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Enhancing Emergency Response

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Report Submitted to:

Chief Mark McDougall

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Abstract

The Nantucket Fire Department (NFD) faces not only the obstacles of every fire department trying to protect lives and property, but also the burden of an enormous summer population and no prospect of mutual aid. Accordingly, the goal of this project was to analyze the response times of the NFD in comparison with their goals and national standards, and recommend effective strategies to enhance response and prepare for the future growth. We conclude that congestion, long travel distances, and call concurrency slow response times. We recommend the Town builds a new fire station at the public safety facility with sufficient space for growth, invests in additional staff, and further examines the effects of satellite stations and forward deployment of resources at peak times.

Acknowledgements

We would like to thank our advisors, Dominic Golding and Stan Selkow, for their continuing support and guidance during this project especially concerning the health and wellness of our team.

We would also like to thank our sponsor liaisons, Chief Mark McDougall and Dr. Peter Morrison, for their assistance, hospitality and advice during our stay on the island. Numerous times they went out of their way to accommodate our requests and needs. We really appreciate everything that we have learned from them as this experience has unfolded. It has meant a lot to know how much impact we have had in such a short time on the island.

We would like to thank all of the firefighters for their insight on the project, a special shout out to Deputy Chief Ed Maxwell, Fire Alarm Superintendent Bob Bates, Fire Prevention Officer Liz Shannon, Captain Frank Hanlon, and Firefighter Matt Avis. Without them, we would have never gotten to experience the island in the way we did. As well as Chris Baldwin from the Omega Group for his assistance and expertise along the way. A special thanks to Nathan Porter and Mike Burns from the Nantucket Planning and Land Use Services for their valuable information on GIS software and traffic. We finally would like to thank Patty Roggeveen, Matt Mulcahy, Deputy Chief Charlie Gibson, Rick Atherton, and Gregg Tivnan for allowing us to interview them.

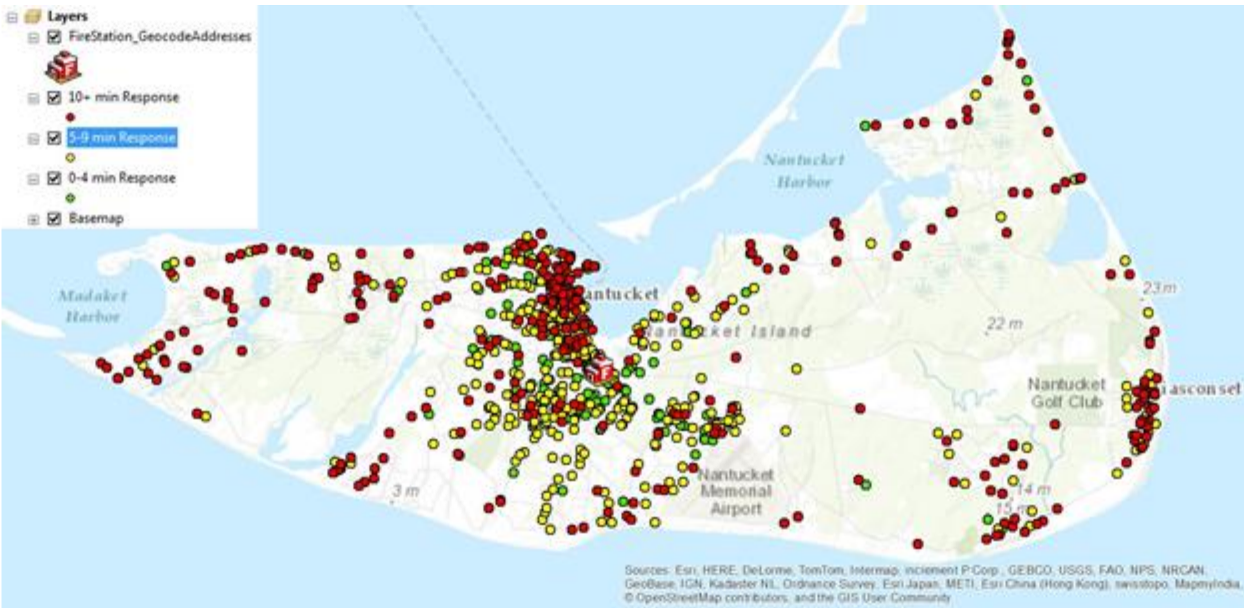
We hope that our work on this project really helped to build a strong foundation in aiding the Nantucket Fire Department get a new central station as well as decrease their response times in the future and help them to continue to protect and save lives and property on the island of Nantucket.

Executive Summary

Fire Departments are a vital public resource, and their response times are critical to public safety. Response times to fire emergencies is significant because of flashover, the point at which the fire becomes more dangerous and difficult to fight, which occurs within the first four to ten minutes of burning (Cote, 2008). Quick response to medical emergencies is also important because in an incident of cardiac arrest, CPR must start as quickly as possible. When responding to calls, the fire department can encounter an abundance of obstacles that increase response time. These include, but are not limited to, traffic, unpaved roads, multiple calls occurring at once, and distance to the incident. The Nantucket Fire Department (NFD) is presented with its own set of unique challenges, besides the ones normally faced by fire departments, as its isolated location as an island severely limits its ability to receive mutual aid. The Island of Nantucket also experiences population flux throughout the year as the summer months bring vacationers and summer homeowners alike which increases the island's population from approximately 10,500 in the off-season to around 56,000 people in the peak travel months. Thus, in the summer, the Nantucket Fire Department receives an increased number of calls and in turn a higher number of concurrent calls while not increasing the number of staff on duty.

Most of our analysis was on the call data from 2007 to 2013. The Nantucket fire department receives around 2500 emergency calls per year and this number is steadily increasing. During the summer months call volume almost doubles from the average off-season months, but the amount of staff that the NFD has remains constant.

The following map shows that in 2013, on Nantucket, 38% of all calls' response time fall under five minutes, while 78% fall under ten minutes. We focused a larger part of our analysis on identifying the factors that affected the 22% of calls where there response time was over 10 minutes.



We found that there were 3 major factors that impacted response times: distance, traffic, and call concurrency. Distance is the obvious factor and makes up the calls with high response times in the Madaket and Siasconset areas. When looking at a map of high response times, we expected to see the majority of those calls on the outer edges of the island but this was not the case. The most significant factor was traffic during the summer, which causes high response times to emergencies close to the station and in the downtown area, where a majority of the calls occur. We found that 40% of non-concurrent calls with a response time of 10 minutes or higher during the summer fell close to the roads deemed as highly congested. Both distance and traffic could be addressed by strategically placing a satellite station on the outskirts of town, so that the department would be in a position to more easily respond to calls both in and outside of town, without having to spend as much time avoiding traffic. Concurrent calls, defined as more than one call occurring at the same time, also affect response times, because they stretch the department's resources to the limit. At any given time, there are enough staff in the central station to comfortably respond to two concurrent calls - after this point, the department relies on call firefighters who may not be able to respond to a call. This leads to a slower response time to the third or subsequent concurrent calls. When looking at calls with a response time of 10 minutes or greater we see that 34% of them were concurrent calls. As there is nothing that can be done to prevent concurrent calls, the solution to this issue is for the department to hire more staff. The final factor that impacts response time is distance. Nantucket is a 14 mile wide island, so the centrally located station is approximately 7 miles away from any calls that occur in Madaket or Siasconset. Placing staff and equipment in satellite stations at these points in times of high call volume, rather than the current satellite stations which only house minimal equipment and no staff, would help mitigate this problem.

We also simulated the impacts on response times of placing satellite stations in different locations. This was done by comparing the estimated time of arrival given by Google for both the central station and the satellite station. From the simulations, we found three potential locations for satellite stations that each have their own advantages.

Through our analysis the group produced various solutions for the Nantucket Fire Departments obstacles of traffic, distance, and concurrent calls. Response times lengthened due to traffic could be addressed by strategically locating satellite stations or forward deployments, so that the fire department would not have to navigate congested downtown roads as much. Response times delayed by distance could also be controlled by satellite stations, but rather than being located in or near town they would need to be located on the outskirts of the island in the Siasconset or Madaket areas. Finally response times which have been delayed due to call concurrency can only be controlled by hiring more staff. The lack of adequate personnel causes the Nantucket Fire Department to reach the limits of its capabilities after only two concurrent calls. Hiring more staff would increase the NFD’s ability to respond to more calls happening at the same time.

Authorship

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Executive Summary	EB, NS, SS, CW	EB, NS, CW
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Literature Review		
Fire Departments	EB, SS	EB, NS, SS, CW
Federal and State Guidelines	NS	EB, NS, SS, CW
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**Note: EB = Emily Brecher, NS = Nate Sauer, SS = Sarah Smith, CW = Carson Wolf

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1.0 Introduction

Fire Departments are a vital public resource, and their response times are critical to public safety. Response time to fire emergencies is significant because of flashover, the point at which the fire becomes more dangerous and difficult to fight, which occurs within the first four to ten minutes of burning (Cote, 2008). Quick response to medical emergency is also important because in an incident of cardiac arrest, CPR must start as quickly as possible. When responding to calls, the fire department, which often includes Emergency Medical Services (EMS), can encounter an abundance of obstacles that cause an increase in their response time. These include, but are not limited to, traffic, unpaved roads, multiple calls occurring at once, and distance to the incident. The Nantucket Fire Department experiences even more challenges than most fire departments as it cannot receive mutual aid in a timely manner because of its isolated location as an island. The Island of Nantucket also experiences population flux throughout the year as the summer months bring vacationers and summer homeowners alike which increases the island's population from approximately 10,000 in the off-season to around 56,000 people in the peak travel months (Beliveau, Hesler, Jaskolka, & Sigety, 2010; Bureau, 2014; "National Fire Department Census Quick Facts," 2014).[1] Thus, in the summer, the Nantucket Fire Department receives an increased number of calls and in turn a higher number of concurrent calls. The department can comfortably respond to two calls simultaneously; however, more than two calls is beyond the Nantucket Fire Department's response capabilities and will result in delayed responses. In 2013, on Nantucket 38% of all calls' response time fall under five minutes, while 78% fall under ten minutes (see Figure 5).

The Nantucket Fire Department has already evaluated the best location for their current centralized station; however, little research has been done on response times from this location and how satellite stations might help them improve their response time to locations across the

[1] It is very difficult to properly estimate the population on Nantucket given its seasonal variation. Census data from April of 2010 states the islands population is 10,172 (Bureau, 2014). This would be considered the islands "off-season" or "year-round" population. There are only estimates using trash data provided by the Nantucket Department of Public Works to calculate approximate summer populations. The last calculations done of this sort occurred in 2010 and estimated approximately 50,000 people (Beliveau et al., 2010). However, due to a recent economic depression at the time, that estimation is thought to be lower than normal so 56,000-60,000 is a more accurate approximation.

island. The fire department is also looking for information on how the volume of emergency calls is predicted to grow in future years and if one centralized station will provide adequate service to meet this increased growth. This project has evaluated the best practices in the analysis of the call data and applied those practices to the Nantucket Fire Department's data. The group also conducted interviews with experts in the field of fire protection and GIS software along with several of the Nantucket firefighters and staff and other key stakeholders. Through careful analysis, the group drew several conclusions on obstacles faced by the Nantucket Fire Department and was able to recommend changes in operations, deployment strategies, and the location of facilities to enhance readiness and response.

2.0 Literature Review

Fire departments, some of which include EMS, across the United States strive to shorten their response times to emergency calls, any call that is not a complaint or inspection, as lower response times aid in saving lives and property. The critical window to extinguish a fire is before the fire reaches the flashover stage. During the flashover stage, all materials in the room reach a temperature in which total combustion occurs and the entire room is engulfed in flames. Flashover typically occurs in the first four to ten minutes of burning (Cote, 2008). Once a location reaches flashover, it is very likely that all victims are now deceased. It is also more dangerous for fire fighters to enter the structure because the fire is hotter, faster moving, and more difficult to fight (Cote, 2008). Thus, it is imperative that the fire service reach any fire as quickly as possible. Emergency Medical Services' (EMS) mission is just as time critical as a firefighter's. For example, in an incident of cardiac arrest where the patient has no blood flow to the brain, cardiopulmonary resuscitation (CPR) must be started as quickly as possible. If the patient receives CPR within the first four minutes of the onset of cardiac arrest, his or her chances of leaving the hospital alive are four-times greater than if CPR were delayed until after four minutes (Cote, 2008). The American Heart Association provides a timeline for cardiac arrest that highlights the need for swift response: If CPR is given within 4 minutes of a patient being in cardiac arrest brain damage is unlikely; CPR within 4-10 minutes of cardiac arrest means brain damage is probable; and CPR beyond 10 minutes of cardiac arrest means brain death is probable (Cote, 2008). Thus both the Fire Department and EMS look for any way to reach their destinations more quickly. The Nantucket Fire Department is unique as it must serve and protect a resort town that has both urban and rural areas and due to its lack of neighboring communities must rely on its own resources as mutual aid is not available.

2.1 Massachusetts Fire Departments

Response times vary from place to place depending on local conditions, such as population distribution, road conditions, and the proportion of the staff who are volunteers. The Commonwealth of Massachusetts has 359 fire departments ("National Fire Department Census Quick Facts," 2014). Of these fire departments, approximately 26.8% are staffed by all volunteer firefighters, 29.1% mostly-volunteer, 17.3% mostly-career and 26.8% all career

("National Fire Department Census Quick Facts," 2014). Fire stations are located in every town except for Mt. Washington, including rural, urban and resort towns (Kling, 2012). As shown in Figure 1, the proportion of volunteer firefighters is much higher in the less populous towns. Fire departments in each of these different types of towns face different kinds of problems in responding to emergency calls. Depending on the time of year, the Nantucket Fire Department falls into different categories of department types; however it is important to note that the fire department does not staff differently in the summer than the winter despite the increase in population and call volume.

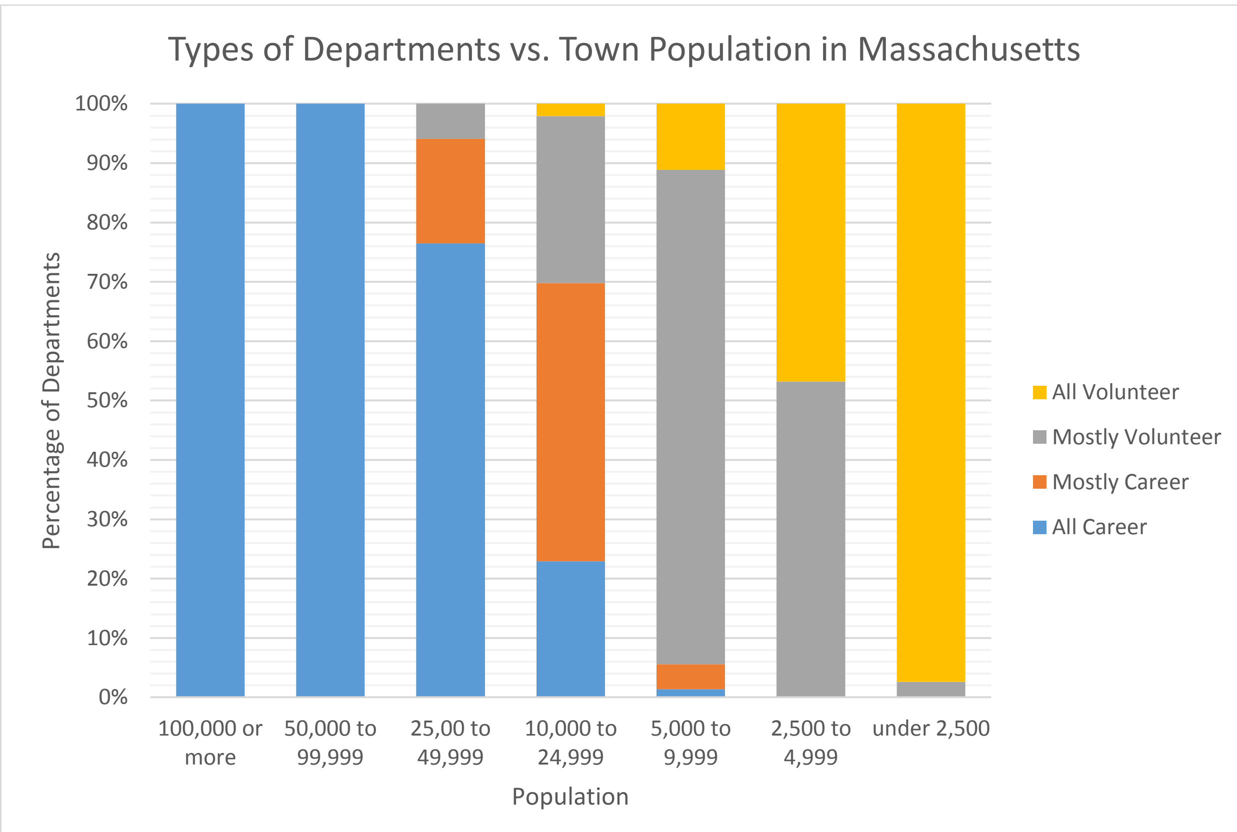


Figure 1 – Types of Departments vs. Town Population in Massachusetts
(Adapted from Carter and Hall, 2004)

2.2 Urban Fire Departments

An area is considered urban if the population density is more than one thousand people per square mile (NFPA, 2014). One would think that a larger staff would result in shorter response times as the department might respond to more concurrent calls at once. While urban fire departments tend to have more firefighters on staff than rural departments, long response times are not uncommon due to traffic congestion (Adams, Comoletti, Gamache, Hall, & Mieszala, 2007). Fire Chief Terry Sheets from Wysox Township, PA, noted that increased traffic congestion is delaying firefighters from getting to the scene of emergencies (Loewenstein, 2011). He says, “I think every fire department in the county is taxed because of (the need for) manpower and the (delayed) response time because of the traffic”(Loewenstein, 2011). At the Port of Tacoma in Washington State, the land and sea traffic is drastically increasing, making it more difficult for emergency vehicles to respond to calls (Martin, 2014). Michael Fitzgerald, Assistant Fire Chief of the Tacoma Fire Department, mentioned that emergency crews are often unaware when trains or heavy traffic will slow their response times until they try to arrive on scene to the Tideflats, which is the heart of the Port of Tacoma area. “As that area continues to develop, emergency response into and out of the Tideflats is becoming more and more difficult,” Fitzgerald said. “The Fire Department has become very concerned.”(Martin, 2014)

Fire departments across the world are taking different approaches to combat the impact of traffic congestion on response times. For example, the City of Tacoma is spending $600,000 to examine traffic patterns and emergency response on the Tideflats (Martin, 2014). The city would like to implement technology to manage the traffic problems and help route emergency crews around obstructions. The Fire and Police Departments of Burnaby, British Columbia, face a similar issue. Burnaby is home to more than 200,000 people and has many roads connecting to two major neighboring cities, Vancouver and Surrey; thus, traffic congestion is an everyday occurrence (Global Traffic Technologies). The City of Burnaby decided to implement a Global Positioning System (GPS) which would allow police and fire personnel to activate a priority green signal on any traffic light in order to alleviate congestion and get to the incident quickly, safely, and more smoothly. The GPS does not require line of sight to work, meaning crews can trigger signal changes at approaching intersections or even around corners (Global Traffic Technologies). Traffic congestion is an obstacle that almost all urban fire departments face that does not have a straightforward solution. Each department faces its own unique challenges and has its own techniques to arrive on scene at incidents most efficiently.

Large cities are home to high-rise buildings which have their own unique challenges that fire fighters face as opposed to low-rise buildings typical of smaller towns and rural areas ("High-rise buildings," 2014). These challenges include longer times and distances to the actual fire from the point of arrival, the need for unique evacuation strategies, and limited fire department accessibility ("High-rise buildings," 2014). Calls at high-rise buildings also require more firefighters on scene as these buildings usually contain more civilians and square footage to cover. While not pertinent to Nantucket, it is still important to note that urban fire departments face these challenges every day.

The types of firefighters on call vary as “career firefighters are found disproportionately in large communities” (see Figure 1); however some departments that are strictly all career departments “are full-time by day but call by night and/or on weekends” (John R. Hall, 2004). Twenty-five percent (90 of 359) of the fire departments in Massachusetts are true full-time departments which is substantially higher than the 12% national average (Kling, 2012). Urban fire departments typically have more full-time firefighters and larger budgets to cover the salaries and benefits of career firefighters.

2.3 Rural Fire Departments

Rural fire departments typically have longer response times than urban areas due to road conditions and the greater distances that vehicles must travel (Lee, 2013). On Nantucket road conditions slow response times dramatically since many roads are narrow, dirt roads with large potholes and overhanging vegetation, banking, and sharp turns that limit access for emergency vehicles. Rural communities are split into service coverage areas that are “designed based on travel times and distance from fixed service locations [as]…planning for the provision of emergency medical services is critical in rural areas because of the large service areas covered” (Lee, 2013). While helpful in many areas around the country, all calls on Nantucket are responded to by vehicles from the one central station. Rural departments face other challenges like “insufficient revenue, difficulty in recruiting employees and volunteers, natural barriers, and changing demographics” (Lee, 2013).

The percentage of volunteer firefighters tends to be higher in rural communities (see Figure 1), which increases response times (John R. Hall, 2004). Volunteer firefighters are typically not present at the station when a call comes in and they often need a significant amount of time to get to their post. Rural firefighters often face longer travel distances and narrow, twisting roads which inhibit emergency vehicle speeds and can add to the delays (Brett, 2012). Keeping the volunteer firefighters trained can be a big problem as it is “costly and time consuming” and many departments face very limited budgets (Brett, 2012). In Sonoma County, for example, “volunteer firefighters have been forced to do fundraisers to cover fuel costs and utility bills for their departments” due to budget shortfalls (Brett, 2012). The time spent raising money takes away from their time working and, if not enough money is raised, can result in inadequate equipment going to a call.

Some rural towns think that the money saved by having a volunteer fire department outweighs the safety risks of longer response times. It is estimated that “volunteer fire departments save local communities approximately $37 billion per year” (Buckman et al., 2004). Many local governments take the volunteer firefighters’ services for granted and “are not willing to assist with even the most basic expenses, such as appropriate safety gear, functional apparatus or station facilities” (Buckman et al., 2004). Despite this, volunteer firefighters are wanted “because of their diverse educational and employment backgrounds” and the fact that they “bring tremendous depth and diversity to any emergency scene based upon their regular jobs and expertise in their communities” (Buckman et al., 2004).

2.4 Resort Town Fire Departments

Resort towns present unique situations and challenges. A resort town is defined as an area where tourism is a large part of the local culture and the population swells during the vacation months. The population of Nantucket grows from approximately 10,000 in the winter months to roughly 56,000 in the summer, much like the town of Duck in North Carolina, a tourist location (Beliveau et al., 2010; Bureau, 2014; "National Fire Department Census Quick Facts," 2014).[2] This causes a strain on the local roads as the population increase brings a higher

[2] See Footnote 1 for information on how population is estimated on the island of Nantucket.

amount of vehicles on the roads and a rise in call volume stretches the department's resources further. This may result in longer response times as traffic and congestion slow emergency response vehicles. While the Duck Volunteer Fire Department (DVFD) and the Nantucket Fire Department are staffed in different ways, volunteer firefighters and call firefighters are run in very similar manners and face the same challenges including responding to a large variety of calls including brush and structure fires, hazardous and medical calls, motor vehicle accidents and surf rescue (Black, 2008). The DVFD performed a self-evaluation of their response times and other statistics and determined the best way to improve their overall service was to hire more firefighters, both career and volunteer (Black, 2008). They also concluded that if they educate the fire department's stakeholders, for example the town staff and community members, about the demands of the fire department, the DVFD would receive support to improve their current operations (Black, 2008).

Resort towns may also present other difficulties in terms of firefighting. This type of towns have a higher proportion of expensive properties, many of which may remain unused for long periods of the year (Brennan, 2012). Houses that are isolated or on private roads can burn unnoticed for long periods before the fire department is called (Daniel, 2006). Expensive houses may be equipped with alarms, but these systems are useless if the houses are located on private roads that are inaccessible to emergency equipment (Daniel, 2006). There are typically fewer fire hydrants in gated and wealthy communities as fire hydrants are often private and installed by a third party. These hydrants may be faulty or too distant from the site of the fire which means water must be trucked in (Daniel, 2006). As seen in Figure 2 below, each dark dot marks the location of a fire hydrant on the island of Nantucket. It is easy to see that hydrants are more frequent around the more populated town areas but outside those areas, the Nantucket Fire Department will need to allocate extra personnel and equipment in order to bring water to incidents outside of fire hydrant coverage areas.

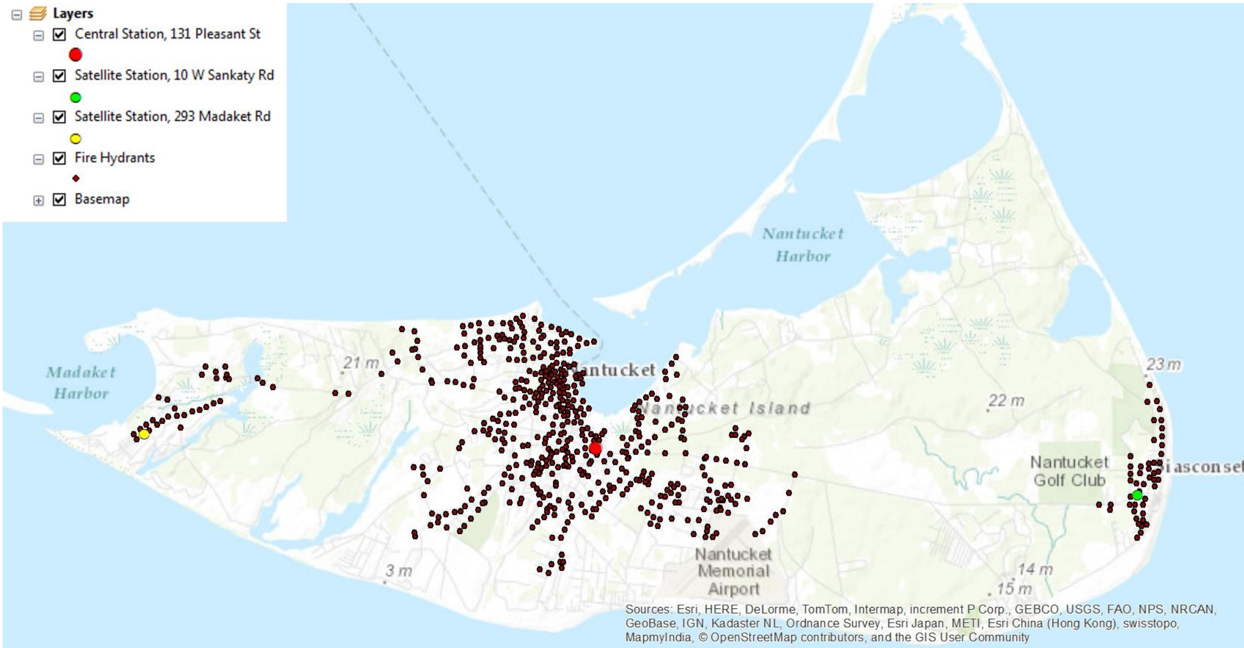


Figure 2 – Fire Hydrant Location on Nantucket
(Nathan Porter, Personal Communication, 2014)

2.5 The Nantucket Fire Department

Nantucket Fire Department is staffed by career and call firefighters and EMT's. The career firefighters and EMTs work schedules that are comprised of a 24 hour shift on, 24 hours off, another 24 hour shift on, and then five days off. The career firefighters/EMTs work in shifts of 4-5 personnel. Call firefighters and EMTs are not volunteer members of the fire department and are paid by the number of calls which they respond to, rather than receiving an hourly wage such as a career firefighter. While a call firefighter may not be classified as a volunteer, their method of deployment is extremely similar to the volunteer model. Nantucket Fire Department currently has a total of 40 members, including: 1 Chief, 1 Deputy Chief, 4 Captains, 16 career firefighter/EMTs, 9 call firefighters, and 6 call firefighter/EMTs. The call firefighters and EMTs are work elsewhere on the island and are alerted by pager when needed. In addition Nantucket Fire Department also staffs 1 Fire Prevention Officer, 1 Fire Alarm Superintendent, and 1 Office Administrator.

After viewing Figure 1, one would expect that the Nantucket Fire Department would be an all-career department based on the population it protects in the summer months (over 56,000 people). However, the department depends heavily on its call firefighters to fill the gaps

in staffing needs during the busy summer months when the call volume more than doubles. The Nantucket Fire Department must be especially aware of how emergencies are handled as mutual aid is hours away by ferry. The first case of mutual aid to Nantucket is believed to be April 1, 2007, when 4 mutual aid trucks were ferried 2 hours from Cape Cod to assist in subduing a large brush fire ("Mutual Aid to Nantucket," 2014). The Nantucket Fire Department is isolated and must be able to handle all emergencies adequately by themselves.
The mission of the Nantucket Fire Department is

> "To protect the lives and property of the residents and visitors of the Town of Nantucket by providing the highest possible level of service through public education, fire prevention, emergency medical services, fire suppression, and mitigation of the effects of natural and man-made disasters consistent with available resources." (Nantucket, 2014)

One of their goals is to "provide response times within the nationally accepted standards" (Nantucket, 2014). While trying to provide the "highest possible level of service," it is difficult for the Nantucket Fire Department to meet their mission due to tight budgets, summer population, increased number of structures, and this is compounded by lack of mutual aid (Nantucket, 2014).

In the past ten years, the number of fires on Nantucket has been greatly reduced. Dr. Peter Morrison, an Applied Demographic Analyst and member of the New Fire Station Work Group Committee, provided the following preliminary analysis of the call data from the Nantucket Fire Department. As seen in Table 1, the number of fires on Nantucket in 2013 was reduced to a quarter of the number in 2004. However, the frequency of alarm calls has risen 25% since 2004. The overall distribution of call types 2004 vs. 2013 can be seen in Figure 3. While there are fewer calls to the fire department for actual fires, the total number of calls (including service and inspection calls that the group will not be analyzing) to which the department responded has decreased by only 19%. Fire, EMS, Hazard, and Alarm calls are classified as emergency calls, while service and inspection calls are not. Figure 4 illustrates the overall trend in call volumes. While the call volume has decreased, much of this was due to the decline in inspection calls, rather than a reduction in emergency calls overall. Despite this drop in call volume, response time has increased slightly over the last several years. As seen in Table 2 and Figure 5, the percentage of runs that meet the 5 minute response standard decreases over the years, while the percentage for the 6-10 minute and 11-15 minute brackets increases.

Annual 12 Month Call Volume Totals											
	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**Percent Change 2004 vs. 2013**
Fire	217	206	188	86	63	56	40	66	41	52	24%
EMS	1324	1243	1449	1354	1254	1405	1142	1110	1255	1231	93%
Hazard	140	248	266	460	245	292	292	284	324	339	242%
Alarm	884	827	850	970	1009	1071	968	1017	990	1104	125%
Service	441	540	423	386	650	669	687	559	358	345	78%
Inspection	1625	1367	1476	804	738	635	694	667	713	702	4%
Total	4631	4431	4652	4060	3959	4128	3823	3703	3681	3773	81%

Table 1 - Annual 12 Month Call Volume Totals
(Nantucket Fire Department Annual Run Stats)

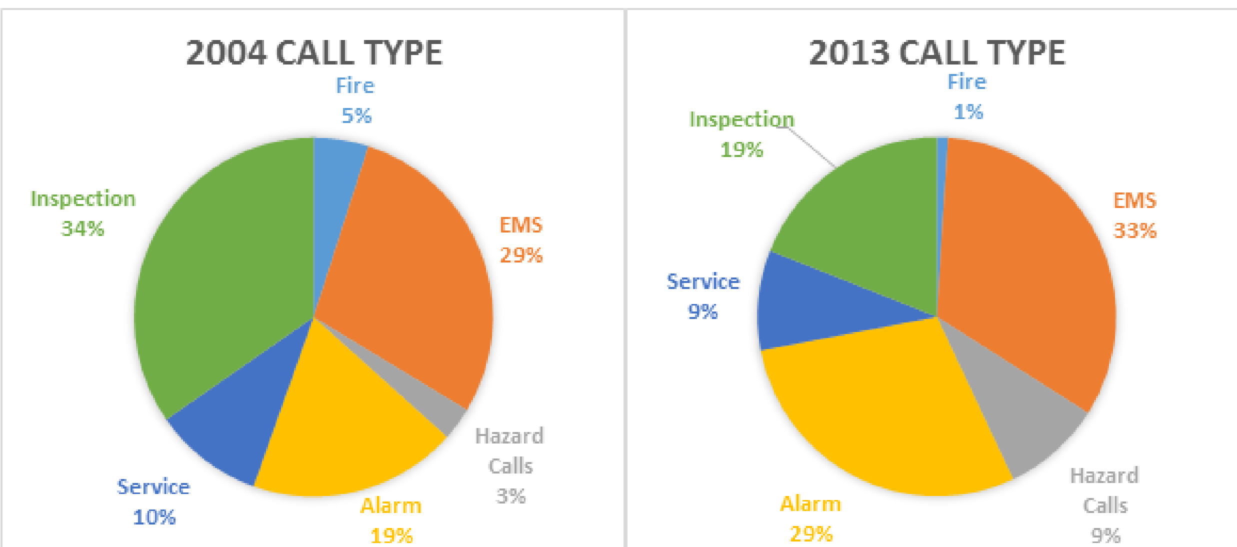


Figure 3 – Comparison of Call Types on Nantucket in 2004 and 2013
(Nantucket Fire Department Annual Run Stats)

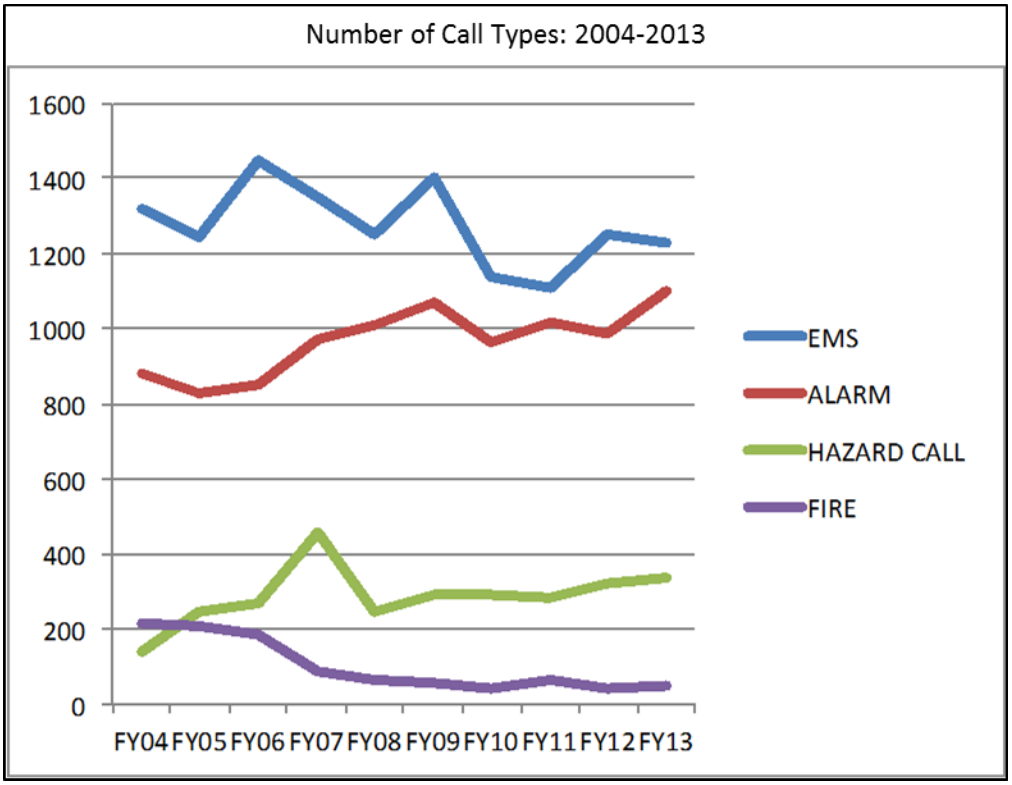


Figure 4 – Number of Call Types: 2004-2013
(Nantucket Fire Department Annual Run Stats)

Annual Response Times: 2006-2013									
	2006	2007	2008	2009	2010	2011	2012	2013	Total
0-5 min.	606	1084	993	976	1043	947	1026	997	7672
6-10 min.	499	831	762	778	855	903	937	1044	6609
11-15 min.	175	246	255	278	290	338	291	347	2220
16-20 min.	55	80	70	73	93	110	97	111	689
Over 20 min.	84	81	96	92	79	89	91	131	743
Total	1419	2322	2176	2197	2360	2387	2442	2630	17933

Table 2 - Annual Response Times: 2006-2013
(Nantucket Fire Department Annual Run Stats)

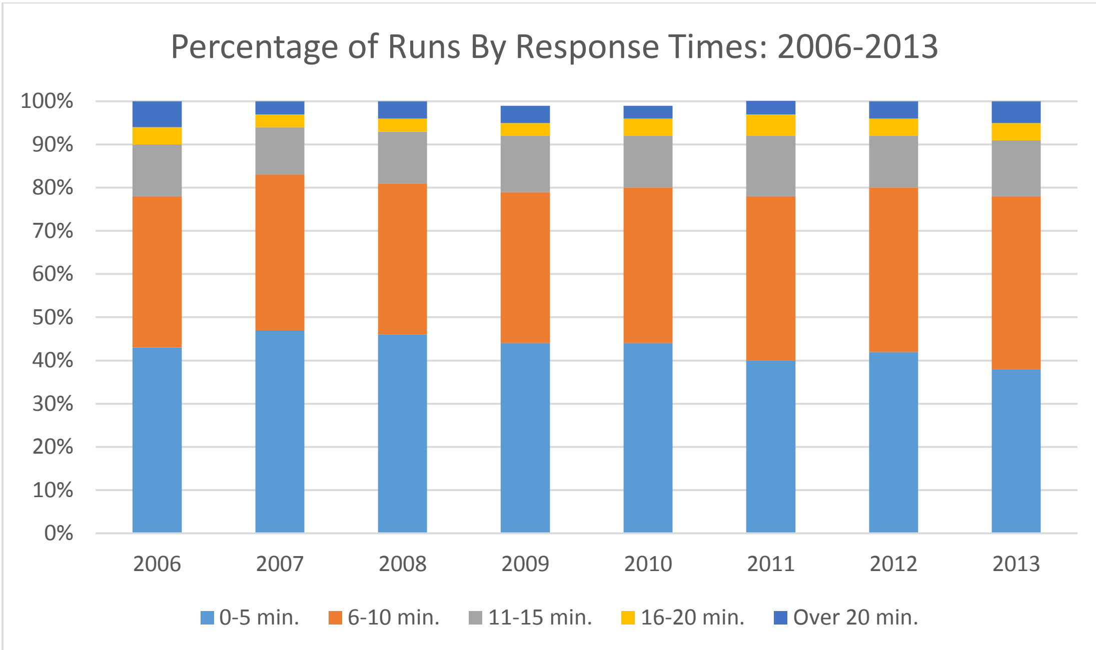


Figure 5 – Percentage of Runs by Response Time: 2006-2013
(Nantucket Fire Department Annual Run Stats)

Further strain is put on the department in the summer months, when the population grows from 10,000 to roughly 56,000 people (Beliveau et al., 2010; "National Fire Department Census Quick Facts," 2014).[3] Since Nantucket is an island without neighboring departments close by, the NFD is ill-equipped to call for mutual aid when its own resources are stretched thin. This is most frequently a problem during the months of June, July and August, the most popular months for travel, when the department receives a higher percentage of concurrent emergency calls. Dr. Peter Morrison notes that instances of two or more concurrent calls generally press NFD to the limits of what it can meet with its available resources (Morrison, 2014). Table 3 highlights the growing issue of concurrent call response by showing that the general trend in number of concurrent calls in peak summer months is increasing slightly from 2008 to 2013.

[3] See Footnote 1 for information on how population is estimated on the island of Nantucket.

Frequency of Concurrent Calls to NFD in Peak Summer Months: 2008-2013												
Concurrent Calls	2008		2009		2010		2011		2012		2013	
	July	August	July	August	July	August	July	August	July	August	July	August
Six	0	0	0	0	1	0	1	0	0	1	0	0
Five	0	0	0	0	1	1	3	2	0	3	0	0
Four	3	0	2	0	16	5	6	1	4	8	8	2
Three	20	1	17	14	30	29	29	26	13	34	22	14
Two	104	25	103	72	100	75	100	104	103	114	103	81
None	284	58	206	196	269	228	227	221	236	221	259	229
Total Calls	414	84	328	282	417	338	366	354	356	381	392	326

Table 3 – Frequency of Concurrent Calls to NFD in Peak Summer Months: 2008-2013
(Nantucket Fire Department Annual Run Stats)

2.6 Federal and State Guidelines

There are no mandatory federal or state response time requirements for fire departments, although the National Fire Protection Association (NFPA) Code 1710 and 1720 sets various response time and staff response objectives based on the type of fire department and other factors such as population density (Table 4). The NFPA, however, is not responsible for creating or enforcing a national standard for response times that fire departments must meet. The Nantucket Fire Department (NFD) is unique as it faces many of the challenges of a volunteer department in certain cases, for example during a concurrent call episode an on-call member may need to respond to the station first to grab equipment and then respond to the incident. Although the Nantucket Fire Department may encounter challenges like a volunteer department they still staff career firefighters, and the additional responding members are on-call firefighters, this makes the NFD a career fire department and they should aspire to respond to calls based on career fire department guidelines. Volunteer fire departments have separate response time metrics based on various factors (Table 4) and it is useful for the group to compare these types of response time objectives to the challenges the Nantucket Fire Department faces.

Demand Zone[1]	Demographics	Minimum Staff to Respond[2]	Response (minutes)[3]	Meets Objective (%)
Urban Area	>1000 people/mi^2	15	9	90
Suburban Area	500-1000 people/mi^2	10	10	80
Rural Area	<500 people/mi^2	6	14	80
Remote Area	Travel distance > 8 mi^2	4	Directly dependent on travel distance	90
1 A jurisdiction can have more than one demand zone				
2 Minimum staffing includes members responding from the AHJ's department and automatic aid				
3 Response time begins upon completion of the dispatch notification and ends at the time interval shown in the table				

Table 4 – Response Time Demographics
(National Fire Protection Association, 2014)

Based on the demand zone, recommended response time objectives vary from 9 minutes or less in urban areas, to 14 minutes or possibly more in rural and remote areas. Nantucket presents an interesting challenge because of its dynamic population density. The 2013 census estimates the year-round island population to be 10,172 ("National Fire Department Census Quick Facts," 2014). However, the population in the summer is estimated to grow to around 56,000 people which undoubtedly places strain on the Nantucket Fire Department and other public resources, thus increasing response times (Beliveau et al., 2010).[4] In the winter, the island of Nantucket can be classified as approximately 40.2% rural, 15.2% suburban, and 44.6% urban according to census data and in terms of the NFPA standards seen in Table 4 (City-Data, 2014). It takes the average home an estimated 14 minutes to burn down (Daniel, 2006). This is the same amount of time as the NFPA standard for the rural area demand zone which raises concerns for public well-being, especially in a location like Nantucket where unpaved roads, traffic congestion, and misleading addresses may delay the fire department even further. As mentioned before, call firefighters are very similar to volunteer firefighters in the way they respond to calls. These benchmark response times laid out by the NFPA are even more difficult for volunteer and call fire departments to meet, given that fire fighters may be substantial distances from the fire station when summoned by a call. A study in Sonoma County California found that six out of 15 volunteer fire departments failed to meet the standard for

[4] See Footnote 1 for information on how population is estimated on the island of Nantucket.

response times, which in this area was 15 minutes or less 80 percent of the time. The Sonoma County Fire Chief noted that he thought the response was “appropriate” in the circumstances; it would require more staffing and money in order to reduce response times (Brett, 2012).

Although it is important to understand how the Nantucket Fire Department compares in response time objectives, we also must understand that the NFD is a career fire department and as such has tighter requirements to meet for response time. NFPA 1710 outlines the standard for the organization and deployment of fire department resources to the public by career fire departments (NFPA, 2010). It is also important to understand the terminology which the NFPA and fire departments use to describe response times. Total measured department response time is a combination of turnout time, and travel time added together give the total department response time. Chris Baldwin, Sales Executive at The Omega Group (referenced later in section 3.1), gave us a chart which illustrates very well how department response time is broken down (See Figure 6).

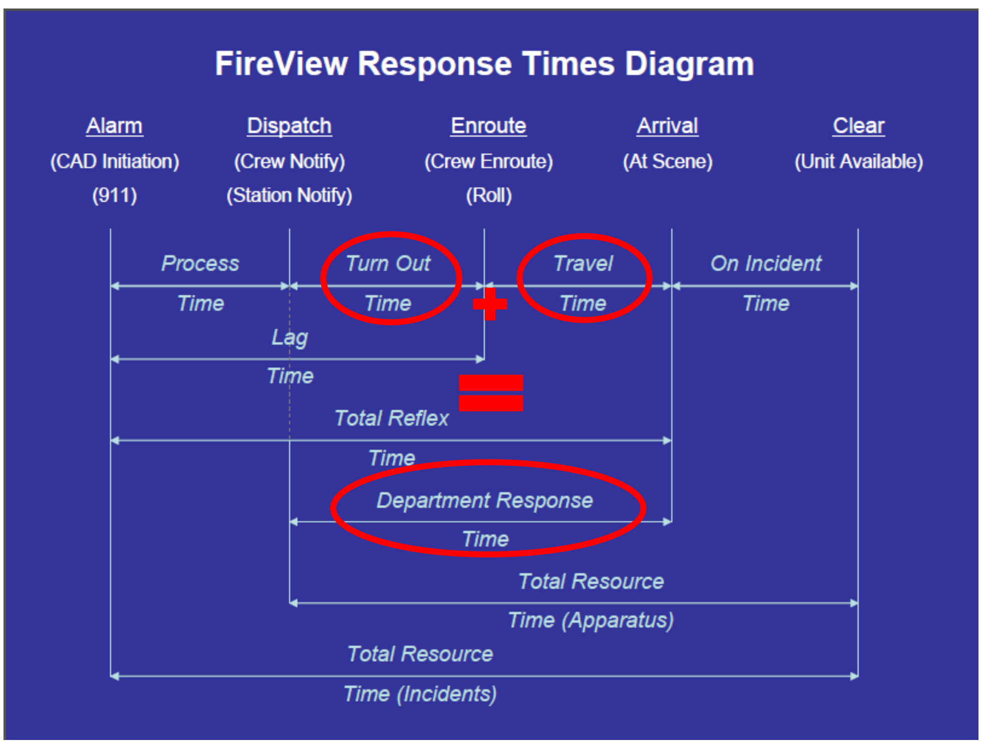


Figure 6 – FireView Response Times Diagram
(Chris Baldwin, Personal Communication, 2014)

NFPA 1710 states that all career fire departments shall establish the following objectives: an 80 seconds or less turnout time for fire and special operations response and a 60 seconds or less turnout time for EMS response, 240 seconds or less travel time for the arrival of the first arriving engine company at a fire suppression incident and 480 seconds of less travel time for the deployment of an initial full alarm assignment at a fire suppression incident, and additionally a 240 seconds or less travel time for the arrival of a unit with a first responder with automatic external defibrillator (AED) or higher level capability at an emergency medical incident (NFPA, 2010). In short, career fire departments should aspire to have a turnout time of 80 seconds or less for fire crews and 60 seconds or less for emergency medical crews, and a travel time of 4 minutes or less for the first response, and 8 minutes or less for the deployment of a full alarm assessment.

In addition to the NFPA guidelines, the Insurance Service's Office (ISO) criteria recommend that a built-up area of the community, like the downtown and village areas of Nantucket, should have a first due engine company within 1.5 miles of the reported incident, and a ladder-service company within 2.5 miles. ISO also calculates predictive response times using a formula developed by the RAND Corporation in a separate study. The RAND Corporation found the average speed of a responding fire apparatus with lights and sirens to be 35 mph, and thus developed the formula: $T=0.65+1.7D$. Here T is predicted response time, 0.65 is the vehicle acceleration constant for the first half mile traveled, 1.7 is the vehicle speed constant, and D is the distance that must be traveled. Using RAND's formula ISO predicted its recommended fire company placement distances would have response times to incidents of 3.2 minutes for the closer engine company and 4.9 minutes for the farther ladder-service company (Incorporated, 2014). These times are well below the recommended response times outlined in NFPA Code 1720, the lowest of which is a 9 minute minimum for urban areas.

2.7 Locational Analyses of Emergency Calls

There are many ways that fire departments analyze their call data. One of the most common ways is to spatially analyze the data to determine locations where emergencies happen more frequently. In order to provide adequate recommendations to the Nantucket Fire

Department about the location of future satellite stations, the group looked at how others did this in similar locations. Students at Grinnell College found an optimal location for the fire department in Rio Rancho, a town of approximately 90,000 people in southern New Mexico. Their model assumed that the city and the roads inside it formed uniform rectangles. Every combination of fire station locations was calculated and each city block was given a demand multiplier. The optimal combination was found using the lowest sum of the response time multiplied by the demand factor of all the city blocks (Goodman, Manbeck, Ricks, & Solow, 1986). This model created by the Grinnell College students works for an ideal situation, with a uniform grid of streets and relatively little traffic congestion, but this model cannot easily be translated to the island of Nantucket.

Baltimore City Fire Department, faced with staff reduction, station closures, and spending cuts, decided to implement GIS software to identify methods to improve response time. Baltimore City took call data and plotted it on a map to determine where their problem areas were located (Engineering, 2011). They used GIS software to evaluate the effect of one station being closed for maintenance. The GIS experts created a digital pegboard that was easy for the fire department employees to use so they could more logically decide how to relocate their staff due to station closure (Engineering, 2011). While we will not be creating a digital pegboard for the Nantucket Fire Department to use, we will be using ArcGIS in a similar way to locate the problem areas on the island.

The city of Oceanside, CA performed an analysis of fire department locations based on population growth. They received projected future growth rates of their response area from the San Diego County Regional Planning Group (SANDAG) and mapped these future growth rates in comparison to current growth rates. They highlighted areas in which the projected growth rate was much larger than the current growth rate, and noted that these areas were the locations where the projected growth rate would indicate a need for an increase in emergency response capabilities (see Figure 7) (Schaenman, 2012). The Oceanside Fire Department (OFD) created a graph that compared the number of incidents annually and from that, a trend line to project the number of calls to expect in the future (see Figure 8). The OFD used GIS software to pinpoint hotspots (see Figure 9 for an example). By mapping the number of calls per year in each location, the fire department can determine the areas in which there are a higher percentage of calls and determine where satellite stations would be helpful. Comparing this current hotspot map with the projected population growth rate, the fire department was able to predict future areas of concern (Schaenman, 2012).

