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Channel Usage Research and Analysis

FINAL REPORT
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Submitted by

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16. Abstract
The NJDOT/OMR (Office of Maritime Resources) emergency response to Superstorm Sandy expedited the development of an asset management system to more efficiently manage NJ's Marine Transportation System. Storm response efforts included a preliminary economic value and vessel usage evaluation for most of the State's channels. Vessel usage was determined in part by compiling data on the availability of waterway services such as slips per marina per channel, residential docks per channel, boat ramps per channel, etc. However, usage is known to vary depending on numerous factors including but not limit to: weather, time of year, origin/destination, size and type of vessel, and availability of alternative routes. Actual vessel count data is required in order to validate the data that was collected and provide a more defensible assessment of actual channel usage. The objective of this research is: 1. To develop and implement a reliable, quality-based scientific method or SOP (Standard Operating Procedure) to efficiently and accurately collect vessel count information, and 2. To collect vessel count information utilizing the selected method on approximately 214 state channels within the state's Marine Transportation System.

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EXECUTIVE SUMMARY

Cambridge Systematics, Inc. and Greenman Pederson, Inc. (the "research team") undertook research on alternative methodologies to count and classify vessels on New Jersey's Marine Transportation System. The research approach consisted of the following steps:

- The research team conducted a literature search to determine what vessel count and methodologies had been performed by state Departments of Transportation (DOTs) and other organizations responsible for maintaining and patrolling marine transportation systems in the U.S. and abroad;
- The research team screened and evaluated potential vessel count methodologies to determine which might be suitable to employ on New Jersey's State Channels; and
- The research team conducted a pilot test of alternative methodologies in the field at four locations around the state on Saturday, August 17, 2013.

The field tests compared four vessel count and classification methodologies:

1. Manual observations;
2. Manual observations combined with still photos of each vessel;
3. Video collection using Miovision's Scout Video Collection Units, combined with manual post-processing of video footage; and
4. Aerial photography collected by SkyComp, Inc.

Field tests of the first three methodologies were conducted from sunrise to sunset on a Saturday in August 2013. Due to the costs associated with aerial photography, the research team worked with SkyComp, Inc. to conduct a test over a shorter period of time to provide enough data to be able to compare the capabilities and results of aerial counts to the other three ground-based count methodologies.

The pilot tests of the four methodologies yielded the following results:

- **All four methodologies yielded similar vessel counts.** All four methodologies yielded similar results, with a maximum of variance of 7 vessels (3.2 percent) between the highest and lowest counts at the four locations across all the methodologies tested at each. (The vessel counts collected by aerial photography were compared to ground-based counts over a consistent time period.) The acceptable margin of error for any given methodology is a policy issue that will have to be determined by NJDOT when more data are available from future field tests.
- **Only ground-based counts are able to provide reliable vessel classification data at a reasonable cost.** Although technologies do exist today to capture high-resolution images from the air, the expense associated with high-resolution aerial photography (related to in-air time and post-processing of images after the flights) would be make this method cost-prohibitive. Methods involving still photo or video capture provide data that can be archived for future validation and verification.

- **More information is needed regarding variables that could affect accuracy and precision of count methodologies.** The pilot tests were all conducted on the same day in the peak season (a Saturday in August) and in ideal weather conditions (sunny with few clouds in the sky). Future research will be needed to determine the impacts of clouds, rain, wind, temperature, or other weather variables on the accuracy and precision of each of the four methodologies and how these variables affect the number of vessels in the water on a given day. The research team speculated that even a partly cloudy day could obscure the study area and reduce the effectiveness of aerial photography. On a rainy day, cloud cover could make aerial photography impossible, and water droplets on a still camera or video camera lens could reduce the effectiveness of those methodologies. Fog could render all four of the count methodologies ineffective.
- **More information is needed regarding variables that could affect count and type of vessels in a channel on a given day.** Weather almost certainly impacts the number and type of vessels in a given channel on a given day, but the magnitudes of the impacts of weather conditions and correlations between weather and non-weather variables are unknown. Logistical needs dictate that vessel counts must be scheduled in advance, but ideal weather conditions cannot be guaranteed. Having a better understanding of the extent to which various weather variables impact vessel use could allow NJDOT to apply correction factors to future vessel counts conducted in less-than-ideal weather conditions.
- **More information is needed to determine applicability of the methodologies to field conditions at all 214 State Channels.** The channels selected for the pilot tests were deliberately chosen so that the ground-based field teams could access a suitable vantage point and so that still images and video images both allowed post processors to discern vessel types across the widths of the channels. After a review of maps covering all 214 State Channels, the research team hypothesizes that there may be some channels that are too wide for a single person, still camera, or video camera to discern vessel types across the entire width of the channel, or even count vessels in some cases. Certain channels may not have a suitable shore-based vantage point because they are located in coastal marshes or because private property owners of land abutting the channels may not grant access to field surveyors for a sunrise-to-sunset count. Additional research and field work is needed to determine which channels may present access or visibility issues and what alternative means could be used to access the channels (e.g., one or more surveyors could be stationed in a boat at anchor in the channel). The Conclusions and Recommendations section of this report presents more detailed findings and recommendations for NJDOT with respect to classifying channels and matching appropriate count methodologies to channel types or attributes.

As a result of the information gleaned from the literature search and experience gained in the pilot field tests, the research team has the following recommendations. NJDOT should:

Develop a classification scheme for state channels, taking into account channel width, the function of the channel in New Jersey's waterway system, and whether one

or more publicly-accessible and technically suitable vantage points are available on the shoreline. This classification scheme also could include information already collected by NJDOT that could indicate the potential demand for use of the channel, which is as important or possibly more important than use data in determining the value of the channel to the state's marine transportation system. The Conclusions and Recommendations section of this report contains additional details about a potential classification scheme.

Conduct additional tests in a wider range of field conditions to determine (a) which variables affect the accuracy and precision of each count methodology, and to what extent, and (b) which variables affect the use channels by vessel type. Additional data also can help NJDOT determine how often count and classification data need to be collected for each channel or type of channel in order for the samples to provide statistically-valid data. A list of specific variables to test is contained in the Conclusions and Recommendations section.

