An Epidemic in the Shadows: Using GIS to Map Opioid Use in the Spokane Valley

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I hereby certify that this paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

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Abstract

Over the past several decades, opioid use and abuse has evolved into a public health crisis that has impacted nearly every corner of the United States. The problem was that the Spokane Valley Fire Department (SVFD) did not understand the scope or nature of opioid use within its jurisdiction. The purpose of this applied research project (ARP) was to develop map products using geographic information systems (GIS) to facilitate an understanding of opioid use and abuse in the Spokane Valley and to present this information in a manner useful to department and community leaders. Action research was used for this project, which included answering the following research questions: (a) What is the nature of opioid use in the United States and the Spokane area? (b) What data best enables opioid incidents to be identified and quantified? (c) What are the best practices for analyzing and presenting health data while protecting patient privacy? (d) How are geographic information systems used to visually present public health data? A review of current literature guided the development of a number of GIS-based products using the ArcGIS software platform. These products were based on SVFD records of naloxone administration (as a proxy indicator of opioid overdose) from October 1, 2016 through September 30, 2017. Results identified that opioid overdoses in the Spokane Valley occurred at a rate much higher than recent opioid-related hospitalizations in Spokane County. Additionally, analysis provided actionable data regarding areas of both high and low administration rates. Recommended initial actions included referring a potential problem facility to the appropriate regulatory agency, identifying needed responder training, and coordinating targeted overdose prevention programs. Recommended longer-term actions included identifying socioeconomic factors in opioid overdoses, applying GIS analysis techniques to other public health challenges, and sharing patient data with auto-aid partners.

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Introduction

The problem was that the Spokane Valley Fire Department (SVFD) did not understand the scope or nature of opioid use within its jurisdiction. The purpose of this applied research project (ARP) was to develop map products using geographic information systems (GIS) to facilitate an understanding of opioid use and abuse in the Spokane Valley and to present this information in a manner useful to department and community leaders. Action research was used for this project and was guided by the following research questions: (a) What is the nature of opioid use in the United States and the Spokane area? (b) What data best enables opioid incidents to be identified and quantified? (c) What are the best practices for analyzing and presenting health data while protecting patient privacy? (d) How are geographic information systems used to visually present public health data?

Background and Significance

The SVFD is an all-hazards fire department that protects its 75 square-mile jurisdiction from 10 strategically located fire stations serving three incorporated municipalities (City of Spokane Valley, City of Liberty Lake, and Town of Millwood) as well as parts of unincorporated Spokane County. The Department employs more than 200 personnel who provide a variety of services to the community including fire suppression, emergency medical services (EMS), hazardous materials response, technical rescue, fire prevention, investigation, and community risk reduction (Spokane Valley Fire Department [SVFD], n.d.). The department is accredited by the Commission on Fire Accreditation International and earned a Class 2 rating from Washington's equivalent of the ISO. SVFD responders provide Emergency Medical Services

(EMS) at both the basic life support (BLS) and advanced life support (ALS) levels. Transport services are contracted through American Medical Response (AMR).

With a collective population of approximately 125,000, the communities that comprise the Spokane Valley serve as the second largest component of the Spokane-Spokane Valley-Coeur d'Alene Combined Statistical Area (CSA) that stretches across the border between Washington and Idaho. With an overall population in excess of 700,000, the CSA is the 69th largest in the United States (https://censusreporter.org/ profiles/33000US518-spokane-spokane-valley-coeur-dalene-wa-id-csa/). As with most large cities, the problem of drug use is not confined to a single area or jurisdiction, but rather appears to spread across all parts of the metropolitan area. Anecdotally, the SVFD appears to be responding to an increasing number of incidents involving opioid intoxication and overdose.

According to Rudd, Seth, David, and Scholl (2016), "the U.S. opioid epidemic is continuing, and drug overdose deaths nearly tripled during 1999-2014" (p. 1445). This increase is in no small part due to illegal opioids such as heroin and synthetic analogues. Between 2010 and 2015, Washington experienced an increase in the age-adjusted rate of overdose deaths to an approximate level of 15 deaths per 100,000 of population. If this rate holds true across the Spokane Valley, there are likely 19 deaths annually that are attributable to overdoses.

Both BLS and ALS responders in Spokane County are authorized to administer naloxone, a medication designed to block the "effects of both narcotics and synthetic narcotics [including opioids]" (Spokane County EMS & Trauma Care Council, n.d., p. 306). This medication is also known by its trade name of Narcan. The use of this medication does provide some organizational challenges including vendor costs and availability. The current cost for a single 2 mg dose of naloxone is $41.26. Due to national supply chain issues in 2017, the SVFD struggled to keep certain medications, including naloxone, in stock.

Each administration of this medication is expected to be documented in a patient care report (PCR) that is specific to individual patients. Prior to 2016, SVFD care providers documented the PCR in a records management program called FDM which provided only limited data search and extraction functionality. Since the third quarter of 2016, the SVFD has used a cloud-based electronic health record (EHR) system within the ESO platform. ESO provides standard, prebuilt reporting formats for a variety of incident types. In addition the platform allows the end-user to design and execute custom searches based on one or more data points. Search output parameters can be modified to include export functions that allow results to be analyzed in other programs.

This recently acquired ability to generate and export customized reports enables the SVFD develop a much more detailed understanding of its response environment than previously possible. With easy access to massive amounts of EHR data, the challenge now becomes one of organizing and presenting information in a usable format. Recognizing the potential for data to become unusable based on its volume, FathiZahraei, Marthandan, Raman, and Asadi (2015) identified that GIS helps “crisis managers to manage” conditions by “by storing data, managing them, analyzing, modeling, and showing on a map in digital format” (p. 84). Resch, Schmidt, and Blaschke (2007) echoed this approach to data management and identified the importance of visualization to achieving “situational awareness” during crisis response (para. 1).

Though the purpose of this ARP is to generate a better understanding of opioid use in the Spokane Valley, the nationwide experience tends to support a unified emergency management approach to this public health crisis (Knowlton et al., 2013, p. 318). This approach is consistent with two of the goals found in the United States Fire Administration's (2014) strategic plan. Goal 2 is "Promote Response, Local Planning and Preparedness for All Hazards," and the response to a potential public health crisis falls within the boundaries of "All Hazards" (p. 9). Similarly, generating situational awareness regarding opioid use is consistent with Goal 3, which is "Enhance the Fire and Emergency Services Capability for Response to and Recovery From All Hazards" (p. 9).

The author attended the National Fire Academy course titled *Executive Analysis of Fire Service Operations in Emergency Management* (EAFSOEM) during June of 2017. One of the course objectives was to "apply the planning process effectively during a simulated large/complex incident" (National Fire Academy, 2016, p. 3). Critical to the completion of this planning process, is the development of adequate situational awareness with respect to the incident being addressed. Using GIS to facilitate the development of situational awareness is consistent with the processes taught in this course.

Literature Review

The literature review for this ARP was initiated during the on-campus delivery of the EAFSOEM course at the National Fire Academy in Emmitsburg, Maryland. Initial research was conducted at the NFA's Learning Resource Center. Internet searches to identify relevant literature were conducted using the Google Scholar search engine. Research material that was not readily available for download was accessed using the Harvard Online Library System (HOLLIS). Additional research was completed in conjunction with the 2018 fall semester course offering of *Introduction to GIS* from the Harvard Extension School.

The mind altering properties of the poppy plant and its associated products have been understood for millennia. Opium was known and used by the ancient Sumerians and many historians believe that Homer included an account of the drug's use in *The Odyssey* (Brownstein, 1993, p. 5391). By the time Europeans first initiated colonization of North America, opium was well known throughout Europe. In fact, as Musto (1991) noted, "colonists regarded opium as a familiar resource for pain relief" (p. 3). With the founding of the United States, Americans began a long and complicated relationship with opioids.

Opium and opioid derivatives of increasing purity were widely available during the 19th century. Without a federal regulatory mechanism in place, states were left to control the distribution of medications as they saw fit. With the medical acceptance of opioids for the treatment of a variety of symptoms, doctors were unwittingly creating large numbers of addicts (Unick, Rosenblum, Mars, & Ciccarone, 2013). Opioids were included in many over-the-counter consumer products such as cough syrup. Growing concern about the problem and impact of opioid addiction led to the first successful federal effort to curtail narcotics. The Harrison Act of 1914 used the taxing authority of the government to eliminate the legal sale of opioids directly to consumers (Musto, 1991).

Regulation changed the public perception of opioid use and, "As prohibition ruled out sanctioned use in the early 20th century, nonmedical heroin use and overdose deaths shifted to marginalized groups"(Unick et al., 2013, para. 1). Musto (1991) also commented on this marginalization and noted that "During the 1920s and 1930s, the opium problem, chiefly morphine and heroin, declined in the U.S., until much of the problem was confined to the periphery of society and outcasts of urban areas" (para. 29). As a result, cultural attitudes towards addiction and attics created a public health crisis that was largely ignored. Addicts were stigmatized and addiction was viewed as a crime, rather than a disease.

Meldrum (2016) found that attitudes towards opioids among medical professionals during the mid-20th century resulted in a significant under treatment of pain. Pharmacological training for doctors and nurses stressed the importance of limiting the amount of opioids prescribed or administered to any one patient. Two articles published in the 1980s reported a low incidence of addictive behavior amongst cancer and non-cancer patients receiving opioid-based pharmaceuticals. These articles formed the basis of a shift in medical attitudes towards the long-term use of opioids for treating chronic pain.

As doctors began to once again prescribe opioids for pain management, the size of the potential patient population began to emerge. Meldrum's (2016) research found the following:

> An estimated 25 million adult Americans, according to the most recent data, suffer daily from pain, and 23 million other suffer from severe recurrent pain, resulting in disability, loss of work productivity, loss of quality of life, and reduced overall health status. (p. 1365)

A potential market of this size encouraged pharmaceutical companies to research new products and delivery methods. One product, OxyContin, was aggressively marketed as a safe alternative for pain management.

