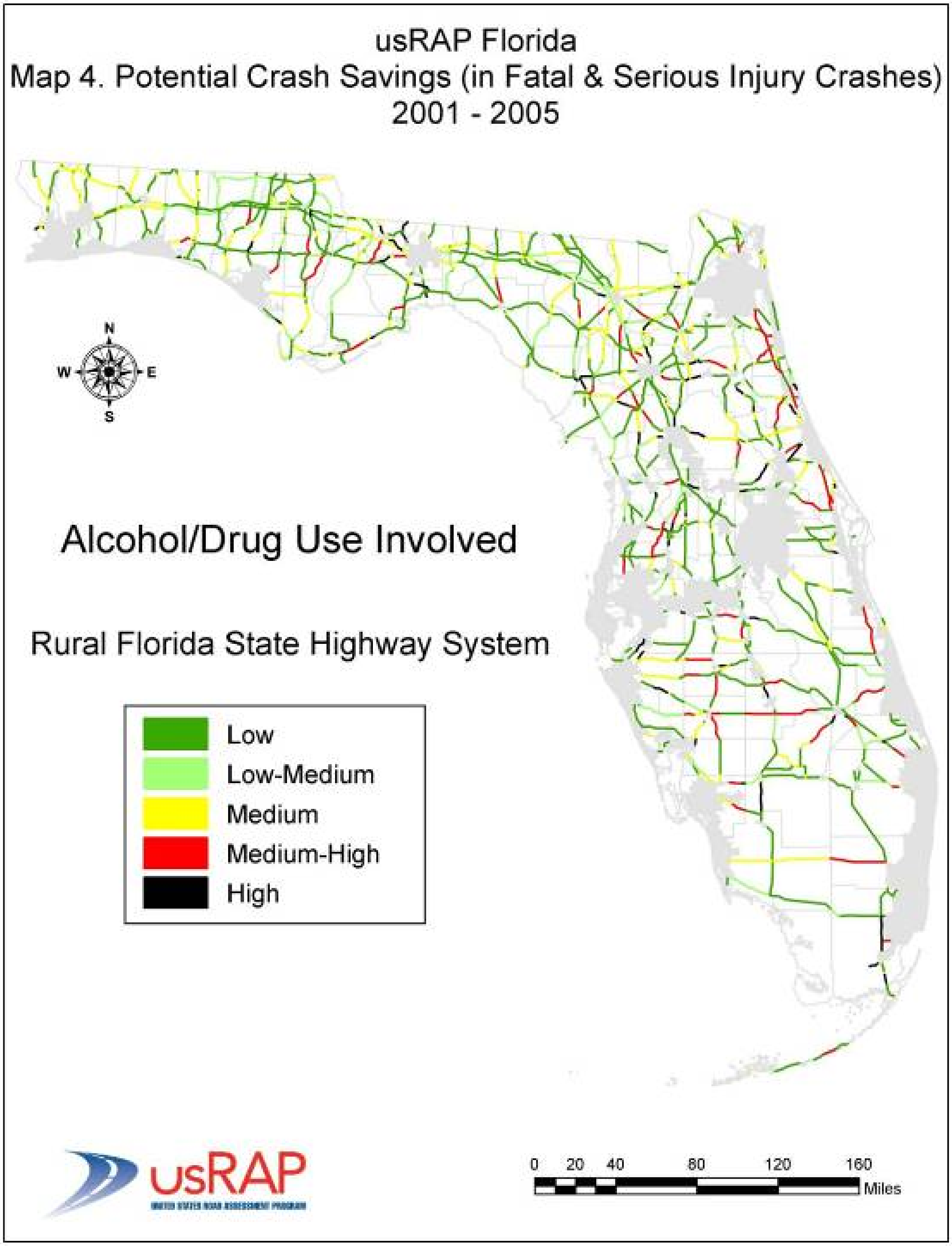

Figure 17. Florida Map 4 for Alcohol- or Drug-Involved Crashes

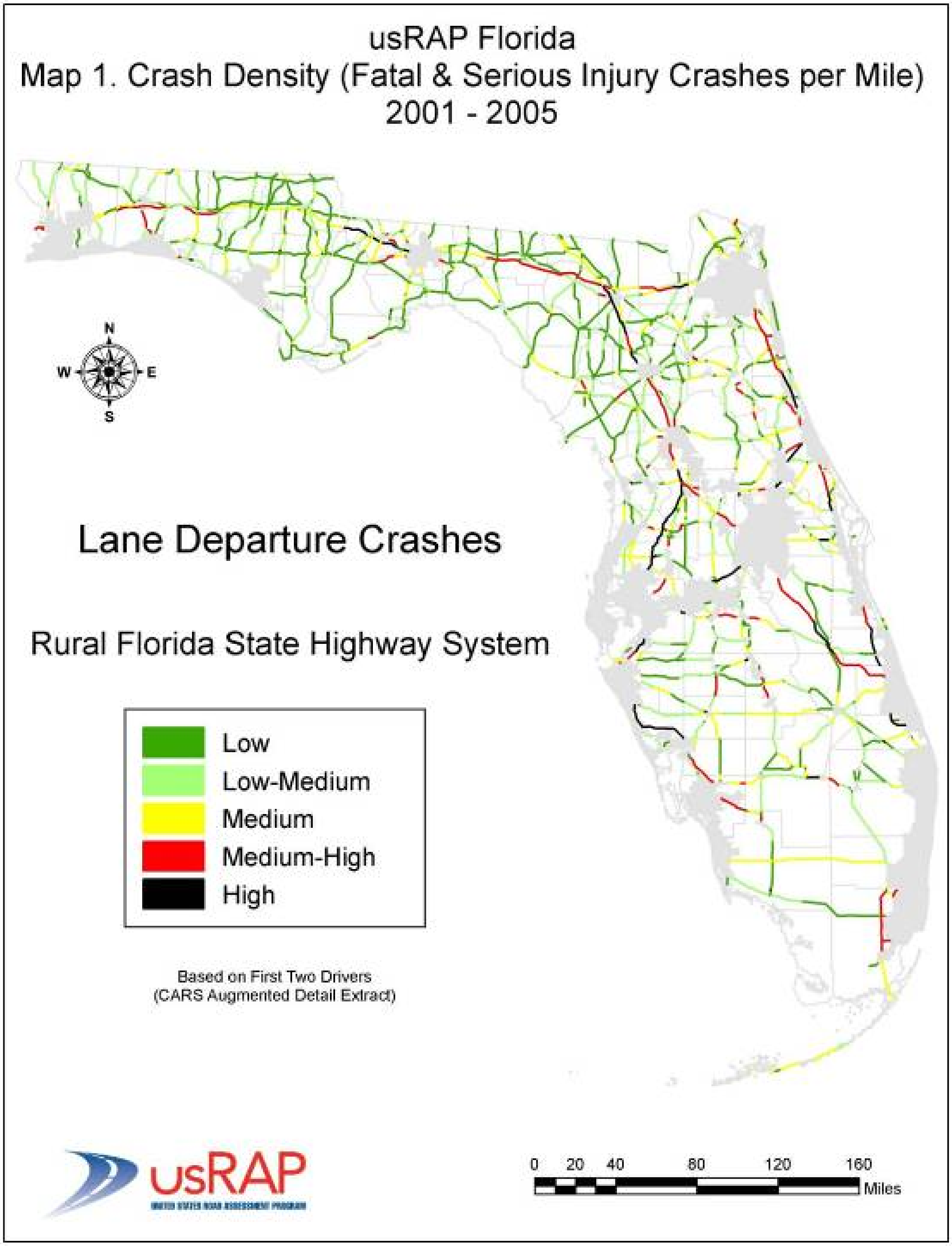

Figure 18. Florida Map 1 for Lane-Departure Crashes

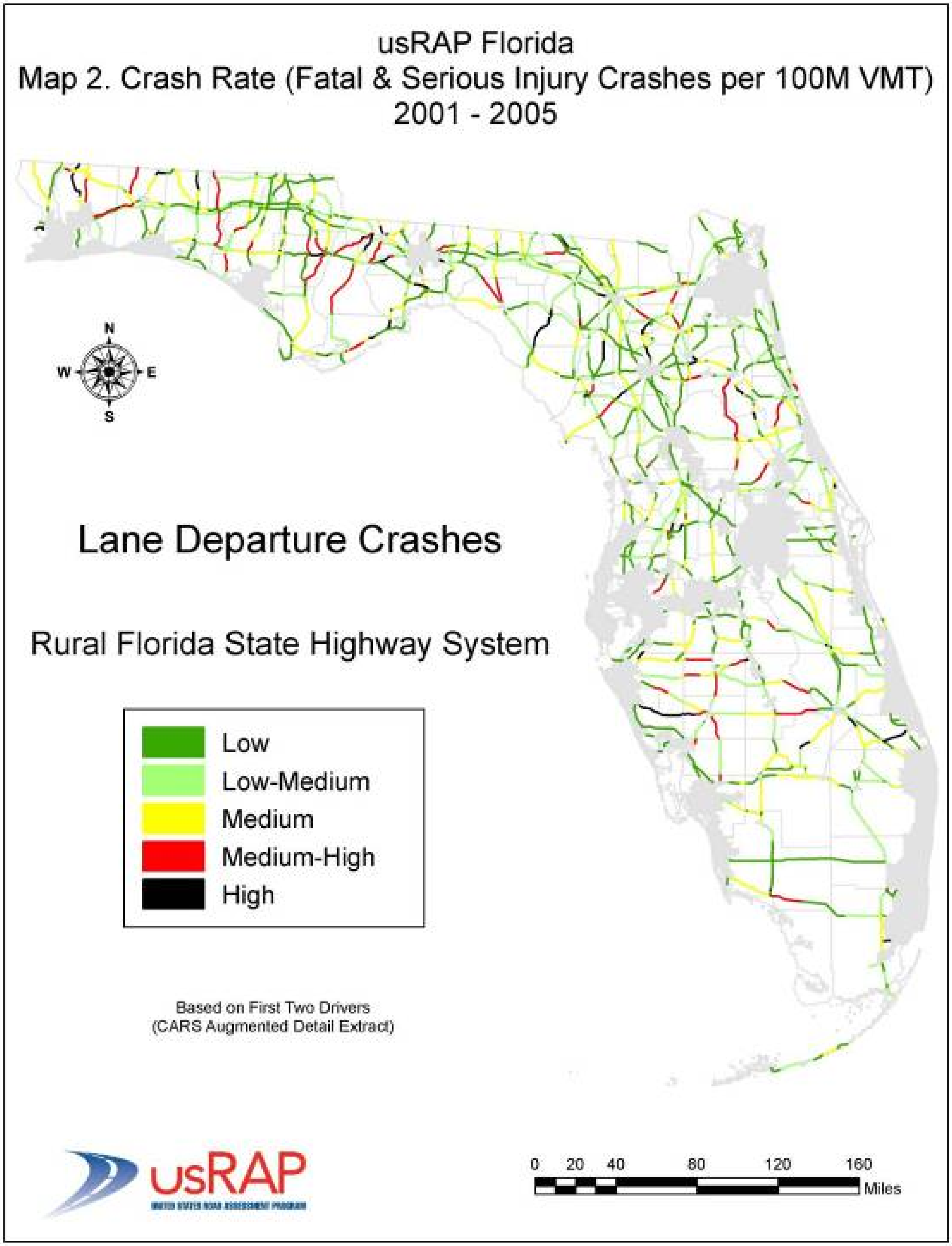

Figure 19. Florida Map 2 for Lane-Departure Crashes

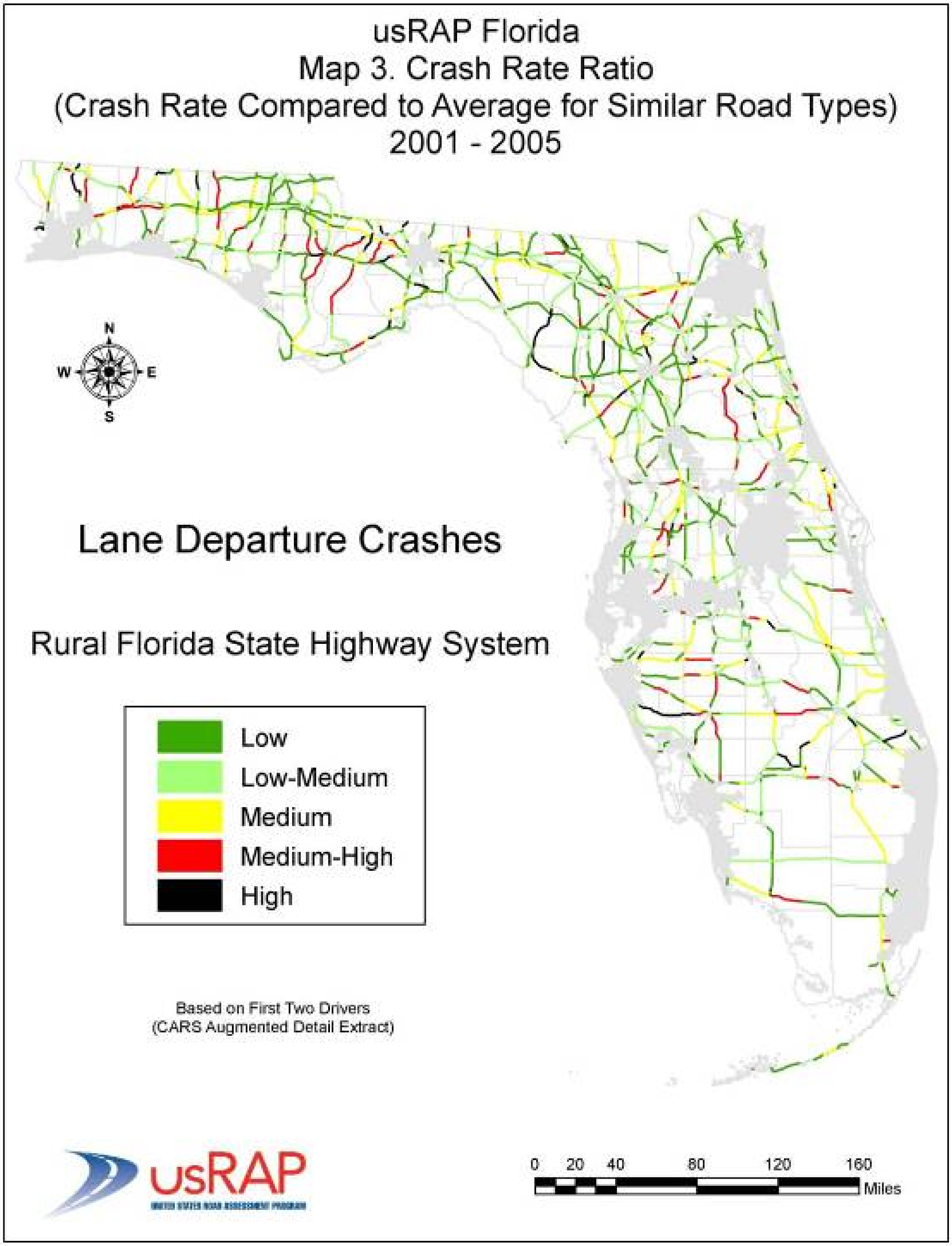

Figure 20. Florida Map 3 for Lane-Departure Crashes

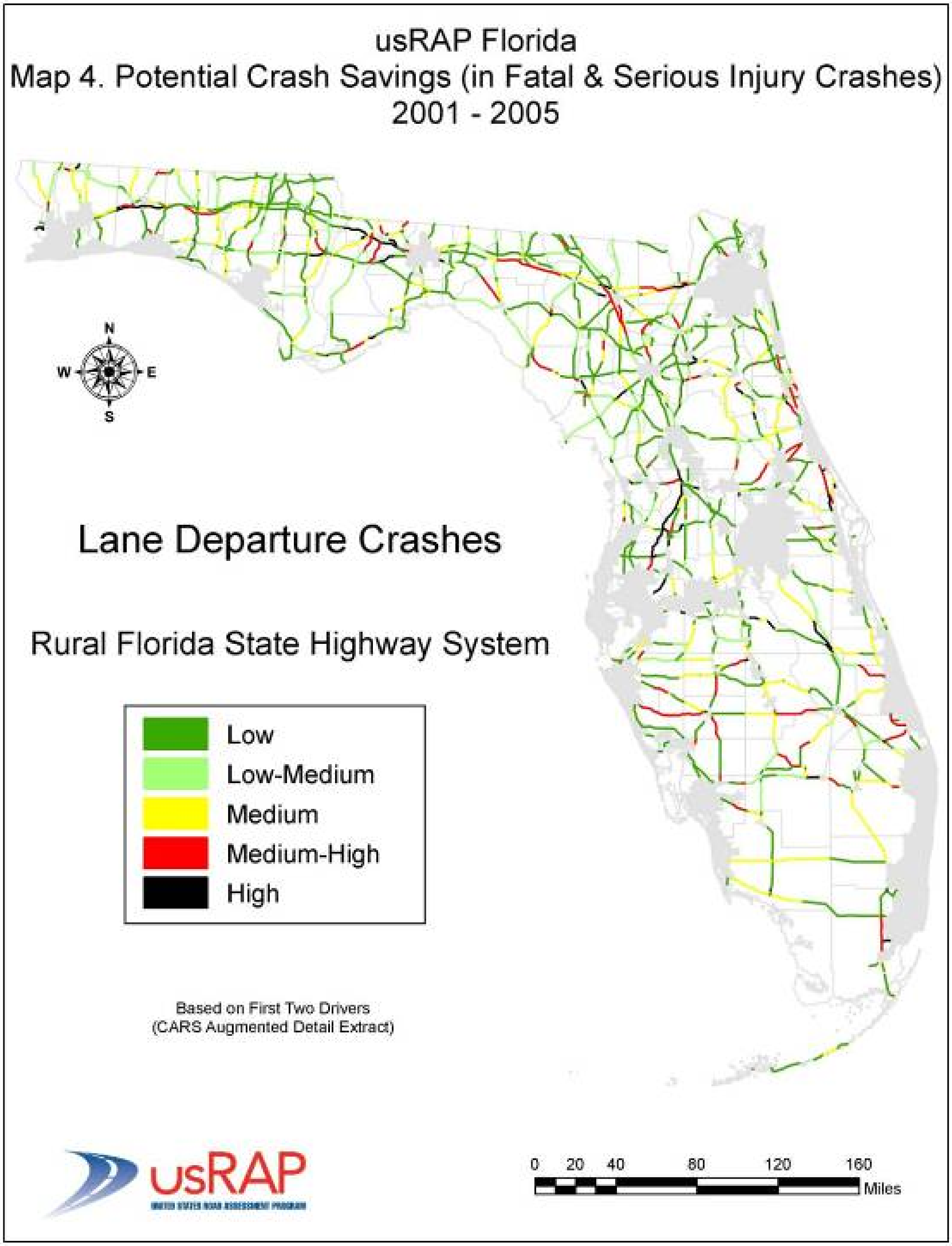

Figure 21. Florida Map 4 for Lane-Departure Crashes

Because of the lack of exposure data for specific vehicle types or driver age categories, only Map 1 was developed for commercial-vehicle-involved crashes, older-driver crashes (i.e., involving at least one driver over the age of 65), and younger-driver crashes (i.e., involving at least one driver under the age of 21). A minimum of three fatal or serious injury crashes of these types was required for a section to be considered medium-high or high risk. Figure 22 presents Map 1 for commercial-vehicle-involved crashes. Commercial vehicle involved crashes were defined as those involving a heavy truck (two or more rear axles), truck tractor (cab-bobtail), or bus (with seating over 15) and a reported use of commercial passenger, as specified by the Florida DOT. Figure 23 presents Map 1 for older-driver crashes, and Figure 24 presents Map 1 for younger-driver crashes in Florida.

2.5 Results of the New Jersey Pilot Study

The New Jersey pilot study was conducted in cooperation with the New Jersey Department of Transportation. This section presents the results of the New Jersey pilot study. The section first discusses general issues concerning the roadway network included in the pilot study, the manner in which that roadway network was divided into road segments for analysis, and the data that were assembled for analysis. The results of risk mapping are then presented.

Unlike the other usRAP pilot studies conducted to date in Iowa, Michigan, and Florida, the New Jersey pilot study included both rural and urban roads. Urban areas constitute such a large portion of the New Jersey road network (over 80 percent) that a pilot study that addressed only rural roads would not address many of the major safety improvement needs of the state.