Develop a set of factors to correct for variables that affect vessel counts and classifications so that count and classification data can be normalized depending on when, where and under what weather conditions the count was conducted. In order to develop these factors, NJDOT will need to conduct additional tests in a wide range of field conditions, on different days of the week and at different points throughout the year.

Develop a pre-survey field guide and checklist to match suitable count methodologies to known field conditions at each channel (including the weather forecasted for the survey day) and inform logistical preparations. For example, given information about physical conditions at each of the 214 State Channels and the weather forecast, NJDOT and its contractors could determine which methodologies would be most appropriate for the location, where there are publicly-accessible locations to station a field surveyor or set up a Miovision camera, and whether more than one surveyor and/or camera would be needed.

Develop a Marine Transportation System data collection program that establishes approved methodologies, procedures, collection techniques, and a proposed channel collection schedule.

All of these recommendations are focused on improving NJDOT's ability to collect channel count and classification data. However, NJDOT also should what information in addition to channel count and classification data is needed to support asset management-related decision making on New Jersey's Marine Transportation System.

BACKGROUND

The NJDOT Office of Maritime Resources (OMR) emergency response to Superstorm Sandy highlighted the importance of developing an asset management system to more efficiently manage New Jersey's Marine Transportation System. Storm response efforts included a preliminary economic value and vessel usage evaluation for most of the

State's channels. Vessel usage was determined in part by compiling data on the availability of waterway services such as slips per marina per channel, residential docks per channel, boat ramps per channel, etc. However, usage is known to vary depending on numerous factors including but not limit to: weather, time of year, origin/destination, size and type of vessel, and availability of alternative routes. Actual vessel count data is required in order to validate the data that was collected and provide a more defensible assessment of actual channel usage.

OBJECTIVES

The primary objective of this research is to help NJDOT develop and implement a reliable, repeatable, and verifiable method or SOP (Standard Operating Procedure) to collect vessel count and classification information by time of day. The research involved field tests of several approaches that could be applicable to a broader statewide effort to collect vessel count information utilizing the selected method on approximately 214 state channels within the state's Marine Transportation System.

The study team was charged with collecting channel usage and classification data on a representative sample of the 214 state channels using a variety of methodologies so that results can be compared and guidance can be provided for future data collection efforts.

INTRODUCTION

Cambridge Systematics, Inc. (CS) and Greenman Pederson, Inc. (GPI) partnered with NJDOT to conduct a literature search of current vessel count and classification methodologies used around the globe and recommend a short list of methodologies to be tested in a pilot effort in the Summer of 2013. CS and GPI then organized and conducted a field count and classification effort as a pilot of the methodologies to help gather information and experience in the field. This report summarizes the results of the literature search and lessons learned from the subsequent field tests.

SUMMARY OF WORK PERFORMED

At the direction of NJDOT, the research team investigated potential vessel count and classification methodologies and conducted a pilot of four methodologies in the field. Specific tasks included:

- Literature review;
- Screening and evaluation of vessel count methodologies;
- Pilot test of vessel county methodologies; and
- Report on the findings from the pilot data collection program and provide recommendations future vessel count programs.

The following sections provide a detailed review of the activities and analyses performed throughout this effort.

LITERATURE REVIEW

The study team conducted a literature search to determine what vessel count and classification methodologies had been performed by state DOTs and other organizations responsible for maintaining and patrolling marine transportation systems in the U.S. and abroad. This section contains a summary of the literature search, focusing on the following three topics:

- Vessel count methodologies
- Vessel classification schemes
- Model for estimating relative vessel volumes and vessel classifications

Vessel Count Methodologies

Agencies ranging from the U.S. Coast Guard and the U.S. Army Corps of Engineers to local municipalities have varying responsibilities for maintaining navigable waterways, regulating use of those waterways, and managing vessel traffic. A thorough search of the literature did not reveal any other agency in the U.S. or abroad that had attempted to establish a regular vessel count program on the scale that NJDOT has proposed. Most vessel counts are performed on an ad-hoc basis, typically related to a dredging project or a study of a new or existing bridge over a navigable waterway.[1]

Furthermore, in most U.S. states, the responsibility for maintaining non-Federal channels lies with local municipalities or private entities, meaning there is no central authority that has a need to conduct large scale vessel counts over a wide area. Therefore, ad hoc manual counts are the predominant method for counting vessels on navigable waterways in the United States and abroad. There are, however, several technologies under development that could provide vessel count and classification information on New Jersey's waterways in the future.

As part of a broader initiative to increase what is known as Maritime Domain Awareness (MDA), the U.S. Coast Guard is expanding its Nationwide Automatic Identification System (NAIS) to provide full coverage of the U.S. coast, and the Coast Guard is developing archiving functionality that will enable users to see the movements of any vessel equipped with an Automatic Identification System (AIS) over a specified time period. Currently, only commercial vessels and certain large passenger-carrying vessels are required to have AIS equipment on board, so the NAIS will not be useful to NJDOT in the short term to count recreational vessels on state channels, but there may

[1] See, for example, Lower CT River Valley Council of Governments, "Boat Monitoring at the Connecticut River, Niantic River and Shaws Cove Movable Railroad Bridges, Memorial Day through Labor Day, 2011", prepared for the Connecticut Department of Transportation, January 2013.

be a point in the future when a future generation of the NAIS could be enhanced to enable monitoring of most or all vessels in U.S. waters, including recreational vessels.[2]

The National Center for Secure and Resilient Maritime Commerce (CSR) at Stevens Institute of Technology has developed the Stevens Passive Acoustic Detection System (SPADES), which relies on unique acoustic signatures of maritime vessels to identify and track vessels. The SPADES system is an example of an emerging technology that could be used in concert with the NAIS to monitor and track vessels in New Jersey waterways. The CSR also is researching the potential application of high-frequency radar to track and monitor vessel movements.[3]

