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Investigating the Role of Geospatial Technologies as a Supplement to Environmental Education: Development of an Environmental Data Collection Application and Its Implementation in the Classroom

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I am submitting herewith a thesis written by Evan James Norton entitled "Investigating the Role of Geospatial Technologies as a Supplement to Environmental Education: Development of an Environmental Data Collection Application and Its Implementation in the Classroom." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geography.

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Investigating the Role of Geospatial Technologies as a Supplement to Environmental Education: Development of an Environmental Data Collection Application and Its Implementation in the Classroom

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ABSTRACT

Informal STEM (Science, Technology, Engineering, and Math) education refers to science learning that takes place in a non-traditional setting, such as a museum, a library, and outside a classroom, based on the methods different from the traditional pen-to-paper style of classroom learning. A critical component of Informal STEM education is to ensure student understanding and using available technologies to better analyze and convey scientific data, particularly for the data that are spatial in nature. Combining mobile technologies with geographic information systems (GIS) in field data collection provides unique opportunities for students to feel stimulated and engaged in what they are learning and to take ownership of their own learning process.

In this thesis, I developed a publicly available and open access data collection application and investigated its impacts on students' engagement and perception of the incorporation of technology in their learning within the environmental science curricula. The analyses of pre- and post-surveys indicate that the inclusion of geospatial technologies as a part of curricula can significantly boost students' engagement by allowing the opportunities to 1) take the lead on their own research, 2) view field data in real-time as opposed to looking at a database in hindsight, and 3) view and analyze multiscale data as it is presented during field analysis. The findings of this study are consistent with previous studies, suggesting a strong correlation between the inclusion of geospatial technologies as a part of curricula and student engagement and performance.

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Chapter One

Introduction

New technologies emerge from the market on a daily basis, all claiming to have a desirable edge over their competitors. Of considerable growth over the last several years has been the number of applications (or apps) developed and released for mobile devices (tools capable of accessing databases through cellular/satellite, Bluetooth, or Wi-Fi networks), including global positioning systems (GPS), smartphones, and tablets. Competition between developers to produce the most capable apps provides educators with the opportunity to introduce new technology such as mobile learning to their classrooms. Mobile learning, the "process of learning mediated by handheld devices" that have the ability to link and access data from Wi-Fi or cellular networks (Christensen & Knezek, 2017), has become prevalent throughout K-12 classrooms, particularly in data-heavy Science, Technology, Engineering, and Math (STEM) courses. For example, almost 300 million educational apps were downloaded from the internet in 2011 (Shuler et al., 2012). However, prevalent issues associated with implementing new technologies in the classroom are the affordability of the technology and a fear of undermining the material intended to be taught in the curriculum (Walshe, 2017). As innovative technologies emerge and are recognized, their costs typically rise along with the cost to provide these technologies to students. It seems that a roadblock exists between the financial restrictions and fundamental understanding of the technology being presented.

In recent years, various versions of educational products have been offered to the public for free, although most of them are simplified versions with less problem-solving capabilities. A GIS is “a set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes” (Burrough & McDonnell, 1998). It is the “building block” of many currently available mobile applications (e.g. Google Maps, MapQuest, Pokémon Go, etc.) The combination of GIS with mobile technologies allows for the streamlining of crowdsourcing data in a user-friendly manner. As the producer of a suite of GIS software packages, ArcGIS, ESRI (Environmental Systems Research Institute) recently released a free app called Collector for Android and iOS operating mobile devices, including smartphones or tablets. This app links the user to a specified account that is hosted by ArcGIS Online, the ESRI’s online GIS mapping platform. A developer/cartographer with an ArcGIS account can create a map of a designated area and customize the desired parameters that will be collected at the study site. By publishing this map as open access, anyone with this app can access and upload data to this digital map.

This Collector app presents a unique opportunity for science educators whose institutions have access to ArcGIS facilities and tools. Many universities have educational outreach programs that offer supplementary materials (e.g., online mapping activities, tutorials of mobile applications, hands-on tangible GIS) to educators and schools in their communities. With this app available, educators can create an interactive data collection map that specifically relates to their lesson plans. The combination of GIS and mobile technology allows for effective promotion of spatial cognition and awareness in an educator's curriculum that is related to various biotic and abiotic features and processes, such as geography, geology, water resources, and environmental science (Britz & Webb, 2016).

A common struggle in STEM education is to keep students physically and mentally engaged with the materials presented in the classroom. This struggle can be attributed to various demographic, educational, and social reasons (Orwat et al., 2017). The frequency of using the term "engagement" has increased over the past several decades and is a key prerequisite and indicator of student success in the classroom (Groccia, 2018). While many variations exist in the definition of engagement, perhaps the most fitting for the scope of this research was defined by the Glossary of Education Reform: student engagement is "the degree of attention, curiosity, interest, optimism, and passion that students show when they are learning or being taught, which extends to the level of motivation they have to learn and progress in their education (Great Schools Partnership, 2016).

A significant positive correlation has been observed between the introduction of an alternative, technology-based learning method and overall student enthusiasm, performance, and willingness to continue learning (Li & Song, 2017). As the development of new technologies continue to innovate and inspire in their capabilities, their presence in an educational setting has gradually become a mainstay in K-12 education. Critical to the success and positive feedback of new technologies in the classroom is to ensure that the introduction of new teaching proxies is supplemented with evidence of their success (Britz & Webb, 2016; Edall & Wentz, 2007). A downside to the development of advanced technology with faster processing and the ability to solve more complex problems is that they are typically more intricately designed, meaning that they are typically more expensive to produce. To convince educators that the use of technologies in the classroom is beneficial to both their students and themselves, it is better to have evidence of such claims, in terms of student productivity and enthusiasm versus cost of implementation. While arguments exist that excess emphasis is made on one single application at a time rather than comparing the advantages of different applications to choose from, it is still evident that collaborative learning supported by computer technology is of benefit to both instructors and students (Sun et al., 2017).

The purpose of this thesis is to assess the potential educational benefits that geospatial technologies can offer students and instructors in environmental education based on a survey of 8th grade environmental science students who used a data collection app to collect water quality data within their school's watershed. The surveys were designed using Likert-type scale questionnaires to rank level of enthusiasm before and after the activity, and with open-ended response questions that were coded to identify broader themes that the students felt were relevant to their experience.

The detailed objectives of this study are to: 1) assess what impacts the implementation of geospatial technologies may have on student engagement and enthusiasm in science curricula, and 2) discuss possible improvements to the developed application, surveys, and stream walk activity for future use and how any alterations may be more successful at boosting student engagement than the initial version. The research hypothesis is that the implementation of geospatial technologies, such as the data collector app, can significantly boost student enthusiasm and engagement in classroom. It is tested by the paired t-tests of Likert-scale responses and themes that were coded from open-ended survey answers by the participants.

This thesis includes 5 chapters. Chapter 1 introduces the purpose of this study, as well as the objectives and hypothesis. Chapter 2 is a review of current and past literature focused on active learning and technology adoption in K-12 curricula, with an emphasis on spatial technology. Chapter 3 focuses on the methodologies, and Chapter 4 focuses on the findings of this study. Chapter 5 summarizes the conclusions and discussions pertaining to the findings.

Chapter Two

Literature Review

One of the most prevalent issues mentioned by environmental educators about student success in the classroom is that it is difficult to keep student engagement and enthusiasm at a sufficient level. A plethora of reasons are presented by the literature on what the biggest causes of student disengagement are during a lesson including personal problems at home (Orwat et al., 2017) and being burnt out on outdated teaching proxies (Pearson, 2018). A general consensus is that the traditional lecture style class is becoming less and less efficient in fostering an environment where students remain attentive and actively engaged in their learning process.

In environmental science curricula, many studies have suggested that the introduction of geospatial technologies has resulted in positive outcomes for both students and educators and helps to address the difficulty that instructors have in conveying information that is applied across multiple spatial scales (Wentz et al., 1999; Britz & Webb, 2016). In this instance, the inclusion of GIS-based tools into environmental science curricula can be of benefit. There are, of course, detractors to this argument, stating that the inclusion of geospatial technology runs the risk of undermining the intended information that is being taught (Walshe, 2017). Scholars still argue that what we teach is more important than how we teach; in other words, content is more important than pedagogy (Elwood & Wilson, 2017). Prior to 1994, little research had been published looking at the benefits of geospatial technology as a teaching proxy for provision of another way of learning for students when compared to other proxies.

There was also little evidence as to whether or not the inclusion of this technology was worth the time or effort required to introduce them within the curricula (Britz & Webb, 2016). In 2003, approximately 2% of high schools introduced some form of GIS into their coursework (Kerski, 2003). The most widely accepted reason for this low number is the slow rate of effective introduction to students and instructors of GIS. However, as technologies continue to improve, more evidence starts to support the idea that implementing geospatial tools can efficiently boost engagement and retention of knowledge in the classroom (Kerski, 2003; Favier & van der Schee, 2014)..

Adventure learning, a term coined by Dr. Aaron Doering of The University of Minnesota, described the unique experience offered to students that used a GIS to guide the course of their own learning experience by exploring topics of their own interest (Hardin, 2016). As more institutions grow their geospatial capabilities, collaborations may occur that promote a sense of geographic exploration, both literally and figuratively, and broaden students' spatial cognition and engagement. The use of GIS allows students to take the lead on their own learning by the design of real-world problems that they can explore across various spatial and temporal scales of analysis (Walshe, 2017). One of the main roadblocks to student engagement in active learning is resistance to social or physical characteristics of the classroom, so by constructing their own explorations with hands-on activities, students are more apt to immerse themselves in their learning (Shekhar & Borrego, 2018). The collaborative efforts are often necessary for GIS learning to be successful and to reinforce the benefits that come with active learning; interactive teamwork enhances the engagement and meaningful participation in ways that solo activities often fail to do (Molinillo et al., 2018). This interactivity that is required by newer, unknown technology boosts the effectiveness of active learning by encouraging emotional and intellectual engagement between students, their peers, and their instructors (Molinillo et al., 2018).

Numerous studies have shown the success of introducing new technologies to the classroom. For example, the use of Apple iPads in an undergraduate level accounting course provided a statistically significant improvement in test scores, student perception of their own attentiveness in class, and overall attendance through group-annotating homework and in-class assignments (Wakefield et al., 2018). Additionally, the implementation of three-dimensional (3-D) GIS toolkits into urban planning courses has shown promising results for increasing the spatial awareness at a more thorough depth than would be allowed by 2-D analysis (Yin, 2010). Finally, by implementing a gamification strategy to content delivered in a Professional Development course, students who used the gaming modules performed significantly better than those who learned using traditional, non-gamified methods (Tsay et al., 2018). This gamification strategy shows encouraging results to boost student engagement and performance, especially for younger students who may be inclined to play video games in their free time (Tsay et al., 2018).

Promoting learning through technological proxies, particularly geospatial ones, can encourage students to analyze data and problems from multiple viewpoints. A common complaint about traditional lecture format classes is that students feel disconnected from the source materials and cannot perceive how it is applicable to their own lives (Benimmas et al., 2011). Some geospatial tools provide students a “birds-eye view” of concepts that they are learning, including geomorphology, urban planning, and water resources. The overwhelming consensus is that a mixed-method approach involving hands-on activities, student-led project planning, and introduction to current and upcoming geospatial technologies is critical for striving for higher levels of student engagement and participation (Bowlic et al., 2016; Wakefield et al., 2018; Zou et al., 2017). The inclusion of curricula that allow for student-led learning significantly increases student retention of the principles being taught. It is also imperative that GIS and other geospatial technologies are not removed from curriculum out of fear of undermining what is being taught (Icnekara, 2010). The necessity to interpret data over multiple spatial and temporal scales makes geospatial technology an invaluable tool to science curricula, as it captures students’ attention more meaningfully and provides students a skillset that is of great value for many career paths.

Chapter Three

Methods

This study was conducted at a public middle school in Knoxville, Tennessee, through a partnership between the middle school and the University of Tennessee's Department of Geography in outreach activities. The identity of the school remains anonymous because of the research regulations of Knox County Schools. The participants are 25 students in an 8th grade Environmental Science class and their instructor. An IRB (Institutional Review Board) proposal was approved, and all students and their guardians completed the necessary consent/assent forms to participate in the study.

The study includes three components:

1) The development of a geodatabase and an application to access, add data to, and analyze the data using the ESRI's Collector application; and
2) Qualitative/contextual and quantitative analyses of impacts on student learning.
3) In addition, the successes and shortcomings of this app were also compared to the findings of other geospatial education outreach programs and studies.