2.5.1 Roads Selected for Inclusion in Mapping

New Jersey has over 38,500 mi of publicly owned and operated roads. Only state-owned roads and toll roads were considered in the New Jersey pilot study (see Figure 25). These roads include Interstate, US, and New Jersey numbered routes, and toll roads.

2.5.2 Road Classification

Roads included in this pilot study were classified into eight types: rural freeway, rural multilane divided highway, rural multilane undivided, rural two-lane roads, urban freeway, urban multilane divided highway, urban multilane undivided, and urban two-lane roads. Road type definition was based on access control, median type, number of lanes and national functional classification (NFS) designation. Unique access control-median type number of lanes combinations were assigned to one of the road-type categories. In some cases, particularly where this combination was atypical, sections were

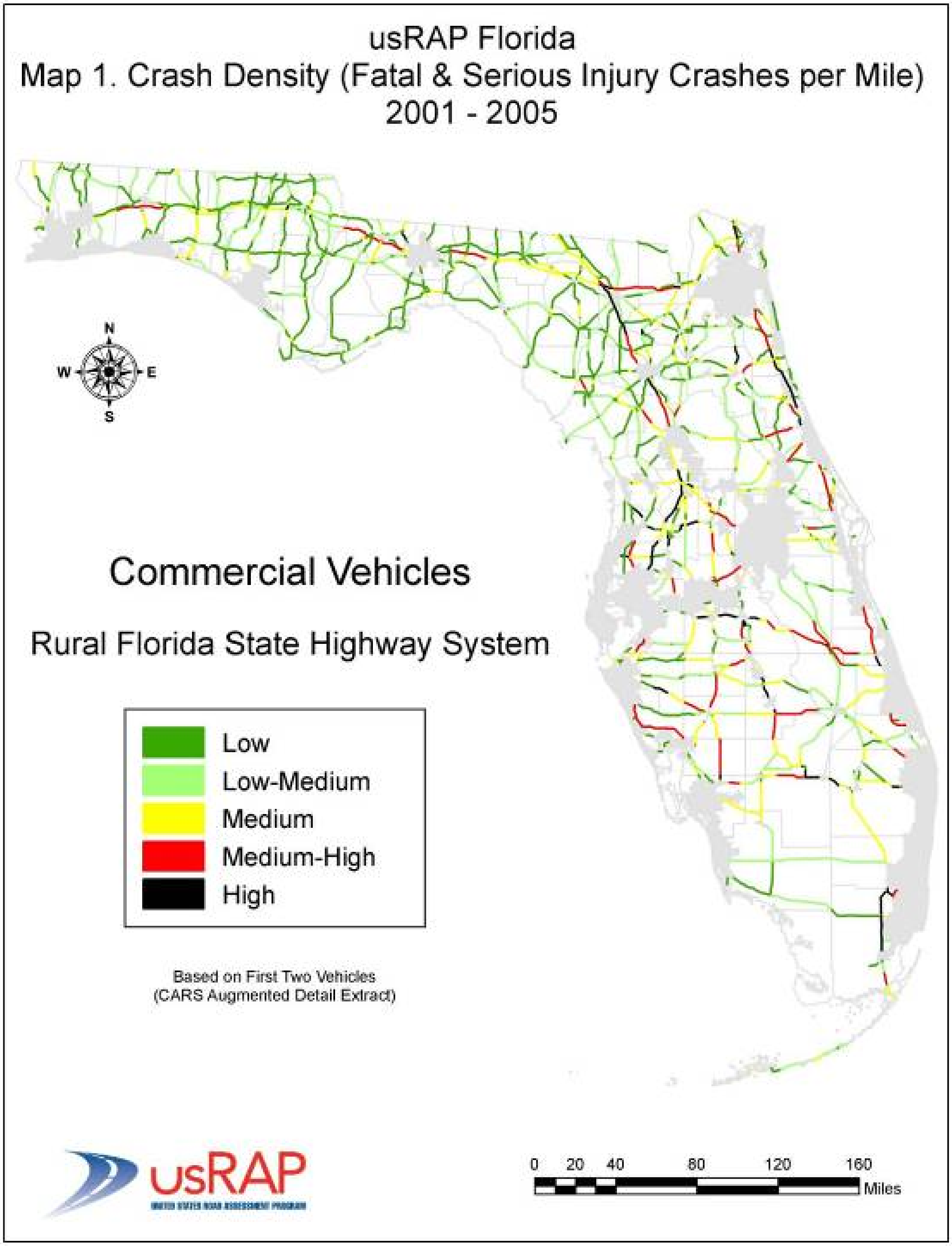

Figure 22. Florida Map 1 for Commercial-Vehicle Crashes

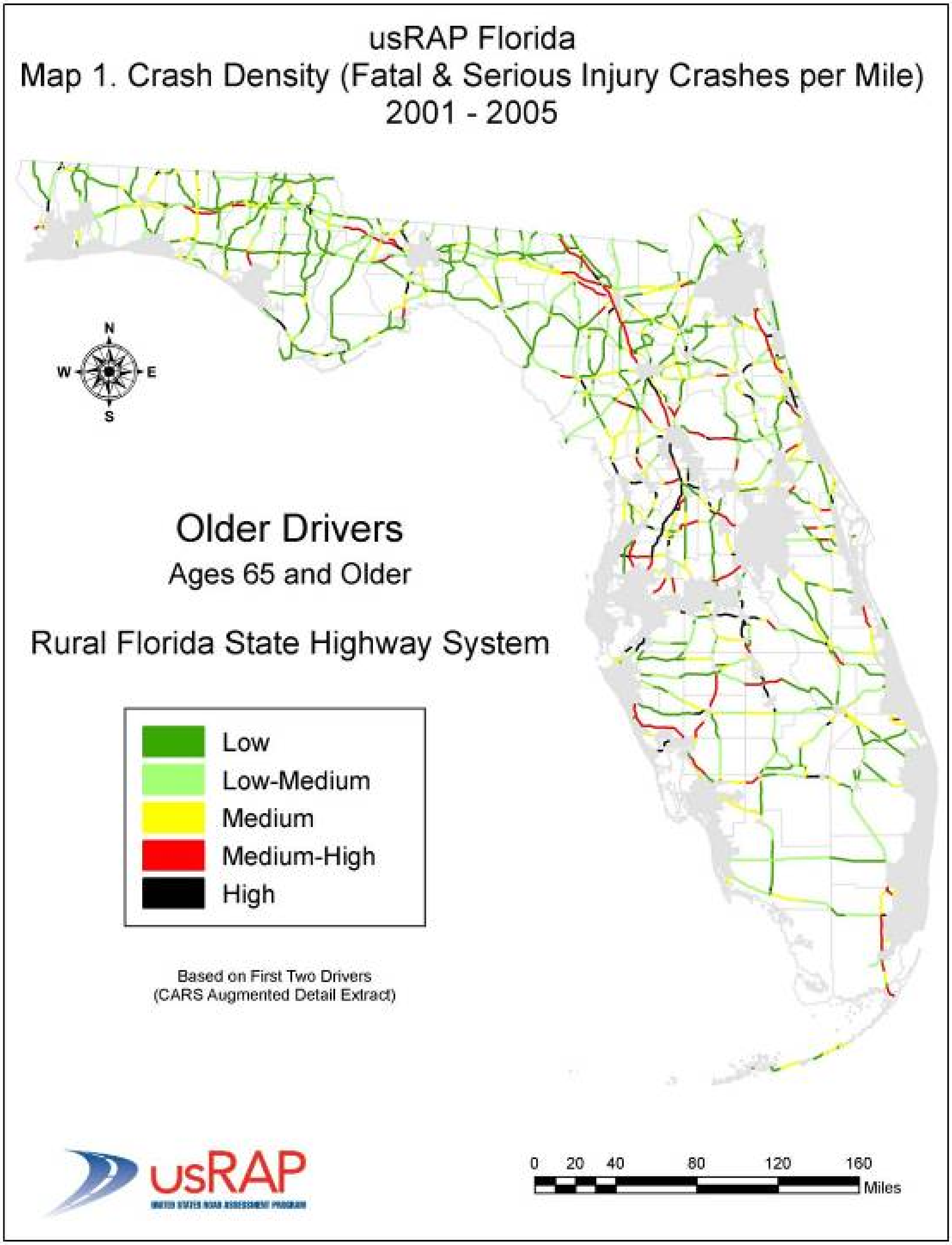

Figure 23. Florida Map 1 for Older-Driver Crashes

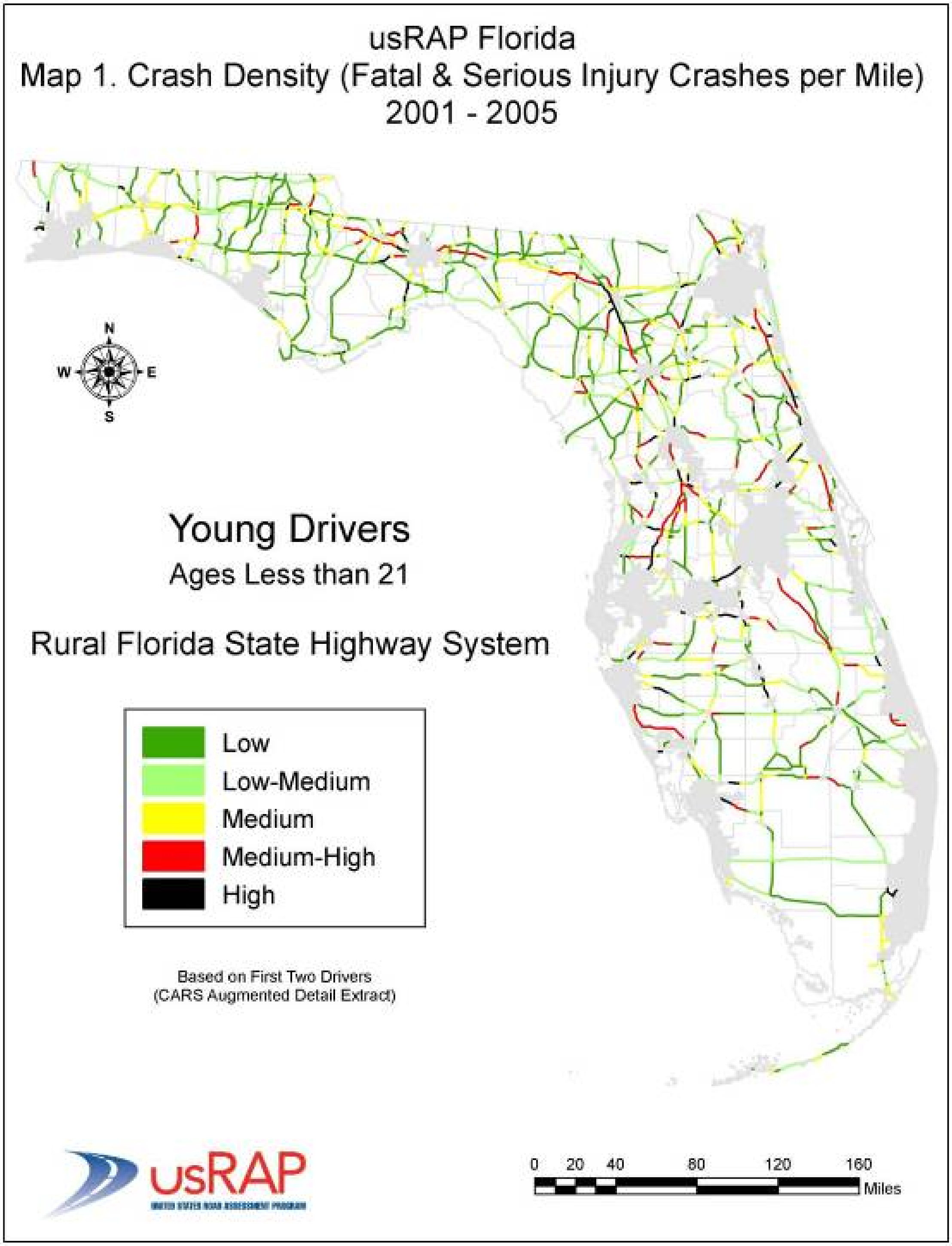

Figure 24. Florida Map 1 for Younger-Driver Crashes

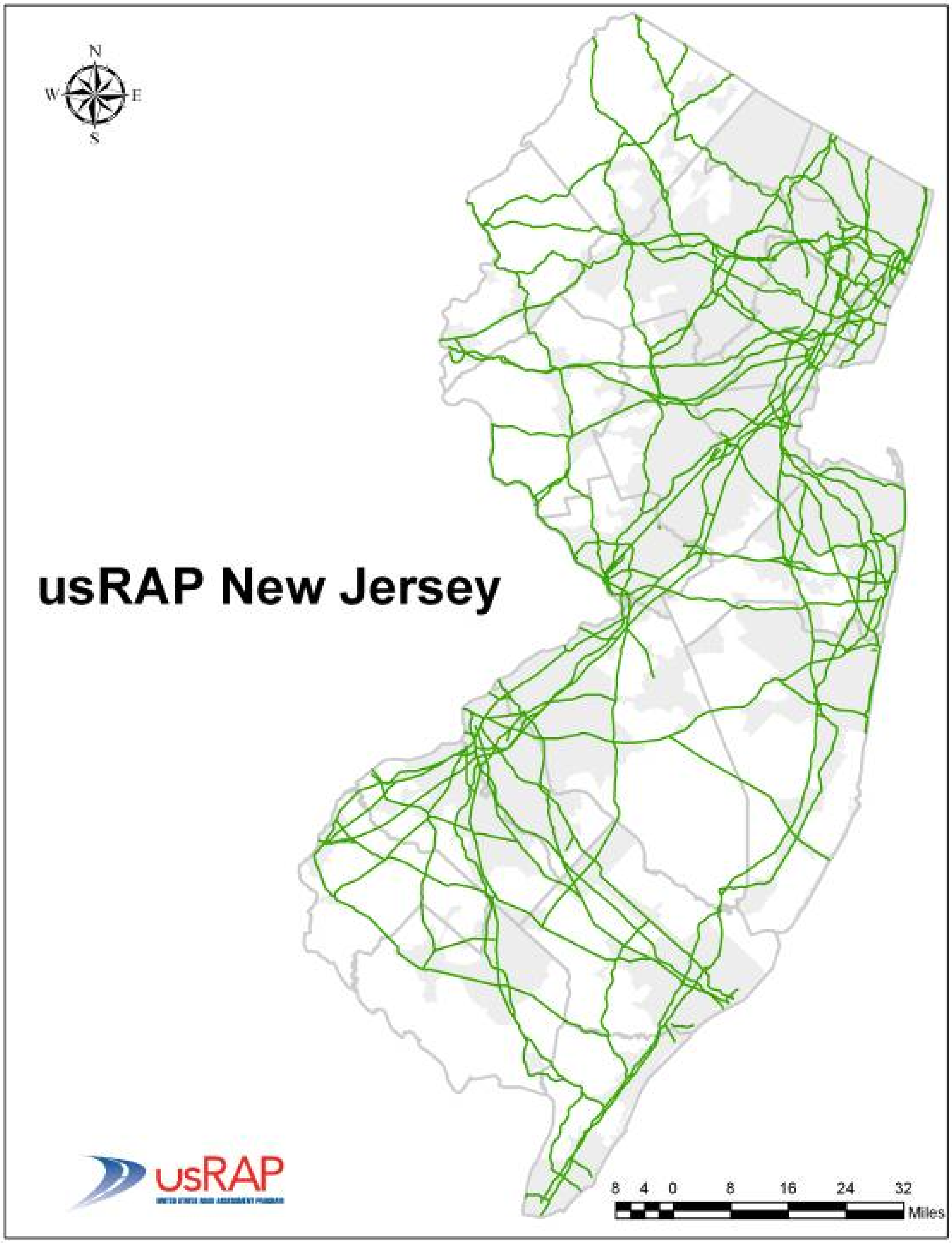

Figure 25. Roads Covered by New Jersey Risk Maps (Statewide)

assessed based on the design type and extent of adjacent road sections. The appropriate category was then assigned based on this assessment.

2.5.3 Scope of Analysis and Mapping

Risk maps were developed for all state-owned and toll roads in New Jersey, including both urban and rural roadways.

2.5.4 Segmentation

The New Jersey DOT maintains roadway characteristics data in several databases. Each database consists of a specific roadway attribute, e.g. ADT, referenced to New Jersey's linear referencing system (LRS). Eight roadway characteristics, in addition to those implicit with the LRS, were required for roadway segmentation and risk mapping. These characteristics included:

- traffic volume (AADT)
- access control
- functional class
- highway type, i.e. undivided, divided
- jurisdiction/owner
- number of lanes
- median type
- speed limit

Since the segmentation of each roadway attribute is based on the homogeneity of that attribute alone, segmentations using different attributes along a given roadway are typically different. A process known as dynamic segmentation was utilized to integrate all roadway characteristics of interest, yielding roadway segments with common termini and homogenous across all attributes. The resulting segmentation was further refined by introducing county and municipal boundaries.

As many of the resulting sections are quite short, the project team joined together adjacent sections with similar characteristics into "analysis sections." Rules were developed to allow aggregation of sections:

- with same county, route number, and road type
- of speed limits within 5 mph
- with ADTs within 20 percent, or within 2,000 veh/day

- with similar ADT, same road type, and speed limits less than or equal to 50 mph in an urban area
- with speed limits less than or equal to 50 mph just outside an urban area with similar sections within the urban area
- with very short sections with speed limits greater than or equal to 55 mph, with same road type and similar ADT
- of extremely short length

In some cases, particularly where extremely short sections were not aggregated, these rules were modified to eliminate unrealistically short analysis sections. Rule modifications included:

- with ADTs within 40 percent, or within 4,000 veh/day
- with very short sections with speed limits greater than 50 mph, with same road type and similar ADT (per above) and speed limits within 10 mph

Even with the aggregation of adjacent road sections described above, the resulting New Jersey sections were very short, averaging only about 2.0 mi in length. This short average section length seems almost unavoidable, given the high proportion of urban roads in New Jersey. Longer sections would necessarily be quite nonhomogeneous.

2.5.5 Crash Type, Selection, and Assignment

For all maps prepared in the New Jersey pilot study, only fatal and incapacitating (major) injury crashes were analyzed. Incapacitating injury crashes in New Jersey were defined in a manner analogous to serious injury crashes in Florida. For the remainder of this section, presentation and discussion of crashes, and crash-based data, are limited to fatal and incapacitating injury crashes.

In New Jersey, crashes are located with respect to the New Jersey roadway network (linear referencing system). Crash locations were defined, and geocoded, based on a mileage along a unique road segment (standard route identification [SRI] system). Once a crash was geocoded, the corresponding geographic coordinates (longitude, latitude) were derived.

2.5.6 Study Period and Data Summary

As in the other usRAP pilot studies completed to date, five years of data (2001-2005) were selected for analysis and presentation.

Tables 5 and 6 present crash totals for urban and rural state highways, respectively, for each year of the study period.

Table 5. Crashes by Severity Level for Urban State Routes in New Jersey

Year	Fatal crashes	Incapacitating injury crashes	Total fatal and incapacitating injury crashes
2001	276	700	976
2002	236	672	908
2003	277	670	947
2004	266	624	890
2005	275	573	848
Total	1,330	3,239	4,569

Table 6. Crashes by Severity Level for Rural State Routes in New Jersey

Year	Fatal crashes	Incapacitating injury crashes	Total fatal and incapacitating injury crashes
2001	26	71	97
2002	33	64	97
2003	41	68	109
2004	39	68	107
2005	54	63	117
Total	193	334	527

2.5.7 Risk Maps

Following is a summary of the urban data used for risk mapping in the New Jersey pilot study:

- Statewide totals for rural state highways
  - 1,204 segments
  - 2,283 mi of road
  - 37.2 billion annual veh-mi of travel (VMT)
  - 4,569 fatal and incapacitating injury crashes
- Statewide averages for analysis sections on rural state highways
  - Average length = 1.9 mi
  - AADT = 44,700 veh/day
  - Fatal and incapacitating injury crashes = 0.76 crashes/section/year
  - Fatal and incapacitating injury crash density = 0.40 crashes/mi/year
  - Average crash rate = 2.46 per 100M VMT

Following is a summary of the rural data used for risk mapping in the New Jersey pilot study:

- Statewide totals for rural state highways
  - 206 segments
  - 523 mi of road
  - 3.6 billion annual veh-mi of travel (VMT)
  - 527 fatal and incapacitating injury crashes
- Statewide averages for analysis sections on rural state highways
  - Average length = 2.5 mi
  - AADT = 18,700 veh/day
  - Fatal and incapacitating injury crashes = 0.51 crashes/section/year
  - Fatal and incapacitating injury crash density = 0.20 crashes/mi/year
  - Average crash rate = 2.96 per 100M VMT

Tables 7 through 9 present summary information for urban state roads, rural state roads, and all state roads, respectively.