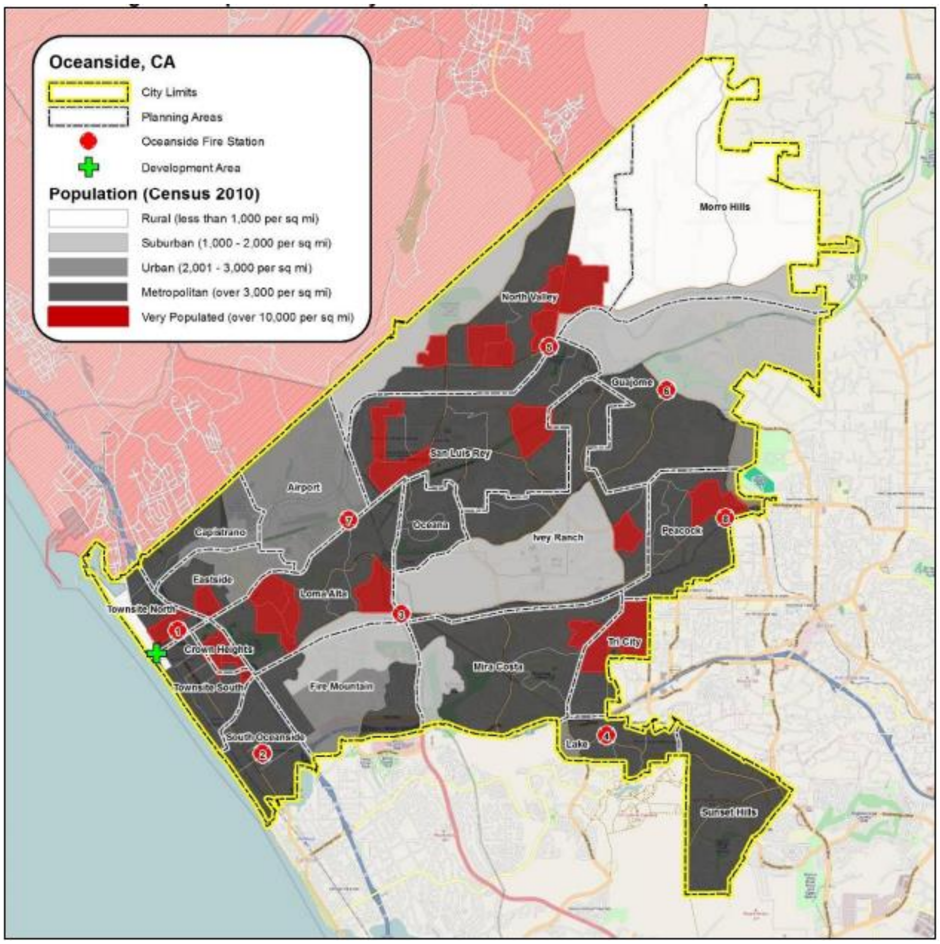


Figure 7 – Population Density with Identified Growth and Development Areas (Schaenman, 2012)

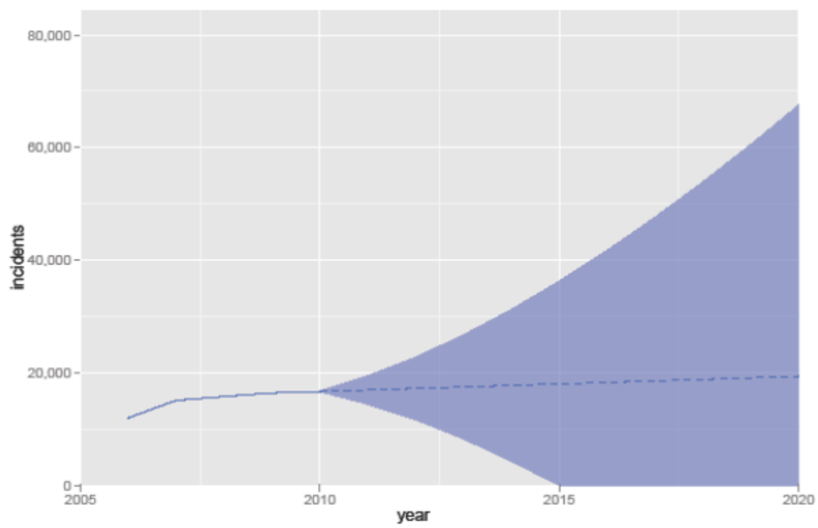


Figure 8 – Total Emergency Incident Projections
(Schaenman, 2012)

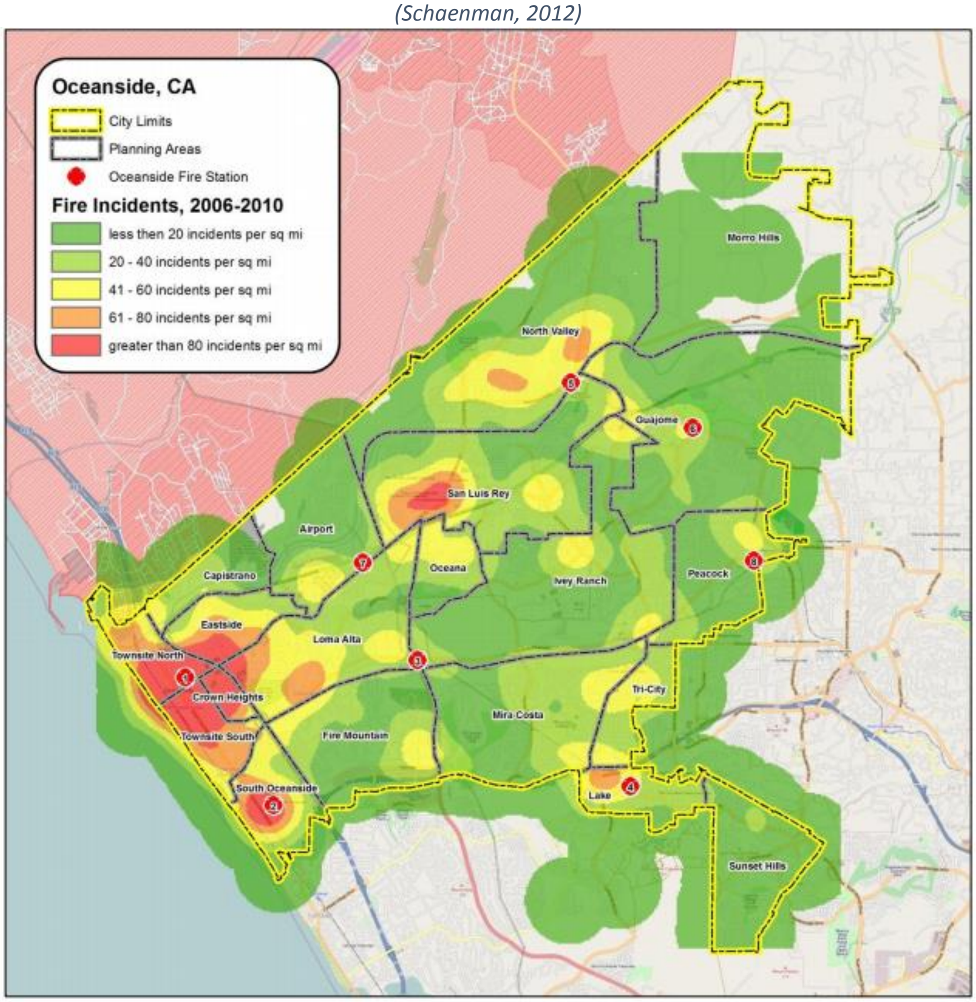


Figure 9 – Fire Incident Density
(Schaenman, 2012)

The Grand Island Fire Department (GIFD), located in Grand Island, Nebraska performed an analysis of their call data to determine the busiest hours in the year (ICMA, 2011). They wanted to determine at what time would be the most likely point for them to receive concurrent calls. The GIFD created a table that compared the number of calls in an hour to its frequency and calculated the percentage over the total year for more than one call to be happening at once. They then analyzed what each emergency vehicle was doing at the time of the call for the top ten busiest hours for the year of 2011. This helped the GIFD conclude that when there is a structure fire happening at the same time as other calls, all emergency vehicles were in use and had to make a number of runs to each call in order to resolve the emergency. To better handle similar situations in the future, the Grand Island Fire Department would benefit from more staff and more equipment.

A common road block encountered when analyzing call data spatially is geocoding because it requires a large table of addresses matched with their respective geocoordinates (Chris Baldwin, Personal Communication, 2014). Geocoding is the process of taking a street address and converting it into latitude and longitude coordinates, which is often necessary because call data location is recorded using an address and most mapping and spatial analyzing tools require a latitude and longitude. Both ArcGIS online and Google API have tools that have the ability to geocode large amounts of data.

The Omega Group, a company partnered with ESRI, the creators of ArcGIS, created software called Fire View that uses GIS to map fire and emergency response data. It allows the user to compare the fire department's own data to the NFPA Standard 1710 compliance. Fire View is equipped with the ability to filter data based on call type, location type, response time, date and time. This software is very beneficial to fire departments as it allows the user to map and analyze the data more efficiently. Fire View also converts both addresses and landmarks to coordinates on a map which is helpful to fire departments as it will be easier for them to perform an analysis. The Omega Group provides Geographic Information Systems software mapping and analysis solutions to public agencies. This is an option that fire departments with large budgets use to perform analyses of their call data to determine where they can improve.

2.8 Conclusion

The Nantucket Fire Department is a small fire department located in an area where it is difficult to receive mutual aid. It must depend on its twenty career firefighters/EMTs and its 15 active call firefighters/EMTs to protect and serve the island of Nantucket, including the thousands of visitors and summer residents that flock to the island. The NFD was looking to analyze its past call data in an effort to better provide safety to its citizens and predict how they can continue to protect with future growth. By locating areas on the island with long response times, the group will provide recommendations that will help the Nantucket Fire Department achieve its goal of meeting national response time standards.

3.0 Methodology

The overall goal of this project was to identify tools and evaluate strategies to enhance future readiness and response of the Nantucket Fire Department. The group:

1. Identified best practices in the analysis of call data, demographics and other related topics to enhance operations and deployment strategies in emergency services.
2. Applied those practices in the analysis the Nantucket Fire Department data.
3. Clarify stakeholder perspectives on operations, deployment strategies, and the location of facilities to enhance readiness and response.
4. Recommended changes in operations, deployment strategies, and location of facilities to enhance readiness and response.

The group spent a considerable amount of time analyzing call data from 2007 through 2013 with our sponsor liaisons and advisors to identify the most pertinent patterns and relations that will inform future policies and operations on Nantucket.

3.1 Objective #1: Identified best practices in the analysis of call data

Throughout the project, the group actively researched ways in which other fire departments and companies had used various programs and methods to analyze fire department call data. We found that many fire departments, as described previously with information from ESRI (the creators of ArcGIS) found in section 2.7, used software called ArcGIS to view and analyze their data spatially. ArcGIS has the capability to perform spatial analysis using fire department call data to find call density. This call density could then be used to determine hotspot locations, points on the map where there are a larger number of calls.

We also received information from various sources about how consulting firms analyze call data and develop program tools for fire departments. Chris Baldwin, Sales Executive at The Omega Group, was an invaluable source of information on how The Omega Group analyzes fire department call data. The Omega Group is a consulting firm which provides law enforcement, public safety, and public education agencies with Geographic Information Systems software that helps to provide better data driven solutions to important issues and decisions. FireView is one of the various software tools that The Omega Group offers. FireView is GIS software that allows fire departments and other emergency response agencies to map and analyze various types of data in order to better make educated decisions about how their department operates.

Although we decided not to use FireView because the software requires a package of configuration and data integration services that only The Omega Group technicians can install, Chris Baldwin provided us with invaluable information about how The Omega Group and FireView tackle many of the same issues our group was facing. In the initial stages of the project we began encountering issues geocoding (explained further in section 3.2.3) and analyzing the call data; missing addresses, poor street centerline data, and generally a lack of expertise on our part of how to utilize ArcGIS to its fullest potential. Through our continuing contact with Chris we determined that most importantly the multi-dimensional nature of our problem is common across fire departments and The Omega Groups Analysis.

3.2 Objective #2: Apply best practices to the analysis of Nantucket Fire Department data

After looking at the best practices to determine the factors that cause slow response times discovered in the previous chapter, the group first needed to decide which was the most appropriate for the analyses planned. Then in order to start any sort of analysis, the data that the group received from the State Fire Marshal's Office needed to formatted and organized into a usable form. This was an ongoing process as each analysis required a different format and set of data. While looking for trends, the group made note of interesting patterns that should be investigated further along with pursuing any suggestions from the sponsor liaisons and advisors. The group mapped the historical data and demographic trends to create expected distributions and growth of emergency calls. Once completing those analyses, the group used the combination of all of the knowledge gathered to conducted analysis on the impact of different facility locations.

3.2.1 Chose Software for Analysis

Once the group researched how other fire departments across the country have performed similar studies (see previous chapter), it became apparent that there were three different software options that used in conjunction with each other would perform all necessary analyses aptly: ArcGIS, Google Maps, Directions and API, and Microsoft Excel. ArcGIS was used for the spatial mapping, Google Maps and API for geocoding (discussed in further sections) and distance calculations, and Microsoft Excel for data sorting and graphing.

ArcGIS is a program that allows the user to input data tied to a location and plot the data on a map. Nantucket maintains much of its town data in ArcGIS so it was an obvious choice when deciding which software to use for spatial analysis. The group determined that the call data provided by the Nantucket Fire Department would be able to be imported and plotted in the system in order to perform different metric analyses. Within the software already, ArcGIS contains many tools that proved vital for the project. After preliminary testing and although the group had no ArcGIS knowledge or background, we decided that ArcGIS would still be the best option for spatial analysis as it has the capability to run various types of statistical tools and geographic plotting functions.

Google Maps, Directions and API was used for assigning geocoordinates to each data point, also known as geocoding (described in section 3.2.3), and for distance calculations. Due to its efficient nature and ability to provide driving directions and distance to and from any location, it was the group's first choice on the matter. Using a macro function in Microsoft Excel, the group performed web queries from Google API to get information on the distance from the central station or other locations for each data point and to get estimated time of arrival (ETA). The group used the ETA to determine which points were affected by traffic and perform scenario analyses to assess the impacts of different facility locations described later in section 3.2.6. Google Maps, Directions and API were extremely helpful for these sorts of distance analyses as expected.

Microsoft Excel was used for data sorting and graphing as the group was already familiar with many of its tools and it offered all of the functionality needed. The pivot chart function and the chart wizard were the two most heavily used and helpful functions. We originally sorted the data by hand each time we performed an analysis but that took a lot of time and was not guaranteed to be correct due to user error. After a quick tutorial on pivot charts, the group found that it was the easiest and most accurate way to manage and categorize information. All of the data points were merged together into one large Excel document which allowed the group to graphically analyze any combination of the data imaginable effectively and efficiently. The other Excel functions which proved useful were the SUM function, the AVERAGE function, the MEDIAN function, the IF and COUNTIF functions, the TIME function, the MROUND function, and the TEXT function. Microsoft Excel was chosen as it held all of the organizational and data analysis tools our project required.

3.2.2 *Obtained, reviewed, and organized data*

The data that the group used came directly from the Nantucket Fire Department through the State Fire Marshal's Office (years 2007-2013). The call data from the NFD were in a raw form that excluded non-emergencies like service calls and inspections. The data was organized into many different formats as each analysis required a different arrangement depending on its purpose. Every data point had an incident number, incident type, exposure number, mutual aid, date, alarm time, arrival time, last unit clear time, response time, total incident time, and an address listed. The group used the incident type codes chart (See Appendix A) from the Massachusetts Fire Incident Reporting System created by the United States Fire Administration to understand what each incident type code meant. There are nine different categories that the calls are organized into: 100 series is fire calls, 200 series is ruptures and explosions, 300 series is rescue and EMS calls, 400 series is hazardous conditions, 500 series is service calls, 600 series is good intent calls, 700 series is false alarm calls, 800 series is severe weather and natural disasters and the 900 series is reserved for special incident type. The incident type that the group looked into the most was the 300 series or rescue and EMS calls as this was more frequent type of call.

After reviewing the data and the information provided for each incident, we determined that there was information that was useless and/or unusable and should be excluded. The group removed both the exposure number column and the mutual aid column as neither of these columns were beneficial to the analysis and were causing the files to be rather large and load slowly. The justification behind removing these columns is that the exposure for every incident was "0" and the mutual aid column read "N" as the island cannot receive mutual aid.

After analyzing the call data from the Nantucket Fire Department, the team determined the need to create the following plan to handle data that are missing a street address, as this occurs approximately one hundred times per year and these points could not be matched with latitude and longitude information. All data points have a street name or an intersection of streets listed; however, some calls are missing a more specific address (ie 123 Main St. as opposed to just Main St.). In the event that an incident was missing a specific address number, we applied the following logic to the road where incident occurred.

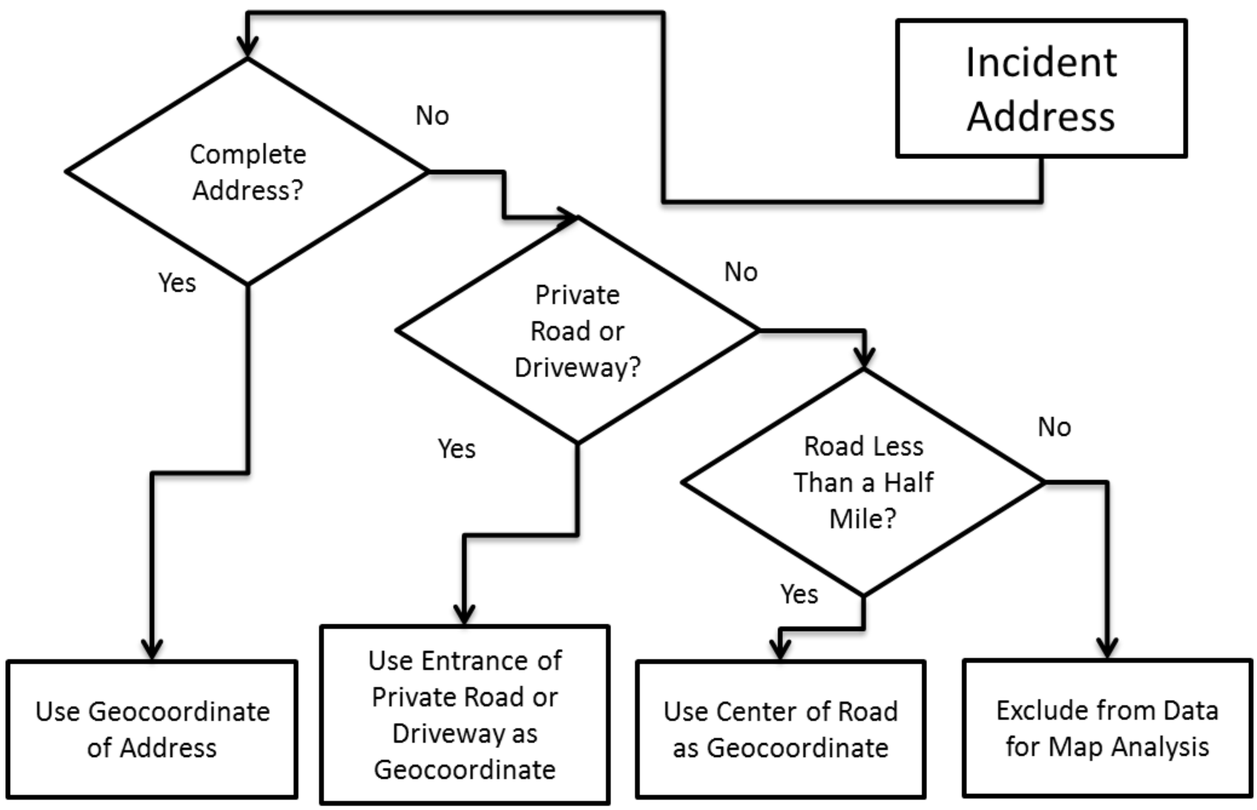


Figure 10 – Missing Address Protocol Flowchart

As shown above in Figure 10, if the road is private or a driveway, we used the intersection of the private road/driveway to the main road as the geocoordinate. If the road in question was public and less than a half mile long, then we placed the geocoordinate at the center of the road. This can be done because a road that is less than a half mile in length will have a low impact on response time regardless of which end of the road the incident occurred on. We excluded from the maps any incident on a road that is greater than a half mile in length with no specific address. This data was not mapped because the location of the specific incident would have affected the response time. Chris Baldwin, from The Omega Group, informed us that our procedure for throwing away outlier points was also common practice in the industry.

This method can be justified as only 155 of the 16,847 calls (0.92%) were removed using this method. Another three calls were excluded as well (0.02%) due to lack of proper address. Due to faulty addresses, a total of 158 of 16,847 calls (0.94%) were excluded from the spatial analyses.

The next type of exclusions that we performed was by type of call. The Nantucket Fire Department frequently is called to be on standby when hospital patients are being flown to and from the island. They often escort the patient to and from the hospital and the airport as well. These calls are referred to as Medflight calls and were easy for the group to distinguish. The reason for excluding certain Medflight calls is because of the way these calls are dispatched. Often, the hospital will call the dispatch center and request Medflight assistance several hours in advance. The dispatch center will input the call into the system which starts the response timer automatically, even if the Medflight is not scheduled until later in the day. This causes many Medflight calls to have response times over 60 minutes and even upwards of 12 hours. These calls can cause a skew in response time distribution as it will seem that the fire department struggles to respond quickly to locations within a mile of the station (ie the hospital). For our analyses of response times, we excluded all Medflight calls over an hour as it was a safe assumption that this “premature entry” was what caused the long response time. For response time analysis, 121 of 16,847 calls (0.72%) were removed due to overestimated response times because of Medflight assistance calls.

In order to even start a preliminary analysis in ArcGIS, the group needed to review and organize the data into a format that the software accepted. We condensed the address information into a single cell using Microsoft Excel’s IF and AND functions and added a column for country with “USA” being the entry for each incident as ArcGIS requires that format for its functions. Using Google Maps and API, we pulled and created a longitude and latitude column for each point as well as driving distance from the central station in miles and meters. The group also collected Google’s ETA to compare with actual time of arrival.

The group created our own column with the data that calculated if there were any concurrent calls happening and how many previous calls were occurring if so. Using a formula in Excel that compared the alarm call time of the current call and the last unit clear time of every call previous, Excel returned the number of calls that were in progress when the current call was received by the station. A “0” meant that the current call was the only call taking place at the time, a “1” meant there was a previous call in progress, etc. Using the TEXT function, the group created a column that listed the day of the week that the call occurred. This was useful in analyses testing the hypothesis that certain calls were more frequent on certain days of the week. We created a column that rounded the alarm time to the nearest hour to make time of day analyses easier. To do this, the group used the TIME and MROUND functions with a 60 min round factor. Anything past the half hour mark was rounded up to the next hour and anything before was rounded down to the current hour. The final column that the group created calculated the average speed of the emergency response vehicles but dividing the driving distance of the call away from the station by the response time minus one minute to account for turnout time. This allowed us to see which calls were slowed down by traffic or other factors that would inhibit the vehicles from travelling their normal speeds. None of the columns created however, changed the data in any way that would make it incorrect.

The data from FY2014 was also available to us from the Nantucket Fire Department, however it is in a different format that only lists the total month statistics and not specifics on each incident. General analysis of these data can be performed however no spatial analysis can be implemented.

3.2.3 Geocoding

In order to spatially analyze the data, we had to change the form of the data from the street addresses to the latitude-longitude locations. This process is called geocoding and we found two resources that could geocode addresses. ArcGIS Online was one resource that we found that had the capabilities to geocode. A disadvantage of using ArcGIS Online to geocode was that it only allowed the user for free to geocode 250 points at a time. This would require the group to split the data into groups of 250 points, taking large amounts of time as there are over 16,800 points total. Another disadvantage to using ArcGIS was after geocoding the data, the software would plot the points directly onto a map. This was actually a problem because if the group ever needed to edit the data by adding more columns to the Excel spreadsheet, the group would need to upload the information again to re-geocode, taking even more time.

The second resource that we found that had the ability to geocode was Google API with Microsoft Excel web queries. Google API would allow us to freely geocode 2500 data points per 24 hour period. The advantages that Google API had over ArcGIS online was Google API recorded the geocoordinates in Excel before they were uploaded to ArcGIS and plotted on the map, which allowed us to organize the data in many different ways and then re-upload it without having to geocode the data again. It also did not require as much data manipulation as ArcGIS online. However, one disadvantage of Google API that the group noticed was that it was difficult to learn how to use with Excel macros.

Through our connection with Chris Baldwin, from The Omega Group, we learned that any geocoding match rate over 90% was adequate for our use. Our match rate using Google API was 99.7% for the year of 2013. Every other year was approximately the same. Thus in the end, we chose to use Google API for geocoding because after learning how to use the software, it was quicker and gave us more information.

3.2.4 Analyze data for major patterns and trends

The group analyzed the call data recorded by the Nantucket Fire Department to look for trends and patterns using tables and graphs to portray the results. As seen in the previous chapter, the team already had a preliminary graph of total annual calls broken down by type. Several charts were created to analyze frequency of each incident type. A chart with the volume of incident types for the summer months (June, July and August) was created to compare incident types in the summer over multiple years. Another similar chart was created to compare incident type volumes for each month within individual years in order to see if any call type trends exist. The group wished to determine whether or not there was a connection between time of year and frequency of call types as well as look at the frequency of each incident type over the years to project the future. Also seen in the previous chapter is the Annual Response Times chart (Table 2), along with the percentage of runs that are responded to within a given amount of time (Figure 5). This, too, was further analyzed to determine how the island as a whole compares to the National Response Time Standards set by the NFPA.

We then further investigated areas that seemed to consistently have longer response times. We also created a table that shows the number of concurrent, or simultaneous, calls per year. While the team already had a chart displaying the concurrent calls during the peak summer months, we decided that another chart displaying all months would be equally beneficial, because the Nantucket Fire Department can comfortably respond to two concurrent calls, the third concurrent call and up almost always experience a lengthier response time than normal due to lack of personnel. We analyzed these data to determine how likely the department would find itself in a situation where its resources were stretched to the limit. We analyzed both the annual concurrent call data, as well as comparing seasonal concurrent calls (i.e. during summer months vs. off-season months).

Through our work and various conversations with Chief McDougall and Nantucket Fire Department employees the group determined that the major factors increasing response times were distance, traffic, and concurrent calls; as such the group created various charts in order to investigate these causes of longer response times including:

- Call volume analysis:
    - Calls per Thousand People
        - All calls
        - EMS calls only
        - Alarm calls only
    - Persons per call
        - All calls
        - EMS calls only
        - Alarm calls only
    - Percentage of runs by response time for all years
    - Response time of call by month
- Concurrent call analysis:
    - Concurrent calls summer months by year
- Traffic analysis:
    - Non-concurrent summer month 21+ minutes response calls
        - Inside congested areas
        - Outside congested areas

  - Non-concurrent calls over 10 minutes distance from station
  - Non-concurrent summer calls 10+ minutes traffic analysis
  - Summer non-concurrent calls over 10 minutes traffic analysis
  - Call distance away from station by month
  - Non-concurrent summer month 21+ minutes response calls
    - Inside congested areas
    - Outside congested areas
- Time of call analysis:
  - Average calls per month (summer vs off-season)
  - Day of call by month by year
    - All calls
    - Only EMS calls
  - Time of call by day and by month

3.2.5 Map historical data in various ways

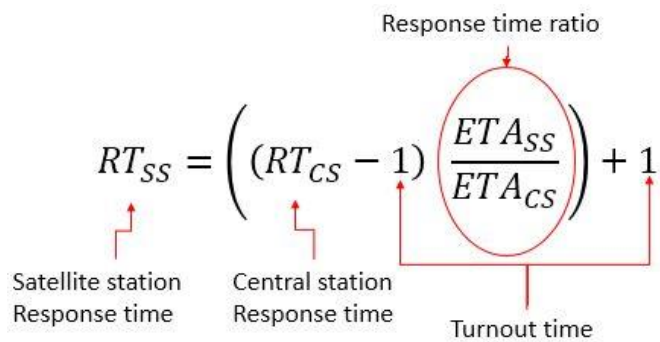
Using the call data acquired from Nantucket Fire Department, the team mapped the call data in ArcMap and performed various types of analysis in order to better analyze and interpret the data.

The group also created a traffic congestion map to determine how often calls fell in the area more often affected by traffic and understand how much of an obstacle traffic is to the fire department. Along with this, a map that distinguished the points by response time was created. It sorted calls into groups of 0-4 min, 5-9 min, 10-15 min, 16-20 min, and 21+ min. This allowed the group to further investigate the determinant factors of long response times. Finally, the group organized the incident types by driving distance from the central fire station at 131 Pleasant St. and highlighted points based on how far they were away from the station as this affects response time.

Using driving distance and response time, the average speed of the vehicles could be calculated and mapped visually. Points that had slower average speeds could be attributed to traffic, this helped the group determine the scale of traffic being a barrier to fire department response times.

3.2.6 Conduct scenario or sensitivity analysis to assess impacts of different facility locations and other operational changes

The group also created a contour map that shows areas that fall within certain response time categories. From this, the group placed satellite stations in areas with high response times and calculated how much each station would improve the total island response time. After performing analyses on past call data, the group conducted analyses on new potential locations for satellite stations. The locations for these satellite stations were chosen for simulation based on the following criteria: land must be owned by the town of Nantucket, points around the location must have a high call density, and a considerable amount of the surrounding points must have response times at or above 10 minutes. The location of the satellite stations in Madaket and Siasconset were also used as locations for the simulations. The group used call data from 2013 and performed the simulations as if the location was equipped with an ambulance, engine and two staff.



$$RT_{SS} = \left((RT_{CS} - 1) \left(\frac{ETA_{SS}}{ETA_{CS}} \right) \right) + 1$$

Figure 11 – Satellite Station Response Time Equation

To determine if the location would improve response times to the area, we first needed to determine if the satellite station would have a lower ETA to the call than the central station would. To do this we compared Google's ETA from the central station to the calculated ETA from the satellite station. We used the formula shown in Figure 11 to calculate the ETA from the satellite station. This formula assumes that the response time is made up of turnout time and drive time only.

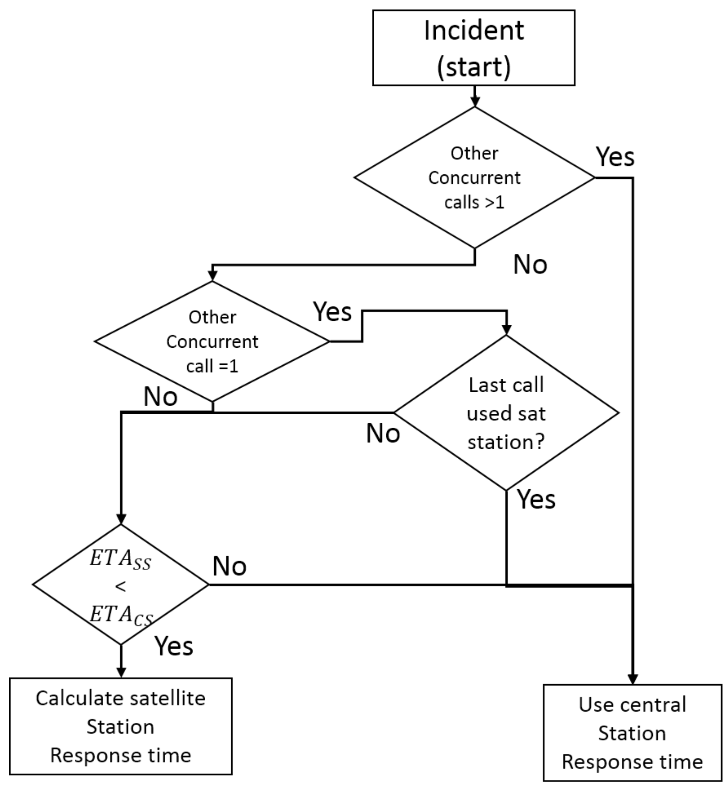


Figure 12 – Simulation Logic Flowchart

We applied the logic shown in Figure 12 to each incident to determine which station responded to the incident. Since the fire department can only comfortably handle two calls, we were unable to calculate the response time from the satellite station for the incident if more than two calls were currently in progress (Chief Mark McDougall, Personal Communication, 2014). The central station's response time was automatically used in this situation. If there was one concurrent call at the time, then we checked to see where the fire department responded from for the previous call as the simulated satellite station would only have enough staff to respond to one call. If the satellite station responded to the previous call, the central station's response time was used. If there were no other calls happening at the time, then the group checked to see if the satellite station would have a quicker ETA than the central station. For the Siasconset station simulation, we had to add additional logic to exclude any calls where the average speed from the central station to the call location was greater than 40 MPH as currently some calls are already responded to from the Siasconset station by local call firefighters.

3.3 Objective #3: Gathered information from stakeholders and field experts

In order to learn more about the political and social context of the proposed new station, the group identified several groups of people who we felt could provide a clearer picture of the politics surrounding the proposed new station. Among these groups were the Nantucket Fire Department, the Nantucket Police Department, the Board of Selectmen, the Finance Committee, and the Town Manager's Office.

The group tried to make the questions that each interviewee was asked as neutral as possible, in order to avoid introducing bias on the part of the people responding. Additionally, we tried to phrase most of the questions in an open-ended way, in order to prompt more of a conversation. The questions that each person/group of people was asked can be found in the Appendix B. We informed the interviewees that their participation was voluntary and asked respondents for permission to quote them and gave them the right to review the report and citations in public presentations before publication. If respondents preferred to remain anonymous we used generic titles and pseudonyms.

In order to be able to make well-informed recommendations, the group needed to have a broader understanding of the situation on Nantucket. The purpose of these interviews was to gain more insight into the social aspects revolving around the idea of a new central station. We had plenty of information from the data that highlighted where the problems most likely were, and from that we could propose plenty of solutions—what we did not know though, was which solutions were feasible based on the island's political and financial situation. That is what we sought to find in these interviews.

3.3.1 The Nantucket Fire Department

By interviewing members of the NFD, the group hoped to learn more about how the members of the department felt about the station. Since the firefighters are the ones who actually have to work in the current station, we thought that they would be able to give us a clearer picture of what challenges they face in their current location and how they think that some of these challenges could be addressed.

3.3.2 The Nantucket Police Department

Since the proposed new station would be located at 4 Fairgrounds, right next to the police station, we thought it would be useful to hear from one of the groups that, in addition to the firefighters, would be most directly impacted by the new station.

3.3.3 The Board of Selectmen

The group decided that, as the branch of the town government responsible for the delivery of town services and long-term planning, the Board of Selectmen would be able to provide valuable information about the likely impact that the new station would have on the island.

3.3.4 The Finance Committee

Part of the picture that the group wanted to provide was the financial context of the new fire station--how people in Nantucket feel about spending $14 million on a new fire station, as well as what the town can and cannot realistically do since the fire station and the new elementary school have come up at the same time. They can also give us an idea of the island's current financial situation.

3.3.5 The Town Manager's Office

As the department responsible for the day-to-day operations of the town, the Town Manager's Office works with both the town employees and the general public. Because of this, the team decided that the Town Managers office would be able to provide a clearer view of the politics surrounding the new station.

3.4 Objective #4: Recommend changes in operations, deployment strategies, and location of facilities.

Based on results of our analysis, the team was able to draw conclusions about the likely impacts of changes in operations, deployment strategies, and the location of facilities on current and future emergency responses. The team tested three hypotheses to explain high response times: high response time is due to driving distance, traffic congestion, and concurrent calls. The outcome of these analyses determines the recommendations the team will make. The group presented sample results of analyses, maps, and charts to sponsors, advisors and other stakeholders. We used feedback to refine our analysis and develop recommendations.

4.0 Findings

Using the Nantucket Fire Department's call data from 2007-2013 and our methods listed above, the group discovered many interesting trends not easily noticed at first glance. The group also performed simulations to mitigate the problems highlighted by these analyses and addressed concerns by stakeholders about the response times of the Nantucket Fire Department and the social context of the solutions of these problems.

4.1 Analyzing Trends Found in NFD's Call Data

Over the course of this project, the group performed more than 50 different types of analyses and created well over 150 maps, charts and graphs (many of which are reproduced in the appendices). We have grouped these analyses into several categories. We begin with an overview of the general temporal and spatial patterns in the data before we discuss in more detail the variations in response times, and the primary factors affecting them, including concurrent calls, distance and congestion.

4.1.1 Overview of Temporal and Spatial Patterns

The total number of emergency calls that the Nantucket Fire Department responds to each year is steadily increasing (Figure 13). This count excludes inspection and service calls as these are scheduled and do not use the emergency resources. There is a noticeable decline in calls from 2007 to 2009 during the economic recession and the number of emergency calls has since increased. During this time, the number of staff at the Nantucket Fire Department has remained relatively constant regardless of increasing call volumes.[5]

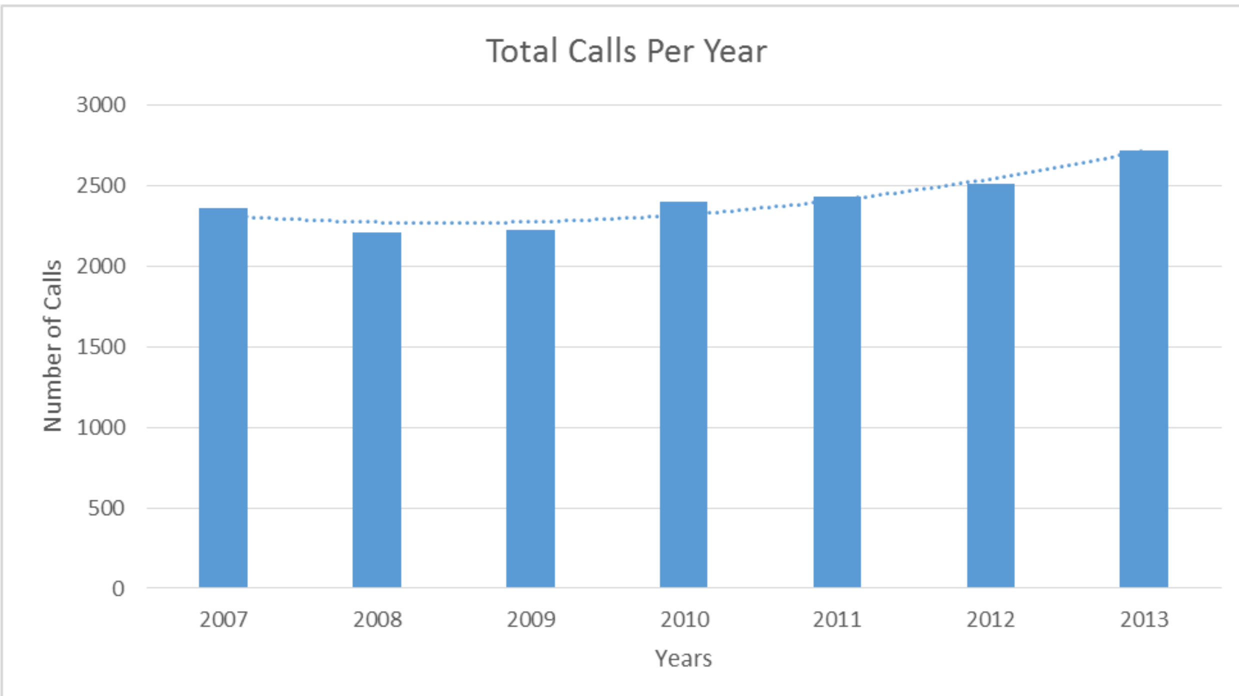


Figure 13 – Total Calls Per Year

To examine the type of calls the Nantucket Fire Department handles most often, we created a line chart for incident type call volume in just the summer months for all years except 2008 (Figure 14). We excluded 2008 because missing data for August skewed the results. Figure 14 shows the number of medical and alarm activation calls are both increasing, and are also the two incident types with the most number of calls. The number of calls related to ruptures and

[5] Staffing at the Nantucket Fire Department since 2007 has remained nearly constant. Although career firefighters have been hired over the years, others have also left. As such each shift has been staffed with 4-5 career firefighters since 2007.

explosions, severe weather and natural disasters, and special incidents were minimal and are excluded from this graph for clarity. See Appendix C for the individual analysis for each month per year.

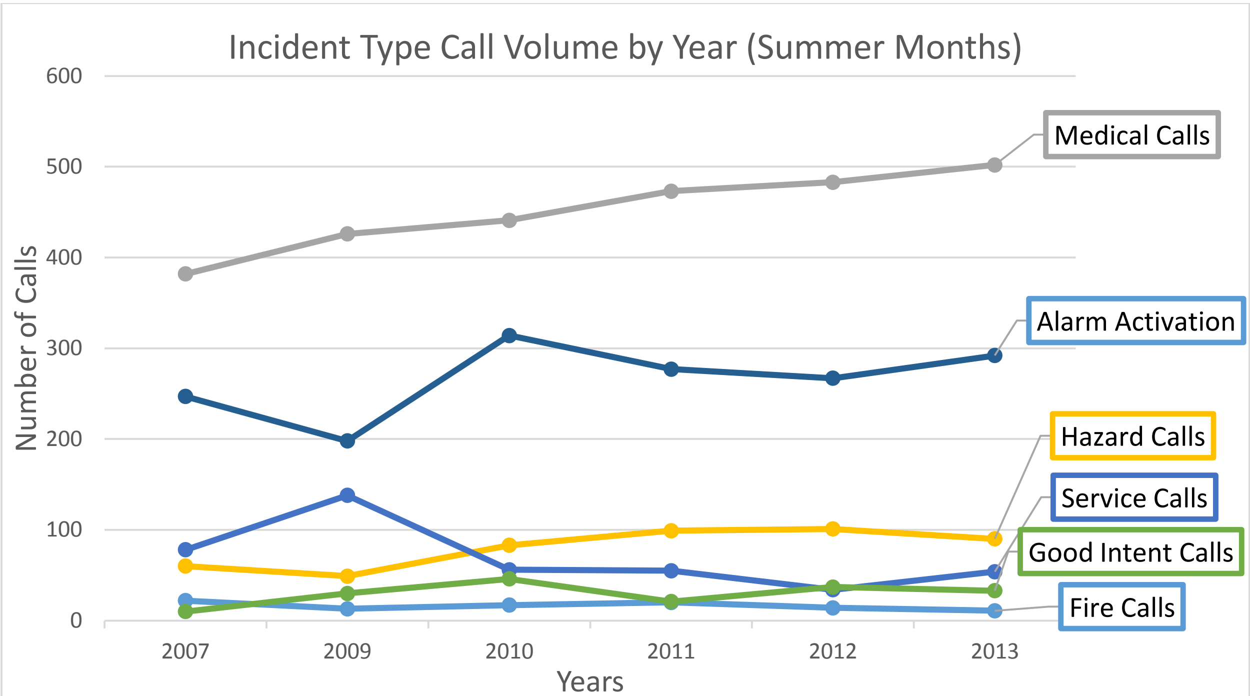


Figure 14 – Incident Type Call Volume (Summer Months)

Figure 15 shows the average response time to all calls by year is increasing, which we attribute to increasing congestion and other factors discussed below. We excluded Medflight and public service calls because they often have inordinately long response times since they are known in advance and entered by the dispatch center at the time of initial notification.

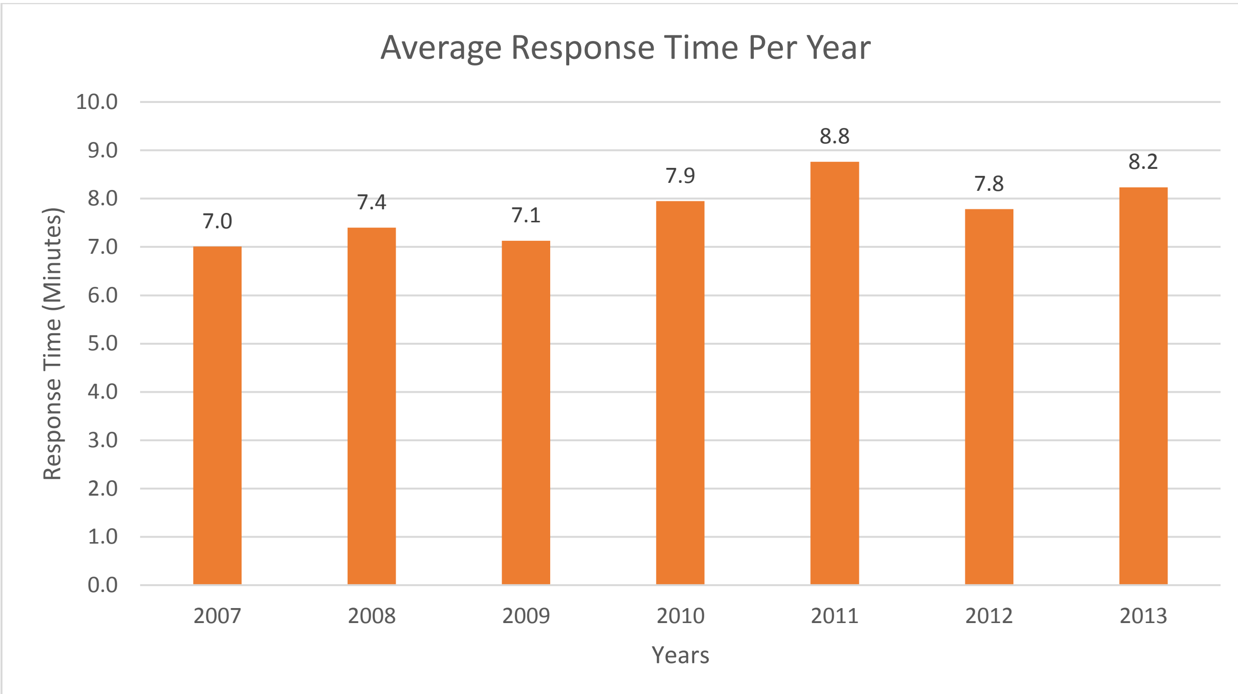


Figure 15 - Average Response Time Per Year

One minute difference in response time in either direction may not seem to be significant overall, but in the event of a serious medical or fire emergency, response time is a matter of life or death. When someone goes into cardiac arrest for example, their chances of leaving the hospital alive are four times greater when CPR is started within four minutes (Cote, 2008). Similarly, the point at which an entire building becomes engulfed in flames and any victims are likely deceased, known as flashover, occurs within four to ten minutes of burning (Cote, 2008).

We also examined the average number of calls per month, comparing the summer months to the off-season months.[6] Figure 16 shows that the volume of calls doubles in the

[6] After speaking with our sponsor liaisons, it was determined that we would consider June, July and August as the summer months.

summer months compared with the off-season months and the volume of calls in the summer is increasing, whereas the volume of calls in the off-season months is staying the same.

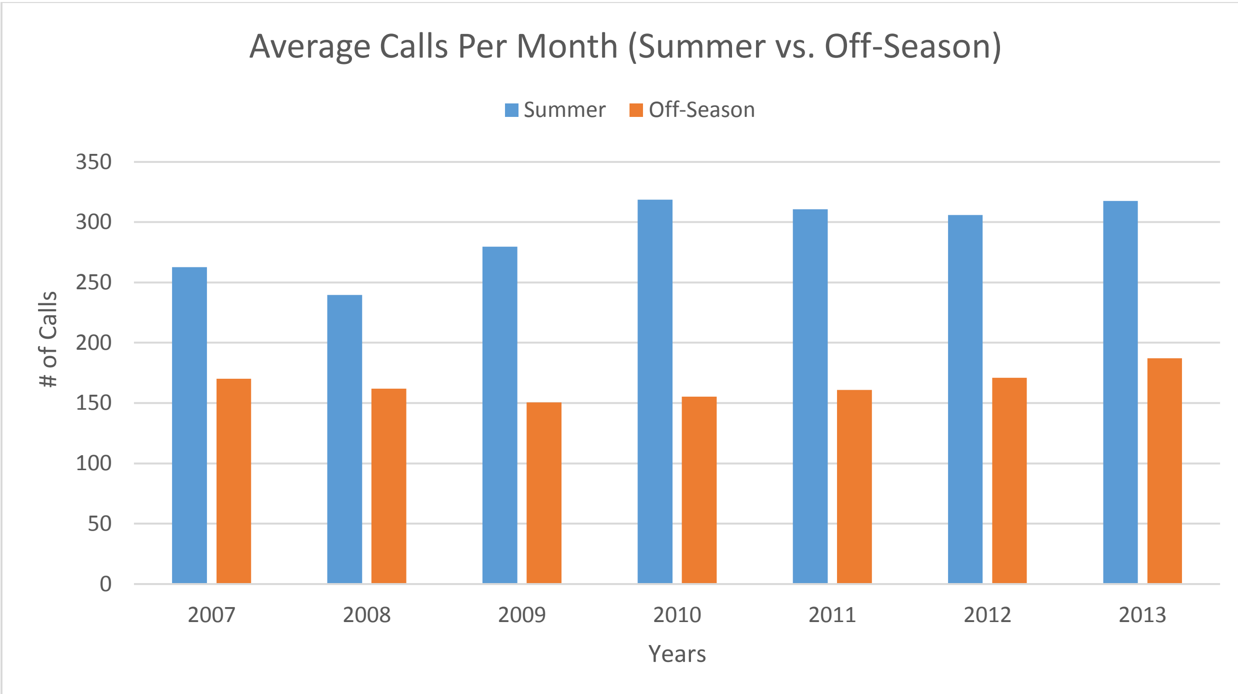


Figure 16 - Average Calls Per Month (Summer vs. Off-Season)

Since medical calls are the most frequent call type (Figure 14) and the highest call volumes are in the summer months (Figure 16), we disaggregated the data on EMS calls for the months of June, July and August. Figure 17 shows that July typically has the most number of EMS calls each year and the number of EMS calls is generally increasing for each of the summer months.

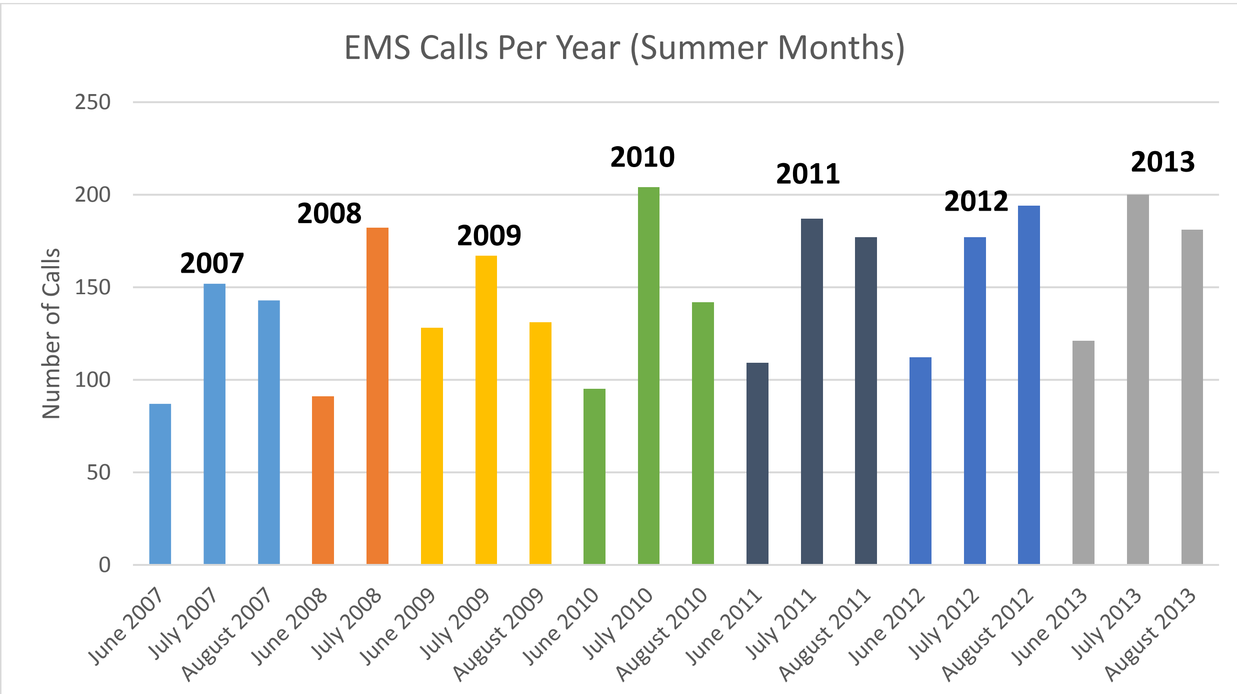


Figure 17 - EMS Calls Per Year (Summer Months)

In addition to the temporal analysis of call data, we also analyzed the spatial patterns. Figure 18 shows the distribution of all calls for 2013. Clearly, the calls are concentrated in areas that are more densely populated, including Town, Siasconset, and Madaket, and along the major roads where houses are typically located. We analyzed the spatial patterns for all years from 2007 to 2013 (see Appendix D), and found there is little variation in the spatial distribution of calls among the different years.