Unick et al. (2013) found "there is evidence of an enormous increase in the availability of prescription opioids is feeling a crisis in addiction nationally, drawing new initiates to these drugs and change in the geography of opiate-related overdoses" (para. 1). Meldrum (2016) expanded on this idea and further correlated the availability of prescription opioids to an increase in heroin use. As the cost of prescription narcotics increased, whether purchased legally or on a secondary market, addicts sought alternative methods of achieving a high. Heroin dealers were quick to capitalize on a new customer base by "driving to meet buyers in safe locations and offering inexpensive product, often giving free samples to encourage customer loyalty" (p. 1366).

Unick et al. (2013) identified the symbiotic nature of prescription opioid misuse and heroin use and believed that the problems were "intertwined" (para. 6). Meldrum (2016) believed the combination of widely available prescription opioids and inexpensive, illegal heroin was directly responsible for the 137% increase in overdose deaths between 2000 and 2014. Over that same period, "overdoses involving prescription opioids and heroin increased 200%" (p. 1366).

Rudd et al. (2016) found a higher increase in drug overdose deaths over nearly the same time period (1999-2014). As previously noted, the study found a near tripling of overdose deaths to a total that exceeded 52,000 in 2015. Of these approximately 63% were attributable to opioids for a total of 33,091 deaths. This increase was directly attributable to increasing usage rates of heroin and other synthetic opioids, including prescription narcotics or unlawfully manufactured analogues. Though there was some local variation noted, nearly every subpopulation studied at a national level experienced an increase in fatal opioid overdoses.

While deaths from opioids have a significant impact on the victim, community, and responders, these statistics do not paint a complete picture. Because opioid overdoses are reversible, a full understanding of the impact of opioids must include statistics related to victims who survived their overdose incident. Riffe (2015) found that hospitalizations for "opioid-related poisoning among Spokane County residents significantly increased 8.9% annually from 2000 to 2014, growing over time from a rate of 4.3 to 14.4 per 100,000" (para. 10).

From an epidemiological and public safety standpoint, this increase in overdoses is particularly relevant because, as Darke (2014) found, "of all commonly used drugs, opioids have by far the highest mortality risk" (p. 109). The likelihood of death is so significant that, "by the age of 50, approximately half of any cohort of opioid users will have died, overdose being the most common cause" (p. 109).

In order to explore common myths surrounding opioid overdoses, Darke (2014) developed a profile of a typical overdose victim. This research found that "the typical overdose victim is a long-term, dependent, drug-injecting user in their 30s or older" (p. 109). This was attributed to the increasing tolerance that is developed by an experienced drug user and the decreasing gap between the dosages needed for euphoric effect and that which induces overdose symptoms. Additionally, Darke noted that the typical overdose occurs in the presence of other intoxicants, including alcohol. Long-held notions that variations in purity or the presence of impurities contributed to overdoses were not found to be accurate

In a study of opioid overdoses specific to Spokane County, Riffe (2015) found that the patient population cohort experiencing the highest number of hospitalizations were in the age range between 60 and 64. The average patient age was 52 years with a range from 1 to 93 years. Males accounted for 41% of opioid related hospitalizations and females accounted for 59%. The average cost of a hospitalization in Spokane County was $28,000 and the total cost of opioid-related hospitalizations between 2010 and 2014 was $10.7 million.

Riffe's (2015) study identified that "In 2013, 1.7% of Spokane County adults (approximately 6,300) used an opioid medication to get high in the last 30 days" (para. 3), a rate that was more than five times higher than in 2011. Also discussed were statistics on emergency responses to opioid overdoses for the region's largest fire service agency, the Spokane Fire Department. The definition for inclusion as an opioid overdose in this data set was "a paramedic impression of overdose, poisoning, unconscious, altered level of consciousness, respiratory arrest, and administration of Narcan" (para. 5). This set of inclusionary criteria identified one issue with the field identification of opioid overdoses for epidemiological purposes, and that is the broad range of symptoms for which the administration of naloxone is indicated. The concomitant administration of naloxone appears to be a singular factor that can be used for the identification and analysis of opioid overdose incidents.

Two recent studies evaluated the use of naloxone administration as proxy data for evaluating opioid use in a population. The first of these was undertaken based on the premise that "it is not clear the extent to which EMS data on naloxone administration may be a reasonable proxy measure of opioid overdose" (Knowlton et al., 2013, p. 3). Nearly 1,300 incidents involving naloxone administration by EMS were analyzed over the 13 month study period. In order to analyze EMS and hospital patients separately, patients who were evaluated in the emergency department (ED) only were segmented from those who were also seen by EMS.

Knowlton et al. (2013) found temporal and demographic consistencies between field naloxone administration rates and hospitalizations for opioid overdoses. The strongest evidence was found in temporal patterns for both seasonal and weekly overdose occurrences. While suggestive of a correlation, the authors noted that "The findings underscore the need for further assessment and enhancement of the validity of EMS records as a proxy indicator of opioid overdose incidents" (P. 9).

A follow-up study was conducted "to validate externally whether prehospital naloxone use is a surrogate marker of community opiate ODs by comparing EMS naloxone administration records to an independent database of ED visits for opiate and heroin ODs in the same community" (Lindstrom et al., 2015, p. 386). A similar temporal relationship was found between rates of EMS naloxone administration and ED visits for opioid overdose. Based on this relationship, the authors concluded that it was reasonable to relate rates of EMS naloxone administration to “community opiate use” (p. 387). However, both this study and the earlier work by Knowlton et al. (2013) cautioned that protocols allowing administration of naloxone without confirmatory evidence of opioid use may result in an overestimation of community overdose rates.

Additional cautionary evidence regarding the use of naloxone administration to track community opioid overdoses was found in a retrospective analysis of overdose events in the Seattle, Washington EMS system. A difference was noted in the prehospital treatment of opioid overdose based on whether the responsible opioid was heroin or pharmaceutical in nature. During the study period, “Patients with pharmaceutical opioid overdose were less likely than those with heroin overdose” (Banta-Green et al., 2017, p. 4).

Sumner et al. (2015) reported a similar disparity in naloxone administration for opioid overdose based on patient demographics and incident characteristics. Medical examiner reports from the state of Rhode Island during the period from January 2012 through March 2014 were examined to identify deaths attributed to opioid overdoses. In this study, “older individuals, females, and those without signs of illicit drug use were at a higher likelihood of not receiving naloxone during resuscitation temps” (p. 223). Inclusionary criteria for this patient population included attempted resuscitation by EMS responders.

Moore, Weber, Cina, and Aks (2017) examined the use of naloxone administration in tracking real-time changes of opioid overdose rates. The authors tracked naloxone administration by the Chicago Fire Department over the course of one year and “found EMS data to be an excellent real-time surveillance mechanism for changes in the rate of opioid overdoses”

(p. 1707). The accuracy of this data was confirmed via cross-correlation with that collected by the Medical Examiner's office.

Garza and Dyer (2016) found the timeliness of EMS data to be among the "three specific advantages making it the very best single source of data for opioid activity within the community" (p. 10). The second advantage is that EMS data can be geo-located which assists with the identification and analysis of historic and current activity. The third advantage of EMS data is the size of the patient population which is particularly relevant when analyzing data from larger metropolitan systems.

A significant concern when using EMS data for mapping public health emergencies is the need to maintain patient privacy. According to Washington State's *Medical Records – Healthcare Information and Disclosure* (1991) statute, "a healthcare provider may not disclose healthcare information about a patient to any other person without the patient's written authorization." This language impacts the ability of EMS agencies to freely share information that may be tied to a specific patient.

Birnbaum, Borycki, Karras, Denham, and Lacroix (2015) reinforced the need to protect patient information from release, as it is "the most sensitive of personal information" (p. 96). Historically, such information was stripped of data elements such as name or birthdate that could easily be used to determine individual patient identities. These procedures were considered sufficient to bring the data into alignment with a *Safe Harbor* convention that protected the releasing entity from liability. However, the Washington State Department of Health found that increasingly sophisticated data management and mining procedures created a situation where confidential patient information could be re-created from information that was believed to be anonymized.

Jung and El Emam (2014) identified a number of studies which demonstrated significant risk of re-identification in instances where the “geographical identifiers can be linked to individuals” (p. 1). In one case, a researcher found that 87% of subjects could be identified based on a cross comparison of three data points with other publicly available data. Another study involving dot maps demonstrated a significant risk of re-identification that varied only with the resolution of the map.

The Safe Harbor convention was subsequently expanded in scope and incorporated the federal standard on the protection of patient information known as the Health Insurance Portability and Accountability Act of 1996 (HIPAA). According to the United States Department of Health & Human Services (HHS, n.d.), there are 18 potential identifiers that must be removed from healthcare data in order to qualify under for Safe Harbor protection under HIPAA. These identifiers include name, all geographic subdivisions smaller than the state, Social Security numbers, and account numbers (see Appendix A for a complete list).

The challenge of releasing public health information in an actionable format and time-frame, while still protecting patient privacy, are two potentially conflicting goals that must be balanced in a manner that protects both the public and individual interest. Birnbaum et al. (2015) identified that for agencies concerned with public health, such “ethical issues at the heart of public trust are of paramount importance because they are intrinsic to the necessary framework” for future service to the public (p. 98). Public agencies that are frequently performing patient care in the public view, such as fire departments, are particularly challenged by this need to patient privacy with public good.

Olvingson, Hallberg, Timpka, and Lindqvist (2002) identified the increasing difficulty of maintaining patient privacy in the face of emerging technology. The study noted that “GIS have the potential to be more threatening to privacy the many other information technologies due to the possible combination of powerful data integration and analysis capabilities with data that are local in nature" (p. 179). The particular threat is the potential for re-identification of confidential patient information through the integration of publicly available data sets. Without a demonstrated commitment to maintain patient privacy, the amount and quality of health data obtained by an organization is likely to decrease.