Table 7. Summary of Urban State Route Risk Mapping Data for New Jersey

						Fatal & incapacitating injury crashes			
Road type	Number of sections	Total length (mi)	Average length (mi)	AADT (veh/day)	Annual VMT (billion)	Total frequency	Annual frequency	Annual density (per mi)	Average rate (per 100M VMT)
Freeway	241	740	3.1	79,544	21.5	1,537	1.28	0.42	1.43
Multilane divided	372	626	1.7	45,895	10.5	1,580	0.85	0.50	3.01
Multilane undivided	215	195	0.9	20,888	1.5	629	0.58	0.65	8.48
Two-lane roads	376	723	1.9	14,259	3.8	823	0.44	0.23	4.37
Total	**1,204**	**2,283**	**1.9**	**44,651**	**37.2**	**4,569**	**0.76**	**0.40**	**2.46**

Table 8. Summary of Rural State Route Risk Mapping Data for New Jersey

						Fatal & incapacitating injury crashes			
Road type	Number of sections	Total length (mi)	Average length (mi)	AADT (veh/day)	Annual VMT (billion)	Total frequency	Annual frequency	Annual density (per mi)	Average rate (per 100M VMT)
Freeway	37	120	3.2	47,334	2.1	183	0.99	0.31	1.77
Multilane divided	28	29	1.0	18,343	0.2	22	0.16	0.15	2.28
Multilane undivided	14	20	1.4	15,785	0.1	21	0.30	0.21	3.69
Two-lane roads	127	355	2.8	9,162	1.2	301	0.47	0.17	5.07
Total	**206**	**523**	**2.5**	**18,**659	**3.6**	**527**	**0.51**	**0.20**	**2.96**

Table 9. Combined Urban and Rural Risk Mapping Data for New Jersey

Road type	Number of sections	Total length (mi)	Average length (mi)	AADT (veh/day)	Annual VMT (billion)	Fatal & incapacitating injury crashes			
						Total frequency	Annual frequency	Annual density (per mi)	Annual rate (per 100M VMT)
Freeway	278	860	3.1	75,053	23.5	1,720	1.24	0.40	1.46
Multilane divided	400	655	1.6	44,683	10.7	1,602	0.80	0.49	3.00
Multilane undivided	229	214	0.9	20,415	1.6	650	0.57	0.61	8.14
Two-lane roads	503	1,078	2.1	12,581	5.0	1,124	0.45	0.21	4.54
Total	**1,410**	**2,807**	**2.0**	**39,803**	**40.8**	**5,096**	**0.72**	**0.36**	**2.50**

2.5.7.1 Selection of Risk Categories for Use on Risk Maps

The statewide risk maps for the New Jersey pilot study use the same risk categories developed in the same manner as the risk categories in the other usRAP pilot studies. The risk categories and their associated colors are as follows:

- dark green (lowest risk) — 40 percent of roadway length
- light green — 25 percent of roadway length
- yellow — 20 percent of roadway length
- red — 10 percent of roadway length
- black (highest risk) — 5 percent of roadway length

The highest risk category (shown in black on the various maps) should assist in meeting the new Federal mandate that states identify 5 percent of locations with the most severe safety needs (see Section 4.2 of the Phase I report).

A key decision in developing the New Jersey maps was whether to define separate or combined risk categories for urban and rural roads. Both approaches were tried and maps with combined risk categories were found to be most useful. Thus, the roads shown in black on the New Jersey maps represent 5 percent of the roadway system with the highest risk and may include both rural and urban roads. Table 10 presents the risk category boundaries for the New Jersey maps shown below.

Examples of all statewide maps for the New Jersey pilot study are presented in below. All maps for the New Jersey pilot study have been developed using five years of data.

As in the other usRAP pilot studies, road sections with two or fewer fatal and major injury crashes in five years were not included in the two highest risk categories. It did not appear appropriate to classify sections with limited crash experience as high risk, since they generally had short lengths or very low traffic volumes, so a criterion was adopted that no road section would be considered for classification in the two highest risk categories (red and black on the various maps) unless it experienced more than two fatal or major injury crashes in five years; such low-crash-count segments with higher risk measures generally appear in the medium risk (yellow) category on the maps presented. The segmentation issues for low-crash-count sections will be considered in future research.

Table 10. Risk Category Boundaries for New Jersey Maps 1 Through 4

Risk category	Color on map	Target percentage of road network	Range of risk measures for specific map types[1]: Map 1 Crash density (crashes per mi)	Map 2 Crash rate (crashes per HMVM)	Map 3 Ratio of crash rate per similar roads	Map 4 Potential crash savings
Low	Dark green	40	< 0.218	< 1.949	< 0.777	< 0.000
Low-medium	Light green	25	0.218-0.398	1.949-4.075	0.777-1.235	0.000-0.269
Medium	Yellow	20[b]	0.398-0.664[b]	4.075-6.763[b]	1.235-1.774[b]	0.269-1.053[b]
Medium-high	Red	10[c]	0.664-0.952[c]	6.763-10.738 [c]	1.774-2.803[c]	1.053-2.178[c]
High	Black	5[c]	> 0.952[c]	> 10.738[c]	> 2.803[c]	> 2.178[c]

[a] Risk measures are based on fatal and incapacitating injuries only.
[b] Upper limit of range may be greater for road sections that experience two or fewer fatal or incapacitating injury crashes during the five-year analysis period.
[c] Medium-high and high risk categories are applicable only to road sections that experience more than two fatal or incapacitating injury crashes during the five-year analysis period.

2.5.7.2 Road Section Crash Density Maps (Map 1)

The first type of risk map developed was the annual crash density map (Map 1). Figure 26 is a typical crash density map for all state highways in New Jersey.

2.5.7.3 Road Section Crash Rate Maps (Map 2)

Risk maps based on the fatal- and incapacitating-injury crash rate were also developed for New Jersey roads. While five years of crash data were used, a single AADT value was used to compute exposure. In some cases, particularly where AADT data were missing, AADT values were obtained from other sources, including point counts, published traffic reports, and straight line diagrams. Figure 27 presents a typical crash rate map for New Jersey roads.

2.5.7.4 Ratio of Crash Rate Relative to Similar Road Types (Map 3)

Figure 28 presents a map based on the ratio of fatal- and incapacitating-injury crash rate for each road section to the average rate of similar roads (Map 3).

2.5.7.5 Potential Crash Savings (Map 4)

Map 4 indicates the potential for reducing fatal- and incapacitating-injury crashes if road sections with above-average crash rates could be brought to the average crash rate for roads of similar type. Figure 29 presents a typical map of potential crash savings for state highways in New Jersey.

2.5.7.6 Supplementary Maps

Supplementary maps have been prepared as part of the New Jersey pilot studies in a manner similar to those prepared for the Florida pilot study. The supplementary map types prepared for New Jersey included:

- speed-related crashes
- alcohol- or drug-involved crashes
- older-driver crashes
- younger-driver crashes
- pedestrian crashes

For all of the New Jersey supplementary maps, a minimum of two or more fatal or incapacitating-injury crashes in five years were required for a section to be considered medium-high or high risk.

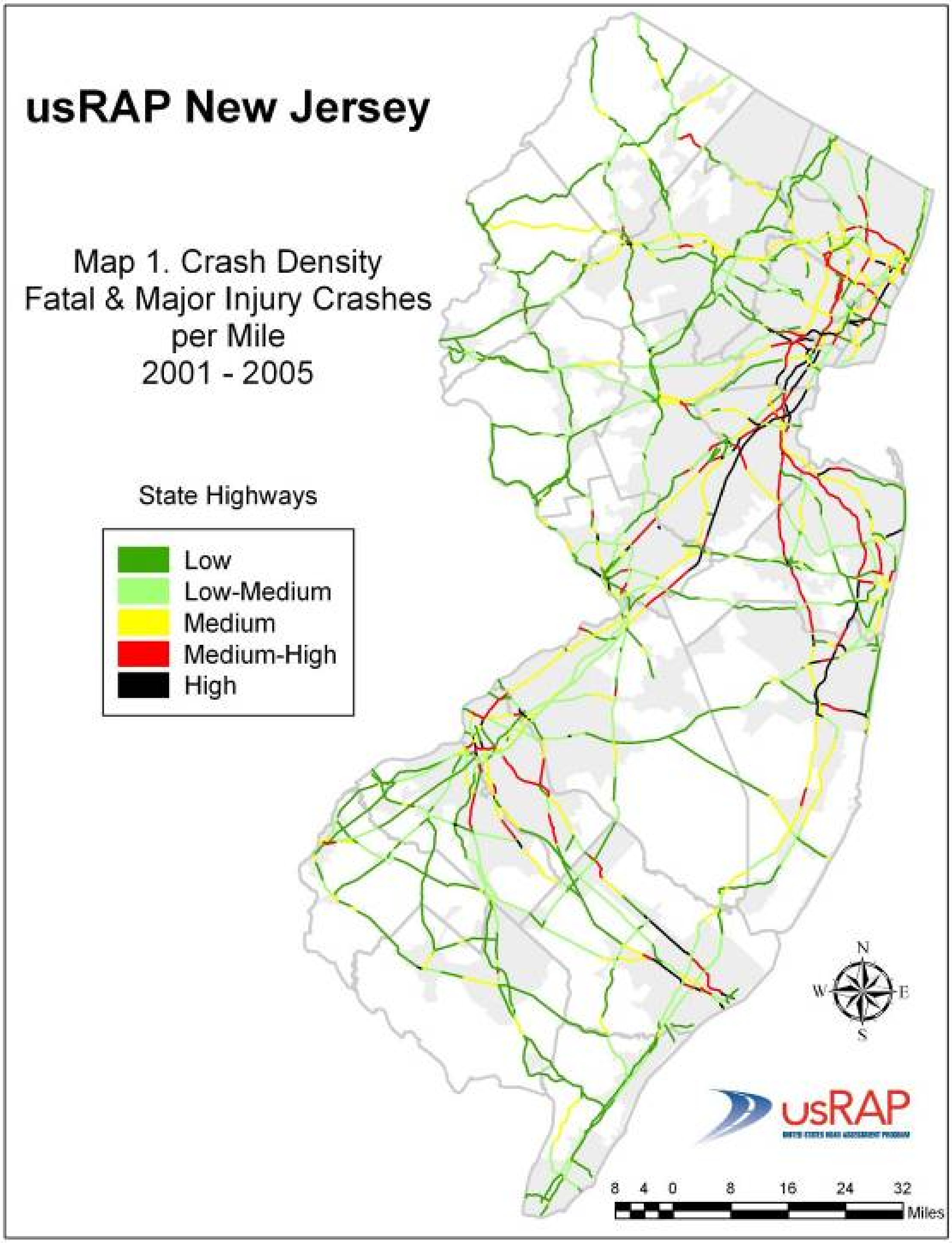

Figure 26. Example of Map 1 for New Jersey

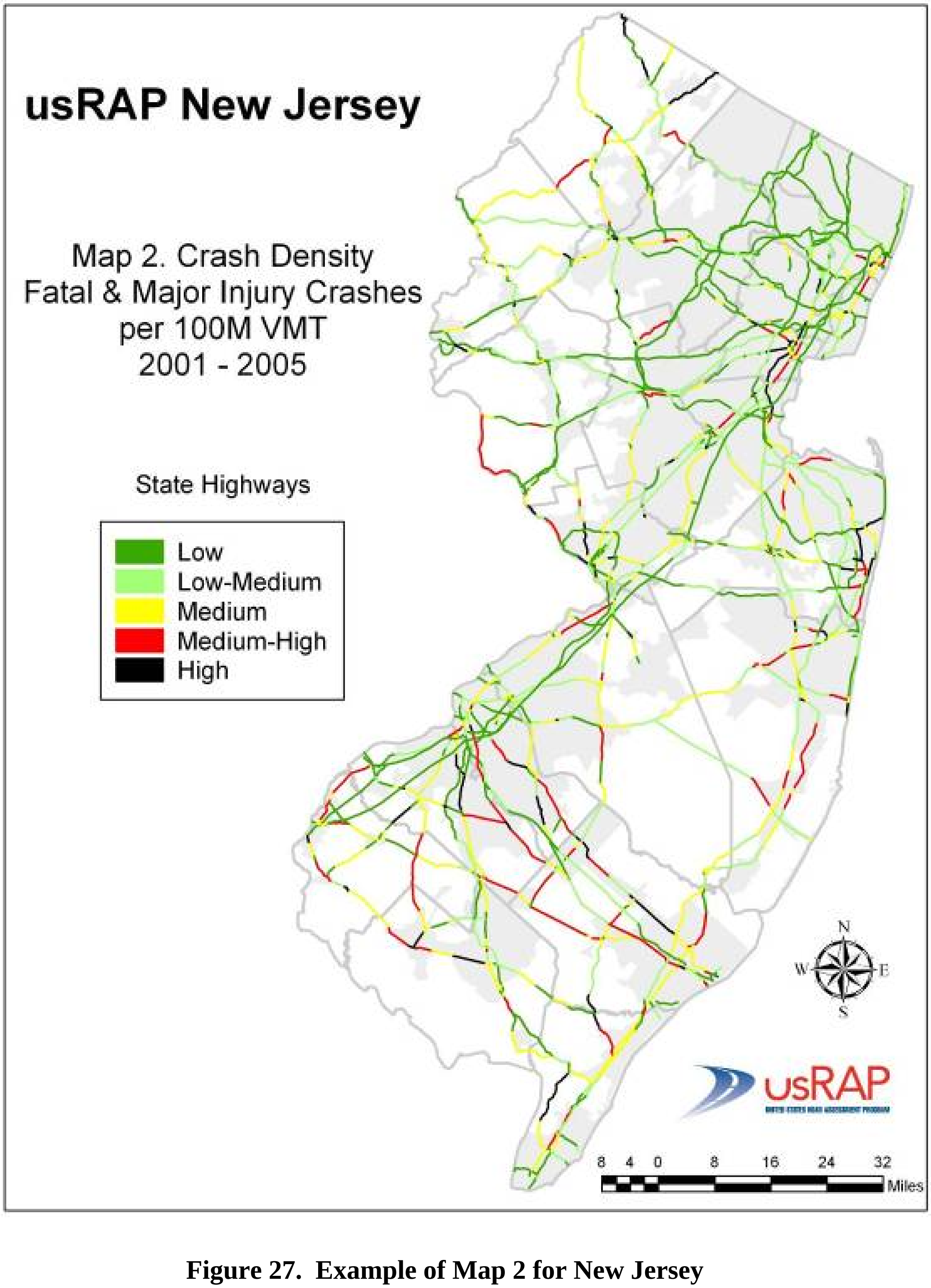

Figure 27. Example of Map 2 for New Jersey

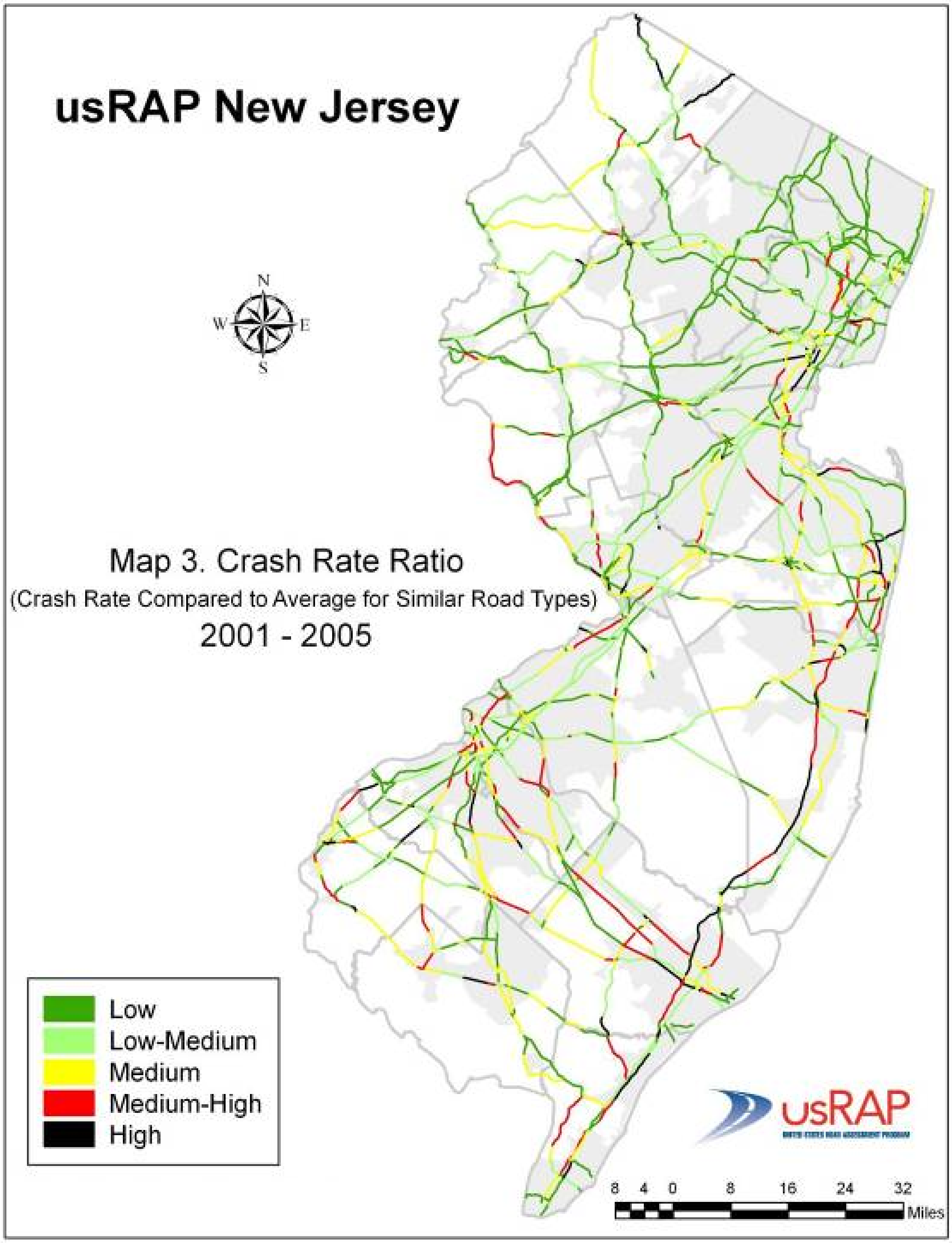

Figure 28. Example of Map 3 for New Jersey

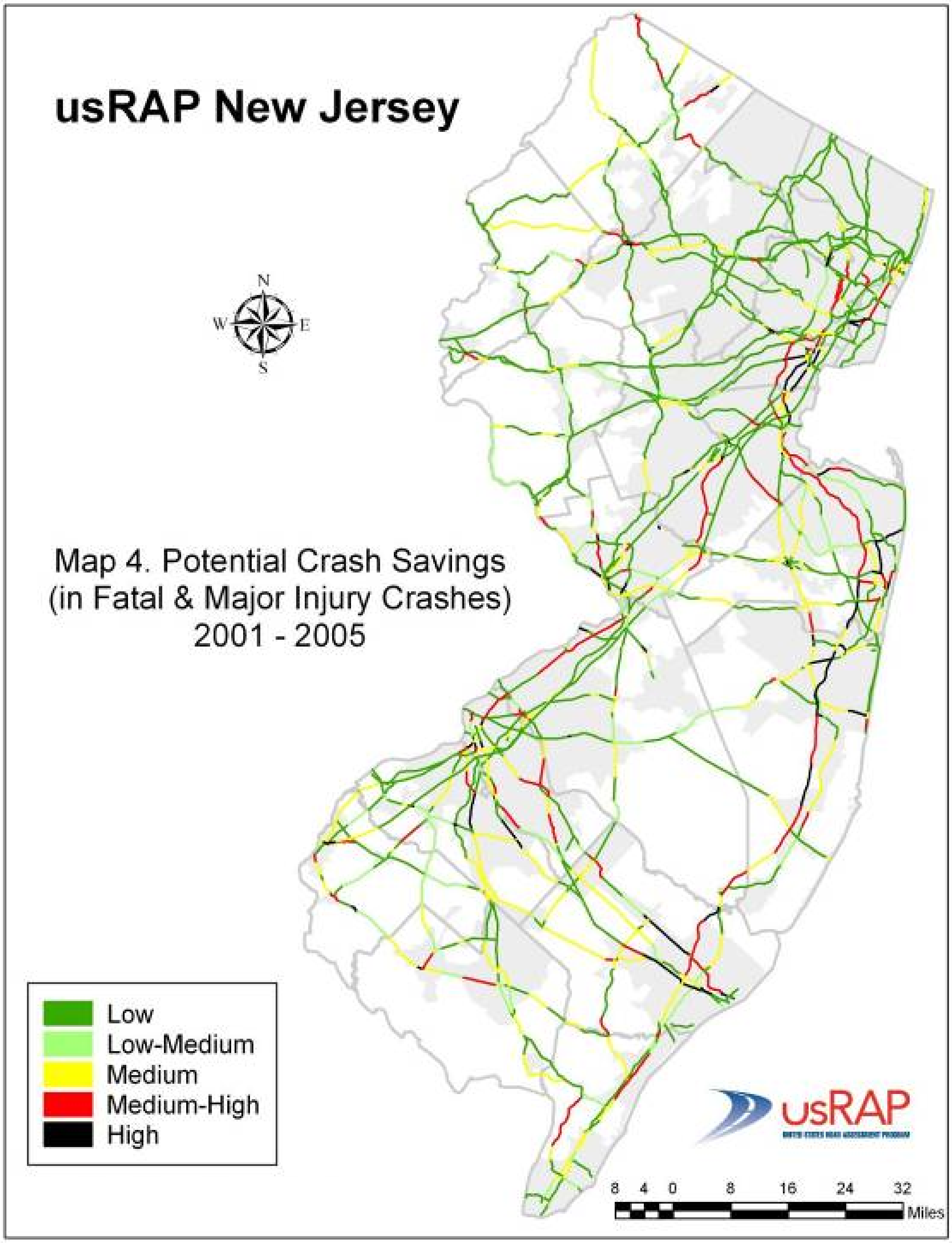

Figure 29. Example of Map 4 for New Jersey

Maps analogous to Maps 1 through 4 were prepared for speed-related crashes in New Jersey (see Figures 30 through 33). The definition of speed-related crashes for New Jersey was similar to that for Florida, as described in Section 2.4.7.6 of this report.

