CAPE COD
COMMISSION

2016 REGIONAL TRANSPORTATION PLAN

Technical Appendix J: Pavement Management

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Technical Appendix J: Pavement Management

As an essential task required by the Cape Cod Metropolitan Planning Organization (MPO) through its Unified Planning Work Program, this report provides the status of pavement condition assessment activities on Cape Cod. The objectives of this effort are to collect data and implement a regional pavement management system for Cape Cod to provide an objective rating of pavement conditions and needs.

The pavement management process is conducted with the intent to keep the roadway system in the best possible condition with the most efficient use of available funds. There are distinct advantages to managing pavement condition and significant cost savings that can take place with preventative or rehabilitation measures rather than waiting until a road is in need of reconstruction. As stated in the MPO-approved Cape Cod Regional Transportation Plan, the goal of the pavement management process is for all federal aid-eligible roads to be maintained in "excellent" condition. Of course, due to the reality of limited financial resources, it is necessary to prioritize pavement repair based on affordability. Deciding which roads to improve and by what technique in a fiscally responsible manner is the essence of Pavement Management.

PAVEMENT MANAGEMENT SYSTEMS - BACKGROUND

Pavement Management is the practice of planning for pavement repairs and maintenance with the goal of maximizing the value and life of a pavement network.

To accomplish this, a community needs to have several repair techniques in its arsenal and the knowledge of when to apply them. This is where pavement management comes into play. With a comprehensive database of road conditions, the pavement management software can model when to perform which repairs on a road network. Of course, engineering judgment is required to finalize any list of street repairs, as no computer model can take every variable analyzed in making a repair decision into account. The computer system is a great springboard to help a community start its repair program for each year and is an excellent method of storing the repair data.

Below is a model of how a street's pavement deteriorates over time. Interpreting the curve, a street starts out in excellent condition when it is newly constructed. Midway through its life, a low cost repair such as crack seal and full depth patch will cost approximately a dollar a square yard. It takes only a few years for the window of opportunity to perform this low cost maintenance to pass after which the road would need an overlay costing $13 - $17 per square yard. By performing timely maintenance, road conditions can be improved today thereby extending the life of the road.

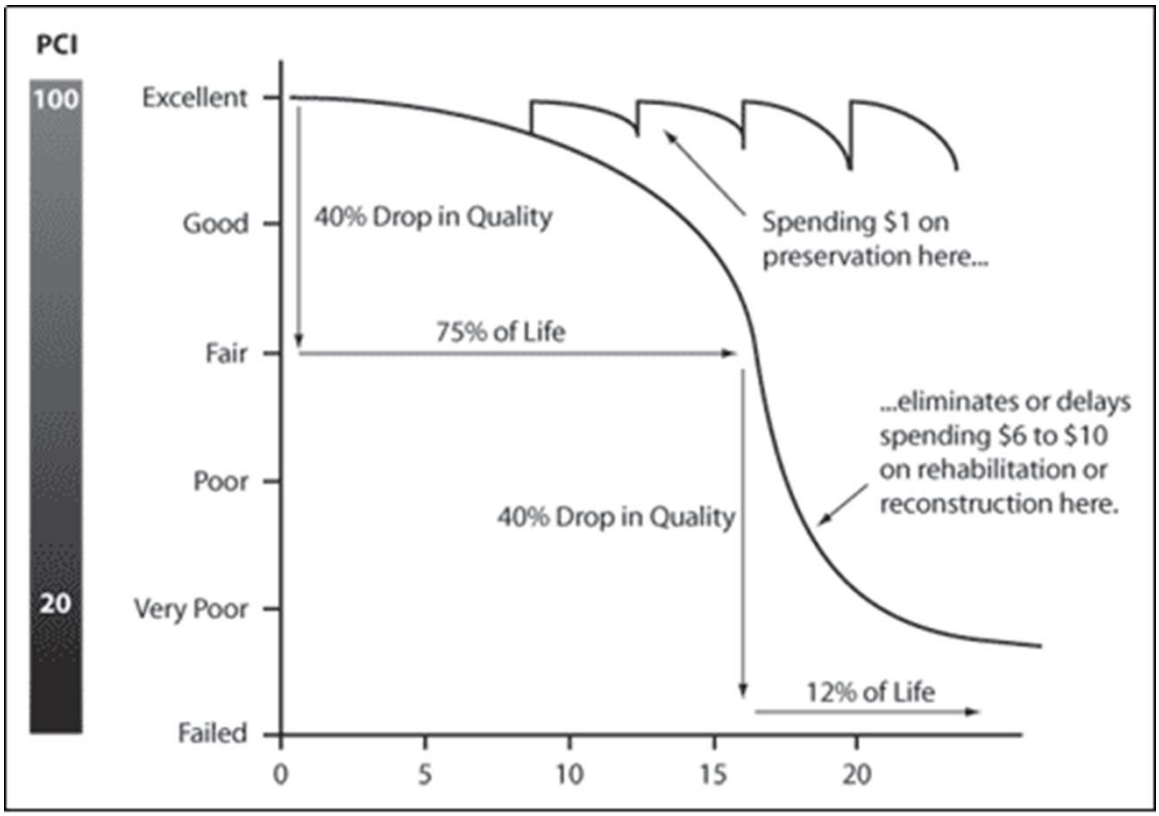

FIGURE 1 - PAVEMENT DETERIORATION CURVE

Source: Federal Highway Administration

EVALUATION CRITERIA FOR CCC DATA COLLECTION

The Cape Cod Commission has continues to collect pavement condition data in 2011 and 2012 through two distinct efforts: a series of "Windshield Surveys" and spot observations at specific locations where the seasonal traffic technicians were installing Automatic Traffic Recorders (ATRs). In both cases observers were given photographs and descriptions of example pavement distresses. Observers used a 1 – 5 rating system and made notations of particular distresses. Copies of the observations are provided in the appendix of this report. The following table is a summary of the guidance given to observers:

TABLE 1 - CCC EVALUATION CRITERIA

CONDITION	DESCRIPTION	CRITERIA
1	Very Good to Excellent	No cracking rutting, raveling/ signs of wear
2	Good to Very Good	No cracking, rutting, showing a little wear
3	Fair to Good	Showing evidence or more wear and possibly repairs that are in good condition
4	Poor to Fair	Evidence of cracking, rutting, serious wear
5	Poor	Severe cracking, rutting, potholes

SURVEY OF CAPE COD COMMUNITIES' PMS ACTIVITIES

In early September 2011, and email survey was sent to each of the 15 towns' Department of Public Works directors. Follow-up inquiries were made in following years. The survey included the following questions:

1. Do you maintain records of pavement quality on your community's roadways?
2. Can you send [electronically preferred] summaries of pavement quality assessments?
3. What system/method do you use to assess pavement quality?
4. Can you send us a report/documentation of methods used?
5. What method do you use to determine repair strategies?
6. Do you have estimated costs for implementing various repair strategies?
7. Can you forward us cost estimates sheets?
8. Do you have a capital plan for pavement improvement?
9. Can you forward us a copy of the capital plan?

Several communities have responded as summarized in the following sections.

BARNSTABLE PMS ACTIVITIES

The Town of Barnstable utilizes detailed survey and analysis performed by VHB as a Consultant. Their work is entered onto Barnstable's database and periodic reports are provided and discussed. The DPW participates in the data analysis, particularly in the cost analysis. DPW reviews project bids received by the Town and establishes base line costs for each pavement treatment band, these costs are discussed with the town's consultant - then utilized in the pavement conditions report. In addition to the VHB work, the DPW maintains a record of roadway repairs and relies upon experienced field personnel to assist in planning for individual maintenance tasks such as crack & chip seal. DPW also informally monitors the performance of all treatments. Key to the pavement management program is coordination with other utilities and proposed roadway rehabilitation information is passed to utility companies. A moratorium is in place for 5 years after application of a new surface. The Town of Barnstable does not maintain a public "5 year plan" - because of political considerations.

Submitted materials include:

- VHB-prepared "2010 Pavement Management Report." See section 1.4.1 for discussion of VHB Pavement Management Systems.

- Excel workbook containing typical costs for various items involved in pavement repair and related road work.

BOURNE PMS ACTIVITIES

Bourne is currently doing road resurfacing on an as-needed basis. The town tries to repave four to five miles of roadway each year. In doing that, the town has kept their main roads as their top priority and then broken off into the subdivisions. Bourne does not currently have a capital plan. The town is in discussion with a consultant to look at Bourne's roads and begin working toward a formal pavement management plan.

BREWSTER PMS ACTIVITIES

Brewster worked with CDM Smith to develop a Pavement Management Plan that will be managed in a MicroPaver database. The Plan, completed in January, outlined road improvement alternatives and the resulting PCI of each. The most proactive plan, approximately $10 million over 5 years, was ultimately approved by voters at the Spring 2015 town meeting. The plan indicated that this level of planning will improve the overall PCI from 73 to 80.

DENNIS PMS ACTIVITIES

The Town of Dennis uses VHB's Pavement Management for guidance. The term "guidance" is used because while VHB keeps Dennis' pavement quality records, does field verification on a 1/5th per year basis, grades the town's roads and makes recommendations for repairs, the town has to spend road funds based on several factors that the program is not designed to consider. These local parameters are: some work in each of Dennis' 5 villages each year, reconstruction of failed roads, resurfacing of dirt roads and lumping the type of repair to give off-cape vendors enough to give the town a reasonable rate.