Specific to the need to protect patient information in the era of geographic information, Mak (2008) posited that "location is an identifier" (p. 2) with numerous variables determining the likelihood of re-identification, such as map scale, currency of information, and population (including density). Production of a high-resolution map with exact point data (location information) for a specific incident or disease type will effectively release protected patient information. Strategies to protect geographic information while still maintaining data usability include:

- aggregating individual data into a geographic area with a high enough population density or activity level to anonymize data;
- removing data for areas with population density or activity levels that are too low to anonymize;
- applying a randomly generated distance offset to prevent the exact location of an incident from being released;
- adding a disclaimer indicating that some information has been removed or a geographic offset applied in order to protect confidentiality; and
- presenting the data in a format that represents event intensity, rather than actual events.

Collectively, these strategies are known as masking methods, which are "methods for concealing locations, or other data associated with locations to protect personal privacy and assure confidentiality" (Rushton, 2007, p. 32). An additional level of masking, known as geographic masking, is intended to protect the identity of patients from others with access to otherwise revealing geographic data. As access to more granular levels of demographic and socioeconomic data increases, geographic masking will become increasingly important for maintaining patient confidentiality. Rushton further identified two questions useful for the evaluation of masked data:

- Is the mask effective at protecting patient location information?
- What is the impact of performing analysis on masked data versus unmasked data?

Mazumdar et al. (2014) found that data aggregation is a common approach to protecting geographic or location data. This approach is based on the principle "that if there are sufficient numbers of records in a defined geographic area such that it is impossible to identify individuals, then individuals are protected" (p. 549). Aggregation also satisfies the privacy principle known as *k-anonymity*, "where an individual's record can be 'confused' with at least *k* other records" (p. 549).

While discussing strategies for protecting individual confidentiality, Zandbergen (2014) addressed the use of data aggregation and noted that the technique greatly reduces the risk of re-identification. Additionally, aggregation is particularly useful in determining incidence or disease rates, as opposed to displaying summative data such as total occurrences. Key to this strategy is the premise that "To preserve confidentiality, only the aggregated data set is published or shared" (p. 4). A complementary visual technique suggested by Sharkova, Zerbe, and Stone (2015) is to display ranges of aggregated values on maps (using a color palette scale) in order to further frustrate any attempt at re-identification. The use of colors to present statistical variability creates what are called *choropleth* maps, which are particularly effective for the visual presentation of geo-data.

While studying the use of GIS to communicate spatial data, Wong, Baker, Webb, Hincks, and Schulze-Baing (2015) identified a central idea in the visual presentation of information. They stated that “analytical output should communicate results in a clear and uncomplicated style” (p. 1021). Information and analytical conclusions should be readily apparent to anyone viewing a map, without the need for specialized training or additional explanation. With respect to sense-making, particularly in a collaborative environment, “the guidance or visioning process would seek to formulate a conception of space in place that can be understood by wide variety of actors, such that it result in a collective way of ‘seeing’” (p. 1023).

Such collaborative sense-making is critical to the role of GIS in emergency management. Wu, Convertino, Ganoe, Carroll, and Zhang (2013) proposed that the goal of GIS in this environment “is to take advantage of the strengths of human agents in recognizing patterns, making abstractions, and assessing ill-defined situations, combined with the strengths of computational tools in processing, storing, and retrieving large amounts of information” (p. 5). By analyzing and presenting information in a visual format, groups of decision-makers are better able to develop a common operating picture and from that, make better decisions.

Shaw and McGuire (2017) reviewed uses of GIS that were specific to the public health domain and found that its use “in health studies can improve the quantity and quality of epidemiological research in addition to healthcare delivery and accessibility as conclusions can be made about a region’s care, services, and overall health” (p. 229). One particular area in which GIS is particularly effective is in disease surveillance, where mapping and modeling can identify areas of concern based on historic and current experience. By using this data, finite resources can be directed to areas where they will have the most impact.

Most emergency management problems cross jurisdictional or functional boundaries and typically result in the assembly of an ad hoc group of organizational leaders with varying levels of experience operating in a collaborative environment. Plans for responding to all-hazards scenarios are often developed well in advance of any actual event and, "People just do not remember the plans very well through many months during which they are not practicing or reviewing the plans" (Wu et al., 2013, p. 4). The use of maps created using GIS facilitates the implementation of emergency management plans by allowing decision-makers to develop enough situational awareness that they are comfortable making critical decisions.

Presenting information using GIS is one strategy to mitigate the impact presented by differences in domain knowledge within a collaborative decision-making environment. Bacic and Appan (2012) found that domain knowledge is often the critical factor in cognitive related tasks. Experts, who demonstrate high levels of domain knowledge, are believed to make better decisions when facing complex problems. However, differences in domain knowledge can create challenges in communications between experts and non-experts that impact the quality of decision-making. This study found that "presentation format is important for effective information communication and hence, decision making" (p. 3). Communicating information in a graphical format is one way to mitigate domain knowledge differences and, therefore, improve decision quality.

Wu et al. (2013) remarked on the advantages provided by tools used in GIS to analyze and manipulate information, including those used for sorting and aggregation. "In particular, when decision-making involves heavy information sense-making activities, these tools should not only allow users to manipulate and examine data in various ways, but also show the interconnections of data points from different data dimensions through coordinated views" (p. 20). Presenting such data in a map format allows decision-makers to quickly identify and understand key relationships.

FathiZahraei, Mathandan, Raman, and Asadi (2015) researched the application of GIS principles and practices to the various interrelated stages or phases of emergency management. Though there are many approaches to segmenting emergency management functions, the four phases that these authors identified for inclusion in their study were mitigation, preparedness, response, and recovery. GIS capabilities that were useful in all phases included mapping, data management, and geostatistical analysis. In particular, the functionality of GIS in "storing data, managing them, analyzing, modeling, and showing on a map in digital format helps crisis managers to manage the crisis condition" (p. 84).

Baker, Jones, and Burkman (2009) explored the use of visual representations of data for the acquisition of situational awareness and subsequent decision-making. The study cited earlier research which concluded that "graphical displays of information can in some cases lead to faster and more accurate decision-making" (p. 534). This research also built on the "Theory of Cognitive Fit which explains that when data presentation format matches the task type, cognitive fit can be achieved, and both decision-making accuracy and decision-making speed can be enhanced" (p. 534).

Baker, Jones, and Burkman (2009) identified that "A visual representation should highlight, rather than hide, patterns in the data, and, ideally, should enable the viewer's attempt to derive meaning from patterns in the data" (p. 539). Visual representations that require significant effort to discern differences or identify patterns detract from presentation effectiveness. Basic visual representations consist "of only three types of features that are perceived by the human viewer: a scene, objects within the scene, and characteristics of the objects" (p. 536). Scenes are identified as the background information or view, objects are discrete items within the same, and characteristics of the objects are attributes that allow comparisons.

All three types of features must be displayed in a complementary manner in order to maximize effectiveness of a visual representation. Features are used to visually convey information in one of five ways:

- the scene alone,
- the object(s) within the scene,
- the characteristics(s) of an object,
- the scene and its relationship to objects, and
- the relationship of an object to another object (Baker, Jones, & Burkman, 2009, p. 538).

The Theory of Cognitive Fit was originally introduced as a way to explain sense-making of information presented in graphical or tabular formats. Baker, Jones, and Burkman (2009) identified that this theory had since been expanded to a variety of other perceptual domains including GIS. Applied to the domain of GIS, the basic theoretical premise is that "when a problem solver has a spatial task, problem-solving will be more efficient and effective when a spatial representation is presented" (p. 538). The challenge in creating visual representations of problems using GIS is in selecting and presenting features in a manner that best facilitates understanding and decision-making based on the Theory of Cognitive Fit.

This literature review identified the long and complicated history of opioids in America. Opioid usage has historically been cyclical in nature and appears to be tied to accessibility. The number of Americans living with chronic pain and availability of prescribed opioids appears to be driving the current upward trend in opioid use. Price appears to have an impact on the type of opioid used with heroin being readily substituted when the cost of pharmaceutical opioids becomes more than an individual user can bear. The national experience of increased opioid overdoses appears to also be impacting Spokane County.

One challenge in tracking overdose rates is the lack of an available or accurate field screening test for drugs. Naloxone administration was identified as a reasonable proxy for identifying opioid-induced overdoses. However, protocols that allow the administration of naloxone with an unknown etiology of symptoms may result in over-reporting of overdoses. Conversely, under-reporting of overdose cases may result from instances where patient demographics or scene conditions were inconsistent with perceptions of overdose scenarios.

A key consideration in presenting health data in a format that can be released outside of the generating organization is the need to maintain the confidentiality of patient information. The increase in both publicly available information and sophistication of software has created an environment where de-identification procedures that were previously believed to be adequate may now allow re-identification of patients. Procedures that are useful for protecting patient geo-data include aggregation and normalization of data across populations.

Visual presentations of data enable decision-makers to develop a robust understanding of the problems being addressed. A variety of conventions are used to maximize the value of information presented based on data in GIS. One key factor in the usefulness of GIS based presentations is the ability to match the format of the visual representation to the type and nature of the decision being made. By paying special attention to all features contained within the visual representation, GIS based presentations can minimize the cognitive requirement for interpretation and maximize the value and quality of subsequent decisions.

Procedures

Action research methodology was used to guide the development of this ARP, with the objective of developing map products using GIS to facilitate an understanding of the scope and nature of opioid use in the Spokane Valley, and its impact on the SVFD. While data used in this project was drawn from a variety of sources, primary information regarding opioid usage (as identified through naloxone administration) was drawn from the SVFD's EHR database. Spokane County's EMS protocols require every provider to document patient interactions (Spokane County EMS & Trauma Care Council, n.d., p. 11). Since the third quarter of 2016, the SVFD has used the ESO platform to complete and maintain this documentation.