Maps analogous to Maps 1 through 4 were prepared for alcohol- or drug-involved crashes in New Jersey (see Figures 34 through 37), using definitions similar to those shown in Table 3 for Florida, as described in Section 2.4.7.6 of this report.

Because of the lack of exposure data for driver age categories, only Map 1 was developed for older-driver crashes (i.e., involving at least one driver over the age of 65) and younger-driver crashes (i.e., involving at least one driver under the age of 21) in New Jersey. Figure 38 presents Map 1 for older-driver crashes and Figure 39 presents Map 1 for younger-driver crashes in New Jersey.

Figure 40 presents a supplementary map for pedestrian crashes in New Jersey, a supplementary map category that was not previously considered in other pilot studies. As in the case of older- and younger-driver crashes, exposure data for pedestrians are not available. The supplementary mapping for pedestrian crashes in New Jersey is presented only for Map 1.

The usRAP team originally intended to develop supplementary maps for lane-departure crashes in New Jersey similar to the lane-departure crash maps developed for Florida. However, it was found that only 14 percent of the roadway segments on the New Jersey Network had two or more lane-departure crashes involving fatalities or incapacitating injuries in the five-year study period. Thus, the New Jersey data were too sparse to prepare supplementary maps for lane-departure crashes. This may result from the relatively short road sections that were used in urban portions of New Jersey to keep individual road sections relatively homogeneous.