The town has not had an assessment prepared of estimated costs for various repair strategies for several years. The town's capital plan for pavement improvement allocates $600,000 per year for "secondary roads." Chapter 90 funds are used exclusively for primary roads.

EASTHAM PMS ACTIVITIES

The Town of Eastham is developing a pavement management system. Current efforts include detailed spreadsheets identifying treatment strategies.

Submitted materials include:

- Spreadsheet listing of town roads with summary of face type
- Spreadsheet listing of Town & Private Roads in Town of Eastham with summary of surface type
- Spreadsheet listing of town roads with itemized surface type

FALMOUTH PMS ACTIVITIES

Falmouth uses VUEWorks Asset Management Software to track their Public Works Assets. Falmouth has just begun to use the Pavement Condition rating system that is a module of the system. It is based on the ASTM rating system. Falmouth has provided a copy of their Pavement Manual, a report of the roads they have rated so far, and a sample report of one of the roads. Falmouth uses a couple of strategies to determine their repair schedule. The town has a 10-year roadway plan for major repairs. This is funded by the town operating budget and a Capital Plan. Falmouth has provided both of these documents. The town also has a service call/ work order system to take requests from the public for signs, potholes, sweeping and grading, etc.

Falmouth does not have cost estimate sheets. The town does some work in-house and contracts its crack sealing and large repairs out. These are covered by the town operating budget and Capital Plan.

Submitted materials include:

- Sample Pavement Condition Form
- VUEWorks Pavement Management System Training Guide
- FY 2013-2022 Capital Improvement Program summary form
- Public Works Department Roadway Maintenance Program FY 2012-2023

HARWICH PMS ACTIVITIES

The Town of Harwich DPW utilizes an online database that was developed with Bonsai Logic (a small local software developer) to maintain a road inventory, to develop cost estimates, to reconcile DPW estimates against actual expenses and to maintain a roadwork history. The DPW does not utilize the database to develop a PCI (Pavement Condition Index). The town rates roads in 1 of 4 structural conditions: good, fair, deficient, intolerable

The DPW does have a 5 year road maintenance plan that is updated every few years and is available on the Harwich website. The town uses Chris Nickerson, Highway Road Manager who is a certified pavement inspector, to develop a plan based on his experience, training and knowledge of Harwich's 481 public roads (142 miles). The town attempts to balance maintenance with repair in an attempt to avoid costly

reconstruction utilizing many different processes and procedures. For costs, the town utilizes county bid pricing (p. 2 of the town's Five Year Maintenance Plan).

Submitted materials include:

Summary of roadwork since 2005: excludes any TIP projects

- FY 12-18 Capital Plan – Proposed spending for town capital improvements including pavement maintenance/repair
- Roadwork job examples - Detailed itemized breakdown at pavement repair work at two town locations.
- 5 Year Road Maintenance Plan FY11-FY15 – detailed plan of various repair proposals for many town roads, including itemized costs.
- Harwich Road Inventory – 2010 listing of all town roads. Includes information such as surface width and type, condition (scale of 1 to 4), and length.

MASHPEE PMS ACTIVITIES

Mashpee has provided a list of recent paving projects completed between 2008 and 2013. Paving has occurred on over 8 miles of roads and bike paths on municipal roadways during this timeframe.

SANDWICH PMS ACTIVITIES

The Town of Sandwich retained the firm of Vanasse Hangen Brustlin (VHB) to perform pavement management services. A comprehensive study was undertaken to re-evaluate pavement conditions in Sandwich and to allow for the analysis of various funding scenarios. VHB performed a detailed inspection of the condition of the pavement on all town-maintained roads and updated a database of this information using VHB's "Road Manager" software.

To determine road repair strategies, the town mainly uses PCI (Pavement Condition Index) and Benefit. For estimated costs for implementing various repair strategies, the town uses the County's bid process and incorporates these into their own spreadsheets. The town's 5-Year plan changes dramatically year-to-year but provides a guide to follow as funds become available.

Submitted materials included the following:

- VHB Presentation on Sandwich Pavement Management
- Road Program Map – color coded map of town roads assigned to years (2006 – 2010)
- Excel workbook listing town roads with PCI, Benefit, and Repair Alternative information
- Excel workbook itemizing bid costs for various repairs by various vendors

- Excel workbook itemized by road, listing planned paving projects
- Excel workbook itemizing repair type, treatment, and comments for town roads, separately for each year 2007-2011
- Pavement Management Update Study – VHB-prepared 2006 report. See section 1.4.1 for discussion of VHB Pavement Management Systems.

TRURO PMS ACTIVITIES

Truro uses local knowledge to determine pavement repair priorities.

YARMOUTH PMS ACTIVITIES

The Town of Yarmouth retained the firm of Vanasse Hangen Brustlin (VHB) to perform pavement management services. VHB services consist of performing a comprehensive study to evaluate pavement conditions in Yarmouth and to allow for the analysis of various funding scenarios; perform a detailed inspection of the condition of the pavement on all town-maintained roads and update a database of this information using VHB's "Road Manager" software.

To determine repair strategies, the town reviews an initial list generated by the software and then decides whether to apply chip seal, double ship seal, or overlay. Main roads are treated with rubber chip seal or overlay. In the town's capital plan, annual spending ranges from $1.3 million to $1.5 million for roadway maintenance.

SUMMARY OF TOWN PMS EFFORTS

Based on responses from the September 2011 email survey and subsequent follow-up, the following table summarizes the techniques that responding towns use for pavement management.

TABLE 2 - SUMMARY OF RESPONDING TOWNS' PMS TECHNIQUES

Town	Pavement Management Technique
Barnstable	VHB Pavement Management System
Bourne	Local knowledge – as needed basis
Brewster	MicroPaver database
Dennis	VHB Pavement Management System
Eastham	Locally developed -spreadsheets
Falmouth	VUEWorks Asset Management Software
Harwich	Bonsai Logic Roadway Inventory
Mashpee	Local knowledge
Sandwich	VHB Pavement Management System
Truro	Local knowledge
Yarmouth	VHB Pavement Management System

VHB PAVEMENT MANAGEMENT SYSTEM

The most prevalent technique (as identified by many of the towns responding to the email survey) is the Pavement Management System developed by Vanasse Hangen Brustlin (VHB). The following sections contain excerpts describing the VHB techniques. These techniques are included in the reports submitted by the various towns:

Methodology

VHB performed a detailed condition evaluation of each town's public roadways to build the pavement management system. The first step was to identify the roadway network. The second step was to further break each street in the roadway network into pavement management sections. The third step was to carefully categorize, measure, and record the individual pavement distresses within each pavement management section and perform the inventory of sidewalks, curbs, and ramps. Finally, the fourth step was to customize the road repair treatment selection and unit costs within the pavement management software through discussions with Town officials. All these steps were performed prior to the study of future funding scenarios.

Network Identification

Network Identification builds an inventory of streets that describe the municipality's complete roadway network. The direction of travel, street length, width, ownership, classification, zone and pavement type are among the items identified at this initial phase in the pavement management process. This integral step ensures the streets surveyed are the definitive set to be analyzed.

Pavement Management Section Identification

Once the Network Identification is complete, the field work begins. Each street contains one or more pavement management sections. A pavement management section defines the limits of previous construction or maintenance activities within each street. Sections are defined by having the same width, typical distresses, functional class, etc. The goal is to set up homogenous areas of pavement to aid in assigning the appropriate repair. A street may be one section, or it may be comprised of several pavement management sections, depending on its construction history.

Surface Distress Assessment

For each pavement management section, the severity and extent of nine major pavement distresses are recorded, and then entered into a weighted formula to arrive at a Pavement Condition Index (PCI). The distresses are categorized as base related or surface related distresses. Base related distresses indicate that the pavement structure is inadequate for the existing traffic load and soil conditions. Streets that show significant

base related distresses may need to have the pavement structure strengthened with either thicker or stronger base or pavement materials. Surface related distresses are caused by age and weathering of the pavement. Streets that have predominantly surface related distresses are excellent candidates for maintenance sealing to inhibit further pavement oxidization (the main effect of aging). Streets with more of the base related distresses will most likely need some full depth patching, structural overlays or reclamation/reconstruction.

The four base related distresses are:
- Potholing or non-utility patching
- Alligator cracking
- Distortion
- Rutting

The five surface related distresses are:
- Block cracking
- Transverse or longitudinal cracking
- Bleeding or polished aggregate
- Surface wear or raveling
- Shoving, slippage or corrugation

PCI Defined

A PCI is generated for each inventoried pavement management section in the town using the surface distress data collected by VHB. PCI is measured on a scale of zero to one hundred, with one hundred representing a pavement in perfect condition and zero describing a road in impassable condition. Each type of observed pavement distress is assigned a deduct value based on the type, severity and extent of the distress. A weighted sum of the deduct points is subtracted from the perfect "one hundred" road in order to generate a PCI for each pavement management section. In general, base related (pavement foundation) distresses are weighted more heavily than surface related distresses. For example, if 15% of a road section had medium severity "Alligator Cracking" it would receive a deduct of 40 points. Whereas the same area of "Block Cracking" would only receive a deduct of 15 points. The actual PCI calculation follows:

PCI = 100 – (Highest Deduct Value) – (25% of remaining base related deduct values) – (10% of remaining surface related deduct values)

The Five Treatment Bands

The pavement management system uses broad ranges to group the individual repair types into five major treatment bands. Treatment bands are a useful tool to summarize data on a Town-wide basis. An individual road segment will fall into a particular category based on the strategy table's output of repair types and will vary due to functional classification. The goal is to gain a broad understanding of the existing conditions in simple yet meaningful terms.