The literature review did reveal several efforts that have employed count methodologies that could be applicable to the channel types typically found in New Jersey. However, unlike manual counts and other methods that capture vessel movements over time (as well as direction, vessel classifications, and other attributes), most alternative methodologies are employed as part of a census of vessels and provide only a snapshot of activity at discrete times. For example, the National Marine Fisheries Service of the National Oceanic and Atmospheric Administration commissioned a study of maritime vessels using waterways in Everglades National Park.[4]The study team chose to use aerial photography to conduct a census of vessels in the Everglades, flying 83 missions over a one-year period and taking snapshots of waterways and access points. While the aerial snapshots did not provide full-day counts as desired by NJDOT, they did allow a single plan to cover a wide area and determine relative use of channels on a given day. Similarly, the State of Michigan Department of Natural Resources compared manual on the ground counts of commercial fishing vessels leaving ports to an aerial census of vessels in Lake Michigan.[5] The study concluded that "The interval-access [manual] survey design is appropriate for the Great Lakes fishery because it relies on limited, well-defined access sites." While the aerial census was found to be more precise than ground-based counts, the ground-based method was found to be more affordable for an occasional count.

Vessel Classification Schemes

A second area of research for this literature review concerns mechanisms for classifying vessels that are counted. Vessel classification information can be used to help NJDOT:

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[2] More information on the NAIS is available on the Coast Guard's website at: http://www.navcen.uscg.gov/?pageName=NAISmain

[3] See http://www.stevens.edu/csr/research/ for details.

[4] Ault, Jerald S., et. al. "Aerial Survey of Boater Use in Everglades National Park Marine Waters – Florida Bay and Ten Thousand Islands." Commissioned by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center,. Miami, Florida. December 2008.

[5] Roger N. Lockwood, Roger N. and Rakoczy, Gerald P. "Comparison of Interval and Aerial Count Methods for Estimating Boating Effort in Lake Michigan Statistical District MM-6." State of Michigan Department of Natural Resources, May 2005.

- Determine the minimum channel depth needed to accommodate marine traffic, and
- Estimate the value of vessel movements to help compare the benefits of dredging various channels.

Three sources were consulted:

1. The **U.S. Coast Guard** classifies vessels that are required to be registered nationally, but the Coast Guard's registration system has only one category for all recreational vessels. This study requires a disaggregated classification system that can distinguish between various subcategories of recreational vessels.

2. New Jersey State Law (NJR§ 13:82-8) requires all recreational vessels to be registered by the **New Jersey Motor Vehicle Commission (MVC)**. As part of the registration application, MVC requires vessel owners to provide the following information that is potentially relevant to vessel classification:

    - The hull material (wood, steel, aluminum, fiberglass, other);
    - The type of boat (open, cabin, houseboat, sail, auxiliary, canoe, other);
    - The type of propulsion (outboard, inboard, sail, inboard/outboard, electric, other);
    - The type of fuel (gas, diesel, other);
    - The make, model and year;
    - The length, measured from end to end over the deck excluding sheer; and
    - The type of use (livery, commercial or pleasure).

3. The **National Marine Manufacturers Association** publishes an annual statistical abstract with data on vessel sales and use.[6] The abstract uses the following classifications for vessel sales:

    - Outboard boats;
    - Inboard boats – Ski/wakeboard boats;
    - Inboard boats – Cruisers;
    - Sterndrive boats;

[6] National Marine Manufactures Association Center of Knowledge, "2012 Recreational Boating Statistical Abstract." Published 2013.

- Canoes;
- Kayaks;
- Inflatables;
- Personal watercraft;
- Jet boats;
- Houseboats; and
- Sailboats.

The NMMA also has a long list of definitions and descriptions of motorized boats that is not relevant to this study.

Models to Estimate and Project Vessel Count and Classification Data

As part of the development of a data collection program to support a broader asset management system for New Jersey's Marine Transportation System, NJDOT may wish to have a set of factors to, for example:

- Estimate vessel counts for a full day when less than a full day's data are available;
- Normalize observed data based on certain factors that may affect vessel counts by class on any given day (for example due to weather or whether the count takes place on or near a holiday weekend);
- Project vessel counts by class in the future, for example when planning for special events.

Although the literature search did not reveal a rigorous investigation of the factors that affect vessel counts on waterways, based on a review of the reports mentioned above, the following factors are hypothesized to affect vessel counts:

- Population of vessels within a certain radius of the channel (where the radius would have to be determined after additional research and data collection);
- Number of vessels using nearby boat launches;
- Time of day;
- Day of week (weekend vs. weekday);
- Proximity of Memorial Day, 4th of July, and Labor Day;
- Proximity of special events, such as boat shows and fishing contests;

- How far into the season the survey takes place (a proxy for boater enthusiasm and hours of sunlight);
- Weather (actual and forecast temperature, cloud cover, wind, and precipitation); and
- Time of day at which high and low tides occur.

Additional factors that may affect the counts in certain vessel classifications include:

a) Channel depth;

b) Channel width; and

c) Presence of vertical clearance constraints and obstructions, including movable and fixed bridges.

SCREENING AND EVALUATION OF VESSEL COUNT METHODOLOGIES

Based on best practices and applicable technologies for conducting roadway traffic counts in New Jersey, the following methodologies were considered for the pilot data collection effort:

- Manual (paper-based);
- Manual with still photo backup;
- Video; and
- Aerial photography.

Table 1 shows a comparison of the pros and cons of these four alternative vessel count methodologies.

Recommended Vessel Count Methodologies for Pilot

Although there were questions about the ability of aerial counts to determine vessel classification and whether the video data capture technology would produce images at a resolution that would allow for counts and classifications, the study team determined that these two methodologies should be tested in the field along with manual counts. The study team developed a pilot data collection plan that would enable the various methodologies to be tested at multiple sites to allow for comparison and validation of results.