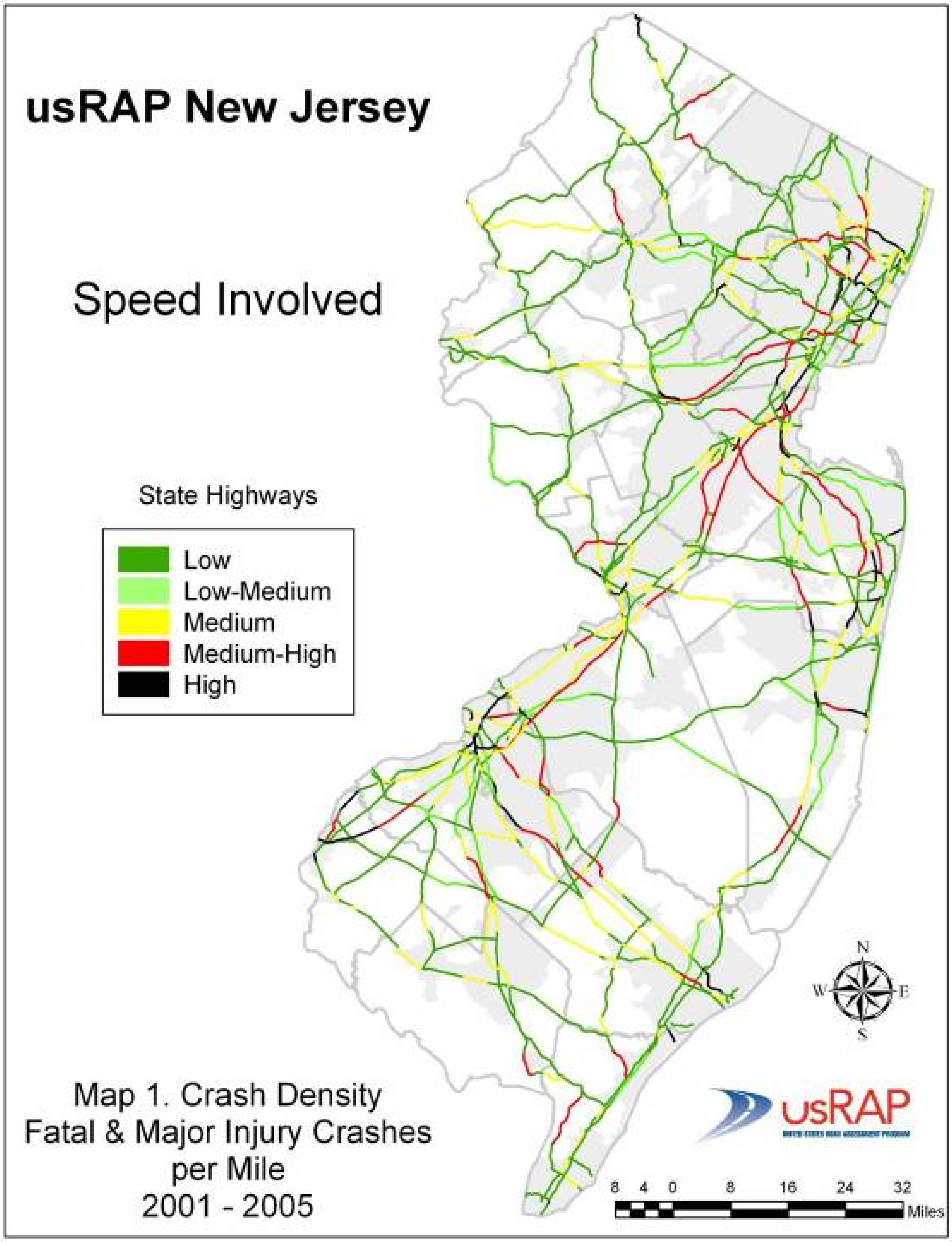

Figure 30. New Jersey Map 1 for Speed-Related Crashes

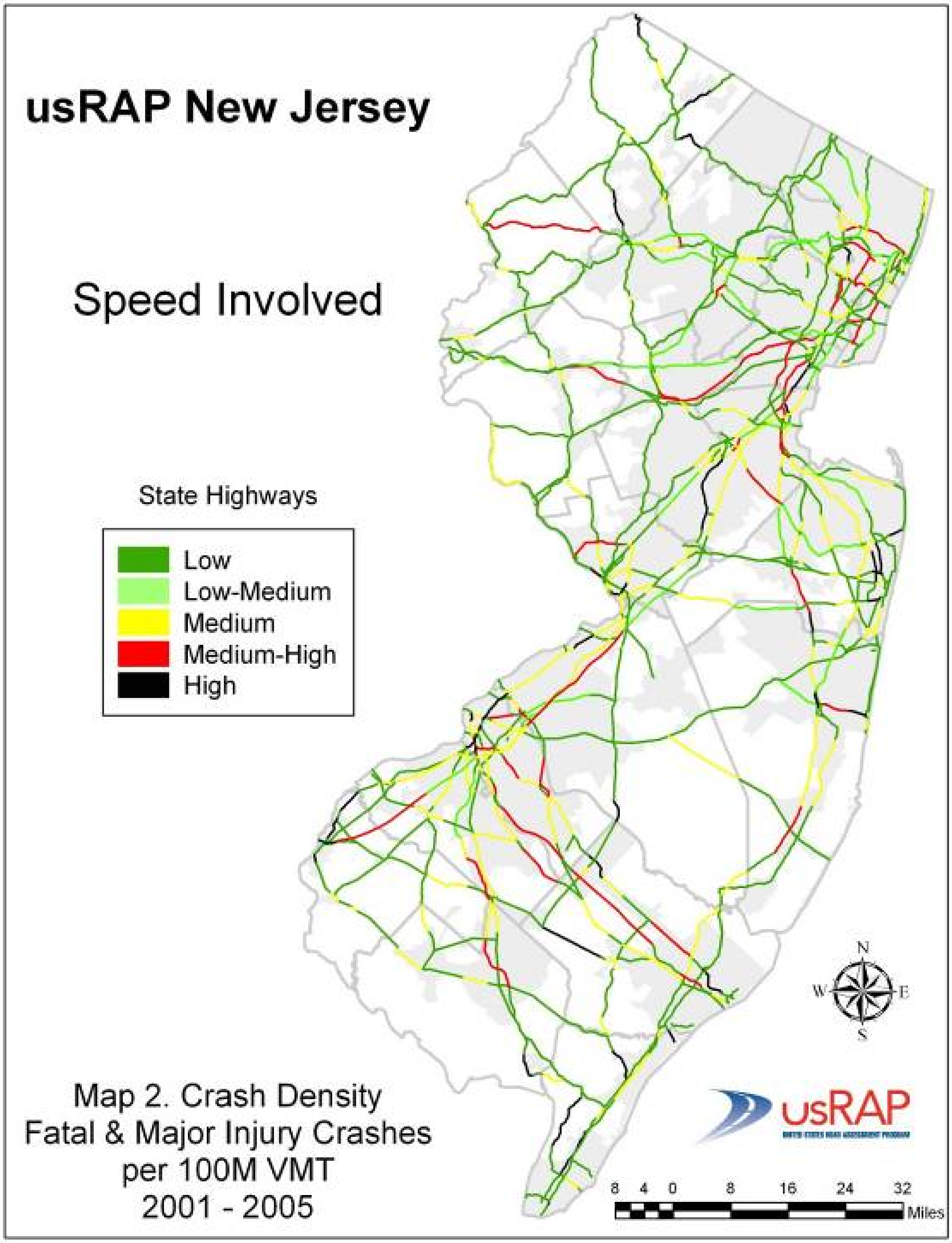

Figure 31. New Jersey Map 2 for Speed-Related Crashes

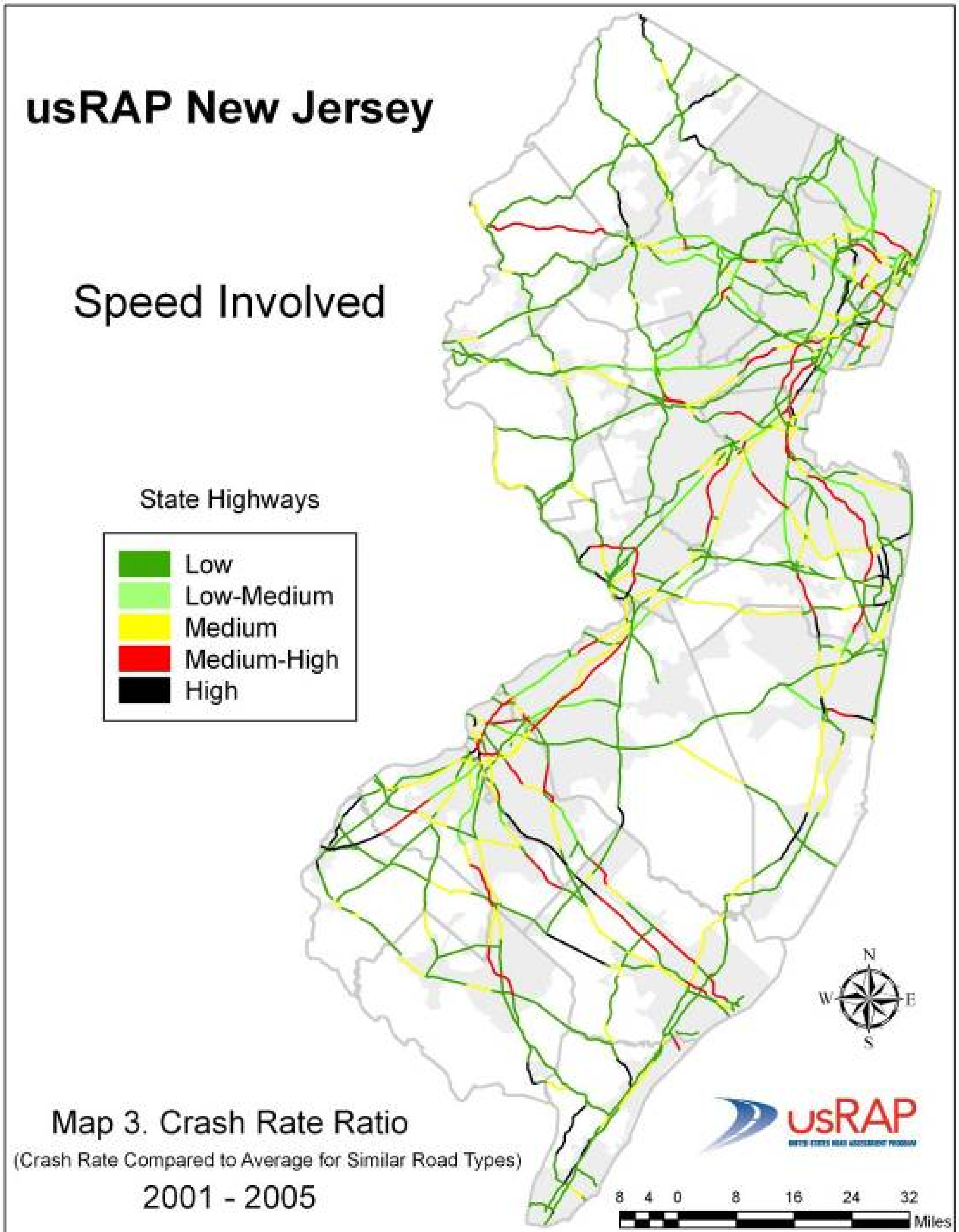

Figure 32. New Jersey Map 3 for Speed-Related Crashes

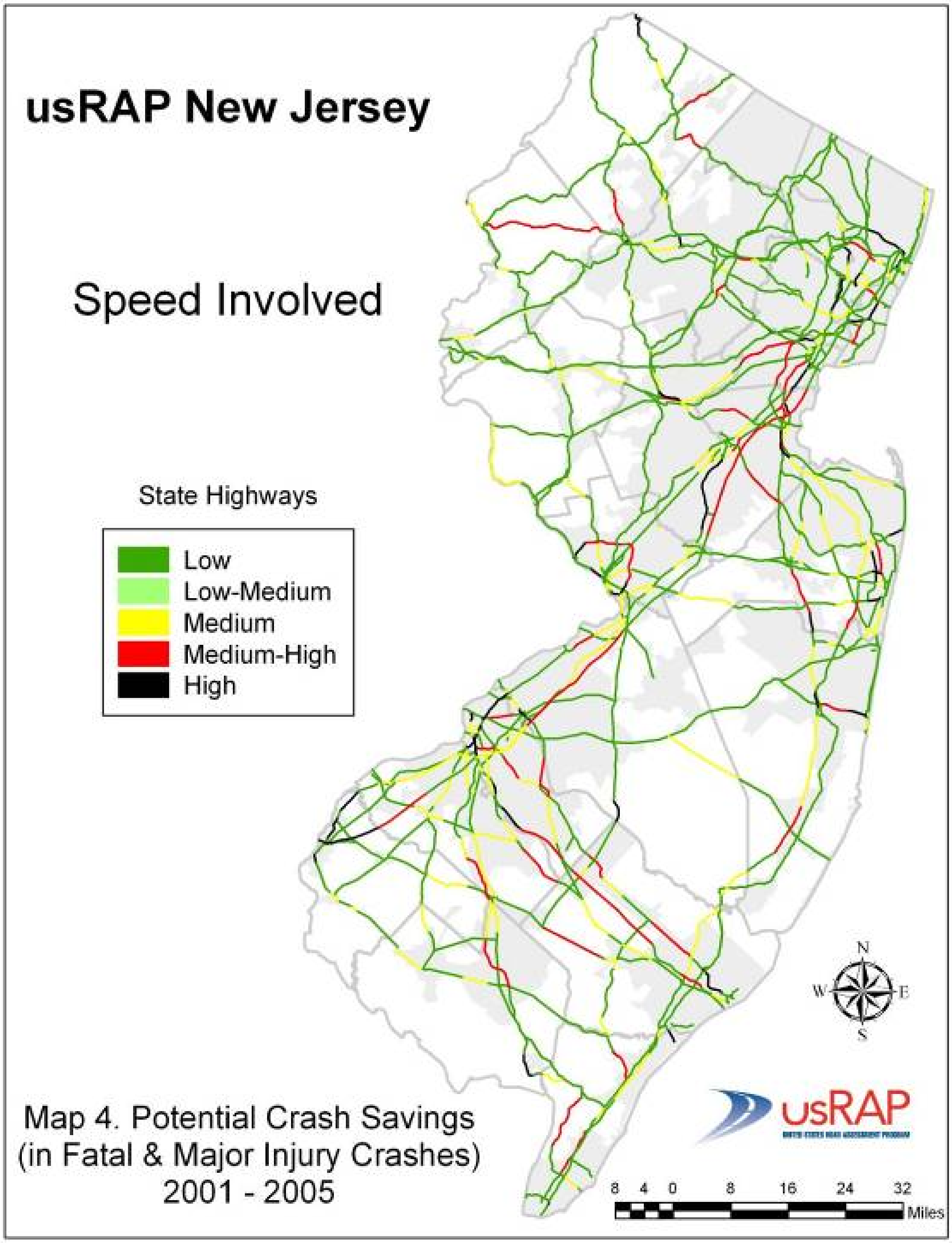

Figure 33. New Jersey Map 4 for Speed-Related Crashes

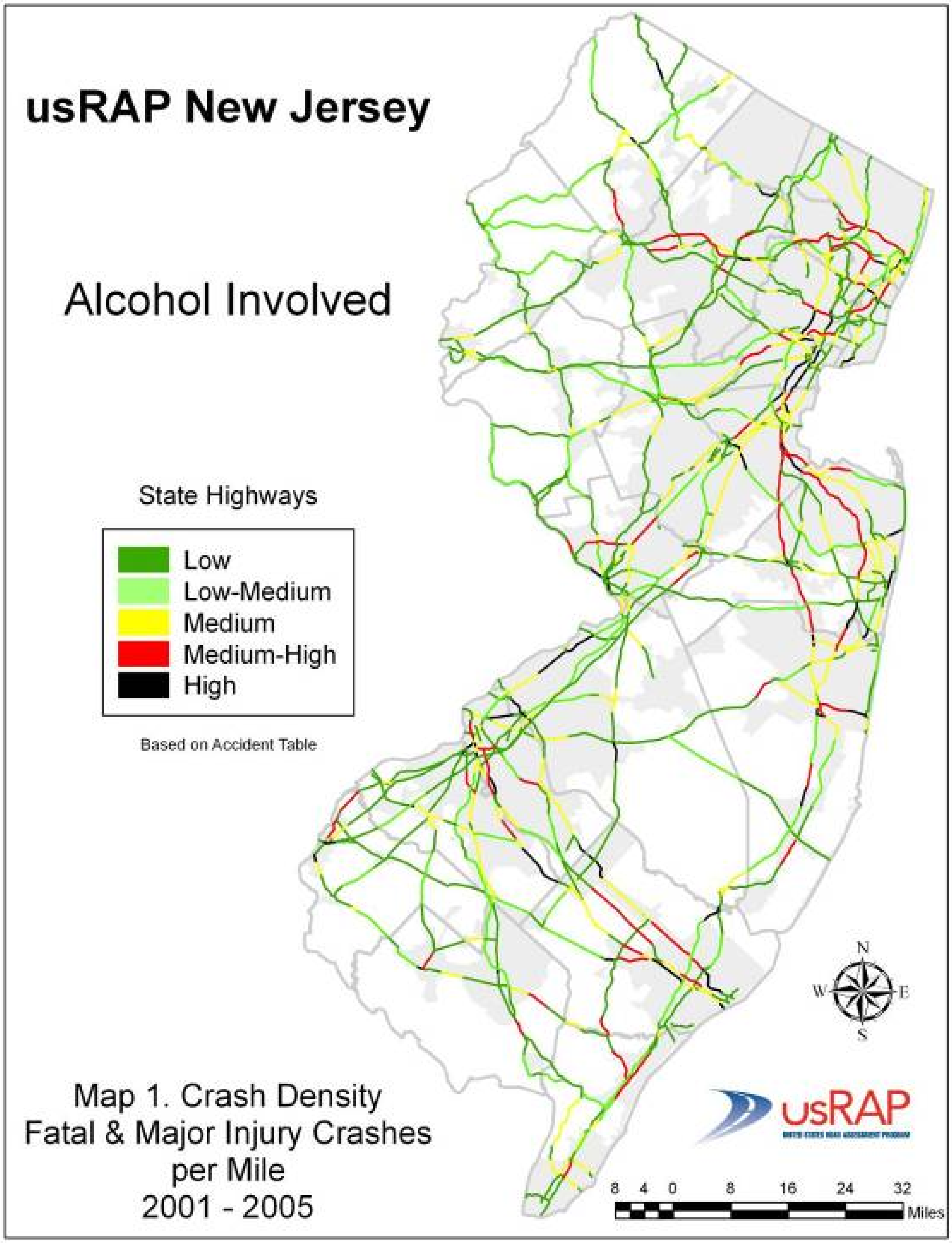

Figure 34. New Jersey Map 1 for Alcohol- and Drug-Involved Crashes

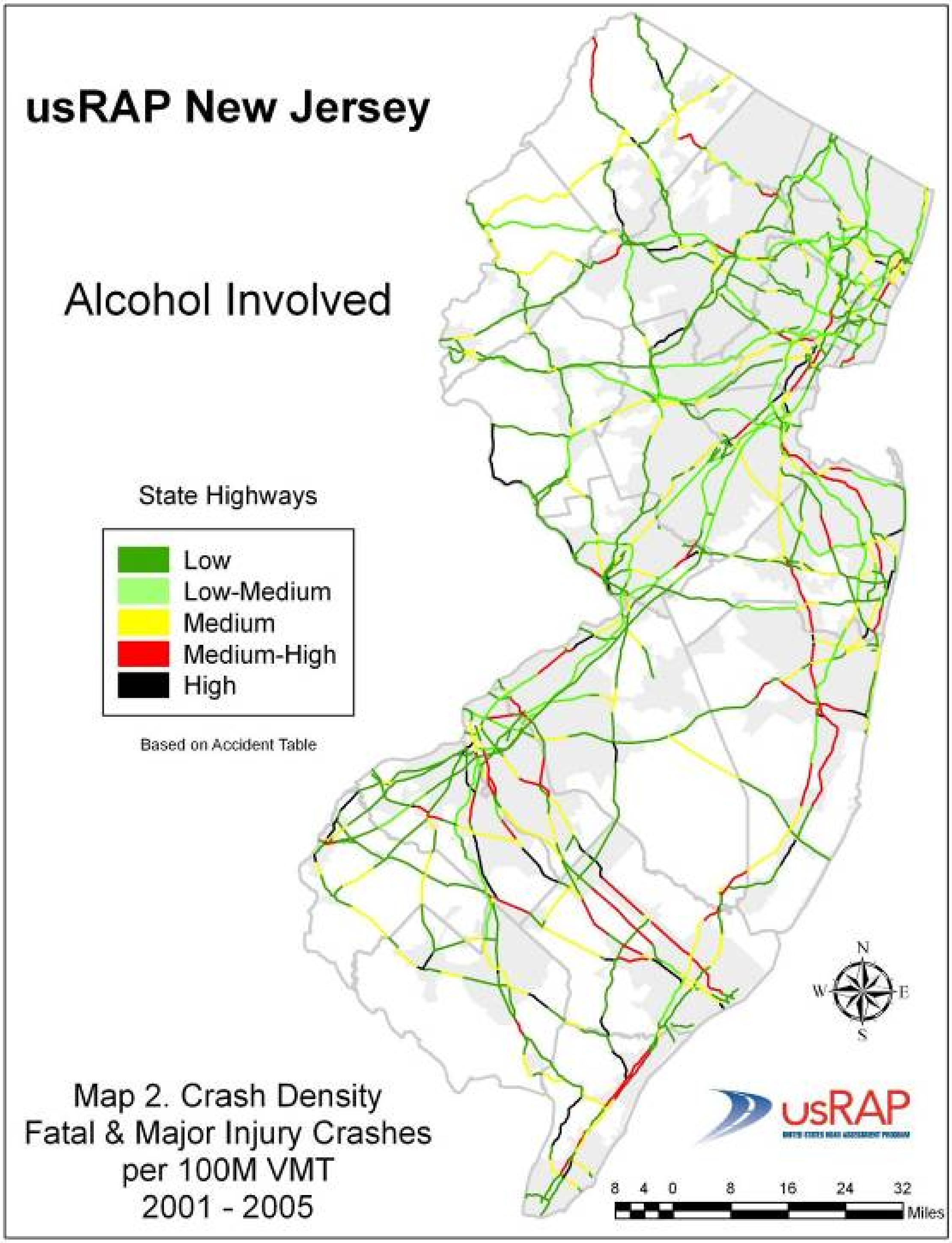

Figure 35. New Jersey Map 2 for Alcohol- and Drug-Involved Crashes

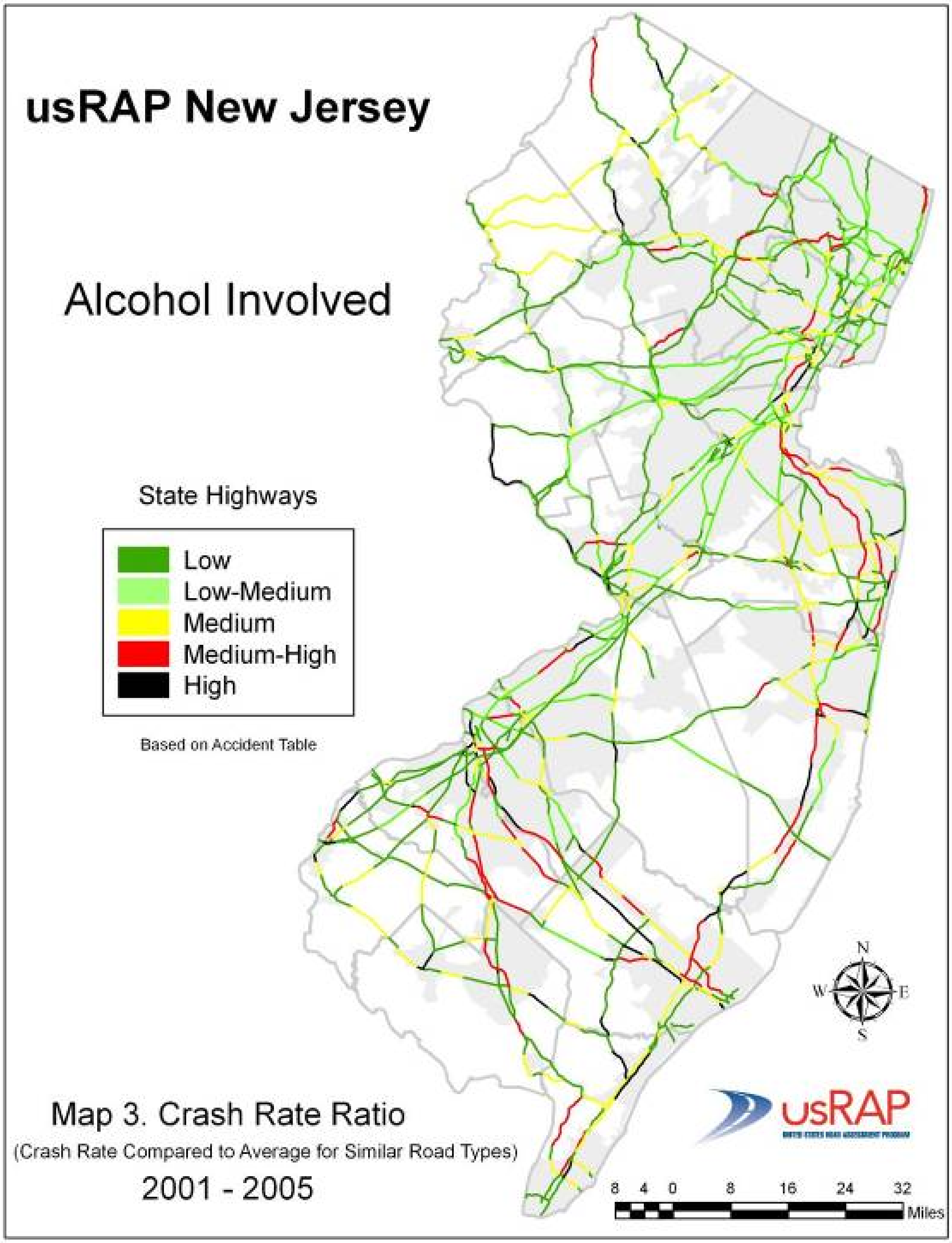

Figure 36. New Jersey Map 3 for Alcohol- and Drug-Involved Crashes

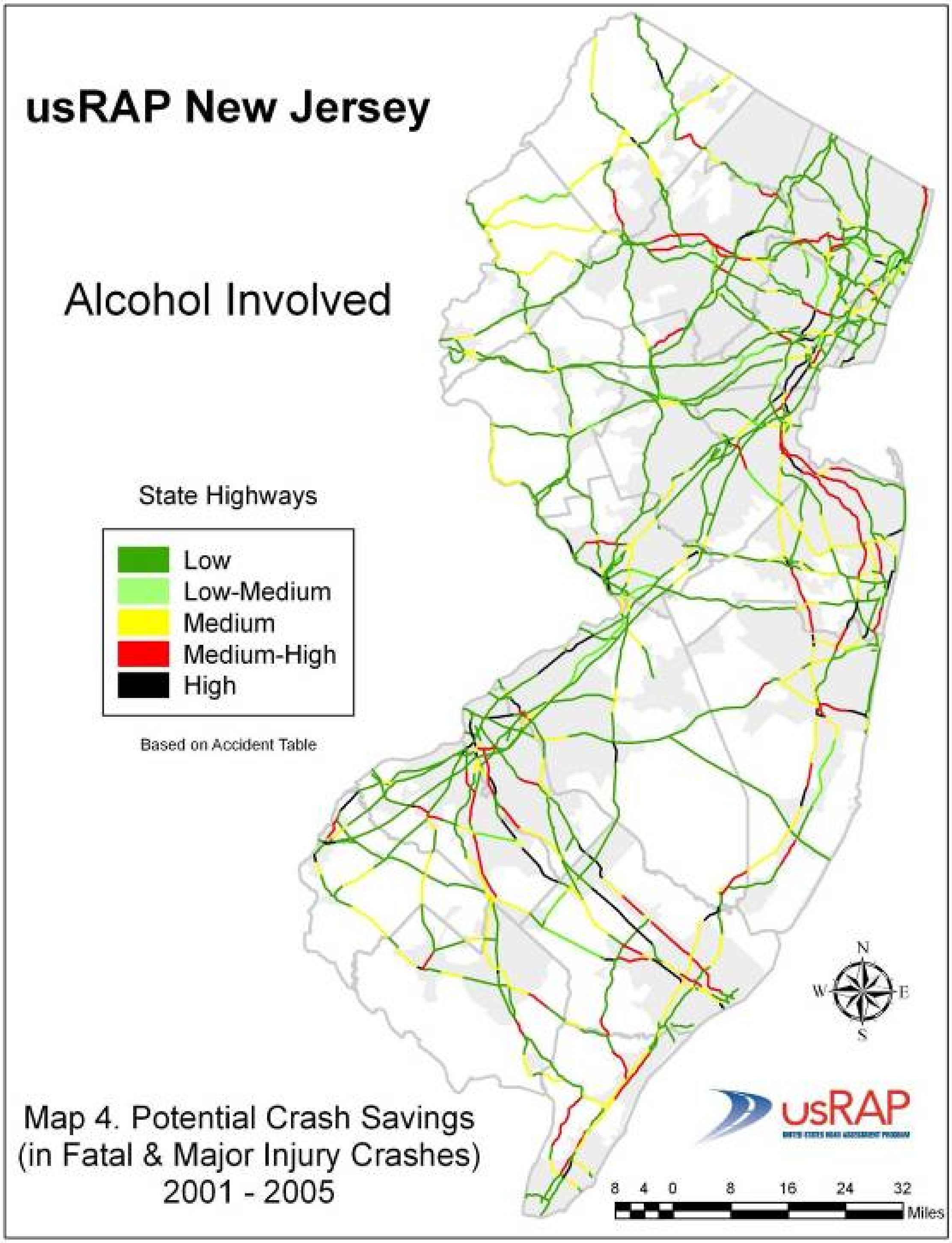

Figure 37. New Jersey Map 4 for Alcohol- and Drug-Involved Crashes

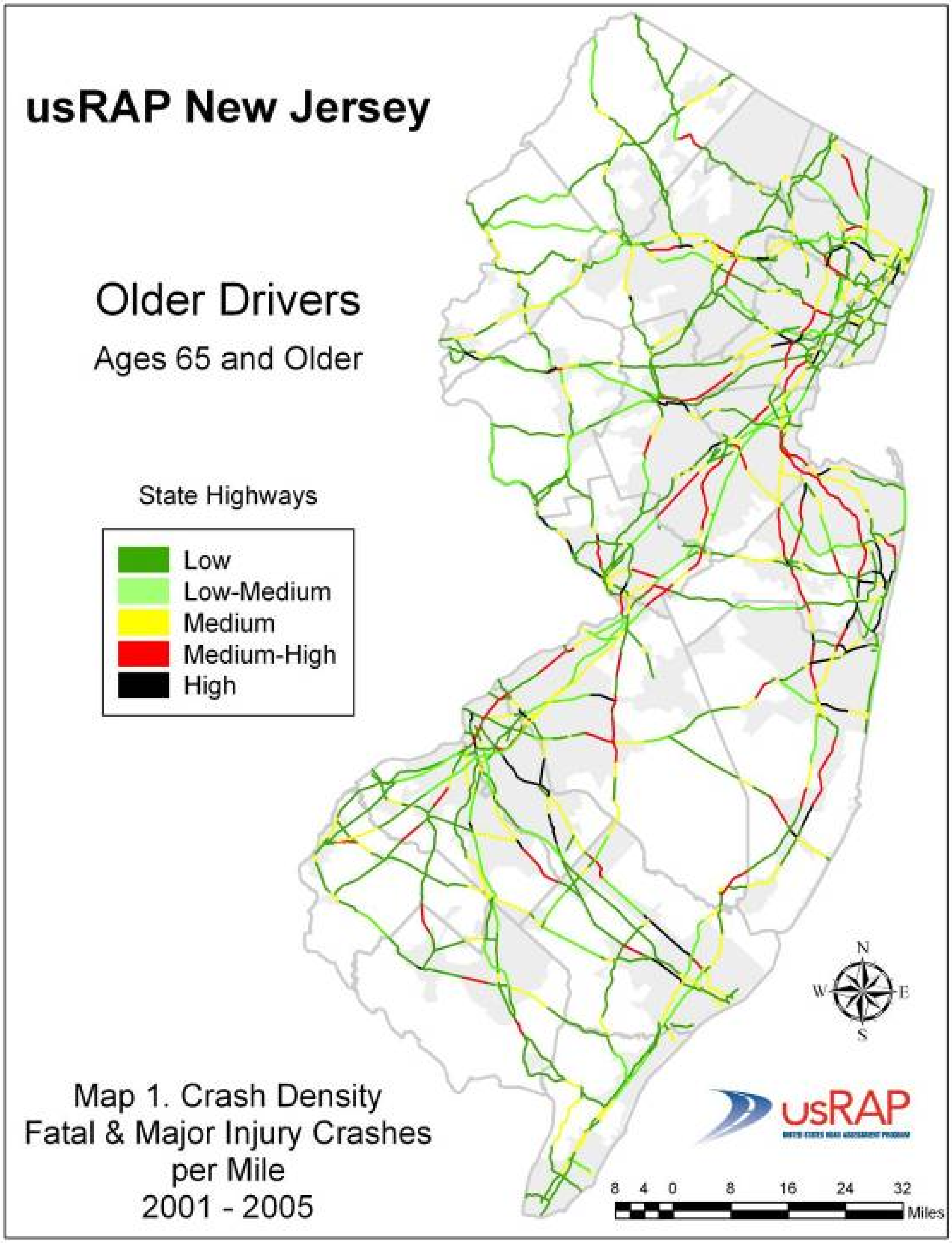

Figure 38. New Jersey Map 1 for Older-Driver Crashes

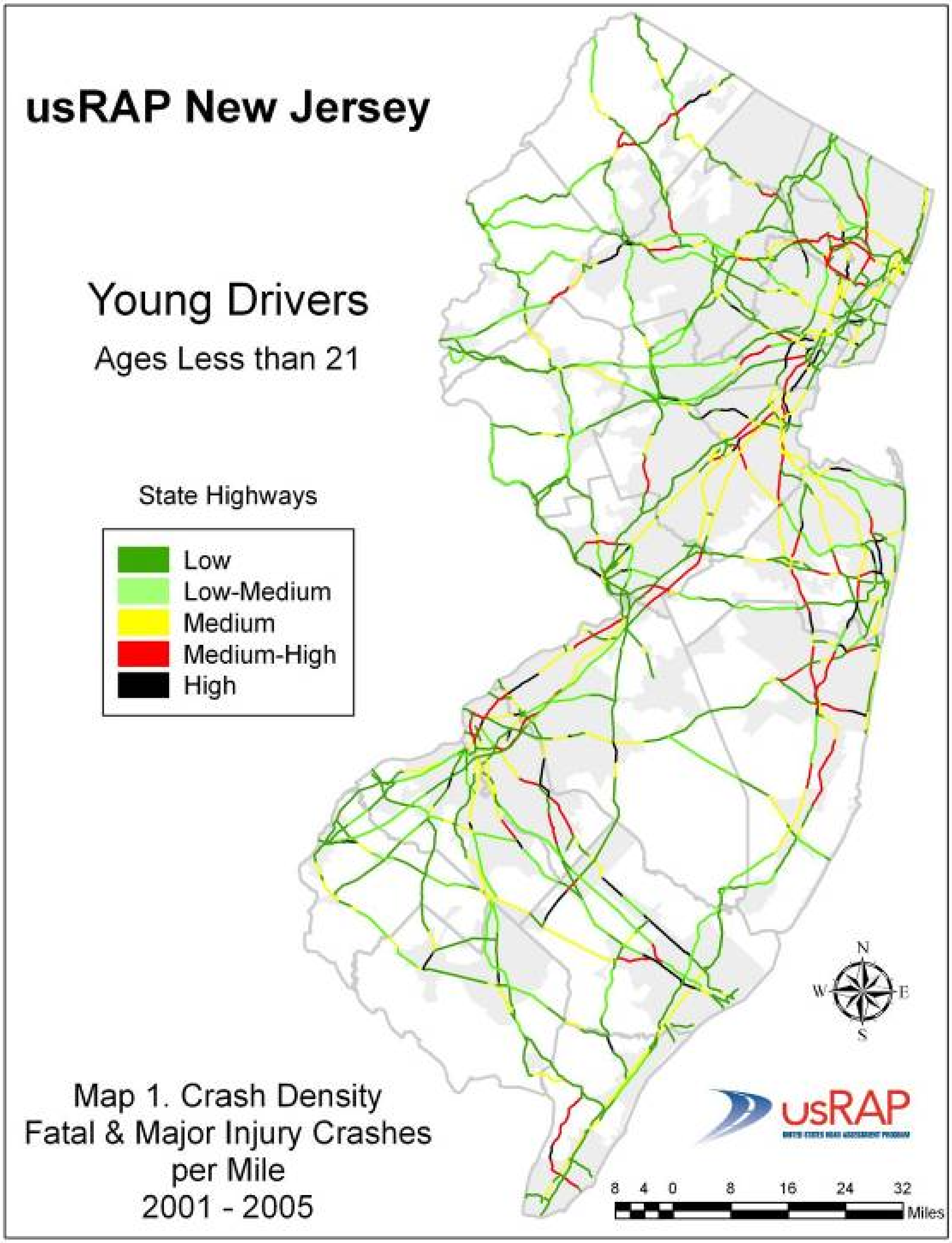

Figure 39. New Jersey Map 1 for Younger-Driver Crashes

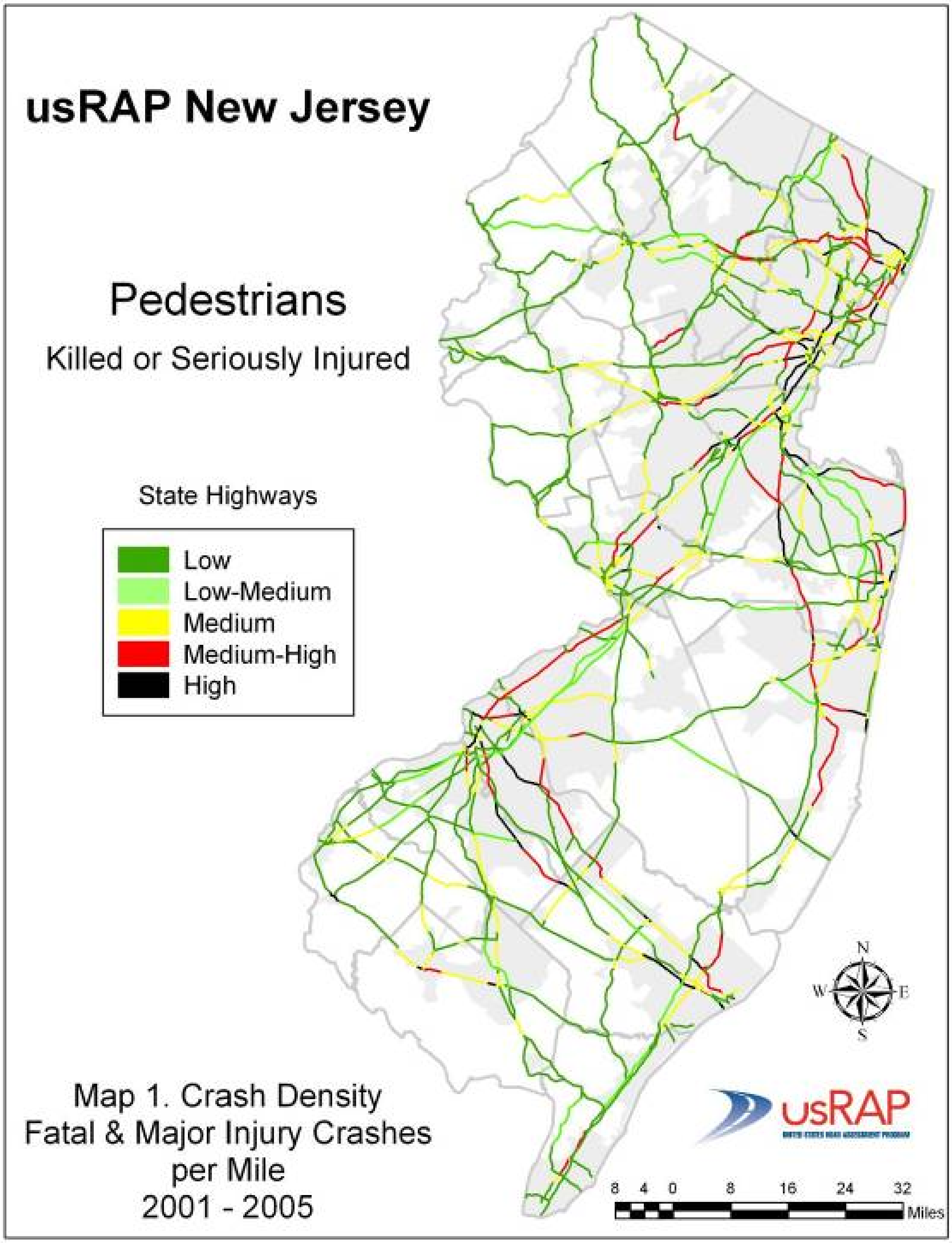

Figure 40. New Jersey Map 1 for Pedestrian Crashes

Section 3.
Further Work With usRAP Phase I Pilot Study States

This section of the report presents an overview of further work conducted with the Phase I pilot study states, Iowa and Michigan, as part of Phase II. Specific activities described in this section include:

- Iowa program development based on Phase I risk maps
- Additional supplementary mapping for Iowa
- Michigan site investigations based Phase I risk maps
- Updated Michigan risk maps
- Michigan performance tracking based on updated risk maps

This further work with the Phase I pilot study states represents an initial investigation of the types of ongoing work that could be performed with participating states as part of an ongoing usRAP program.

3.1 Iowa Safety Program Development Based on Phase I Risk Maps

The Iowa Department of Transportation has used the usRAP Phase I results in developing its ongoing safety improvement program. One element of the safety program development involved further crash analysis of sites identified as high risk on the usRAP Phase I maps. Figures 41 and 42 show examples of spot maps and pie charts that were developed to investigate a particular site with several fatal and serious injury crashes.

The Iowa Department of Transportation also considered the usRAP Phase I results in developing their approach to their 5-percent report for 2006 submitted to FHWA. After consideration of possible approaches, Iowa chose to base their 5-percent report on lane-departure crashes involving fatalities and serious injuries, rather than on total fatal-and-serious-injury crashes as in the Phase I maps. The approach used by Iowa for their 5-percent report used the same segmentation of the roadway network that was developed for usRAP Phase I and is similar to the approach used to develop the Phase II supplementary map for lane-departure crashes in Florida shown in Figures 18 and 19.

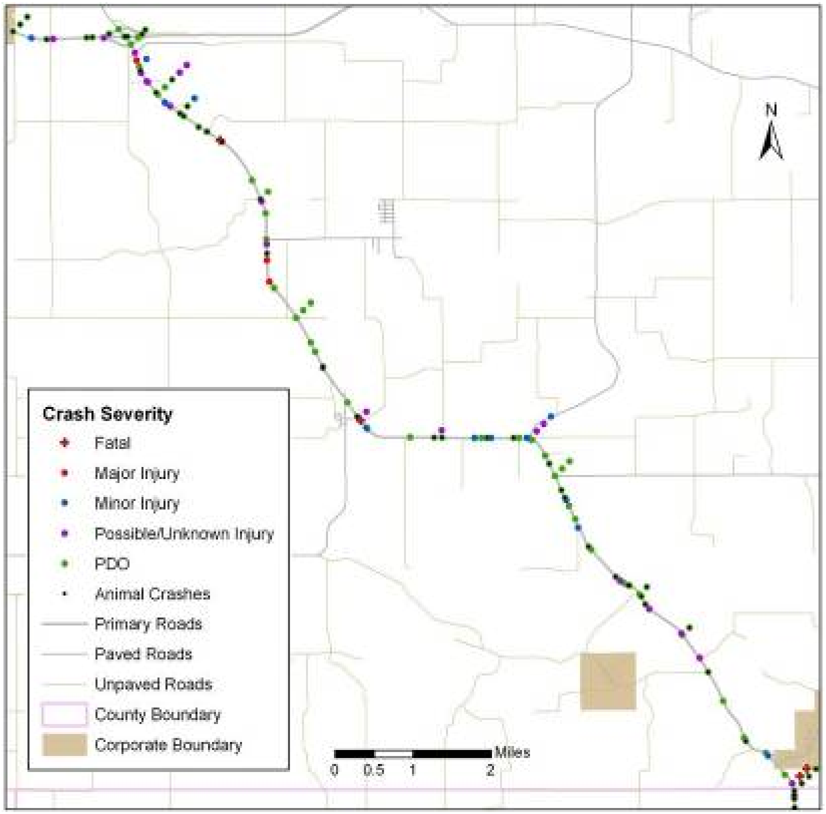

Figure 41. Typical Crash Location Map Used for Site Review by the Iowa Department of Transportation

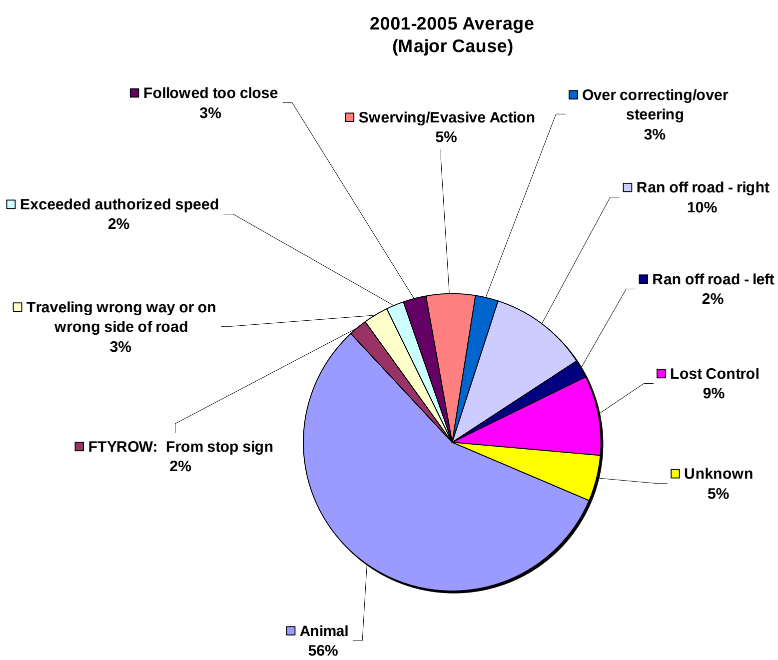

Figure 42. Typical Pie Chart for Crash Type Distribution Used by the Iowa Department of Transportation for the Roadway Shown in Figure 41

3.2 Additional Supplementary Mapping for Iowa

The usRAP Phase I report presents several types of supplementary maps for Iowa that add to the information on the basic risk maps (Maps 1 through 4). These supplementary maps include:

- crash loss density (total crash loss per mi)
- crash loss rate (crash losses per veh-mi of travel)
- intersection crash frequency (crashes per year)
- intersection crash rate (crashes per hundred million entering vehicles)

During Phase II, we attempted to develop an additional supplementary map for Iowa. This new supplementary map was intended to be a modified version of Map 2 that presents the crash rate per hundred million veh-mi for crashes involving older drivers. The map was to be based on veh-mi of travel for drivers of all ages, because separate exposure data for older drivers are not available. However, it was found that the older-driver crash data for Iowa were too sparse to prepare a meaningful map. In particular, only 14 percent of the roadway segments in Iowa experienced two or more fatal or serious injury older-driver crashes in a five-year study period. Therefore, no supplementary map was developed. This finding indicates that development of supplementary maps based on some crash types may not be feasible if there are not enough crashes of that type distributed over the roadway system.