The ESO system allows agency end-users to develop and apply custom search queries to their EHR database. A search query was designed and applied to the SVFD ESO database for patients receiving naloxone between October 1, 2016 and September 30, 2017 (inclusive of these dates). For each incident identified, the following data points were pulled:

- Incident Date,
- Incident Number,
- Address,
- City,
- State,
- Patient Name,
- Patient Date of Birth,

- Patient Age, and
- Treatment Response.

The search revealed a total of 129 documented instances of naloxone administration during the identified time frame. A review of these records for accuracy revealed one instance of the same naloxone administration being documented twice due to a user error in the documentation process. This error was forwarded to the responsible officer for correction and the record was removed from the project data set.

The number of naloxone doses administered to an individual patient may vary, based on scene conditions and patient response. Therefore, the next step in preparing this data for analysis was to identify distinct incident responses by limiting the data set to one administration per incident. The report was exported to Microsoft Excel, and a function was performed on data in the Incident Number column to find and remove duplicate incident numbers. This process revealed that a total of 90 distinct patients received naloxone during the study time frame.

Next, functions were applied to the data set to identify multiple responses to individual addresses and multiple responses to individual patients. The analysis of responses to individual addresses revealed eight locations where SVFD resources responded two or more times and naloxone was administered. Four patients required naloxone administration on multiple occasions during the study. One of these patients generated responses to two separate addresses.

The raw data (minus the extraneous entry) and the data on distinct incidents, multiple responses to one address, and multiple responses to one patient were saved as individual pages within an Excel workbook. This workbook was imported into the GIS platform that was used for this project, ArcGIS Desktop 10.5.1 from Esri. ArcGIS has a number of tools for importing and exporting data from the program and, in this case, the *Excel To Table* conversion tool was used to convert the Excel workbook into an ArcGIS usable format.

In order for data in a tabular format to be placed onto a map, it must undergo a geocoding process. According to Esri (2017), "Geocoding is the process of transforming a description of a location—such as a pair of coordinates, an address, or a name of a place—to a location on the earth's surface" (para. 1). The ArcGIS geocoding process was applied to the geo-data associated with distinct incidents in order to convert the tabular data to geographic points for placement on a map.

One important step in the geocoding process is the selection of the correct geographic coordinate system (GCS) and datum. A GCS "uses a three-dimensional spherical surface to define locations on the earth" and defines the standards used for the creation of each map and associated elements (Esri, 2016, para. 1). The statutorily required GCS for use in Spokane County is the "North zone" of the "Washington coordinate system of 1983," which is based on the North American survey of 1983 (Boundaries and Plats, 1989). This GCS was used for all maps and map elements developed for this ARP.

A boundary map of the Spokane Valley Fire Department's jurisdiction and neighboring areas was created using several sources. A base map background titled "Terrain with Labels" was selected from the Esri library. This base map shows geographic features and major roads, such as interstates or state highways. The SVFD's jurisdictional boundary was added to the map based on a shape file obtained from Spokane County GIS. Similarly, point data was added to the map showing locations of SVFD and neighboring fire stations. One neighboring fire station in Idaho required manual entry and geocoding because Spokane County GIS information did not extend beyond the county's boundary lines. A newly constructed SVFD replacement station was not included in the information from Spokane County and also required manual entry. The SVFD logo was assigned as a symbol for each SVFD station, with a generic Florian cross assigned to other fire stations (Appendix B).

Each incident where naloxone was administered during the time frame of the study now appeared on the map as an individual point. Visual observation revealed that the data included responses to locations outside of the SVFD's jurisdiction. Because this ARP focused on the Spokane Valley, these extra-jurisdictional responses needed to be excluded. The ArcGIS *Clip* tool was employed to limit responses to only those occurring within the SVFD's boundary. The resulting 88 SVFD specific incidents were exported to Excel for statistical analysis, including descriptive statistics and temporal analysis of naloxone administration by month and day of the week. An example of this map containing point data of individual responses is not included in the appendices due to patient privacy concerns.

Census geo-data was next added to the map in order to provide usable, neighborhood-level boundaries and population information for use in normalizing response data for presentation and analysis (Appendix C). The United States Census Bureau provides TIGER/Line shape files of the various geographic strata used in census data collection and analysis (https://www.census.gov/en.html). Census block groups (CBGs, or CBG in singular usage) were selected for use in this project based on their size, which is large enough to provide limited geographic masking when used with an aggregation process, yet small enough to be useful for targeted community risk reduction campaigns. The most recent census year, 2010, was selected as the base year for this shapefile data. Estimated population data from 2016 was downloaded from the American Fact Finder section of the Census Bureau's website and affiliated with each CBG using the *Joins* function within ArcGIS.

Geo-data from each response was affiliated with the CBG shape file data using the *Tabulate Intersection* tool to generate a map layer which showed occurrences per CBG. Map symbology was manipulated to display graduated colors for each CBG based on the range of naloxone administrations occurring within each geographic area during the study period. Display colors ranged from dark green to denote zero administrations to red which indicated 7 to 10 administrations during the study period. At the geographic level of a CBG, data aggregation in and of itself does not provide adequate geographic masking. As a result, patient privacy concerns precluded inclusion of this map in the appendices.

In order to evaluate and compare opioid overdose rates from an epidemiological standpoint, it is necessary to normalize the information with respect to population data. Total occurrences for each CBG were divided by the estimated population for that group. This number was then multiplied by the population normalization number to calculate the naloxone administration rates per 100,000 of population. Again, the map symbology was manipulated to display graduated colors for each CBG based on the normalized administration rate. Colors varied from dark green for no administrations to red for the highest administration rates, with light green, yellow, and orange noting increasingly higher rates (Appendix D).

Geo-data analysis was performed using the ArcGIS *Emerging Hot Spot Analysis* tool which identifies trends in the data. Use of this tool is a two-step process that first requires application of the *Create Space Time Cube By Aggregating Points* tool which aggregates data points into bins with both spatial and temporal attributes. These attributes were subsequently analyzed to identify and categorize any trends in data clusters (Appendix E). An overlay analysis was performed to identify CBGs that were both consecutive hot spots and normalized areas of high usage (Appendix F). One CBG fit this criteria and a map was produced of this area (Appendix G).

Separate maps were also created which identified CBGs with multiple responses to one address and multiple responses to one individual patient. Due to patient privacy concerns, examples of these maps are not included in the appendices. Each map created during this ARP process was provided with a legend which described and defined the symbology. Additionally, a title, north arrow, and distance scale was added to each map. For aesthetic purposes, each map was rotated -2.7 degrees in order to align boundaries with the vertical and horizontal axes of the map.

One potential limitation of this study is that it only contains information from the SVFD's EHR database. The SVFD operates in a metropolitan environment that uses automatic vehicle locator (AVL) technology to dispatch the closest, most appropriate resource to an incident. Several areas of the SVFD's jurisdiction are geographically closer to fire stations belonging to other agencies (see SVFD base map, Appendix B). As a result, other agencies may be administering naloxone within the SVFD's jurisdiction. The SVFD currently has no mechanism in place for capturing information about patient care provided by outside agencies.

Results

In addition to internally generated SVFD response data, this ARP used a review of the relevant literature to guide development of GIS-based map products. These map products are intended to facilitate an understanding of opioid usage patterns within the Spokane Valley. Because of the multi-functional and multi-jurisdictional nature of emergency management or public health problems (such as opioid abuse), these maps should be in a format that can be shared with regional response partners and other agencies concerned with addressing this problem. The literature review sought to develop answers to the following for research questions: (a) What is the nature of opioid use in the United States and the Spokane area? (b) What data best enables opioid incidents to be identified and quantified? (c) What are the best practices for analyzing and presenting health data while protecting patient privacy? (d) How are geographic information systems used to visually present public health data?

Research question one asked, “What is the nature of opioid use in the United States and the Spokane area?” Research revealed that humanity’s knowledge and use of opioids stretches back to antiquity. Opioids have been present in the United States since the founding of the country and likely arrived with the wave of European explorers and colonists (Musto, 1991, p. 3). America’s modern experience with opioids can best be described as cyclical with acceptance and use appearing to wax and wane every few generations.

It is clear within research that the United States is currently experiencing an increase in opioid usage along with associated overdoses and deaths. Various studies found that over the approximate 15 year period between 2000 and 2015 overdoses more than doubled (Meldrum, 2016, p. 1366) or even tripled (Rudd et al., 2016). Darke (2014) develop a profile of the typical overdose victim as a long-term user in their 30s. Locally, Riffe (2015) found that the average age of a patient hospitalized for overdose was 52 years, with an age range from 1 to 93 years. Males accounted for 41% of opioid-related hospitalizations in Spokane County, with females accounting for 59%.

An analysis of SVFD jurisdictional responses between October 1, 2016 and September 30, 2017 identified that a total of 88 patients received naloxone. Based on an estimated resident population of 125,000, the normalized naloxone administration rate was 70.4 per 100,000 of population. The average age of a patient was 48 years, with a range from 11 to 94 years. Males accounted for 52% of patients receiving naloxone, with females accounting for 48%.

Temporal analysis of naloxone administration within the SVFD's jurisdiction shows both seasonal and weekly variations of overdose patterns. *Figure 1* shows an apparent seasonal trend of higher usage during summer and fall months and lower usage during winter and spring. *Figure 2* shows an apparent variation in opioid usage rates depending on the day of the week. Wednesday and Thursday experience the highest rates of naloxone administration with 16 each. Monday and Tuesday demonstrated the lowest rates of administration with nine each.