GIS Data Collection App

The GIS data collection app was developed using ESRI's Collector framework and customized with the parameters associated with the 8th grade's environmental science curriculum on watershed sciences. Specifically, the app was customized to collect a set of visual and chemical characteristics of a stream that the students would examine, such as bank stability, presence of algae, odor, etc. Supported by various technologies of the Android or Apple Operating System (OS), including display, Wi-Fi and cellular data access, camera, and GPS, this data collection app allows students to record and upload their observations to an online, open-access geodatabase. A geodatabase is a digital method of storing varying types of GIS data in one large, collective file. The geodatabase had basemap layers consisting of streams, roads, aerial photos, satellite images, etc. This allowed students to conduct real-time spatial analyses and queries or ask relational questions of the gathered data through access to this geodatabase.

The structure and features of the geodatabase were developed using ESRI's suite of geospatial tools including ArcCatalog (used to create, organize, and manage geodatabases that can be then be analyzed in ArcMap), ArcMap 10.5 (a GIS used to edit, view, and analyze the contents of the geodatabase), and ArcGIS Online (similar to ArcMap but hosted on the internet, making one's data publicly available and able to be utilized in a web map and/or mobile application). A new geodatabase was created in ArcCatalog. Then, an empty of data "point feature class" was created with various attributes, including temperature (entered as degrees Fahrenheit), water odor, water color, algae presence, current weather conditions, past twenty-four-hour weather conditions, and bank stability, associated with the stream walk assessment. The geodatabase and empty feature class were packed and published as a usable layer in a web map by connecting to ArcGIS Online.

In the field, a drop-down menu within ArcGIS Online was presented to the student recorder for each collected data point that allows them to enter the observed physical attributes of the stream that they observed in the field in order to populate the various attributes listed above in the point feature class/geodatabase. The collected point is then sent from the app, used on Apple iPads, by way of accessible Wi-Fi or the available cellular network to the online web map. This allows inspection of the individual or accumulated data points and visualization of their mapping distribution in real time from the iPad's browser or later from a connected computer.

During this research process, three separate versions of the application (app/web layer) were developed. The first version, V1.1, was developed in preparation for a similar stream sampling activity for a US Environmental Protection Agency (EPA) Urban Waters project with the Boys & Girls Clubs of Knoxville, TN and the University of Tennessee's Departments of Geography, Social Work, and Civil Engineering (Figures 3.1, 3.2, and 3.3, all Figures and Tables are located in the appendix). V1.1 was used in a pair of iSTEM summer science camps that centered around teaching local youth (ages 8 to 15) about watershed health and water quality (See Figures 3.7, 3.8, and 3.9 for field photos of iStem camps). In addition to the basic function of V1.1, V1.2 (Figure 3.4) and V2 (Figures 3.5 and 3.6) contained additional attributes on the chemical properties of watersheds in the drop-down menu, including stream water nitrogen content and pH. V1.2 was a separate app developed to train the camp's students on the technology they would be using for the stream water sampling activity. V1.2 was used by the camp students to plot locations of trash and recyclables in the vicinity of the camp's grounds. The final version, V2, which is the focus of this thesis, had less attributes available for logging compared to V1.1, as the participants of this study did not participate in any kind of water quality testing/chemical analysis. The locations used between the three versions of the app differed as well, so the base layers, e.g., streams, roads, etc.. of V1.1, V1.2, and V2 were set to differing locations. For field photos of summer camp students, see Figures 3.7, 3.8, and 3.9. For detailed flowchart explaining creation of mobile app V2, see Figure 3.10.

Survey Development

The participants of this study include 25 students in an 8th grade Environmental Science class and their instructor. A pre-survey and a post-survey were conducted before and after the data collection activity. The purpose of the pre-survey was to understand the current attitudes of the students in terms of the roles of technology in their lives, such as how frequently the students use technology (e.g. mobile phones, computers, tablets, etc.) in their free time, in other classes, etc. The pre-surveys also sought to understand how the opportunity to include a technological aspect would increase the enthusiasm and participation of the student by asking, for example, whether or not they prefer to read from a textbook or a screen, and whether or not having a hands-on activity makes them enjoy the curriculum more than if they were to only read the intended material from a textbook or while listening to a lecture. Open-ended short response questions were designed to ask personal opinions about how current school courses could be made more interesting with students who become inattentive. In addition, a Likert-Scale was implemented to quantify how students perceived technology before the planned data collection activity.

The post-survey focused on student impressions of the environmental data collection and mapping app, their preferences for this type of electronic data collection in comparison to traditional paper formats, and their thoughts on applying this type of technology to other courses. Another Likert-Scale questionnaire was administered to assess how the students' opinions changed after field survey and quantify how engaged the students felt throughout the activity and how this type of technology could aid the students in connecting with the curriculum and its materials.

Survey Analysis

Pre- and post-surveys contained questions that can be analyzed using quantitative and qualitative methods. Likert-Scale questions associated with preferences for hands-on and technology-driven lessons, perceptions of daily technology use, and enthusiasm for new technologies were analyzed to determine if the exercise had any positive or negative effects on how students perceive technology in the context of the curriculum. The Likert-scale used in this study included five letters (A, B, C, D, and E), corresponding to "strongly agree", "somewhat agree", "neither agree nor disagree", "somewhat disagree", and "strongly disagree", respectively. These letters were converted to the numbers 1, 2, 3, 4, and 5, respectively, for further analysis.

Paired two-tailed t-tests were used for Likert-scale questions that were repeated between the two surveys to quantify if statistically significant differences exist in student enthusiasm and opinions before and after the data collection activity. A retrospective power analysis was also conducted for these questions to determine the power to detect the difference between the two surveys. This power analysis also provides the minimum detectable difference and the minimum required sample size necessary to detect the difference (Gerald et al., 1998).

Responses to short answer questions were coded to identify any reoccurring themes that the students mentioned (e.g., enjoyment, ease of use, attention). The content coding helps remove the extraneous data that may be considered “noise” caused by excessive text (Cope, 2010). This analysis also helps identify the overarching themes and sub-themes of the findings.

Of the 25 participants that took part in this study, 16 were female and 9 were male. This provides a slight bias in the analysis of surveys as female responses produce more noticeable changes in average gender-combined scores than males responses.

Chapter Four

Findings and Discussion

GIS Data Collection App and its Application

The stream walk assessment activity took place over a roughly one-hour class period. Students observed and logged 31 separate data points along the stream on the school's property. The activity was started with a short tutorial on using the app and any troubleshooting issues the students had (e.g., needing to start a point over, losing place on base map). Then, students used the app to assess the stream on their grounds and log the appropriate data. Initial observations indicated that the ease-of-use of the app increased the productivity of the field work instead of spending time troubleshooting technical issues with more intricate, sophisticated apps or manually writing data. For user manual explaining use of mobile app and access of collected data, see Appendix.

Pre-Surveys

Background Data

Twenty-five participants from an 8th grade environmental science class (16 female and 9 male students) responded the pre- and post-surveys of this study. The majority of the survey responses indicated that participants used technology in their free/recreation time each day and used it multiple times per week to aid their homework (Table 1). Most participants use technology in at least two different classes at school per week. Responses indicate that computers and smartphones are the most frequently used electronic devices, with some students indicated that they also occasionally utilized tablets as well (e.g., iPads, Kindles, etc.). Male students, on average, reported more frequent use of technology in all questions than female students. In general, technology seems to play a fairly frequent role in each participant's life, regardless of gender. Based on responses, most students entered into this study with strong exposure to various technologies and frequent uses of them throughout their daily lives.

Pre-Survey Likert-scale Responses

The Likert-scale ranged from 1, 2, 3, 4, and 5, corresponding to "strongly agree", "somewhat agree", "neither agree nor disagree", "somewhat disagree", and "strongly disagree", respectively. Student response scores indicate that they are in favor of, and generally tend to enjoy, non-traditional teaching methods based on computers and other technologies (Table 2). With an average response of 1.56, students strongly agreed that they are identified as hands-on learners, and generally felt more comfortable with their learning process and information uptake when given the opportunity to physically partake in what they are learning, as opposed to reading from a book or listening to a lecture. Participants also generally enjoyed learning to use new technologies, with an average response score of 1.96. Of particular importance, the students felt somewhat comfortable working with computers and related technologies and felt confident in their own abilities to use them, with an average response of 2.04. This result, in combination with generally enjoying the learning of new technologies and being hands-on learners, is supportive of the idea that new geospatial technologies could be beneficial to a student's learning experience, as discomfort and uncertainty with technology in general would probably cause students to shy away from and become disinterested with new technology-driven teaching proxies.

Post-Surveys

Post-Survey Likert-scale Responses

Average response scores indicated a positive experience with the app, as well as a positive outlook in its potential applicability in other courses (Table 3). With an average response of 1.64, the survey results indicate that participants would like to see activities similar to this one in their other courses. Not only would they enjoy seeing similar activities, they also believe that they would be beneficial to the curricula, as indicated by an average response of 1.52. The results also indicated that students are able to view the map of the area that they were working in helping them better visualize the concepts they had learned about, as opposed to trying to visualize them conceptually in the classroom. Students mostly agreed that they stayed interested throughout the entire duration of the activity, which can be attributed to their background exposure mentioned in the pre-survey and their post-survey responses.

Repeated Likert-scale Responses

After completing the data collection activity, the responses of repeated Likert-scale questions suggest a significant positive increase in the students' beliefs that technology can be a positive contributor to humans and their day-to-day lives, with the average response score to "*Technology has a positive impact on our lives*" going from

2.28 on the pre-survey to 1.56 on the post-survey (Table 4). When responses from male and female participants were analyzed separately, the changes observed from male students did not pass the 95% statistically significance level, whereas the change in female response score did. Female participants made up 64% (16) of the total survey responses, which may explain why female-specific scores have an overall higher impact on the significance of the combined responses.

The activity also prompted a significant positive increase in the opinion that using new technologies is an enjoyable experience in the classroom, per the Likert-scale question *"I enjoy getting to use new technologies in the classroom"*, with responses jumping from 1.92 to 1.36. This observation was statistically significant among both female and male participants.

While response scores improved for *"Using technology makes me feel more interested in lesson being taught."*, the difference was found to be insignificant for both males and females, as well as combined. A retrospective power analysis of this t-test revealed a power of only 30% to detect a significant difference, with a minimum required difference of 0.66 between the means, or a sample size of at least forty-seven participants.

Content Analysis of Short-Answer Questions

The pre-survey contained one short-answer question, *"Whenever you find yourself becoming uninterested during class, what are some things the instructor could do to make the lesson more interesting?"*. Many responses touched on topics such as interactivity, electronics, games, and being hands-on. The prevalent theme in the responses was the desire for the instructor to offer an alternative to the traditional pen-paper lecture style format.

The post-survey contained two short-answer questions. The first was "*Would you rather have recorded your data on a worksheet or in the iPad? Please provide a 1 or 2 sentence explanation of your choice."* Of the twenty-five participants, only four stated that they prefer writing their data manually as opposed to storing it digitally. Of the twenty-one responses who said they prefer to use the iPad, eighteen mentioned the terms "easier" or "easy" when describing why they made that choice. Five participants used the terms "convenient" and "quicker", and stated that they felt writing data by hand is much more time consuming than creating points in the app. One participant mentioned a preference for the iPad because they do not believe they have good handwriting, and the use of the iPad ensures their words/ideas will not be misread. One participant also stated that it is easy to lose sheets of paper and the use of iPad ensured that one could not lose track of the collected data.

The second short-answer question on the post-survey was *"What other topics do you think would be interesting to collect data about in an app like the one you used in the field today?"* Twenty responses featured subjects or themes related to physical, biological, and environmental sciences. Seven participants stated that this kind of app would be helpful with exploring biodiversity data of an area. One response indicated that it would be interesting to see a similar app used to record the locations and counts of stars in the sky from a particular viewpoint. Several responses were less specific about what particular subject the students thought to be interesting to use the app with, but the students did respond that this type of technology would be good for creating and storing records of various types of environmental data (e.g., temperature changes, stream speeds, water chemistry, etc.).

In summary, content analysis revealed that students are much more apt to embrace newer technologies if the data logging methods are faster, easier, and more convenient than hand-written logs. The data collection app provides more time for students to focus on their fieldwork instead of manually recording all the information on paper. Participants enjoyed that the app allows for a new level of interactivity and hands-on work to their lessons, the topics that they also mentioned when responding to the pre-survey question concerning teachers making classes more engaging.