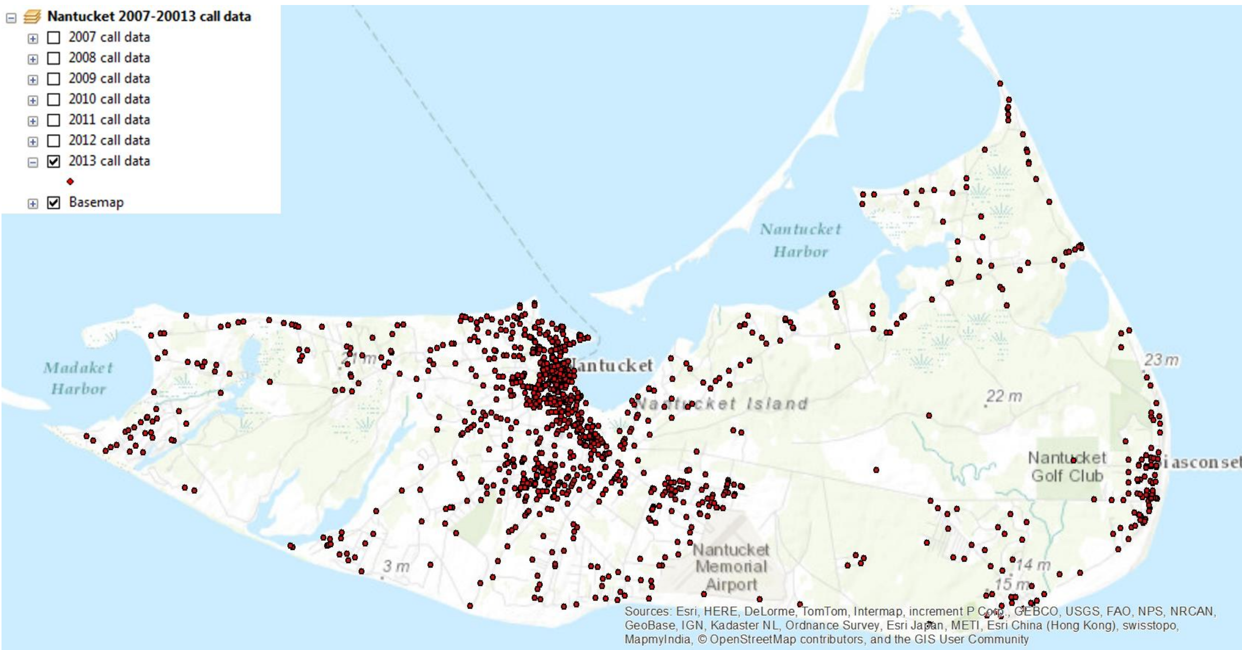


Figure 18 - Spatial Distribution of Calls (2013)

4.1.2 Nantucket Fire Department Response Times

The Nantucket Fire Department encounters many obstacles which delay their response times. It is no surprise with congestions issues, a large coverage area, and a constant amount of personnel tackling an ever-increasing volume of calls, the Nantucket Fire Department struggles to meet its response time aspirations. Based on NFPA standard 1710, the NFD should aspire to respond all to calls with an 80 second turn-out time and a 240 second travel time (5 minutes 20 seconds total response), and to EMS calls with a 60 second turn-out time and a 240 second drive time (5 minutes total response). These NFPA standards are simply recommendations, not requirements, as the NFPA does not have any authority to enforce these standards. On top of the NFPA's recommendations, the Nantucket Fire Department has set a goal of a consistent 5 minute response time for itself. In many cases, this response time would put firefighters and EMTs in an ideal position to respond to most emergencies before they escalate beyond control.

Figure 19 shows all of the call data for 2013 sorted into broad categories for response times: 0-4, 5-9 and 10+ minutes for each month. The graph highlights that all response time categories increase during June, July and August as expected. The 5-9 minute response time category experiences the greatest increase during the summer months. It is also interesting to note that during the first half of the year (January to June) the 0-4 minute category is the second largest category, however for the second half of the year (July to December) the 10+ minute category becomes the second largest.

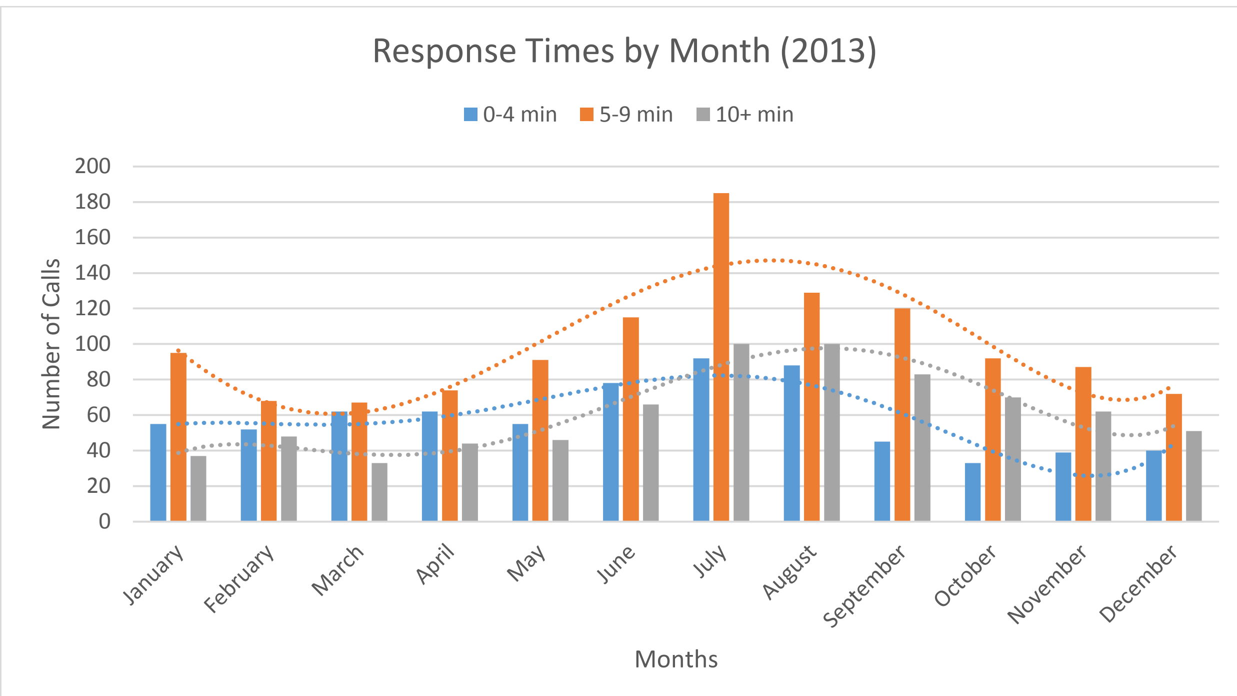


Figure 19 - Response Times by Month (2013)

The previous analysis was then translated to a map. Figure 20 depicts a map of the call data from 2013 with each point color coded based on its response time. This map show that distance is not the only factor that affects response time and a large portion of the 10+ minutes falls in and around the downtown area. To see each category individually, reference Appendix E.

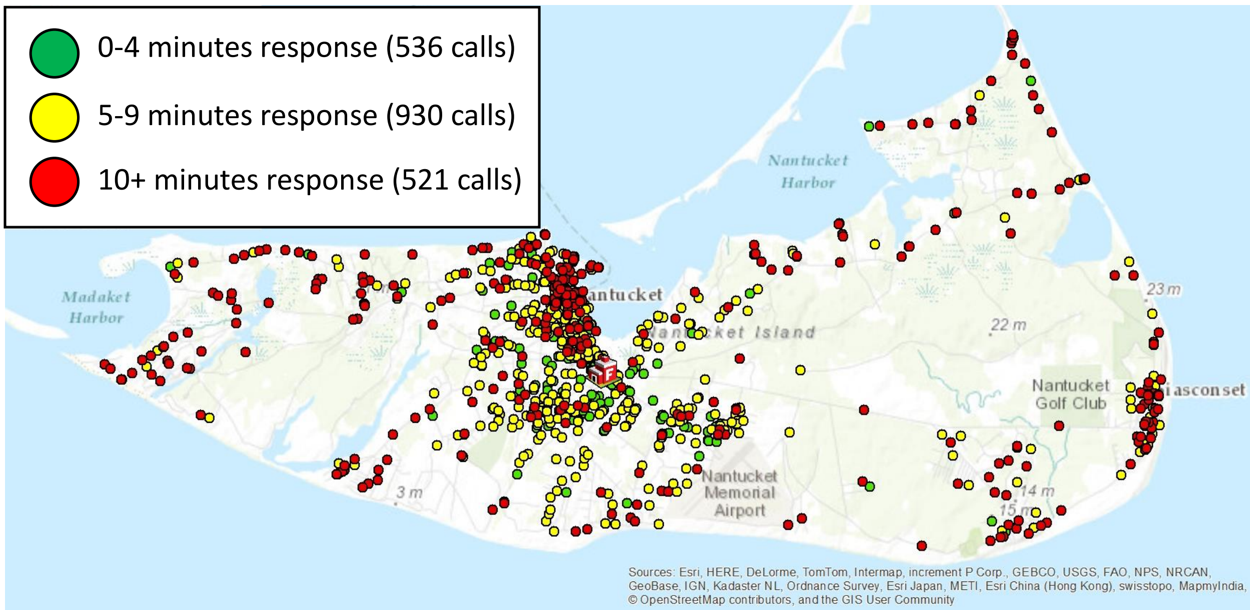


Figure 20 – Spatial Distribution of Response Times on Nantucket

The list of response times from 2013 (excluding the Medflight and public service calls) was isolated and organized shortest to longest by response time length. The calculated average response time from 2013 (calculated for the Average Response Time Per Year column bar chart) was subtracted from each response time to get a value called the Travel Time Mean Difference. By plotting the frequency of this value on a line graph (Figure 21), we can see how the Nantucket Fire Department's response time compares to their average. The x-axis of the graph shows the Travel Time Mean Difference and the y-axis shows the frequency of calls with this difference.

The green line on the graph marks 0.0 which is the mean (average), as a response time of 7.7 minutes minus the average would equal zero. A large majority of the response times fall under the average however, there are still a significant number (820 calls or 35%) that are over the average. This causes the graph to have a positive skew which means that "the extreme scores are at the positive end of the distribution. This exhibits the tail on the right side and pulls the mean to the right" (FEMA, 2004). The yellow line marks the median, defined as the middle value (50% of the data is above and 50% is below), and is shown at -1.70 min as the median value of this data set is 6 minutes. The mode or orange line, is the value which occurs most frequently in a distribution, and is shown at -4.70 min as 3 minutes is the most common response time. While there are approximately 35% of calls over the mean, the most common value in the distribution is 3 minutes, a value well below the standard given by the NFPA (5 minutes to 5 minutes and 20 seconds).

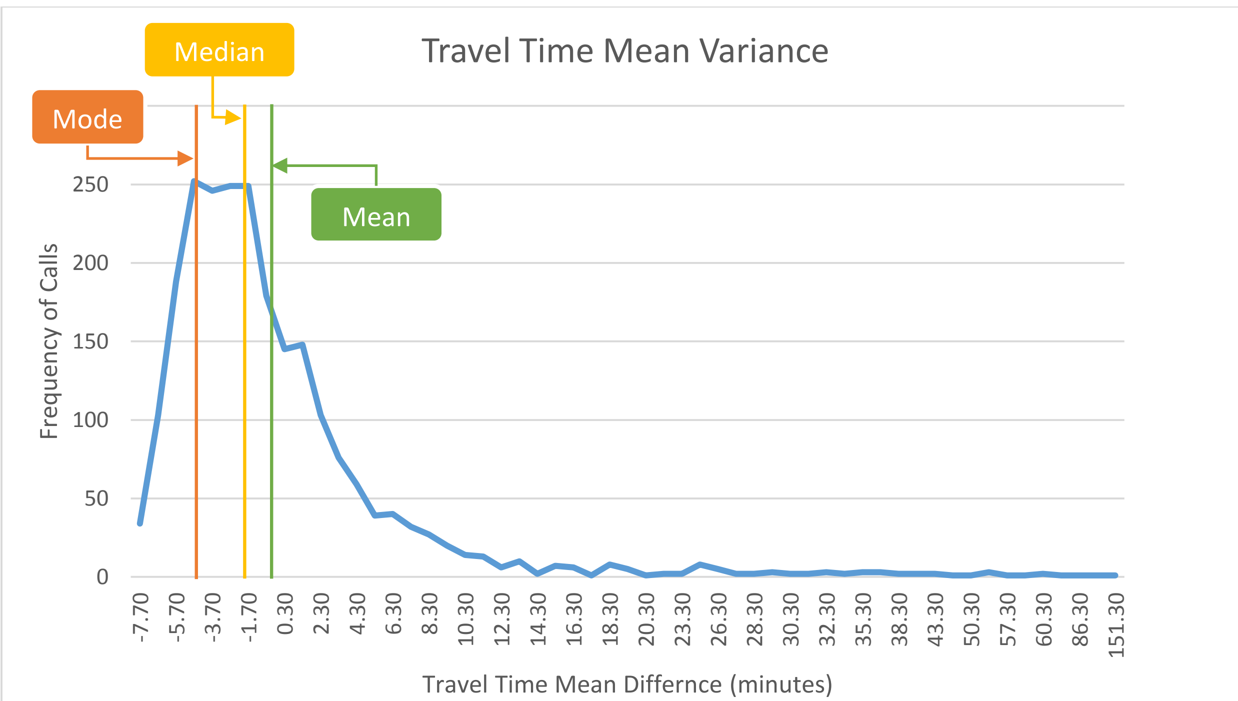


Figure 21 - Travel Time Mean Variance

As shown in Figures 19, 20, and 21, many of Nantucket Fire Departments response times fall within the NFPA standard. However, we can also see that during the summer months response times above the standard dramatically increase. In order to recommend any solutions, the group needed to determine the factors which are causing the longer response times.

4.1.3 Explanation of Length of Calls

Nantucket has only one central station covering a 15 mile wide island (see red dot on Figure 22 below). Because of this, response times to the far ends of the island (Siasconset and Madaket) are much longer than response times to the main town area. In addition to distance though, response times are increased by traffic conditions and concurrent calls. Many of the roads on Nantucket are narrow, particularly those in town. Even in light traffic conditions, cars are not always able to pull over far enough to allow fire trucks to pass. In summer months, when the population more than quadruples and especially when the car ferry unloads, traffic conditions worsen enough to the point that some roads become impassable for fire trucks. On top of this, when concurrent calls occur there are not always enough staff to immediately respond to all calls coming in, further increasing response times.

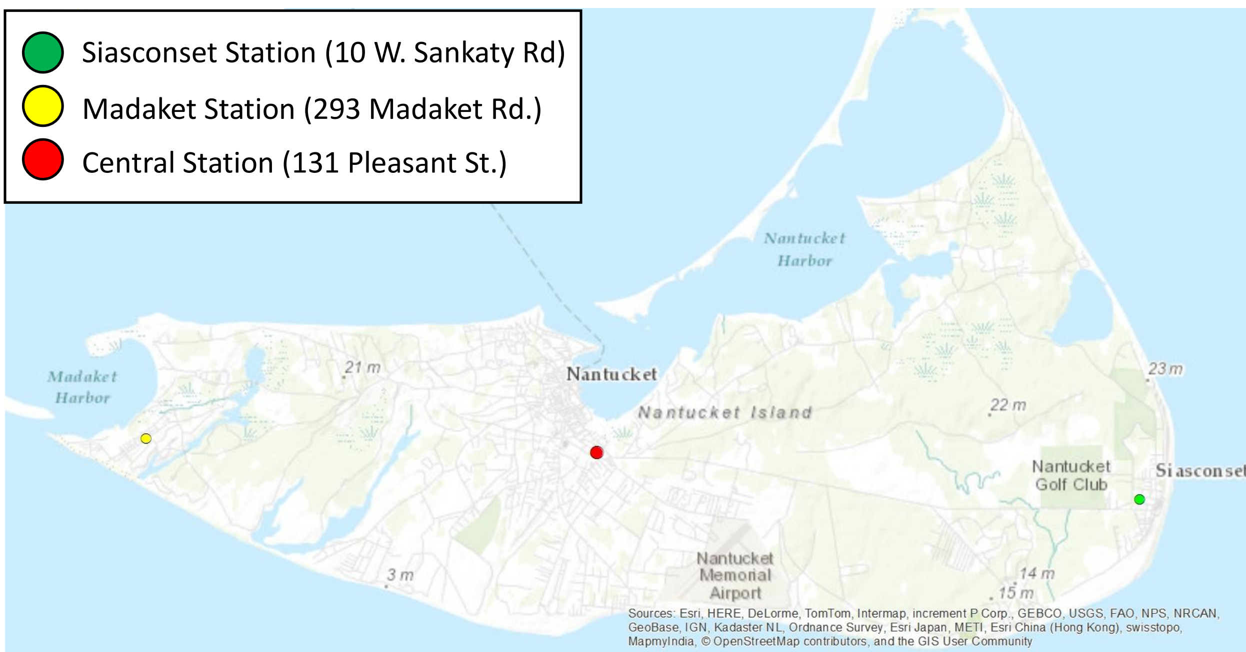


Figure 22 - Map of Nantucket Marking Station Location

Presently, there are two “satellite” stations on Nantucket. These stations are not fully staffed, though. The station in Madaket (see yellow dot on Figure 22) is nothing more than a garage with a single engine stored in it and no personnel in the vicinity. The engine holds 750 gallons of water and can pump 1250 gallons per minute. It is the smallest engine that the Nantucket Fire Department owns and is almost only used when members of the fire department need to stand by when fuel is brought to the island on a barge. The engine in Madaket is used approximately 1-2 times a week in the summer months and at least once every two weeks in the off-season. The station in Siasconset (see green dot on Figure 22) is more useful and beneficial, as it not only houses a tanker and an engine but has space to store turnout gear as well. The tanker holds 1200 gallons of water. The Siasconset satellite station also has seven call firefighters in the vicinity, including the Call Deputy of Siasconset, who can make use of the equipment stored there. In most cases when a call comes in for the Siasconset area, the call firefighters will go to the satellite station, get the engine, and go to the call. They radio the state of the call back to the central station, which can deploy additional resources if necessary. The central station always deploys an engine to calls in Siasconset as it is never certain if there will be call personnel in Siasconset ready to respond. If there are no call firefighters in Siasconset, the central station will deploy a response and the Siasconset firefighters may drive to the satellite station and get ready in case they are needed. This station is used 2-3 times per week year round.

4.1.4 Distribution of Calls Relating to Concurrency

Concurrent calls are defined as two or more simultaneous calls, meaning that the department is already responding to one or more calls and another comes in while the previous calls are still in progress. This becomes a problem because there are only four to five career firefighters on duty per shift. At least two firefighters are required to adequately respond to each call, so if a third call comes in while all four are responding to other calls, the department must tone-out, notify that there is an emergency, for call firefighters who may not be able to respond or may take longer to respond. Since there is no way to reduce the number of concurrent calls, the only real solution to this problem is to have more career firefighters on staff.

Figure 23, below, shows the frequency of each concurrent call type for 2013 (1, 2, 3, 4, and 5+ calls happening at one time). See Appendix F for the remaining years. The “1” category represents the first call happening at the time and “2” represents the first instance of a concurrent call. Instances of 3 or more calls substantially impair the fire department’s ability to respond to calls in a timely manner. June, July, and August (the summer months) have the highest number of incidents where there are 3 or more calls happening at once.

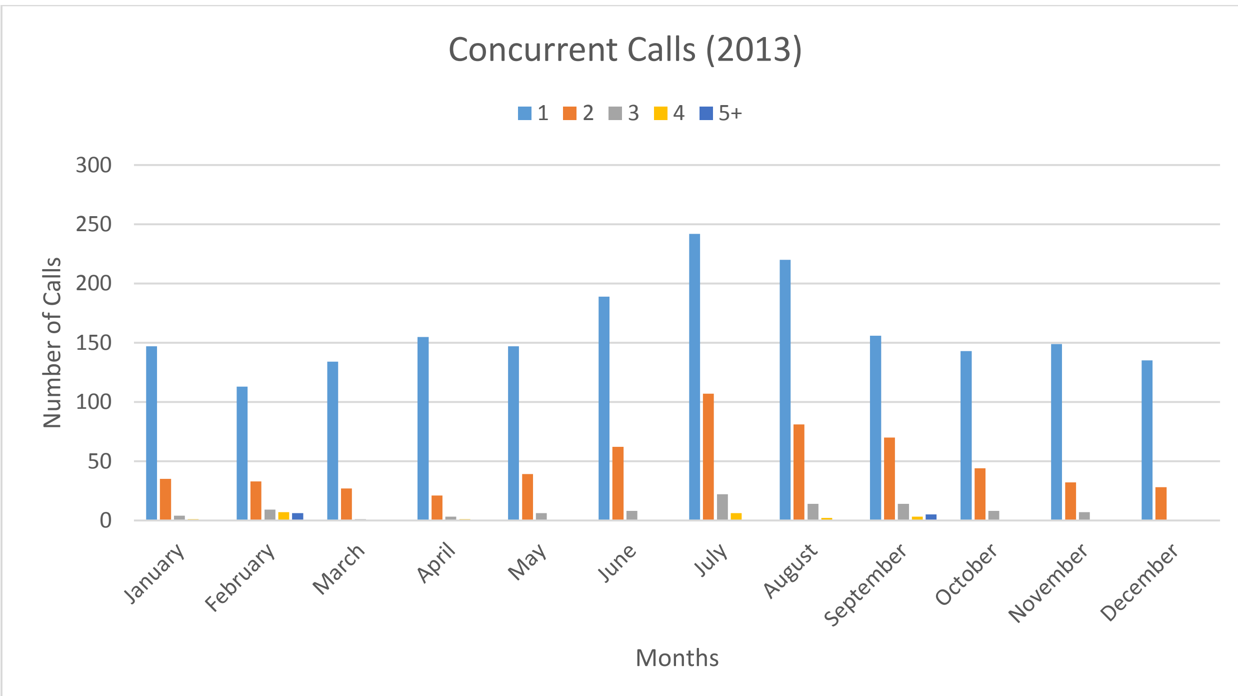


Figure 23 - Concurrent Calls (2013)

Figure 24 shows the summer months isolated to investigate a possible trend over the years for different concurrent call loads. It seems that all types of concurrent calls are increasing at a steady rate. This was expected because the total call volume is growing as well. If concurrent calls are plotted by their percentage of the total call volume, the percentages stay almost the same over the years.

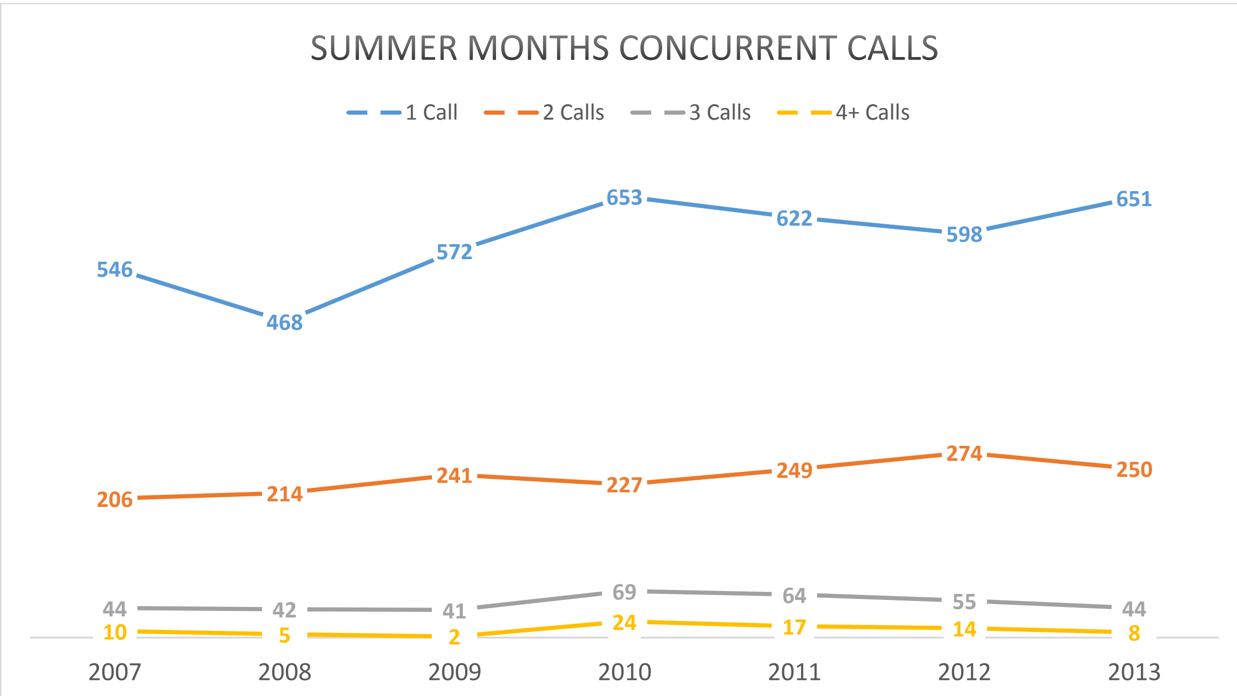


Figure 24 - Summer Months Concurrent Calls

Now knowing that concurrent calls types are growing over the years, the group decided to investigate how concurrent calls affect response times. Clearly concurrent calls delay response times but by how much was uncertain.

Figure 25 compares the concurrency of calls with response times over 10 minutes. The pie chart shows us the percentage of calls over 10 minutes that are concurrent or non-concurrent. Every 1 out of 3 calls (34% or 274 calls) has a response time over 10 minutes due to concurrency.

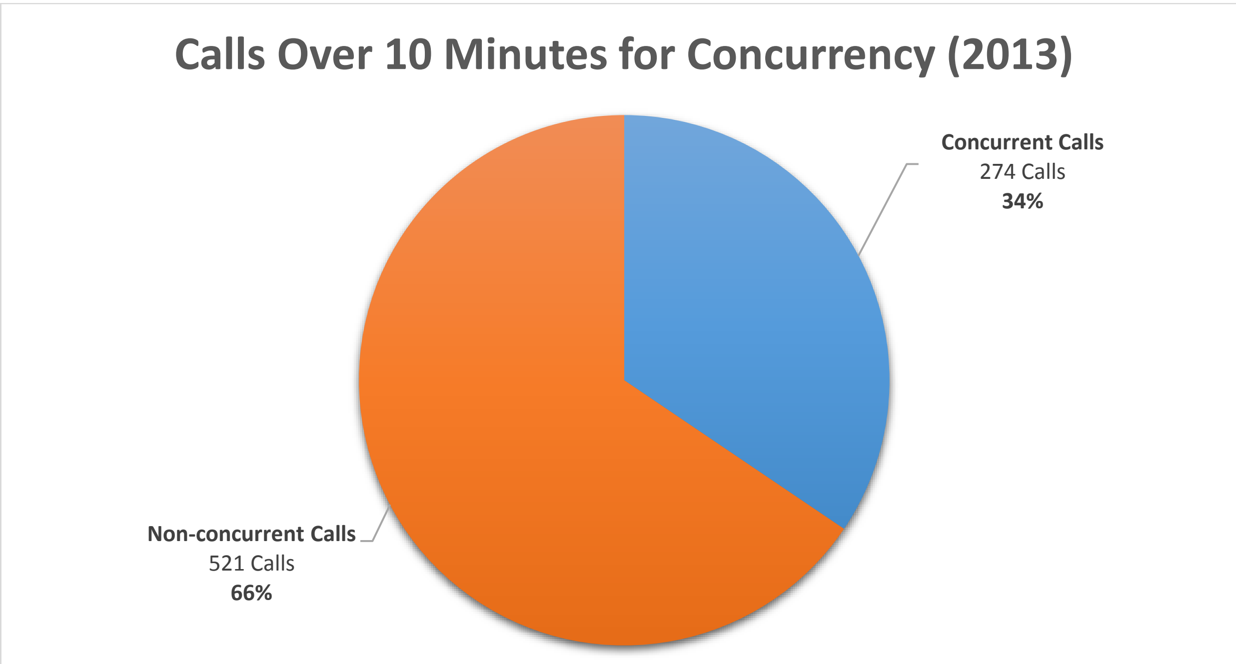


Figure 25 - Calls Over 10 Minutes for Concurrency (2013)

To determine how many concurrent calls the department can handle, the following pie series of pie charts was created. Figure 26 depicts how many concurrent calls are over 10 minutes and how many are under 10 minutes. This is the baseline to compare the following charts to as the distribution between Figure 25 and 26 is fairly similar suggesting that 2 concurrent calls is the most the department can comfortably handle given its current staffing situation.

See Figure 27 for the same analysis for 3+ simultaneous calls. Compared to Figure 26 with the 2nd call being over 10 minutes 37% (274 calls) of the time, the percentage of calls over 10 minutes jumps to 44% (59 of 133 calls). The frequency of calls being over 10 minutes increases by 10% when observing the 3rd call vs the 2nd call. This pretty clearly confirms our hypothesis that the Nantucket Fire Department begins to have trouble responding to any more than 2 calls at the same time.

Figure 28 once again repeats this analysis but for 4+ simultaneous calls. Response times lengthen even more as now, the 4th call is over 10 minutes 49% (17 of 35 calls) of the time. This means that the 4th person calling 911 will not receive aid until after 10 minutes nearly half of the time.

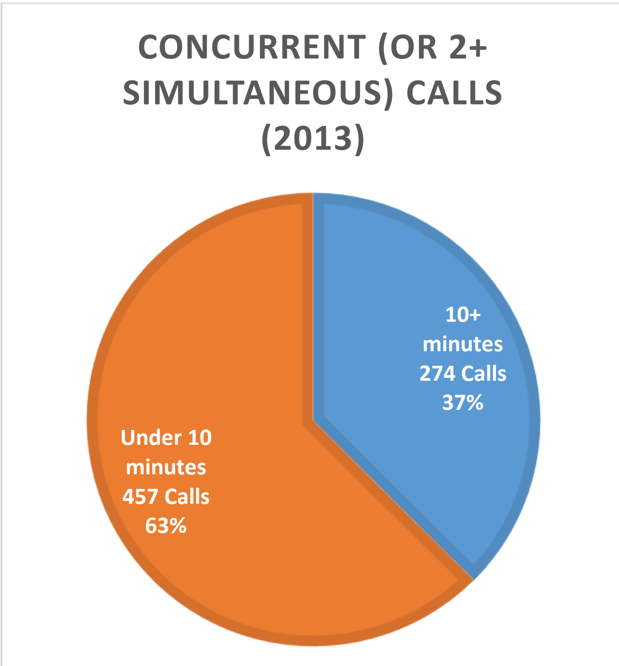


Figure 26 - Concurrent (or 2+ Simultaneous) Calls (2013)

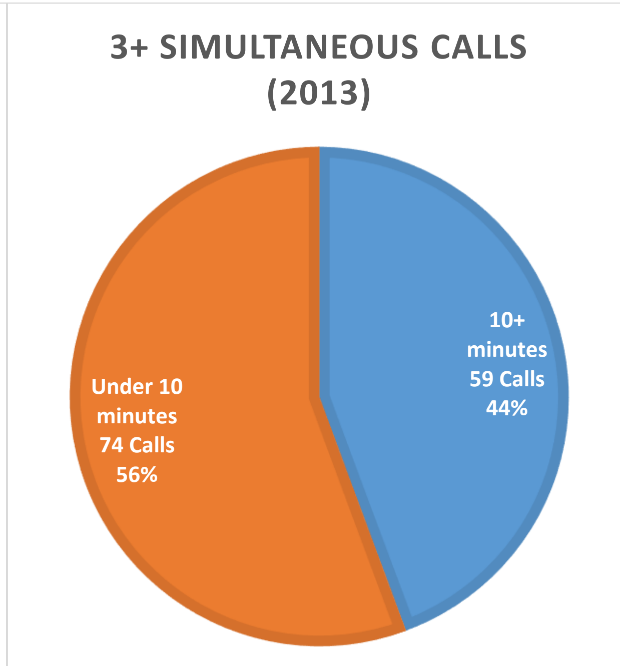


Figure 27 - 3+ Simultaneous Calls (2013)

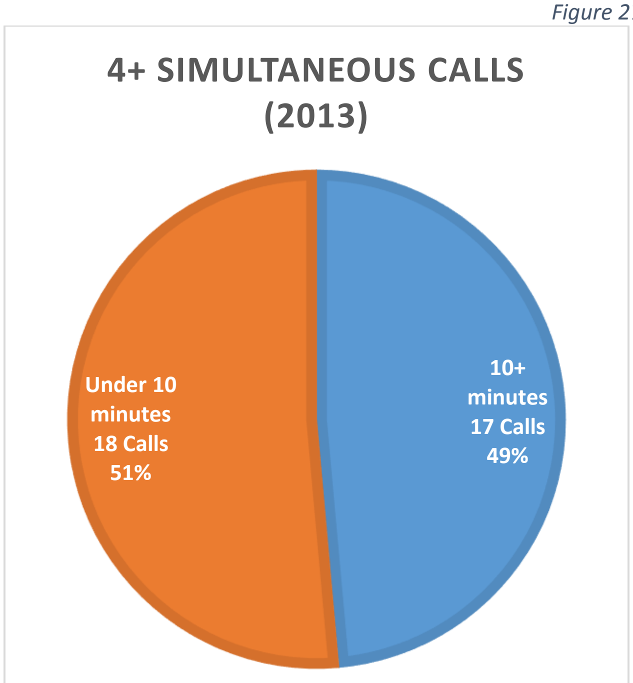


Figure 28 - 4+ Simultaneous Calls (2013)

Figure 29 visually displays the distribution of concurrent calls throughout the year. In the summer months (June, July, August) the Nantucket Fire Department handles 42% (115 of 274 calls) of its concurrent calls for the year. In ¼ of the year, NFD sees a little less than ½ of its concurrent calls. This does not exactly come as a surprise, but it certainly emphasizes the point that Nantucket Fire Department sees much more call volume in the summer months.

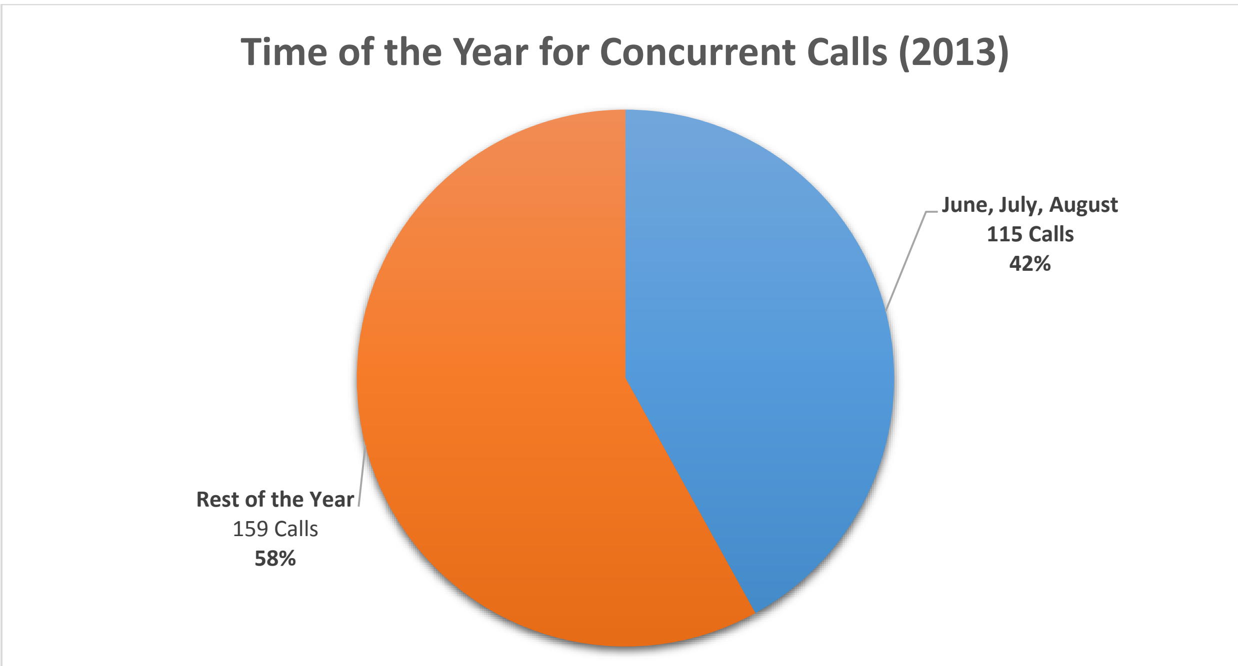


Figure 29 - Time of the Year for Concurrent Calls (2013)

Figure 30 shows the calls per thousand people in the summer months for the years 2007 through 2010 excluding August 2008 as incomplete call data for that month skewed the graph. We gathered the population estimation data from the past IQP *Feasibility of a Smart Grid on Nantucket* (see Appendix G). Organized by year, the graph shows that there is an increase in number of calls per person over the years. With the population increasing and the people per call decreasing, we can project that the Nantucket Fire Department will see a higher call volume than ever in the upcoming years. This means that there will be an increased number of concurrent calls because as there are more people there will be more calls and therefore a higher chance of call concurrency.

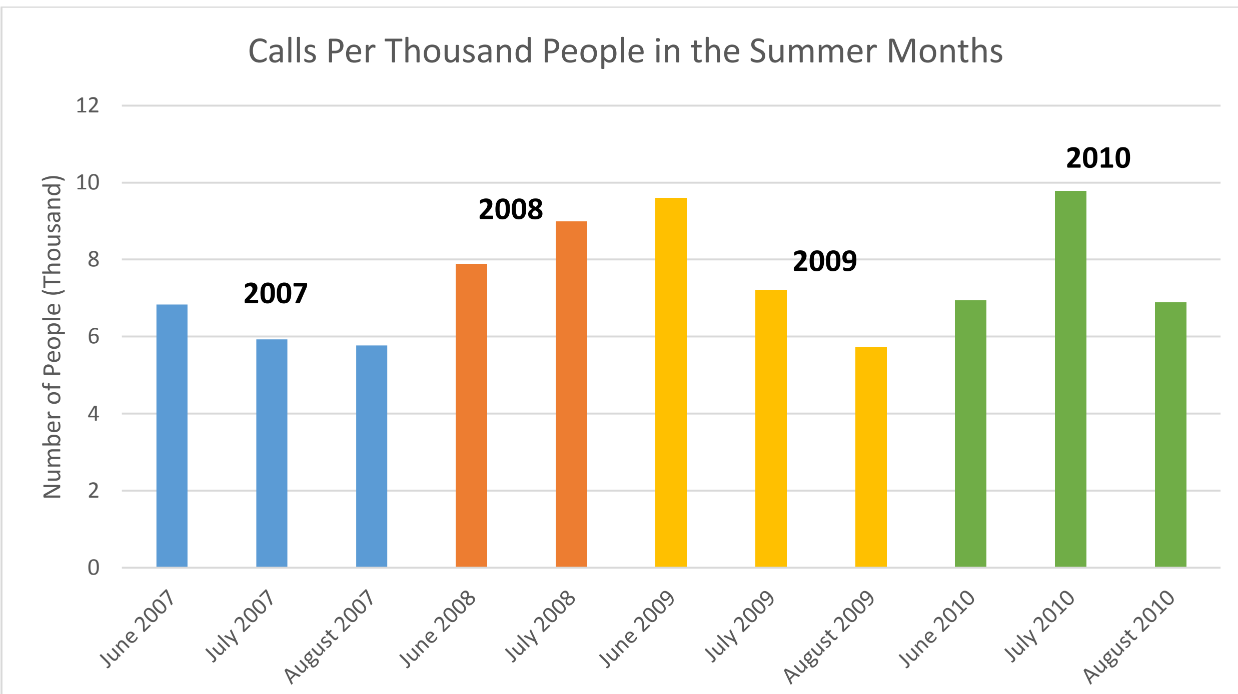


Figure 30 - Calls Per Thousand People in the Summer Months

The same analysis was performed for specifically EMS calls only and Alarm Activation calls only, in order to view the trend of various types of calls per thousand people across years. See Appendix H for both of these analyses. Overall, concurrent calls are one of the major factors that lead to long response times on Nantucket.

4.1.5 Distance Related Analyses

While the central station is well positioned to respond to the majority of calls, which occur in the central town area, many calls still occur in Madaket and Siasconset, communities which are up to 7 miles away. In those cases, the Nantucket Fire Department's goal and the NFPA standard of a 5 minute response time is unobtainable even under ideal traffic and road conditions.

Figure 31 shows all call data from 2013 organized by driving distance from the central station. The distance categories were split into six categories: 0-1 miles, 1-2 miles, 2-3 miles, 3-4 miles, 4-5 miles, and 5+ miles. The distance data was collected using Google API Map Direction and is not necessarily the distance traveled by the firefighters but the route Google identified as the shortest. There are 837 points in the 0-1 mile range, 1060 points in the 1-2 mile range, 232 points in the 2-3 mile range, 140 points in the 3-4 mile range, 85 points in the 4-5 mile range, and 357 that are greater than 5 miles away. From this we can see that 70% of all calls are within 2 miles from the central station.

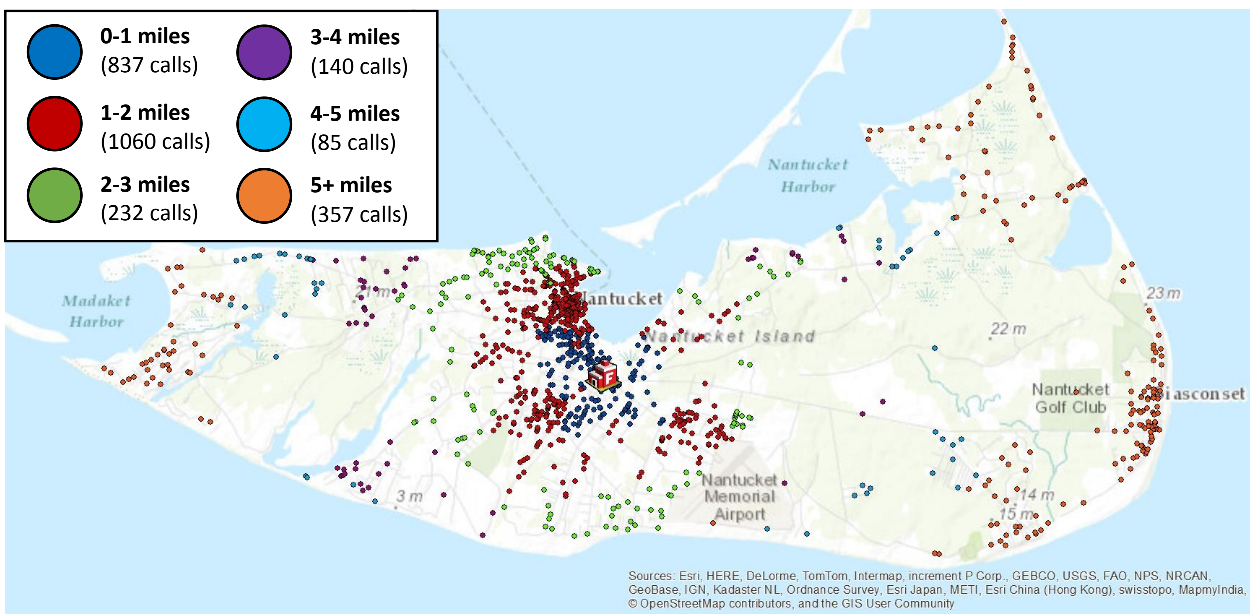


Figure 31 - Driving Distance from Central Station

The points from the map were sorted for only 10+ min responses then translated into a pie chart (Figure 32) to easier see the distribution of distances. The 0-2 mile range contains 45% of 10+ minute response time points most likely due to traffic, whereas the 5+ mile range holds 30% of the 10+ minute response time points which can be attributed to distance.

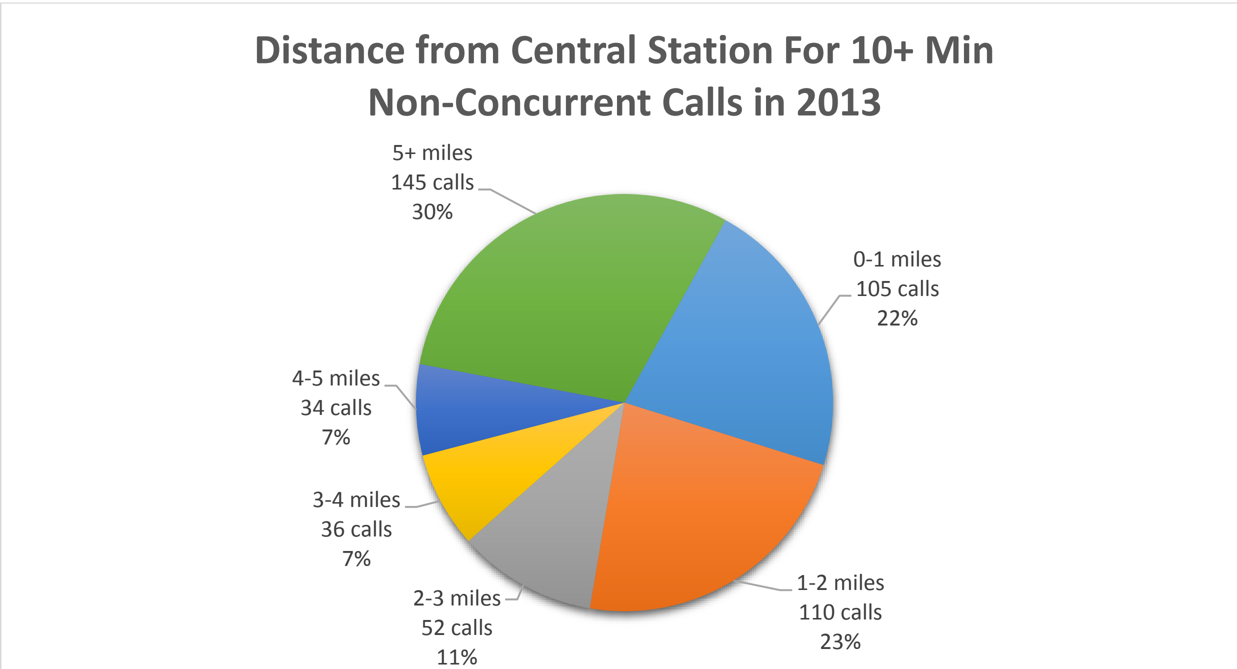


Figure 32 - Distance from Central Station (2013)

4.1.6 Limitations in Response Caused by Congestion

The group discovered that the problem of lengthening response times was due to many compounding factors and could not be simply attributed to one factor and thus one solution. One of the factors delaying response times that is more difficult to measure is traffic, specifically summer traffic in the downtown area. Narrow roads, high curbs, and a large volume of vehicles create a very difficult environment for the fire department to navigate downtown in the summer months.

Figure 33 organizes the points by average speed of the engine or ambulance on its way to the call. This map is a preliminary analysis of congestion as calls with low average speeds can be attributed to traffic. The speed was calculated using the distance from Google and dividing by the response time minus 1 for turnout time. Most slow points fall within a few miles of the central station and in downtown areas (where traffic is most likely to occur), while most of the points with higher average speeds are in the Siasconset area. This is logical because in the downtown area, traffic and congestion is more frequent, while travelling to Siasconset the firefighters can increase their average speed down Milestone Road. See Appendix I for each category shown individually.

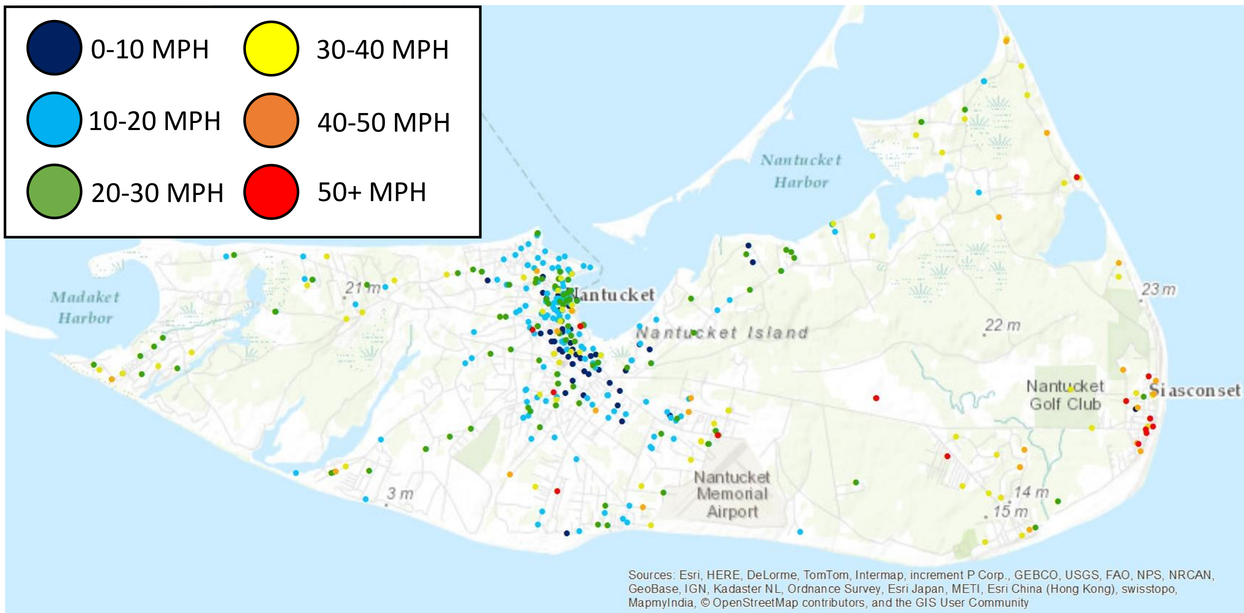


Figure 33 - Speed Map (2013)

To develop a method of relating the response times of points to predicted road congestion in the area, the group contacted Mike Burns, the Town of Nantucket's Transportation Planner. He gave us a list of congested roads and intersections during our meeting with him, in which he had pinpointed as the highly congested roads in and around town. If the fire department has to travel to or through these roads, they will certainly experience delays due to high congestion, especially in the summer. See Figure 34 below, for a visual of the zone that we defined as the congestion area. These roads and intersections highlighted by Mike Burns were: the Milestone Road rotary, Four Corners Intersection, the Sparks Avenue approach to Four Corners and the Surfside Road approach to Four Corners, Five Corners Intersection, the Quaker Road approach to Madaket Road, Orange Street, Union Street, Francis Street, Washington Street, and portions of Old South Road.