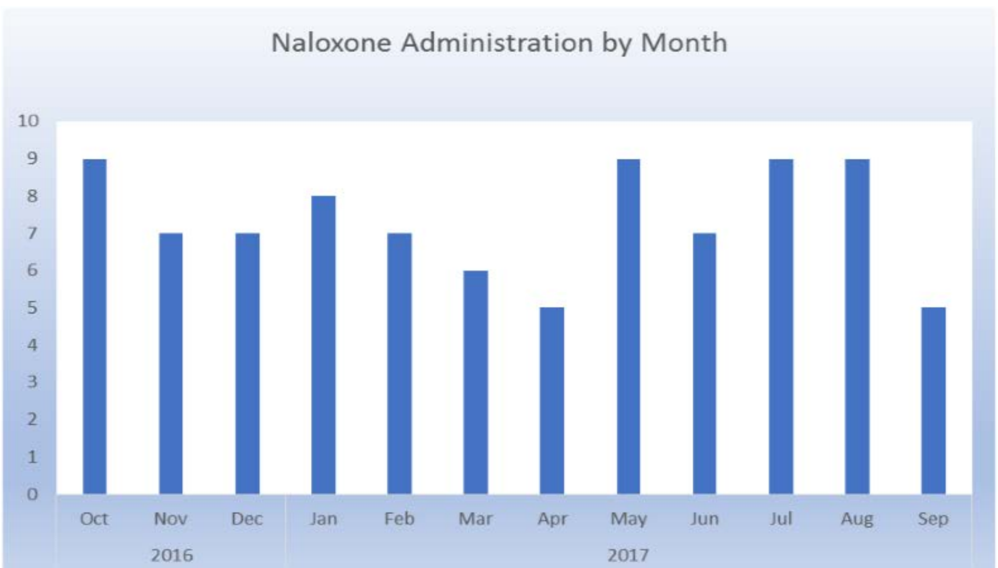

Figure 1. Naloxone administration by month. This figure illustrates the number of administrations per month over the study period.

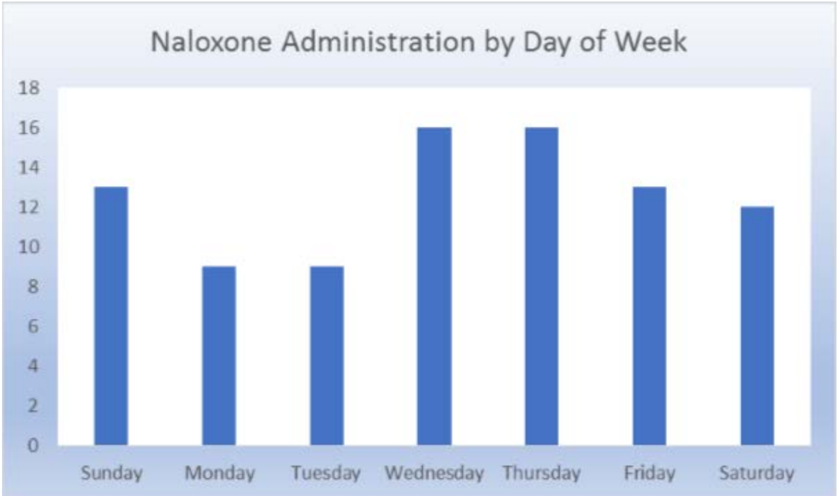

Figure 2. Naloxone administration by day of week. This figure illustrates the number of patients receiving naloxone on each day of the week.

Research question two asked, "What data best enables opioid incidents to be identified and quantified?" Recent work has focused on the use of naloxone administration as a proxy indicator of an overdose. Two of the studies found a likely temporal correlation between field administration rates of naloxone and rates of hospital admission for opioid overdose. Both studies cautiously confirmed the use of naloxone administration to track opioid overdoses but indicated that additional research was necessary to address certain issues raised in the analysis, such as demographic differences between patients in the field and those reporting to the emergency room (Knowlton et al., 2013; Lindstrom et al., 2015).

One potential issue with the use of naloxone administration data for tracking opioid overdoses is the disparate treatment provided to patient populations based on differences in patient demographics, scene dynamics, and even type of opioid involved in the suspected overdose. Patients who were female, older, or found at a scene with no evidence of illegal drug use were less likely to receive naloxone (Sumner et al., 2016, p. 223). Another study found that patients overdosed on heroin were more likely to receive naloxone than those overdosed on pharmaceutical opioids (Banta-Green et al., 2017, p. 4). These studies identify that use of naloxone administration as a basis for determining overdose rates may result in an underreporting of those rates.

Riffe's (2015) study on opioid overdose rates in Spokane County, used a variety of reported symptoms for inclusionary criteria in addition to administration of naloxone. Such broadly defined inclusionary criteria may result in over-reporting of opioid overdose rates. In Spokane County, naloxone is indicated for both known and suspected opioid overdose with respiratory compromise or with a coma of unknown etiology which may, result in over-reporting. However, since it is Spokane County's only medication specifically administered for opioid overdose, naloxone is the most logical marker for tracking overdoses in the Spokane Valley.

Several studies identified specific advantages in using naloxone administration as a proxy indicator for calculating opioid overdose rates. The first of these was in the real-time tracking of changes in opioid usage. Because EMS data can be quickly captured and documented, naloxone administration records provide nearly instantaneous notification of an opioid overdose (Moore, Weber, Cina, & Aks, 2017, p. 1707). Another identified advantage was that EMS data is geo-located, making it particularly useful in GIS applications. Finally, the size of the patient population in larger metropolitan EMS systems tends to increase the value of this data from a research perspective (Garza & Dyer, 2016, p. 10).

Research question three asked, "What are the best practices for analyzing and presenting health data while protecting patient privacy?" Since the focus of this ARP is on developing map products that can be shared with external agencies, it is important from both an ethical and legal standpoint to ensure that patient privacy is maintained. The historical practice of removing basic patient information, such as name and birthdate, is no longer sufficient in the face of powerful computers and large amounts of publicly available data. The Washington State Department of Health found that confidential patient information was able to be re-associated with patient identities using relatively simple algorithms (Birnbaum, Borycki, Karras, Denham, & Lacroix, 2015, p. 96)

The federal law which mandates the protection of patient privacy and outlines minimum procedures for the identification is HIPAA. This act incorporated an existing patient de-identification convention known as Safe Harbor and expanded it to include 18 potential identifiers that must be removed from patient data prior to release. Alternatively, data may be presented in such a manner as to defeat any attempts at re-identification.

Strategies associated with defeating re-identification are known as masking methods, and those specific to GIS are referred to as geographic masking (Rushton, 2007, p. 32). Two geographic masking strategies identified in the literature are particularly useful for studying disease or injury occurrence rates. These are data aggregation, where individual results are bundled with others occurring within a geographic area, and presenting data in a format that represents event intensity, rather than actual occurrence numbers (Mak, 2008). Multiple studies confirmed the efficacy of these de-identification approaches (Mazumdar, Hewett, Bagheri, McRae, & Del Fante, 2014; Zandbergen, 2014).

The fourth research question asked “How are geographic information systems used to visually present public health data?” A key tenet in the use of GIS to communicate data is that information should be clearly communicated and interpretable without specialized training or knowledge (Wong, Baker, Webb, Hinks, & Schulze-Baing, 2015, p. 1021). Visual representations of data should be able to be interpreted without significant cognitive effort on the part of the viewer (Baker et al., 2009, p. 539)

The mitigation of emergency management or public health emergencies typically requires resources and input from a variety of agencies, and all participants must develop a common operating picture to ensure the efficient and effective use of resources. Often, decision-makers have varying levels of domain knowledge and experience and the format of GIS data presentation can partially compensate for those differences (Bacic & Appan, 2012, p. 3). Effective visual representations of data can assist with collective sense-making and lead to better and faster decisions (Baker et al., 2009, p. 534)

The Theory of Cognitive Fit, which posits that the decision-making will be more effective and efficient when the format of a visual adjunct matches the form and nature of the problem. The three types of features contained within a visual representation are the scene, objects within the scene, and characteristics of the objects. These objects must be presented in a complementary manner in order to maximize effectiveness of the visual representation (Baker et al., 2009, p. 536).

The map of normalized naloxone administration rates (Appendix D) demonstrates application of the Theory of Cognitive Fit to GIS products. This map contains the scene, which is an outline of the jurisdiction on a base map, the objects, which are CBGs, and the characteristics of the objects, which are colors intended to convey relative differences and intensities. Patient information associated with this map has been de-identified in several different ways. First, summative information about individual instances of naloxone administration aggregated into CBGs and then normalized for rates per 100,000 of population.

Second, this information is displayed on the map using ranges and not specific numbers that could be reverse engineered to find rates for specific CBGs or actual occurrence counts.

This map identified three CBGs with naloxone administration rates exceeding 360 per 100,000 of population. Based on anecdotal information, one of these CBGs was expected to be in the higher range. However, the appearance of the other two CBGs in this highest range was unexpected. Another unexpected finding was that the area surrounding Station 6 did not contain any CBGs in the highest range. This area has historically been considered the highest activity area for overdose responses but, as the map demonstrates, other areas are more likely generate these responses. This lower activity level was confirmed on the non-normalized map which showed summative data of naloxone administration by CBG (this map not included due to patient privacy concerns).

Another surprising finding on the map of normalized naloxone administration rates (Appendix D) was the block of seven contiguous CBGs, anchored in the southeastern corner of the SVFD's jurisdiction, which experienced no naloxone administration during the study period. These CBGs have a combined population of nearly 16,000 and include the entirety of the City of Liberty Lake. Both the City of Liberty Lake and its immediate suburbs are considered to be among the more affluent areas of the Spokane Valley.

The map identifying naloxone administration hot spots (Appendix E) shows the results of the application of the Emerging Hot Spot Analysis tool from ArcGIS. Prior to performing this analysis, the jurisdiction was divided into a grid containing one square-mile cubes that contained both spatial and temporal data. The tool uses the Getis-Ord Gi* statistic for each unit of area on the map to identify hot spots. Identified hot spots are then analyzed using the Mann-Kendall trend test and each grid square is classified into one of 17 categories (Esri, 2016, para. 1).