Gender-Specific Findings

There were instances in the analysis of repeated Likert-scale responses where, when viewed independent of each other, males and females had varying levels of significance in terms of changes in response scores. There are two possible explanations for this observation. The first explanation is that the female-to-male ratio presented by the participants is biased. Females, comprising 64% of the sample population, have a stronger impact on the combined average scores than males. At the same time, a change in the response of one female participant between the pre- and post-surveys would have less impact on average female scores than the change of one male participant would have on the average male scores.

The second possible explanation is that females and males learn differently, respond differently to the introduction of technology, and have different perceptions about technology. Current literature is lacking in a consensus about what role gender plays in terms of engagement in response to technology. Broad studies focusing on education have shown that female students are statistically more inclined to have more receptive attitudes towards academic participation, although there is no clear explanation (Zhang et al., 2017). One study indicated that notable difference exists between genders in terms of preference for “smart classrooms” that rely heavily on technology (Macleod et al, 2018), while another study indicated that while there is a clear difference in how different genders engage in the classroom, no clear correlation is presented between the engagement difference and gender (Zou et al., 2017).

Findings are more clearly defined when the scope is specifically narrowed to the role of gender in a STEM environment. Females are generally disinclined to pursue careers in STEM fields due to factors pertaining to gender stereotypes and perceived competence. Post-adolescence interested in STEM-related careers typically wanes among females due to the dominant stereotype that paints the sciences as a field of work for men (Barth et al., 2017). Furthermore, females typically already pictured themselves underrepresented in both STEM academics and jobs, so while their own perceived competence is shown to be near equal that of their majority male counterparts, the marginalization of their gender may make them feel less inclined to pursue STEM learning (Hilts et al., 2018). These factors naturally present challenges to female students in terms of participation and engagement in the classroom, but interventions, such as after-school programs and extracurricular clubs, have shown effective at boosting female participation and enthusiasm as opposed to a traditional classroom setting (Kim et al, 2018).

Although the differences in mean scores between males and females for the repeated Likert-scale responses was not significantly different, females did tend to provide lower scores in terms of attitudes towards technology. Background questions showed that female students used technology slightly less in their day to day lives than male students did as well. These findings appear to be in line with the literature regarding female engagement and enthusiasm in STEM. Further studies are needed to investigate what role gender may play in these differences, specifically for adolescents.

Limitations of This Study

Several limitations still exist in the methodology of this study that may affect some of the findings. First, the relatively small sample size produced lower-than-ideal powers for the t-test analyses. While some tests produced statistically significant results, others did not. Recruiting a larger sample size could have helped improve the statistical significance level of t-test analyses. If this study were to be repeated, it would be advisable to ensure that a sufficient sample size, as determined by a power analysis, be recruited to improve the results.

It is also important for future studies to include a control group during the sampling activity. All participants used the iPads and the developed app to see how it would increase their level of engagement and enthusiasm. While the increases could be deemed significant, other than the pre-survey scores, there is no comparison to the score improvements to. A control group consisting of students logging their observations on a worksheet in the traditional pen-to-paper style learning could partake in the same activity, with a pre- and post-survey revised to gauge how the pen-to-paper method made them feel, if they would have preferred to use a different method using technology. This would allow us two sets of observations and t-tests to compare to examine more conclusively whether or not the inclusion of the technology was what actually caused the improvement.

Chapter Five

Conclusions

This study reinforces the notions found in the literature that introducing new technologies, particularly geospatial ones, into environmental science curricula could increase student engagement in the activity and raise interest in the topics being presented. A positive correlation exists between the introduction of alternative tech-based methods and student engagement (Li & Song, 2017). The introduction of apps, such as the one for this study, can benefit science courses by providing easier methods of data logging, speeding up the data collection process, and providing hands-on interactive methods to keep students physically partaking in their lessons. Technological support, especially in collaborative learning, is beneficial to both students and instructors (Sun et al., 2017). It is evident that technology is more than just part of the acronym for STEM; it is also at least partly responsible for STEM education's success in raising student engagement and the positive reception from students and instructors alike. The growth of STEM, particularly informal STEM, has allowed for science curricula to integrate new teaching proxies that help students overcome the feelings of burn-out they encounter when overexposed to traditional teaching methods (Pearson, 2018).

Survey analysis suggests that students see themselves as hands-on learners, enjoy learning to use new technologies, feel relatively comfortable using computers, and are confident in their knowledge of how computers work. Participants acknowledged that they could see similar applications being useful in other courses and would like more experience using them in other classes. They use different types of technology multiple times per week, both at home and in school, and indicate that prefer reading information from an electronic device as opposed to a textbook. Most students indicated that they felt engaged during the duration of the stream walk activity, and while this may or may not be due to use of the iPads to log their data, the notion is reinforced by studies using iPads to aid in collaborative learning scenarios where students reported higher levels of self-perceived attentiveness (Wakefield et al., 2018). Students also indicated a desire to include some sort of game activities with their lessons, an idea that could further increase levels of attention as well as academic performance (Tsay et al., 2018).

While the app was developed for the purposes outlined in this thesis, it also ended up having practical uses for the students as well. As part of their watershed curriculum, groups of 3 to 4 students were conducting final projects investigating watershed-related concepts of their choosing. While there was no follow-up at the end of the academic school year to see how the data was applied to each project, the students informed me that they had chosen topics concerning algae growth, concentration of litter/trash in varying parts of the stream, and abundance of animal species present. The stream walk assessment prompted students to collect data that can be directly applied to their project investigations, and thanks to the accessibility of the data provided by ArcGIS Online, they could access their collected points as often as they need to supplement their projects.

A common complaint among students in both this study and in the literature is that the traditional lecture format causes a disconnect with the material being taught; students are not able to see how it is applicable to real life (Benimmas et al., 2011). The use of geospatial technologies presents students with the opportunity to learn about environmental sciences in a manner that allows visualization of data and provides context concerning how this data is relevant to their own lives, resulting in heightened student attentiveness and engagement. Previous studies support the notion that early disengagement from course materials (whether it be due to lack of exposure to topic or the pressure from existing stereotypes) is substantially lower likelihoods of students pursuing careers in STEM related fields. To counter this phenomenon, it is critical to include geospatial technologies in environmental science curricula as earlier as possible. By ensuring students of all ages and genders to remain engaged in the classroom, the popularity of informal STEM learning, as well as the number of students interested in STEM careers, would likely continue to increase.

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APPENDIX

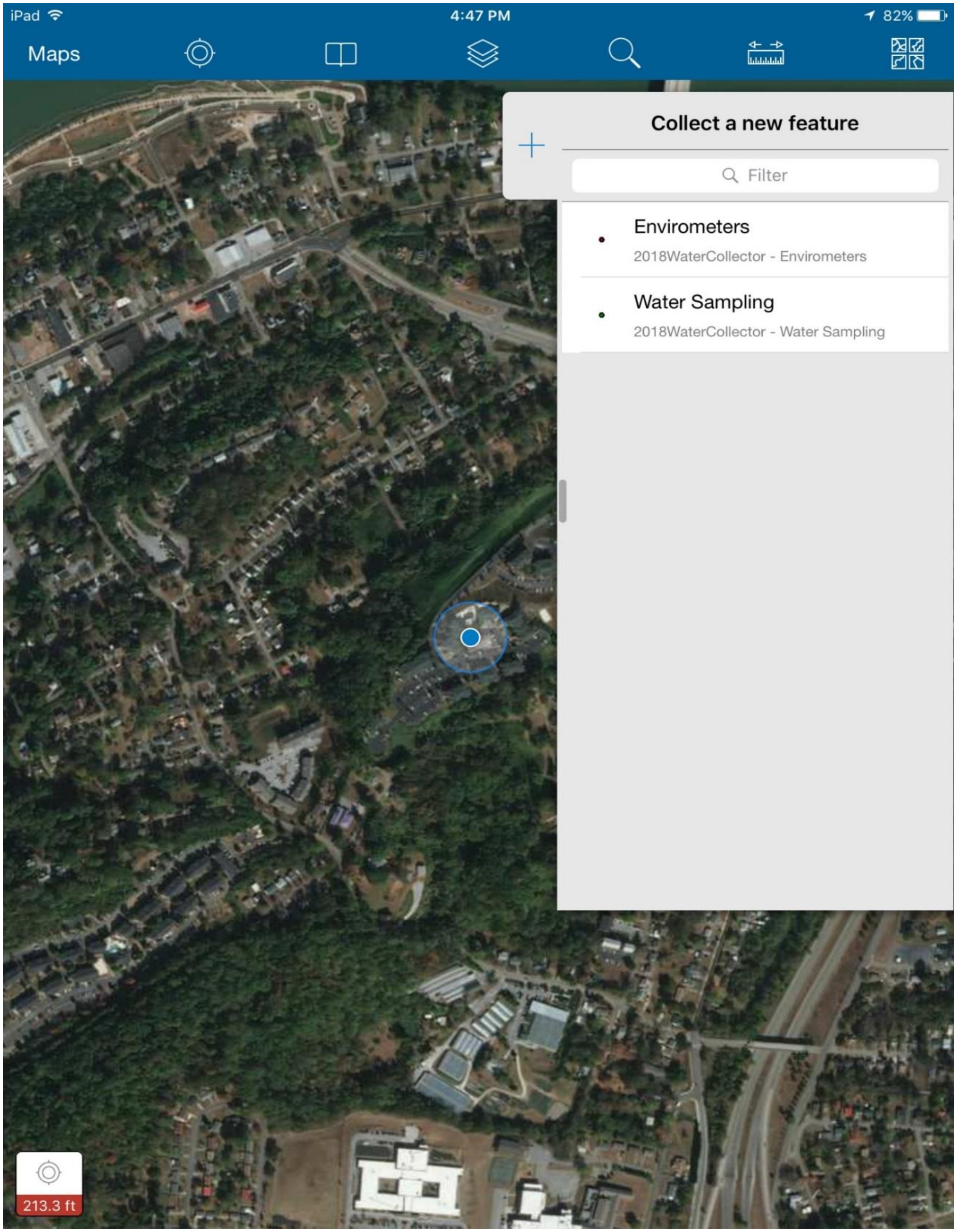


Figure 3.1: Collector App V1.1 (Feature Class Selection Screen)

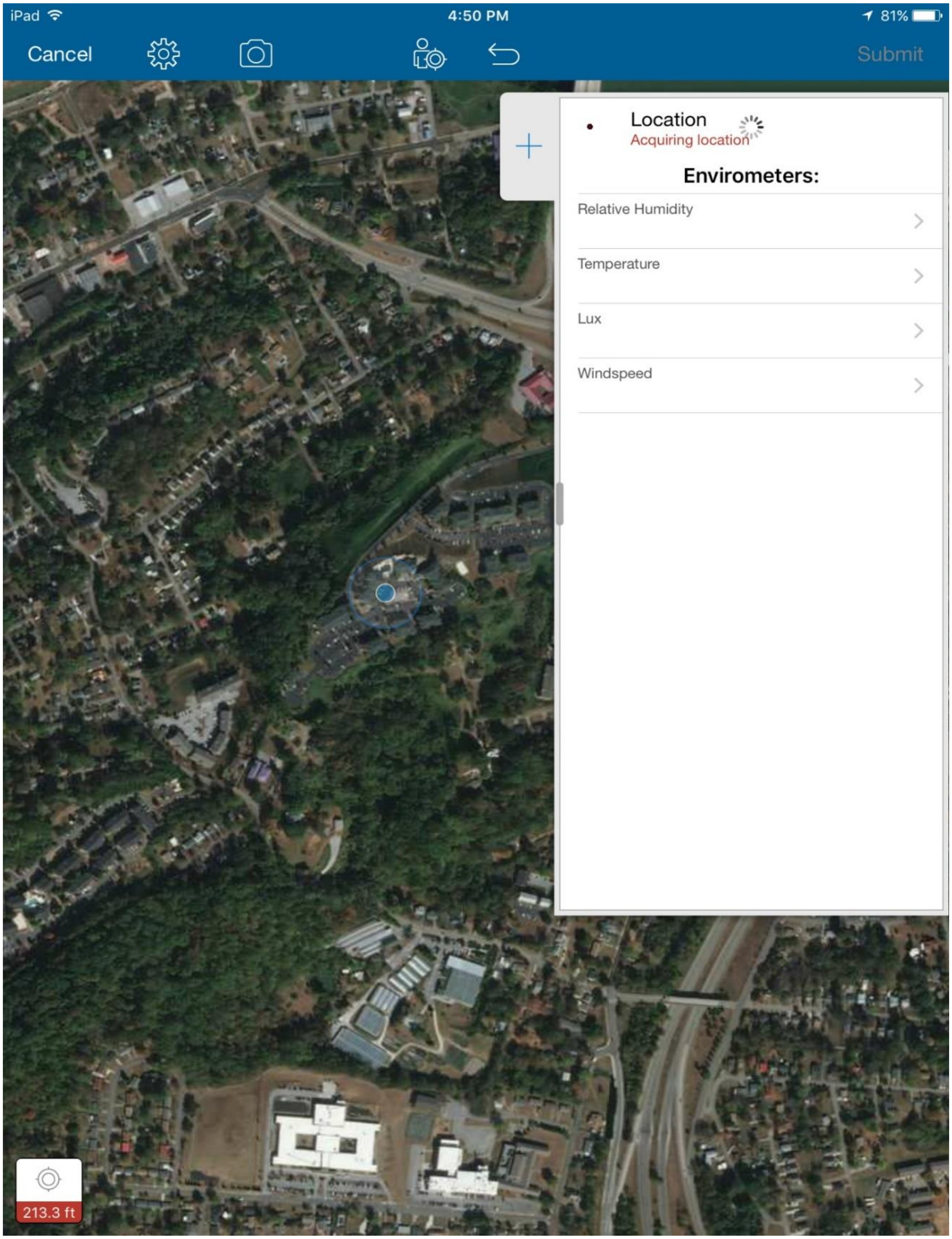


Figure 3.2: Collector App V1.1 (Envirometer Feature Class Creation)