TABLE 3 - TREATMENT BAND DESCRIPTIONS

TREATMENT BAND	PCI*	DESCRIPTION
DO NOTHING	93-100	Excellent condition - in need of no maintenance.
ROUTINE MAINTENANCE	86-92	Good condition – may be in need of crack sealing or minor localized repair.
PREVENTIVE MAINTENANCE	76-85	Fair condition – pavement surface may be in need of surface sealing, full depth patch and/or crack sealing.
STRUCTURAL IMPROVEMENT	56-75	Deficient condition – pavement surface structure in need of added strength for existing traffic. Typical repairs are overlay with or without milling.
BASE REHABILITATION	0-55	Poor condition – in need of base improvement. Typical repairs are reclamation or full depth reconstruction.

**Note: Treatment bands are defined below. These are only general PCI ranges for reference purposes, and represent only one pavement type. There are several fields considered by the strategy table when assigning repair types to each individual street. Source: VHB*

Do Nothing

The Do Nothing category exhibits roads which are in need of no maintenance. These roads are in excellent condition and existing distresses generally do not need to be addressed.

Routine Maintenance

Routine maintenance activities are those which are taken to correct a specific pavement distress. Routine maintenance usually addresses localized pavement defects and includes activities such as:

- Full depth patching;
- Skin patching;
- Crack sealing.

Preventive Maintenance

Preventive maintenance activities are those which are performed at planned intervals to protect and seal the pavement. Seals are designed to provide one or more of the following benefits:

- Prevent the intrusion of air and moisture;
- Fill small cracks and voids;
- Rejuvenate an oxidized binder;
- Provide a new wearing surface.

Structural Improvement

Structural improvement includes the work necessary to restore the pavement to a condition that will allow it to perform satisfactorily for several years. Generally a structural improvement will consist of a milling the existing pavement down and applying a new Hot Mix Asphalt Overlay allowing existing grades to be maintained. When the existing grade can be increased a new Hot Mix Asphalt course can simply be placed upon the existing surface. Structural improvements also include the work necessary to prepare the pavement for an overlay, either with or without milling. The major activities involved in the rehabilitation process are:

- Partial depth patching;
- Full depth patching;
- Joint and crack sealing;
- Grinding and milling;
- Hot Mix Asphalt Leveling Courses.

Base Rehabilitation

Base rehabilitation utilizes one of two methods:

- Reclamation;
- Reconstruction.

Reclamation is the process of rehabilitating existing deteriorated pavements. The existing pavement and base, subbase, and possibly subgrade are pulverized and blended to create a homogenous pavement base. This reclaimed pavement base is then paved with a new Hot Mix Asphalt surface. Reconstruction is the complete removal and replacement of a failed pavement, and might also involve widening, realignment, traffic control devices, safety hardware, and major base and drainage work.

Customizing Repair Strategies

VHB meet with the Town DPW to review VHB's typical repair strategies, and to learn how to customize these strategies to meet the Town's specific needs. VHB also refines repair unit costs. VHB's goal was to understand the town's decision making process and simulate that process in the budget analysis software based on the pavement condition and other criteria of each pavement section.

Preparing Budget Scenarios

Once the roadway conditions are inventoried and analyzed, and the repair strategies are defined, the impact of various spending programs on the roadway network is assessed. These studies can range from 1 to 20 years; typically 5-year studies are used. The purpose of the budget planning process is to determine the impact of various spending levels to find a funding level that will best meet the town's needs. The budget analysis

software uses pavement deterioration curves, unit costs, and the strategy tables developed in the repair strategy definition phase to assign each street a repair type and associated cost for each year of the study. The software also assigns each street a benefit value that is used to prioritize which streets the software will select for repair each year. It is important to understand that a pavement management system is a network-wide planning tool, and is not intended to give definitive street-by-street repair data. Field verification and testing are recommended to confirm any street repair list generated.

Deterioration Curves

In order to properly plan for future repairs, the budget analysis feature of the pavement management system uses deterioration curves. The deterioration curves estimate the rate at which the pavement condition decreases over time. These pavement deterioration curves depict two major categories of functional classification - arterials and collectors in one curve and local roads in the other. An example deterioration curve is presented in the following figure:

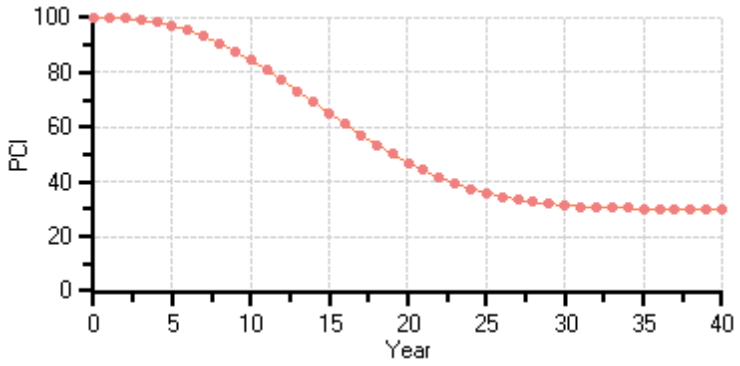

FIGURE 2 - SAMPLE DETERIORATION CURVE

Source: VHB

Strategy Table

The pavement management system uses a table of repair strategies to assign specific road repair types to individual roadway segments. The repair strategy table incorporates PCI ranges as well as functional class and pavement type to simulate decisions consistent with Barnstable's repair practices and procedures.

Project Prioritization

The budget analysis software prioritizes needed system repairs based on the estimated "Benefit Value". The Benefit Value formula is calculated using variables representing traffic volume, repair service life, PCI, and unit repair costs for each pavement management section. For each plan year, the software prepares a future roadway

condition projection, exhausts the assigned budget, and then produces an annual list of roads included in the repair program. The system also allows the user to enter an inflation rate to account for estimated increases in future year construction costs. A 4% inflation rate is typically used.

The Benefit Value prioritization process generally favors cost effective maintenance alternatives. Repair actions are typically delayed on those sections that require reconstruction or major rehabilitation because the benefits for dollars spent are generally lower than maintenance candidates. After the relatively good roads are "saved," improvements are directed towards the poorer arterial and collector roads, and then to the local roads in need of major rehabilitation.

ANALYSES

The data collected in the monitoring process will be continually compared to the measures developed to define congestion. The comparison will be used to identify congested areas and trigger an investigation into the nature of the demand problems

MASSDOT EVALUATIONS OF PAVEMENT CONDITIONS

As seen in the following table presented in the Cape Cod Regional Transportation Plan, the Cape Cod Region possesses 738.98 miles of roadway eligible for federal funding. Of those miles, 541.19 are under the jurisdiction of the Cape's local communities.

TABLE 4 – RTP MASSDOT DATA AVAILABLE BY JURISDICTION

		Jurisdiction - Ownership				Available Data for Local Jurisdiction	
	Total Miles	MassDOT	%	Municipal	%	Data Miles	%
Cape Cod	738.98	197.79	26.77%	541.19	73.23%	85.25	15.75%

MassDOT evaluates roads under their own jurisdiction and a selection of municipally-owned roadways. The following table lists the corresponding rating from Excellent to Poor, based on a "PSI" (Pavement Serviceability Index) rating – roughly analogous to the "Pavement Condition Index" (PCI) commonly used.

Pavement Condition	Excellent	Good	Fair	Poor
"PSI" Range	PSI >=3.5	PSI 2.8-3.5	PSI 2.3-2.8	PSI < 2.3

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The following map identifies the roadways that have been evaluated (shown in red) and those that lack evaluation (shown in blue).