The results of the Emerging Hot Spot Analysis identified that most of the grid squares in the SVFD had no detectable trend pattern. However, five squares were categorized as Sporadic Hot Spots, which Esri defines as “A location that is an on-again then off-again hot spot. Less than ninety percent of the time-step intervals have been statistically significant hot spots and none of the time-step intervals have been statistically significant cold spots” (Esri, 2016, para. 8). Three squares fell into the Consecutive Hot Spot category, which are locations “with a single uninterrupted run of statistically significant hot spot bins in the final time-step intervals. The location has never been a statistically significant hot spot prior to the final hot spot run and less than ninety percent of all bins are statistically significant hot spots” (para. 4). The eight squares that were either categorized as Sporadic or Consecutive Hot Spots are grouped in the northwest corner of the Spokane Valley. Station 8 is within this grouping of squares, and Stations 1 and 2 border the edge of this grouping.

Overlay analysis identified one CBG that fit the criteria of both high normalized administration rates (over 360 per 100,000) and was within an identified Consecutive Hot Spot (Appendix F). This CBG is located between SVFD Stations 2 and 8 and was an unexpected result. Anecdotally, the area contained within this CBG has not historically been associated with opioid use. A complementary, smaller scale map highlights the location and general boundaries of this CBG (Appendix G).

Additional maps that are not included in the appendices were used to identify areas with multiple responses to the same addresses or to individual patients. The geo-data associated with these maps created a slight risk of patient re-identification. The map containing multiple responses to the same address identified seven CBGs with addresses fitting this criterion. One of these addresses was already known to be in this category, but the other six were unknown prior to this analysis. A total of eight patients received naloxone during at least two separate incident responses or the time period of the study. This includes one individual who was treated at two separate addresses in different CBGs.

Discussion

The literature is in agreement that United States has experienced a dramatic increase in opioid use since the turn of the current century, with the only disagreement being on the scale of this increase. Meldrum (2016) described a more than doubling of overdose deaths attributable to opioids between 2000 and 2014, while Rudd et al. (2016) identified a near tripling of these deaths between 1999 and 2014. In Spokane County, Riffe (2015) identified that hospitalizations related to opioid overdose showed steady annual growth between 2000 and 2014, ultimately resulting in an annual normalized hospitalization rate of 14.4 per 100,000 of population.

Interestingly, over the one-year timeframe that this ARP examined, naloxone was administered to 88 individual patients. While a known or suspected opioid overdose is the primary indication for naloxone administration (Spokane County EMS & Trauma Care Council, n.d., p. 306), it may also be administered by a paramedic evaluating a coma of unknown origin as a way to rule out overdose as a causative agent. This may have resulted in an upward skewing of overdose rates. Conversely, Spokane County EMS protocols do not indicate administration of naloxone during resuscitation. As a result, overdoses that precipitate a cardiac arrest may not have been included in the data set, resulting in a downward skewing of overdose rates. Regardless of the reason for administration, the number of patients receiving naloxone in the Spokane Valley during the study period resulted in a normalized administration rate of 70.4 overdoses per 100,000 of population, which is significantly higher than the Spokane County hospitalization rate identified by Riffe (2015).

Absent a rapid and effective field test for the presence of opioids in the bloodstream, naloxone administration is the only proxy indicator for establishing opioid overdose rates available to the SVFD. Both Knowlton et al. (2013) and Lindstrom et al. (2015) cautiously confirmed the use of naloxone administration data for approximating opioid usage and overdose rates. Both of these studies identified differences in patient demographic information collected during EMS contact and emergency room visits as a source of their caution regarding the use of naloxone administration data.

Demographic differences were also noted between SVFD data and that analyzed for Riffe's (2015) summary of Spokane County opioid-related hospitalizations. While patient ages were relatively similar in both data sets (48 in the SVFD's data versus 52 in Riffe's study) there were notable differences in gender composition. Riffe found that males accounted for 41% of Spokane County hospitalizations and females accounted for 59%. A review of SVFD patients receiving naloxone found that 52% of patients were male and 48% female.

Two potential sources of this difference bear further examination. First, there may be a gender difference in the likelihood of a patient to refuse transport after receiving naloxone. As long as a patient can demonstrate the cognitive ability necessary to refuse care, they cannot be forcibly transported to a hospital and these patients may not self-report to an emergency department. Another potential explanation for this difference is found in the study by Sumner et al. (2015) which noted lower naloxone administration rates for overdosed females.

One particularly notable feature in the data that became readily apparent when it was viewed through the GIS lens was the lack of any naloxone administration in the seven contiguous CBGs in and around the City of Liberty Lake. When the nearly 16,000 residents of these CBGs are removed from consideration, the normalized rate of naloxone administration in the rest of the SVFD increased to more than 80 per 100,000 of population. At this normalized usage rate, given the population in and around the City of Liberty Lake, approximately 12 individuals would be expected to have received naloxone during the timeframe of the study. Again, Sumner et al. (2015) presents a possible explanation for this data anomaly. The study found that a lack of indicators of illicit drug use resulted in an underutilization of naloxone. Because this area is generally more affluent than many other areas of the Spokane Valley, there may be some type of socioeconomically driven diagnosis bias present.

A concerning fact was found during the combined examination of multiple responses to one address and multiple responses for individual patients. One care facility was found to have generated 9% of the responses where naloxone was administered. Additionally, one patient who generated multiple responses at different addresses appears to be a resident of this facility and if that additional response is tied to this facility, it is responsible for more than 10% of the naloxone administrations.

The ability to access, manipulate, and analyze geo-data related to naloxone administration holds great promise for the Spokane Valley Fire Department's ability to plan for and respond to the public health crisis created by easy access to opioids. Identification of specific geographic areas of interest allows the department to conduct targeted community risk reduction efforts in conjunction with other aligned organizations. Additionally, the ability to identify emerging hot spots will allow the SVFD to operate in a proactive manner rather than simply reacting post-overdose.

The recognition of population centers with no naloxone administration recorded may indicate a need for additional training in overdose recognition. There are local opportunities to develop in-house drug recognition experts who can then develop and deliver EMS focused training. In-person training based on a recognized and legitimate need or deficit frequently appears to be better received than training that is recorded and delivered in an online format.

Recommendations

Opioid use in the United States over the past couple of decades has demonstrated a strong upward trend with no indication of slowing. What is rightly called an epidemic must be addressed from a public health or emergency management standpoint. One of the initial steps in responding to any crisis that threatens the public health and welfare is developing an adequate understanding of the scope and nature of the crisis. Using the techniques and tools available in GIS software facilitates development of a complete picture of the spatial and temporal aspects of this overdose problem.

The GIS-based map products developed in the course of completing this ARP provide the SVFD with the tools and information needed to better understand opioid use within its jurisdiction. Over the past several years, the department has focused on a data driven organization that can justify expenditures and measure performance. The use of GIS data to facilitate an understanding of opioid use is in alignment with this focus and will support subsequent actions and recommendations.

Three specific and relatively immediate actions will be taken based on information developed during this project. First, the branch of the Washington State Department of Health that regulates care facilities will be contacted regarding the significant percentage of naloxone administration incidents involving the previously discussed facility. Second, findings regarding the lack of naloxone administrations in the Liberty Lake area will be discussed with the SVFD's Medical Program Director to identify any potential training or care issues. Third, naloxone administration information will be shared with the Spokane Regional Health District in order to initiate discussion regarding coordinated overdose prevention actions and programs.

Several long-term projects are anticipated based on the results of this ARP. First, additional GIS data mining and manipulation will be used to further explore opioid use in the SVFD and to identify any additional trends or patterns. For example, several areas showing higher usage rates contain significant numbers of renter occupied housing units. If renters are shown to be at a higher risk of opioid overdose, then the SVFD has an opportunity to capitalize on its positive relationship with property managers and owners by providing educational materials and programs for specific apartment complexes or housing units. Similarly, the SVFD can capitalize on its easy access to schools in higher usage areas to implement a public education campaign for kids of all ages (the youngest patient in the data set was 11).

Another long-term project will be to apply these GIS-based techniques to other public health issues present in the SVFD's jurisdiction, such as cardiac arrest. The SVFD has focused much effort on improving survival rates over the past several years and has implemented a multi-prong approach of improved access to early CPR, early application and use of defibrillators, and team-focused, high-efficiency resuscitation. An examination of cardiac arrest and survival using GIS tools may yield valuable insights.

A third long-term project involves coordinating patient care information with other agencies who respond to the SVFD's jurisdiction based on the AVL dispatch system. Both of the SVFD's closest neighbors use the ESO platform for creating and maintaining their EHR databases. Implementing a data sharing relationship with these agencies is a relatively straightforward process that will facilitate the two-way exchange of response data and enable each jurisdiction to develop a more comprehensive understanding of incident responses.

One recommendation for others wishing to replicate this GIS-based evaluation of opioid use (or any other public health issue) is to pay particular attention to the literature regarding patient privacy and legal protections. The consequences of revealing protected patient information can be significant. Though it may impact the apparent usability of data, the bias must be towards protecting the patient. The true challenge for the researcher lies with identifying which data can be released and what format presents the data in the most meaningful way.

In conclusion, this project enabled the SVFD to develop an understanding of the scope and nature of opioid use within its jurisdiction. This understanding will guide future training and operations and will have a positive impact on the citizens of the Spokane Valley. Given its cyclical nature, the opioid usage rates may eventually wane of their own accord. Until then, the Spokane Valley Fire Department will be better able to meet the challenge presented by opioid overdoses. Bathed in the glow of data, this epidemic is no longer in the shadows.