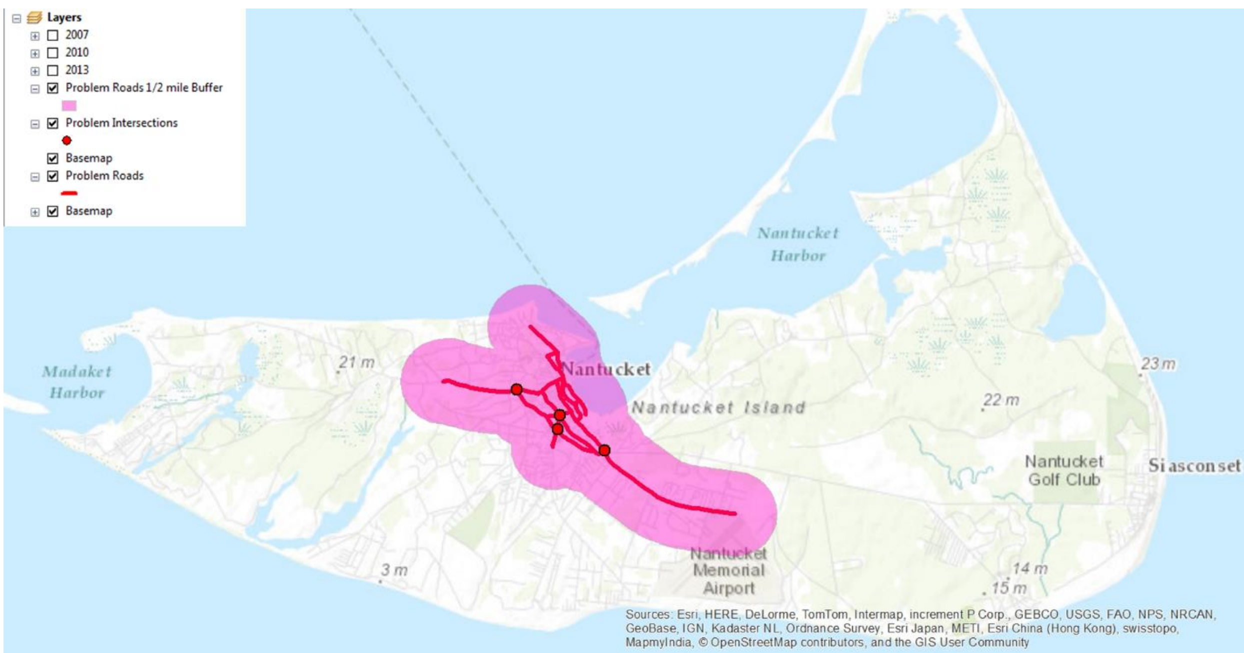


Figure 34 - Map of Congestion Area

The roads in the downtown area of Nantucket also produce unique challenges that the Nantucket Fire Department must face when responding into the downtown area. Narrow streets that are difficult for a large fire engine to navigate even when deserted, high curbs mean cars cannot move out of the way or park up on the shoulder of the road thus making roads even narrower, and cobblestone paved streets which slow down traffic in general and the fire engines themselves. The high level of pedestrian traffic downtown during the summer also means that the fire department must navigate this area extremely carefully, as even with lights and sirens vehicles and pedestrians frequently do not move out of the way for emergency vehicles. This is the daily reality for the Nantucket Fire Department in the summer, every day of the week means congested summer roads and delayed response times to emergencies.

Figures 35, 36, and 37 are from the years 2007, 2010, and 2013 (respectively) and show all non-concurrent calls from the summer months (June, July and August) where response time is over 20 minutes. From looking at the following pie charts, we discerned that the number of high response time calls coming from the congested area is increasing, therefore traffic is becoming a larger problem for the fire department. For example in 2007 (Figure 35), only 27% of non-concurrent summer calls over 20 minutes come from inside of the congested area. We see a steady rise in this percentage every year and now in 2013 (Figure 37), 40% of calls come from inside of the congested area. The total number of calls over 20 minutes is also increasing. In 2007 (Figure 35), only 11 calls had a response time over 20 minutes. The year 2013 (Figure 37) had 20 calls with a response time over 20 minutes.

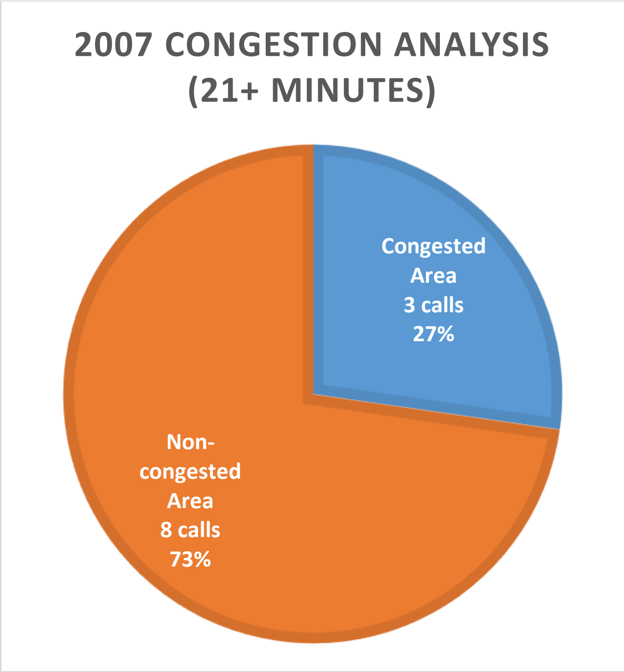


Figure 35 - 2007 Congestion Analysis (21+ Minutes)

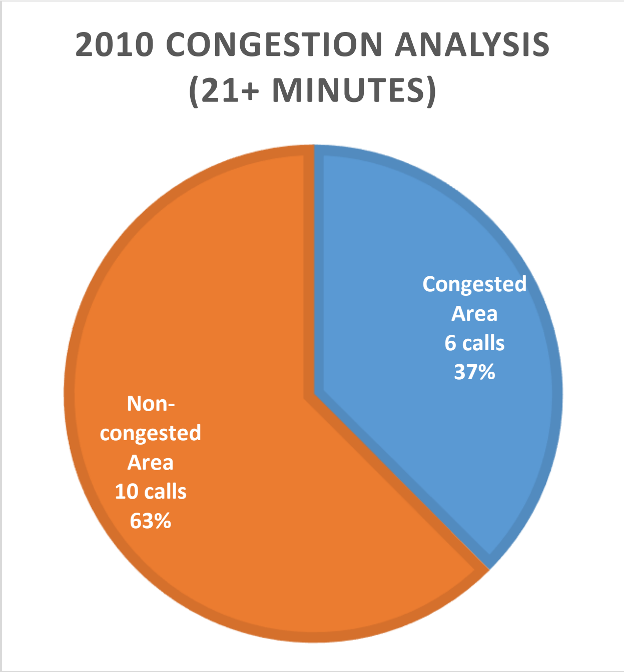


Figure 36 - 2010 Congestion Analysis (21+ Minutes)

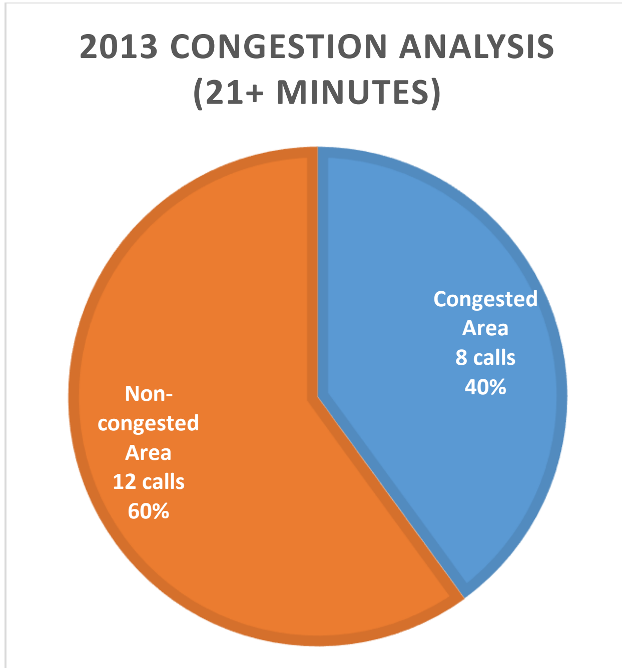


Figure 37 - 2013 Congestion Analysis (21+ Minutes)

See Figure 38 below for the map of the total clips of all time categories of non-concurrent summer calls inside of the congested area for 2013. See Appendix J for all of the time clips for 2013 and for the combined clips for 2007 and 2010.

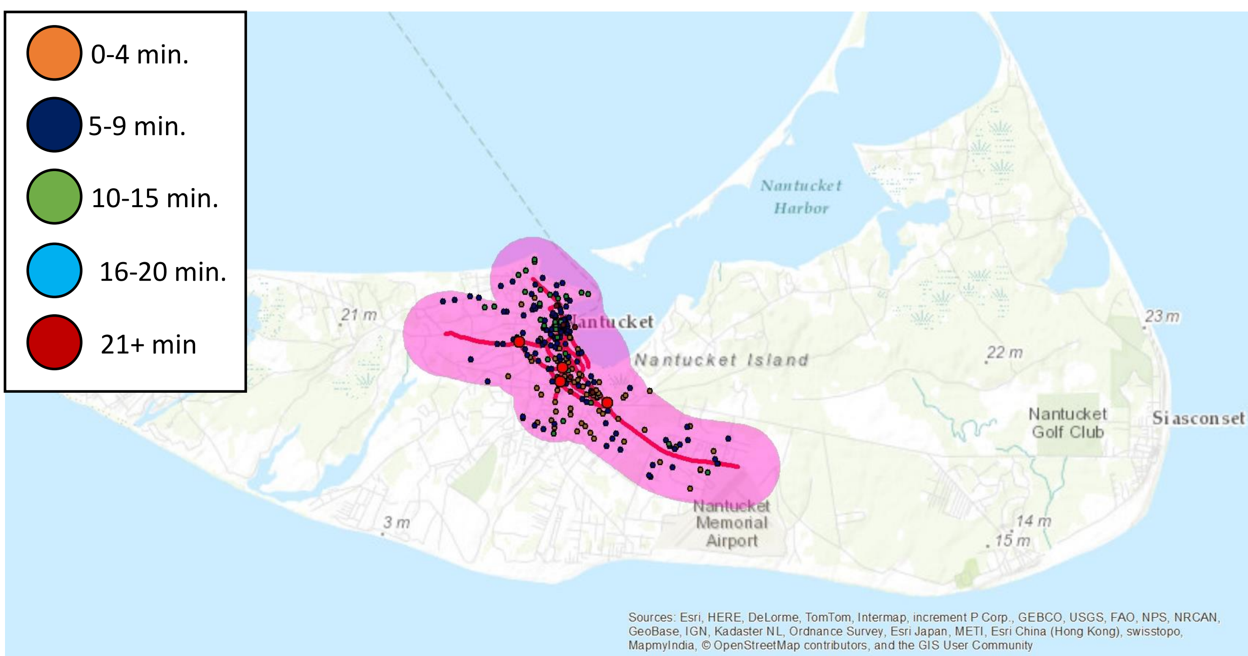


Figure 38 - Congestion Map (2013)

Using our traffic analysis map with problem roads and intersections marked with added half mile buffers, Figure 39 was created grouping the totals into three categories (10-15, 16-20, and 21+ minute response times) and compared their locations. We noticed that the congested area was more dominated by calls that were in the 21+ minute response time category; whereas calls outside of the congested area were found more in the 10-15 and 16-20 minute response time categories. This suggests that calls which have a high response time due to distance are usually on the lower end of high response times, whereas calls which take a long time to respond to due to traffic usually have a response time much longer (21 or more).

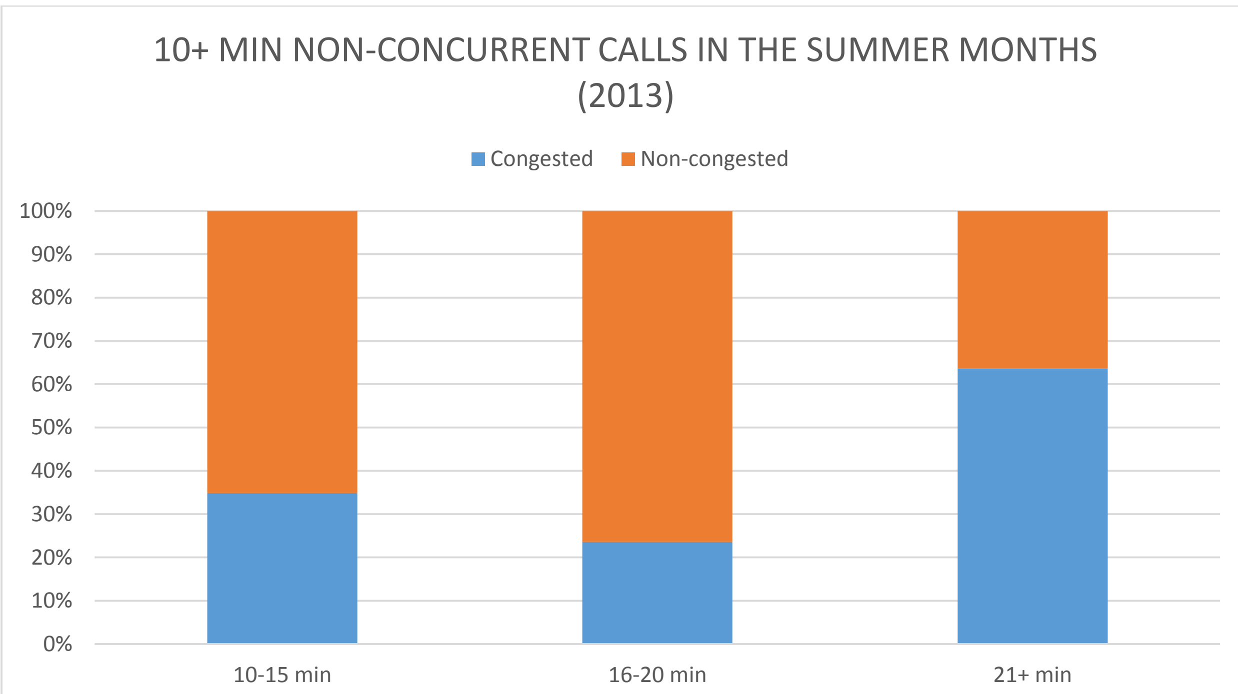


Figure 39 - 10+ Non-concurrent Calls in the Summer Months (2013)

Figure 40 compares the number of calls inside of the congested area to outside of the congested area. As we can see 63 of the 159 non-concurrent calls that are in the summer months and have a response time over 10 minutes, fall in this congested area. This means we can generally assume that 40% of non-concurrent summer calls which have a response time over 10 minutes have a high response time due to traffic. The NFD is aware of this problem however, there is not much they can do to combat the traffic besides avoiding the congested roads altogether which would increase the response time because of the distance covered to circumvent the congested core district.

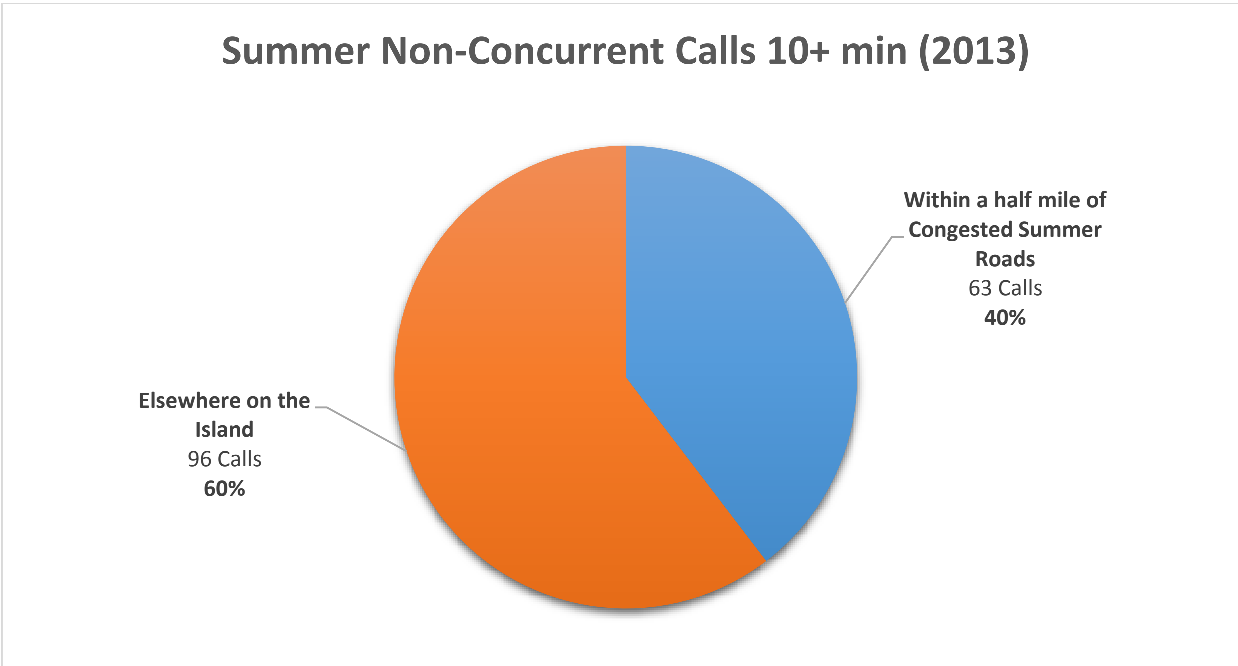


Figure 40 - Summer Non-concurrent Calls 10+ min (2013)

Traffic on the island is further impacted by the fact that Nantucket is a historic town. This means that there is a Historic District Commission that has regulations that directly relate to traffic conditions on the island. For example, many of the roads in the downtown area are still the original cobblestones. While these look nice and certainly fit the description of historic, they were not designed to have fire trucks driving on them. When a call occurs in the downtown area and the fire department has to drive an engine down any of these cobblestone roads, they are forced to drive at a significantly reduced speed which lengthens response time. Additionally, these old roads were built when fire trucks were pulled by horses. Because of this, many of the roads are narrow enough that they are now one-way streets, which adds further difficulty to navigating the downtown area. There are also narrow roads that are not quite narrow enough to be designated as one-way only, that a fire truck can barely fit down. This becomes a problem on such narrow roads that allow street parking, especially in the summer. In order to bypass parked cars and travel down these roads, fire trucks are sometimes forced to drive partially on the sidewalk—and even this is impossible in places where there is a car parked on one side of the road and a utility pole on the other.

Many of these roads often flood in bad weather as well, making parts of the downtown area even harder to access than normal as the roads are impassible due to standing water. The final historic factor that has a potentially significant impact on response times is the fact that the island of Nantucket has no traffic lights. Instead, traffic flow is regulated by an abundance of rotaries and traffic circles, which are difficult for fire trucks to navigate. The lack of traffic lights also means that the Nantucket Fire Department does not have the option of using a system that would allow them to change the color of traffic lights when approaching an intersection, which many cities have used with great success (Global Traffic Technologies, n.d.). As it has been made apparent, there are many contributors to the congestion problem on Nantucket, making it a large obstacle for the fire department.

4.2 Mitigation of Nantucket Fire Department response times

4.2.1 Satellite station simulations

In order to recommend a location for a new potential satellite station, the group ran multiple simulations on the 2013 call data as if a satellite station was operational from a certain address. The group performed four analyses on the following addresses: 20 South Water St, 48 Cliff Rd, 293 Madaket Rd, and 10 West Sankaty Rd. Below are the results from these simulations.

20 South Water St. Station Simulation

The old police station in the downtown area at 20 South Water St. was one of our locations for a simulated satellite station. This address was chosen because of its proximity to a large percent of the call volume that Nantucket handles each year and already has a structure owned by the town that could be modified for the fire department's use. As you can see in Figure 41, this satellite station improved response times for 29% of all calls. It also breaks down percentages of how much the response times were improved. The most significant improvement was in the 2-3 minute section. In Table 5, you can see the number of calls that fall into each category.

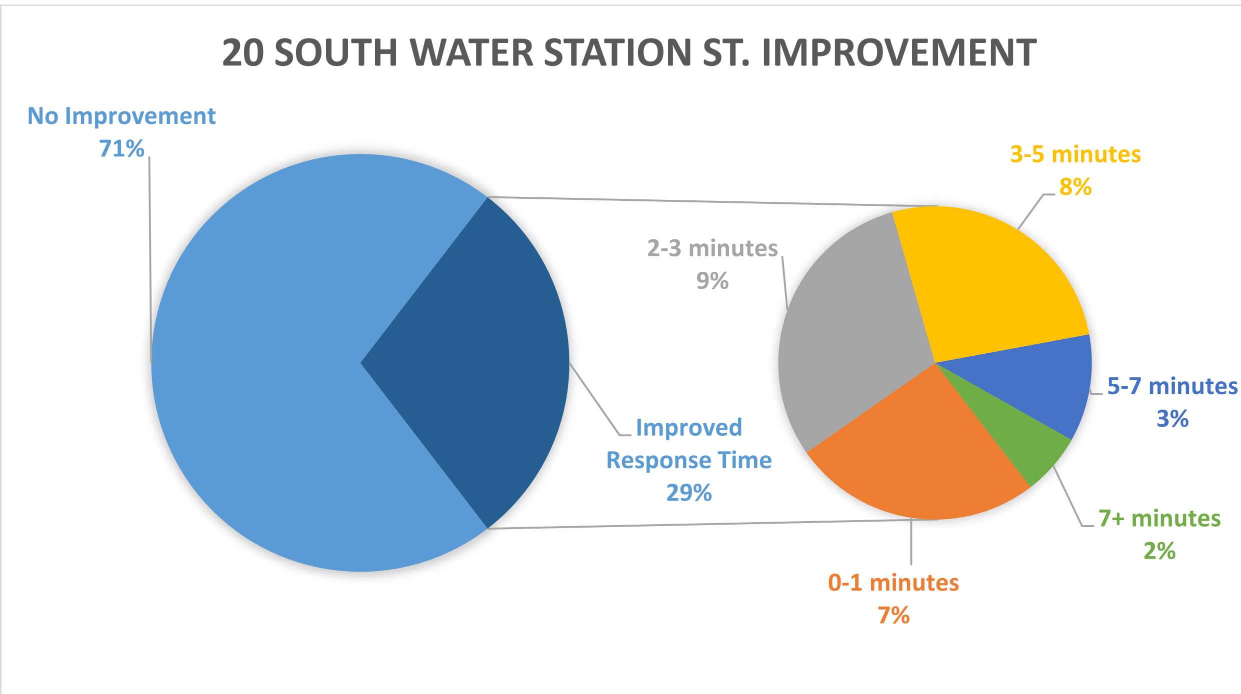


Figure 41- Simulation Results from 20 South Water St Station

20 South Water St. Station Improvement	
Minutes Improved	**Number of Calls**
No Improvement	1861
0-1 minutes	197
2-3 minutes	232
3-5 minutes	203
5-7 minutes	85
7+ minutes	49
Total Points Improved	**766**
Total Points	2627

Table 5 - 20 South Water St. Station Improvement

The average response time for the island was 9.31 minutes before the simulation. After the simulation, the overall average response time for Nantucket decreased to 8.4 minutes. At almost a full minute improvement, this address would be a good location to consider placing a new satellite station especially since the average improvement of the calls response time is 3.11 minutes. This means that for every one of the 766 calls improved by this location, the response time was decreased by an average of 3.11 minutes.

Looking at the spatial distribution of the calls improved by the 20 South Water St. station in Figure 42 below, we can see that the station dramatically decreases response times in the downtown area. The color of the points indicate the conjectured improvement of the response times. From this map however, we can see that this location fails to improve calls out in Madaket by more than a minute.

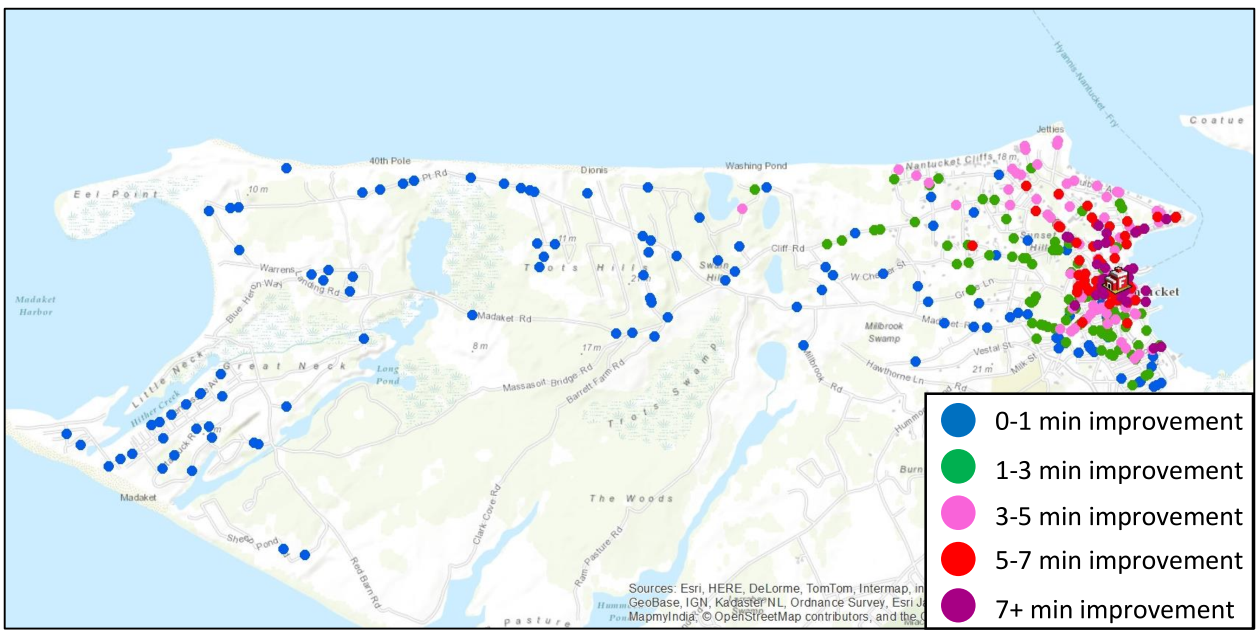


Figure 42 - Map from 20 South Water St. Station Simulation

48 Cliff Rd. Station Simulation

Coffin Park is located at 48 Cliff Rd. which sits right outside on the northeast side of downtown, was another location we chose for simulation. This location was chosen as it is empty land owned by the Town and located in an area with easy access to both Madaket and town. Having a satellite station on Cliff Road would allow the fire department to respond to calls on the opposite side of town from the central station without being affected by the downtown traffic. As shown by Figure 43, the satellite station improved response times for 23% of all calls. The percentages of how much the calls were improved are shown as well. It is important to note that the 0-1 minute category had little improvement. The other sections experienced greater improvement, signifying a larger impact that this location had on response times as a whole. Table 6 shows the exact numbers of how many calls were improved by this satellite station location.

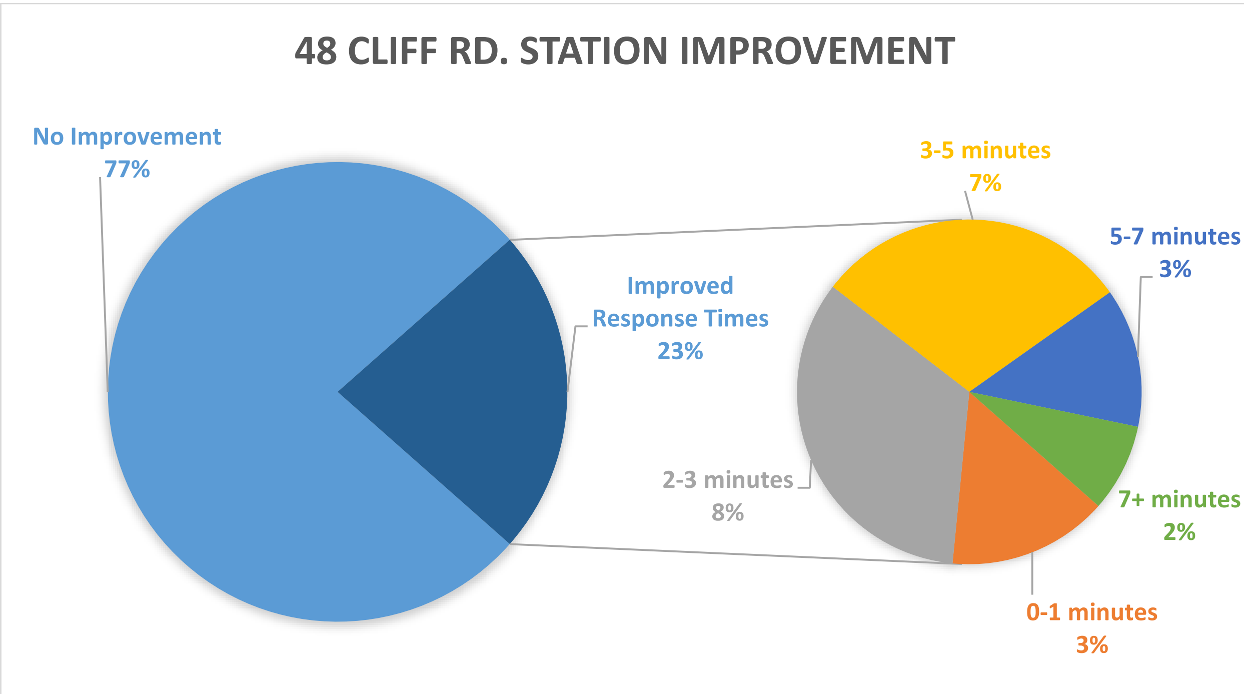


Figure 43 - Simulation Results from 48 Cliff Rd Station

48 Cliff Rd. Station Improvement	
Minutes Improved	**Number of Calls**
No Improvement	2022
0-1 minutes	91
2-3 minutes	205
3-5 minutes	180
5-7 minutes	79
7+ minutes	50
Total Points Improved	**605**
Total Points	**2627**

Table 6 - 48 Cliff Rd. Station Improvement

The average response time for the island was 9.31 minutes before the simulation. After the simulation, the overall average response time for Nantucket decreased to 8.48 minutes. At a 43 second improvement, this address would be a good location to consider placing a new satellite station especially since the average improvement of the calls response time is 3.61 minutes. This means that for every one of the 605 calls improved by this location, the response time was decreased by an average of 3.61 minutes.

Looking at the spatial distribution of the calls improved by the 48 Cliff Rd. station in Figure 44 below, we can see that the station dramatically decreases response times in the downtown area as well as out in Madaket and the Eel Point Rd areas. The color of the points indicate how much time the response time was improved by. From this map however, we can see that this location would service Madaket up to 5 minutes faster than the 20 South Water St. station would.

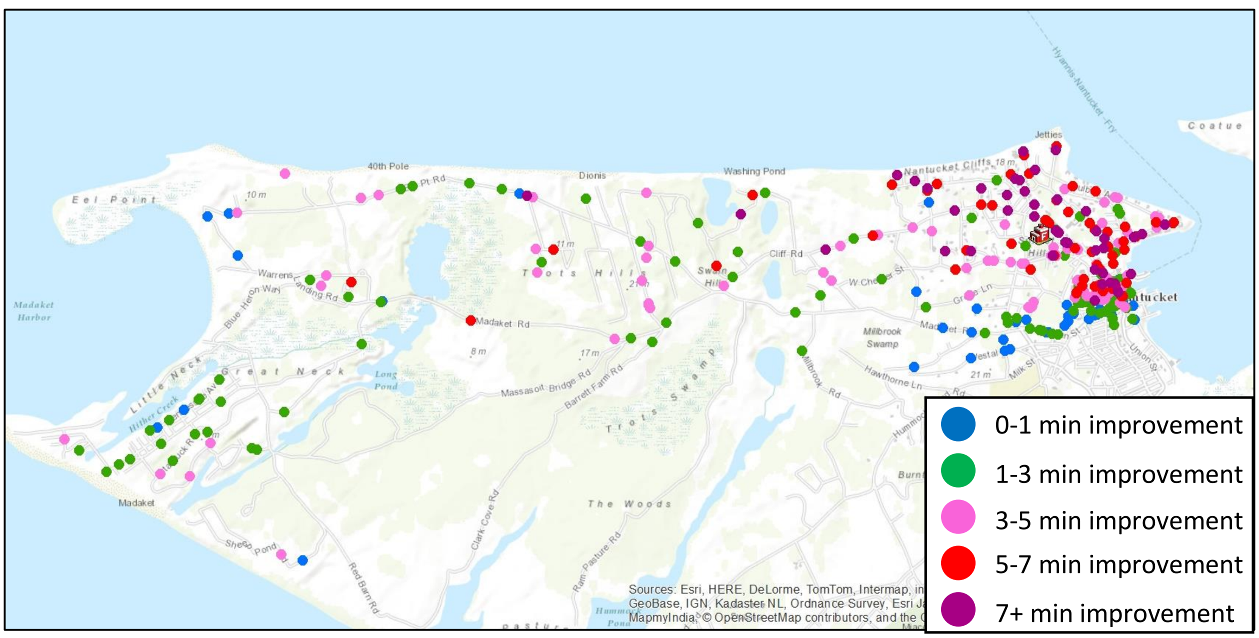


Figure 44 - Map from 48 Cliff Rd. Station Simulation

293 Madaket Rd. Station Simulation

The current unmanned satellite station at 293 Madaket Rd. that currently has one fire engine housed in it was the location of another simulation. If equipped with two staff and an ambulance as well, the satellite station would improve response times of 5% of all calls (seen in

Figure 45). This location was an obvious choice as the fire department already has a facility at this address, however it is important to note that this building would need significant alterations to adequately house an ambulance and working quarters for the staff. Figure 45 breaks down percentages of how much the response times were improved. While this location did improve many calls overall, the largest section that was affected by this address was the 7+ minute category. This really proves that the largest obstacle that the fire department faces in this area is distance. Table 7 shows exact numbers on how many calls were improved by this location.

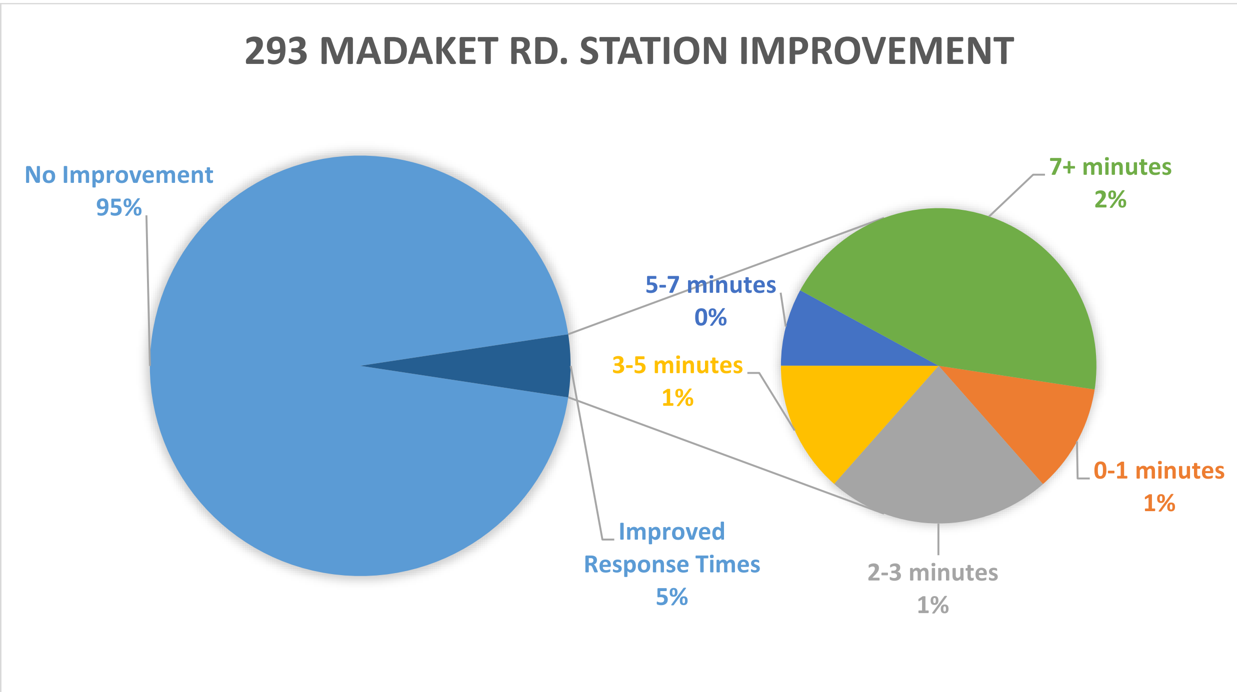


Figure 45 - Simulation Results from 293 Madaket Rd. Station

293 Madaket Rd. Station Improvement	
Minutes Improved	**Number of Calls**
No Improvement	2501
0-1 minutes	14
2-3 minutes	29
3-5 minutes	17
5-7 minutes	10
7+ minutes	56
Total Points Improved	**126**
Total Points	**2627**

Table 7 - 293 Madaket Rd. Station Improvement

The average response time for the island was 9.31 minutes before the simulation. After the simulation, the overall average response time for Nantucket decreased to 9 minutes. At not even a 1/3 of a minute improvement, this address would not be a good location to consider placing a new satellite station despite the average improvement of the calls response time is 6.48 minutes. This means that for every one of the 126 calls improved by this location, the response time was decreased by an average of 6.48 minutes.

Looking at the spatial distribution of the calls improved by the 293 Madaket Rd. station in Figure 46 below, we can see that the station dramatically decreases response times in the Madaket area, in many places often for than 7 minutes. The color of the points indicate how much time the response time was improved by. We can see from Figure 46 that while this location would also cover calls on Madaket Road and Cliff Road, it would not be the most cost effective way for the town to lower response times for the entire island.

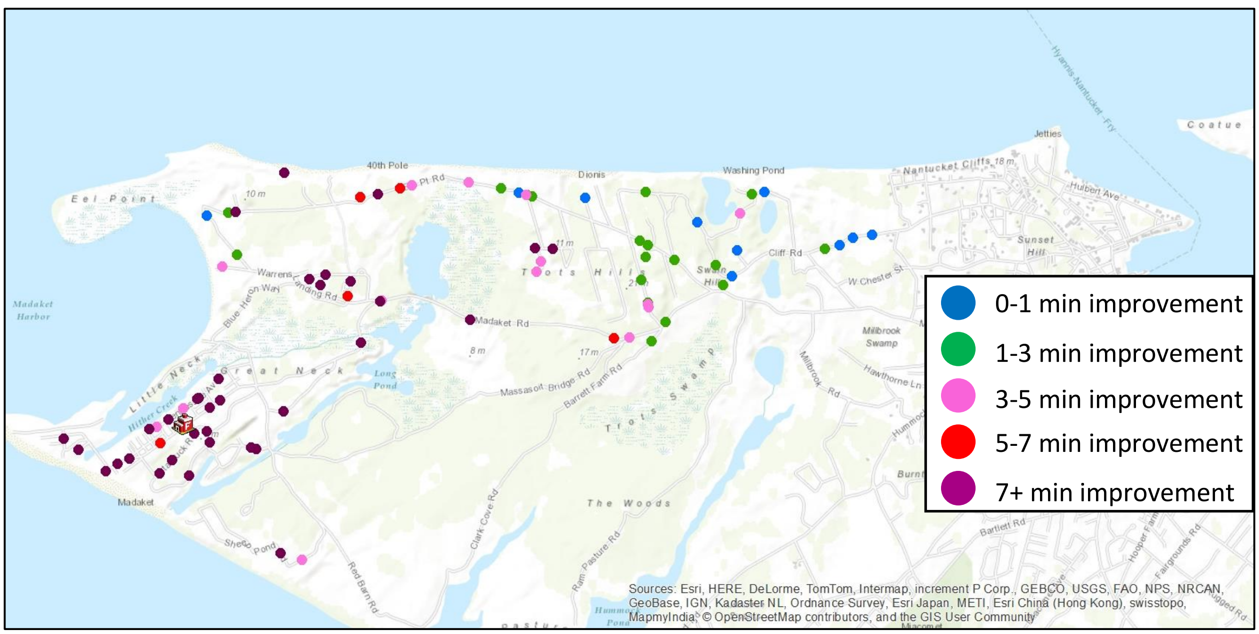


Figure 46 - Map from 293 Madaket Rd. Station Simulation

10 West Sankaty Rd. Station Simulation

The unmanned satellite station at 10 West Sankaty Rd. was another location on which we chose to perform a simulation. The Siasconset station currently has one fire engine and a tanker and is currently responded to by call firefighters. This simulation was different than the others as currently, the call firefighters may sometimes respond to an incident from the Siasconset station. Any call that was thought to be responded to by a call firefighter was improved by one minute to represent the time saved by an on duty career firefighter responding from the Siasconset station. As seen in Figure 47, the satellite station improved response times of 12% of all calls. Figure 47 (below) breaks down percentages of how much the response times were improved. We can assume that the large section that was responded to by the Siasconset call firefighters would have improved response times had the station been manned. Table 8 shows exact numbers on how many calls were improved by this location.

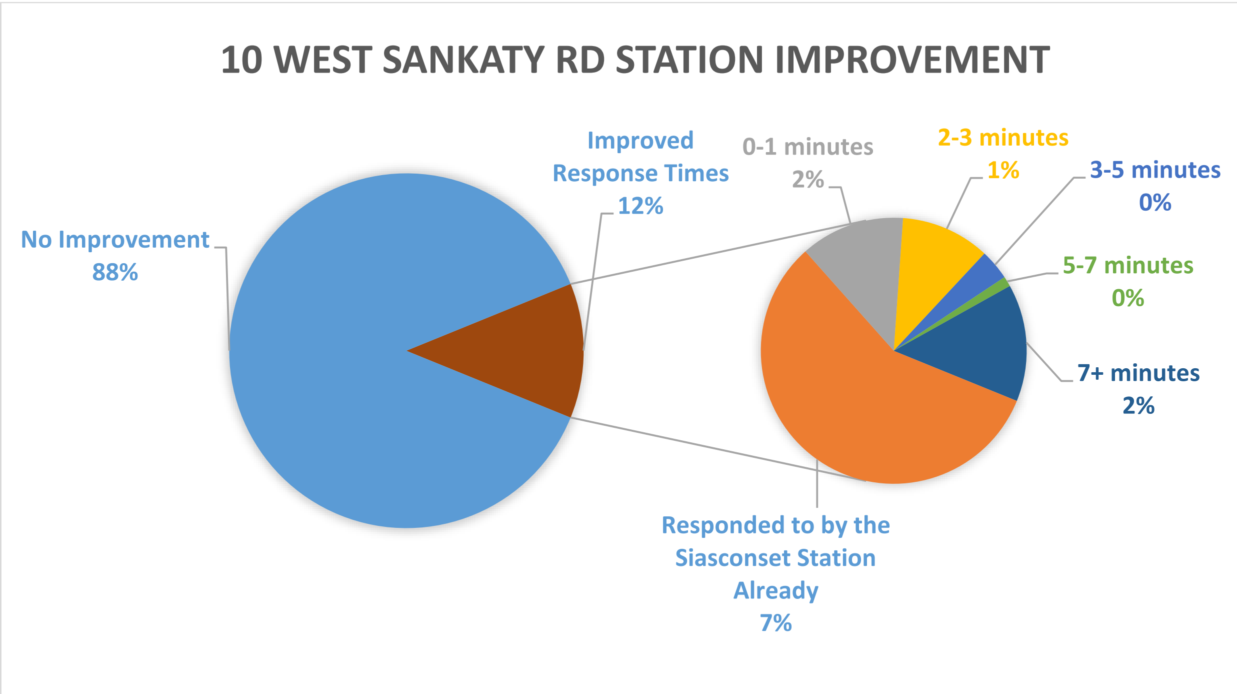


Figure 47 - Simulation Results from 10 West Sankaty Rd. Station

10 West Sankaty Rd. Station Improvement	
Minutes Improved	**Number of Calls**
No Improvement	2304
Responded to by the Siasconset Station Already	185
0-1 minutes	41
2-3 minutes	35
3-5 minutes	12
5-7 minutes	4
7+ minutes	46
Total Points Improved	**323**
Total Points	**2627**

Table 8 - 10 West Sankaty Rd. Station Improvement

The average response time for the island was 9.31 minutes before the simulation. After the simulation, the overall average response time for Nantucket decreased to 8.63 minutes. At about a 1/2 minute improvement, this address would be a decent location to consider placing a new satellite station especially since the average improvement of the calls response time is 5.55 minutes. This means that for every one of the 323 calls improved by this location, the response time was decreased by an average of 5.55 minutes.

Looking at the spatial distribution of the calls improved by the 10 West Sankaty Rd. station in Figure 48 below, we can see that the station dramatically decreases response times in the Siasconset, Wauwinet, and Tom Nevers areas. The color of the points indicate how much time the response time was improved by. It is harder to draw conclusions from this map as it is unclear exactly how much this station would improve response times. From this map we can say that all calls in Siasconset would improve by several minutes and the station being staffed by career firefighters would offer aid in the communities bordering this area.

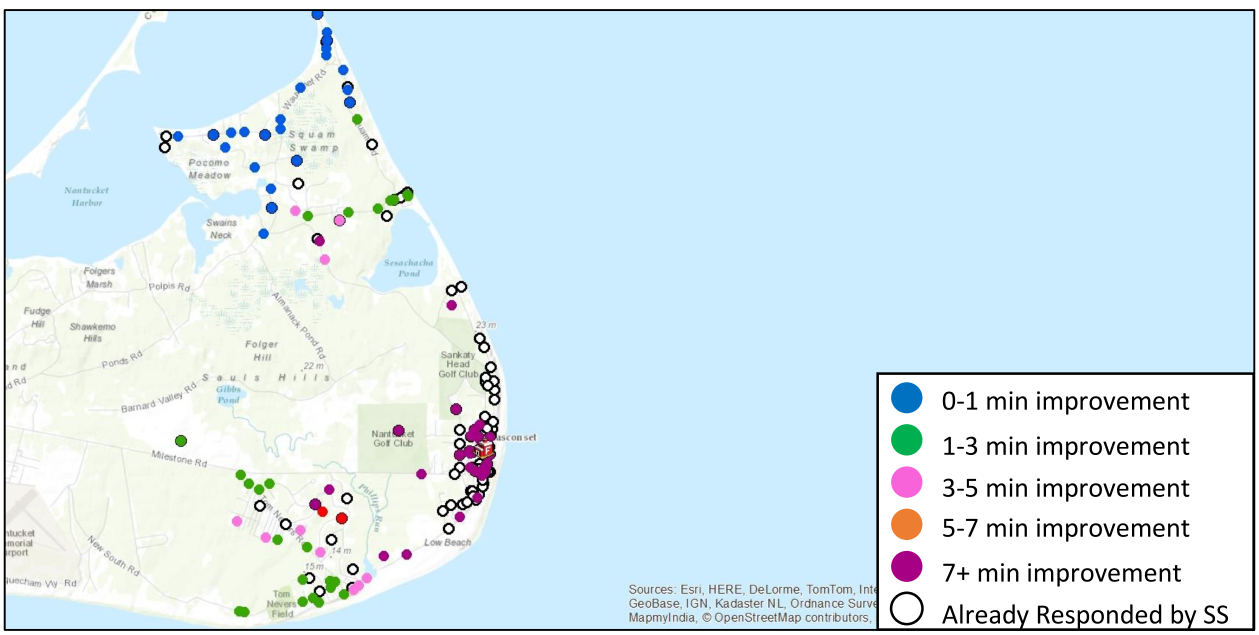


Figure 48- Map from 10 West Sankaty St. Station Simulation

Although we had to make some assumptions, conclusions can still be drawn from these simulations. From the four simulations, we can conclude that the 20 South Water St. station had the best results from the tested locations. Even though the 20 South Water St. station has a lower average improvement, it still had more calls improved in every time category than any other simulation location. The 48 Cliff Rd. simulation produced similar time improvements as the 20 South Water St. station but has a larger improvement range than the 20 South Water St. station, allowing the satellite station to respond to downtown and Madaket. It is important to note that the Siasconset station might have produced better results if more data were known about the calls that were responded from the Siasconset station.

4.2.2 Increased Staffing and its' Impact

In an effort to more accurately recommend when the fire department should deploy supplemental personnel, the group wanted to identify when calls come in most frequently. This was split into two different types of analysis: day of the week and time of the day. If we could determine a specific day of the week and time of the day combination where the fire department could expect an increased number of emergencies, shifts with supplemental personnel could be created at these times to attempt to abate the call influx.

Day of Call Analysis

Figure 49 compares the popularity of each day of the week for all calls in 2012 and 2013. Neither year's distribution showed anything significant for volume of calls by day of the week, other than showing no correlation whatsoever.

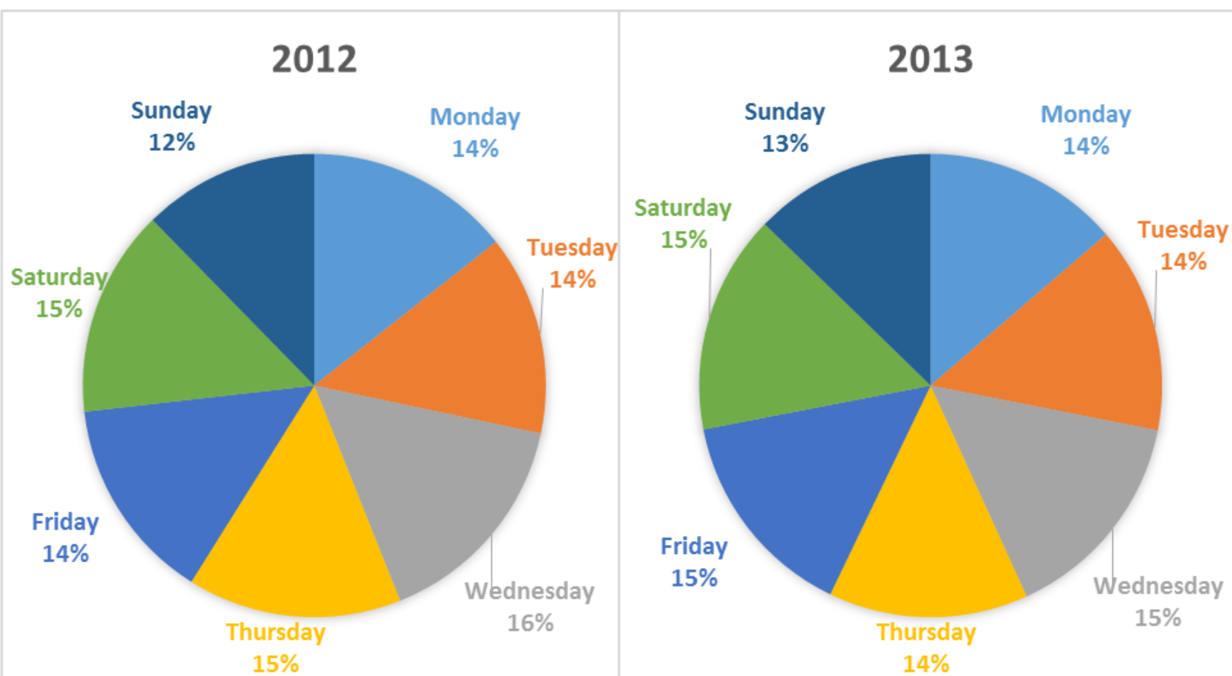


Figure 49 - Day of Call Pie Charts (2012 & 2013)

The stacked area charts for 2012 and 2013 were created to see if time of the year affected the popularities of each day (see Figures 50 & 51). We noticed a large spike in call volume for the summer months however, still no day was found to have a larger call volume than any other consistently throughout the year.