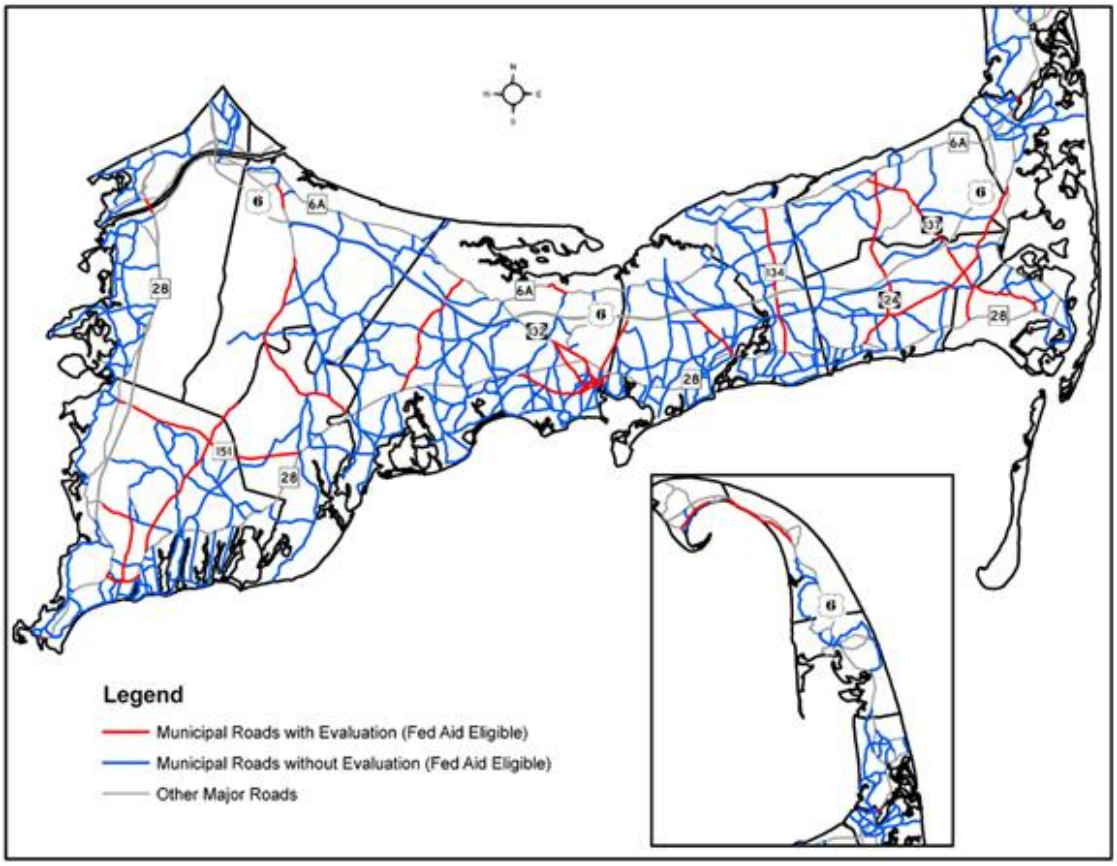

FIGURE 3 - MASSDOT EVALUATION OF MUNICIPAL ROADS

Source: MassDOT 2006-2009

CCC EVALUATIONS OF PAVEMENT CONDITIONS – WINDSHIELD SURVEYS

Using the MassDOT pavement evaluation discussed in the previous section as a basis for new data collection, CCC staff undertook a series of "windshield" surveys throughout Barnstable County. Data collection began in 2011 with a goal of evaluating approximately one-third of the mileage of federal-aid eligible municipal roadways each year. Roadway selection and segmentation was not-standardized at that time which made data processing time-consuming and inefficient. Much of the route selection and data recording were done using paper maps and field sheets.

Starting in 2014, a new data collection strategy was deployed, based on Geographic Information Systems' needs and strengths. Data-collection regions of each town were identified which contained roughly one-third of the mileage of federal-aid eligible municipal roadways. The quality and accuracy of the data collection was greatly improved through the use of GPS-capable tablet computers. The following chart identifies the data collection cycle (data collected in 2014 corresponds to the blue-colored roadways.

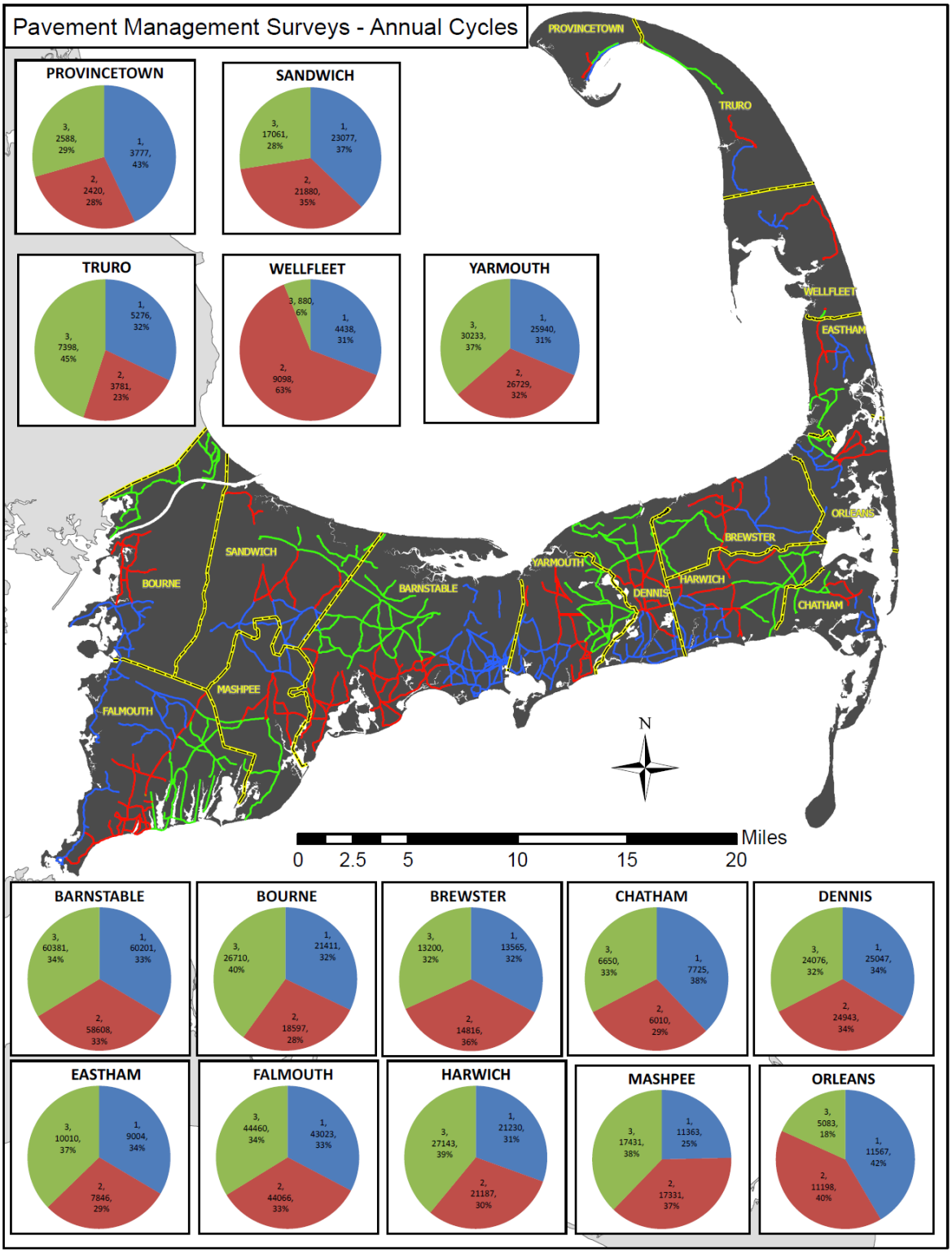

FIGURE 4 - PAVEMENT DATA COLLECTION CYCLES

The following table provides a summary by town of CCC windshield survey data.

TABLE 5 – 2011-2014 CCC SURVEYS OF PAVEMENT CONDITION - MILES

Town	Very Good to Excellent	Good to Very Good	Fair to Good	Poor to Fair	Poor	Totals
Barnstable	3.7	16.0	56.5	28.7	0.9	105.8
Bourne	3.6	3.5	26.3	5.7	1.0	40.1
Brewster	1.3	9.3	7.2	7.3	0	25.0
Chatham	2.6	2.8	6.3	0.4	0	12.1
Dennis	6.5	11.0	24.7	2.8	0	44.9
Eastham	0	1.9	10.4	3.9	0	16.1
Falmouth	2.8	19.5	24.0	12.2	0.1	58.5
Harwich	2.9	19.6	13.8	2.0	0	38.3
Mashpee	1.5	8.2	19.1	0.1	0	29.0
Orleans	0	5.1	6.2	5.2	0	16.4
Provincetown	0	1.1	1.4	2.8	0	5.3
Sandwich	6.0	4.1	13.4	8.7	0.8	33.0
Truro	1.2	2.1	5.0	1.7	0	10.0
Wellfleet	0	1.7	3.1	1.5	0	6.2
Yarmouth	1.2	9.4	32.1	7.2	0.6	50.6
Totals	33.3	115.3	249.3	90.0	3.5	491.3

As shown in the table above, almost 500 miles of survey data were collected throughout the 15 towns of Barnstable County from 2011-2014. The most common rating "Fair to Good" yielded almost 250 miles. This is followed by almost 115 miles of "Good to Very Good", 90 miles of "Poor to Fair," over 33 miles for both "Very Good to Excellent" and slightly over three miles of "Poor."

The following figures provide a graphic of the CCC survey data in a series of four maps (Upper Cape, Mid-Cape, Lower Cape and Outer Cape). The CCC evaluations are shown as colored parallel lines ranging from Blue (Very Good to Excellent) to Red (Poor).