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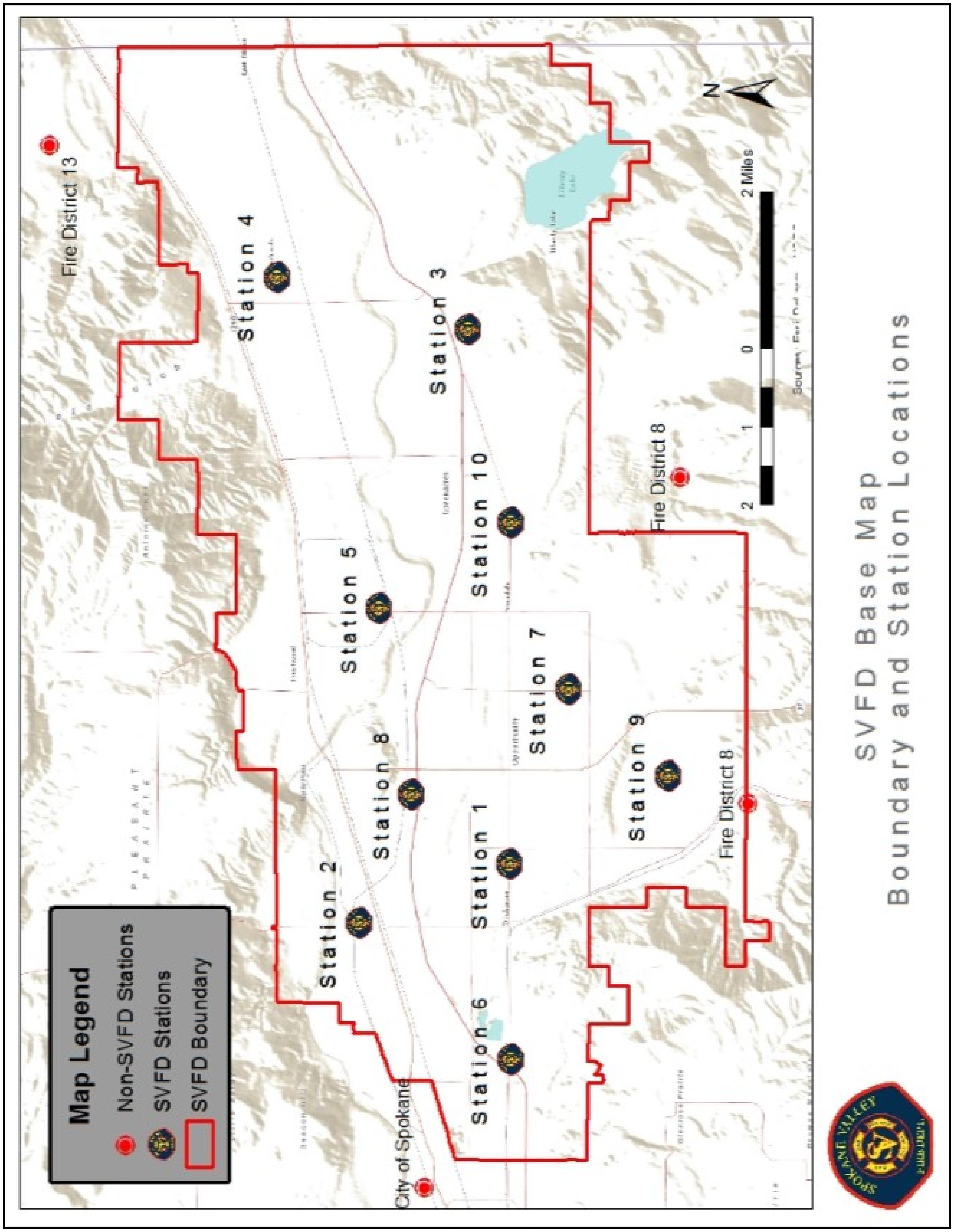
Appendix A

List of HIPAA Potential Identifiers

- Names;
- All geographic subdivisions smaller than the state;
- All elements of dates (except year) for dates that are directly related to an individual;
- Telephone numbers;
- Vehicle identifiers and serial numbers, including license plate numbers;
- Fax numbers;
- Device identifiers and serial numbers;
- Email addresses;
- Web Universal Resource Locators (URLs);
- Social Security numbers;
- Internet Protocol (IP) addresses;
- Medical record numbers;
- Biometric identifiers, including finger and voice prints;
- Health plan beneficiary numbers;
- Full-face photographs and any comparable images;
- Account numbers;
- Any other unique identifying number, characteristic, or code; and
- Certificate/license numbers (HHS, n.d., p. 1).