Table 1 – Comparison of count methodologies (pre-pilot)

Count Methodology	Manual Observation	Manual with Still Photo	Video	Aerial Photography
Basic data (volume, direction, time of day)	■	■	■	■
Origin-Destination information	Direction Only	Direction Only	Direction Only (for ground-based video)	Full O-D Data (see note)
Classification data	■	■	■	TBD
Reliability	TBD	TBD	TBD	TBD
Replicable (all 214 channels)	TBD	TBD	TBD	TBD
Cost of field data collection	Between video and aerial	Between video and aerial	Lowest	Highest
Post-Processing Required	■	■	■	■
Ability to save raw data and use QA/QC to compensate for human error	Data collection depends on accurate entry; no ability to review or verify counts	Classification can be verified by reviewing photos, but photos must be taken and images must be clear	With archived video, both count and classification data can be reviewed and verified	Archived aerial photos can be reviewed and count data verified
Ability to archive data	(counts only)	■	■	■

Note: SkyComp, Inc. has developed a methodology through which multiple planes flying over the same area can capture enough images over time (every two seconds over 40 minute sets) to enable SkyComp to determine origins and destinations of a sample of highway vehicles crossing pre-defined screen lines on the roadway network. Previous study areas have covered up to a 5 mile radius, including examples like a toll plaza and adjoining ramps or an urban street grid. This methodology has not been tested for a marine environment in which vessels are more free to move in space.

Recommended Vessel Classification Scheme for Pilot

Based on the various vessel classification schemes in use, the following classifications were recommended for use in the initial pilot tests to be performed in the field. These classifications reflect a combination of what is used by MVC and industry sources and what characteristics can reasonably be distinguished by a trained observer:

1. Personal watercraft
    - Canoes, kayaks and other nonmotorized vessels
    - Jet skis, waverunners, and other motorized personal watercraft
2. Small motorboat: No cabin or small cuddy-cabin:
    - Runabouts, bowriders, towboats
    - Small center-console fishing boats
3. Large motorboat: More than one deck
    - Cabin cruisers with significant below-deck space
    - Yachts with multiple decks, portholes, etc.
4. Larger fishing boats (charter boats)
5. Small sailboat: Single mast, no cabin
6. Medium sailboat: Single mast with cabin
7. Large sailboat: Two or more masts and/or more than one hull

In addition, where possible, the study team proposed to indicate if a vessel had obvious commercial value. For example, the following types of vessels could be considered to have commercial value:

- Rental vessels, including personal watercraft (e.g., those traveling in groups or those with recognizable markings);
- Water taxis and small ferries; and
- Charter vessels.

PILOT DATA COLLECTION PROGRAM

Preparation for Pilot Data Collection Effort

The project team prepared for the pilot data collection as follows:

- NJDOT Office of Maritime Resources staff suggested a long list of potential count locations to the research team.

- The project team reviewed aerial photographs of each of the channel locations and met with NJDOT Office of Maritime Resources staff to discuss issues associated with conducting counts at each potential location. The meeting resulted in a short list of sites for conducting the pilot tests.

- The research team visited each site on the short list to determine the best data collection methodology to be used and to determine the most suitable location for equipment and field count staff. One of the channel locations was not visually accessible via public property. The NJDOT Office of Maritime Resources arranged for the research team to use the back yard of a private residence to perform the count.

- Prior to the pilot test, the research team performed a preliminary field test at Lake Hopatcong located in Sussex County to ensure the equipment and technology would perform and provide useful vessel data. The Lake Hopatcong location was chosen due to its proximity to the home of the member of the research team responsible for overseeing the pilot tests in the field.

- The research team and NJDOT Office of Maritime Resources coordinated with and notified local officials and police regarding the vessel counts. All were provided with an NJDOT project authorization letter as well as a 24/7 contact information.

- The research team organized a training session for staff who would be conducting the field counts to familiarize staff with count equipment and procedures and to review vessel classification categories. The training session was intended to improve reliability of data collection and reduce discrepancies in vessel classification data, particularly given the subjective nature of the vessel classification scheme. Staff were trained to classify vessels using a standardized set of categories, and photos of examples of vessels in each category were provided to the counters as part of their field manuals.

Overview of Pilot Test Procedures and Locations

Vessel classification counts were performed at five (5) NJDOT-selected channels on Saturday August 17th, 2013 from 6:00 AM to 8:00 PM. In the field (for manual counts) or during post-processioned (for video and aerial counts), personnel noted the vessel classification and the directional of travel as a vessel crossed a pre-determined screen line. The following five locations were surveyed::

1. Gunners Ditch – Brick Township, Ocean County
2. High Bar Harbor - Long Beach Township, Ocean County
3. Liberty Thorofare - Beach Haven Borough, Ocean County
4. St. George's Thorofare - City of Brigantine, Atlantic County
5. Spicer's Creek - Cape May City, Cape May County

Tested Data Collection Methodologies

Three (3) methods of data capture (in addition to traditional still digital photography) were tested during this count including classified manual collection using GPI field staff, aerial photography collection using SkyComp, Inc. and video collection using Miovision's Scout Video Collection Unit. Table 2 shows which count methodology was used at each location.

Table 2 – Count Methodology Used at Each Count Location

Location	Manual Observation	Manual with Still Photo	Video	Aerial Photography
Gunner's Ditch	■			
High Bar Harbor	■			
Liberty Thorofare	■			
St. George's Thorofare	■	■	■	■
Spicer's Creek	■	■	■	■

Classified Manual Counts

Field count staff traveled to all five locations to visually count and classify the types of vessels that passed a pre-determined screen line in each designated channel. Each field staff person used an electronic count board formatted to collect vessel counts by direction of movement and by classification. In some cases, due to the distance of the channel from the staff's view point, they used binoculars to identify the vessel classification and direction. For reporting purposes, the raw counts were aggregated into both 15 minute and 1 hour intervals. Although the accuracy of the raw data could not be verified after entry, the raw and aggregated data sets were reviewed as part of a quality assurance and quality control process to ensure there were no outstanding and unreasonable results.

Manual Counts with Still Photography

At St. George's Thorofare and Spicer's Creek channels the field staff conducted manual counts as described above, and they also took digital photographs and recorded the registration numbers, home port, direction of travel and time of as many vessels as possible that passed through the channel. A vessel log sheet was generated that included the vessel class, registration number, direction of travel, time, home port (city and state) and the photo identification numbers. If a photograph was taken that included multiple personal water craft (motorized and non-motorized vessels) then the number of vessels and people were noted next to the photo identification. Quality assurance and quality control (QA/QC) was performed in the office on the digital photographs to verify the accuracy of the vessel classification and registration numbers recorded in the field.