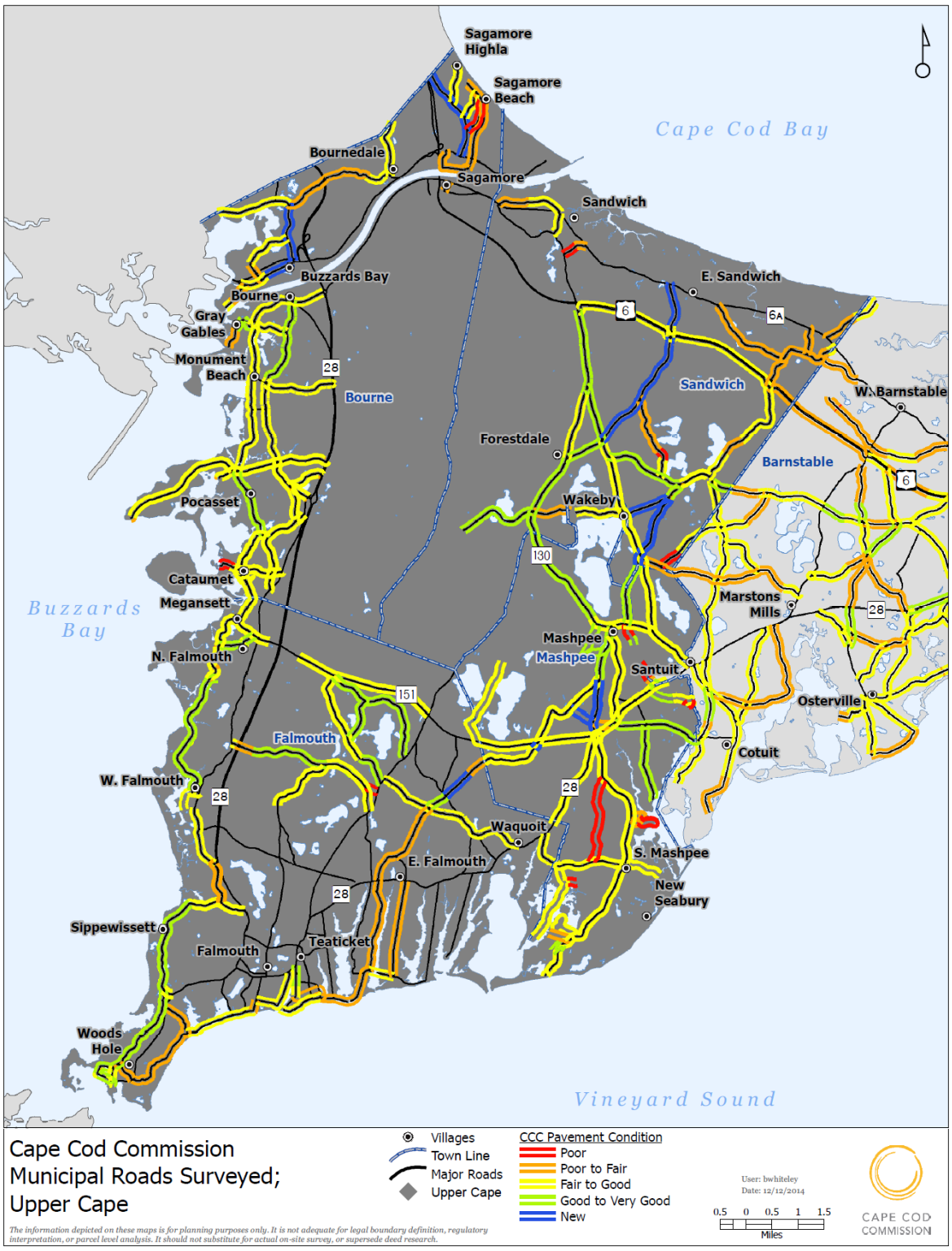

FIGURE 5 - 2011-2014 CCC PAVEMENT CONDITION SURVEYS: UPPER CAPE

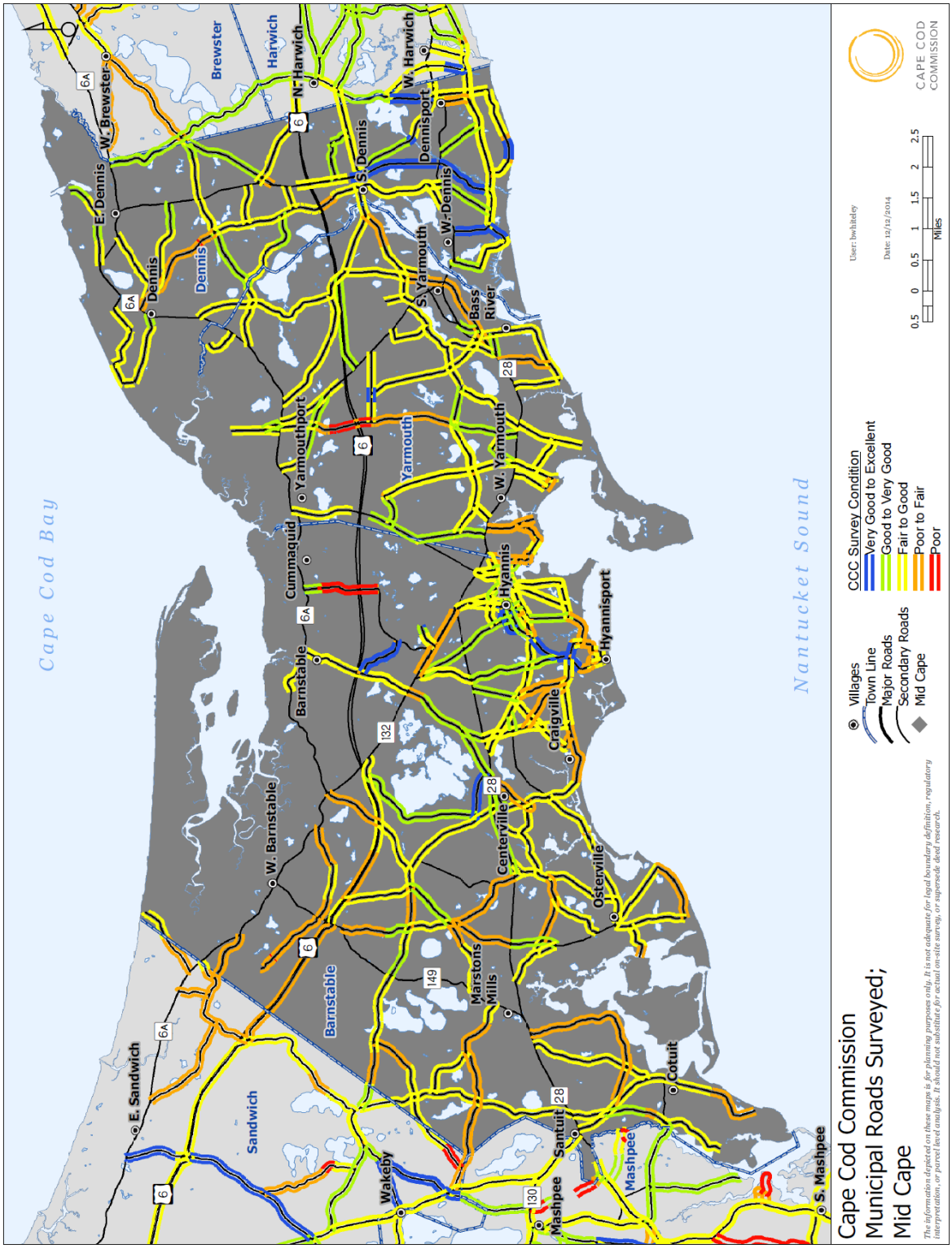

FIGURE 6 - 2011-2014 CCC PAVEMENT CONDITION SURVEYS: MID-CAPE

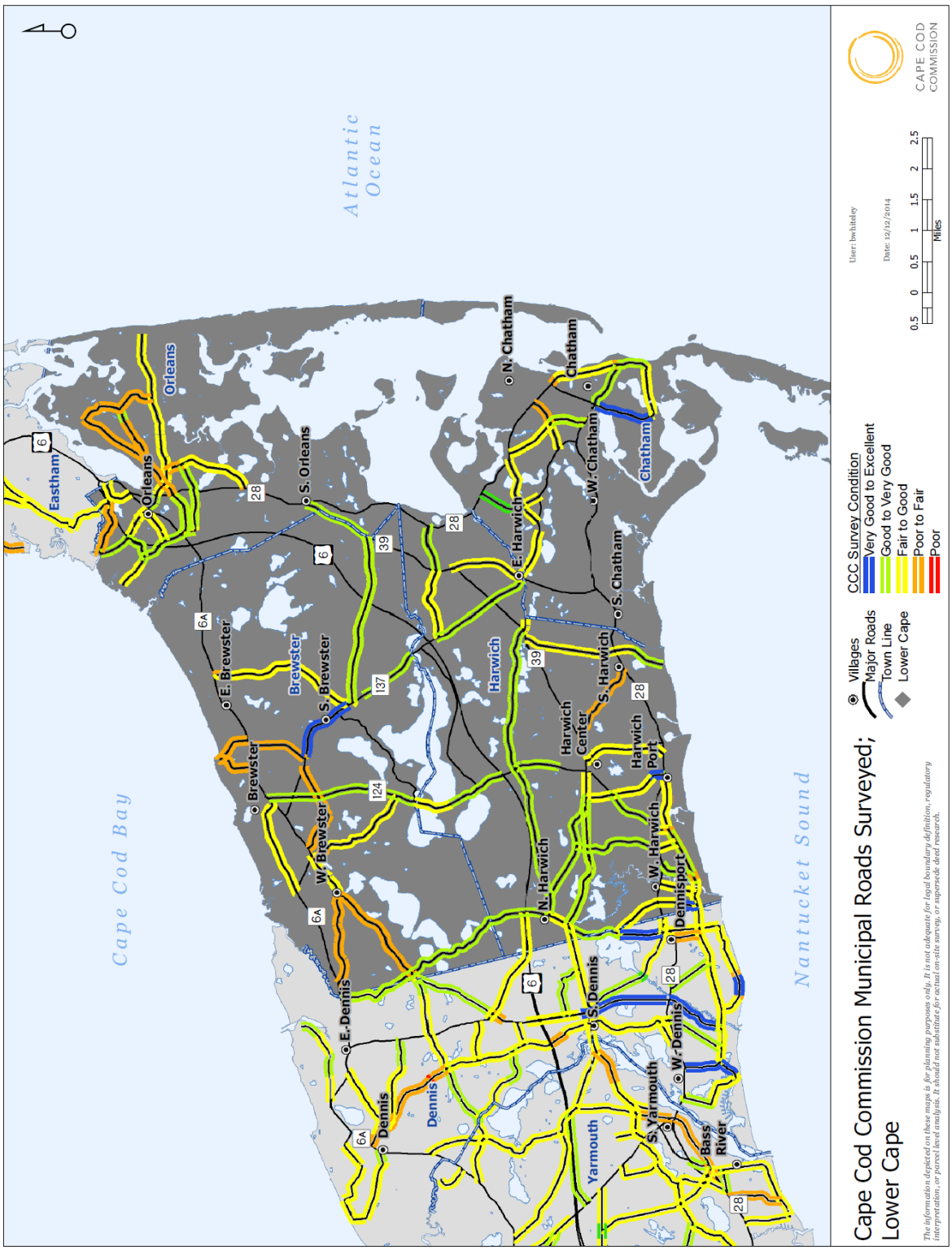

FIGURE 7 - 2011-2014 CCC PAVEMENT CONDITION SURVEYS: LOWER CAPE

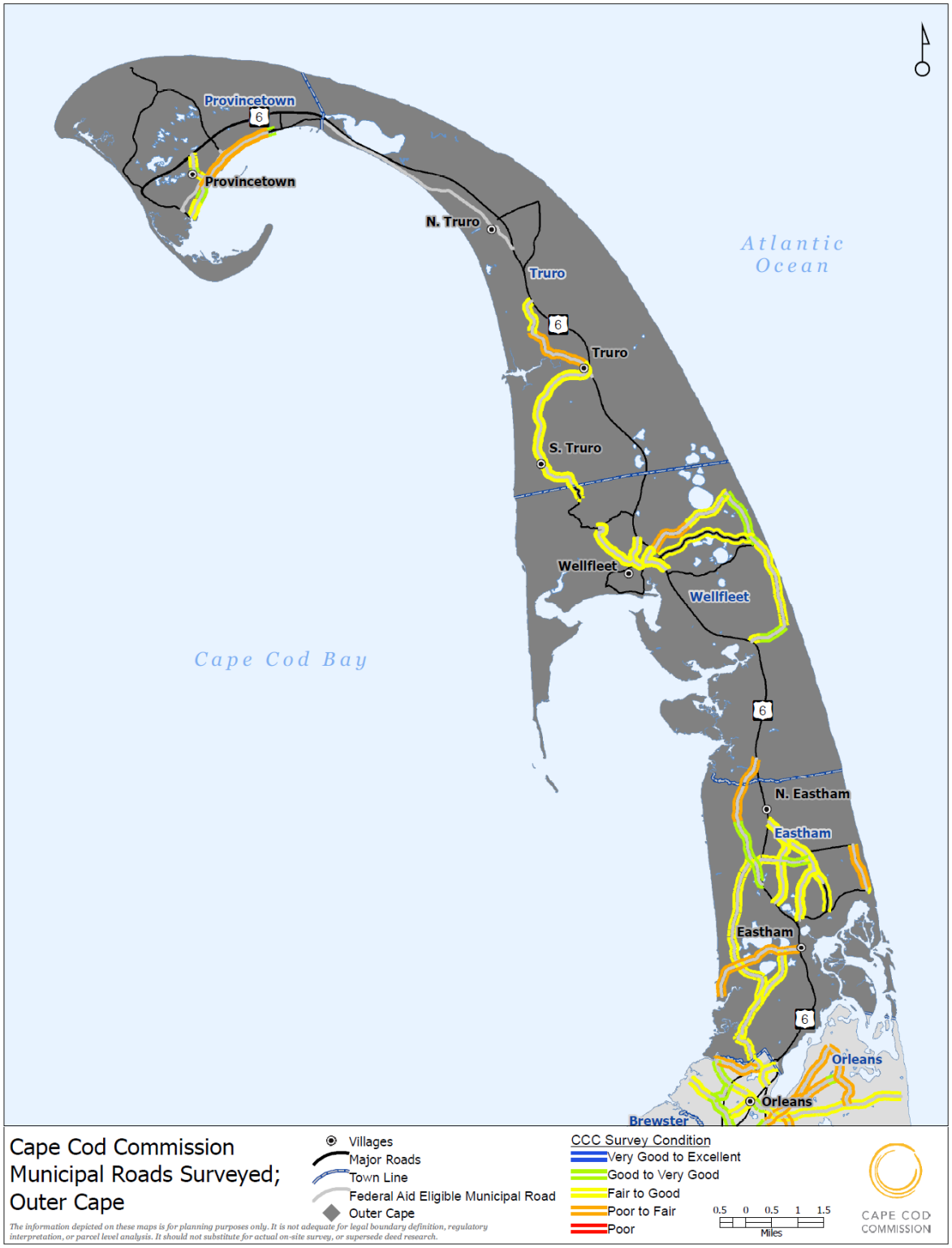

FIGURE 8 - 2011-2014 CCC PAVEMENT CONDITION SURVEYS: OUTER CAPE

CCC EVALUATIONS OF PAVEMENT CONDITIONS – ATR SITES

Starting in mid-summer of 2011, CCC traffic technicians were tasked with collecting pavement condition data as part of their work in setting up Automatic Traffic Recorders (ATRs). Including data collected in 2012 and 2013, this yielded pavement condition data at 410 unique locations throughout the Cape's 15 towns. Also, since a 48-hour traffic count was collected from each ATR, results include a "Weighted" pavement condition for each town. By multiplying the Annual Average Daily Traffic at each location times that locations' observed pavement condition, we then totaled these results and divided by the sum of Annual Average Daily Traffic from that town's ATR's. Annual Average Daily Traffic is calculated by multiplying the appropriate MassDOT monthly