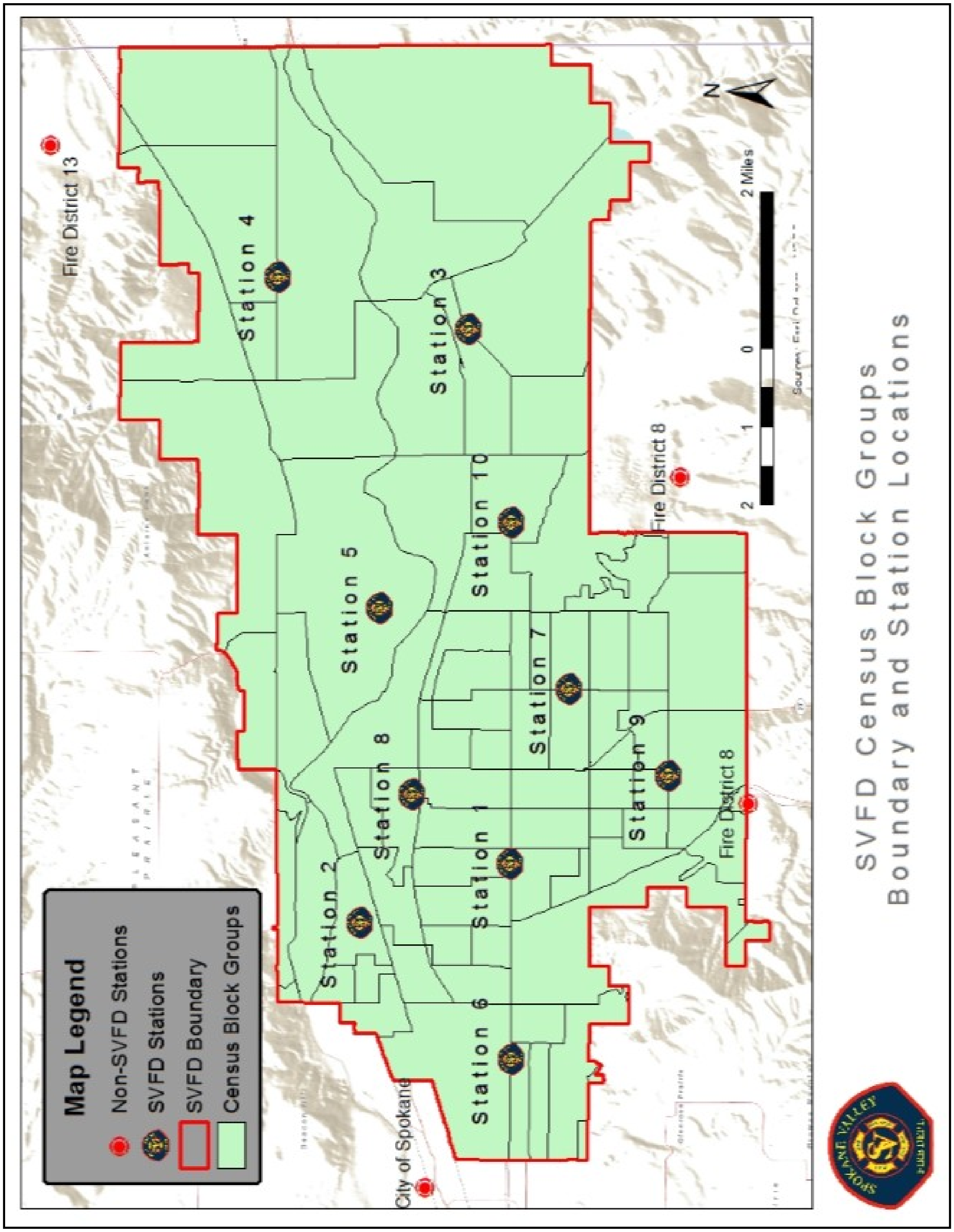
Appendix B

Spokane Valley Fire Department Base Map



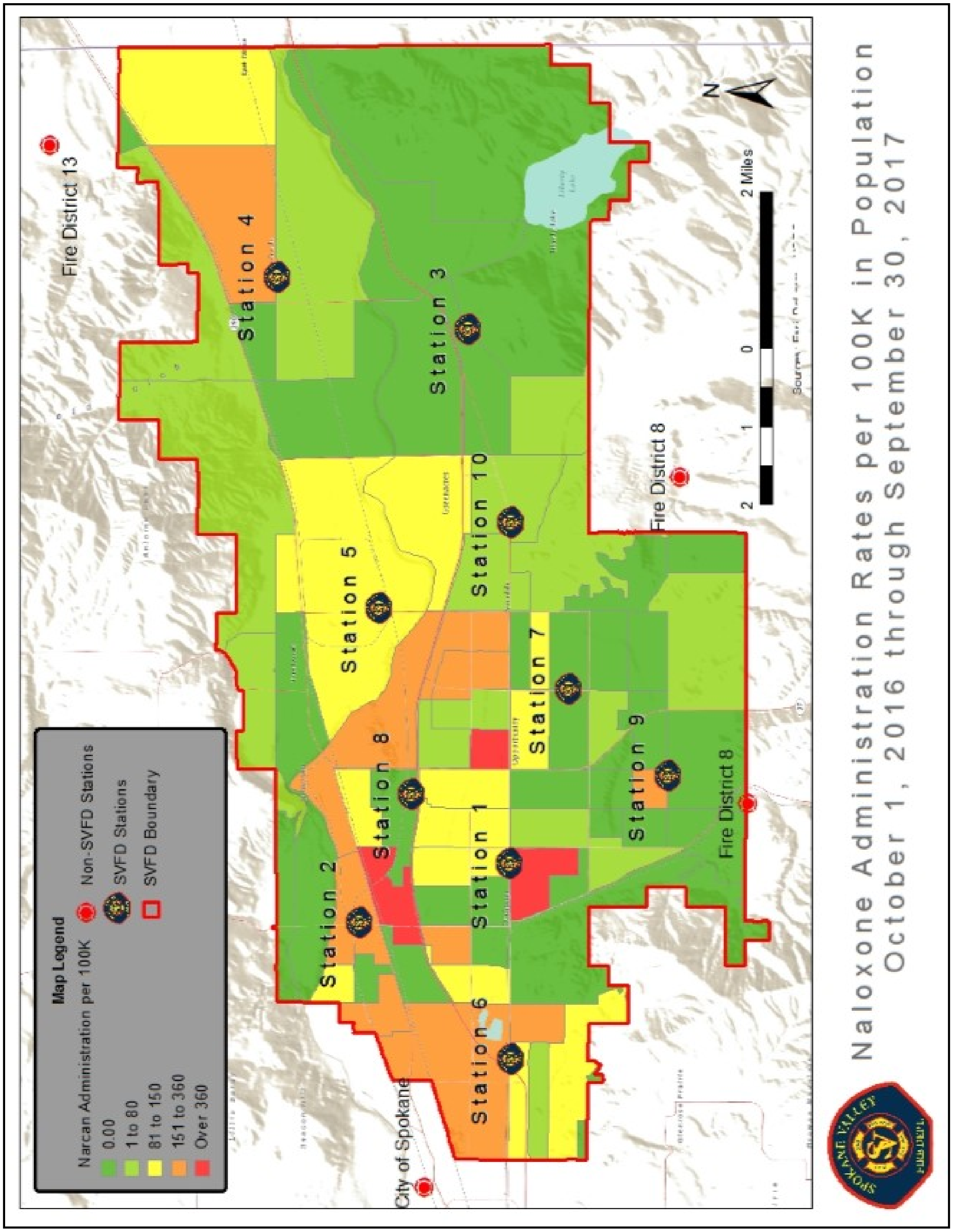
Appendix C

SVFD Census Block Groups



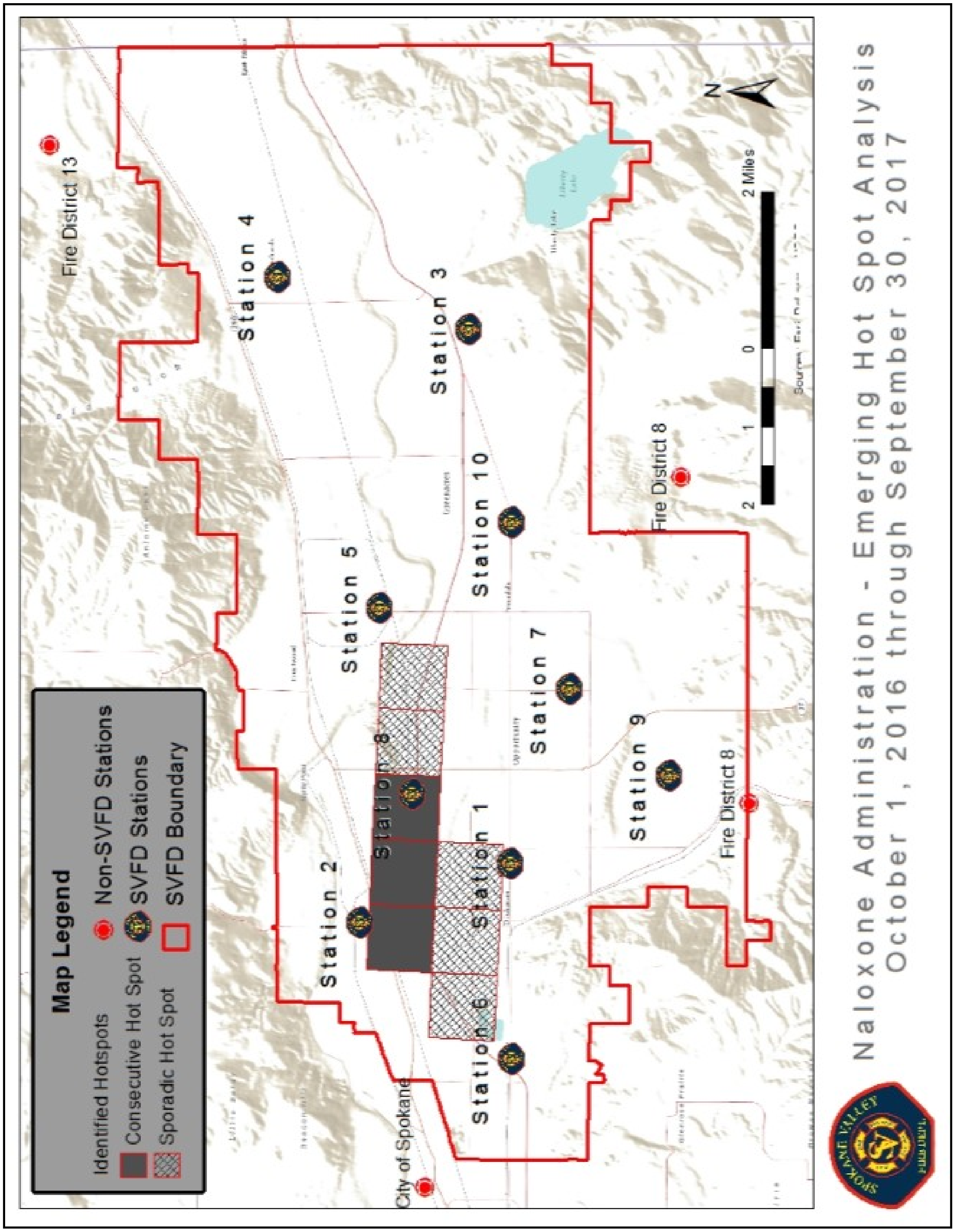
Appendix D

Normalized Naloxone Administration



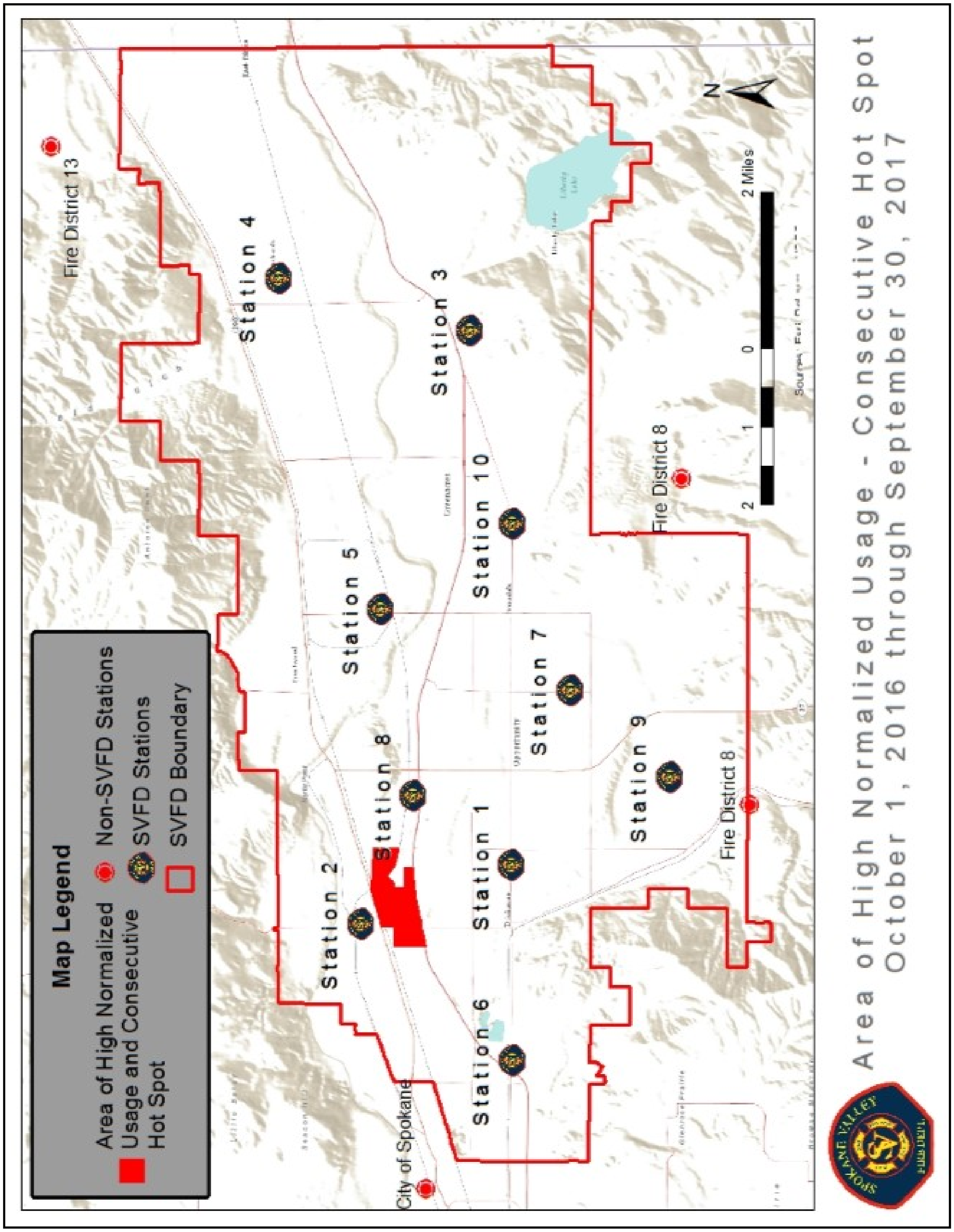
Appendix E

Emerging Hot Spot Analysis



Appendix F

Areas of High Normalized Usage and Consecutive Hot Spot



Appendix G

Area of High Normalized Usage and Consecutive Hot Spot (Close-Up View)