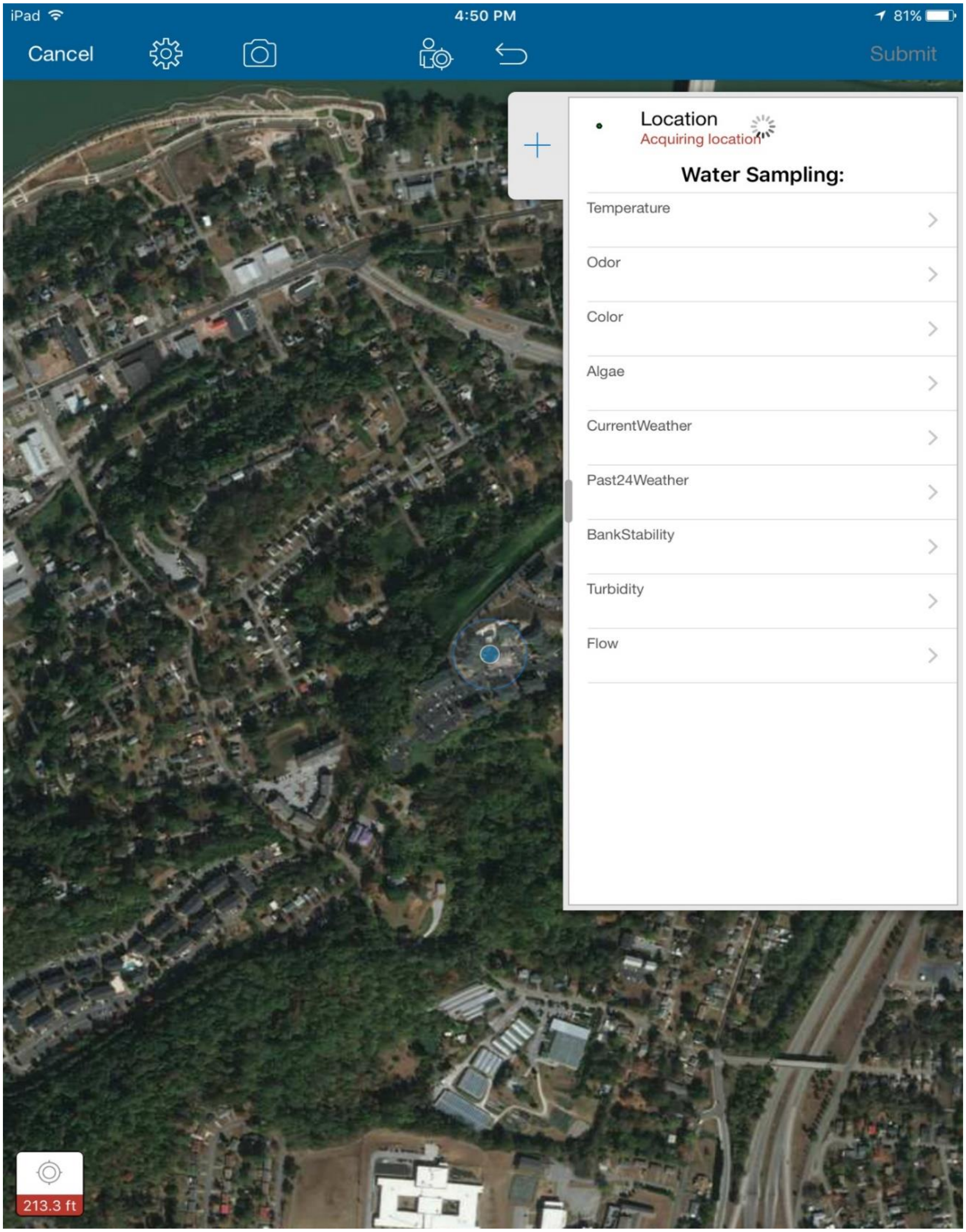


Figure 3.3: Collector App V1.1 (Water Sampling Feature Class Creation)

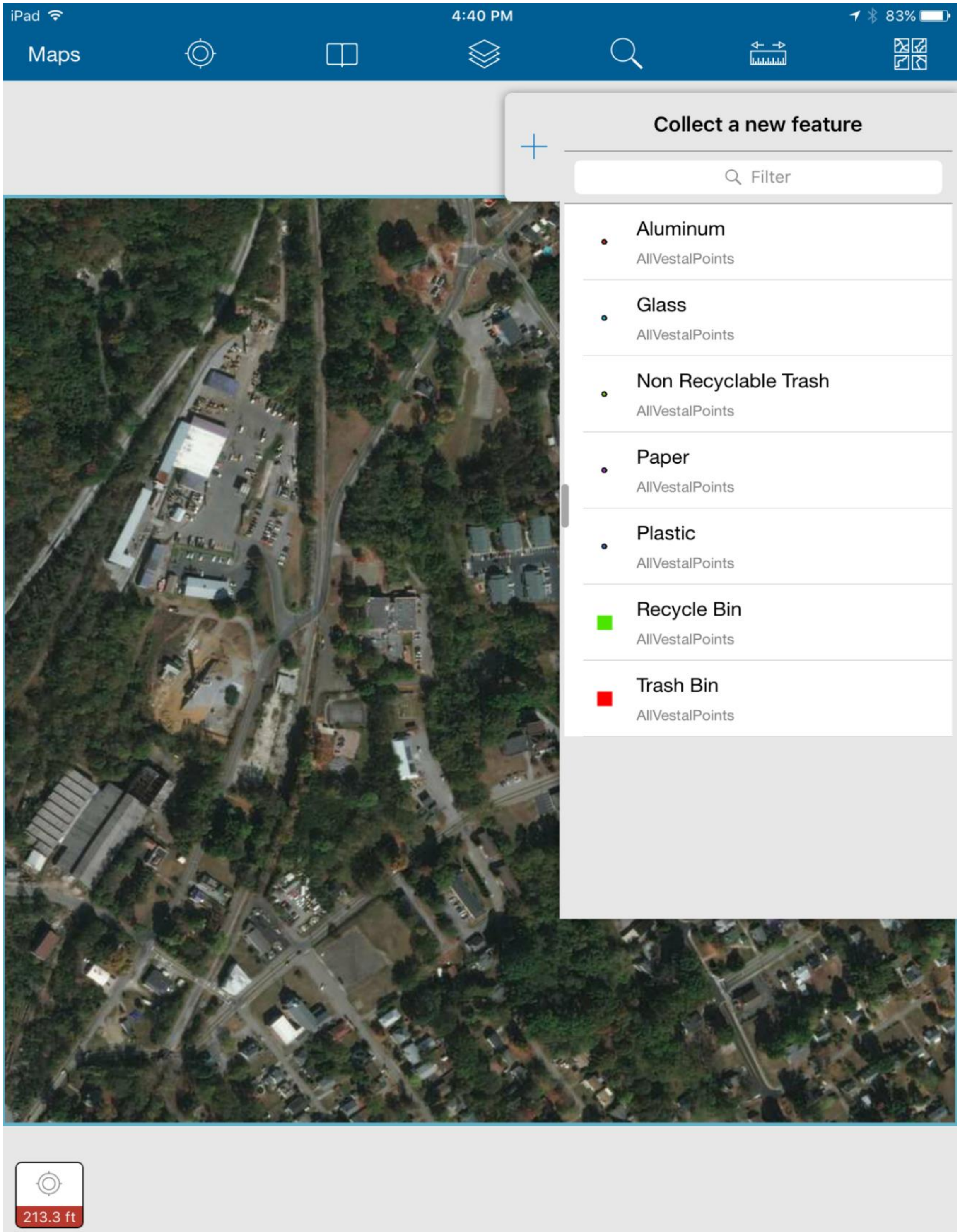


Figure 3.4: Collector App V1.2 (Trash and Recycling Feature Class Creation)

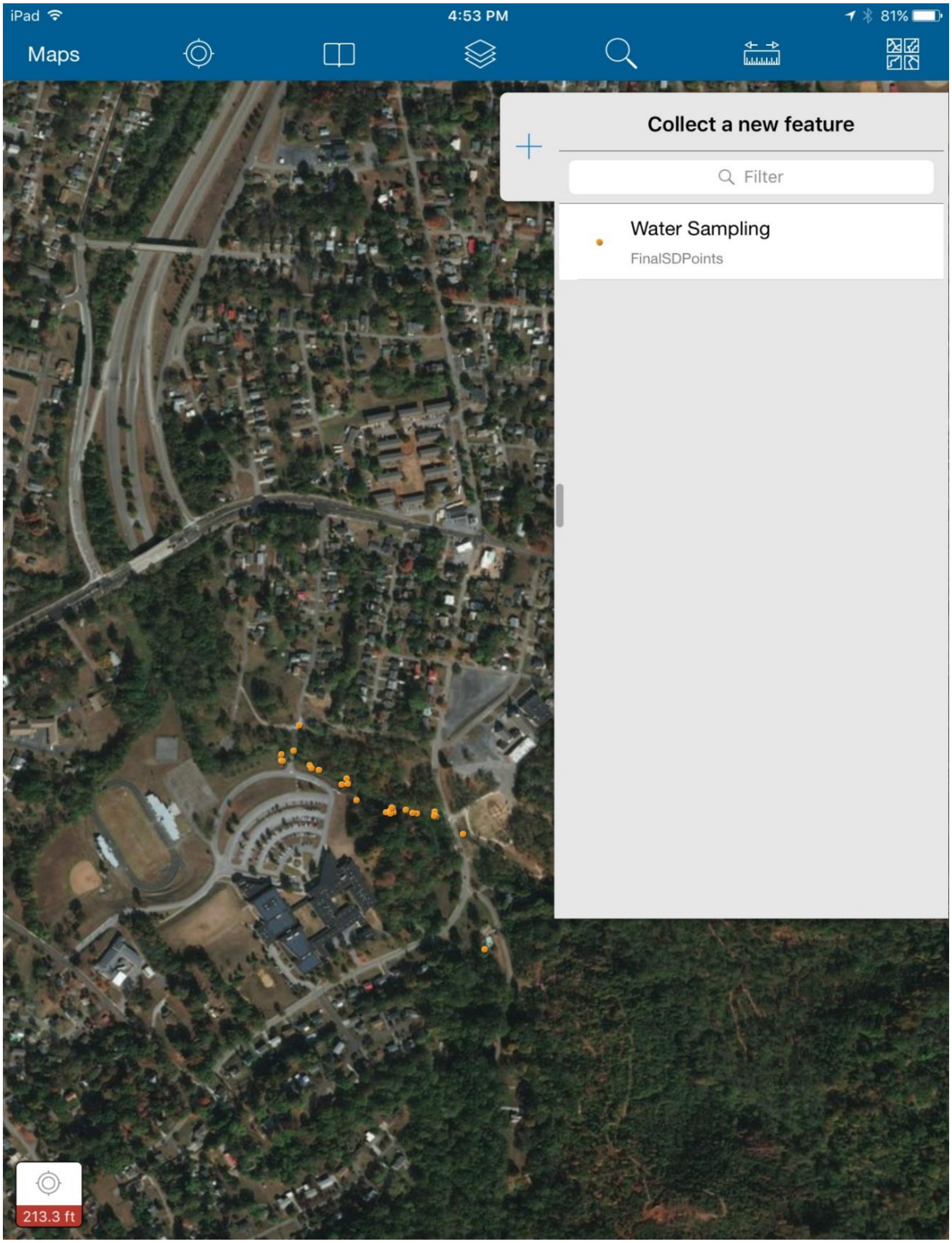


Figure 3.5: Collector App V2 (Water Sampling Feature Class Creation)