3.3 Michigan Site Investigations Based on Phase I Risk Maps

The Phase I risk maps for Michigan were used in a set of site investigations to test the usefulness of the maps in identifying sites as candidates for safety improvements. It was decided that it would be reasonable to investigate roadway segments which met the following criteria on the usRAP maps developed in Phase I:

- shown in red or black on Map 2, indicating a relatively high crash rate per million veh-mi of travel, and
- shown in red or black on Map 4, indicating a relative high potential reduction in crashes if the observed crash rate could be reduced to the average crash rate for similar sites

Review of the Phase I risk maps for a four-county area in southwestern Michigan identified eleven sites that met these criteria. Crash summaries were prepared for these sites and each site was visited and reviewed in the field.

Figure 43 illustrates the locations of the sites selected for field review. Figure 44 illustrates a collision location map for one particular roadway section prepared as part of the field review. The field review identified some sites which safety improvements had already been made by the Michigan Department of Transportation and other sites that appear to be logical candidates for future improvements. The potential improvement types at the selected sites included concentrations of crashes at particular intersections and more widely distributed patterns of lane departure and run-off-road crashes. Furthermore, at some sties there were no apparent safety concerns related to road infrastructure; such sites deserve further investigation for driver behavioral issues such as alcohol usage and speeding. Enforcement and education efforts may be needed to address such sites. Supplementary risk maps related to these issues may also be useful.

3.4 Updated Michigan Risk Maps

The risk maps in the Phase I report were prepared using crash data for the years from 2000 to 2004, inclusive. Updated risk maps have now been prepared with crash data for the years from 2002 to 2006, inclusive. Thus, these updated risk maps are based on three years of crash data (2002 to 2004) that were not available at the time the Phase I maps were developed. The updated Michigan risk maps were developed using the same procedures and criteria as the Phase I risk maps. Thus, the colors shown on the maps represent the same percentages of the road system as the other pilot studies. Figures 45 through 48 present the updated Michigan risk maps for the years 2002 through 2006, inclusive, for Maps 1 through 4, respectively.

3.5 Michigan Performance Tracking Based on Updated Risk Maps

The updated crash data were also used in performance tracking to identify changes in risk over time for rural roads sections in Michigan. Table 11 presents summary statistics for the updated Michigan risk maps. Table 12 compares overall road safety statistics for the 2000 to 2004 and 2002 to 2006 periods, indicating that the frequencies and rates of fatal and severe injury crash rates have generally decreased.

To compare the safety performance of individual road sections, two slightly modified versions of Maps 1 and 2 were developed using the updated crash data (see Figures 49 and 50). These maps use boundaries between risk categories that are identical to those used for the corresponding Phase I risk maps. Thus, the percentage of the road network in each risk category may have changed, but any change in color for a road section between the original and updated maps represents a definite change in the underlying risk measure. This approach was best suited to performance tracking to compare changes in safety between the two time periods of interest, 2000 to 2004 and 2002 to 2006.

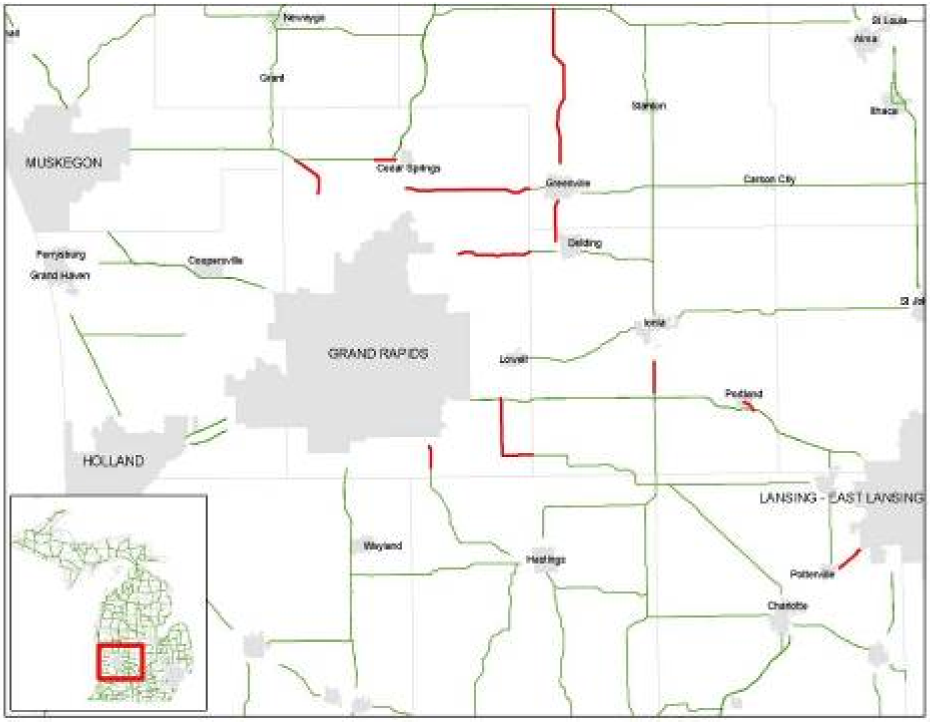

Figure 43. Locations of Sites Selected for Michigan Field Reviews

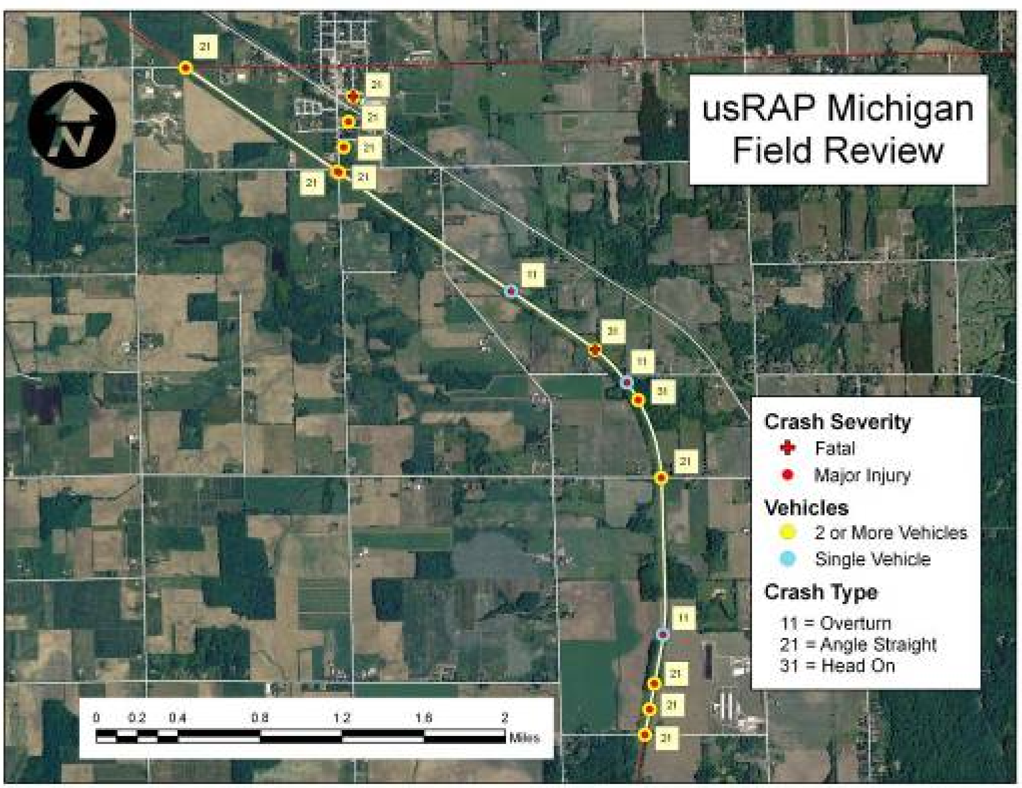

Figure 44. Typical Collision Location Map for a Selected Michigan Site

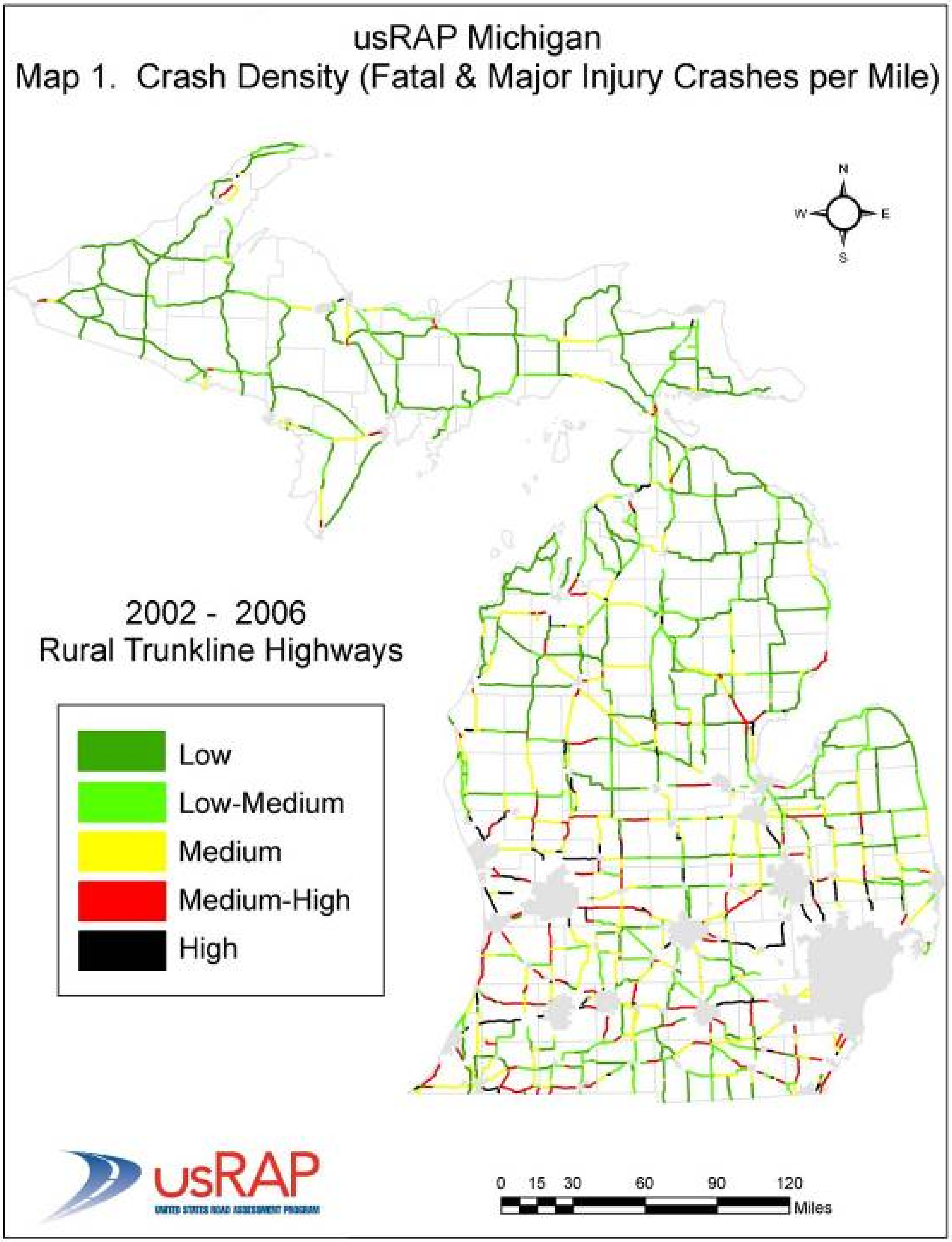

Figure 45. Updated Version of Map 1 for Michigan (2002 to 2006)