adjustment factor times the observed average daily traffic over the 48 hour ATR data collection period. The following table presents town-wide averages of the pavement condition information collected at ATR sites.

TABLE 6 - SUMMARY OF PAVEMENT CONDITIONS AT ATR SITES

TOWN	# OF SITES	AVG. AADT	AVG. CONDITION	WEIGHTED CONDITION
Barnstable	56	8,145	2.84	2.85
Bourne	36	6,067	2.92	2.92
Brewster	13	6,000	3.38	3.41
Chatham	25	5,915	3.08	3.14
Dennis	39	6,197	2.79	2.87
Eastham	18	3,032	2.94	2.49
Falmouth	62	6,844	3.00	2.91
Harwich	31	7,152	2.71	2.61
Mashpee	28	7,145	2.82	2.93
Orleans	26	6,187	2.88	2.97
Provincetown	19	3,496	3.16	3.46
Sandwich	47	5,724	2.83	2.76
Truro	25	2,766	3.00	2.75
Wellfleet	26	3,130	2.88	2.86
Yarmouth	55	7,001	2.62	2.71

See Table 1 for descriptions of pavement conditions (ranging from "Excellent" = 1 to "Poor"=5). Pavement conditions including comments and other ATR data for each of the 250 collection sites are presented in the appendix. The following figures are a graphical display of the individual site data for sections of Barnstable County (Upper Cape, Mid-

Cape, and Lower Cape). The pavement condition at each ATR site is shown as a colored circle ranging from Blue (Very Good to Excellent) to Red (Poor).