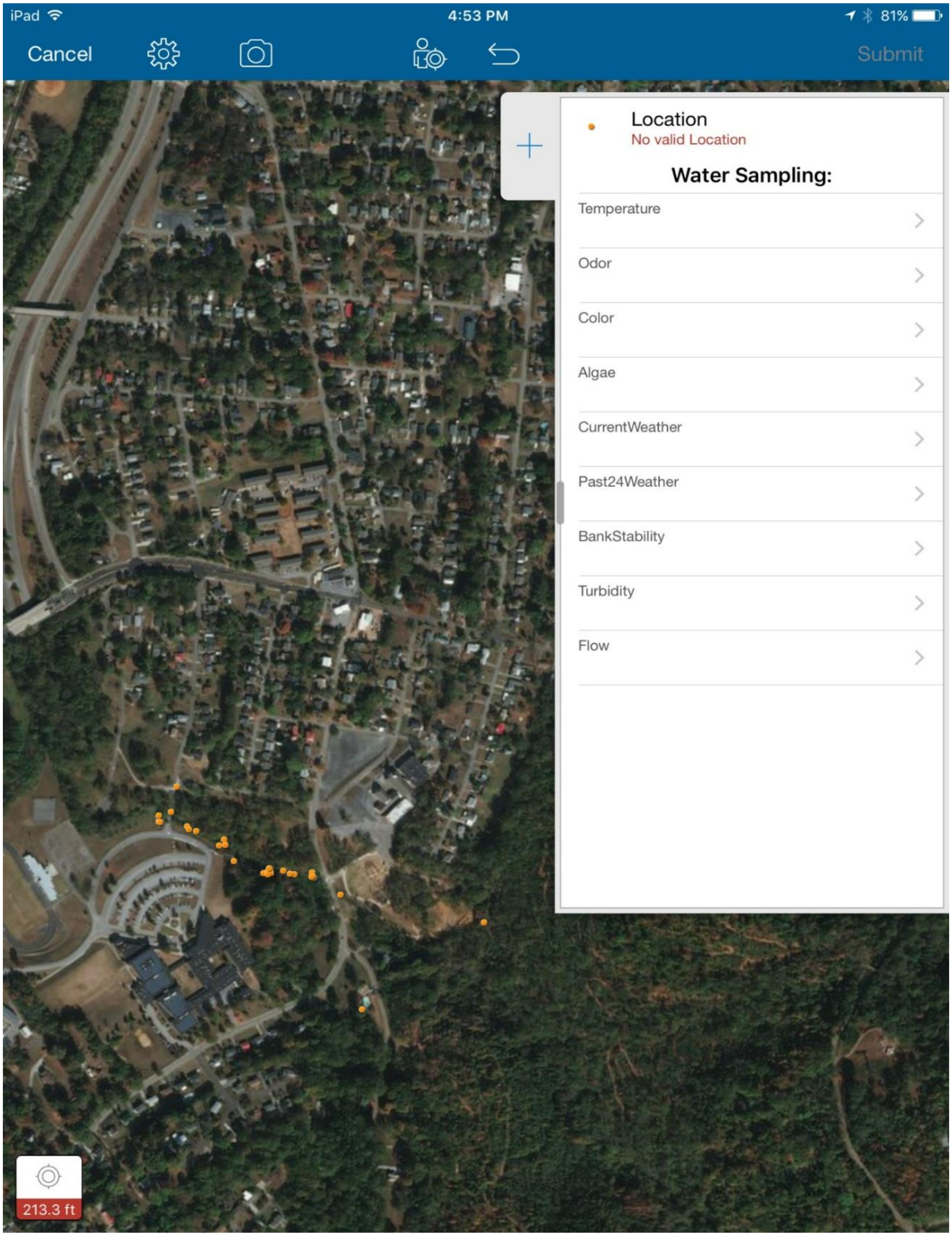


Figure 3.6: Collector App V2 (Water Sampling Feature Class Attribute Selection Screen)

Figure 3.7: Students and volunteers examining a water monitoring station during summer camps

Figure 3.8: Students conducting chemical analysis on water samples

Figure 3.9: An instructor explains sampling protocol to students during summer camps

Figure 3.10: Flowchart detailing creation of mobile app (cont. on next page)

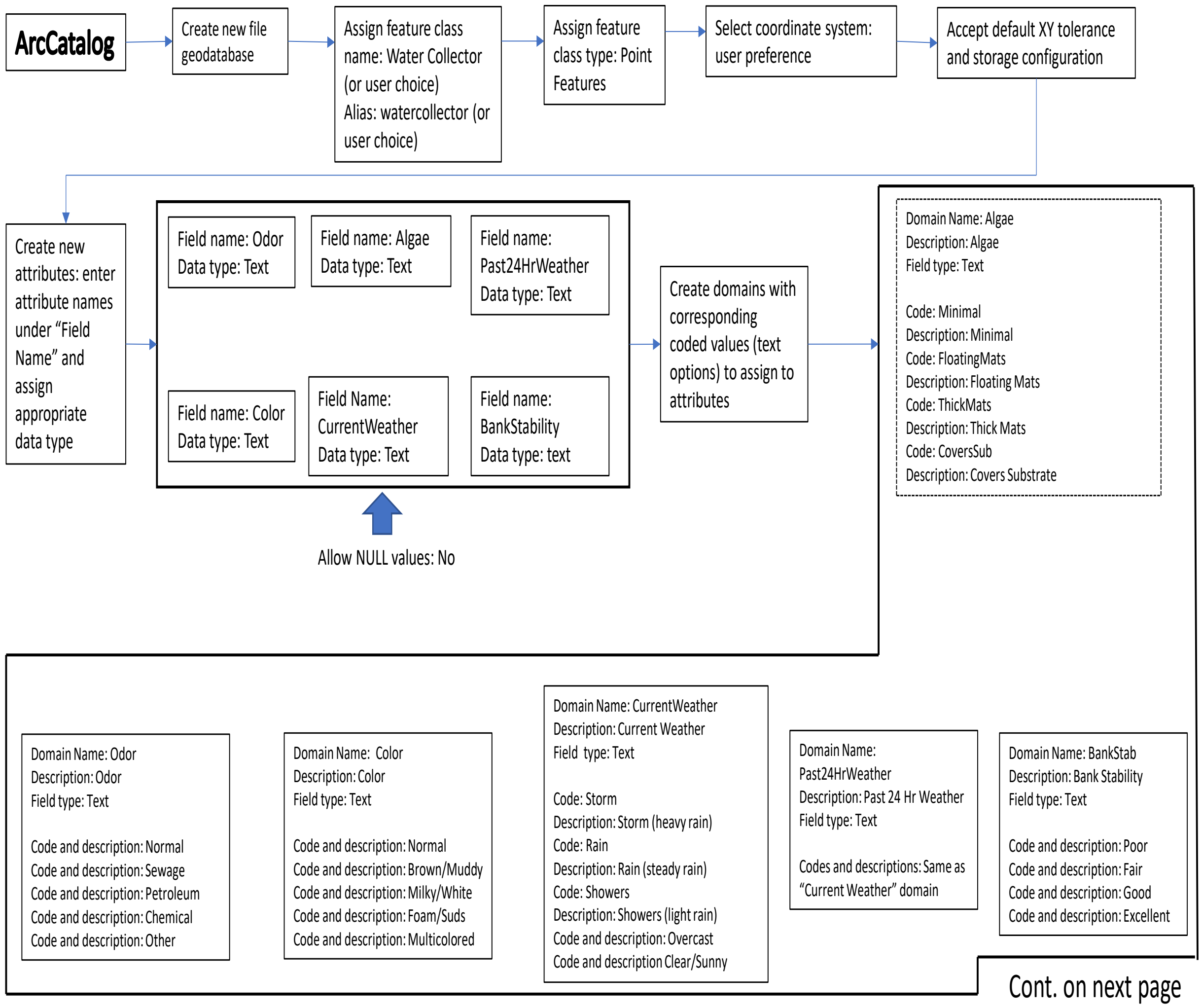


Figure 3.10 cont.

Cont.

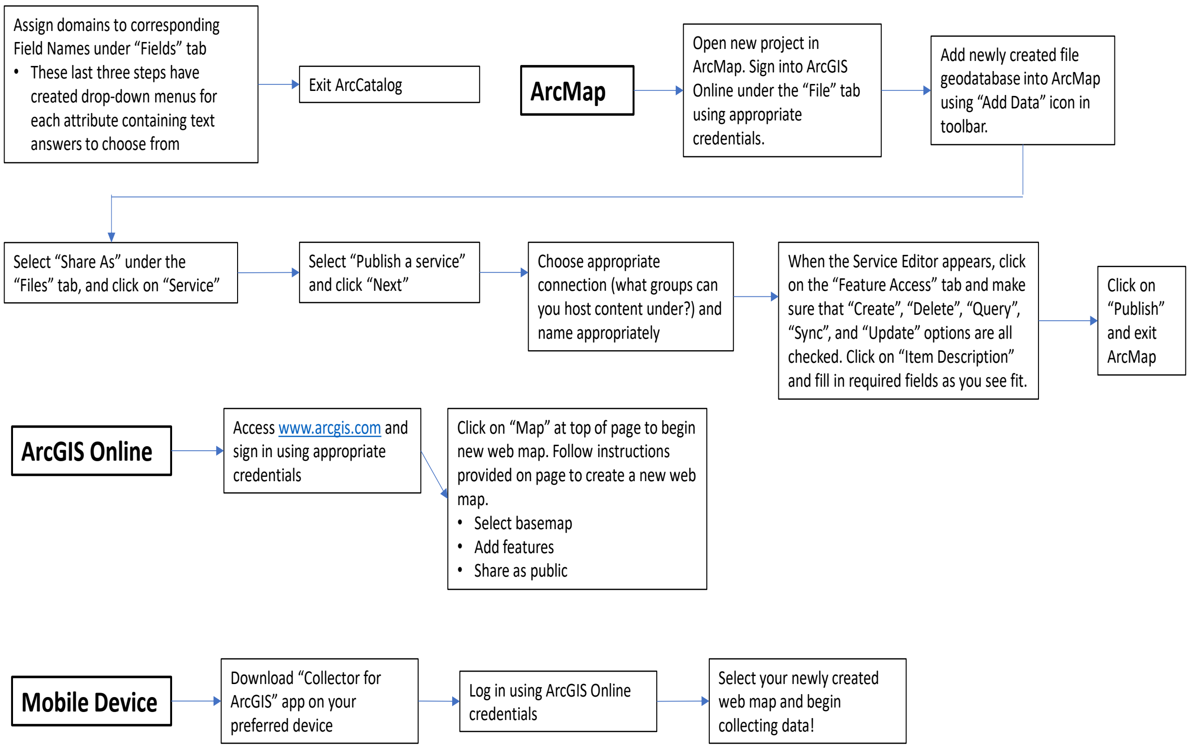


Table 1: Background questions exploring opinions and uses of technology

Question	A	B	C	D	E
"How frequently do you use technology in your free time (think computers, iPads, video games, etc.)?"	Never	Once per day	Multiple times per day	Once per week	Multiple times per week
"How frequently do you use technology to aid you in homework?"	Never	One or two times per week	Several times per week	N/A	N/A
"How frequently do you use technology in your classes at school?"	Never	One class per week	Two classes per week	More than two classes per week	N/A
"Which of these electronics do you use the most in your daily life?"	Smartphone	Computer	iPad/Tablet	Other (please provide name______)	N/A
"Would you prefer to read information from a textbook or from an electronic device (computer, tablet, etc.)?"	Textbook	Electronic Device	N/A	N/A	N/A

Table 2: Pre-survey Likert-scale responses ranking comfort and preferences towards technology in the classroom