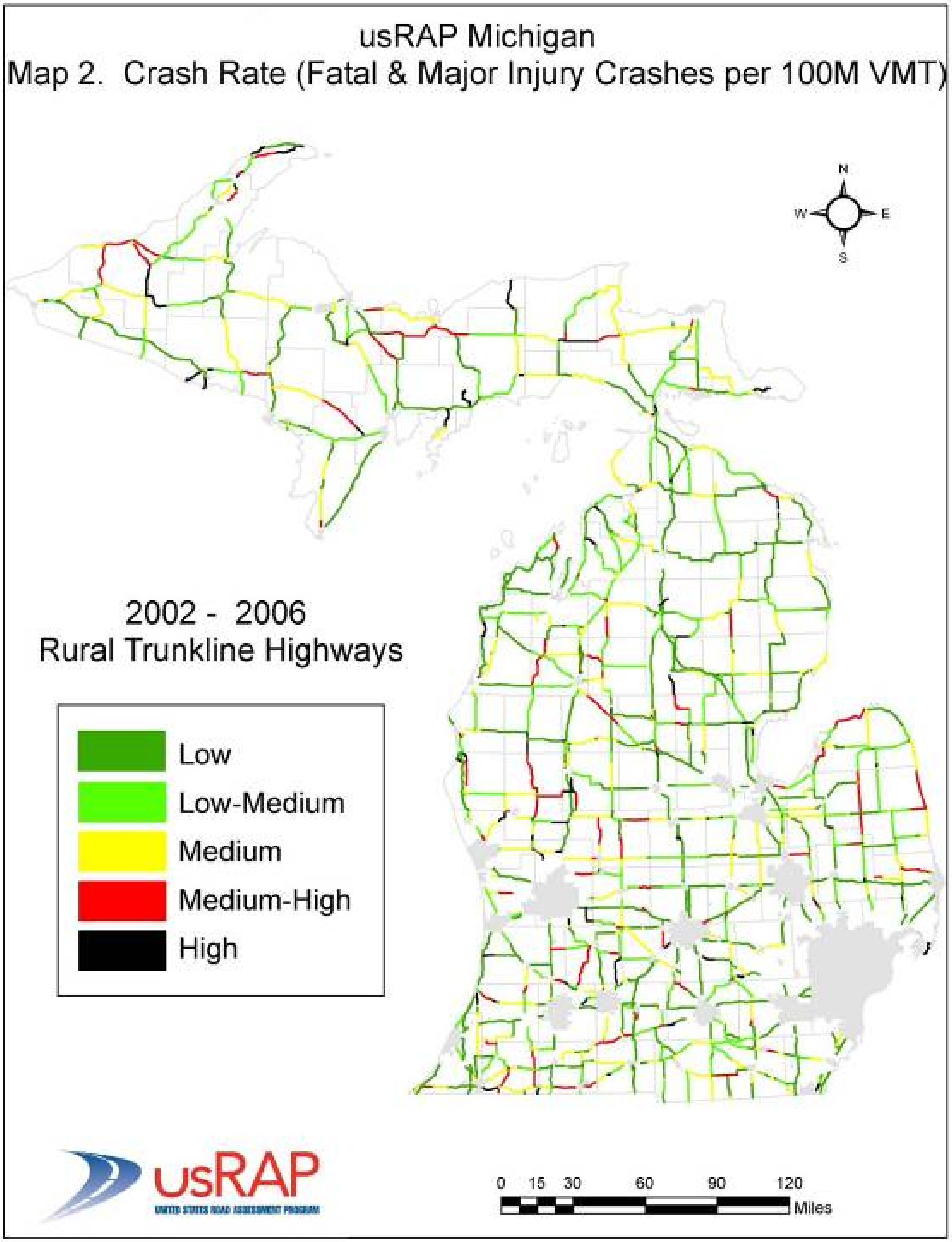

Figure 46. Updated Version of Map 2 for Michigan (2002 to 2006)

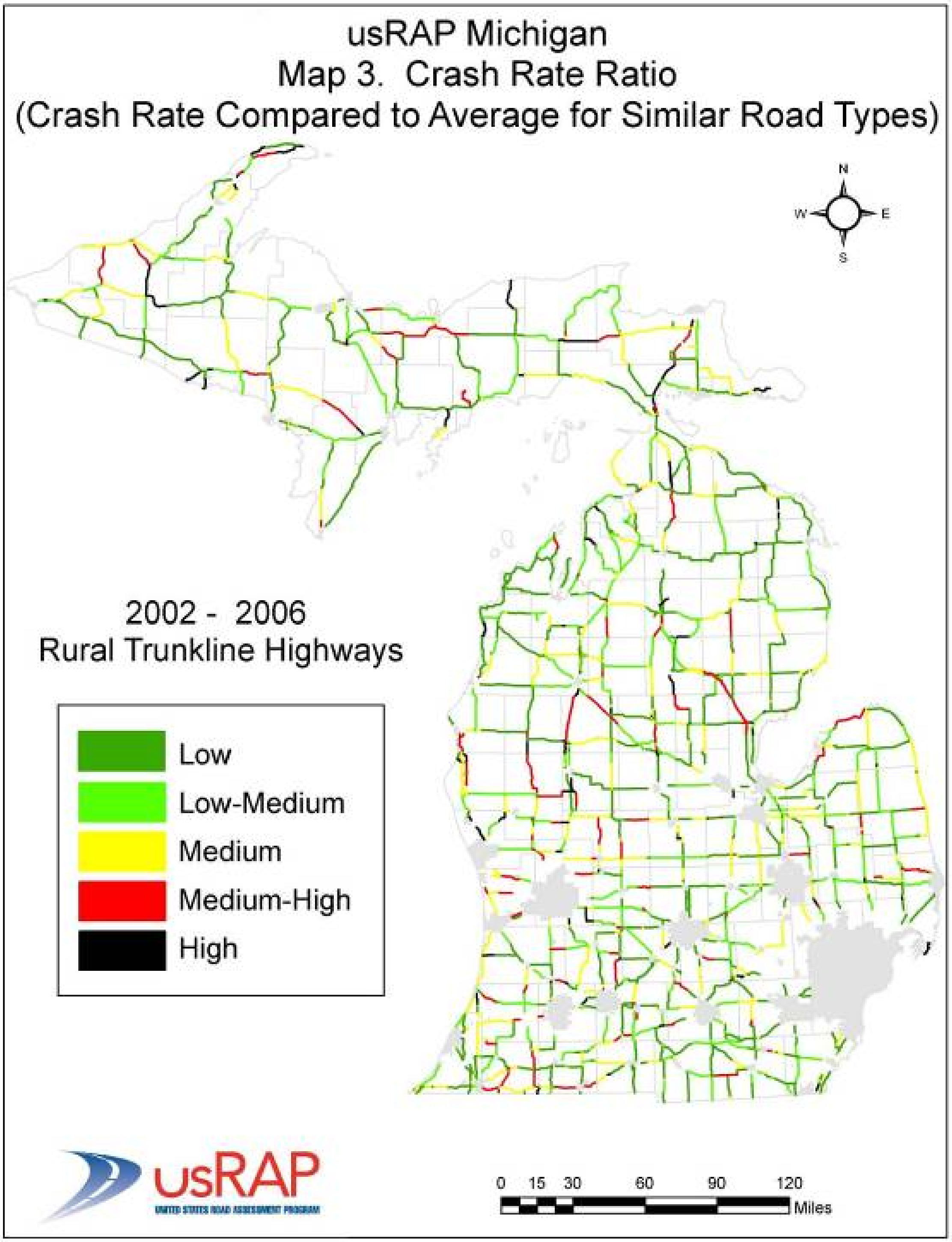

Figure 47. Updated Version of Map 3 for Michigan (2002 to 2006)

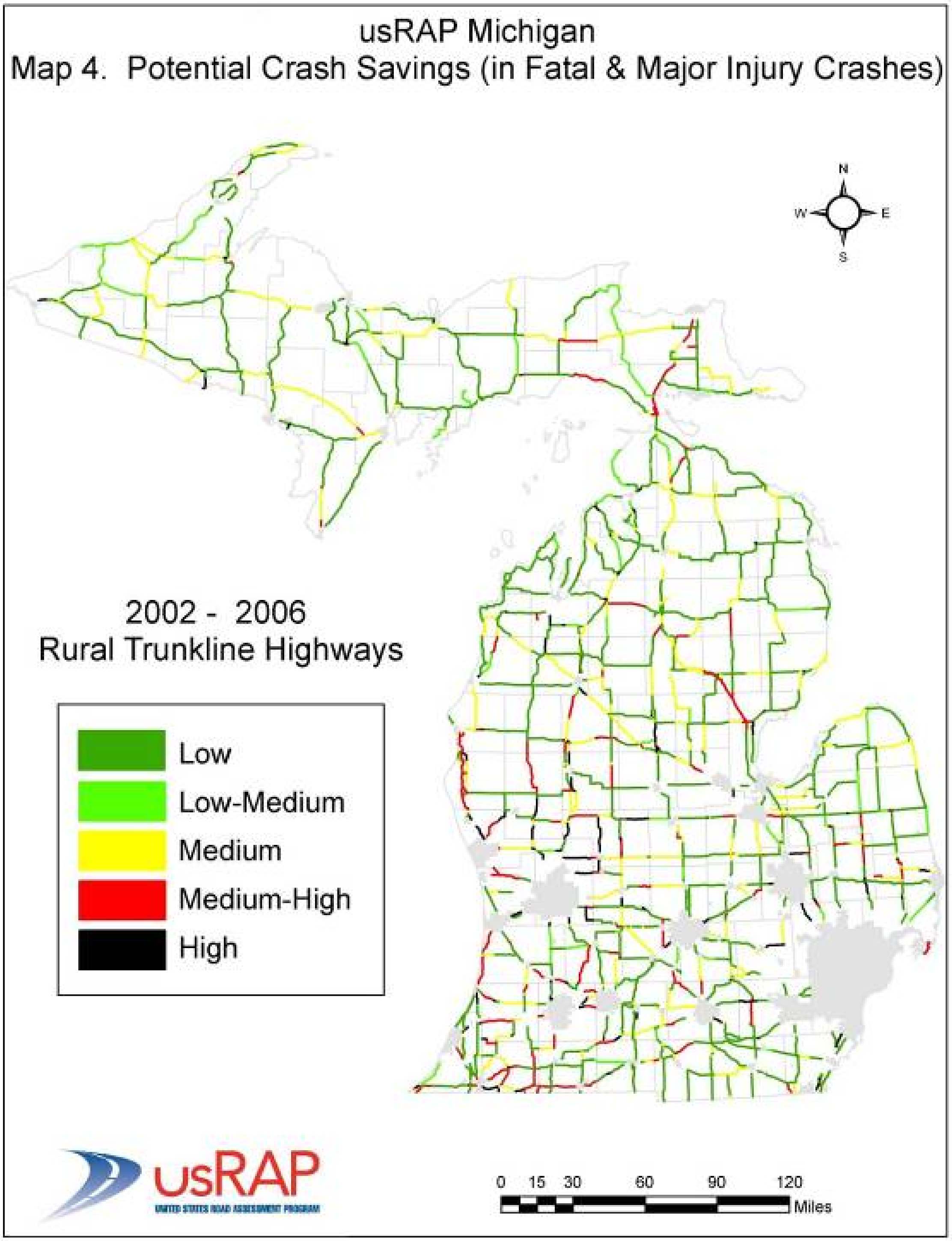

Figure 48. Updated Version of Map 4 for Michigan (2002 to 2006)

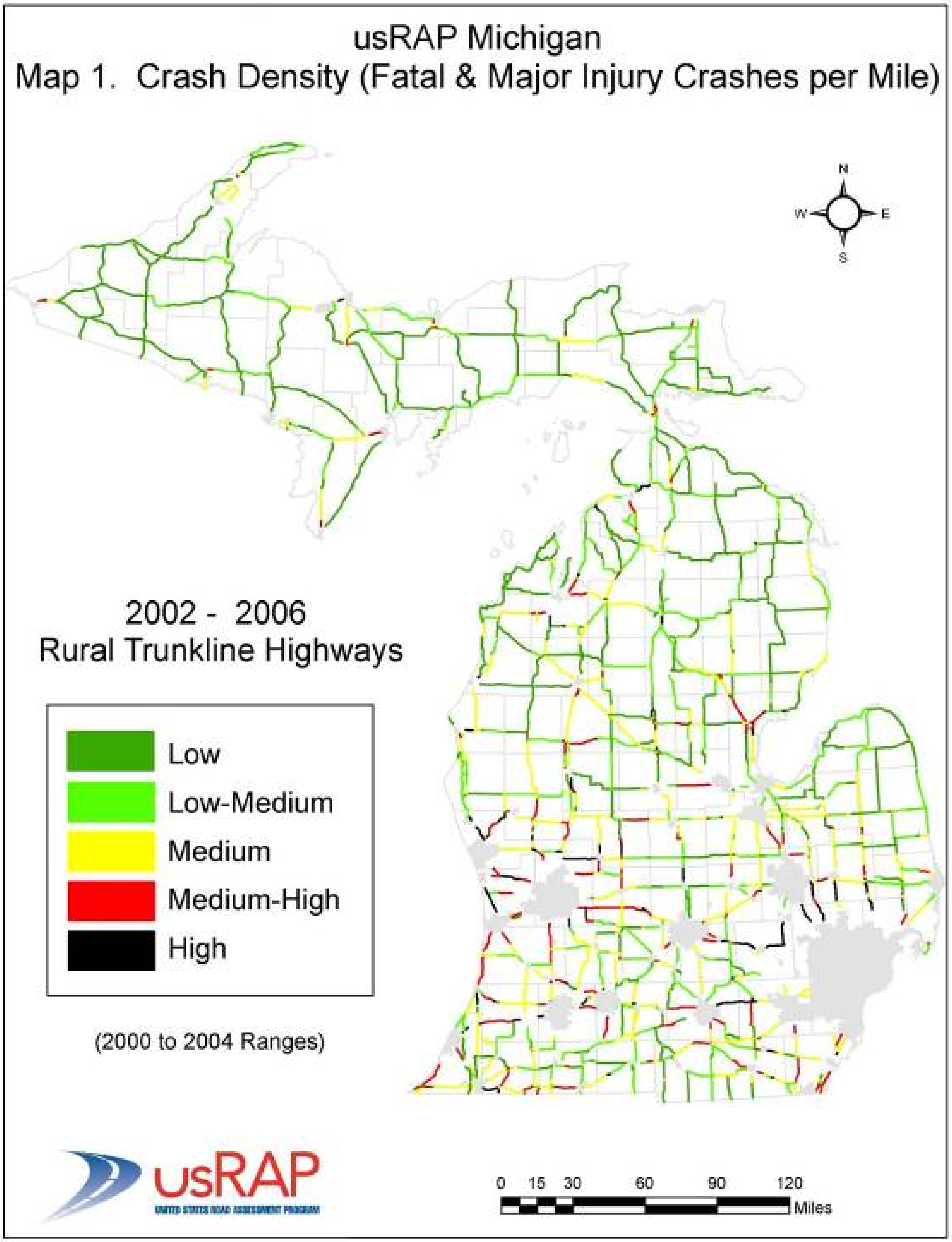

Figure 49. Updated Version of Map 1 for Michigan Using 2002 to 2006 Crash Data and Phase I Risk Categories

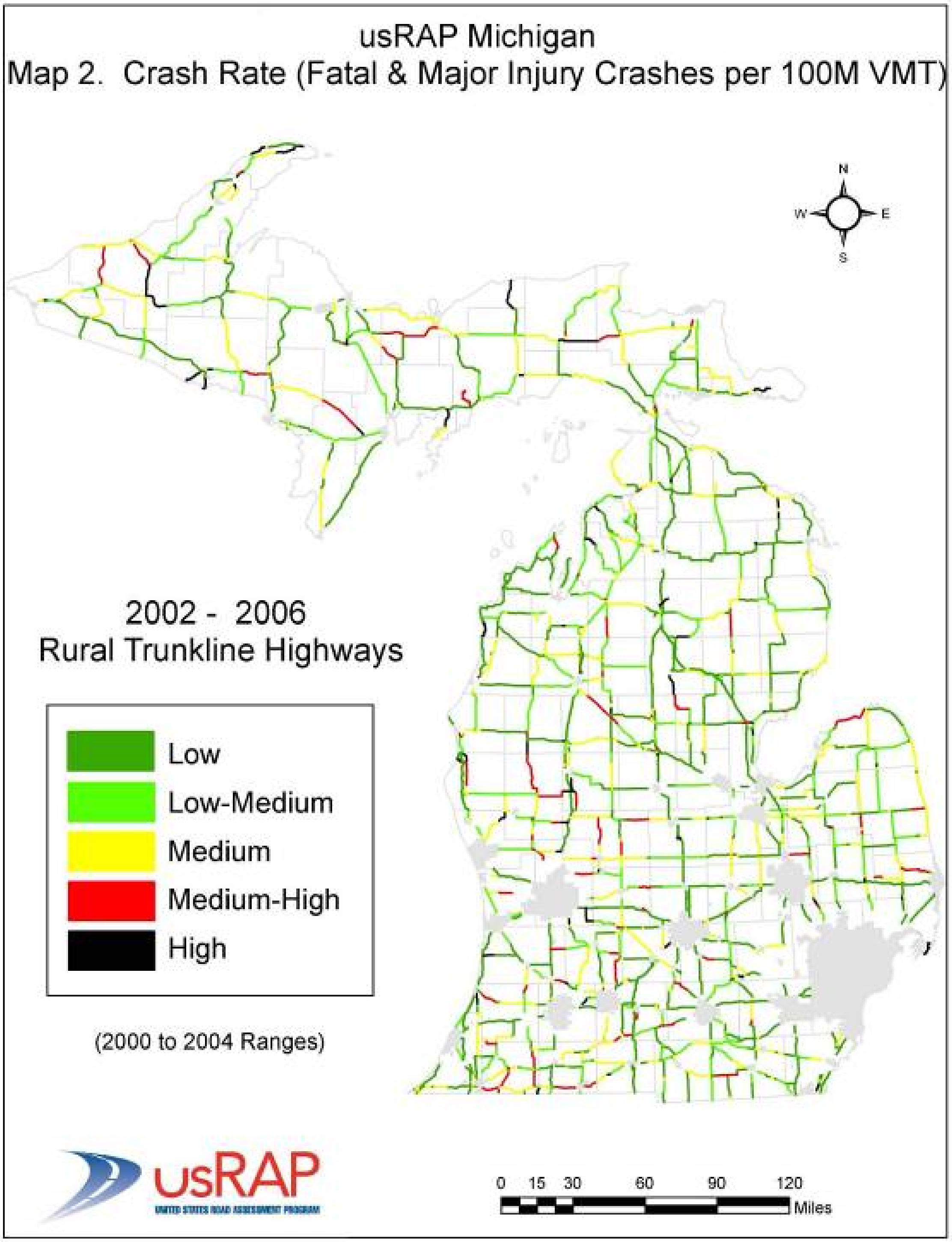

Figure 50. Updated Version of Map 2 for Michigan Using 2002 to 2006 Crash Data and Phase I Risk Categories

Table 11. Michigan Risk Mapping Data (2002-2006)

Road type	Number of sections	Road miles	Average length (mi)	AADT (veh/day)	Annual VMT (billion)	Fatal & major injury crashes: Total frequency	Annual frequency	Annual density (per mi)	Average rate (per 100M VMT)
Freeway	160	1,001	6.3	23,922	8.7	1,297	1.62	0.26	2.97
Multilane divided	33	85	2.6	13,937	0.4	104	0.63	0.25	4.84
Multilane undivided	38	78	2.1	11,259	0.3	153	0.80	0.39	9.46
Two-lane roads	1,126	5,970	5.3	4,492	9.8	4,320	0.77	0.14	8.83
Total	**1,357**	**7,134**	**5.3**	**7,405**	**19.3**	**5,874**	**0.87**	**0.27**	**6.09**

Table 12. Comparison of Safety Performance of Michigan Roads for 2000-2004 and 2002-2006 Periods

Road type	Fatal and major injury crashes: Total frequency 2000-2004	Total frequency 2002-2006	Annual frequency 2000-2004	Annual frequency 2002-2006	Annual density (per mi) 2000-2004	Annual density (per mi) 2002-2006	Average rate (per 100M VMT) 2000-2004	Average rate (per 100M VMT) 2002-2006
Freeway	1,355	1,297	1.69	1.62	0.27	0.26	3.10	2.97
Multilane divided	116	104	0.70	0.63	0.27	0.25	5.38	4.84
Multilane undivided	148	153	0.78	0.80	0.38	0.39	9.17	9.46
Two-lane undivided	4,552	4,320	0.81	0.77	0.15	0.14	9.30	8.83
Total	**6,171**	**5,874**	**0.91**	**0.87**	**0.29**	**0.27**	**6.40**	**6.09**

Based on the updated version of Map 2 in Figure 50, an analysis was conducted to identify road sections in Michigan whose safety was most improved between the 2000 to 2004 and 2002 to 2006 periods. However, we found that the ability to identify "most improved" roads was limited because the updated risk maps are based on only two "new" years of crash data. A more reliable set of "most improved" section can be identified when five years of "new" crash data (2005-2009) are available.