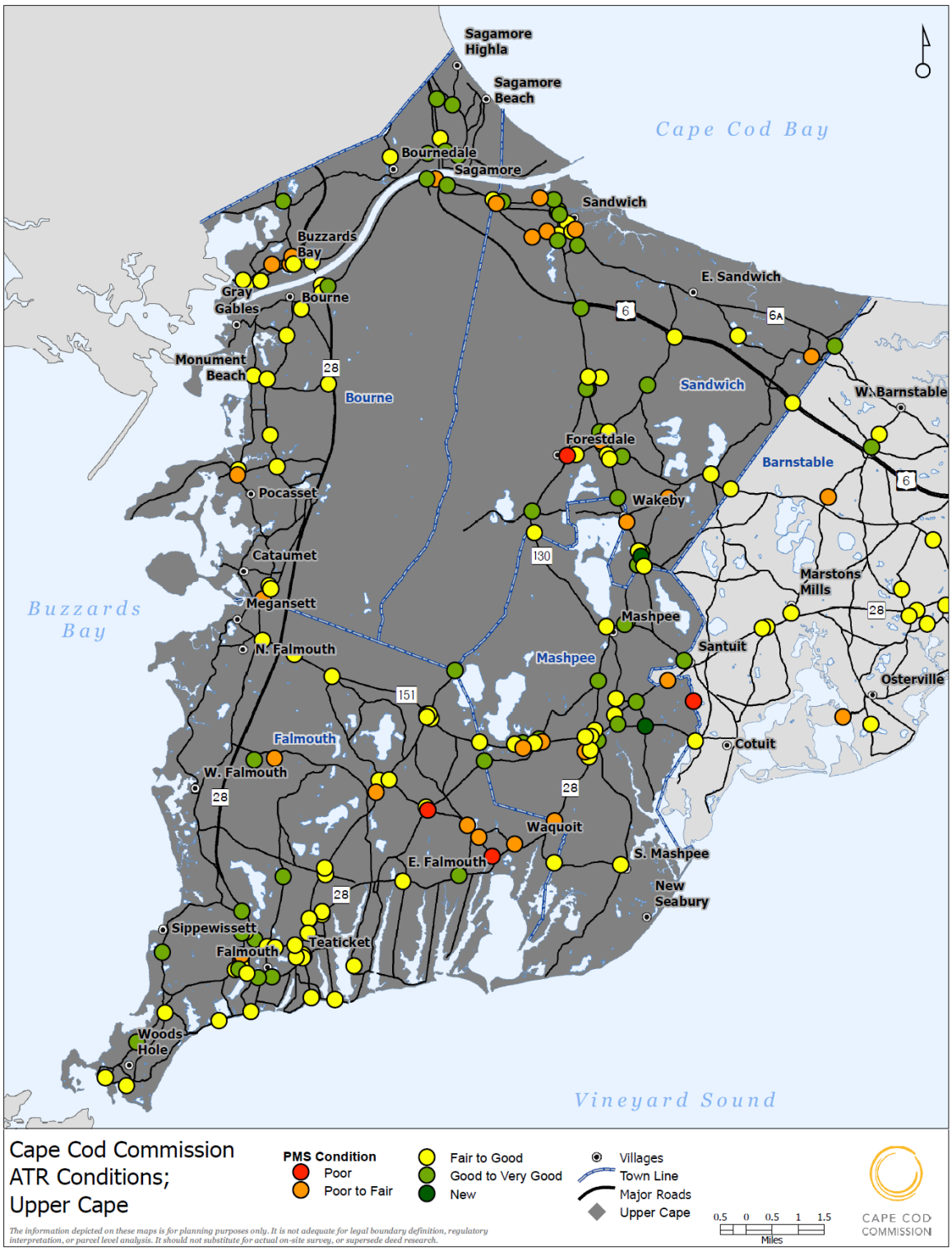

FIGURE 9 - 2011-2014 PAVEMENT CONDITIONS AT ATR LOCATIONS: UPPER CAPE

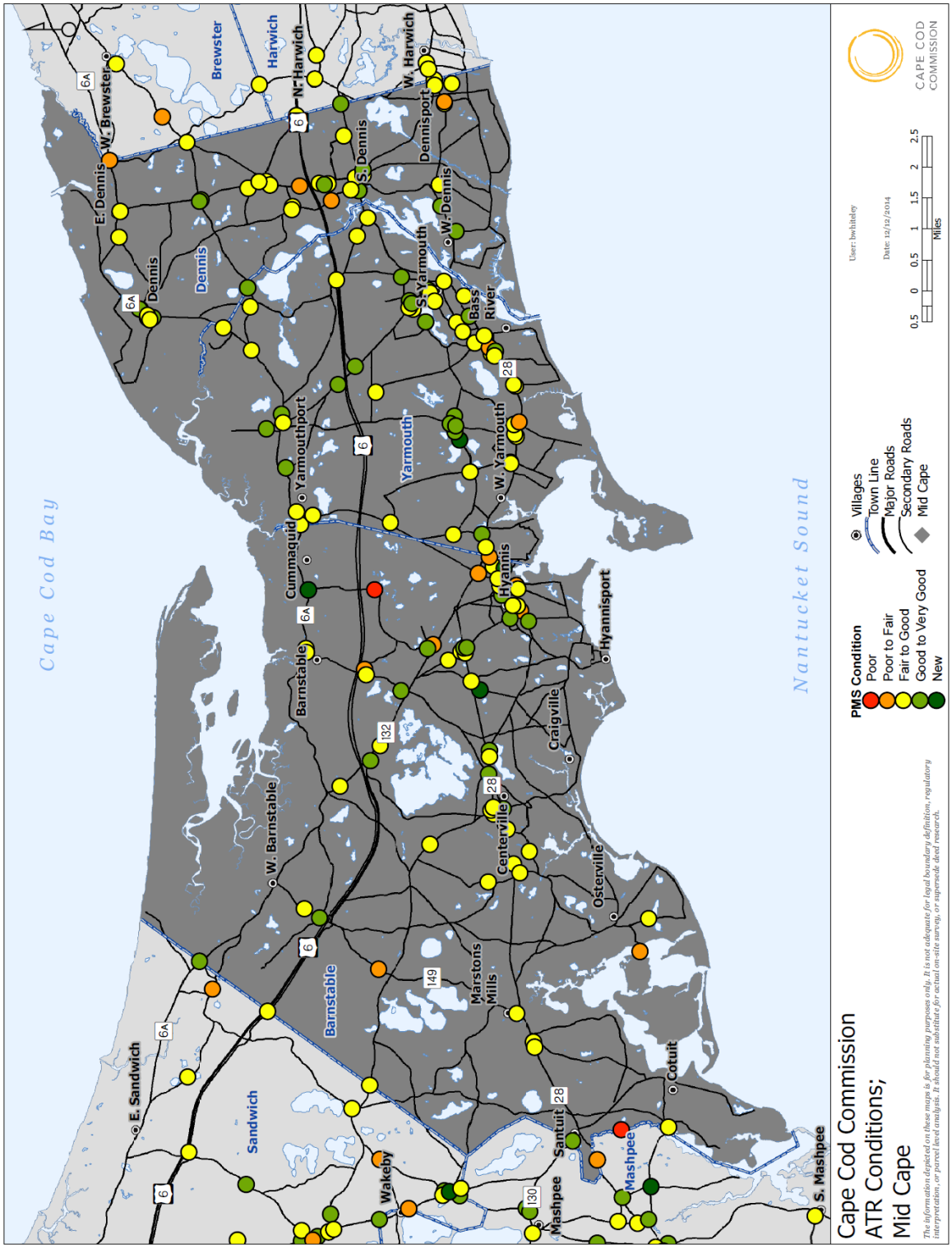

FIGURE 10 - 2011-2014 PAVEMENT CONDITIONS AT ATR LOCATIONS: MID-CAPE

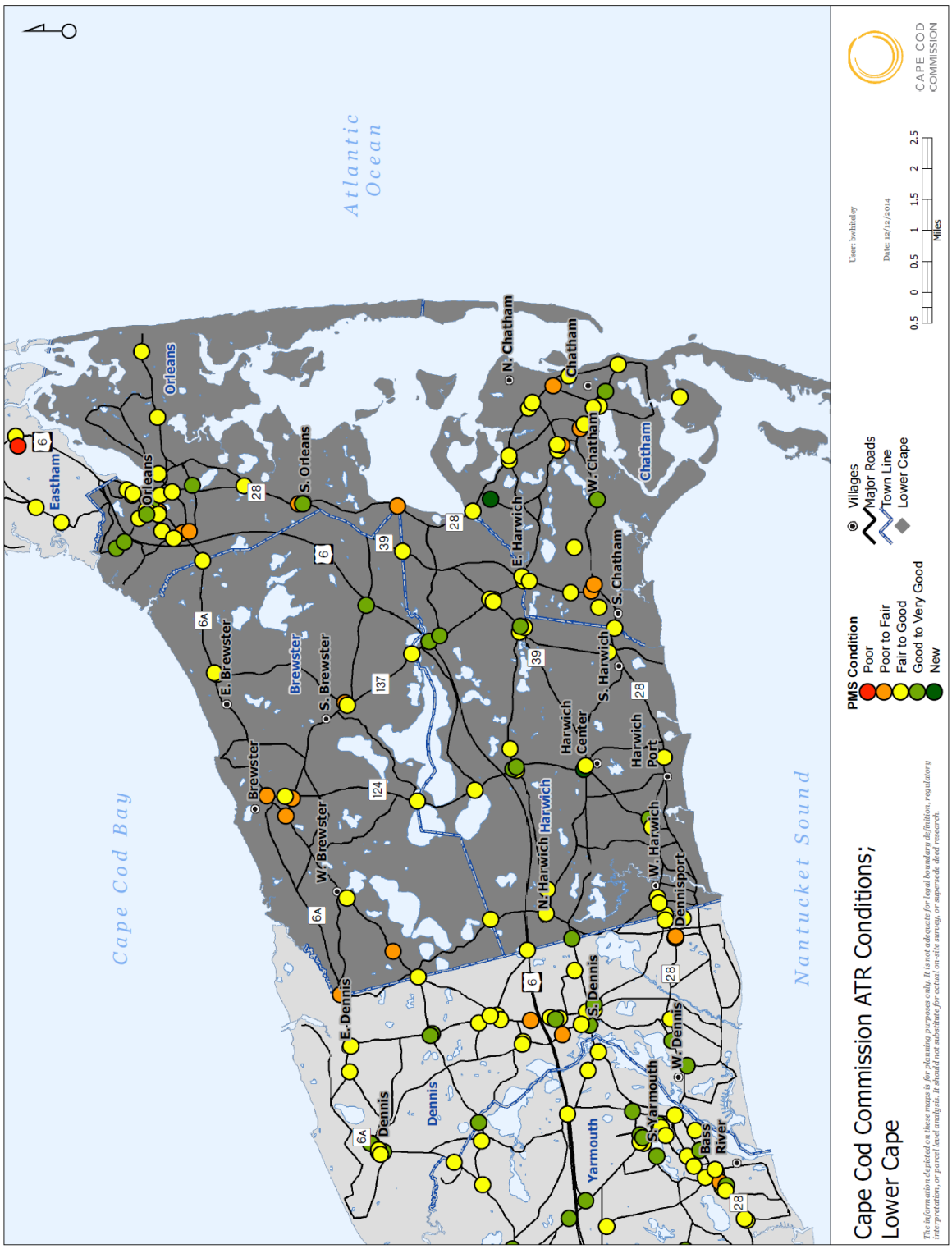

FIGURE 11 - 2011-2014 PAVEMENT CONDITIONS AT ATR LOCATIONS: LOWER CAPE

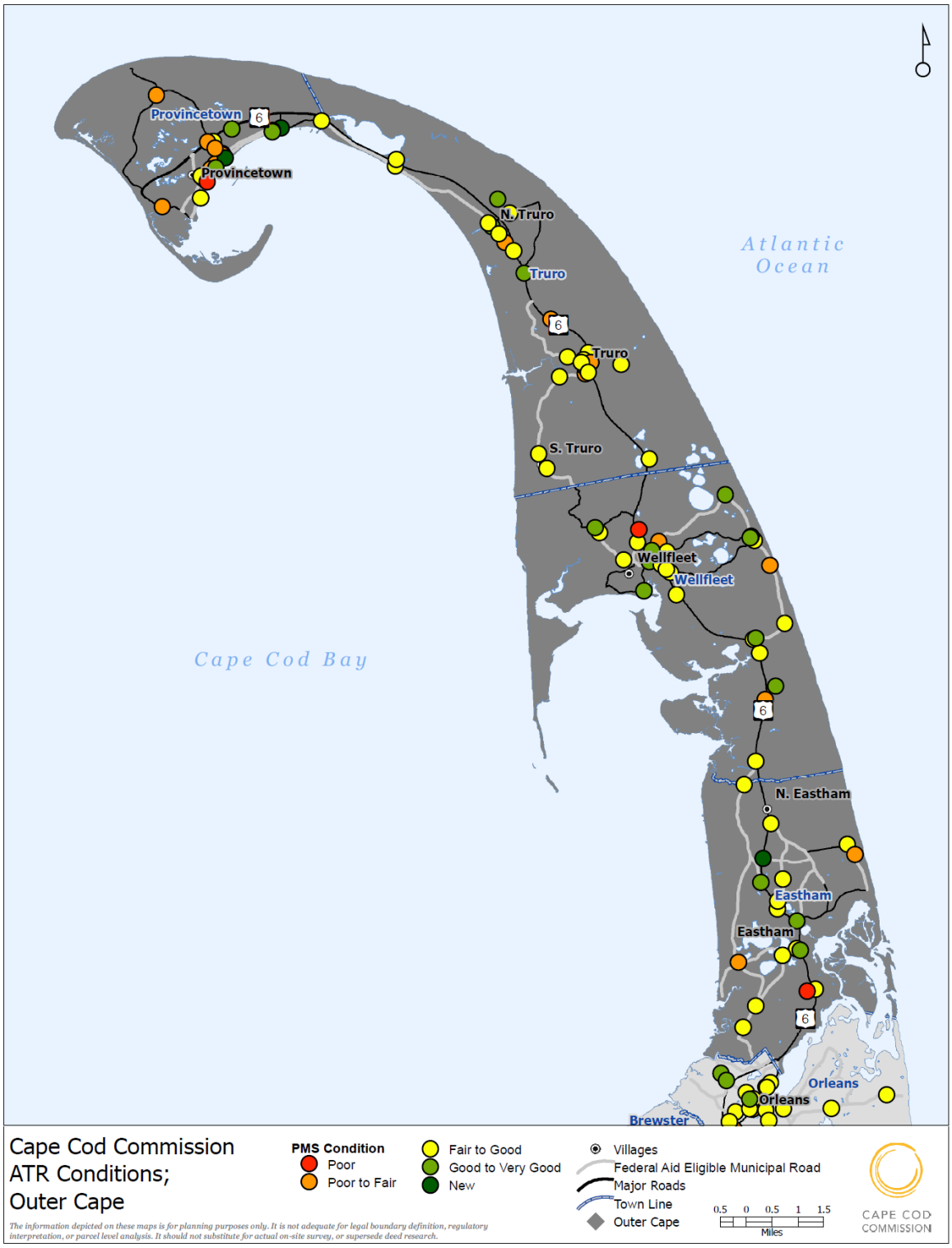

FIGURE 12 - 2011-2013 PAVEMENT CONDITIONS AT ATR LOCATIONS: OUTER CAPE

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RECOMMENDATIONS FOR ACHIEVING IMPROVED PAVEMENT CONDITION

The pavement deterioration curve shown in Figure 1 demonstrates the advantages of maintaining good roads in order to avoid expensive rehabilitation and reconstruction. For each level of Pavement Condition there is a corresponding Pavement Condition Index (PCI) – indicated by the column "PCI Start" in the table below.

By plotting the PCI for each condition level on the deterioration curve we are able to estimate the PCI after 5 years (this number corresponds to the 5-year "time bands" used in the Regional Transportation Plan for programming transportation projects). This is indicated by the column "5 Year – PCI No Repair" in the table below.

Repair strategies for each pavement "Starting Condition" vary according to starting PCI. For example, pavement currently categorized as "Good" or better (PCI greater than 89.0) may undergo "Maintainance" (e.g. crack sealing, cleaning catch basins, etc.) with an associated modest cost per mile. Pavement currently categorized from Fair to Good (PCI of 80.5) would undergo "Rehabilitation" and a higher cost and pavement below Fair condition (PCI below 65.5) would require the most expensive repair of "Reconstruction." The estimated costs per mile for each repair strategy were originally estimated by the Old Colony Planning Council.

On average, pavement categorized as Good or above that is maintained would retain the same PCI. Pavement that is rehabilitated or reconstructed would on average achieve a PCI equal to "Very Good – Excellent" (PCI 96.5).

Therefore, it is possible to calculate a "Benefit" (i.e., the difference in the PCI between performing a repair and doing nothing). For example, if a segment of road is currently assessed to be at a PCI of 80.5 (Fair to Good) there are two possibilities: (1) rehabilitate the pavement resulting in an average PCI of 96.5 or (2) allow the pavement to deteriorate over the five year time span down to a PCI of 29.7. In this case, the benefit of performing the repair (i.e., rehabilitation) is calculated to be the difference from 96.5 minus 29.7, or 66.8.