Likert-scale Questions	Average Response Score
"I am a hands-on learner. (Do you learn better by physically doing what you are learning about, or just reading about it?"	1.56
"I enjoy learning to use new technology."	1.96
"I feel comfortable using computers and other technology. I feel confident in my understanding of how they work."	2.04

Table 3: Post-survey Likert-scale responses gauging opinions concerning the app students used as well as how this kind of technology could be useful in other courses

Likert-scale Questions	Average Response
"I would like to see more activities that use technology like this in my other classes."	1.64
"Being able to view a map of the area we were working in helped me better visualize the concepts we were learning about."	2.0
"I remained interested during the entire stream walk assessment."	2.08
"I think this application would be useful in other science courses."	1.52

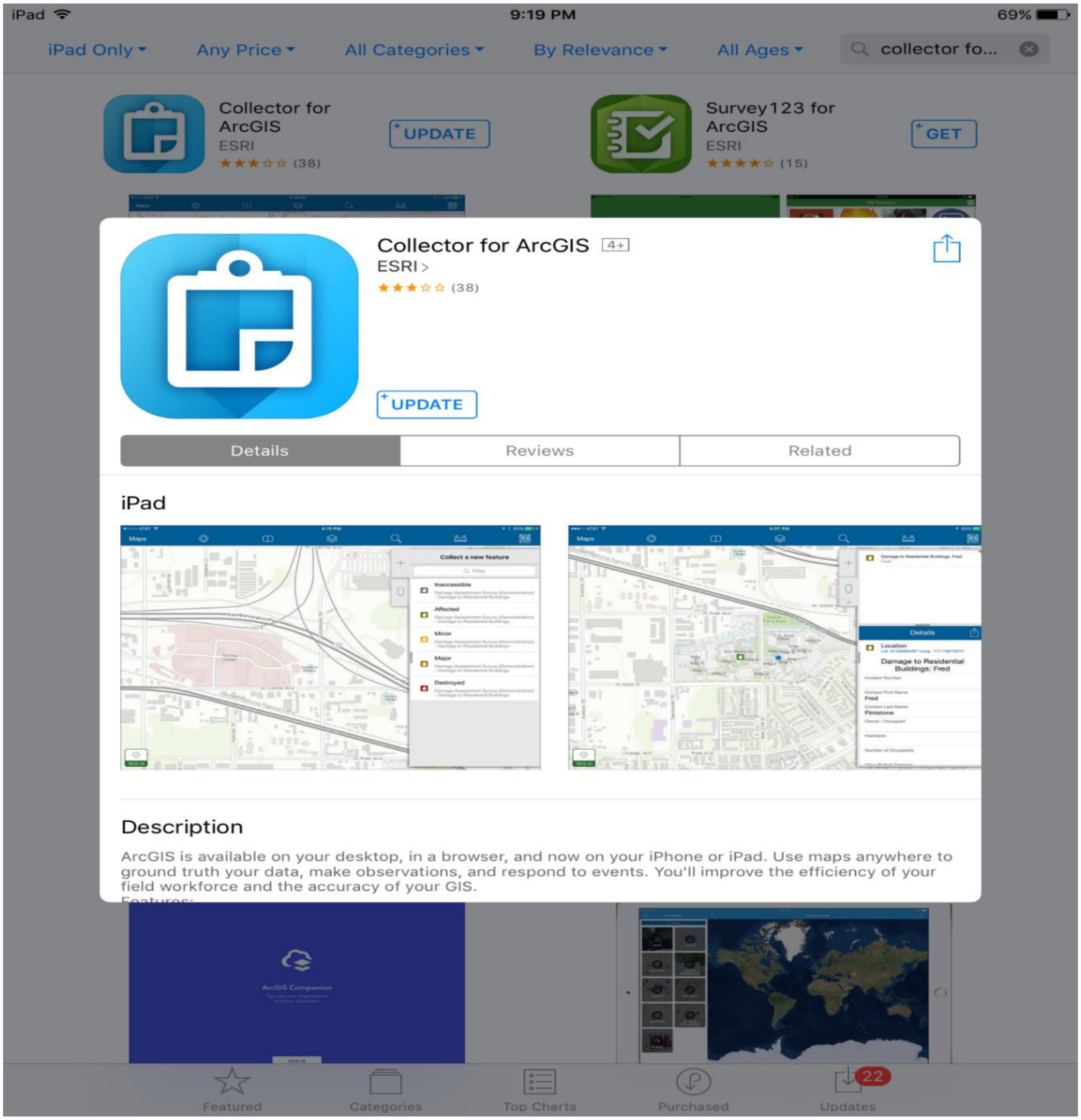
Table 4: Repeated Likert-scale responses comparing pre- and post-survey responses and analyzing significance of changes

Likert-scale Questions	Pre-Survey Combined Average Score	Male Pre-Survey Average Score	Female Pre-Survey Average Score	Post-Survey Average Score	Male Post-Survey Average Score	Female Post-Survey Average Score	Paired t-test Results for Combined Scores	Male Paired t-test Results	Female Paired t-test Results	Power Analysis for Combined t-test
"Technology has a positive impact on our lives."	2.28	2.33	2.25	1.56	1.56	1.56	0.002	0.02	0.08	86%
"I enjoy getting to use new technology in the classroom."	1.92	1.89	1.94	1.36	1.34	1.38	0.01	0.01	0.01	93%
"Using technology makes me feel more interested in lesson being taught."	2.28	2.56	2.13	1.80	1.78	1.81	0.15	0.02	0.21	30%

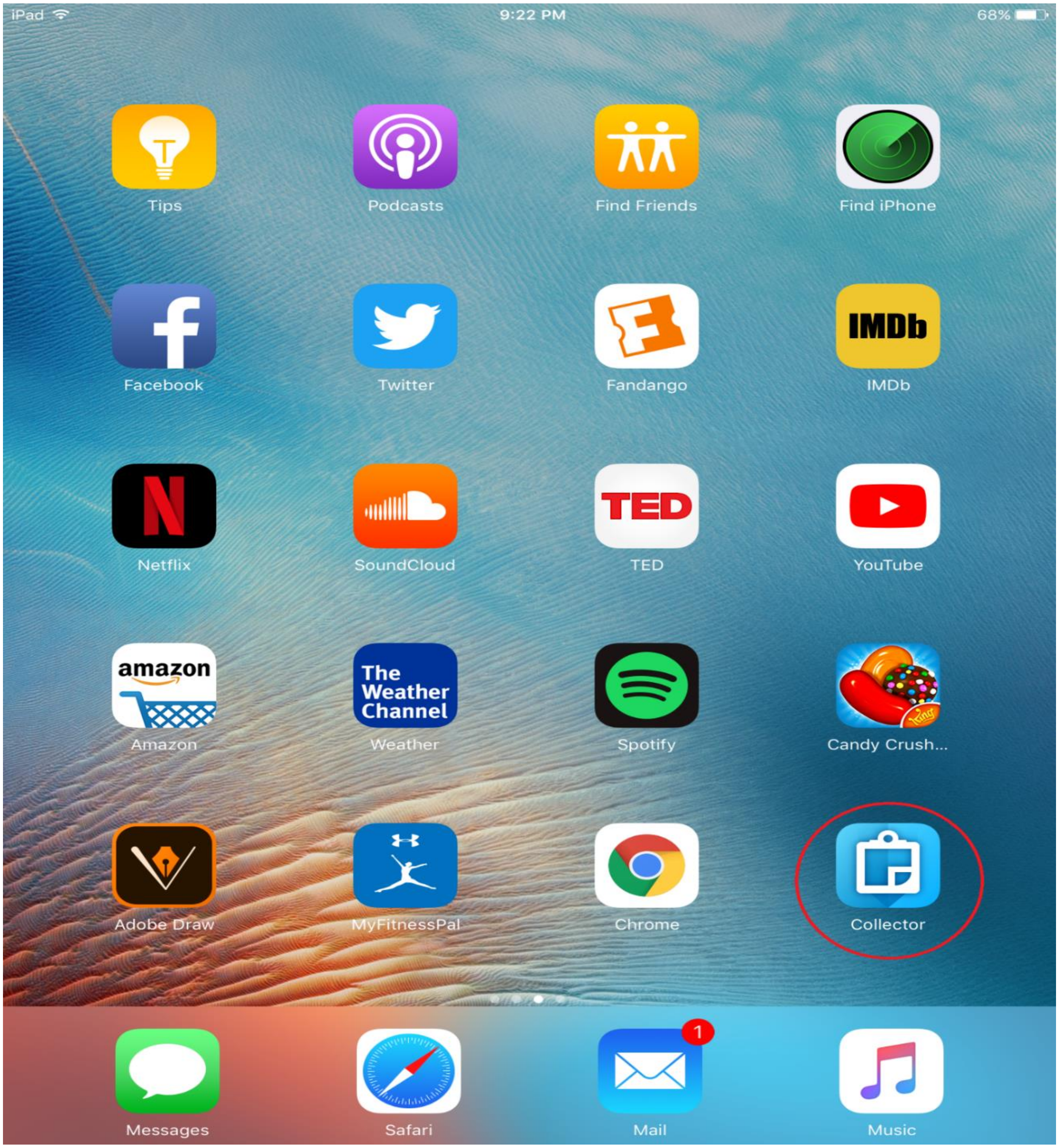
User Manual for Mobile Data Collection App