Video Photography

The project team utilized Miovision Scout Video Collection Unit (SVCU) to capture video photography, and then analyze and generate classified vessel count data based upon these records. The SVCU's, which each consists of a mounting pole, camera with standard definition video resolution of 720 by 480 and battery pack, were installed and calibrated to capture video imagery from 6:00 AM to 8:00 PM at the Spicer's Creek and St. George's Thorofare channels.

A member of the field count team was present at each location to monitor the unit and ensure any issues were immediately addressed. The units were installed as close to the channels as possible to ensure the highest quality of video was captured. The video imagery analysis/reduction was accomplished by uploading the imagery to the Miovision website so the proprietary imagery could be converted to MP4 video files. Once the files were converted, a technician viewed all imagery and recorded the vessel class, direction and time into a table. The data were then aggregated into both 15 minute and hourly intervals. QA/QC was performed to check the vessel data entered into the table.

Aerial Photography

SkyComp, Incorporated is an aerial photography firm located in Columbia, MD that specializes in documenting traffic flow parameters. SkyComp assisted the project team by capturing aerial photography on August 17th between the hours of 6:00 AM and 8:00 PM. The flight time was divided between St. George's Thorofare and Spicer's Creek channels due to their close proximity and to maximize the amount of imagery captured during the count period. The plane flew at an altitude of 5,500 feet over Spicer's Creek and 7,500 feet over St. George's Thorofare. Imagery was captured approximately every 30 seconds from the circling aircraft and coverage was only interrupted for aircraft refueling every 3-4 hours. The data analysis/reduction was accomplished by reviewing the imagery and counting vessels that crossed an imaginary line in the channel and recording the counts into 15 minute intervals by direction. SkyComp and the study team performed QA/QC on the collected data to ensure the counts were accurately recorded and aggregated into 15 minute intervals.

Pilot Field Notes

The following is a summary of the data collection efforts that took place at each of the five (5) vessel count channel locations from 6:00 AM to 8:00 PM on August 17th, 2013. All locations had two (2) field staff working in split shifts from 6:00 AM to 1:00 PM and 1:00 PM to 8:00 PM utilizing electronic count boards and binoculars to collect and classify vessel data. The weather conditions were sunny and averaged 78 degrees.

Gunners Ditch

The Gunners Ditch channel is located in Brick Township, Ocean County. Gunner's Ditch and the parallel Intracoastal Waterway Channel function as north-south connectors, with the Metedeconk River, Beaver Dam Creek, Bay Head Harbor, and the Manasquan River (via the Point Pleasant Canal) to the north and Barnegat Bay to the south.

Field staff conducted counts from Traders Cove Marina, just south of Gunners Ditch. The methodology chosen for this location was a classified manual count due to the sight distance from the marina which was approximately 2,400 feet or 0.47 miles. Field staff noted that the Gunners Ditch channel appeared to get more use than the Intercostal Waterway channel. One field staff person noted that a local resident told him that most boaters avoid using the federal channels due to regulations.

High Bar Harbor

The High Bar Harbor channel located in Long Beach Township, Ocean County. This channel is the access route to residential docks and boat slips located in the Viking Village development, a coastal residential community at the north end of Long Beach Island near Barnegat Inlet.

Vessels using the High Bar Harbor channel were counted from a private residence located at 46 Meadows Lane within Viking Village. Due to the location of the channel the count could not be collected from public property. This count location required some coordination between the NJDOT Office of Maritime Resources and the property manager of Viking Village. The methodology chosen for this location was a classified manual count due to the sight distance from the private residence which was approximately 470 feet. Aside from the absence of suitable, publicly-accessible site to collect data, no other issues were reported at this location.

Liberty Thorofare

Liberty Thorofare is located in Beach Haven Borough, Ocean County. The channel is used to access a marina and docks associated with private residences in Beach Haven Borough. Both ends of the Thorofare connect to Little Egg Harbor, so the Thorofare can be used by through vessel traffic as well.

Vessels using Liberty Thorofare were counted from the terminus of Amber Street. The methodology chosen for this channel was a classified manual count due to the sight

distance from Amber Street which was approximately 450 feet. Field staff noted that a large school of small sailboats passed through the channel leading him to believe that they were part of a sailing school or camp located within the area. No issues were reported at this location.

St. George's Thorofare

St. George's Thorofare located in the City of Brigantine, Atlantic County. The channel connects directly to Absecon Inlet across from Atlantic City. There is a designated safe harbor refuge in St. George's Thorofare Bay for vessels to anchor during storms, there are private docks and slips in the Bay, and the Bay is a popular destination for day boaters from around the region, including tourists who navigate personal watercraft rented in Atlantic City across Absecon Inlet to the Bay. Brigantine Beach, where the counts were conducted, is a popular recreation area where personal vehicles are allowed on the beach. A mix of fishers, sun bathers, and boat watchers congregate on the beach.

Vessels using St. George's Thorofare were counted from Brigantine Beach at the mouth of the Thorofare. All data collection methodologies were chosen for this channel due to the accessibility and distance from the beach to the channel, which was approximately 100 feet. In addition to a manual classification count, field staff captured a still photograph of each vessel with a digital camera and recorded the vessels' registration numbers and ports of call, if available. The Miovision SVCU also was deployed for the entire day, and SkyComp captured aerial photography from 1:30 PM – 5:00 PM and 6:00 PM – 8:15 PM. Field staff reported that near the end of the day the tide was coming in and getting close to the vehicle and equipment. The tide never reached either, but this concern should be considered during planning and site set-up for future counts. The enumerator also noted that St. Georges' Thorofare was consistently active throughout the day. No issues were reported at this location.

Spicer's Creek

Spicer's Creek is located in Cape May City, Cape May County. There are several large marinas on Spicer's Creek with a range of vessels from small sailboats to large yachts.