By relating the PCI Benefit of performing roadway repairs to the repair cost per mile, it is possiblible to calculate a Benefit/Cost ratio. These ratios are shown in the right-most column of the table below. To make the comparisons easier to review, the Benefit/Cost ratio of all of the pavement conditions have be factored by 10,000.

TABLE 7 - CHANGE IN PAVEMENT CONDITION – IMPROVEMENT STRATEGY

STARTING CONDITION	PCI START	5 YEAR - PCI NO REPAIR	REPAIR STRATEGY	REPAIR COST PER MILE	5 YEAR PCI REPAIR	PCI BENEFIT	BENEFIT / COST (SCALED BY 10,000)
Very Good to Excellent	96.5	83.6	Maintenance	$35,000	96.5	12.9	3.69
Good to Very Good	89.0	54.6	Maintenance	$45,000	89	34.4	7.64
Fair to Good	80.5	29.7	Rehabilitation	$100,000	96.5	66.8	6.68
Poor to Fair	65.5	22.2	Reconstruction	$550,000	96.5	74.3	1.35
Poor	27.5	16.6	Reconstruction	$554,000	96.5	79.9	1.44

The table above indicates that the most cost-effect repair strategy would be focused on performing maintenance on “Good to Very Good” roads with an estimated Benefit/Cost of 7.74, closely followed by performing rehabilitation on “Fair to Good” roads with an estimated Benefit/Cost of 6.68.

As a matter of policy, it is also recommended that funds be reserved to reconstruct a subset of “Poor to Fair” and “Poor” Roads.

The Cape Cod MPO is committed to exploring improved pavement management strategies and techniques to help optimize investment and achieve maximum improvement in overall PCIs.

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CONCLUSION/RECOMMENDATIONS FOR PMS ENHANCEMENT

During FY 2015, Cape Cod Commission staff will continue advance PMS activities throughout the 15 towns of Barnstable County. Efforts will continue such as:

- Identify individual towns' methods for pavement condition evaluation and programming for improvements
- Identify "gaps" in pavement condition information on Municipally-owned Federal Aid eligible roadways – and – prioritize and implement CCC data collection activities on these roadways
- Improve CCC skills in performing pavement evaluations
- Analyze local communities' bid prices to develop Cape-specific improvement costs of various pavement conditions

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