Evan Norton

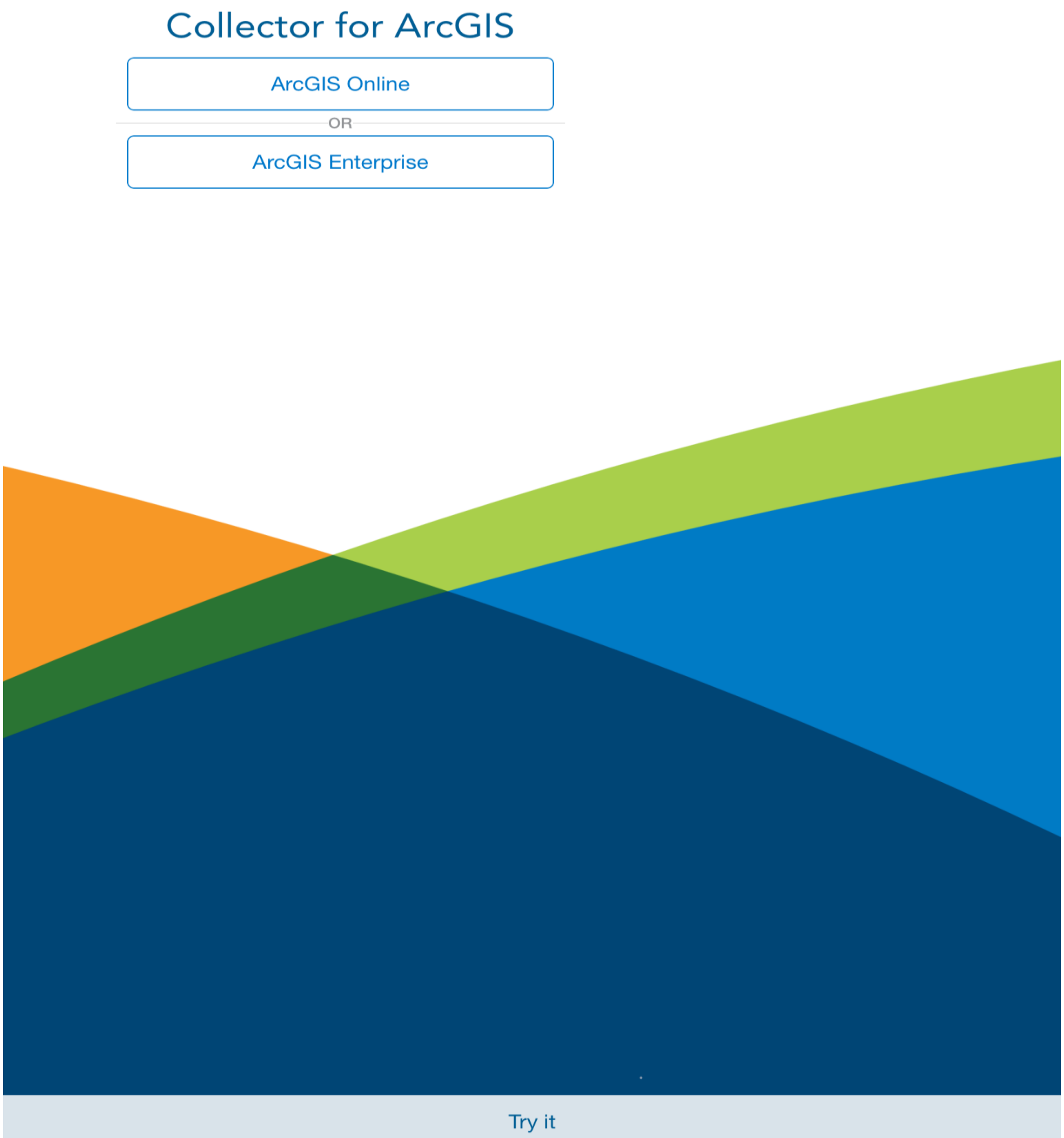
August 2018



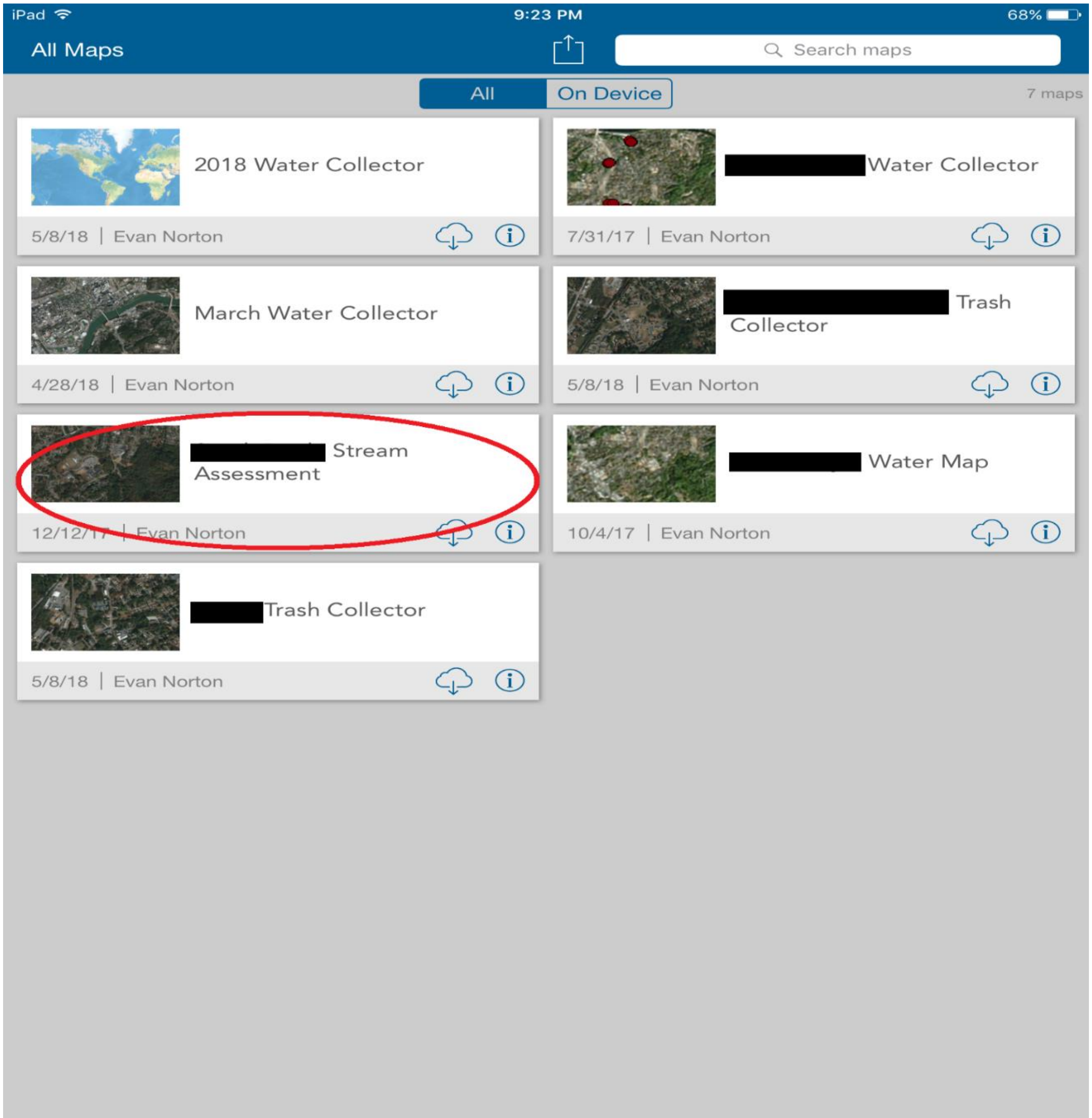
- From your mobile device's store, search for "Collector for ArcGIS", created by ESRI.
- Upon installing, allow permission for app to access your device's location and camera (this may be asked again later when app is in use).



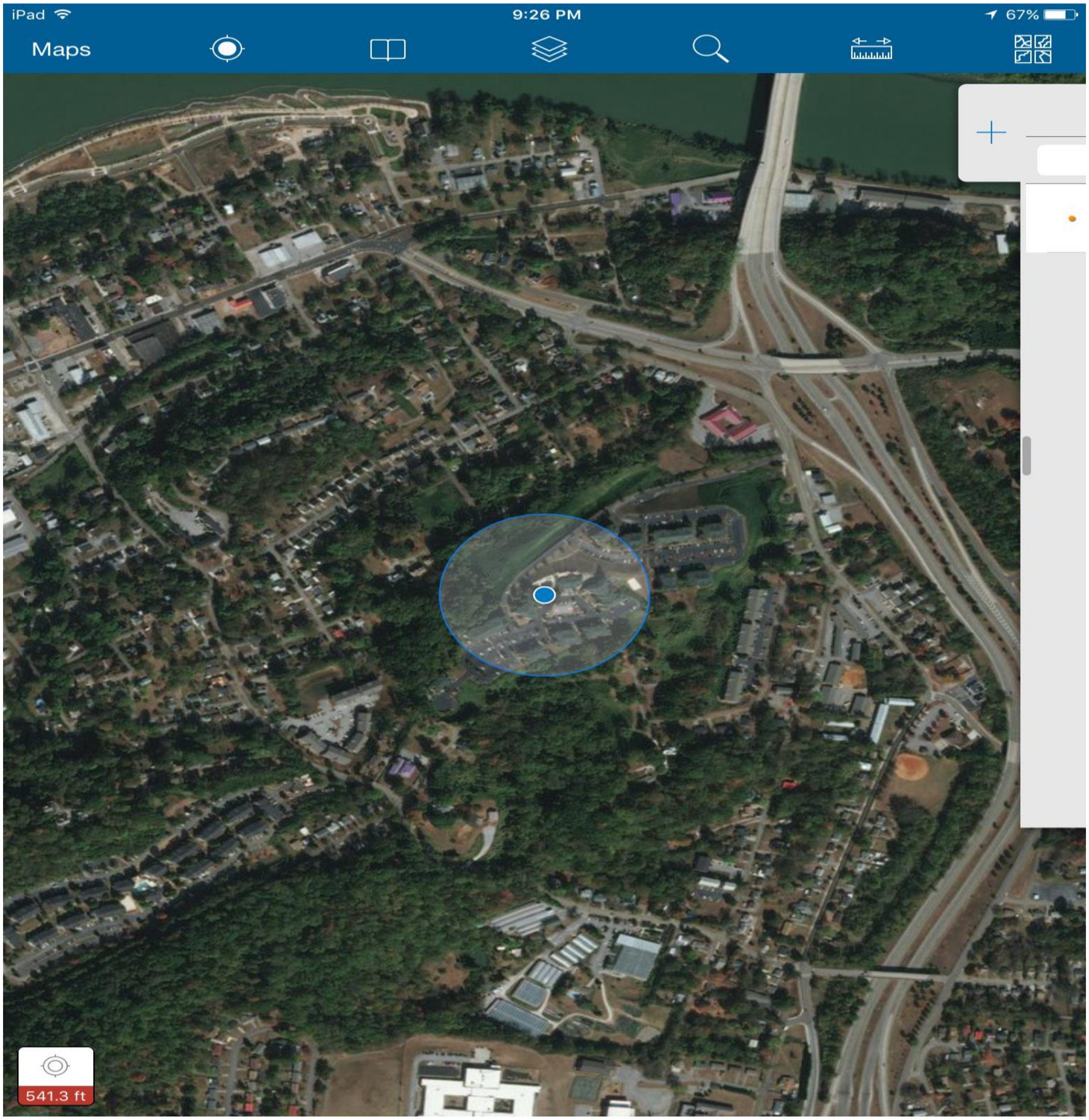
- After installing app onto your device, it will be represented by an icon resembling a blue clipboard, with the word “Collector” listed underneath.



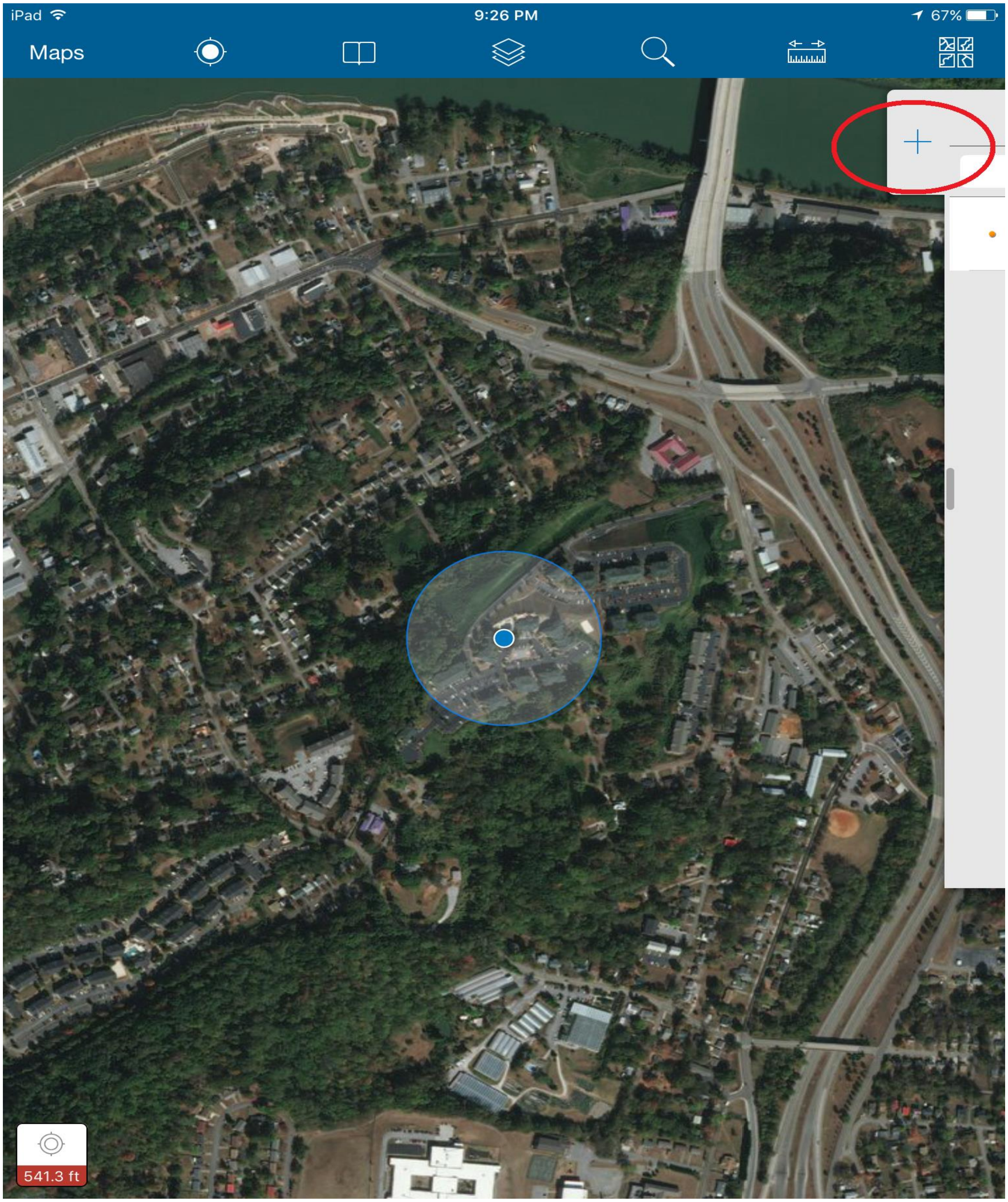
- Select ArcGIS Online when prompted to make a login selection.
    - Use the following credentials:
        - Username: BoysGirlsClub01
        - Password: password2