A challenge in implementing the performance tracking protocol is that highway agencies do not routinely compile lists of all road sections for which safety may have benefited from an improvement project. Locations of safety projects are readily accessible, but not locations of all projects that may have potentially benefited safety. Many improvement projects implemented for reasons other than safety may also have substantial safety benefits.

Section 4.
Findings and Recommendations

This section presents the findings and recommendations of the usRAP pilot program to date, including both the Phase I and II pilot studies. The following discussion addresses the three usRAP protocols—risk maps, star rating maps, and performance tracking—as well as plans for Phase III of the usRAP pilot program.

4.1 Risk Mapping

As a result of the usRAP Phase I and II pilot studies and the work accomplished to date by EuroRAP and AusRAP, risk mapping is becoming a mature protocol. usRAP has now prepared Maps 1 through 4 for four states, as illustrated earlier in this report. EuroRAP has also worked with Maps 1 through 4, while AusRAP has focused on Maps 1 and 2. The best approaches to the development of risk maps using data typically available to U.S. highway agencies have been identified. Key principles that are well accepted include:

- risk maps should, whenever possible, be based on fatal and serious injury crashes; where this is not possible, risk maps based on fatal and all injury crashes may be considered
- multiple maps based on a range of risk measures should be developed, because no single risk measure provides a sufficiently complete description of the safety performance of a broad range of sites
- while multiple maps based on a range of risk measures are useful in completely describing the relative risks for specific roadway sections for safety professionals, the general public is likely to be confused if maps with more than one risk measure are presented. For communication with the general public, it is recommended that maps focusing on a single risk measure be used.
- the use of five risk categories, represented on risk maps by a defined sequence of five colors, appears appropriate
- the definition of risk categories based on percentages of road system length makes sense given the current state of safety data for the U.S. highway system. The use of a highest risk category representing 5 percent of the highway system in any jurisdiction is consistent with the SAFETEA-LU requirement for state highway agencies to identify 5 percent of roads with the most severe safety needs. It would be desirable to define risk categories based on uniform national benchmark risk levels, but this is difficult at present because consistent nationwide data on serious injury crashes are lacking.
- four road types are appropriate for defining average crash rates for use in preparing Maps 3 and 4. These road types are: freeways; multilane divided highways; multilane undivided highways; and two-lane highways. These road

types can be defined from data on number of lanes, median type, and access control. The sample size of multilane undivided highways is limited in some jurisdictions, but it still appears desirable to maintain multilane undivided highways as a road type distinct from multilane divided highways because of the increased risk inherent in the absence of a median.

- the results presented on risk maps must be carefully interpreted to avoid any suggestion that the display of a road segment in red or black on a particular map necessarily implies that the road segment has a safety problem that is correctable by a road infrastructure improvement. Some road sections shown in usRAP risk maps in red or black may have safety concerns that are correctable by road infrastructure improvements and others may not. A road segment may appear in red or black on Map 1 simply because that road has a high traffic volume with many vehicle-vehicle interactions that provide an opportunity for crashes to occur. A road segment may appear in red or black on Map 2 because it is traveled by a high proportion of impaired drivers or by a high proportion of vehicles with high rates of severe crashes, such as motorcycles. The maps prepared in the pilot study are useful, even though the crashes that occur on a given road may not be related to the design features of that road, because any concentration of crashes provides an opportunity for highway agencies and their safety partners to identify appropriate engineering, enforcement, and education strategies to reduce those crashes. A road section with a sufficient number of crashes can provide an appropriate location for implementing crash reduction strategies, even if the frequency of crashes on that road section is not unusually high given the characteristics of the road and the traffic that travels on it.
- the duration of the study period for preparing a risk map should be three to five years. Longer periods are desirable to obtain higher crash frequencies, especially for road types with relatively low traffic volumes. However, study period durations longer than five years are not desirable because they increase the likelihood that changes in road characteristics will occur.

Some key issues that remain to be resolved are:

- How should the tradeoff between the desire for long road segments that include a desirable minimum number of crashes and the desire for road segments that are relatively homogeneous be resolved? EuroRAP has sought segments that are sufficiently long to experience, on average, 20 fatal-and-serious-injury crashes in a three-year period. In Britain, this criterion can be met with segments that average approximately 12 mi in length. In many U.S. states, applying this same criterion would require road segments as long as 50 mi in length. Such long road segments would undoubtedly be nonhomogeneous.
- What minimum number of crashes per road section is appropriate, especially for supplementary maps that address only one particular crash type?
- Would it be desirable to use longer road segments in preparing supplementary maps for crash types with sparse data rather than on risk maps prepared for all

crash types combined? This would increase the proportion of road segments with a specified minimum number of crashes of specific types.

- What risk measure should be used in presenting risk maps to the general public? The risk measure for Map 2, fatal-and-serious-injury crashes per hundred million veh-mi of travel, appears most appropriate because it represents the risk to an individual motorist in traversing a particular road section. EuroRAP has used Map 2 for this purpose. AusRAP initially released both Maps 1 and 2, but found that the public was confused by differences between the two maps in the risk categories for particular road segments. AusRAP has now focused on Map 1 for public release on the grounds that crash densities would be more easily understood by the general public who may not easily grasp the meaning of a crash rate.
- What national benchmark risk categories would be appropriate for comparing travel risks across the nation? Such national benchmark risk categories can probably be developed only if serious injury crash frequencies with reasonably uniform definitions can be defined for all or most states
- Should usRAP risk mapping continue to focus on rural roads or should urban roads be included as well, as was done in the New Jersey pilot study?
- Can risk mapping for urban roads be effective given the relatively short section lengths needed to keep the sections relatively homogeneous?
- Should greater emphasis be placed on intersection risk mapping, as was done in the Iowa pilot study, since a substantial proportion of fatal and serious injury crashes occur at intersections?

4.2 Star Rating Maps

Star rating maps based on inspection of roads to determine the presence of features that reduce crash likelihood and severity have been developed in EuroRAP, AusRAP, and the usRAP Phase I pilot studies. The star rating protocol was first developed in EuroRAP based on a rating of road features that protect road users from death or serious injury, known as the Road Protection Score (RPS).

The star rating concept has evolved in AusRAP and in the usRAP Phase I pilot studies to include road features related to the reduction of crash likelihood, as well as features related to crash protection (i.e., crash severity reduction). Crash likelihood has also been introduced into a revised RPS methodology for ongoing iRAP pilot studies in low- and middle-income countries.

In the usRAP Phase I pilot studies, a revised RPS methodology was developed that incorporated crash likelihood concepts and available U.S. safety research results. This methodology was presented in Appendix A to the usRAP Phase I report. Figure 51 presents an example of a star rating map developed in Phase I from the revised usRAP RPS methodology.

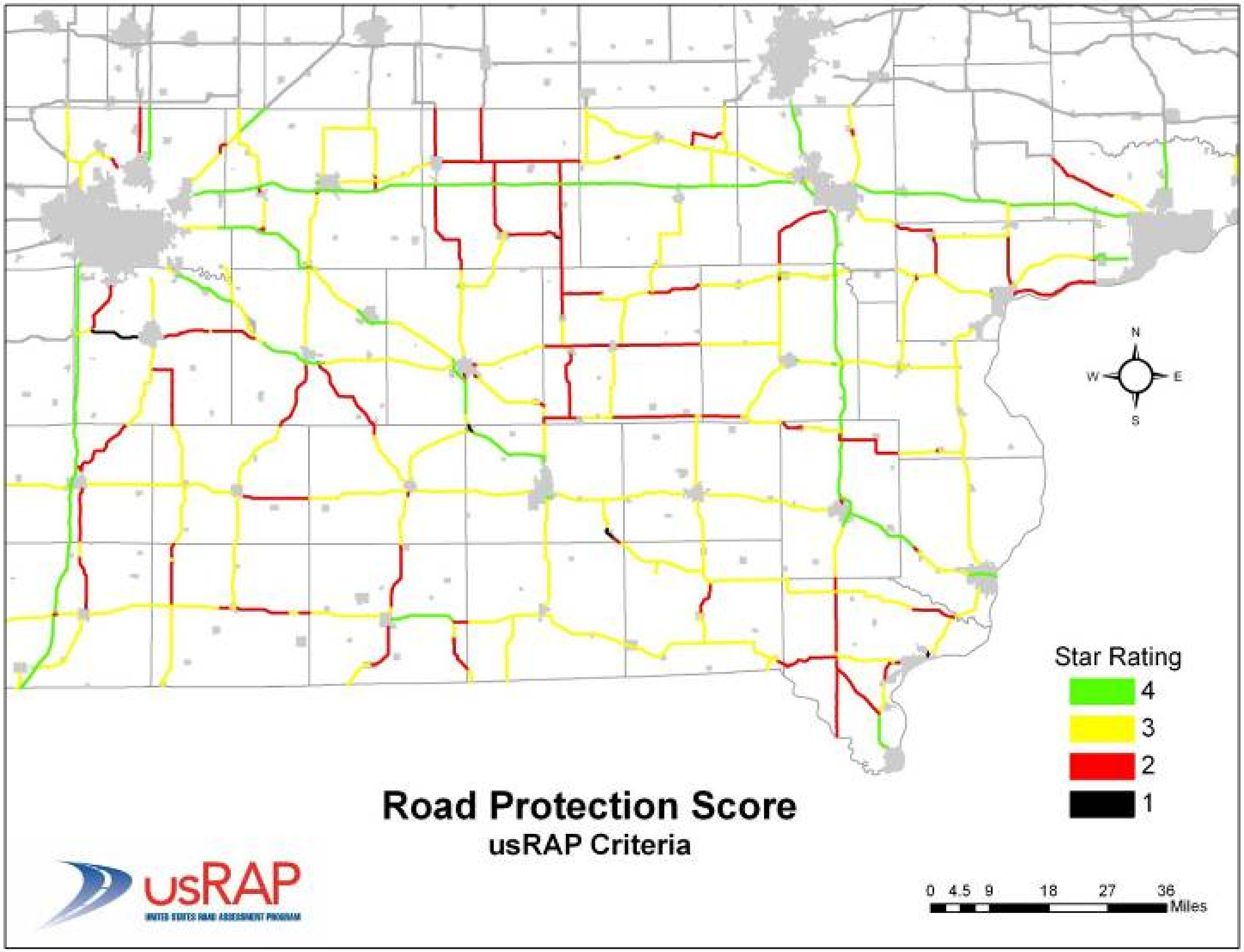

Figure 51. Example of Star Rating Map From Phase I Report

The assessment of the revised usRAP RPS methodology at the end of Phase I was that it represented an important step forward for RPS application in the U.S., but that it was not yet sufficiently proven for widespread application in the U.S. Additional work is needed on the RPS methodology to address crash likelihood factors more fully and to demonstrate the relationship of the star ratings to actual crash data.

While no further work on star ratings has been performed in Phase II of the usRAP pilot program, there have been important advances in RPS development since the end of Phase I. First, AusRAP has completed an initial star rating methodology that includes more extensive consideration of likelihood factors than EuroRAP. Second, an iRAP RPS methodology has been developed and is currently being tested that combines concepts from EuroRAP, AusRAP, and usRAP and gives extensive consideration to both crash likelihood and crash protection.

No further star rating maps have been developed in usRAP Phase II because of the assessment of the research team and the usRAP advisory panel that further research was needed to develop the RPS concept for application in the U.S. Funding for that additional research on the RPS concept has now been identified and improvement of the star rating map capability will be addressed in usRAP Phase III.

4.3 Performance Tracking

The performance tracking protocol was originated in EuroRAP, and initial U.S. work has been conducted in usRAP Phase II. Results of this effort have been presented in Section 3 of this report. The performance tracking concept appears promising, but may potentially be limited in rural areas of many U.S. states to longer-term analyses, since data for short-term analyses (e.g., two additional years of data in the Michigan analyses presented in Section 3) may be too sparse for meaningful results. Further development of performance tracking protocol is anticipated.

4.4 Plans for usRAP Phase III

Phase III of the usRAP pilot program has begun in 2007. The planned work activities for usRAP Phase III are discussed below. We anticipate that the Phase III work will be completed in mid-2008, depending upon the number of states in which additional pilot studies will be performed.

4.4.1 Additional Pilot Studies in Three to Five States

The usRAP team completed pilot studies in Iowa and Michigan in usRAP Phase I and pilot studies in Florida and New Jersey in usRAP Phase II. Plans are being made to perform pilot studies in three to five additional states as part of Phase III. These additional pilot studies in Phase III will further develop the risk mapping protocol and provide experience in developing risk maps with a broader range of state data systems. It is also planned to include additional local agencies, particularly rural counties, in the Phase III activities. At the conclusion of Phase III, a decision will be made as to whether to proceed with full national implementation of usRAP. More details about planning for potential national implementation of usRAP are presented below. Any work with states beyond Phase III would no longer be considered pilot studies, but would be considered part of the full implementation of usRAP.

4.4.2 Further Work with Previous Pilot Study States

As part of the Phase III program, further work will be performed with the four states where pilot studies have already been completed—Florida, Iowa, Michigan, and New Jersey. This further work will include preparation of updated risk maps as additional years of crash data become available and further work on developing and implementing the performance tracking protocol, that was initially tested in Michigan, as part of Phase II.

4.4.3 Further Development of the Road Protection Score Methodology for Application in the U.S.

RPS provides a methodology to assign safety-based star ratings to roads based on road inspection data. Star rating maps based on RPS serve as a supplement to risk maps based on crash data and have the potential to serve as a basis for programming safety improvements for roads when crash data are not available.

The RPS methodology was originally developed for application by EuroRAP prior to the start of usRAP. An assessment of RPS in Phase I of usRAP concluded that, for application in the U.S., the EuroRAP RPS approach would need to be adapted to address factors related to crash likelihood as well as crash severity. In addition, U.S. research results were identified that could serve as a basis for several elements of RPS scoring. A preliminary set of changes was made to adapt the EuroRAP RPS methodology to U.S. conditions as part of the usRAP Phase I work and the revised methodology was applied to the southeast portion of Iowa and two counties in Michigan. The revised RPS methodology and the Iowa and Michigan results were reviewed by the usRAP advisory panel at the end of Phase I, and it was concluded that wider implementation of RPS in the U.S. would be premature until an additional research and development effort on RPS could be undertaken. The conduct of this research is anticipated as part of Phase III of the usRAP pilot program.

Since the completion of usRAP Phase I, there have been new international developments related to RPS. AusRAP has completed development of an RPS concept that addresses some of the same concerns about the absence of crash likelihood factors that were identified in usRAP, and has published star rating maps of the Australian national highway system. In addition, the International Road Assessment Program (iRAP), of which usRAP is a member, has developed an RPS methodology for application in low- and middle-income countries combining concepts from EuroRAP, AusRAP, and usRAP. The iRAP RPS methodology is currently being tested in pilot studies in Chile, Costa Rico, Malaysia, and South Africa. Recent progress in the U.S. on the *Highway Safety Manual* and on FHWA's *SafetyAnalyst* software tools should also be reflected in RPS.

Research is planned in Phase III to fully develop, test, and validate an RPS concept for application in the U.S. This concept should draw upon the most applicable portions of the EuroRAP, AusRAP, usRAP, and iRAP methodologies. Specific elements of the methodology should be developed or calibrated from U.S. research literature. The methodology should be tested through application to videologs of actual roadway sites and should be validated by comparison to observed data for fatal and serious injury crashes.

4.4.4 Support for Survey and Focus Group Efforts

As part of its ongoing effort to understand and improve safety culture in the U.S., AAAFTS is planning to conduct surveys of the general public on safety-related issues. AAAFTS may also support related survey efforts by other national safety organizations. In addition, AAAFTS is considering sponsoring a study on communications strategies to assess the potential use of usRAP maps in communicating highway safety information to the public; this effort may involve surveys and/or focus group sessions. The usRAP team will support all of these efforts and, specifically, will suggest target audiences and relevant questions for surveys and focus group sessions.

4.4.5 Planning for National Implementation of usRAP

A plan will be developed in Phase III for national implementation of usRAP. The plan will then be discussed with the usRAP advisory panel and other interested stakeholders, with the intention that a decision on whether to proceed with national implementation of usRAP will be made at the conclusion of Phase III. The plan will recommend institutional arrangements and funding levels needed for national implementation. If national implementation is recommended, a goal of involving all 50 states in the usRAP program within five years is anticipated.

The plan will present a vision for a fully operational center for managing usRAP and indicate how the transition from the pilot study effort to a national program would be managed. Specific issues to be addressed are:

- How many new states per year should be brought into the usRAP program?
- What will be the required cost and time per state to bring each state into usRAP and prepare an initial set of risk maps?

- What will be the required cost and time to maintain each state in usRAP, with annual updates of the maps and with annual performance tracking?
- Should star rating maps be prepared for each state? What will be the required time and cost to prepare and maintain star rating maps?
- Should the center operate with a full-time staff, with contractor staff, or with a combination of full-time and contractor staff?
- What communication strategies should be employed by the operational center? Should communication be directed toward highway safety professionals, toward the motoring public, or both? What media should be used to communicate new results as they are obtained: technical reports? brochures? web sites?

The plan will indicate the level of funding needed for a national usRAP program. A draft of the plan will be reviewed and revised in response to those comments from all interested stakeholders.

4.4.6 Program Coordination and Technical Communications

The usRAP pilot program will continue to be managed in coordination with the usRAP advisory panel, representing highway agencies, auto clubs, and other interested stakeholders. A final report for the Phase III work will be prepared for publication by AAAFTS. Presentations at technical meetings and preparation of papers for appropriate publications will continue.