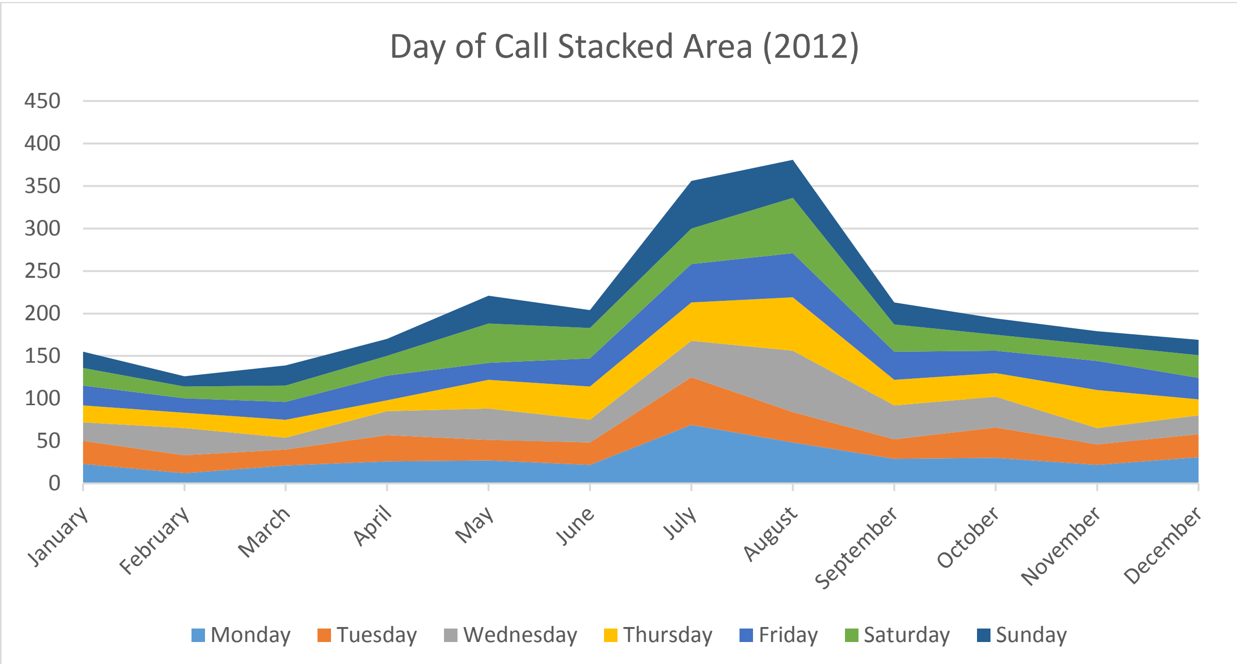


Figure 50 - Day of Call Stacked Area (2012)

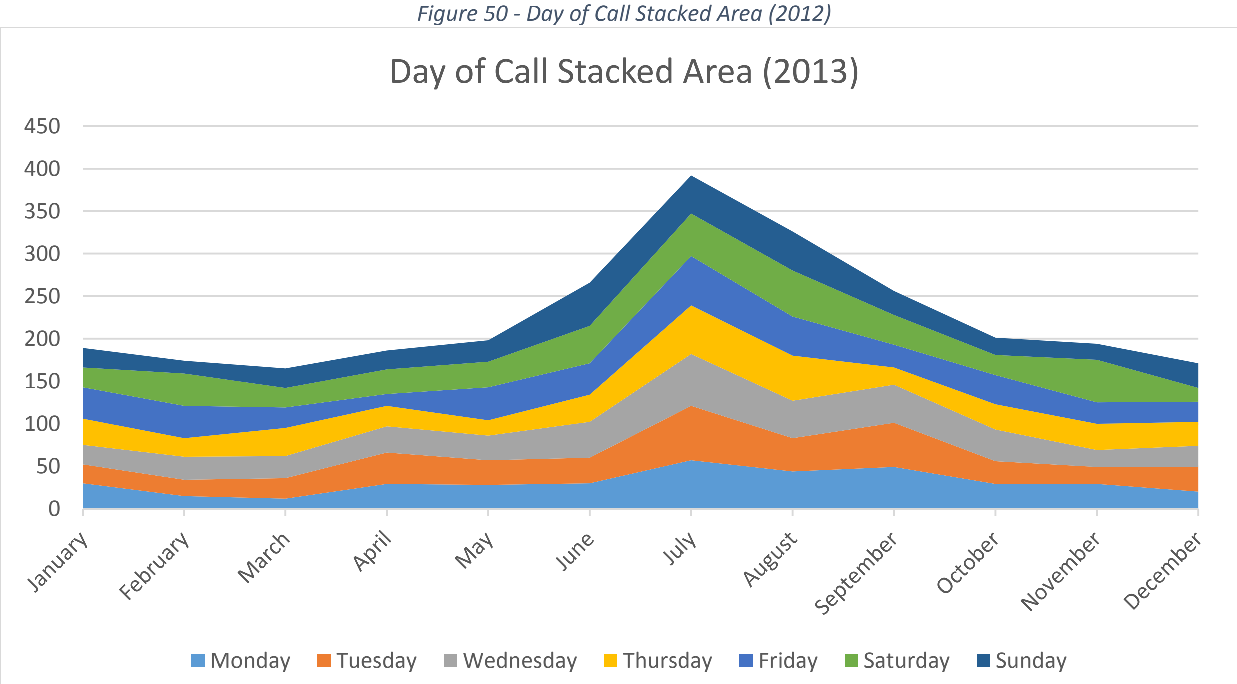


Figure 51 - Day of Call Stacked Area (2013)

Figure 52 was created to analyze call volume per day of the week in the summer months as the previous figures (Figure 50 and 51) highlighted the increased number of calls in June, July and August (see Appendix K for all years). The group noticed that Thursday had a slightly higher percentage than the other days, however after viewing every year, the pattern was not strong enough to call a trend.

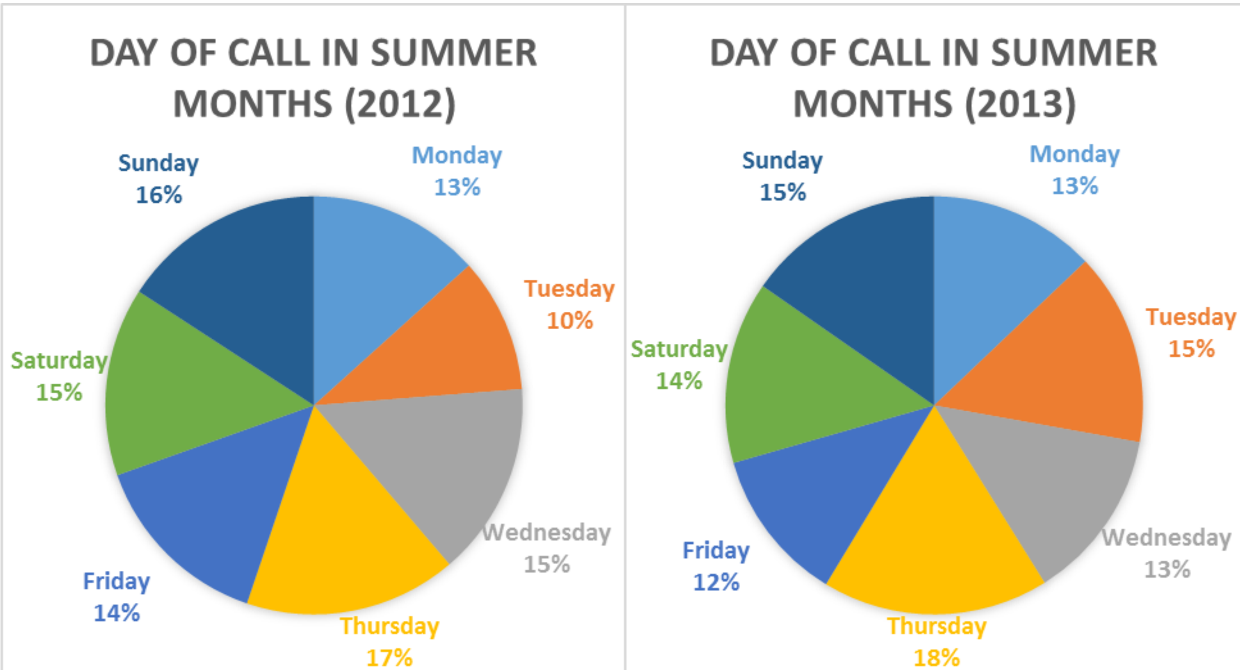


Figure 52 - Day of Call in Summer Months (2012 & 2013)

Again after not finding any significant correlation across years, only EMS call volume by day of the week for each year was examined to determine if call type had an impact on day of the week popularity, and thus created the stacked column bar charts (see Appendix L for all years). After viewing Figures 53 & 54, it is apparent that Thursday has a slightly higher volume of calls than all other days however, the correlation was not significant enough to say for certain.

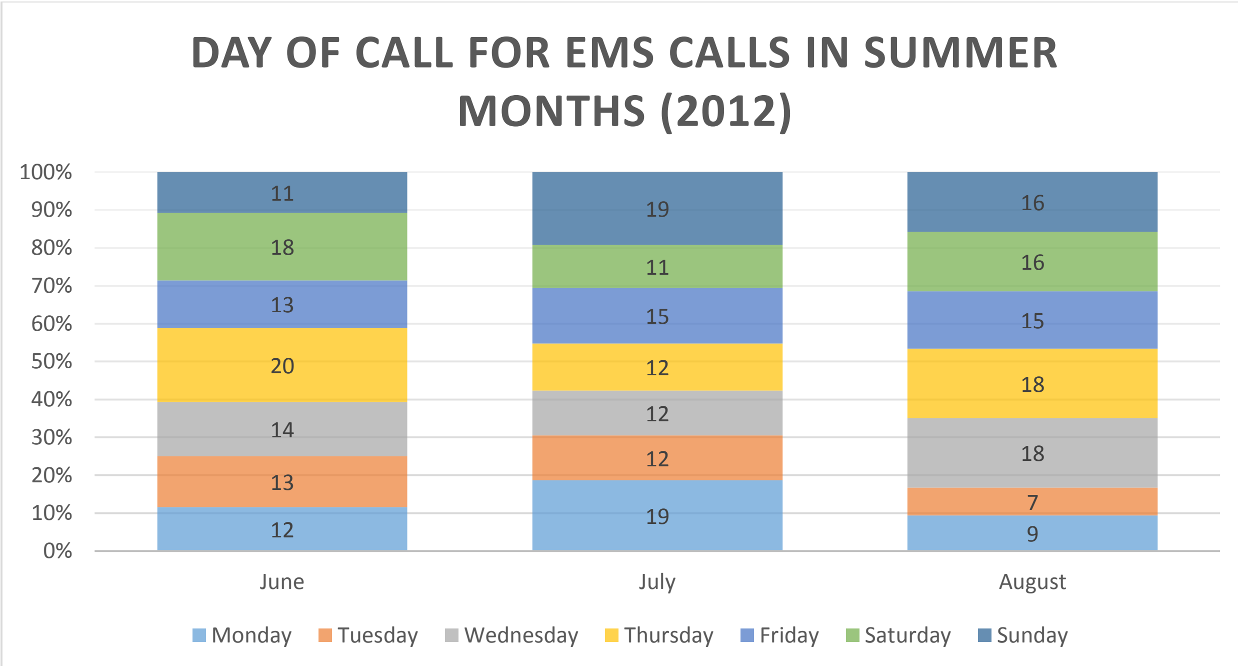


Figure 53 - Day of Call for EMS Calls in Summer Months (2012)

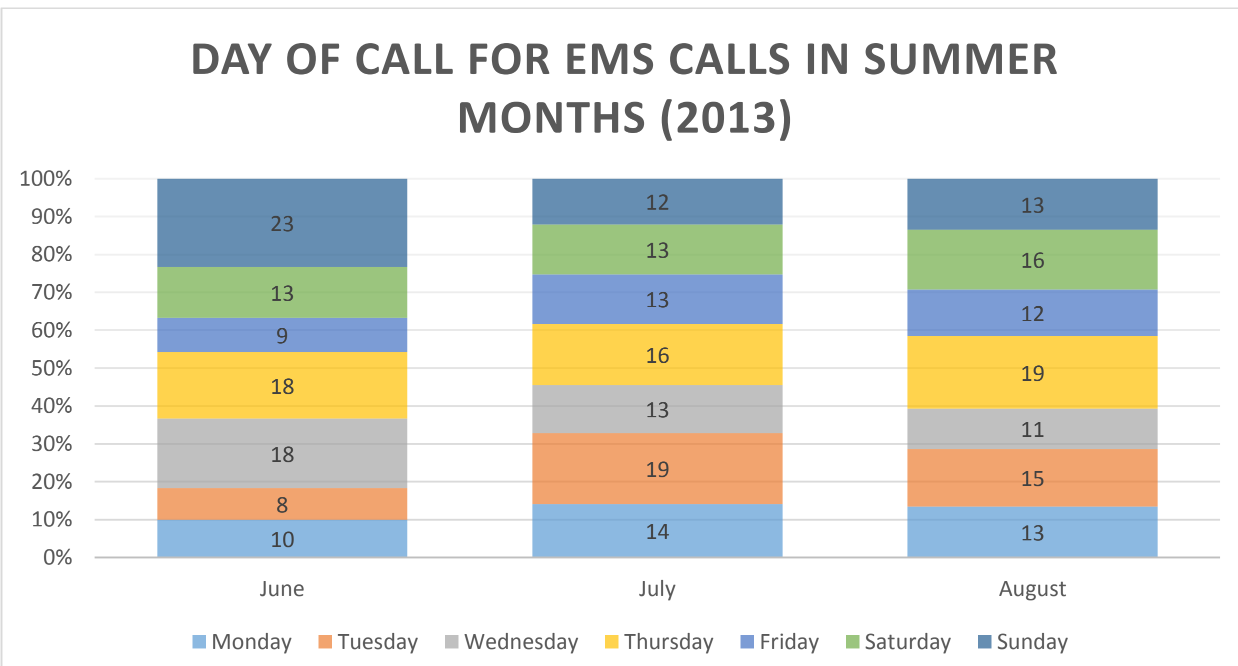


Figure 54 - Day of Call for EMS Calls in Summer Months (2013)

A chi-square test was conducted in order to further evaluate the correlation between day of the week and number of calls. The chi-square test is a statistical hypothesis test in which we can test one or more distributions to determine whether there is a significant difference between the expected frequencies and the observed frequencies. We sorted and totaled the data for number of calls by day of the week for each year. These are considered the actual values for number of calls. We then totaled the number of calls in each year separately and divided by seven (days in the week) to find the expected number of calls if each day had the same number of calls as this is the hypothesis we were trying to test. We subtracted the expected value from the actual value for each day of the week to find the difference in number of calls. We then squared the difference, and divided this by the expected value. To find our margin of error, we totaled these squared values and compared this final margin of error to 12.59 which we determined was our critical value for 6 degrees of freedom (seven days minus one) and our desired level of significance (0.05; the lowest and most commonly used level of significance available in the table. The 0.05 value “would indicate that results exceeding the critical value will be statistically significant 95% of the time”(FEMA, 2004)). See Table 9 for the calculations for 2013. The remainder of the years can be seen in Appendix M.

2013	Actual 2718	Expected 388.2857	Actual - Expected	Squared	Chi-Square
Sunday	346	388	-42	1764	4.546391753
Monday	372	388	-16	256	0.659793814
Tuesday	392	388	4	16	0.041237113
Wednesday	410	388	22	484	1.24742268
Thursday	379	388	-9	81	0.208762887
Friday	403	388	15	225	0.579896907
Saturday	416	388	28	784	2.020618557
					9.304123711

Table 9 - Chi Square Table for 2013

After performing a chi-test for every year, we found that there was a correlation between number of calls and day of the week for the years of 2007, 2008 and 2009 but that the correlation started to fade after this year and the remainder of the years had no connection between day of the week and number of calls. See Table 10 for the calculated values for all years. Any year with a calculated value over the critical value is marked in red. Years with calculated values under the critical value are marked in green.

Total Call Chi-Square Test	
Year	Computed Value
2007	19.07715
2008	40.33333
2009	20.34591
2010	4.116618
2011	4.807471
2012	11.00279
2013	9.304124
Critical Value	12.59

Table 10 - Total Call Chi-Square Test

This test was performed once more for every year for just medical calls. For tables of calculations, see Appendix N. There was even less of a correlation for this set of data and only 2007 had a chi-squared value that exceeded the critical value. A chi-squared value that is higher than the critical value means that there is a statistical correlation in number of calls and day of the week.

EMS Chi-Square Test	
Year	Computed Value
2007	21.48147
2008	7.879039
2009	3.968117
2010	12.46259
2011	8.389615
2012	6.168085
2013	3.561644
Critical Value	12.59

Table 11 - EMS Chi-Square Test

To once and for all determine if there was a connection between day of the week and frequency of call, Figure 55 was created graph the trend of popularity of each day over all of the years. We found that across all of our analyses Thursday seemed to be one of the most or the most popular day each year ever so slightly, with the exception of 2008 and 2011 (2008 data is also incomplete). After separating out each day the strongest trends were shown in Figure 56. Thursday call volume is steadily increasing in contrast with Saturday which is steadily decreasing.

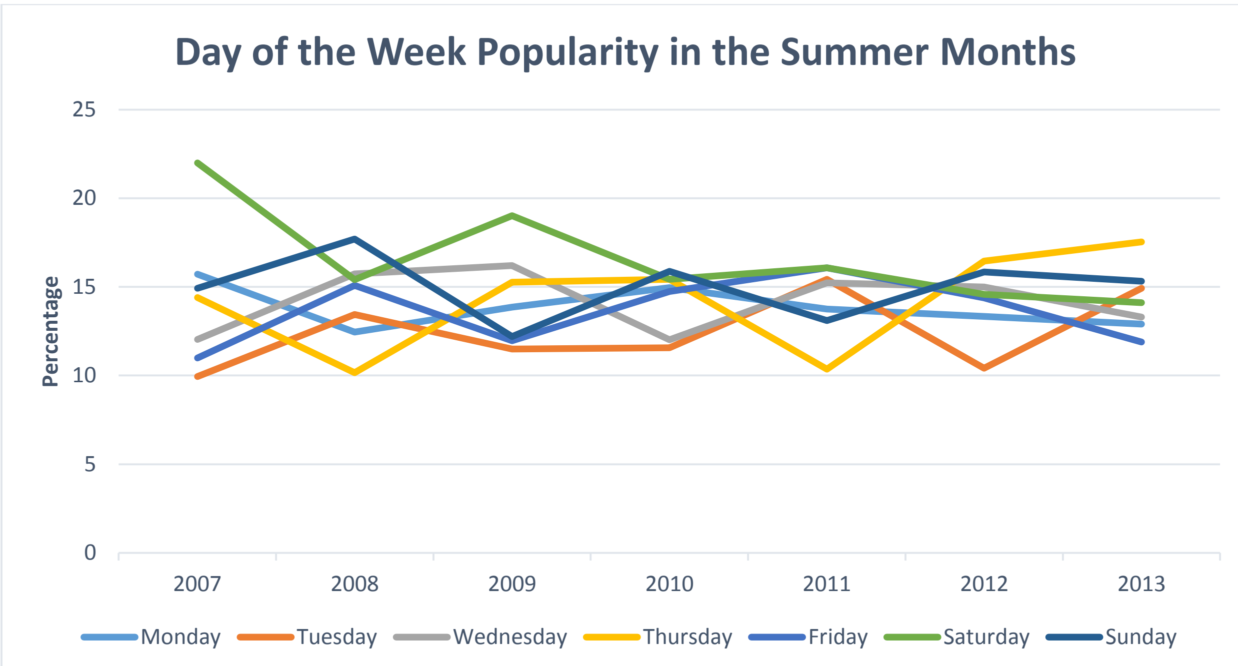


Figure 55 - Day of the Week Popularity in the Summer Months

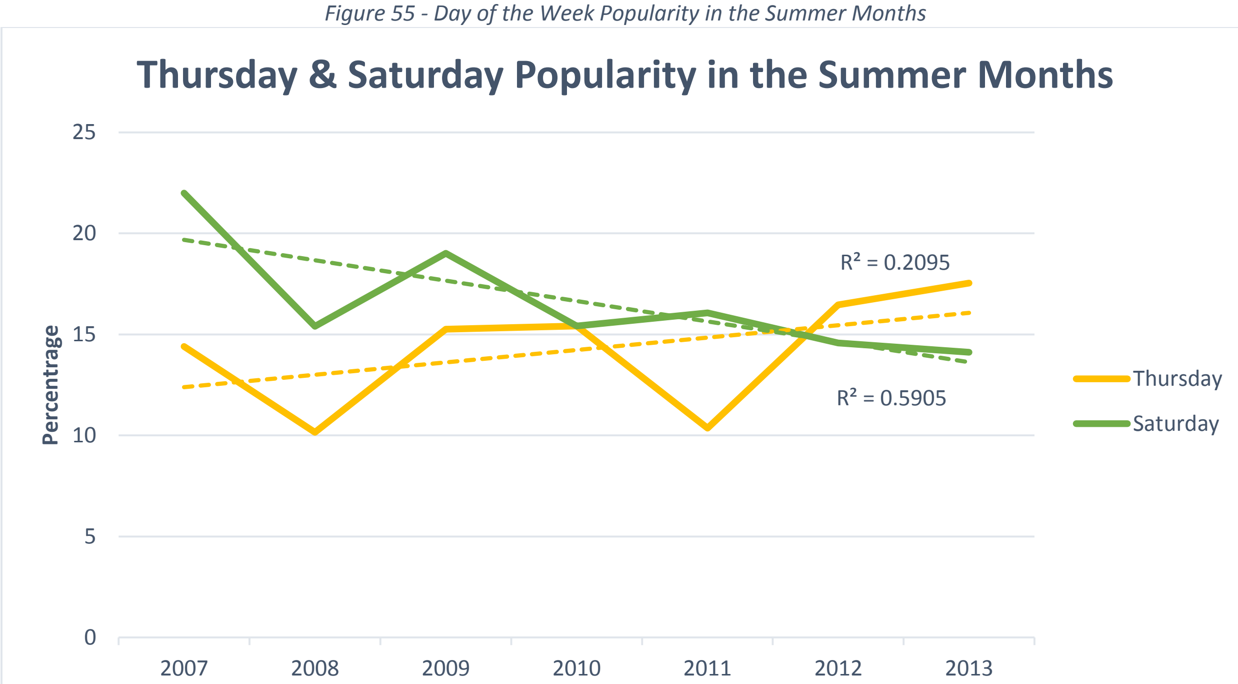


Figure 56 - Thursday & Saturday Popularity in the Summer Months

Time of Call Analysis

Figure 57 was created as a general analysis for the year of 2013. It broke down all calls in the year 2013 into different time brackets: Early Morning (12:00AM-5:59AM) Late Morning (6:00AM-11:59AM), Early Afternoon (12:00PM-5:59PM), and Night (6:00PM-11:59PM). This analysis was performed for each month of the year in 2013, and a stacked area chart was created, the x-axis being the month, the y-axis being the call volume, with each time bracket having its own color, as seen on the chart. In this type of chart, the color with the thickest area for a certain month would be the most popular time bracket for that month. We can easily see that all time brackets experience an increase in volume during the summer months, with Early Afternoon and Night being the most popular.

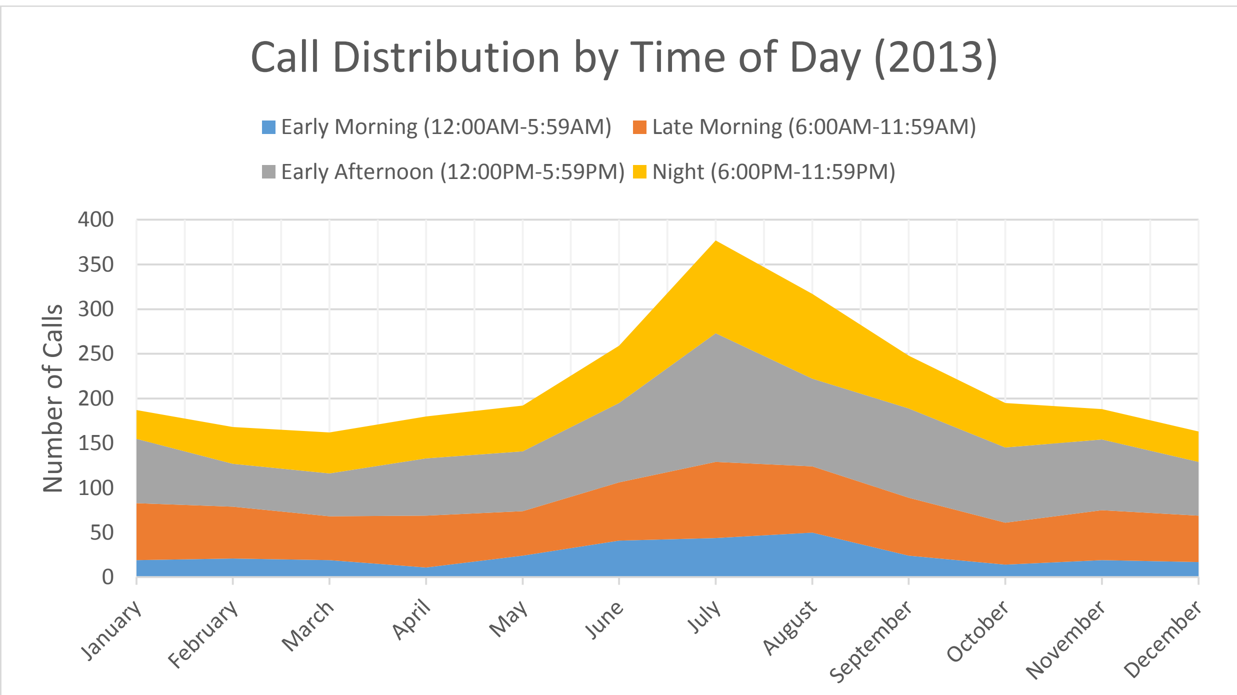


Figure 57 - Call Distribution by Time of Day (2013)

Figure 58 was created to display the number of calls broken down by each hour of the day, for the years 2007-2013 (see Figure 58). Using this chart we can easily see that 10:00AM to 3:00PM is the busiest time of the day. It can be seen that there is some change in busy hours over the years.

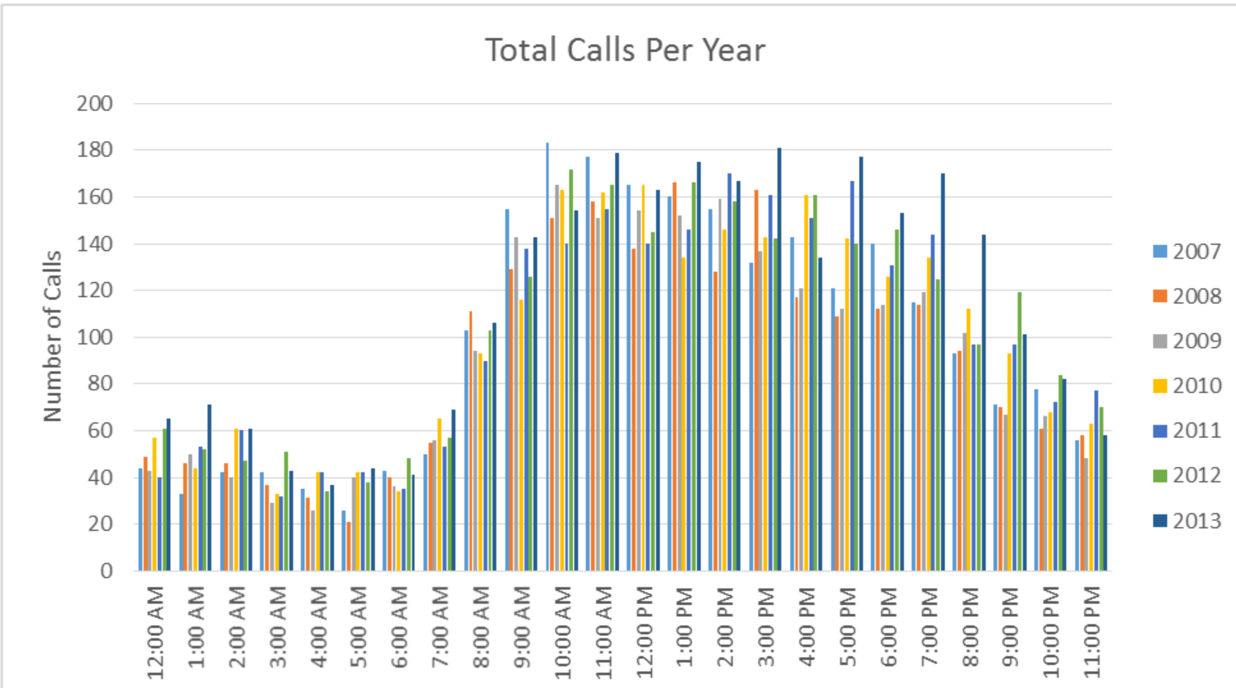


Figure 58 - Total Calls Per Year

In order to observe this change more clearly, Figure 59 was created to compare only 2007 and 2013 in the same clustered column bar chart. In 2007 the busiest times were 10:00AM to 2:00PM whereas in 2013 the busiest times are now 11:00AM to 7:00PM. It is now more clearly shown that the busiest time of the day has not changed, but rather grown to encompass a larger time block. In 2007 the time block was 4 hours, now in 2013 the busy time block has grown to 9 hours. This further emphasizes that the number of calls is growing and the fire department is having to work much harder in order to keep up with the growth of emergency calls.

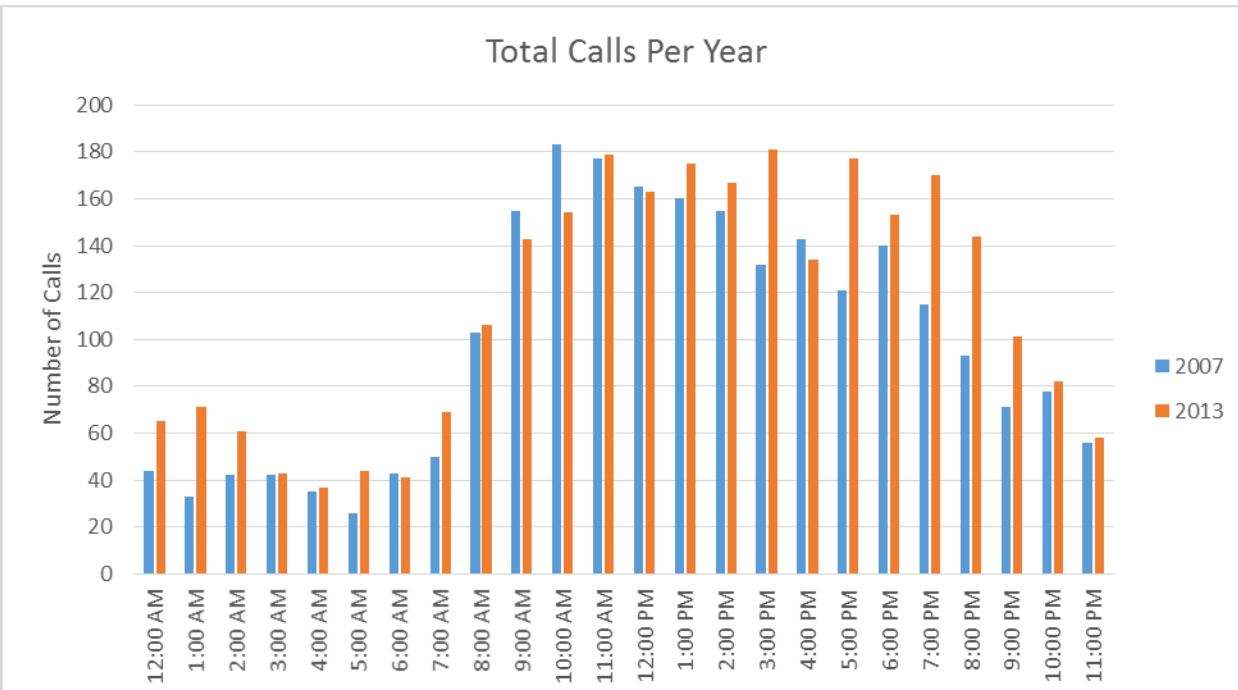


Figure 59 - Total Calls Per Year (2007 & 2013)

4.2.3 Views on the New Central Station

In order to better understand the other issues surrounding the new station, we conducted interviews with members of the Fire Department, the Town Manager's Office, the Board of Selectmen, the Nantucket Police Department, and the Finance Committee. From these interviews, we have put together a picture of how the public seems to feel about the new station, as well as what these groups feel needs to be done in order to gain public support for the new station.

As one might expect, support for the new fire station is far from unanimous. Gregg Tivnan, the Assistant Town Manager, believes that part of the lack of support comes from misconceptions about the Fire Department; some people believe that they are too pampered, that too much money is being spent on them, or that they do not actually need a new station. It also seems to him that, since the fire department has been doing a good job with current resources, people fail to see why they might need more. This is added to the fact that the majority of people on Nantucket have never really had any issue with a fire or needing emergency medical assistance, so many of them are unlikely to fully know what the Fire Department is dealing with. Tivnan estimates that 75% of year round residents have never been inside the fire station. He also added that he has heard people complaining about the new police station, as many people here do not care for large buildings. It is his concern that the island has grown but the fire station is not capable of growing with it.

Rick Atherton, the Chairman of the Nantucket Board of Selectmen, also believes that the money may be an issue, as voters are always concerned with spending money. The fact that money for the school is also up for a vote in 2015 may dissuade some voters. He raised the concern that the proposed new location is a minute further from town and may negatively impact response times to fires in the core district, an area full of the island's historic buildings.

Matt Mulcahy, the head of the Finance Committee, hopes that votes will rethink the idea that the school and the Fire Department are competing for funds. He wants to highlight that both are essential for the island but are completely separate issues, one being focused around education and the other on public safety. He also believes that there will always be people who will not support any proposal that would affect their taxes. The group learned several things about the process of approving spending on Nantucket and about the financial situation on the island from Mulcahy. The Finance Committee duties include making recommendations on the Annual Town Meeting Warrant which could include a recommendation for funding a new fire station. If so, the committee will justify its position on Town Meeting floor. Mulcahy explained that the new fire station can be funded in two ways: through existing revenue, such as from the sale of town lands, or through debt exclusion, typically done using a 20 year bond. As capital debt service will be retiring, the opportunity exists to fund new projects with less impact on property taxes. This may prove to be an optimal time to undertake major capital projects.

Gregg Tivnan believes that, in order for the public to support the new station sufficiently for it to pass, the Fire Department and the New Fire Station Work Group need to educate the public about why the new station is important. The town administration and the fire department must be united in their outreach regarding the new station. This includes showing that the island has grown, but that there is no room at the current location for the new station to grow with the island. He also believes that the Fire Department needs to show the public that they are strongly in favor of the new station—part of the reason that the station did not pass in 2008 was that the fire union remained neutral, rather than stating outright that they wanted the new building.

From the Nantucket Police Department, we interviewed Deputy Chief Charlie Gibson. Deputy Chief Gibson said that the Fire Department needs to show the public that they all support the new station in order to win the vote. In his opinion, sharing the space with the Fire Department would have no significant impact on the Police Department, since each department would have its own space. He believes that the Fire Department needs the new facility and that they outgrew their current building the day that they moved into it.

We were able to interview two firefighters, both of whom support the new station. They feel that the current station does not meet the department's needs. It is also their opinion that the new station would also have the effect of improving department morale. The consensus from the firefighters seems to be that 4 Fairgrounds is the best location for the new station and that the fact that they would be sharing that space with the police department would be beneficial for both departments. The firefighters strongly feel that more staff would benefit the fire department's ability to respond to calls. Not only would it provide relief in the shared workload, it would also allow the Nantucket Fire Department to deploy more vehicles at a time equipped with more personnel. Deputy Chief Gibson agrees that the Fire Department's biggest problem is that they do not have enough personnel to respond to calls and Gregg Tivnan supports this, saying that additional firefighters are necessary, not just a new building with the same level of staffing.

It should be noted that this section is based on interviews with six people. There may be many other reasons for people on the island to support or oppose the new station that are not represented here.

5.0 Conclusions & Recommendations

Like all fire departments around the country, the Nantucket Fire Department faces challenges responding to emergency calls every day. With the citizens of the island's property and lives at stake, it is imperative that emergency response vehicles arrive at their destination as quickly as possible. Before this project, no formal analysis of the Nantucket Fire Department's call data had been made (Peter Morrison, Personal Communication, 2014). There had been some attempts to analyze general themes and trends found within the data, however there had been no effort to predict the growth of volume of calls or evaluate the strain that concurrent calls puts on the Nantucket Fire Department's limited resources. This project highlighted the major problems in not having any sort of previous analysis, as the number of calls continues to increase annually, average response times are growing ever steadily, and responding to calls especially in the summer months with increased congestion is becoming more and more problematic.

Distance, concurrent calls and traffic are the three main causes of long response times. Distance is not as significant of a problem as originally thought. This is partially due to the size of the island. With the central station close to center of the island, the outskirts of the island are no more than 7 miles away (see Figure 22). This means that distance can only affect response times to a certain limit. Staffing and/or modifying satellite stations in the outlying towns is one possible solution to this problem. However, this is not to say that distance is not an obstacle large enough to prevent the Nantucket Fire Department from achieving their goal and the NFPA standard of a 5 minute response to every call. Referencing Figure 32, 30% of all non-concurrent calls over 10 minutes in 2013 were further than 5 miles from the central station. By placing staff and equipment in a satellite station closer to those long distance calls, the fire department would be able to more efficiently arrive on scene of an emergency call before the situation can escalate dangerously.

Currently the Nantucket Fire Department can comfortably respond to two emergency calls happening at the same time (Figures 26, 27, and 28). If more than two calls occur at the same time, there is no guarantee that personnel will be available in the central station to respond to the emergency or that a sufficient number of call firefighters will be able to respond.

Unfortunately, very little can be done to have a large impact on the frequency of concurrent calls. The Nantucket Fire Department has very few options which could help mitigate the strain that concurrent calls place on the fire department. The most obvious solution is to increase staffing, as increased personnel on staff would mean the Nantucket Fire Department could actually utilize all of their resources (trucks, etc), and the extra personnel would certainly improve the Department's ability to bear the load of multiple calls.

The final and most significant obstacle that slows the Nantucket Fire Department during their response to emergency calls is traffic. It causes high response times to emergencies close to the station, in Town, where a majority of the calls occur. Referencing Figure 32, one can see that 45% of non-concurrent calls over 10 minutes fall within 2 miles of the central station. We assume that these lengthier response times are due to traffic in the congested area labelled by Mike Burns, Nantucket's Transportation Planner. We defined the congested area as the specific roads and intersections that Mike Burns highlighted as problem areas, as well as a half mile buffer around these roads and intersections. The non-congested area includes everywhere on the island not on these problem roads or inside the half mile buffer. After viewing Figure 32**,** approximately 40% of all non-concurrent calls with a 10 minute or more response time fall in the congested area in the summer. A satellite station placed strategically on the outskirts of the town would be beneficial, as the fire department could respond to calls both inside and outside of the congested area. A satellite station in the center of the congested area would be less effective, due to the fact that the department would still need to move through traffic to respond to emergencies elsewhere on the island.

It would also be valuable for the department to consider alternative deployment strategies. One useful strategy would be to add a floating shift during the summer—that is, have one or two firefighters work a 12 hour shift for example, from 8 am to 8 pm. Another useful strategy is forward deployment of ambulances. For example, stationing one ambulance with two EMTs at the old Police Station at 10 South Water St during the summer may allow the department to respond more quickly to medical calls during peak call times. This method would also allow for further analysis of potential satellite station locations. By examining call response times with EMS personnel stationed at a potential satellite site, conclusions could be drawn about the effectiveness of these locations, based on changes in response times. Future studies of Nantucket Fire Department data, especially those relating to the location of future satellite stations, would also be aided by the installation of a program like FireView, which is designed specifically for use by fire departments and has tools for things like choosing the best location for new stations. While FireView is expensive and is potentially out of the budget for the Nantucket Fire Department, we think that it would still be beneficial for the department to consider it as a future investment.

Currently, calls in Siasconset are sometimes responded to from the satellite station there—that is, call firefighters who live in the area can respond to calls from the Siasconset station which stops the timer prematurely, because personnel responding from the central station has yet to arrive on scene. However, since the Siasconset station is not staffed by a full crew, this time is not accurate for actual emergencies where the central fire station is still required to respond. Because of this, it would have been useful to know which calls were responded to from the central station and which ones were responded to from the Siasconset station, so that we could have filtered out the misleading short response times from the Siasconset station. The group was able to infer some bounds on which calls were responded to by call firefighters as it is a safe assumption that any call with a response time of less than 12 minutes were answered by the Siasconset call firefighters as it is impossible for an engine from the central station to travel to Siasconset in under that time. However, an actual record in the data would have been more definitive in trying to sort out these data points.

Further data collection should be done on the actual population change that happens on the island during the summer. The numbers that we have for summer population are an estimate based off of the work done in a previous IQP; actual numbers, especially broken down by month, would have been incredibly helpful on this project and will likely help with future projects. We also recommend that a more in-depth study be done on summer traffic patterns and traffic congestion in town. As traffic is a significant factor in call response time, new strategies to reduce traffic in town would benefit both the Fire Department and the town as a whole.

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Appendices

Appendix A – Incident Type Codes Chart

Modified from Massachusetts Fire Incident Reporting System Version 5 ("Massachusetts Fire Incident Reporting System Version 5: Quick Reference Guide," 2012)

INCIDENT TYPE CODES	
Fire. Includes fires out on arrival and gas vapor explosions (with extremely rapid combustion).	
Structure fire	
111	Building fire. Excludes confined fires (113–118).
112	Fire in structure, other than in a building. Included are fires on or in piers, quays, or pilings; tunnels or underground connecting structures; bridges, trestles, or overhead elevated structures; transformers, power or utility vaults or equipment; fences; and tents.
113	Cooking fire involving the contents of a cooking vessel without fire extension beyond the vessel.
114	Chimney or flue fire originating in and confined to a chimney or flue. Excludes fires that extend beyond the chimney (111 or 112).
115	Incinerator overload or malfunction, but flames cause no damage outside the incinerator.
116	Fuel burner/boiler, delayed ignition or malfunction, where flames cause no damage outside the box.
117	Commercial compactor fire, confined to contents of compactor. Excluded are home trash compactors.
118	Trash or rubbish fire in a structure, with no flame damage to structure or its contents.
Fire in mobile property used as a fixed structure. Includes mobile homes, motor homes, and camping trailers.	
121	Fire in mobile home used as a fixed residence. Includes mobile homes when not in transit and used as a structure for residential purposes; and manufactured homes built on a permanent chassis.
122	Fire in a motor home, camper, or recreational vehicle when used as a structure. Includes motor homes when not in transit and used as a structure for residential purposes.
123	Fire in a portable building, when used at a fixed location. Includes portable buildings used for commerce, industry, or education and trailers used for commercial purposes.
120	Fire in mobile property used as a fixed structure, other.
Mobile property (vehicle) fire. Excludes mobile properties used as a structure (120 series). If a vehicle fire occurs on a bridge and does not damage the bridge, it should be classified as a vehicle fire.	
131	Passenger vehicle fire. Includes any motorized passenger vehicle, other than a motor home (136) (e.g., pickup trucks, sport utility vehicles, buses).
132	Road freight or transport vehicle fire. Includes commercial freight hauling vehicles and contractor vans or trucks. Examples are moving trucks, plumber vans, and delivery trucks.
133	Rail vehicle fire. Includes all rail cars, including intermodal containers and passenger cars that are mounted on a rail car.
134	Water vehicle fire. Includes boats, barges, hovercraft, and all other vehicles designed for navigation on water.

135	Aircraft fire. Includes fires originating in or on an aircraft, regardless of use.
136	Self-propelled motor home or recreational vehicle. Includes only self-propelled motor homes or recreational vehicles when being used in a transport mode. Excludes those used for normal residential use (122).
137	Camper or recreational vehicle (RV) fire, not self-propelled. Includes trailers. Excludes RVs on blocks or used regularly as a fixed building (122) and the vehicle towing the camper or RV or the campers mounted on pickups (131).
138	Off-road vehicle or heavy equipment fire. Includes dirt bikes, specialty off-road vehicles, earth-moving equipment (bulldozers), and farm equipment.
130	Mobile property (vehicle) fire, other.
Natural vegetation fire. Excludes crops or plants under cultivation (see 170 series).	
141	Forest, woods, or wildland fire. Includes fires involving vegetative fuels, other than prescribed fire (632), that occur in an area in which development is essentially nonexistent, except for roads, railroads, power lines, and the like. Also includes forests managed for lumber production and fires involving elevated fuels such as tree branches and crowns. Excludes areas in cultivation for agricultural purposes such as tree farms or crops (17x series).
142	Brush or brush-and-grass mixture fire. Includes ground fuels lying on or immediately above the ground such as duff, roots, dead leaves, fine dead wood, and downed logs.
143	Grass fire. Includes fire confined to area characterized by grass ground cover, with little or no involvement of other ground fuels; otherwise, see 142.
140	Natural vegetation fire, other.
Outside rubbish fire. Includes all rubbish fires outside a structure or vehicle.	
151	Outside rubbish, trash, or waste fire not included in 152–155. Excludes outside rubbish fires in a container or receptacle (154).
152	Garbage dump or sanitary landfill fire.
153	Construction or demolition landfill fire.
154	Dumpster or other outside trash receptacle fire. Includes waste material from manufacturing or other production processes. Excludes materials that are not rubbish or have salvage value (161 or 162).
155	Outside stationary compactor or compacted trash fire. Includes fires where the only material burning is rubbish. Excludes fires where the compactor is damaged (162).
150	Outside rubbish fire, other.
Special outside fire. Includes outside fires with definable value. Excludes crops and orchards (170 series).	
161	Outside storage fire on residential or commercial/industrial property, not rubbish. Includes recyclable materials at drop-off points.
162	Outside equipment fire. Includes outside trash compactors, outside HVAC units, and irrigation pumps. Excludes special structures (110 series) and mobile construction equipment (130 series).
163	Outside gas or vapor combustion explosion without sustained fire.
164	Outside mailbox fire. Includes drop-off boxes for delivery services.
160	Special outside fire, other.
Cultivated vegetation, crop fire	

171	Cultivated grain or crop fire. Includes fires involving corn, wheat, soybeans, rice, and other plants before harvest.
172	Cultivated orchard or vineyard fire.
173	Cultivated trees or nursery stock fire. Includes fires involving Christmas tree farms and plants under cultivation for transport off-site for ornamental use.
170	Cultivated vegetation, crop fire, other.
Fire, other	
100	Fire, other.
Overpressure Rupture, Explosion, Overheat (No Fire). Excludes steam mistaken for smoke.	
Overpressure rupture from steam (no ensuing fire)	
211	Overpressure rupture of steam pipe or pipeline.
212	Overpressure rupture of steam boiler.
213	Overpressure rupture of pressure or process vessel from steam.
210	Overpressure rupture from steam, other.
Overpressure rupture from air or gas (no ensuing fire). Excludes steam or water vapor.	
221	Overpressure rupture of air or gas pipe or pipeline.
222	Overpressure rupture of boiler from air or gas. Excludes steam-related overpressure ruptures.
223	Overpressure rupture of pressure or process vessel from air or gas, not steam.
220	Overpressure rupture from air or gas, other.
Overpressure rupture from chemical reaction (no ensuing fire)	
231	Overpressure rupture of pressure or process vessel from a chemical reaction.
Explosion (no fire)	
241	Munitions or bomb explosion (no fire). Includes explosions involving military ordnance, dynamite, nitroglycerin, plastic explosives, propellants, and similar agents with a UN classification 1.1 or 1.3. Includes primary and secondary high explosives.
242	Blasting agent explosion (no fire). Includes ammonium nitrate and fuel oil (ANFO) mixtures and explosives with a UN Classification 1.5 (also known as blasting agents).
243	Fireworks explosion (no fire). Includes all classes of fireworks.
244	Dust explosion (no fire).
240	Explosion (no fire), other.
Excessive heat, scorch burns with no ignition	
251	Excessive heat, overheat scorch burns with no ignition. Excludes lightning strikes with no ensuing fire (814).
Overpressure rupture, explosion, overheat, other	
200	Overpressure rupture, explosion, overheat, other.
Rescue and Emergency Medical Service Incident	
Medical assist	
311	Medical assist. Includes incidents where medical assistance is provided to another group/agency that has primary EMS responsibility. (Example, providing assistance to another agency-assisting EMS with moving a heavy patient.)
Emergency medical service incident	

321	EMS call. Includes calls when the patient refuses treatment. Excludes vehicle accident with injury (322) and pedestrian struck (323).
322	Motor vehicle accident with injuries. Includes collision with other vehicle, fixed objects, or loss of control resulting in leaving the roadway.
323	Motor vehicle/pedestrian accident (MV Ped). Includes any motor vehicle accident involving a pedestrian injury.
324	Motor vehicle accident with no injuries.
320	Emergency medical service, other.
Lock-In	
331	Lock-in. Includes opening locked vehicles and gaining entry to locked areas for access by caretakers or rescuers, such as a child locked in a bathroom. Excludes lock-outs (511).
Search for lost person	
341	Search for person on land. Includes lost hikers and children, even where there is an incidental search of local bodies of water, such as a creek or river.
342	Search for person in water. Includes shoreline searches incidental to a reported drowning call.
343	Search for person underground. Includes caves, mines, tunnels, and the like.
340	Search for lost person, other.
Extrication, rescue	
351	Extrication of victim(s) from building or structure, such as a building collapse. Excludes high-angle rescue (356).
352	Extrication of victim(s) from vehicle. Includes rescues from vehicles hanging off a bridge or cliff.
353	Removal of victim(s) from stalled elevator.
354	Trench/below-grade rescue.
355	Confined space rescue. Includes rescues from the interiors of tanks, including areas with potential for hazardous atmospheres such as silos, wells, and tunnels.
356	High-angle rescue. Includes rope rescue and rescues off of structures.
357	Extrication of victim(s) from machinery. Includes extrication from farm or industrial equipment.
350	Extrication, rescue, other.
Water and ice-related rescue	
361	Swimming/recreational water areas rescue. Includes pools and ponds. Excludes ice rescue (362).
362	Ice rescue. Includes only cases where victim is stranded on ice or has fallen through ice.
363	Swift-water rescue. Includes flash flood conditions.
364	Surf rescue.
365	Watercraft rescue. Excludes rescues near the shore and in swimming/ recreational areas (361). Includes people falling overboard at a significant distance from land.
360	Water and ice-related rescue, other.
Electrical rescue	
371	Electrocution or potential electrocution. Excludes people trapped by power lines (372).
372	Trapped by power lines. Includes people trapped by downed or dangling power lines or other energized electrical equipment.
370	Electrical rescue, other.
Rescue or EMS standby	

381	Rescue or EMS standby for hazardous conditions. Excludes aircraft standby (462).
Rescue, emergency medical service (EMS) incident, other	
300	Rescue and EMS incident, other.
Hazardous Condition (No Fire)	
Combustible/flammable spills and leaks	
411	Gasoline or other flammable liquid spill (flash point below 100 degrees F at standard temperature and pressure (Class I)).
412	Gas leak (natural gas or LPG). Excludes gas odors with no source found (671).
413	Oil or other combustible liquid spill (flash point at or above 100 degrees F at standard temperature and pressure (Class II or III)).
410	Combustible and flammable gas or liquid spills or leaks, other.
Chemical release, reaction, or toxic condition	
421	Chemical hazard (no spill or leak). Includes the potential for spills or leaks.
422	Chemical spill or leak. Includes unstable, reactive, explosive material.
423	Refrigeration leak. Includes ammonia.
424	Carbon monoxide incident. Excludes incidents with nothing found (736 or 746).
420	Toxic chemical condition, other.
Radioactive condition	
431	Radiation leak, radioactive material. Includes release of radiation due to breaching of container or other accidental release.
430	Radioactive condition, other.
Electrical wiring/equipment problem	
441	Heat from short circuit (wiring), defective or worn insulation.
442	Overheated motor or wiring.
443	Breakdown of light ballast.
444	Power line down. Excludes people trapped by downed power lines (372).
445	Arcing, shorted electrical equipment.
440	Electrical wiring/equipment problem, other.
Biological hazard	
451	Biological hazard, confirmed or suspected.
Accident, potential accident	
461	Building or structure weakened or collapsed. Excludes incidents where people are trapped (351).
462	Aircraft standby. Includes routine standby for takeoff and landing as well as emergency alerts at airports.
463	Vehicle accident, general cleanup. Includes incidents where FD is dispatched after the accident to clear away debris. Excludes extrication from vehicle (352) and flammable liquid spills (411 or 413).
460	Accident, potential accident, other.
Explosive, bomb removal	
471	Explosive, bomb removal. Includes disarming, rendering safe, and disposing of bombs or suspected devices. Excludes bomb scare (721).
Attempted burning, illegal action	

481	Attempt to burn. Includes situations in which incendiary devices fail to function.
482	Threat to burn. Includes verbal threats and persons threatening to set themselves on fire. Excludes an attempted burning (481).
480	Attempted burning, illegal action, other.
Hazardous condition, other	
400	Hazardous condition (no fire), other.
Service Call	
Person in distress	
511	Lock-out. Includes efforts to remove keys from locked vehicles. Excludes lock-ins (331).
512	Ring or jewelry removal, without transport to hospital. Excludes persons injured (321).
510	Person in distress, other.
Water problem	
521	Water (not people) evacuation. Includes the removal of water from basements. Excludes water rescues (360 series).
522	Water or steam leak. Includes open hydrant. Excludes overpressure ruptures (211).
520	Water problem, other.
Smoke, odor problem	
531	Smoke or odor removal. Excludes the removal of any hazardous materials.
Animal problem or rescue	
541	Animal problem. Includes persons trapped by an animal or an animal on the loose.
542	Animal rescue.
540	Animal problem or rescue, other.
Public service assistance	
551	Assist police or other governmental agency. Includes forcible entry and the provision of lighting.
552	Police matter. Incudes incidents where FD is called to a scene that should be handled by the police.
553	Public service. Excludes service to governmental agencies (551 or 552).
554	Assist invalid. Includes incidents where the invalid calls the FD for routine help, such as assisting a person in returning to bed or chair, with no transport or medical treatment given.
555	Defective elevator, no occupants.
550	Public service assistance, other.
Unauthorized burning	
561	Unauthorized burning. Includes fires that are under control and not endangering property.
Cover assignment, standby at fire station, move-up	
571	Cover assignment, assist other fire agency such as standby at a fire station or move-up.
Service call, other	
500	Service call, other.
Good Intent Call	
Dispatched and canceled en route	
611	Dispatched and canceled en route. Incident cleared or canceled prior to arrival of the responding unit. If a unit arrives on the scene, fill out the applicable code.