Vessels on Spicer's Creek were counted from the terminus of Harbor Lane. All data collection methodologies were chosen for this channel due to the accessibility and distance from Harbor Lane, which was approximately 180 feet. In addition to a manual classification count, field staff captured a still photograph of each vessel with a digital camera and recorded the vessels' registration numbers and ports of call, if available. The Miovision SVCU was deployed from 7:45 AM – 8:00 PM, and SkyComp captured aerial photography from 5:45 AM – 8:30 AM and 9:00 AM – 12:30 PM. The Miovision camera was deployed late at this location. No other issues or concerns were reported at this location.

Summary of Pilot Data Collection Results

Of the five channels at which data were collected, Gunner's Ditch had the highest number of observations , totaling 1,125 vessels. Directionally, the distribution at this location was balanced, with 541 vessels traveling in the northbound direction and 584 vessels traveling in the southbound direction. The vessel volume recorded at each channel appears to directly correspond to the physical and economic surrounding of the area. Table 3 summarizes the total number of vessels counted at each channel. The appendix to this report contains more detailed data.

Table 3 – Total vessel volumes by channel

Channel	Total Vessels
Gunner's Ditch	1,125
High Bar Harbor	321
Liberty Thorofare	273
St. George's Thorofare	362
Spicer's Creek	404

Table 4 shows the percentage of vessels per class taken from the classified manual count at each count location. The classification summary of the data indicates that the small motorboat class made up the highest percentage of vessels for four out of five channels, while the second largest class of vessels at most locations was the motorized personal water craft.

The small sailboat class was the most-observed class of vessels at Liberty Thorofare, due to the presence of sailing schools in close proximity to the channel. Field staff observed a large number of non-motorized personal water craft in Spicer's Creek, attributed to kayak and paddle board rentals and tours in the area.

Spicer's Creek and St George's Thorofare channels had all data collection methodologies implemented at various points during the collection period; therefore only volume was compared between these methods. A comparison between each of the methods collected indicating the difference in volume and the percent difference is shown in the following table. The volume in the tables below includes only the intervals when all three methodologies were deployed at the same time.

Table 4 – Percentage of vessels by class by channel

Channel	Small Motor boat	Medium Motor boat	Large Motor boat	Small Sailboat	Medium Sailboat	Large Sailboat	PWC Non-Motorized	PWC Motorized
Gunner's Ditch	71.64%	12.09%	0.27%	0.18%	0.98%	0.00%	1.51%	13.33%
High Bar Harbor	56.70%	1.56%	0.00%	2.18%	0.31%	0.00%	8.72%	30.53%
Liberty Thorofare	37.36%	2.20%	0.37%	47.62%	0.00%	0.00%	3.66%	8.79%
St. George's Thorofare	45.86%	5.80%	1.66%	0.00%	0.55%	0.28%	5.80%	40.05%
Spicer's Creek	48.51%	8.42%	2.97%	0.99%	1.24%	0.00%	29.70%	8.17%

Table 5 – Comparison of vessel volume by data collection method

Channel	Manual	Miovision	Aerial	Manual vs. Miovision Difference	Manual vs. Aerial Difference
St. George's Thorofare	218	221	211	3 (1.36%)	7 (3.21%)
Spicer's Creek	70	76	71	6 (7.89%)	1 (1.41%)

Slight differences in the volumes collected for each method could be due to the manual counter in the field pressing the electronic button a little earlier than when the vessel actually crosses the screen line used when post processing the aerial photography and the video imagery. When this happens, the numbers are not always included within the same 15 minute interval, and therefore the interval totals can fluctuate. The aerial photography post processing times may also show greater differences versus the manual and Miovision counts if to the hardware and software internal clocks are not in sync. When manual and Miovision counts are performed, the internal clocks of the electronic count board and the SVCU are synced with a cell phone to ensure the devices are placing data into the same 15 minute intervals.

At Spicer's Creek and St. George's Thorofare channels, still photographs captured by digital camera were utilized after the count to estimate the number of commercial vessels that passed through the channel during the count period. Field staff counted 21 commercial vessels crossing the screen line at Spicer's Creek, or 5.97 percent of the 352 vessels counted. A total of 10 commercial vessels crossed the screen line in St. George's Thorofare, or 2.83 percent of the 353 vessels counted. In some cases the

same commercial vessel may have passed through the channel a number of times and was counted each time. For example, a water taxi operating across Spicer's Creek and serving boats at anchor crossed the screen line numerous times over the course of the day, and a pontoon boat selling food and beverages crossed the screen line at St. George's Thorofare twice, once in the morning and once in the evening.

CONCLUSIONS AND RECOMMENDATIONS

A procedure to conduct vessel counts and classifications at regular intervals could be developed and implemented at relatively low cost statewide. Count and classification data associated with channel use could be combined with other existing NJDOT data, including information on the number and types of vessels docked in each watershed, to help NJDOT determine its asset management needs and priorities for the Marine Transportation System.

Research and field experience gained from the pilot data collection effort led to the following findings, conclusions, and recommendations.

Summary of Findings from the Pilot Field Tests

- **All four methodologies yielded similar vessel counts.** All four methodologies yielded similar results, with a maximum of variance of 7 vessels (3.2 percent) between the highest and lowest counts at the four locations across all the methodologies tested at each location (see Table 5). Accuracy alone is not a differentiating factor in choosing a count methodology. The acceptable margin of error for any given methodology is a policy issue that will have to be determined by NJDOT when more data are available from future field tests, but for purposes of determining relative magnitudes of vessels using a channel, a 3.2 percent margin of error most likely would not be a concern.

- **Only ground-based counts are able to provide reliable vessel classification data at a reasonable cost.** Although technologies do exist today to capture high-resolution images from the air, the expense associated with high-resolution aerial photography (related to in-air time and post-processing of images after the flights) would be make this method cost-prohibitive. Methods involving still photo or video capture provide data that can be archived for future validation and verification.

- **More information is needed regarding variables that could affect accuracy and precision of count methodologies.** The pilot tests were all conducted on the same day in the peak season (a Saturday in August) and in ideal weather conditions (sunny with few clouds in the sky). Future research will be needed to determine the impacts of clouds, rain, wind, temperature, or other weather variables on the accuracy and precision of each of the four methodologies and how these variables affect the number of vessels in the water on a given day. The research team speculated that even a partly cloudy day could obscure the study area and reduce the effectiveness of aerial photography. On a rainy day,

cloud cover could make aerial photography impossible, and water droplets on a still camera or video camera lens could reduce the effectiveness of those methodologies. Fog could render all four of the count methodologies ineffective.

- **More information is needed regarding variables that could affect count and type of vessels in a channel on a given day.** Weather almost certainly impacts the number and type of vessels in a given channel on a given day, but the magnitudes of the impacts of weather conditions and correlations between weather and non-weather variables are unknown. Logistical needs dictate that vessel counts must be scheduled in advance, but ideal weather conditions cannot be guaranteed. Having a better understanding of the extent to which various weather variables impact vessel use could allow NJDOT to apply correction factors to future vessel counts conducted in less-than-ideal weather conditions.

- **More information is needed to determine applicability of the methodologies to field conditions at all 214 State Channels.** The channels selected for the pilot tests were deliberately chosen so that the ground-based field teams could access a suitable vantage point and so that still images and video images both allowed post processors to discern vessel types across the widths of the channels. After a review of maps covering all 214 State Channels, the research team hypothesizes that there may be some channels that are too wide for a single person, still camera, or video camera to discern vessel types across the entire width of the channel, or even count vessels in some cases. Certain channels may not have a suitable shore-based vantage point because they are located in coastal marshes or because private property owners of land abutting the channels may not grant access to field surveyors for a sunrise-to-sunset count. Additional research and field work is needed to determine which channels may present access or visibility issues and what alternative means could be used to access the channels (e.g., one or more surveyors could be stationed in a boat at anchor in the channel).

Comparison of Pilot Data Collection Methods

Table 6 summarizes the lessons learned from the pilot field tests of four data collection methods.

Table 6 – Comparison of pilot data collection methods

Count Methodology	Manual Observation	Manual with Still Photo	Video	Aerial Photography
Set-up considerations and ability to replicate on all 214 state channels	• Need public access to shoreline or permission from private property owner • Difficult or impossible to employ in coastal wetlands where there are no accessible shorelines, except by boat • Ability to collect accurate count and classification data depends on channel width and weather conditions (e.g., rain or fog) • Could require more than one surveyor or camera for wide channels; additional post-processing required to reconcile data collected from multiple vantage points			Best results on completely clear days; partial cloud cover can obscure study area
Data collected	• Volume • Direction of travel • Time of day • Classification	• Volume • Direction of travel • Time of day • Classification	• Volume • Direction of travel • Time of day • Classification	• Volume • Time of day
Reliability	All methodologies produced similar results			
Cost of field data collection	$5,000 and up per location per day	$5,000 and up per location per day, depending on post-processing time	$3,000 and up per location	$8,500 per day, but one plane can survey multiple channels in close proximity
Ability to save raw data and use QA/QC to compensate for human error	Data collection depends on accurate entry; no ability to review or verify counts	Classification can be verified by reviewing photos, but photos must be taken and images must be clear	With archived video, both count and classification data can be reviewed and verified	Archived aerial photos can be reviewed and count data verified

- **Ground-based manual observations** were found to be reliable compared to other methodologies, but the data are not verifiable (particularly the vessel classifications recorded by count personnel in the field). Manual observations can be undertaken in many field locations, with the notable exceptions of channels with shorelines that cannot be readily accessed (e.g., in a marsh or where there is private property with

no public access) and channels that are too wide for a surveyor to see across the channel and classify vessels at a distance. The combined costs associated with labor, travel, equipment, and data post-processing are the second highest of all the alternatives, primarily due to the need to station an observer in the field from sunrise to sunset and provide relief at breaks. The price to just mobilize staff and perform a manual count is approximately $1,500 to $2,000 per location per 12-hour count based on current rates. However, the combined costs associated with labor, travel, equipment, data post-processing, analysis, and QA/QC makes manual data collection a costly data collection method

- **Manual observations combined with still photos** provide the ability to verify data recorded in the field for both counts and vessel classifications. Reliability suffers slightly as cameras can run out of battery or storage, camera lenses can be clouded or obscured by salt spray, and photo quality can be affected by weather and lighting conditions as well as the operator's skill in operating the camera. Manual observations can be undertaken in many field locations, with the notable exceptions of channels with shorelines that cannot be readily accessed (e.g., in a marsh or where there is private property with no public access) and channels that are too wide for a surveyor to see across the channel and classify vessels at a distance. The labor costs to perform a manual count with still photography is similar to manual counts without photography, but equipment and data post-processing can be more costly (although the additional QA/QC capabilities are beneficial in terms of reliability and validation of data). .

- **Ground-based video photography** has high reliability, within an acceptable margin of error for both vessel counts and vessel classifications compared to manual observations. Video cameras have limitations in field of vision and the distance (no further than 200-250 feet from the point of collection) at which vessels can be distinguished for purposes of counting, and this distance is significantly reduced if classification data are required. Therefore, video photography may not be a suitable methodology for counting and classifying vessels on all 214 state channels. Video photography can be archived, and therefore count and classification information can be verified and re-reviewed during and after post processing. The main costs associated with video photography are in setup (primarily travel time to the site at the start and end of the day) and post-processing of data. However, video photography, particularly for a sunrise-to-sunset field count, is more cost effective than manual observation. The price to mobilize the Miovision equipment, monitoring time, post processing and QA/QC time is approximately $3,000 per channel location.

- **Aerial photography** has high reliability, with an acceptable margin of error for vessel counts, but aerial photography cannot provide the information needed to classify vessels. Personal watercraft are the most likely vessel types to be missed in aerial photography. Aerial photographs can be archived, and counts can verified and re-reviewed during and after post-processing. The area covered in the frame of a single aerial photograph may encompass several channels; therefore, the cost of aerial photography can be reduced on a per-location basis if multiple channels are surveyed with one aircraft. However, the quality of aerial photographs can suffer

even on moderately cloudy days. The cost to mobilize a plane for the day, deliver the imagery and post process the data is $8,500, but can provide data for multiple locations (dependent upon the proximity of channels).