Wrong location, no emergency found	
621	Wrong location. Excludes malicious false alarms (710 series).
622	No incident found on arrival at dispatch address.
Controlled burning	
631	Authorized controlled burning. Includes fires that are agricultural in nature and managed by the property owner. Excludes unauthorized controlled burning (561) and prescribed fires (632).
632	Prescribed fire. Includes fires ignited by management actions to meet specific objectives and have a written, approved prescribed fire plan prior to ignition. Excludes authorized controlled burning (631).
Vicinity alarm	
641	Vicinity alarm (incident in other location). For use only when an erroneous report is received for a legitimate incident. Includes separate locations reported for an actual fire and multiple boxes pulled for one fire.
Steam, other gas mistaken for smoke	
651	Smoke scare, odor of smoke, not steam (652). Excludes gas scares or odors of gas (671).
652	Steam, vapor, fog, or dust thought to be smoke.
653	Smoke from barbecue or tar kettle (no hostile fire).
650	Steam, other gas mistaken for smoke, other.
EMS call where party has been transported	
661	EMS call where injured party has been transported by a non-fire service agency or left the scene prior to arrival.
HazMat release investigation w/no HazMat found	
671	Hazardous material release investigation with no hazardous condition found. Includes odor of gas with no leak/gas found.
672	Biological hazard investigation with no hazardous condition found.
Good intent call, other	
600	Good intent call, other.
False Alarm and False Call	
Malicious, mischievous false alarm	
711	Municipal alarm system, malicious false alarm. Includes alarms transmitted on street fire alarm boxes.
712	Direct tie to fire department, malicious false alarm. Includes malicious alarms transmitted via fire alarm system directly tied to the fire department, not via dialed telephone.
713	Telephone, malicious false alarm. Includes false alarms transmitted via the public telephone network using the local emergency reporting number of the fire department or another emergency service agency.
714	Central station, malicious false alarm. Includes malicious false alarms via a central-station monitored fire alarm system.
715	Local alarm system, malicious false alarm. Includes malicious false alarms reported via telephone or other means as a result of activation of a local fire alarm system.
710	Malicious, mischievous false alarm, other.
Bomb scare	
721	Bomb scare (no bomb).

System or detector malfunction. Includes improper performance of fire alarm system that is not a result of a proper system response to environmental stimuli such as smoke or high heat conditions.	
731	Sprinkler activated due to the failure or malfunction of the sprinkler system. Includes any failure of sprinkler equipment that leads to sprinkler activation with no fire present. Excludes unintentional operation caused by damage to the sprinkler system (740 series).
732	Extinguishing system activation due to malfunction.
733	Smoke detector activation due to malfunction.
734	Heat detector activation due to malfunction.
735	Alarm system activation due to malfunction.
736	Carbon monoxide detector activation due to malfunction.
730	System or detector malfunction, other.
Unintentional system or detector operation (no fire). Includes tripping an interior device accidentally.	
741	Sprinkler activation (no fire), unintentional. Includes testing the sprinkler system without fire department notification.
742	Extinguishing system activation. Includes testing the extinguishing system without fire department notification.
743	Smoke detector activation (no fire), unintentional. Includes proper system responses to environmental stimuli such as non-hostile smoke.
744	Detector activation (no fire), unintentional. A result of a proper system response to environmental stimuli such as high heat conditions
745	Alarm system activation (no fire), unintentional.
746	Carbon monoxide detector activation (no carbon monoxide detected). Excludes carbon monoxide detector malfunction.
740	Unintentional transmission of alarm, other.
Biohazard scare	
751	Biological hazard, malicious false report.
False alarm and false call, other	
700	False alarm or false call, other.
Severe Weather and Natural Disaster	
811	Earthquake assessment, no rescue or other service rendered.
812	Flood assessment. Excludes water rescue (360 series).
813	Wind storm. Includes tornado, hurricane, or cyclone assessment. No other service rendered.
814	Lightning strike (no fire). Includes investigation.
815	Severe weather or natural disaster standby.
800	Severe weather or natural disaster, other.
Special Incident Type	
Citizen complaint	
911	Citizen’s complaint. Includes reports of code or ordinance violation.
Special type of incident, other	
900	Special type of incident, other.

Appendix B – Interview Questions

- Questions for the Fire Department:
    - New Facility
        - Do you think that the new facility is necessary? Why or why not?
        - How do you feel about the proposed facility at 4FG?
        - How do you think it would affect the department's ability to respond to calls in a timely manner?
        - Do you think a new building would benefit the department and the town? If so, how?
    - Staffing
        - Do you think that there are enough career firefighters at the department?
        - Is there a noticeable shortage of personnel year-round? Is there a particular time of year when it's more noticeable?
    - Traffic
        - What kind of effect does the traffic in town (especially during summer months and/or when the car ferry arrives) have on response times?
        - How often do you find yourselves avoiding the town and driving around the core district to get to calls up around Cliff Rd and the Brandt Point area?
    - Distance
        - Are there areas of the island that are difficult to respond to? Where are they?
        - What kind of effect do you think that having a satellite station (with people stationed at it) would have on response time to those areas?
        - Is there a potential location for a satellite station that you think would have a positive effect on response times?
- Questions for the Police Department:
    - Shared Space
        - What's your opinion about sharing the space at 4FG with the Fire Department?
        - What kind of impact do you think both departments sharing a space would have?
        - What is the relationship between the Police Department and Fire Department like?
        - Do you think that the Fire Department needs a new facility?
        - What has your experience been with the Police Department's new facility? Has it been beneficial to your department?

- Questions for the Board of Selectmen:
    - General info about the new station
        - How long has the new station been a work in progress?
        - What opposition does the new station face?
        - What impact do you think the new station would have on the island?
        - How well do you think the current station serves the island's needs?
- Questions for the New Fire Station Work Group:
    - Still not completely sure what information we want to get from them
        - What caused the new station to become a priority? Was there a specific event that led to the proposal of a new station and the formation of the Work Group?
        - How long has the Work Group been working on getting the new station?
        - What do you think are some of the reasons that people have for supporting the new station?
        - What do you think are some of the reasons that people have for opposing the new station?
        - Do you think that the new station will be approved in the upcoming vote?
        - What challenges has the Work Group faced?
        - Is there anything else that you feel is important for us or people in general to know about the fire station?

- Questions for the Finance Committee:
    - How do people on the island feel about potentially spending $14 million on a new fire station?
    - From what I understand, cost was a large part of why the new fire station wasn't approved when the new police station was. Do you think that things have changed enough that that won't be the case this time?
    - How do you feel about potentially spending $14 million on a new fire station? Do you think it's necessary?
    - The possibility of building a new elementary school has also been brought up. What effect do you think this will have on the town's ability to fund a new fire station?

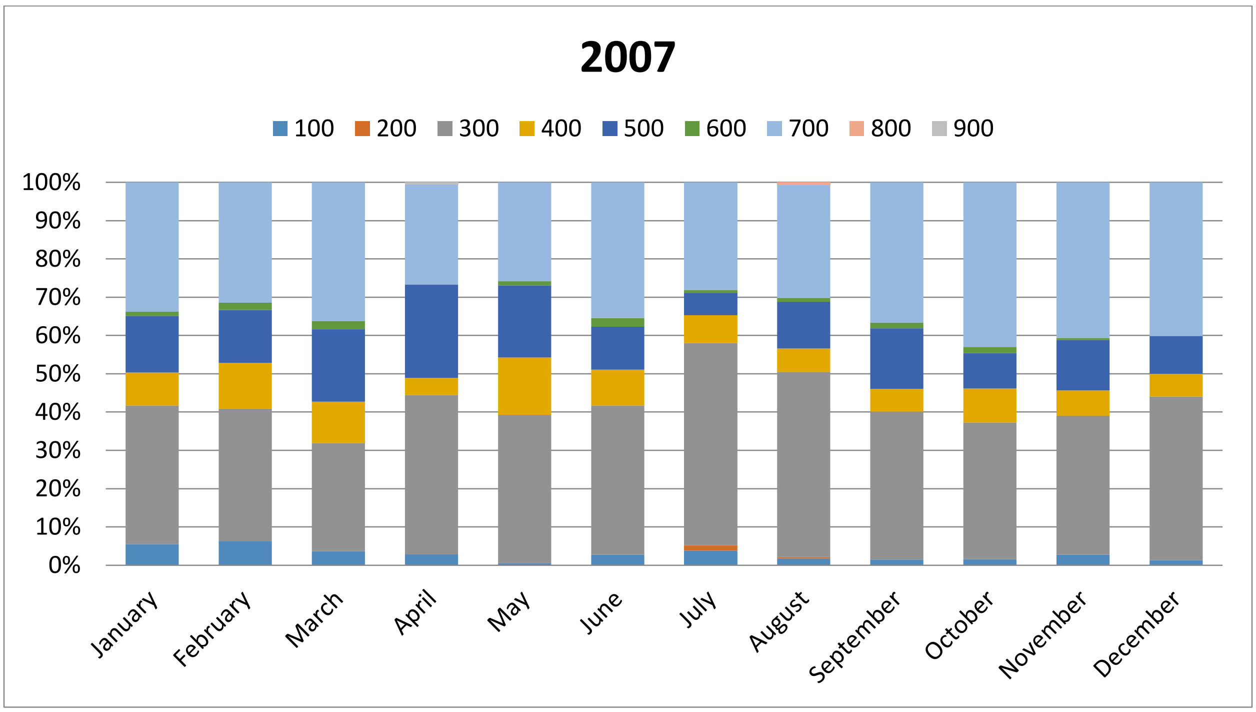
- Questions for the Town Manager's Office:
    - Politics about new station
        - How do you feel about the fire station?

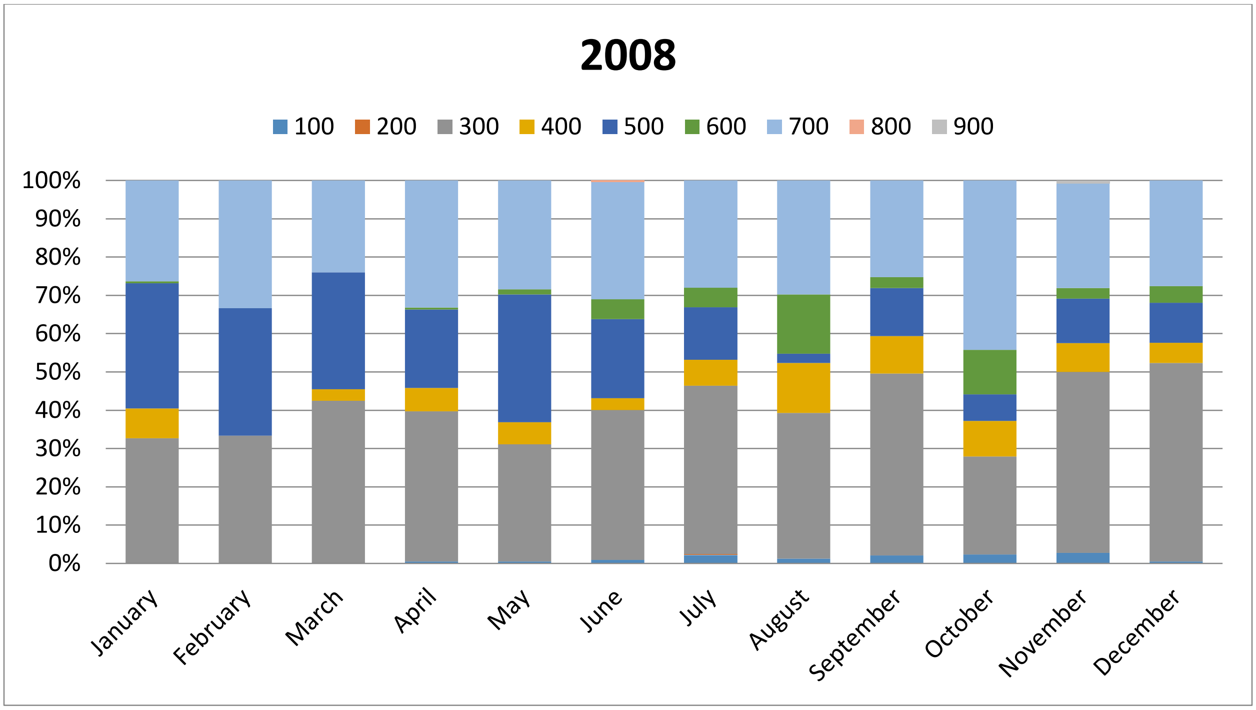
- Do you think the new fire station will pass? Why or why not? If not, do you think it's more likely to be because of the cost or because people don't think that it's important?
- How do the people you work with feel about the new station?
- Do the town workers feel that it's important?
- Do you feel that the fire department is adequately serving the town?
- How do you think the town feels about the fire department?

Appendix C – Incident Type By Month (2007-2013)

For the graphs in this section, please refer to the following key:

- 100 – Fire Calls
- 200 – Rupture and Explosion Calls
- 300 – Medical Calls: Rescue and EMS
- 400 – Hazardous Calls
- 500 – Service Calls
- 600 – Good Intent Calls
- 700 – Alarm Calls
- 800 – Severe Weather and Natural Disasters
- 900 – Special Incidents

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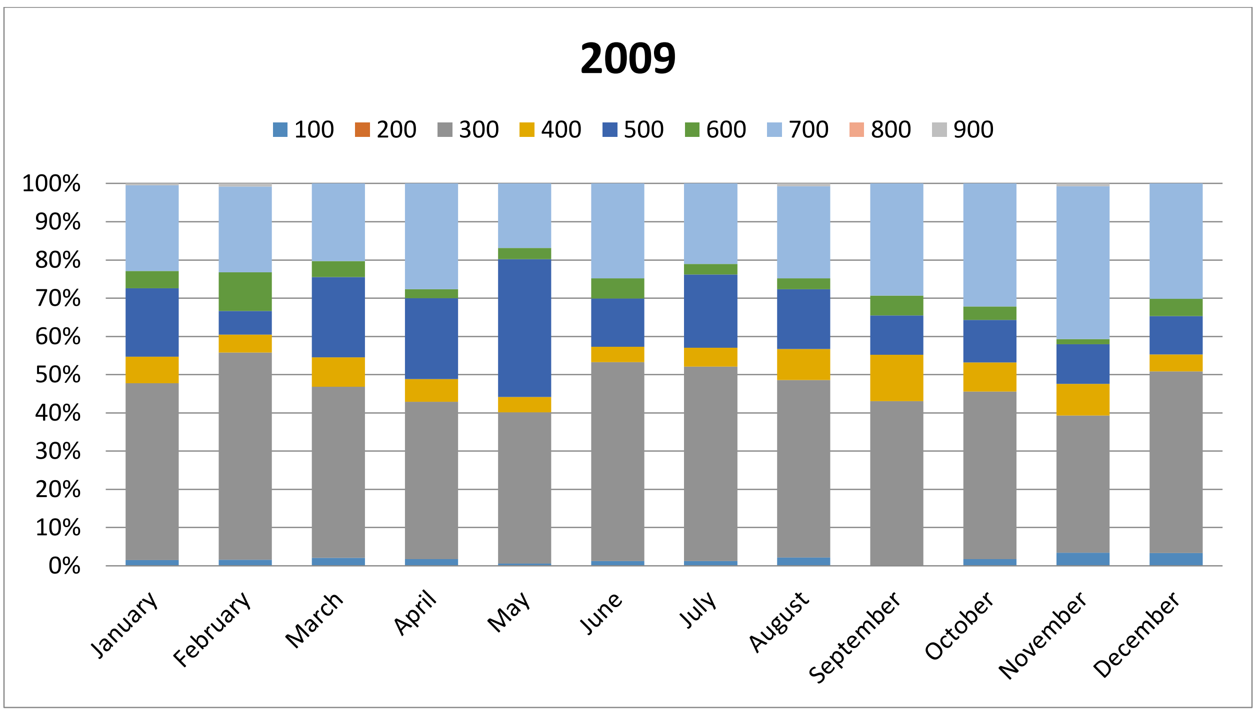
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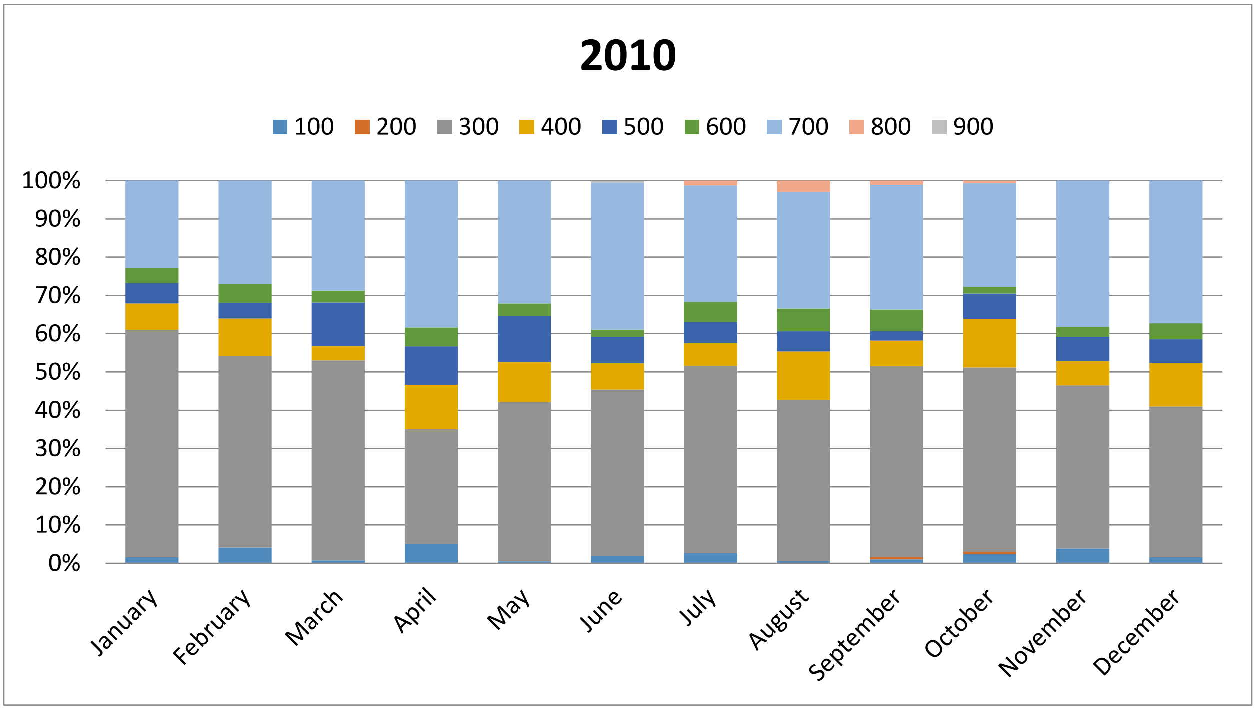
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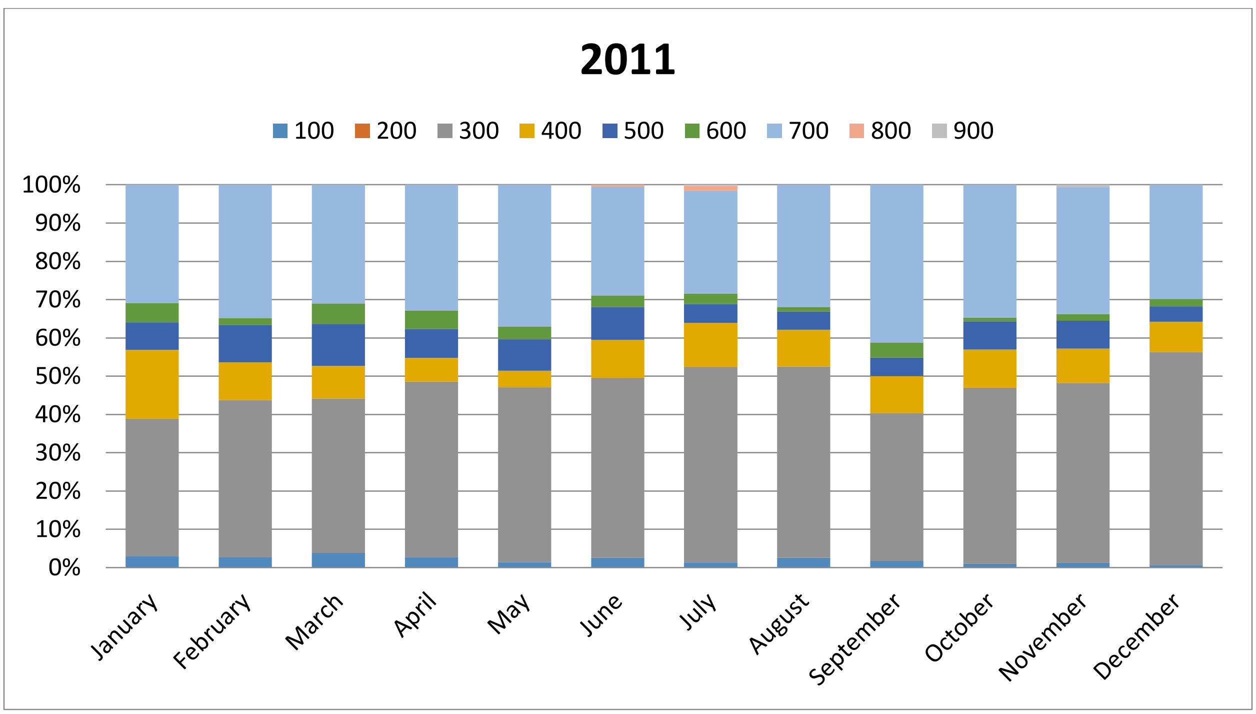
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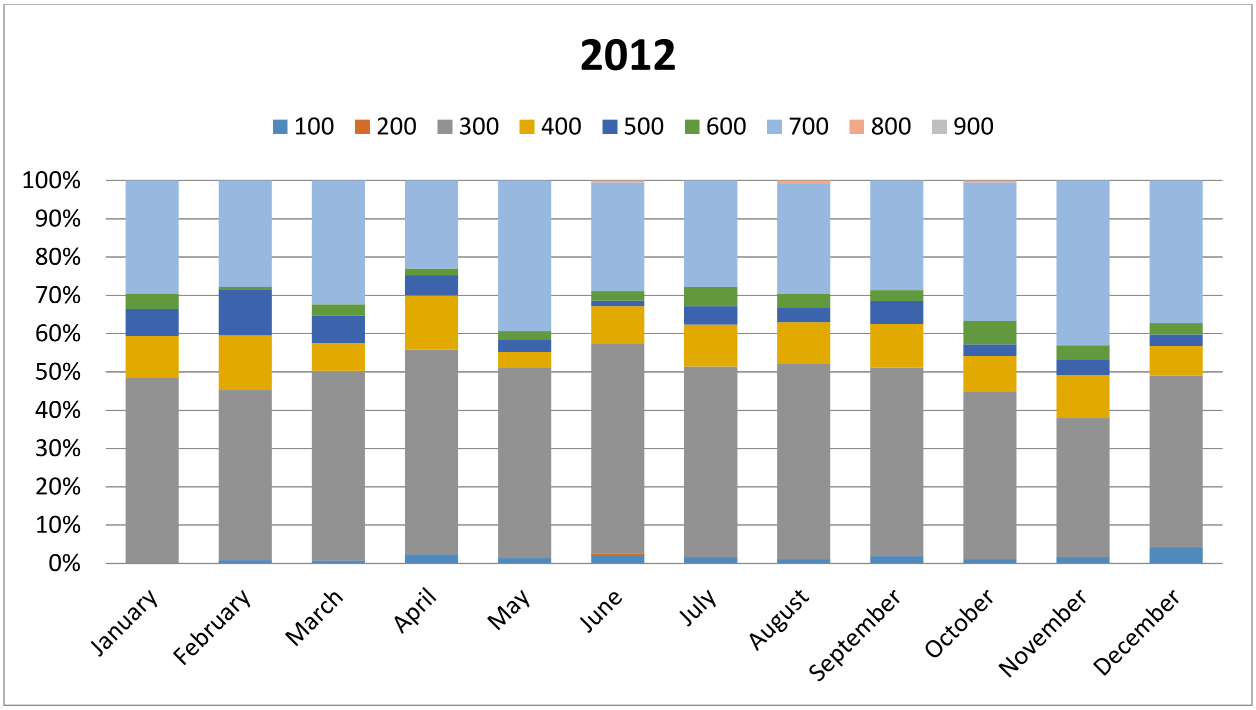
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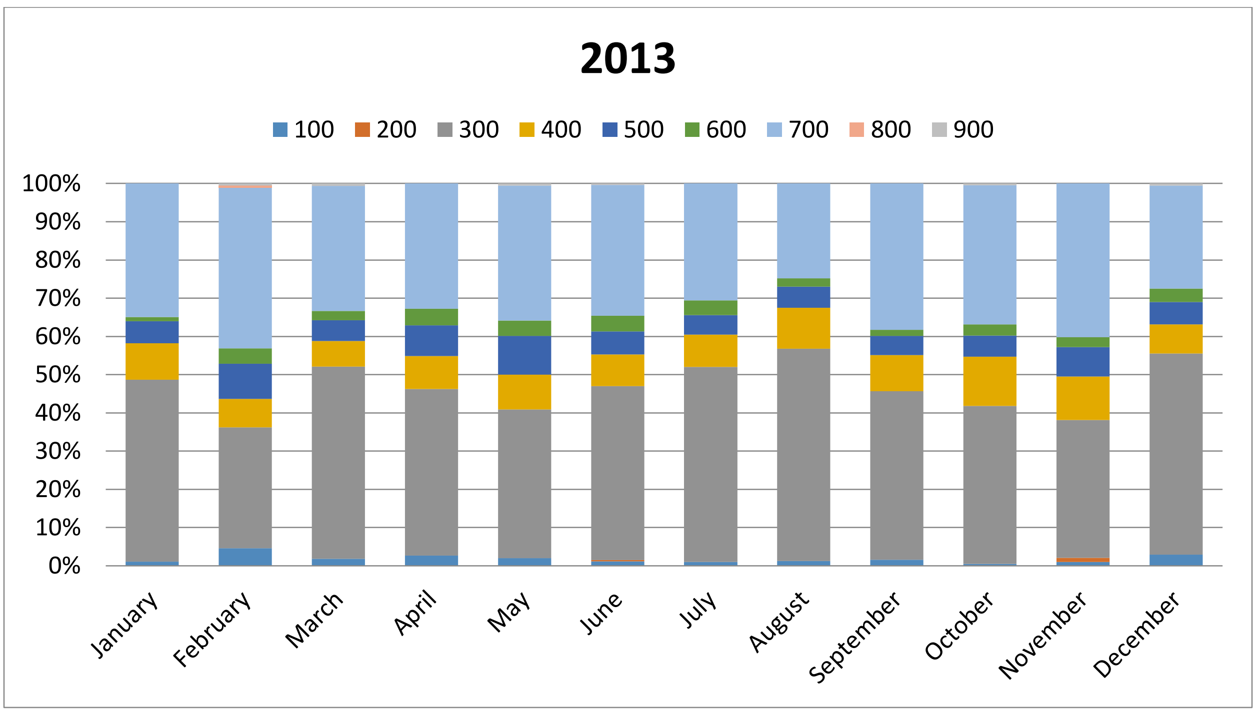
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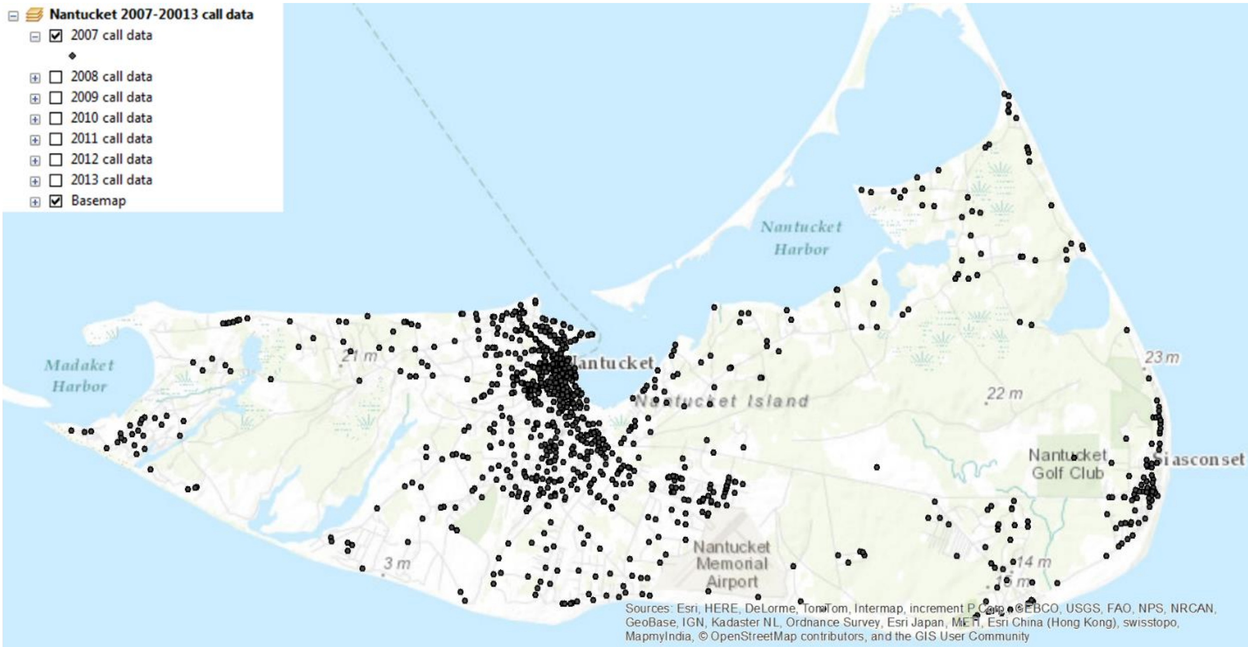
Appendix D – Spatial Distribution of All Calls (2007-2013)

2007



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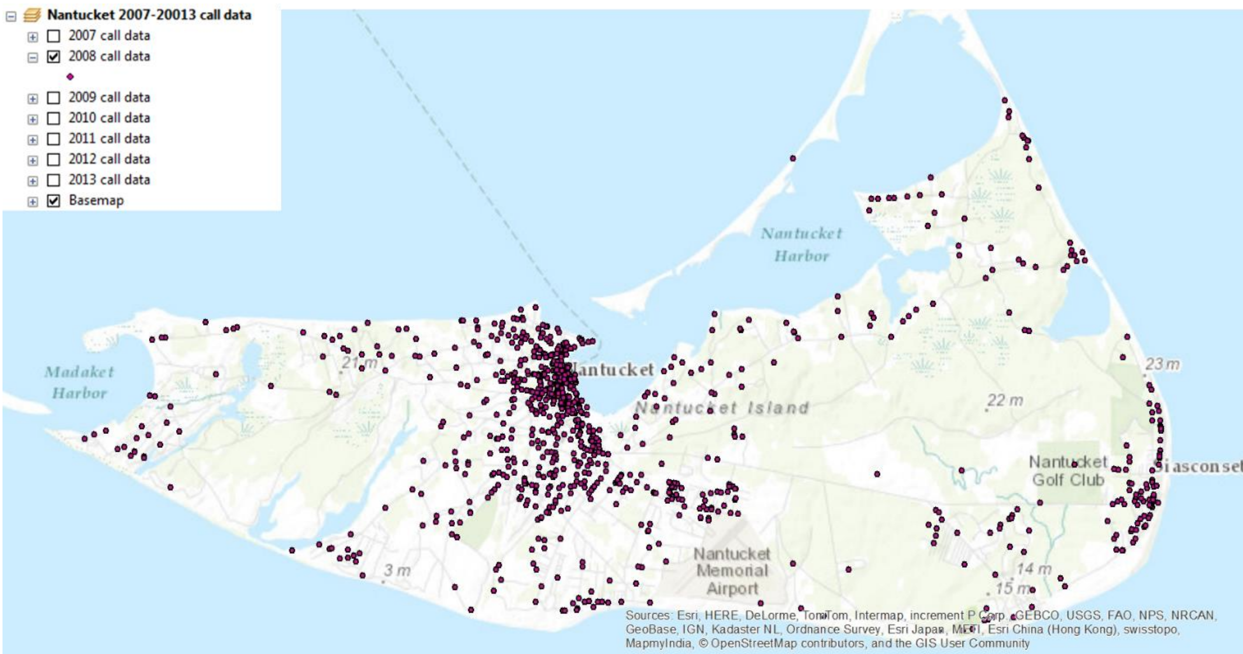

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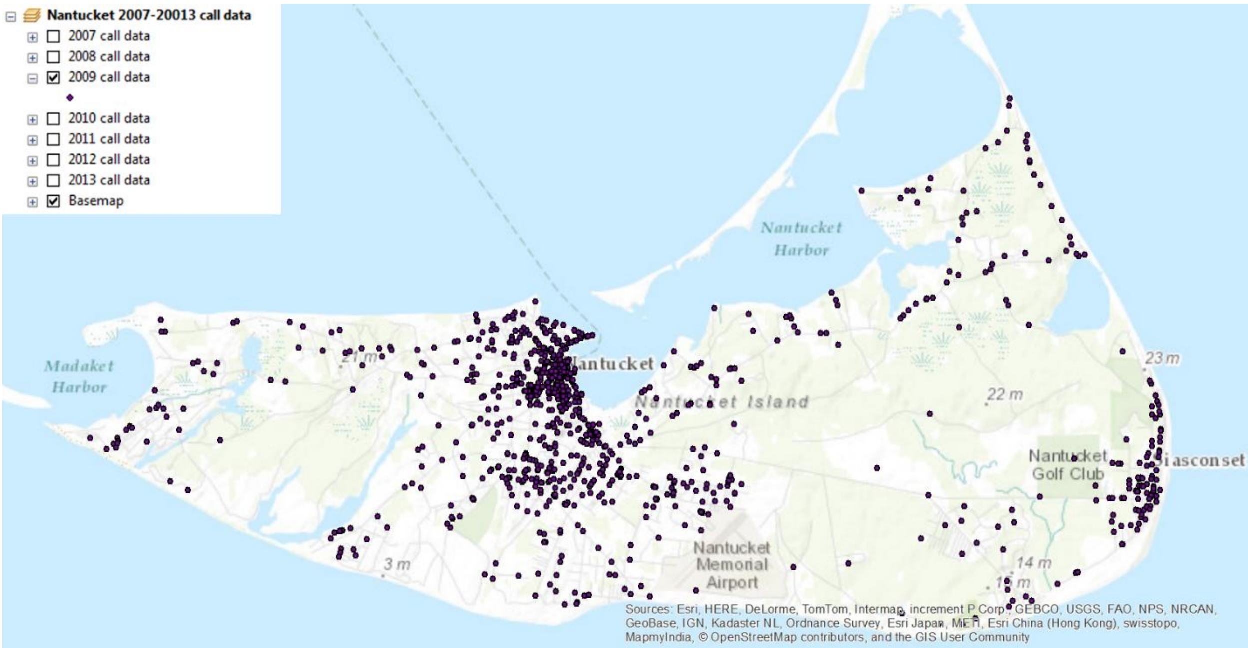
Nantucket 2007-20013 call data
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2013 call data
Basemap
Nantucket Harbor
Madaket Harbor
Nantucket Island
Nantucket Golf Club
Nantucket Memorial Airport
Siasconset
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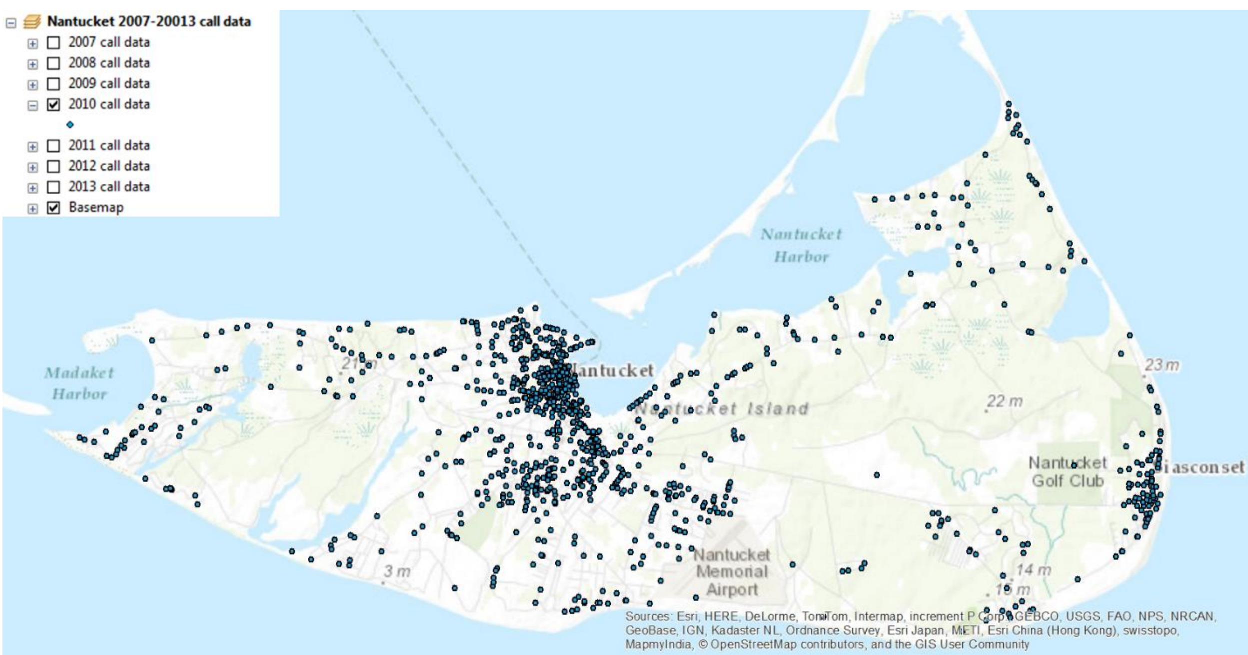
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

2010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Madaket Harbor
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Nantucket Memorial Airport
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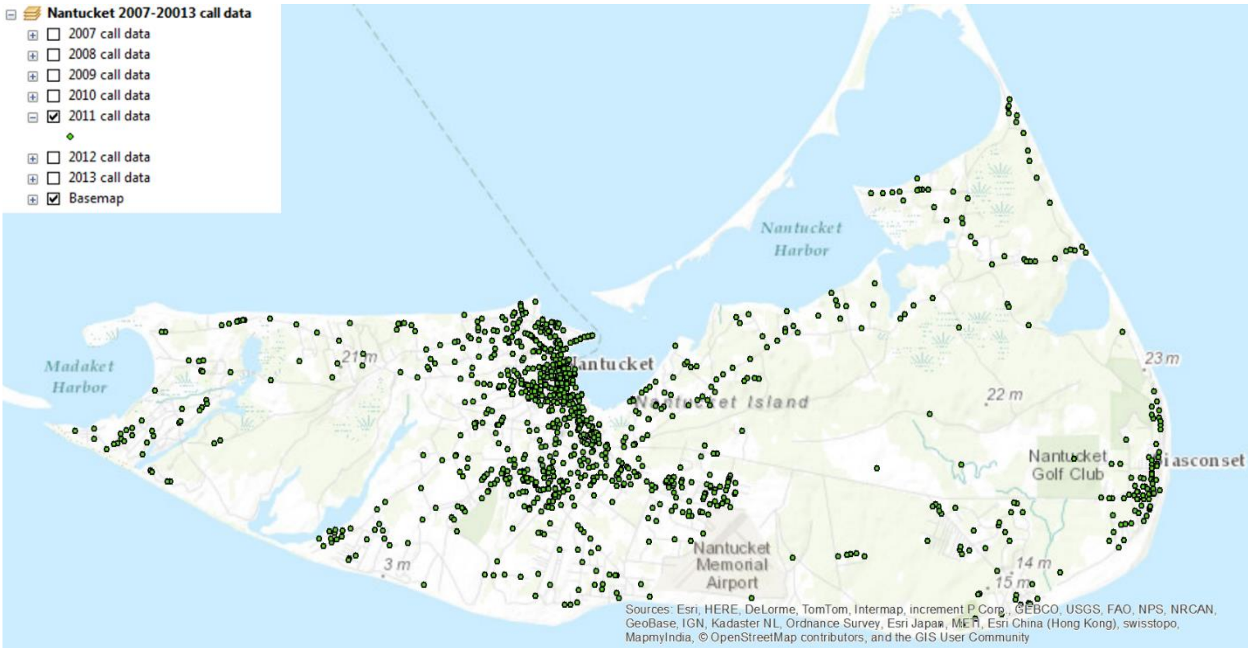
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

2011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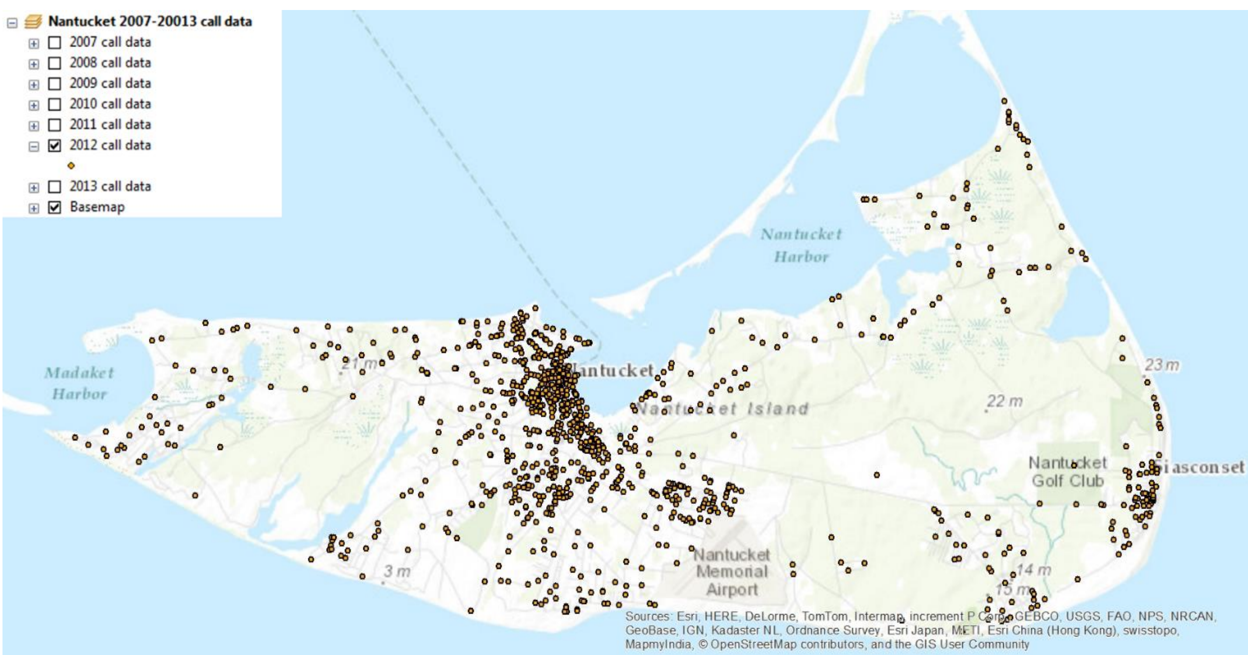
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

2012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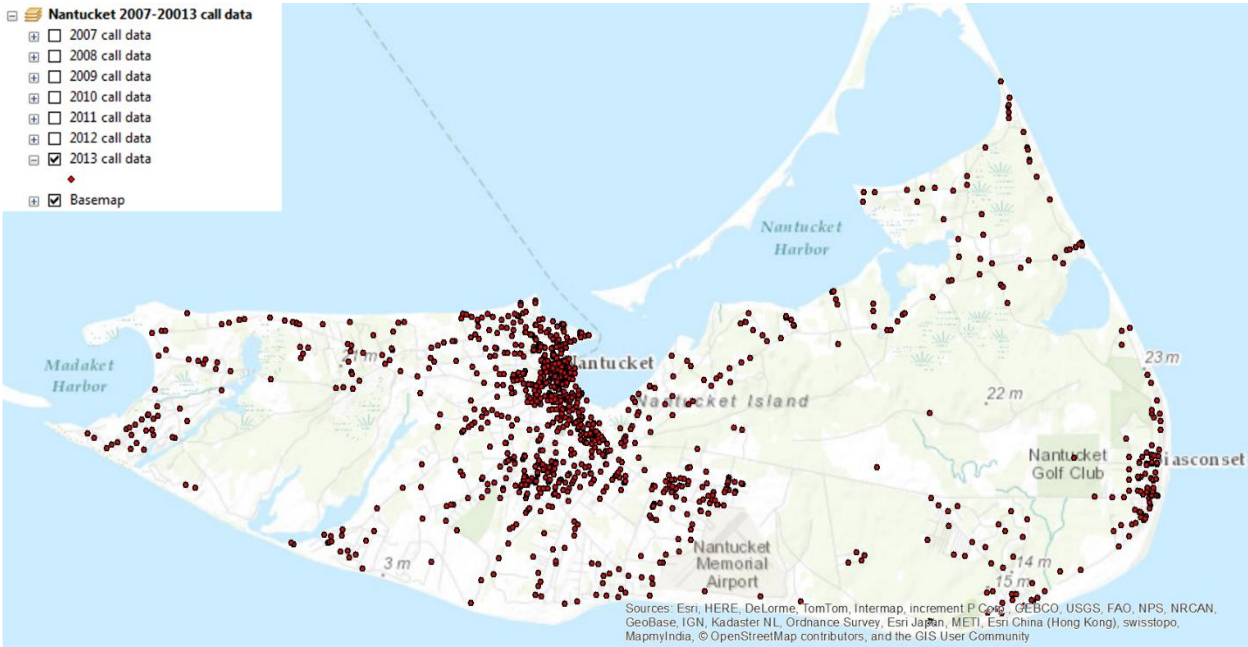
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

2013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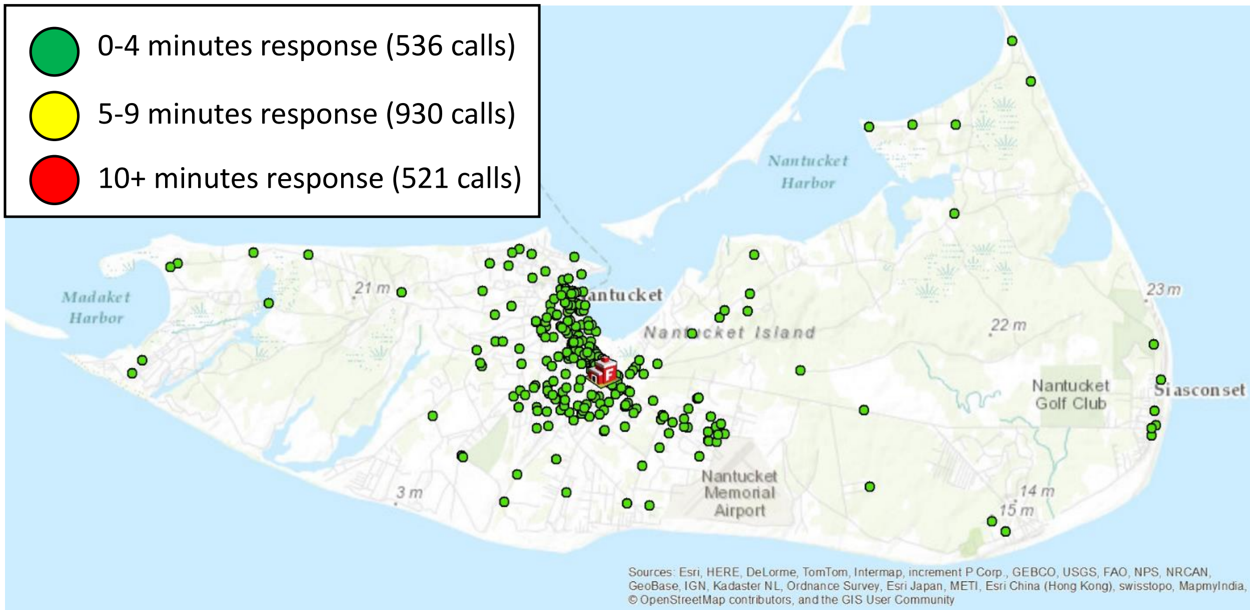
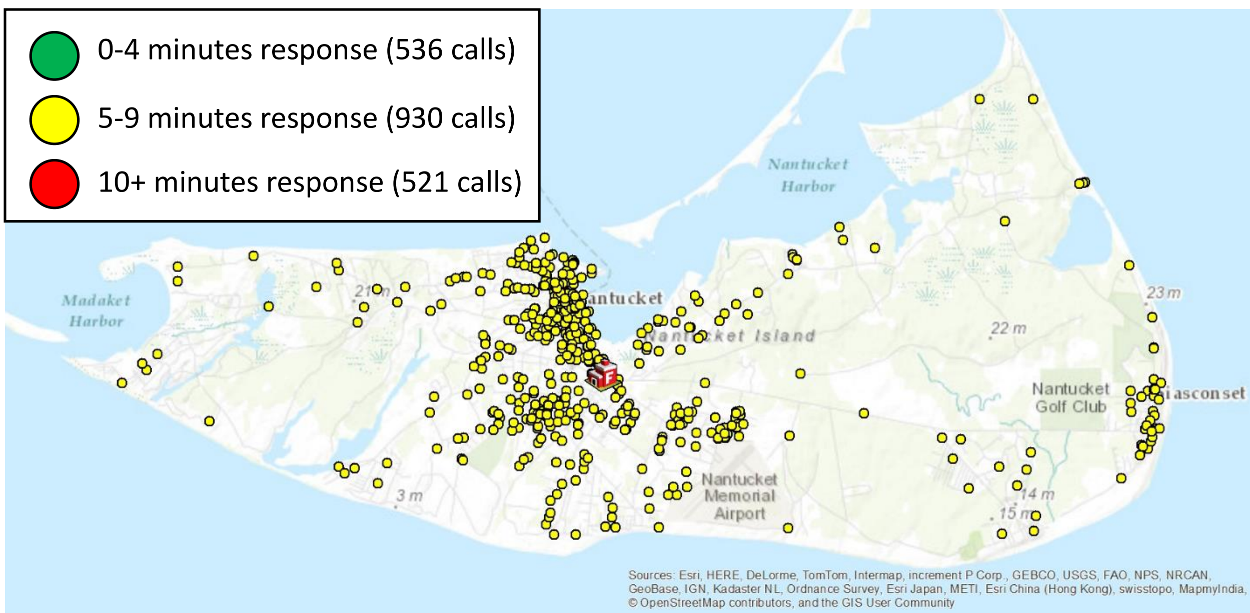
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Appendix E – Response Times on Nantucket

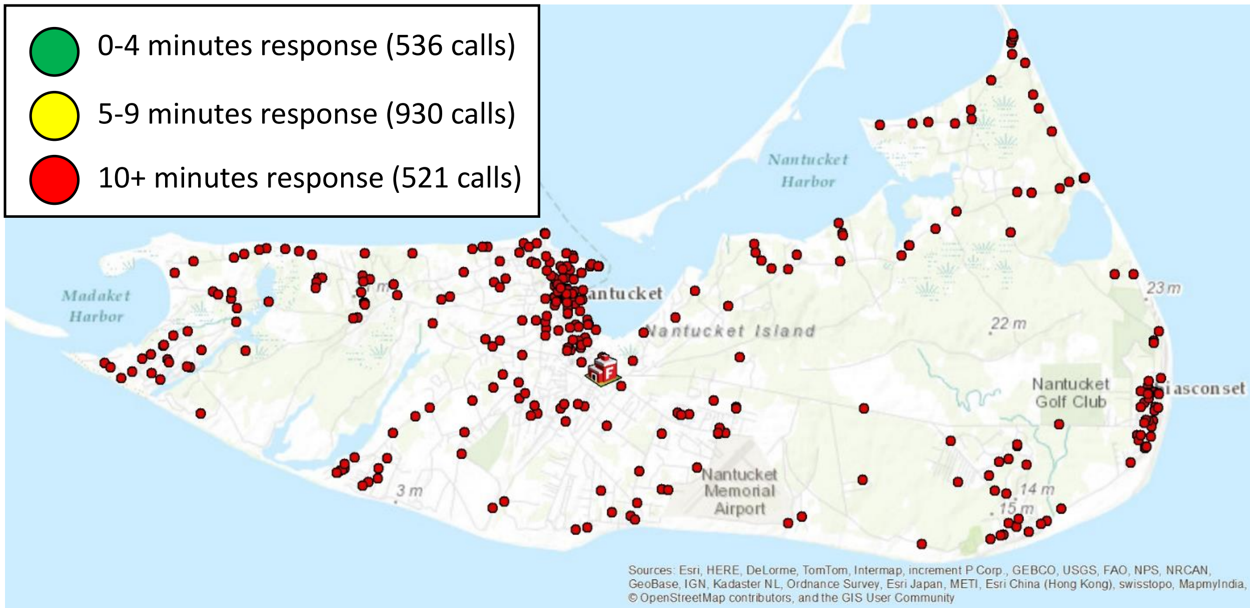
0-4 min Response



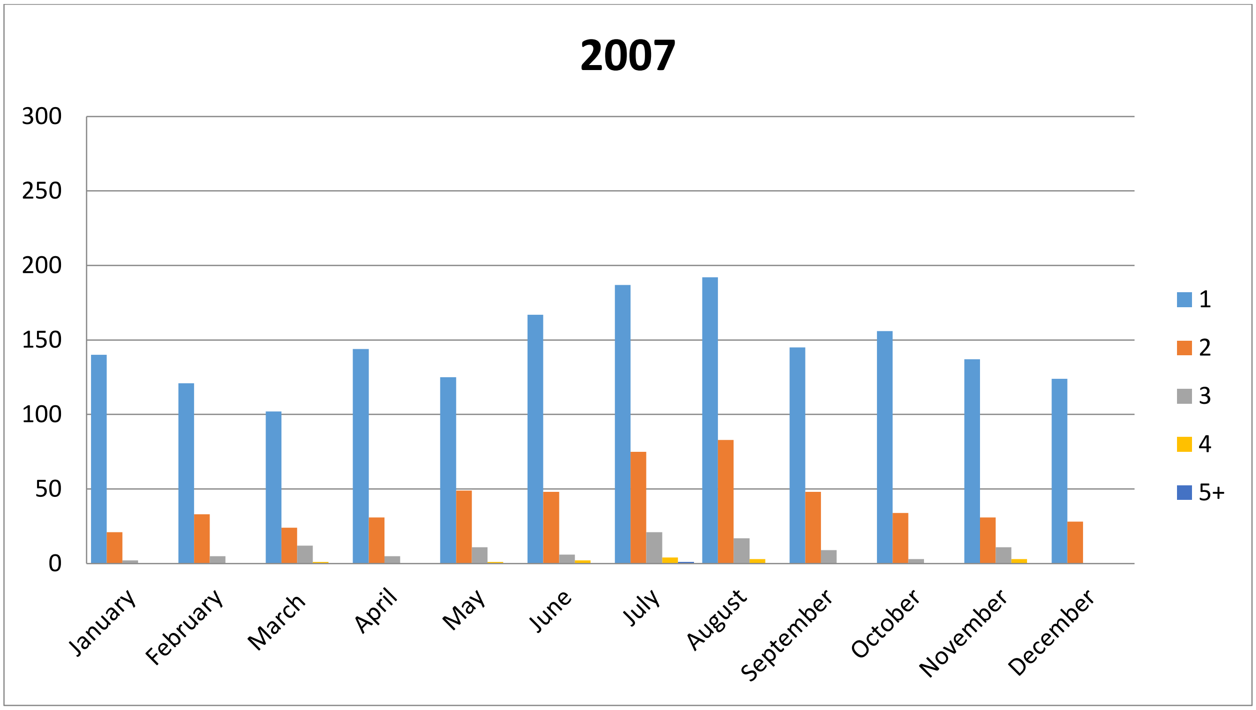
5-9 min Response

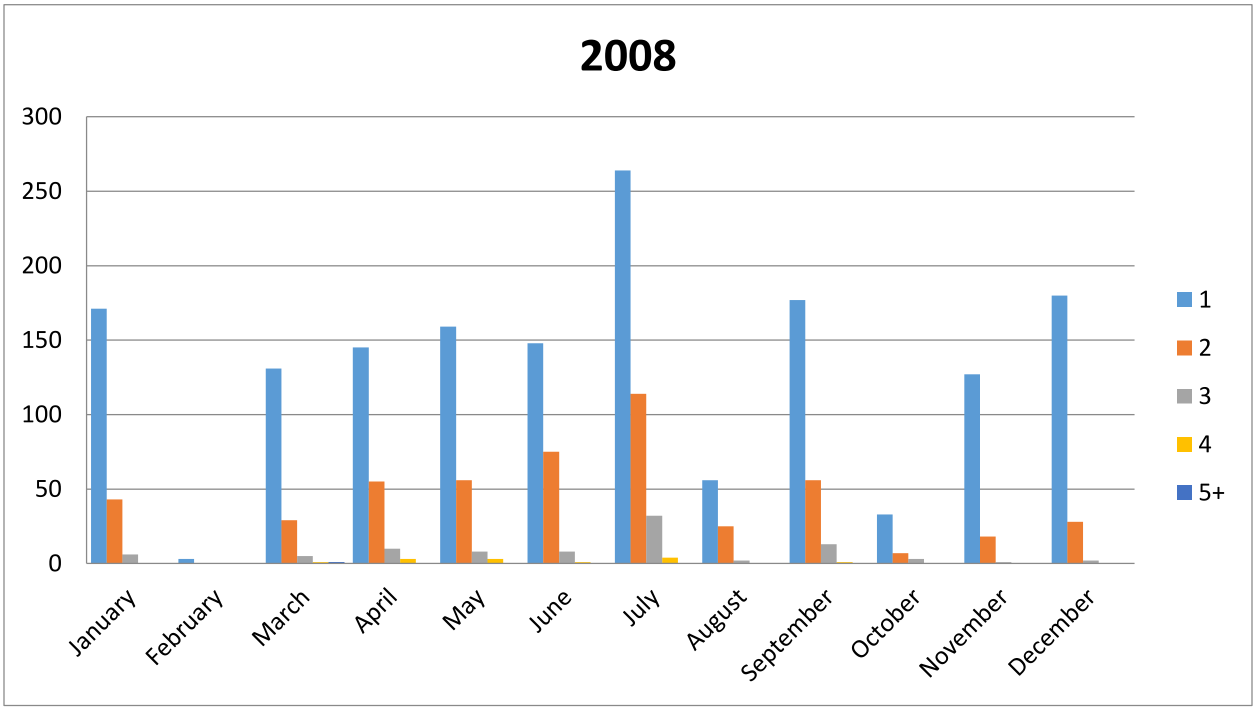


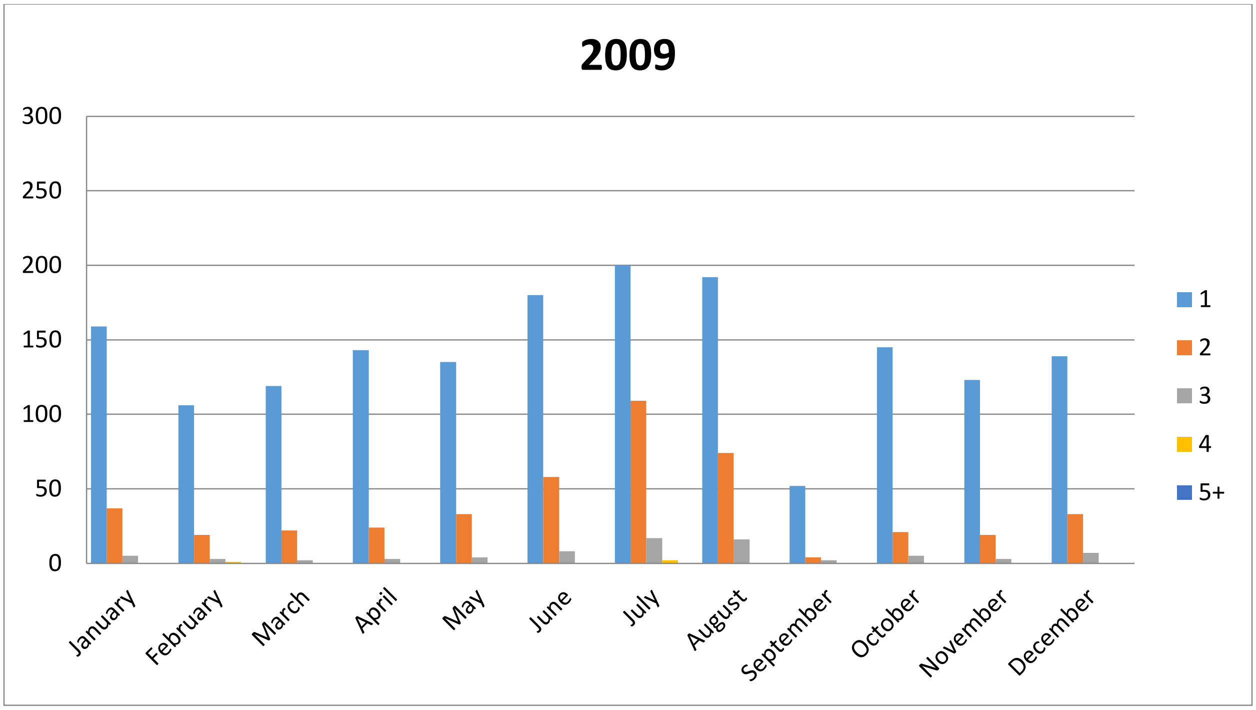
10+ min Response



Appendix F – Concurrent Calls by Month (2007-2013)



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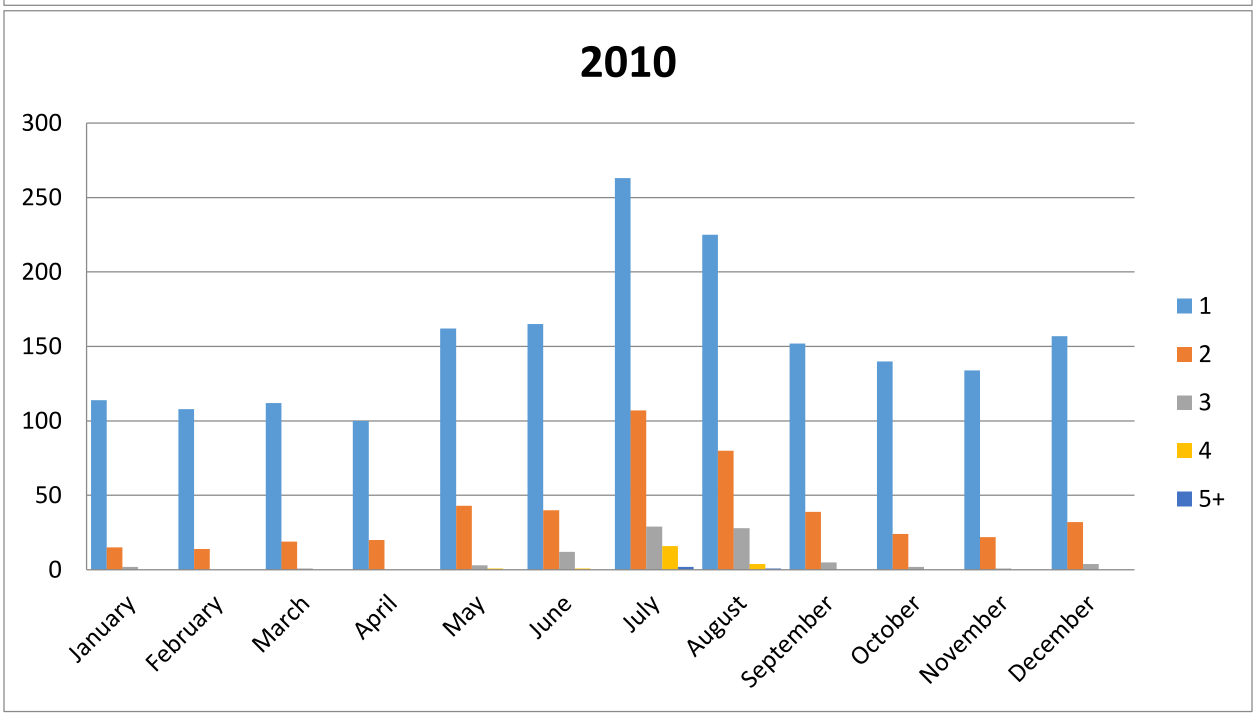
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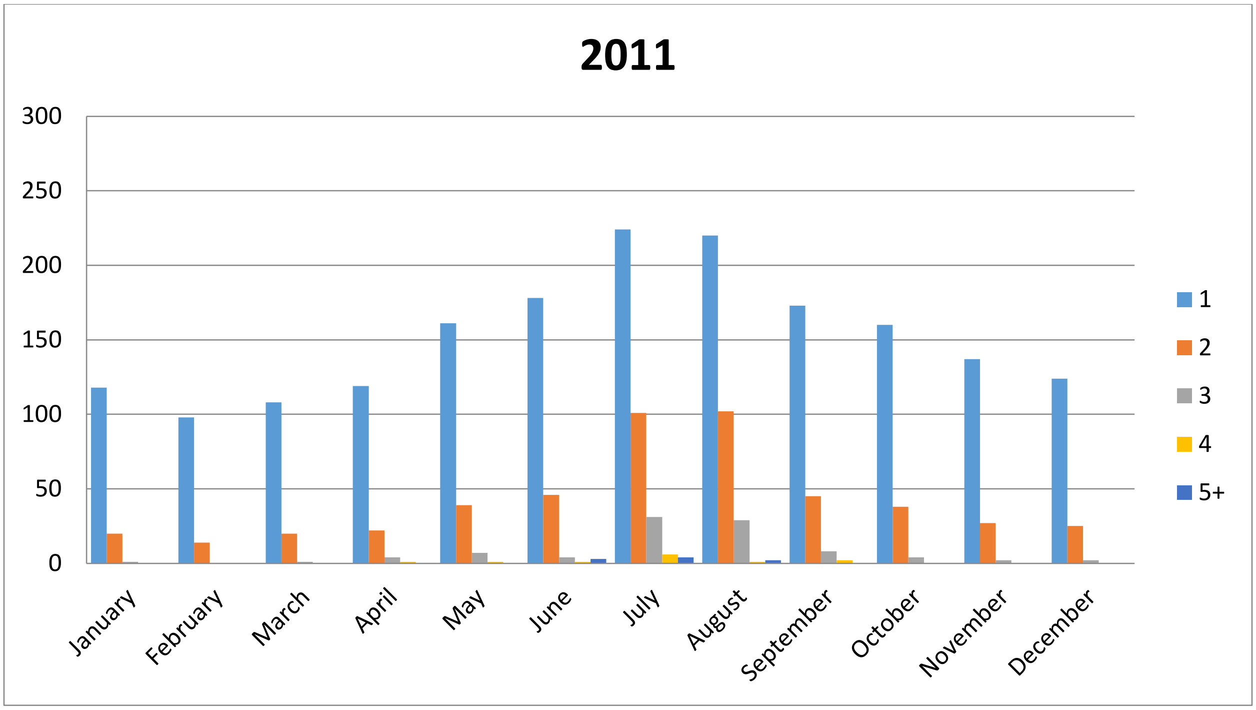
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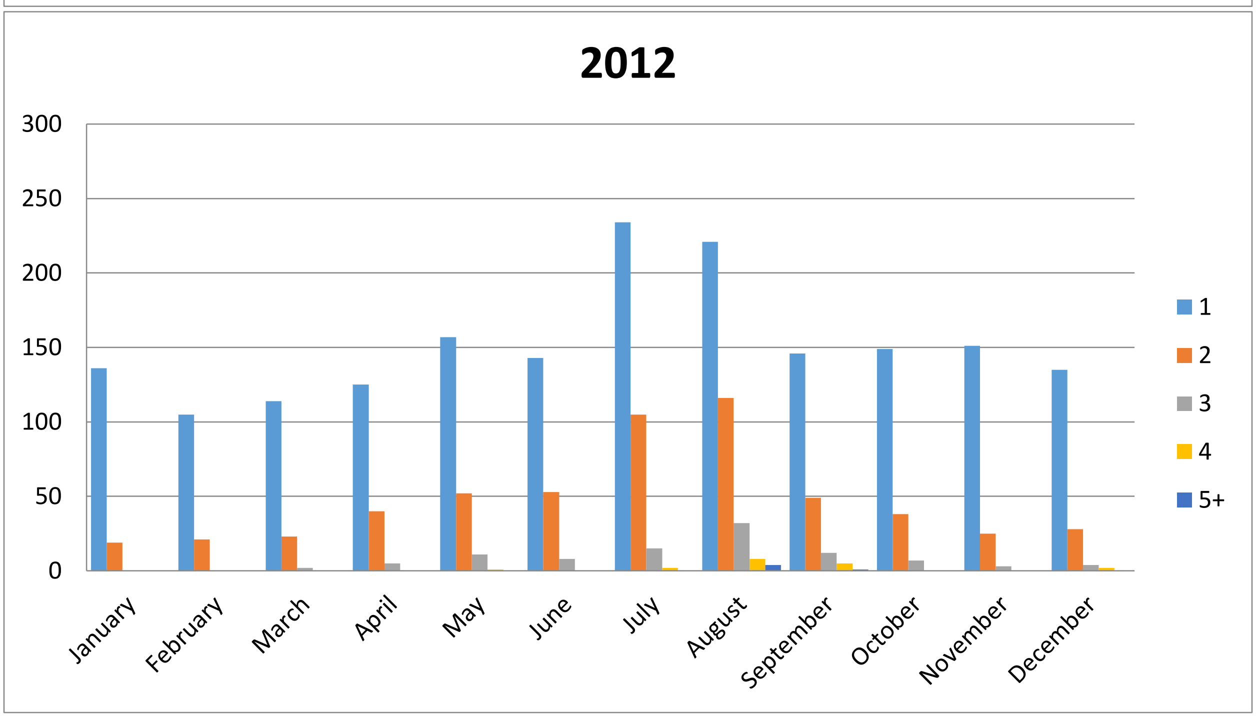
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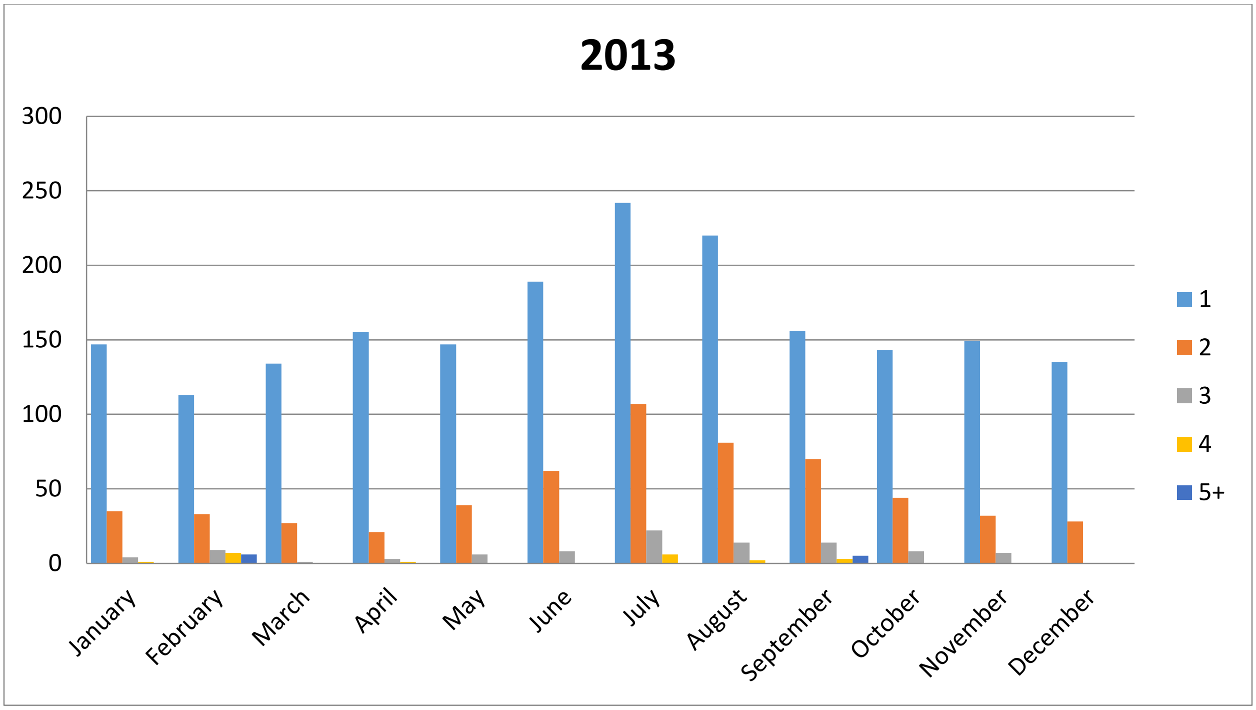
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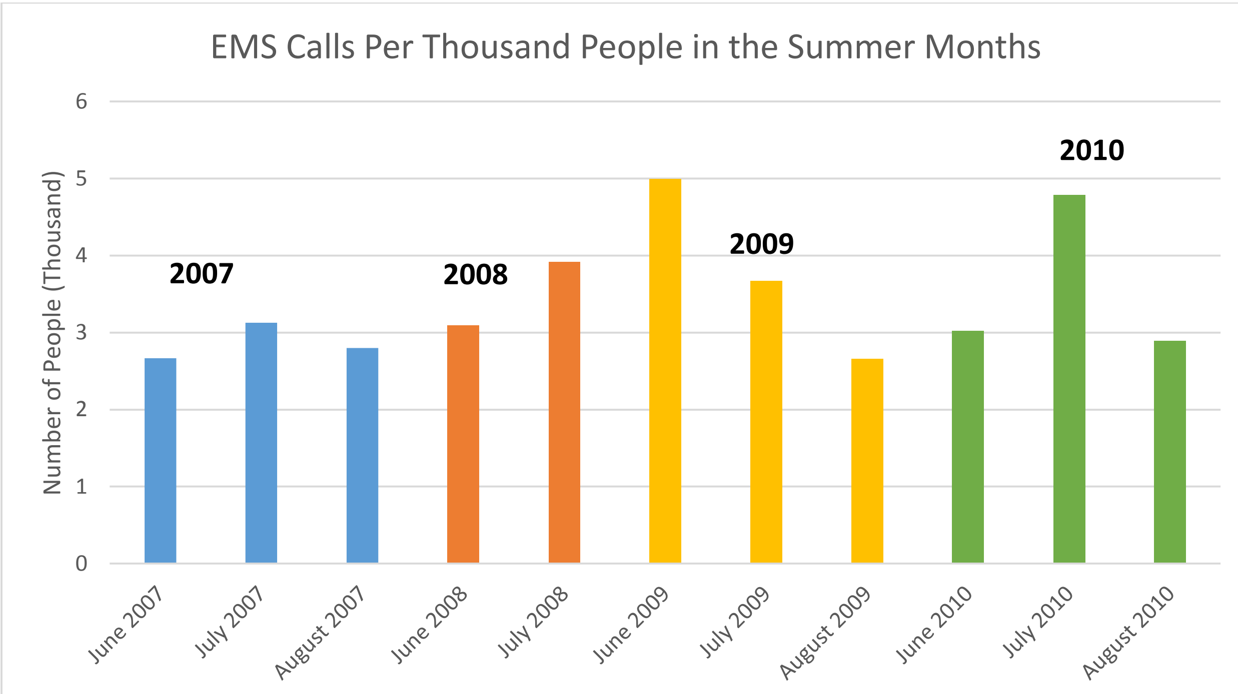
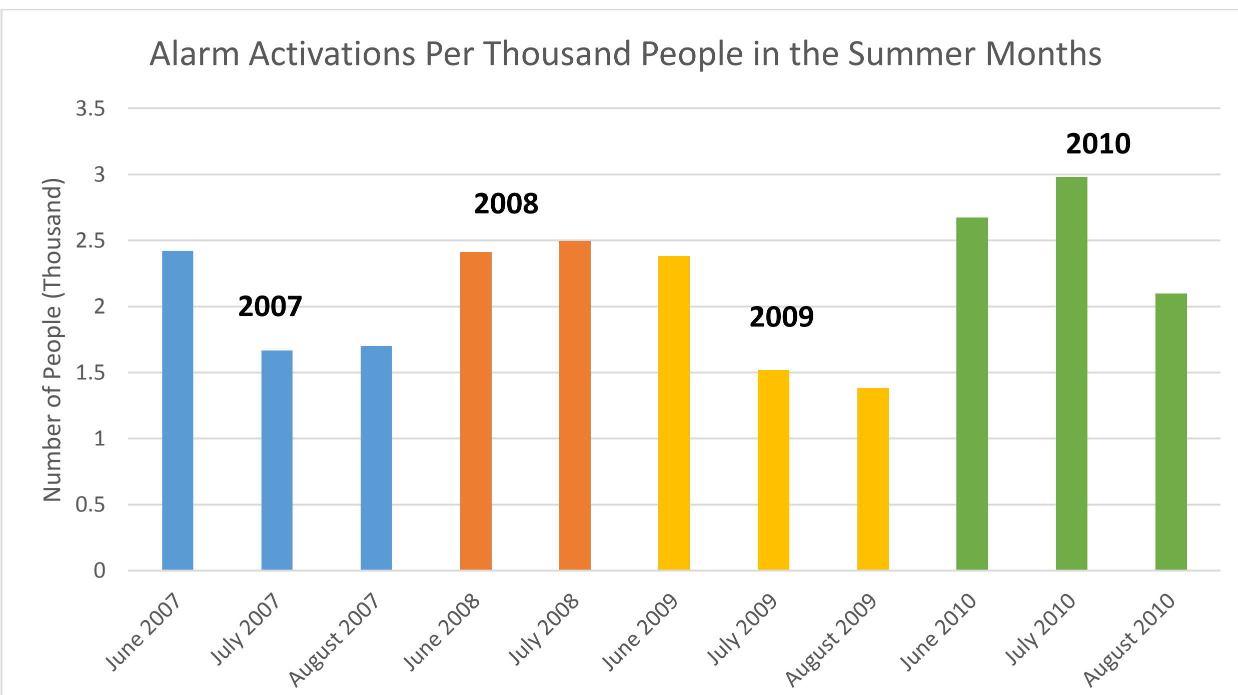
Appendix G – Population Data from Trash Tonnage

The following information was modified from information from *Feasibility of a Smart Grid on Nantucket (Beliveau et al., 2010).*

People/Month												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2006							50747	54337	35554	26275	20870	18845
2007	15915	13267	15384	19198	27364	32639	48611	51106	32780	24983	19020	18198
2008	15643	13632	14373	16075	22292	29429	46485	46853	28152	19842	12319	12751
2009	11766	9573	10405	12945	15653	25622	45518	49266	30623	20334	15371	17315
2010	13480	11512	11788	16189	19735	31426	42622	49111	29350	22750		

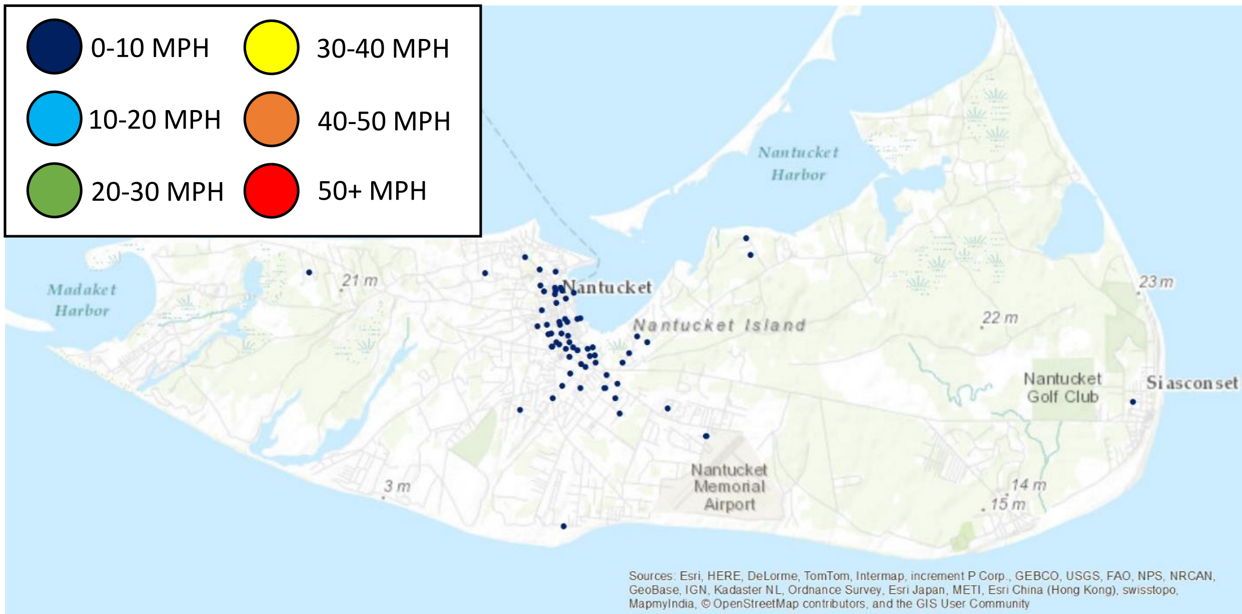
Appendix H – EMS Calls and Alarm Activation Calls Per Thousand People



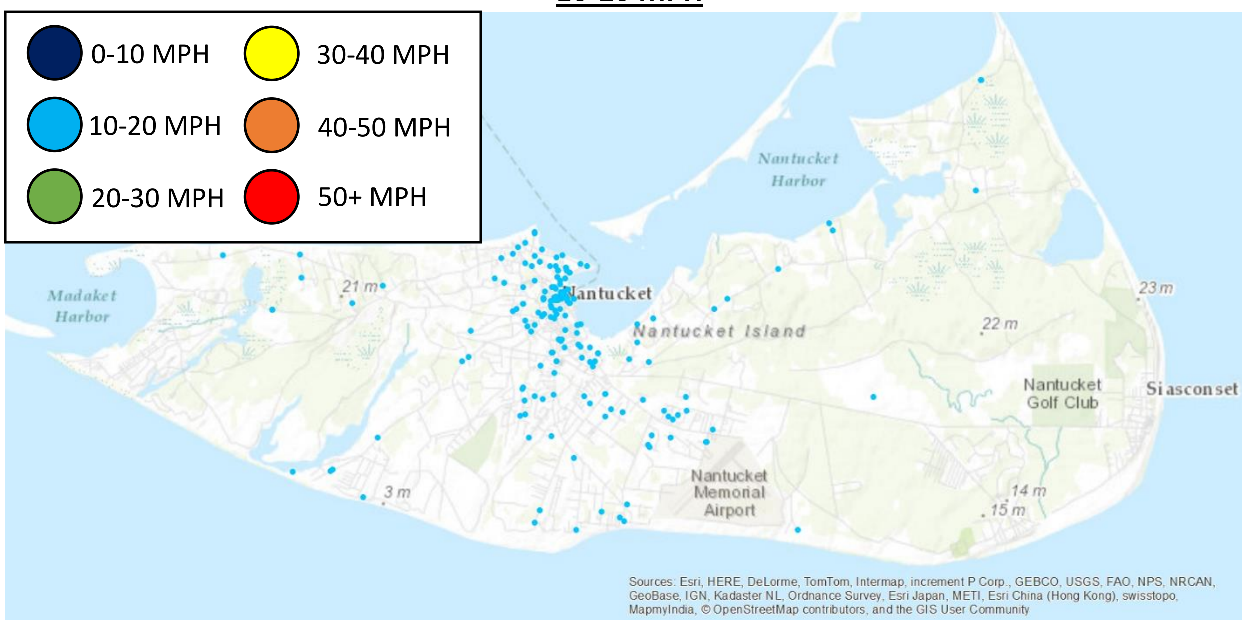


Appendix I – Speed Maps Per Category (2013)

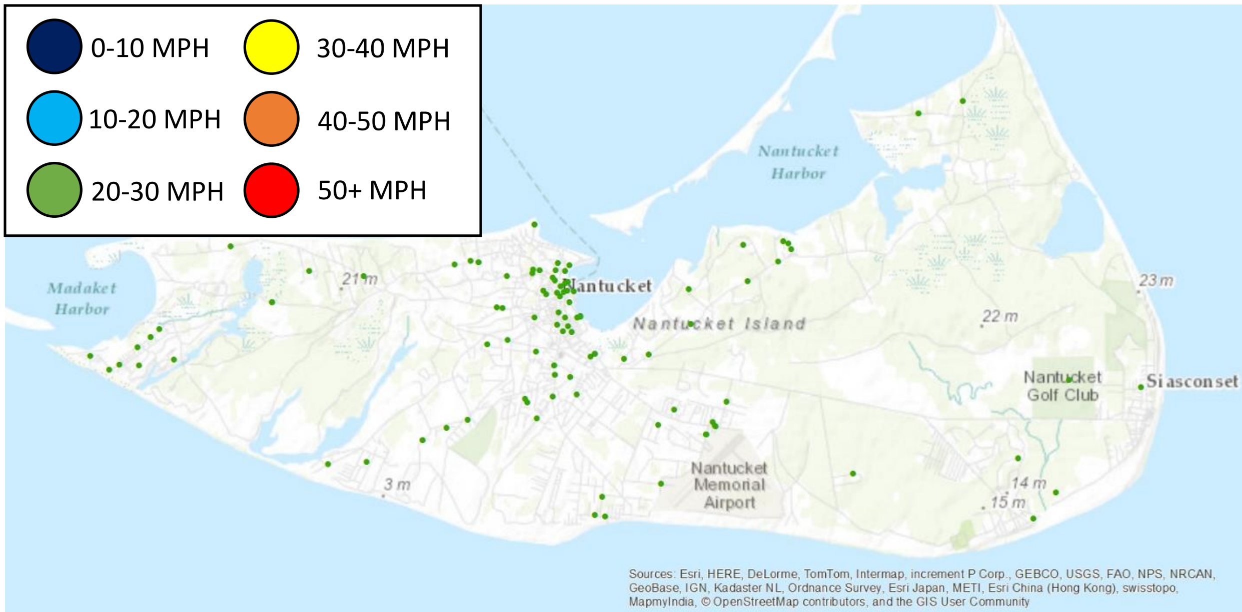
0-10 MPH



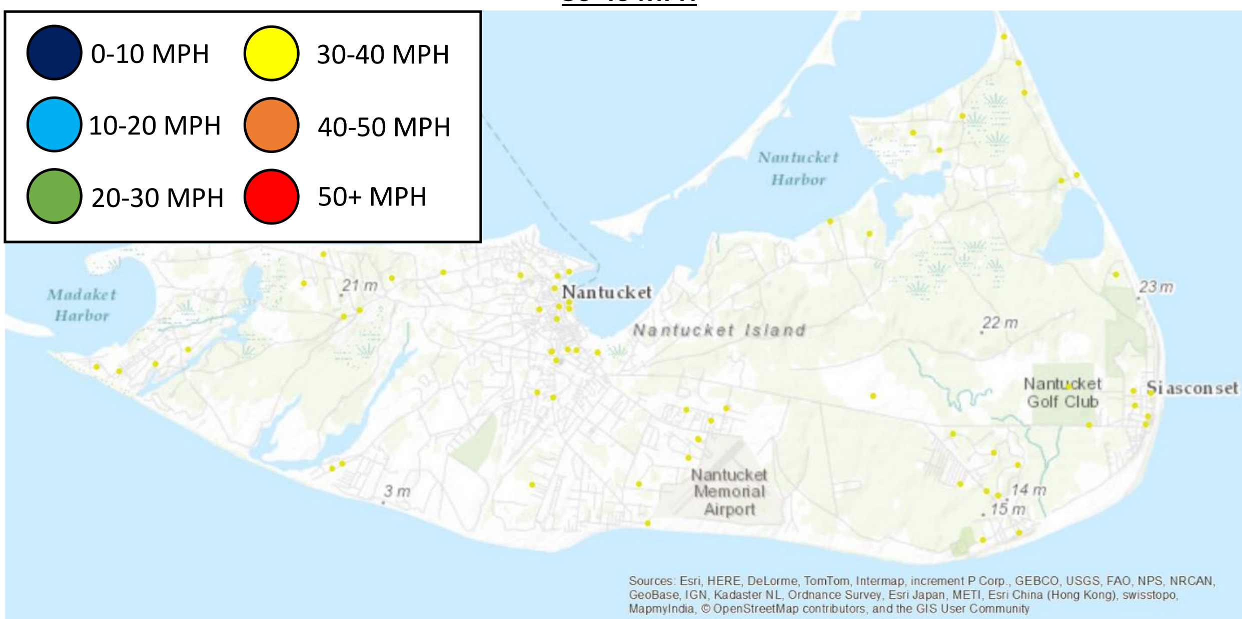
10-20 MPH



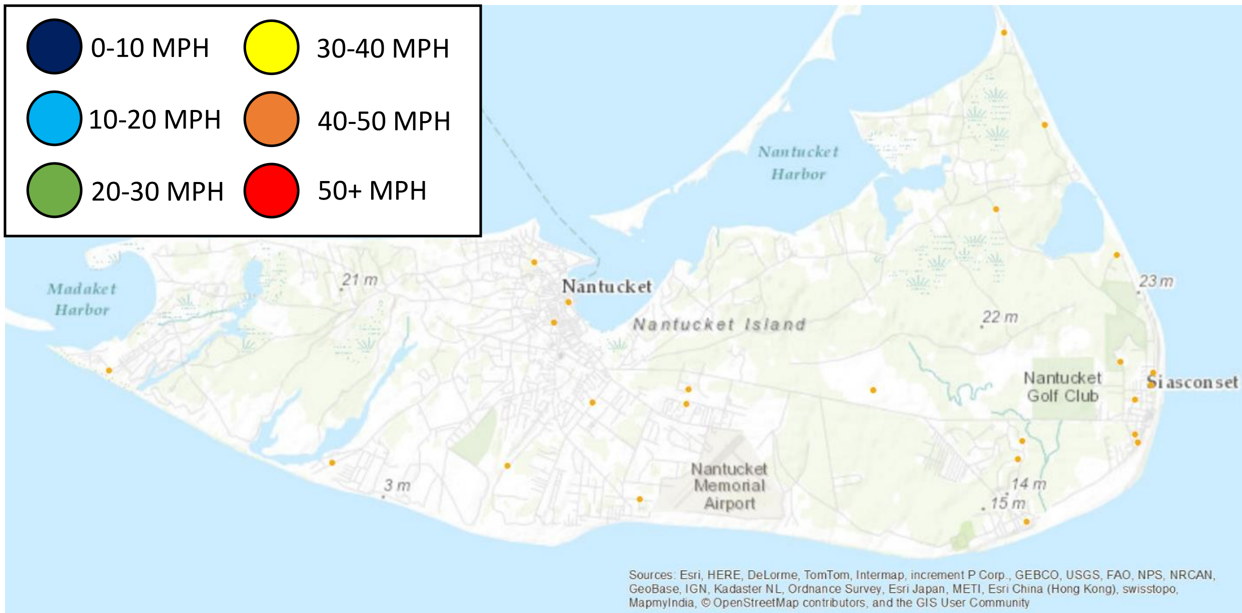
20-30 MPH



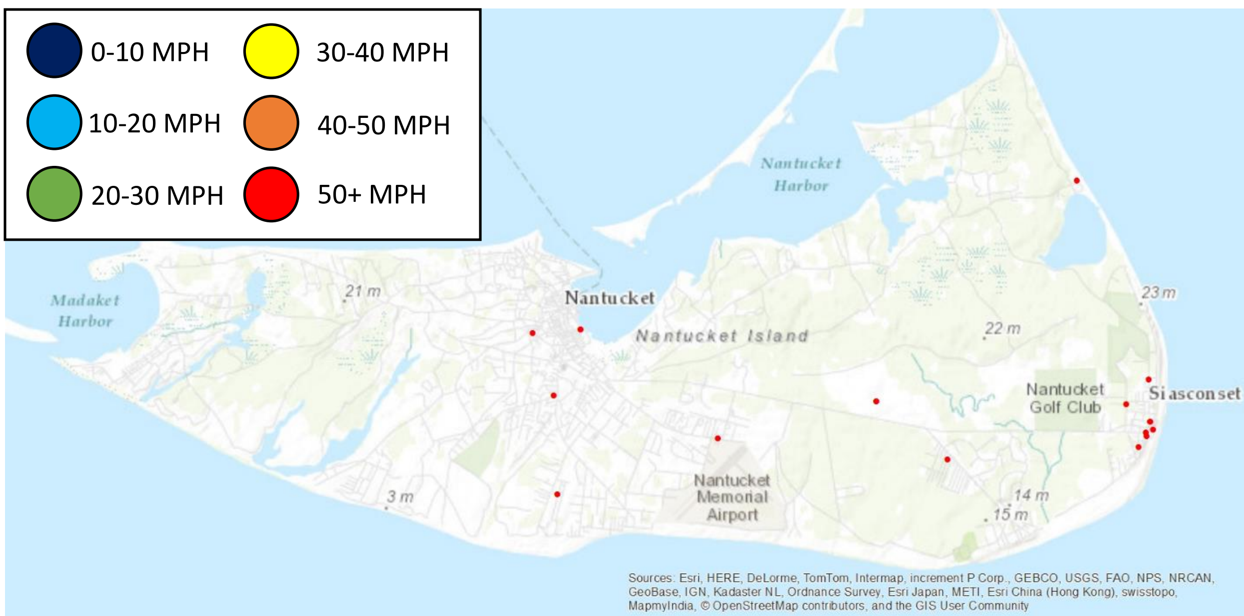
30-40 MPH



40-50 MPH

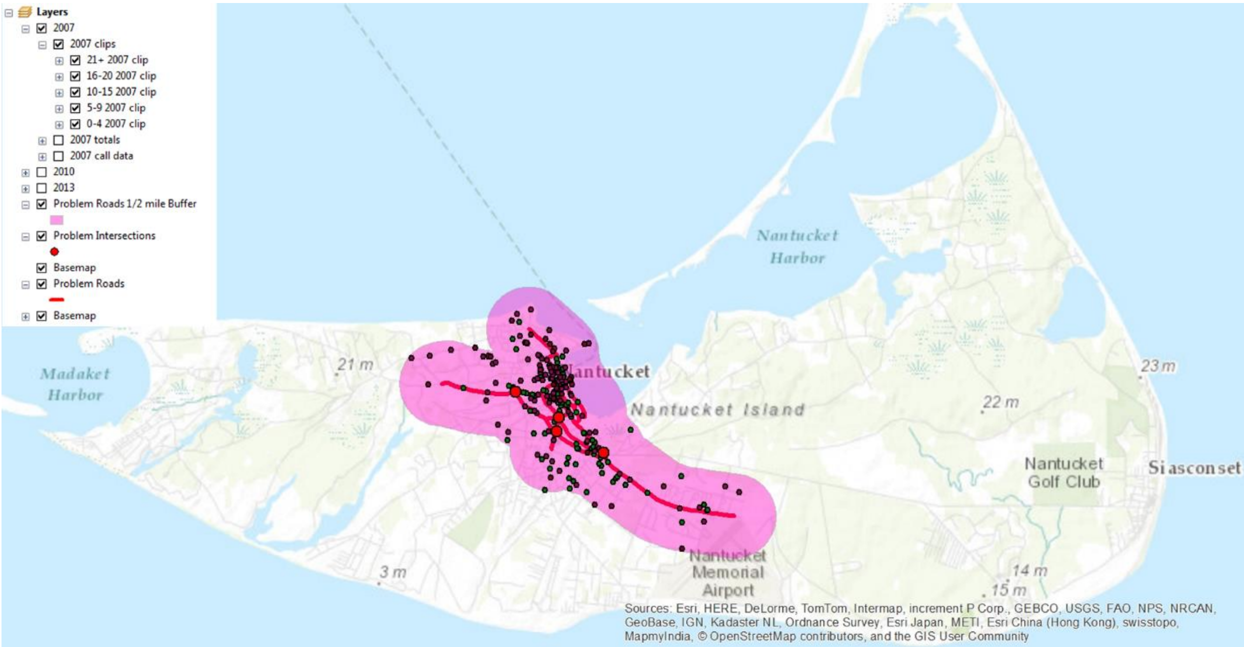


50+ MPH

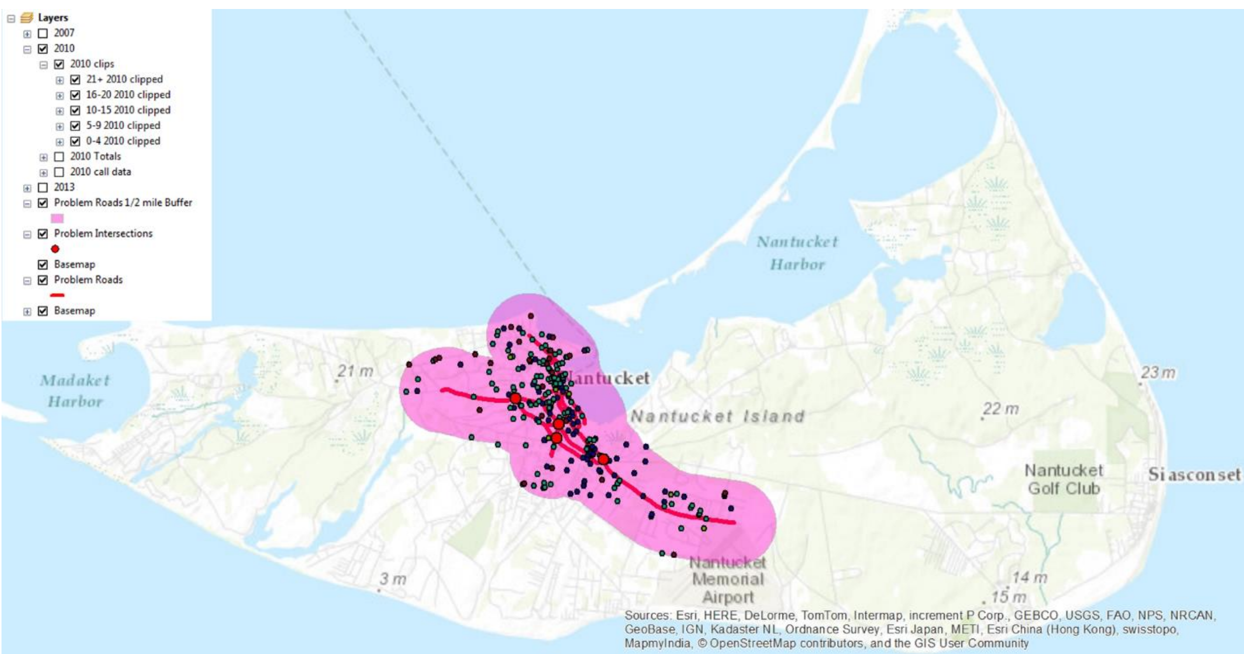


Appendix J – Congested Area Maps (2007, 2010, 2013)