Recommendations

The research team has the following recommendations for NJDOT:

1. NJDOT should test all four alternative count and classification methodologies in a wider range of field conditions, including wide channels and channels without readily-accessible shoreline vantage points for manual observations or video photography, and also including a range of weather conditions (e.g., windy, cloudy, or colder days).

2. As part of the development of a data collection program to support a broader asset management system for New Jersey's Marine Transportation System, NJDOT should develop a model and set of factors to, for example:

    - Estimate vessel counts for a full day when less than a full day's data are available;

    - Normalize observed data based on certain factors that may affect vessel counts by class on any given day (for example due to weather or whether the count takes place on or near a holiday weekend); and

    - Project vessel counts by class in the future, for example when planning for special events.

    The following factors are hypothesized to affect vessel counts:

    - Population of vessels within a certain radius of the channel (where the radius would have to be determined after additional research and data collection);

    - Number of vessels using nearby boat launches;

    - Time of day;

    - Day of week (weekend vs. weekday);

    - Proximity of Memorial Day, 4th of July, and Labor Day;

    - Proximity of special events, such as boat shows and fishing contests;

    - How far into the season the survey takes place (a proxy for boater enthusiasm and hours of sunlight);

    - Weather (actual and forecast temperature, cloud cover, wind, and precipitation); and

- Time of day at which high and low tides occur.

Additional factors that may affect the counts in certain vessel classifications include:

a) Channel depth;

b) Channel width; and

c) Presence of vertical clearance constraints and obstructions, including movable and fixed bridges.

3. NJDOT should develop a channel classification scheme that would take the following into account:

   - The channel's geometry, including depth and width;
   - The presence of vertical clearance constraints and obstructions, including movable or fixed bridges;
   - The presence or absence of a publicly-accessible vantage point for conducting manual or video counts;
   - Whether the channel is in a low/no-wake zone or in a medium/high wake zone;
   - The channel's function in the state's marine transportation system (e.g., is the channel the access point to a watershed with a large population of vessels, is it a connector between two bays, is it on an important route to access an inlet to the Atlantic Ocean or a mooring field that is a place of refuge in a storm, and so on);
   - The population of and types of vessels docked in the channel's watershed or in watersheds that use the channel to access inlets and other important destinations; and
   - The share of transient vs. resident vessels using the channel.

4. NJDOT should determine what kind of data are needed and can be collected for each channel type and how often the data need to be refreshed. There may be circumstances in which vessel count data may be sufficient at a given site and classification is not needed. Origin-destination or direction of movement may be important data to collect on some channels in every count but more occasionally (or not at all) on others. Table 7 shows the types of data that can be collected in several circumstances where channel attributes a varied.

Table 7 – Summary of available data outputs by selected channel attributes

Channel Attributes	Data Outputs				
	Volume	**Vessel Classification**	**Digital photo archive**	**Video imagery archive**	**Database**
• Shoreline accessible • Sight distance 0 – 300 feet • No/low wake zone	■	■	■	■	■
• Shoreline accessible • Sight distance 0 – 300 feet • Medium/high wake zone	■	■	Limited (digital photos may not have resolution to capture registration info, and vessel classification may be difficult to discern)	■	Limited (vessel information)
• Shoreline accessible • Sight distance > 300 feet • Varying wake zones	■	Limited (possibility of greater human error in recording vessel class)			Limited (vessel information)
• Shoreline not accessible • Limited or no sight distance	■				

5. After completing steps 1 through 4, NJDOT should develop a Marine Transportation System data collection program with the following steps and elements:

    a) Based on the types of data that need to be collected, match appropriate count methodologies to channel types (see an example in Table 8).

    b) Develop a pre-survey field guide and checklist to match count methodologies to known field conditions at each channel (including the weather forecasted for the survey day) and inform logistical preparations. For example, given information about physical conditions at each of the 214 State Channels and the weather forecast, NJDOT and its contractors could determine which methodologies would be most appropriate for the location, where there are publicly-accessible locations to station a field surveyor or set up a Miovision camera, and whether more than one surveyor and/or camera would be needed.

    c) Develop a Request for Proposals (RFP) for firms to conduct counts on a specified set of channels using specified methodologies. The RFP should specify that counts must be collected from sunrise to sunset (unless NJDOT has the ability to model or extrapolate full-day counts by vessel class using a smaller sample of data) and that the contractor is responsible for ensuring they have proper equipment, transportation, and access to suitable vantage points on the shore of every channel to conduct the counts. The RFP should also specify that the contractor is responsible for training of field staff and for QA/QC on the data during post-processing. The contractor also should be responsible for providing still images or video photography that can be archived and used to verify and validate the data provided.

    d) Occasionally check and validate recorded data using archived photos and videos.

    e) Track channel-specific count and classification data over time to observe trends in use of the system and help make decisions about relative priorities of the channels.

6. To support post-processing, NJDOT should coordinate with the New Jersey State Motor Vehicle Commission to match vessel registration data collected in the field to attributes associated with that registration number, including vessel classification, age, and place of registry.

7. NJDOT should determine what information in addition to channel count and classification data are needed to support asset management-related decision making on New Jersey's Marine Transportation System.

Table 8 – Summary of preferred data collection methods by channel attributes

Channel Attributes	Classified Manual Counts	Manual Counts with Still Photography	Manual Counts with Record of Vessel Registration	Manual class count, Digital Photographs, and Record of Vessel Registration	Video Photography (Miovision)	Aerial Photography (SkyComp)
• Shoreline accessible • Sight distance 0 – 300 feet • No/low wake zone	■	■	■	■	■	
• Shoreline accessible • Sight distance 0 – 300 feet • Medium/ high wake zone	■	Limited (dependent on resolution of digital photos)	Limited (difficult to capture vessel information on fast-moving vessels)	Limited (dependent on resolution of digital photos; difficult to capture vessel information on fast-moving vessels)	■	
• Shoreline accessible • Sight distance > 300 feet • Varying wake zones	■ with binoculars	Manual class data only	Limited (vessel information)			
• Shoreline not accessible • Limited or no sight distance						■

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