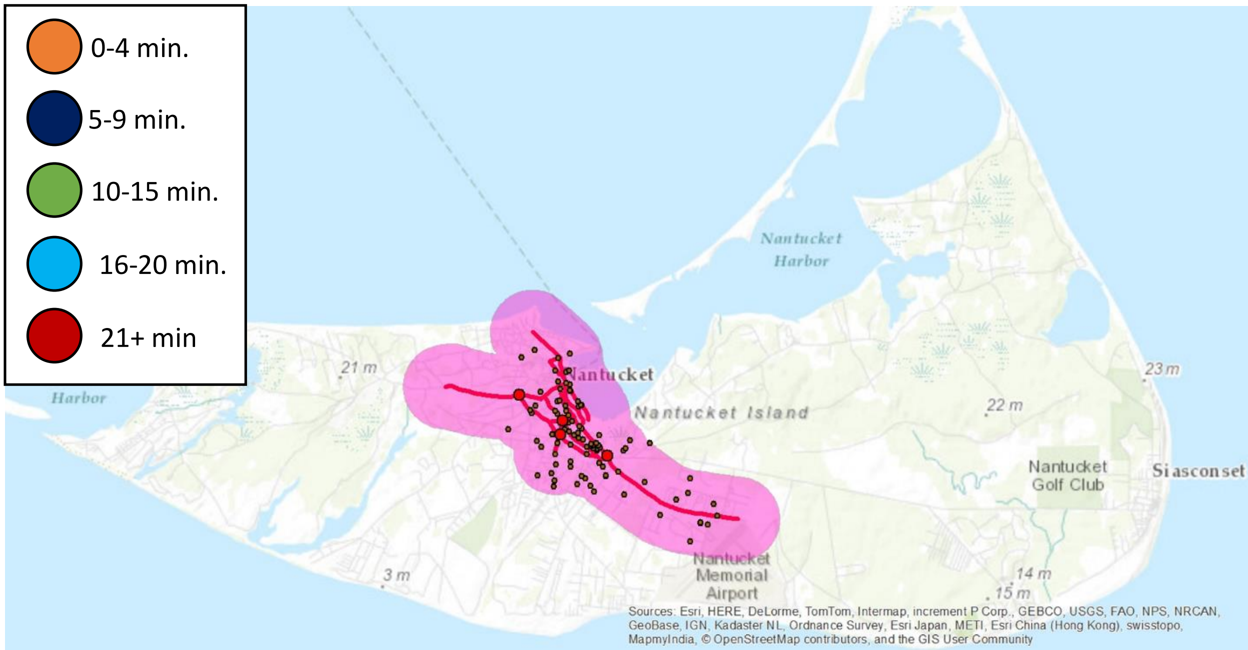
2007 – Summer Non-concurrent Calls clipped to congested area



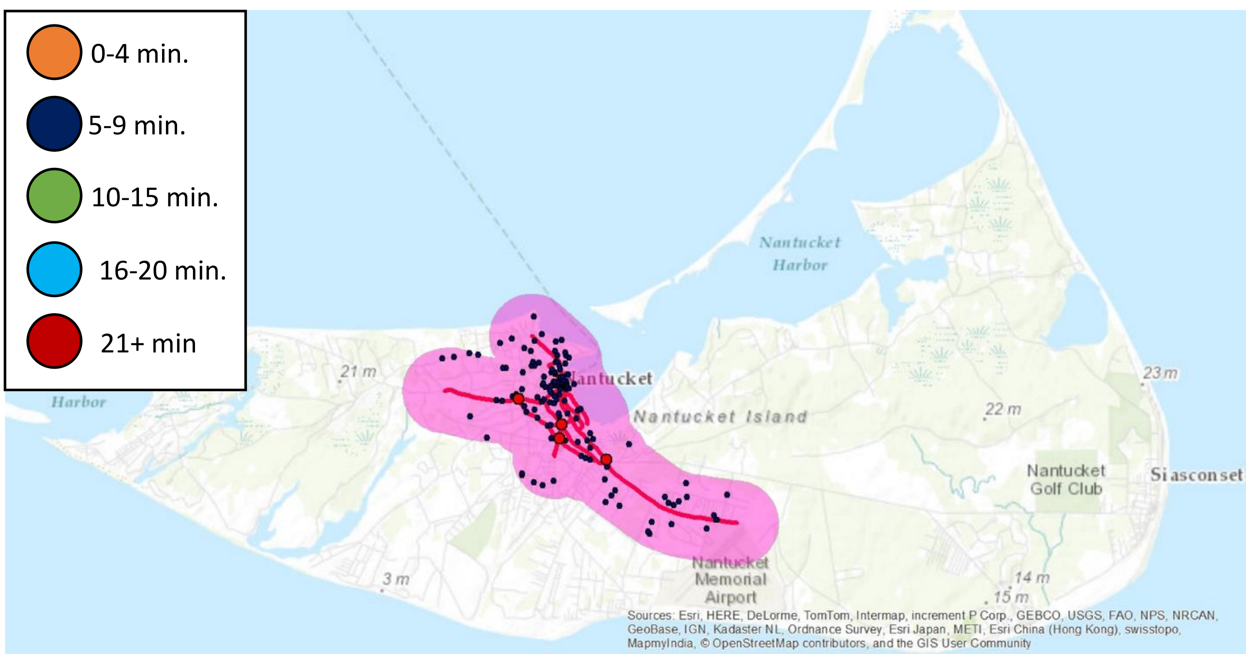
2010 – Summer Non-concurrent Calls clipped to congested area



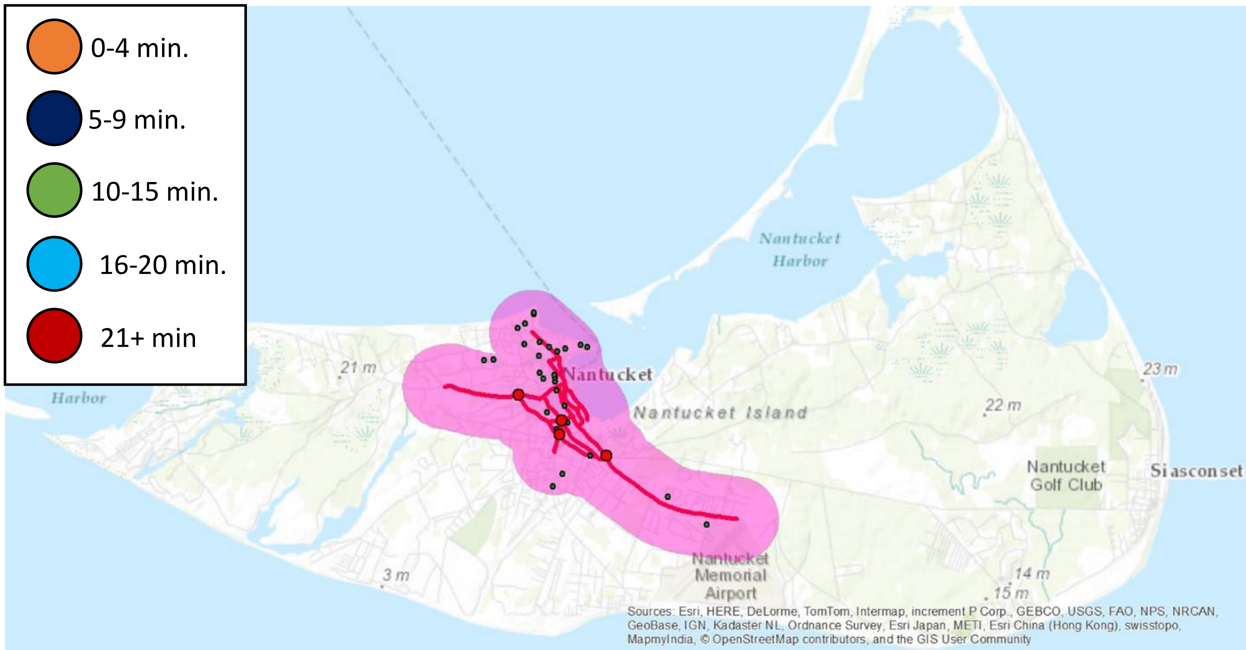
2013 – Summer Non-concurrent Calls with 0-4 min response time clipped to congested area



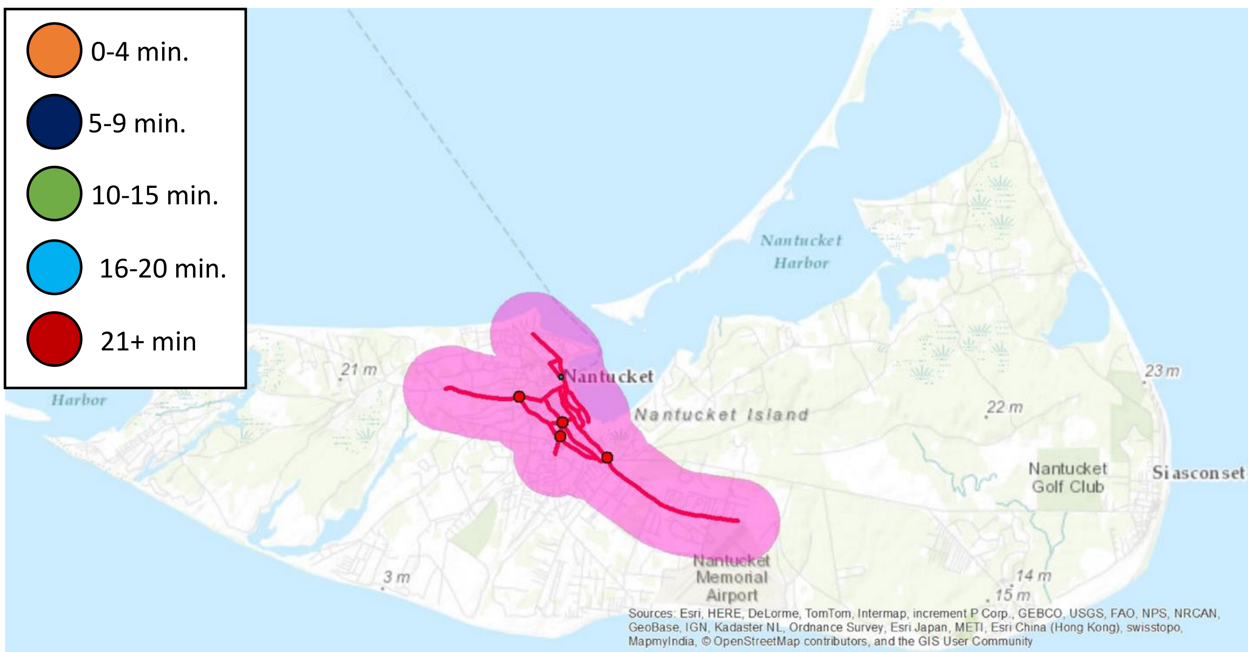
2013 – Summer Non-concurrent Calls with 5-9 min response time clipped to congested area



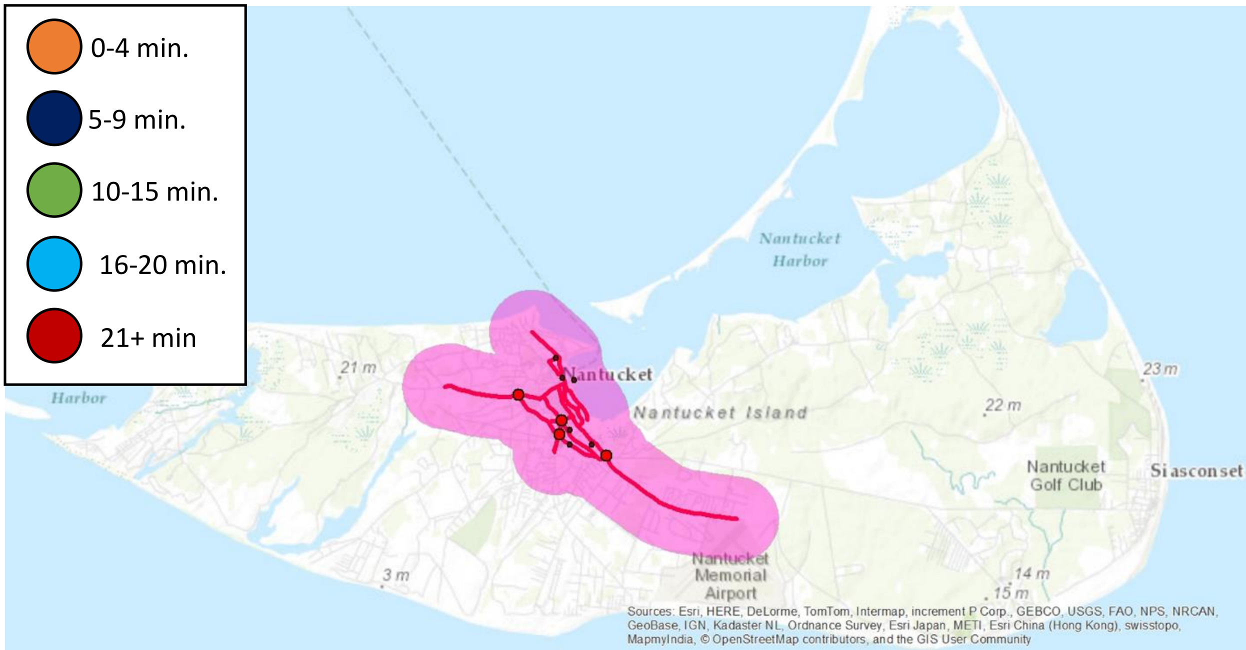
2013 – Summer Non-concurrent Calls with 10-15 min response time clipped to congested area



2013 – Summer Non-concurrent Calls with 16-20 min response time clipped to congested area

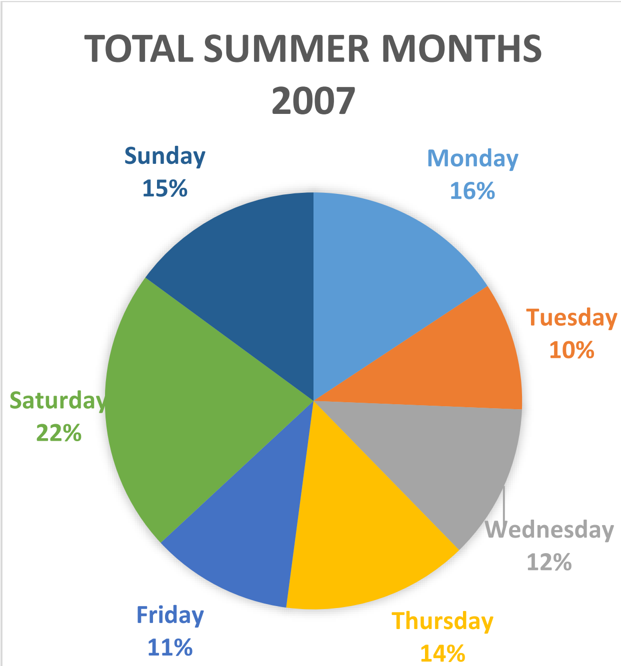


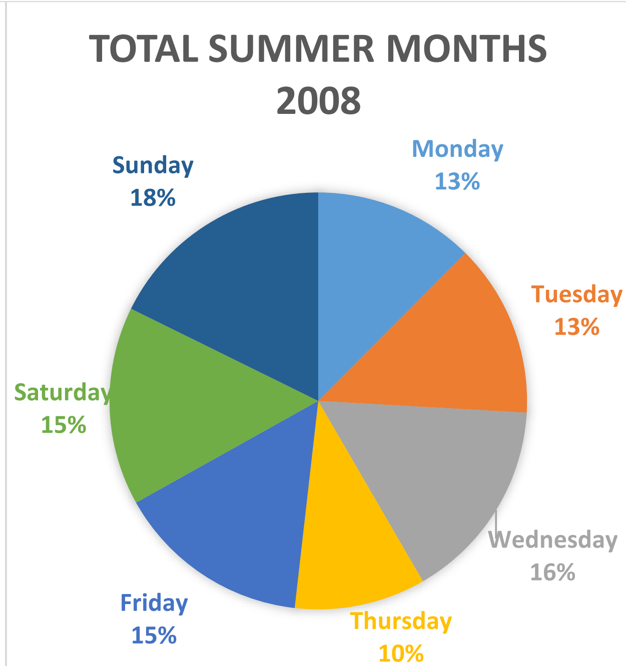
<u>2013</u> – Summer Non-concurrent Calls with 21+ min response time clipped to congested area

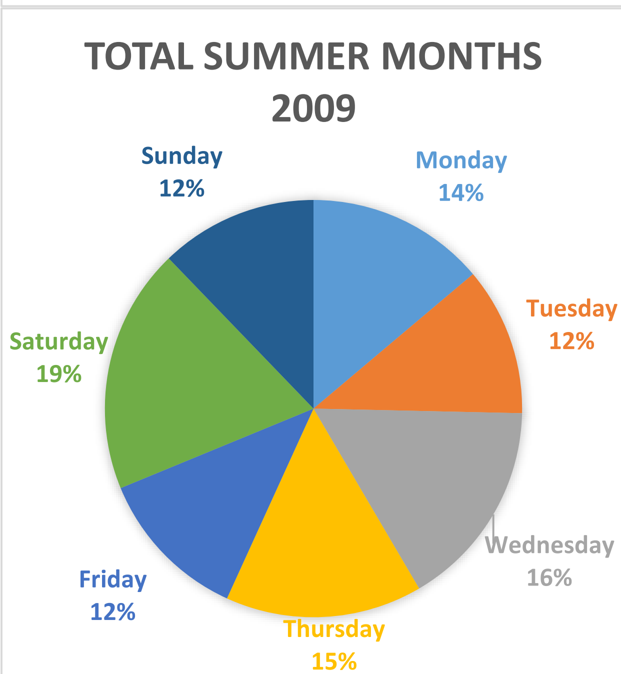


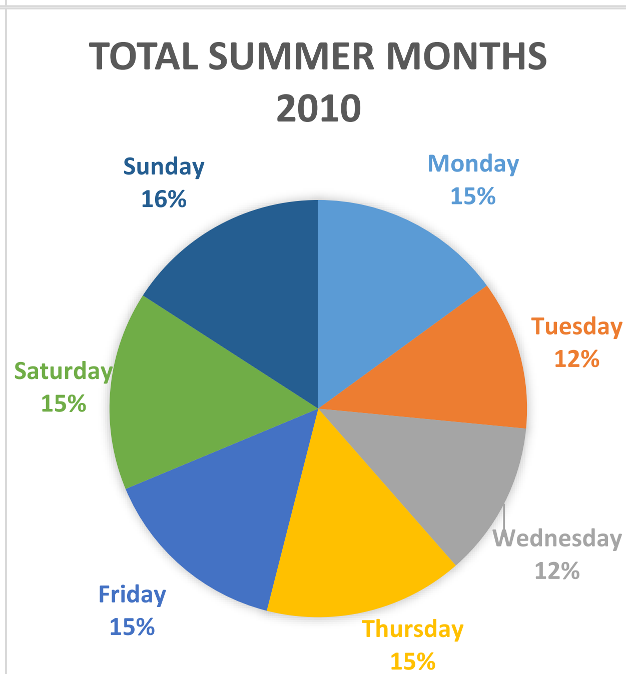
Appendix K – Day of Call in Summer Months (2007-2013)

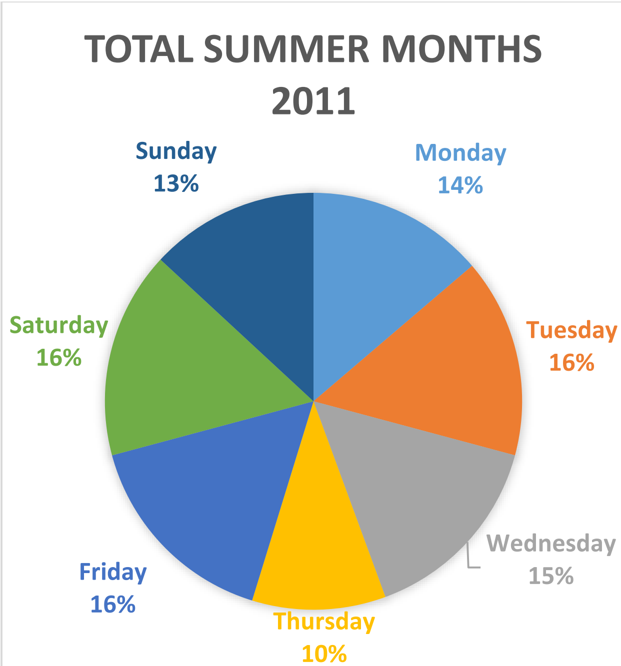
The summer months were defined as June, July and August for this analysis.

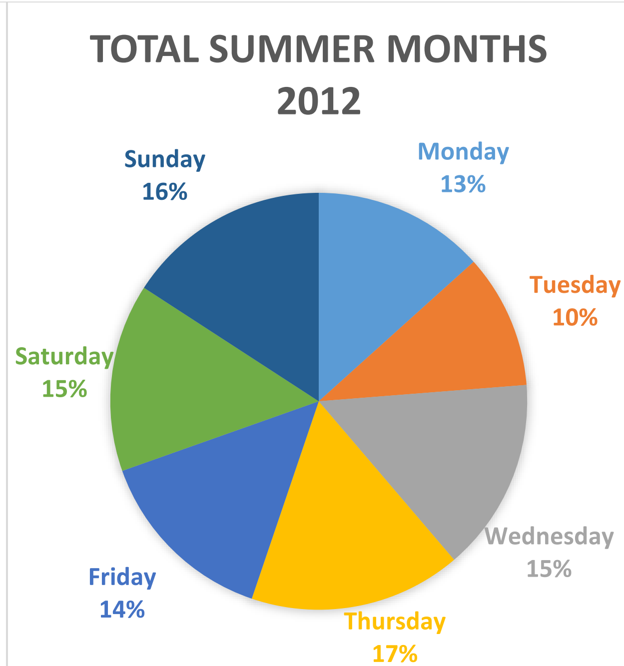


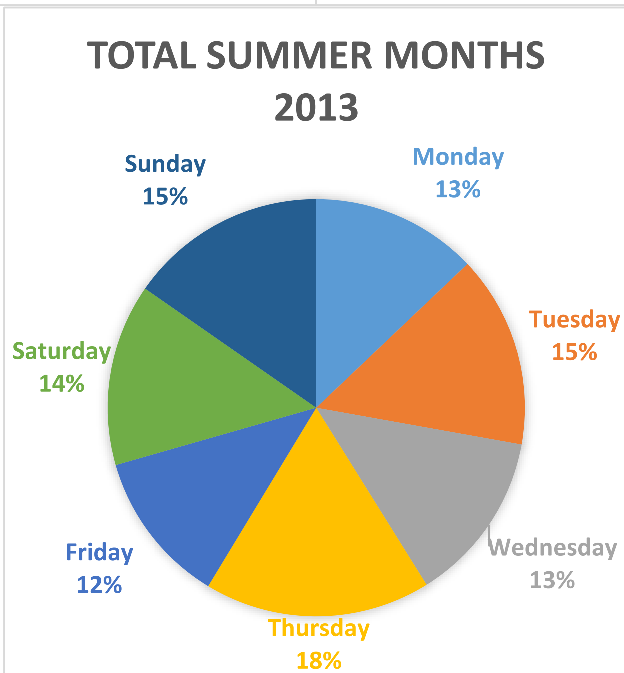






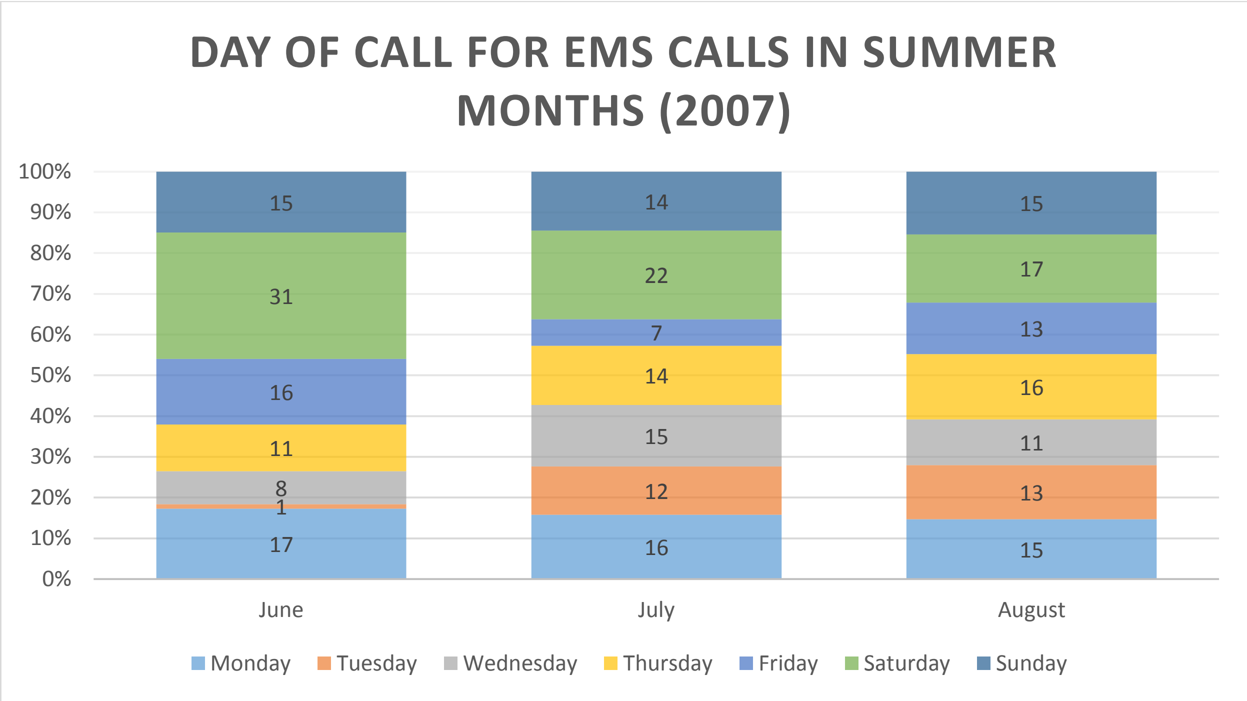

TOTAL SUMMER MONTHS 2011
Sunday 13%
Monday 14%
Tuesday 16%
Wednesday 15%
Thursday 10%
Friday 16%
Saturday 16%

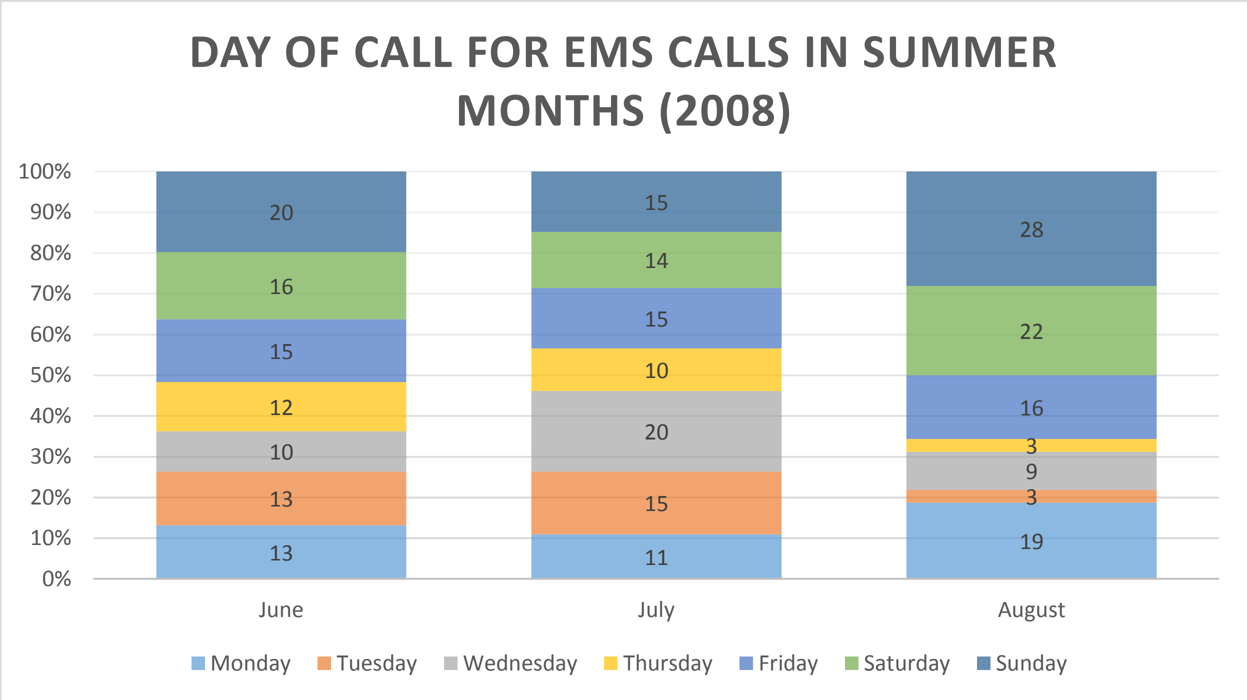

TOTAL SUMMER MONTHS 2012
Sunday 16%
Monday 13%
Tuesday 10%
Wednesday 15%
Thursday 17%
Friday 14%
Saturday 15%

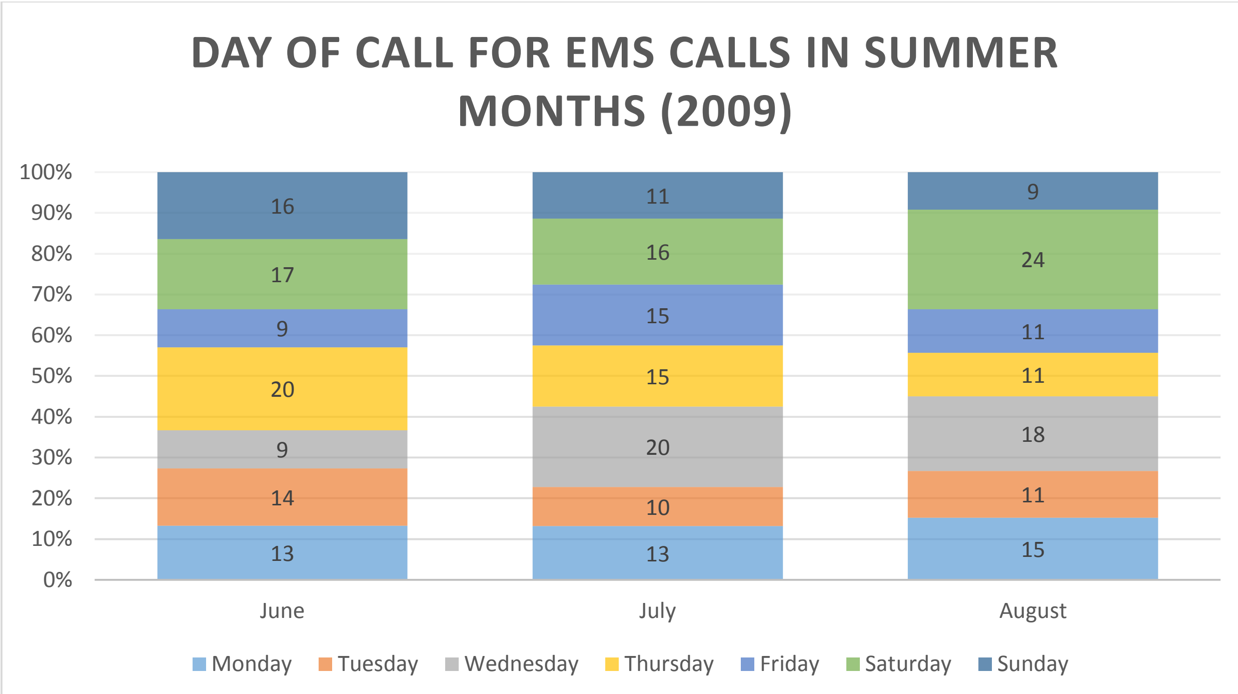

TOTAL SUMMER MONTHS 2013
Sunday 15%
Monday 13%
Tuesday 15%
Wednesday 13%
Thursday 18%
Friday 12%
Saturday 14%

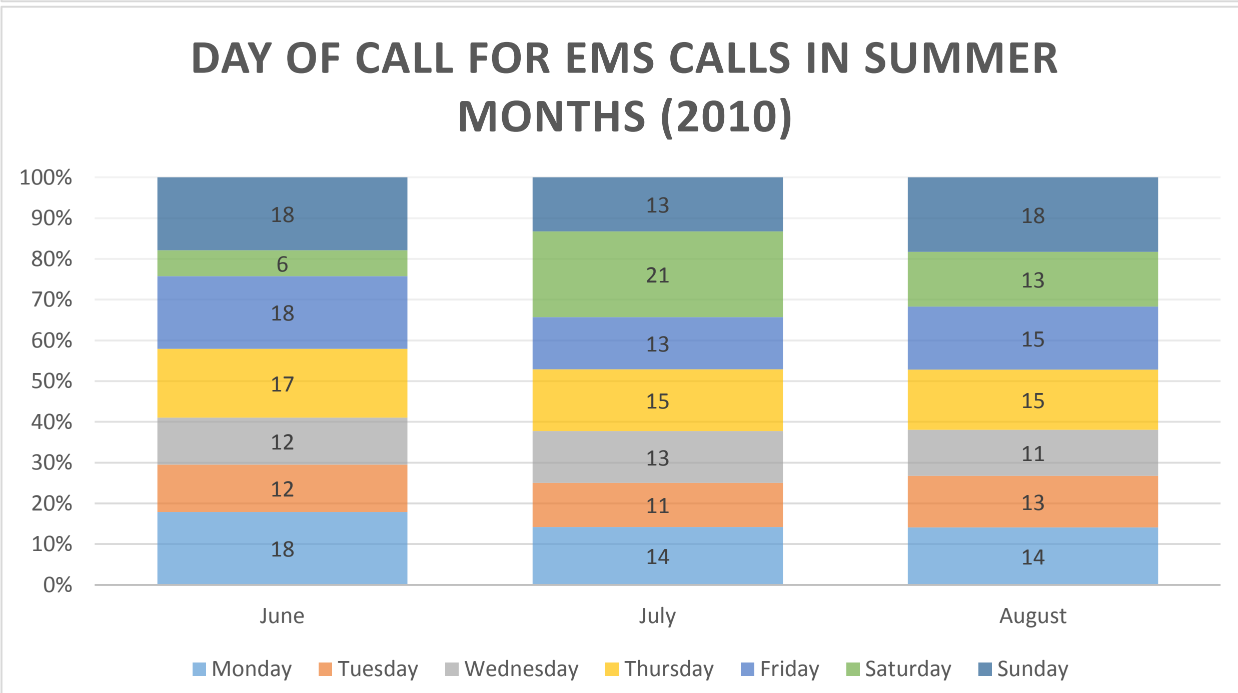
Appendix L – Day of Call for EMS Calls in Summer Months (2007-2013)

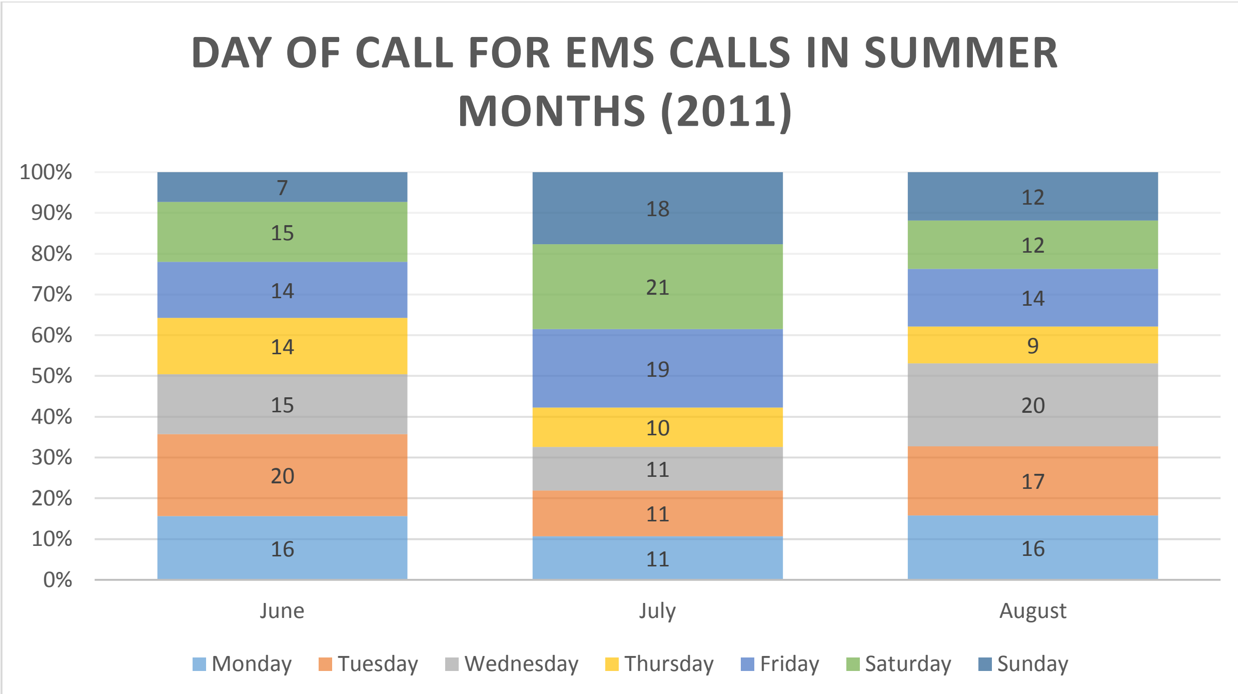
The values labeled on the graphs are the percentage of calls on each day.

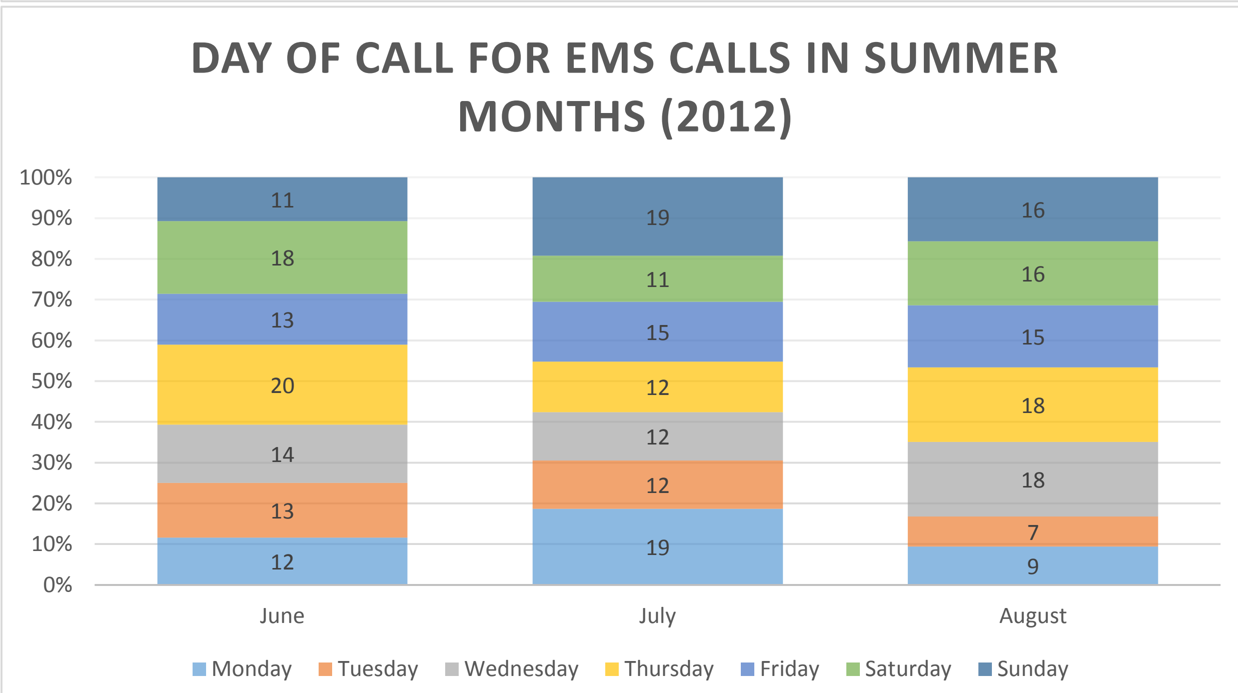


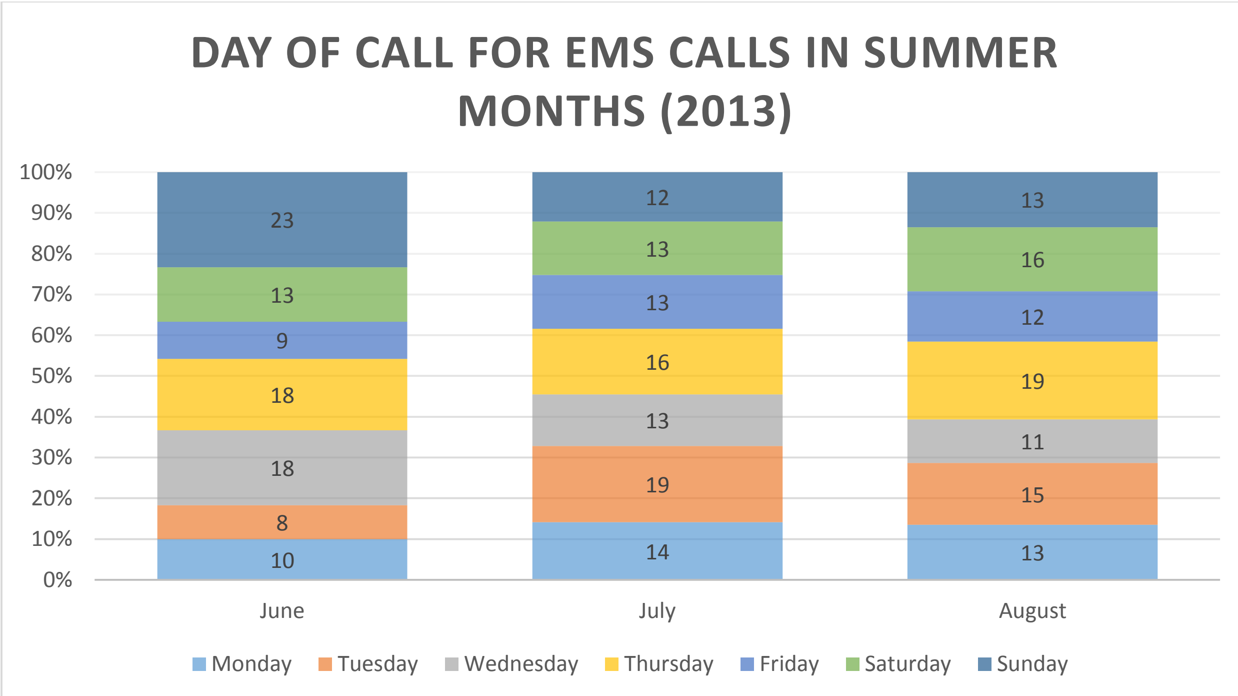



DAY OF CALL FOR EMS CALLS IN SUMMER MONTHS (2009)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
16
17
9
20
9
14
13
11
16
15
15
20
10
13
9
24
11
11
18
11
15
June
July
August
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday


DAY OF CALL FOR EMS CALLS IN SUMMER MONTHS (2010)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
18
6
18
17
12
12
18
13
21
13
15
13
11
14
18
13
15
15
11
13
14
June
July
August
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday


DAY OF CALL FOR EMS CALLS IN SUMMER MONTHS (2011)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
7
15
14
14
15
20
16
18
21
19
10
11
11
11
12
12
14
9
20
17
16
June
July
August
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday


DAY OF CALL FOR EMS CALLS IN SUMMER MONTHS (2012)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
11
18
13
20
14
13
12
19
11
15
12
12
12
19
16
16
15
18
18
7
9
June
July
August
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday


DAY OF CALL FOR EMS CALLS IN SUMMER MONTHS (2013)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
23
13
9
18
18
8
10
12
13
13
16
13
19
14
13
16
12
19
11
15
13
June
July
August
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday

Appendix M – Total Call Chi-Square Calculations (2007-2013)

The critical value that we used to compare our calculated chi-square values with was 12.59. Any year with a calculated value over the critical value is marked in red. Years with calculated values under the critical value are marked in green.

2007	Actual 2362	Expected 337.4286	Actual - Expected	Squared	Chi-Square
Sunday	275	337	-62	3844	11.40653
Monday	361	337	24	576	1.709199
Tuesday	345	337	8	64	0.189911
Wednesday	345	337	8	64	0.189911
Thursday	335	337	-2	4	0.011869
Friday	323	337	-14	196	0.581602
Saturday	378	337	41	1681	4.988131
					19.07715

2008	Actual 2204	Expected 314.8571	Actual - Expected	Squared	Chi-Square
Sunday	254	315	-61	3721	11.8127
Monday	340	315	25	625	1.984127
Tuesday	324	315	9	81	0.257143
Wednesday	376	315	61	3721	11.8127
Thursday	325	315	10	100	0.31746
Friday	334	315	19	361	1.146032
Saturday	251	315	-64	4096	13.00317
					40.33333

2009	Actual 2224	Expected 317.7143	Actual - Expected	Squared	Chi-Square
Sunday	271	318	-47	2209	6.946541
Monday	318	318	0	0	0
Tuesday	309	318	-9	81	0.254717
Wednesday	362	318	44	1936	6.08805
Thursday	352	318	34	1156	3.63522
Friday	326	318	8	64	0.201258
Saturday	286	318	-32	1024	3.220126
					20.34591

2010	Actual 2399	Expected 342.7143	Actual - Expected	Squared	Chi-Square
Sunday	361	343	18	324	0.944606
Monday	354	343	11	121	0.35277
Tuesday	336	343	-7	49	0.142857
Wednesday	319	343	-24	576	1.6793
Thursday	337	343	-6	36	0.104956
Friday	358	343	15	225	0.655977
Saturday	334	343	-9	81	0.236152
					4.116618

2011	Actual 2433	Expected 347.5714	Actual - Expected	Squared	Chi-Square
Sunday	325	348	-23	529	1.520115
Monday	356	348	8	64	0.183908
Tuesday	372	348	24	576	1.655172
Wednesday	362	348	14	196	0.563218
Thursday	332	348	-16	256	0.735632
Friday	344	348	-4	16	0.045977
Saturday	342	348	-6	36	0.103448
					4.807471

2012	Actual 2507	Expected 358.1429	Actual - Expected	Squared	Chi-Square
Sunday	309	358	-49	2401	6.706704
Monday	360	358	2	4	0.011173
Tuesday	350	358	-8	64	0.178771
Wednesday	392	358	34	1156	3.22905
Thursday	375	358	17	289	0.807263
Friday	358	358	0	0	0
Saturday	363	358	5	25	0.069832
					11.00279

2013	Actual 2718	Expected 388.2857	Actual - Expected	Squared	Chi-Square
Sunday	346	388	-42	1764	4.546391753
Monday	372	388	-16	256	0.659793814
Tuesday	392	388	4	16	0.041237113
Wednesday	410	388	22	484	1.24742268
Thursday	379	388	-9	81	0.208762887
Friday	403	388	15	225	0.579896907
Saturday	416	388	28	784	2.020618557
					9.304123711

Appendix N – EMS Call Chi-Square Calculations (2007-2013)

The critical value that we used to compare our calculated chi-square values with was 12.59. Any year with a calculated value over the critical value is marked in red. Years with calculated values under the critical value are marked in green.

2007	Actual 688	Expected 98.28571	Actual - Expected	Squared	Chi-Square
Sunday	106	98.2	7.8	60.84	0.619552
Monday	104	98.2	5.8	33.64	0.342566
Tuesday	78	98.2	-20.2	408.04	4.155193
Wednesday	90	98.2	-8.2	67.24	0.684725
Thursday	93	98.2	-5.2	27.04	0.275356
Friday	83	98.2	-15.2	231.04	2.352749
Saturday	134	98.2	35.8	1281.64	13.05132
					21.48147

2008	Actual 641	Expected 91.57143	Actual - Expected	Squared	Chi-Square
Sunday	98	91.6	6.4	40.96	0.447162
Monday	103	91.6	11.4	129.96	1.418777
Tuesday	81	91.6	-10.6	112.36	1.226638
Wednesday	100	91.6	8.4	70.56	0.770306
Thursday	81	91.6	-10.6	112.36	1.226638
Friday	100	91.6	8.4	70.56	0.770306
Saturday	78	91.6	-13.6	184.96	2.019214
					7.879039

2009	Actual 740	Expected 105.7143	Actual - Expected	Squared	Chi-Square
Sunday	101	105.7	-4.7	22.09	0.208988
Monday	116	105.7	10.3	106.09	1.00369
Tuesday	96	105.7	-9.7	94.09	0.890161
Wednesday	109	105.7	3.3	10.89	0.103027
Thursday	110	105.7	4.3	18.49	0.174929
Friday	95	105.7	-10.7	114.49	1.08316
Saturday	113	105.7	7.3	53.29	0.504163
					3.968117

2010	Actual 801	Expected 114.4286	Actual - Expected	Squared	Chi-Square
Sunday	137	114.4	22.6	510.76	4.464685
Monday	105	114.4	-9.4	88.36	0.772378
Tuesday	95	114.4	-19.4	376.36	3.28986
Wednesday	104	114.4	-10.4	108.16	0.945455
Thursday	110	114.4	-4.4	19.36	0.169231
Friday	118	114.4	3.6	12.96	0.113287
Saturday	132	114.4	17.6	309.76	2.707692
					12.46259

2011	Actual 836	Expected 119.4286	Actual - Expected	Squared	Chi-Square
Sunday	130	119.4	10.6	112.36	0.941039
Monday	125	119.4	5.6	31.36	0.262647
Tuesday	125	119.4	5.6	31.36	0.262647
Wednesday	117	119.4	-2.4	5.76	0.048241
Thursday	96	119.4	-23.4	547.56	4.58593
Friday	110	119.4	-9.4	88.36	0.740034
Saturday	133	119.4	13.6	184.96	1.549079
					8.389615

2012	Actual 921	Expected 131.5714	Actual - Expected	Squared	Chi-Square
Sunday	143	131.6	11.4	129.96	0.987538
Monday	119	131.6	-12.6	158.76	1.206383
Tuesday	127	131.6	-4.6	21.16	0.16079
Wednesday	121	131.6	-10.6	112.36	0.853799
Thursday	128	131.6	-3.6	12.96	0.09848
Friday	151	131.6	19.4	376.36	2.859878
Saturday	132	131.6	0.4	0.16	0.001216
					6.168085

2013	Actual 1022	Expected 146	Actual - Expected	Squared	Chi-Square
Sunday	146	146	0	0	0
Monday	145	146	-1	1	0.006849
Tuesday	156	146	10	100	0.684932
Wednesday	149	146	3	9	0.061644
Thursday	146	146	0	0	0
Friday	127	146	-19	361	2.472603
Saturday	153	146	7	49	0.335616
					3.561644