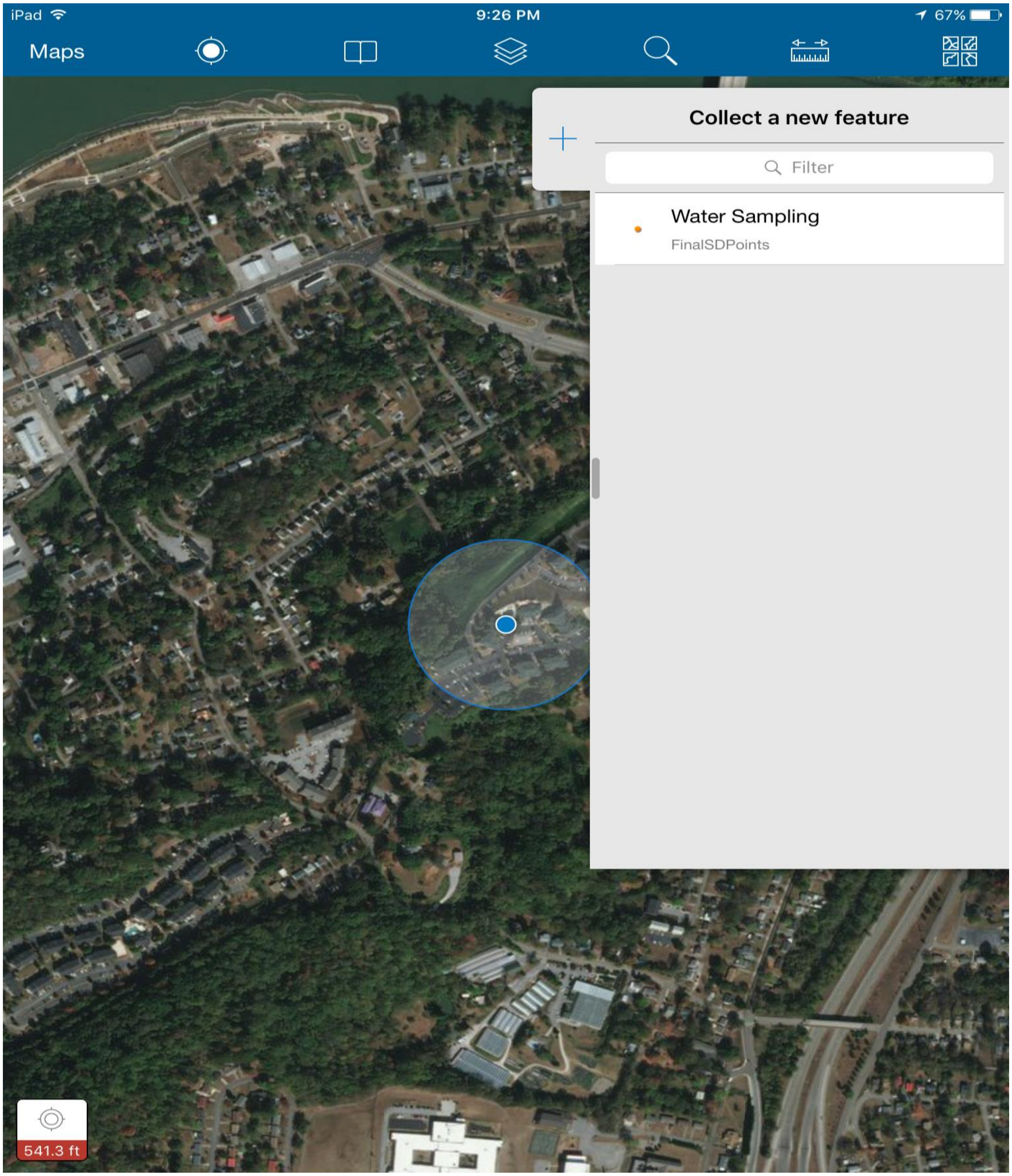
- After logging in, you will see all the web maps connected to your username. Notice at the top of the screen, a tab can be found that says “On Device”; this is where we can download a web map to use in the field if our study site does not have internet access.
- The app used for this thesis was “XXXXX Stream Assessment”.
  - Other apps were previous versions or were used for past Boys and Girls Club activities.
  - Several names have been blurred to keep school identity anonymous.



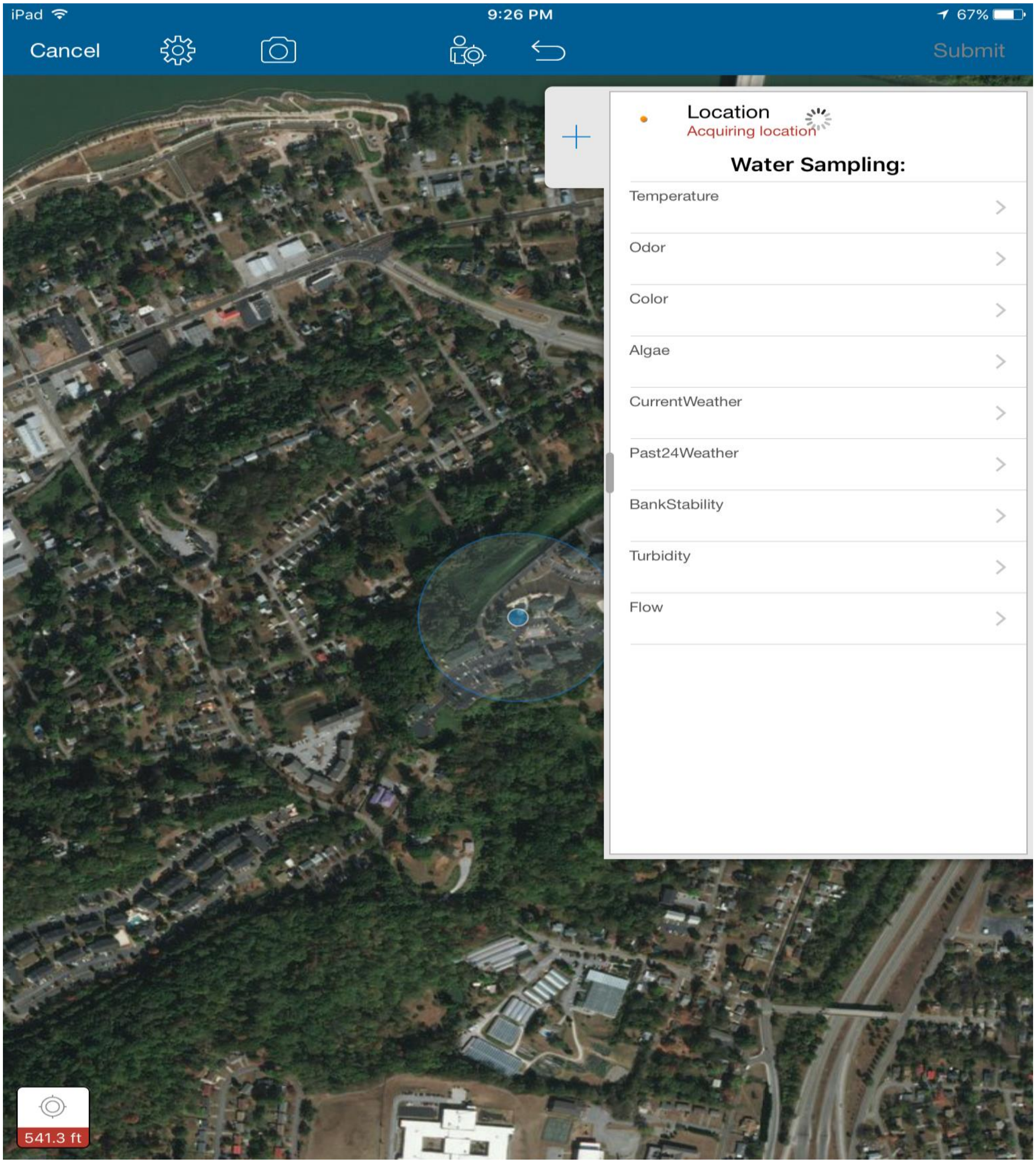
- Upon opening the corresponding web map, a blue dot will jump to where your current location is within the map extent. Notice the blue circle around the dot; this indicates the accuracy of your position as read by the mobile device's location relative to your actual location in real life. The accuracy is noted in the small icon in the bottom left corner. In the instance this screenshot was taken, there was fairly low accuracy. While the device believes we are located at where the blue dot is on the map, realistically, we could be anywhere within the blue circle, or anywhere within 541.3 feet of the blue dot.



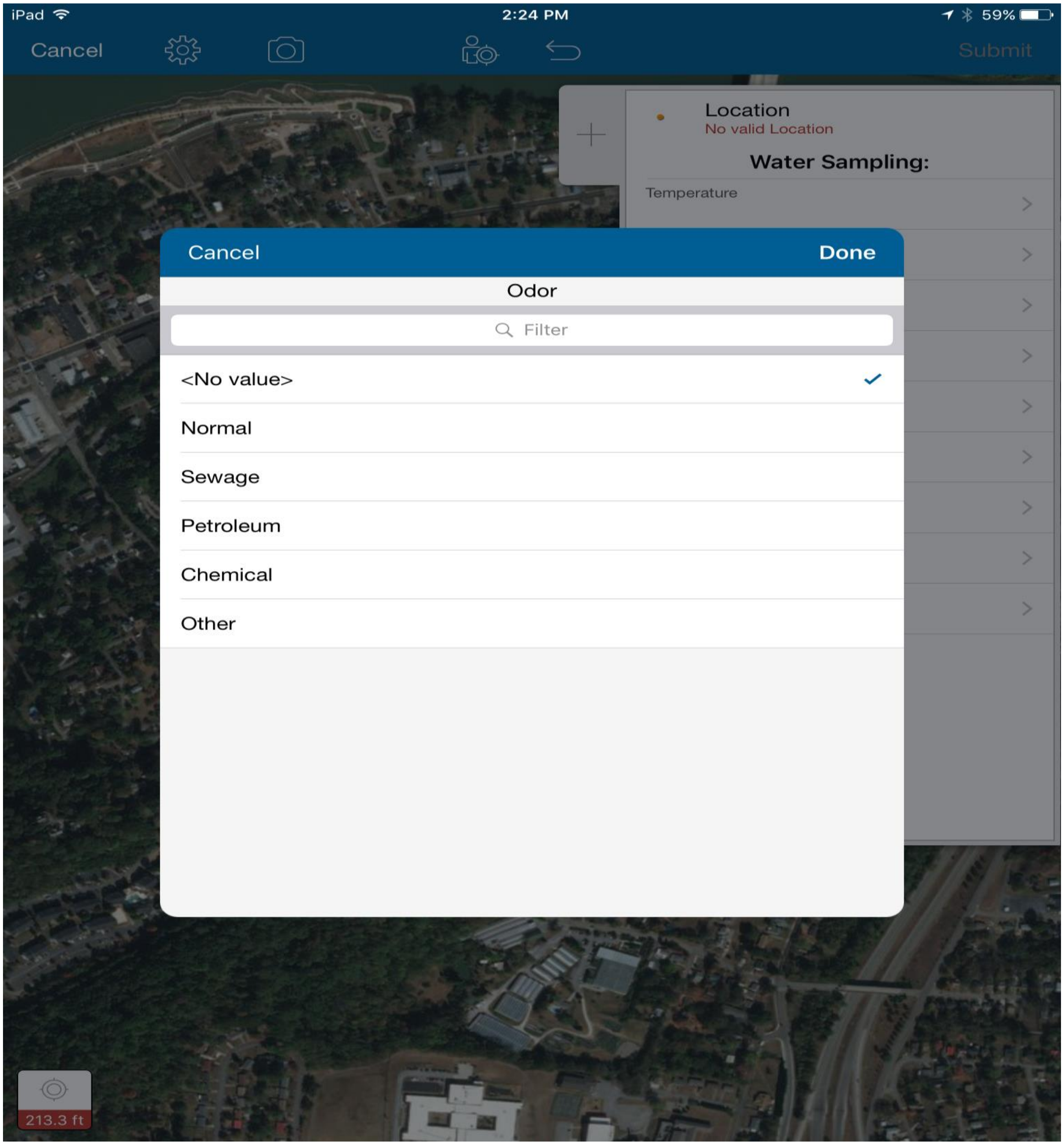
- While in this view, you will notice a sidebar on the right-hand side of the screen. By clicking on the plus sign indicated by the red circle, you can select a feature class to begin collecting data at your location.



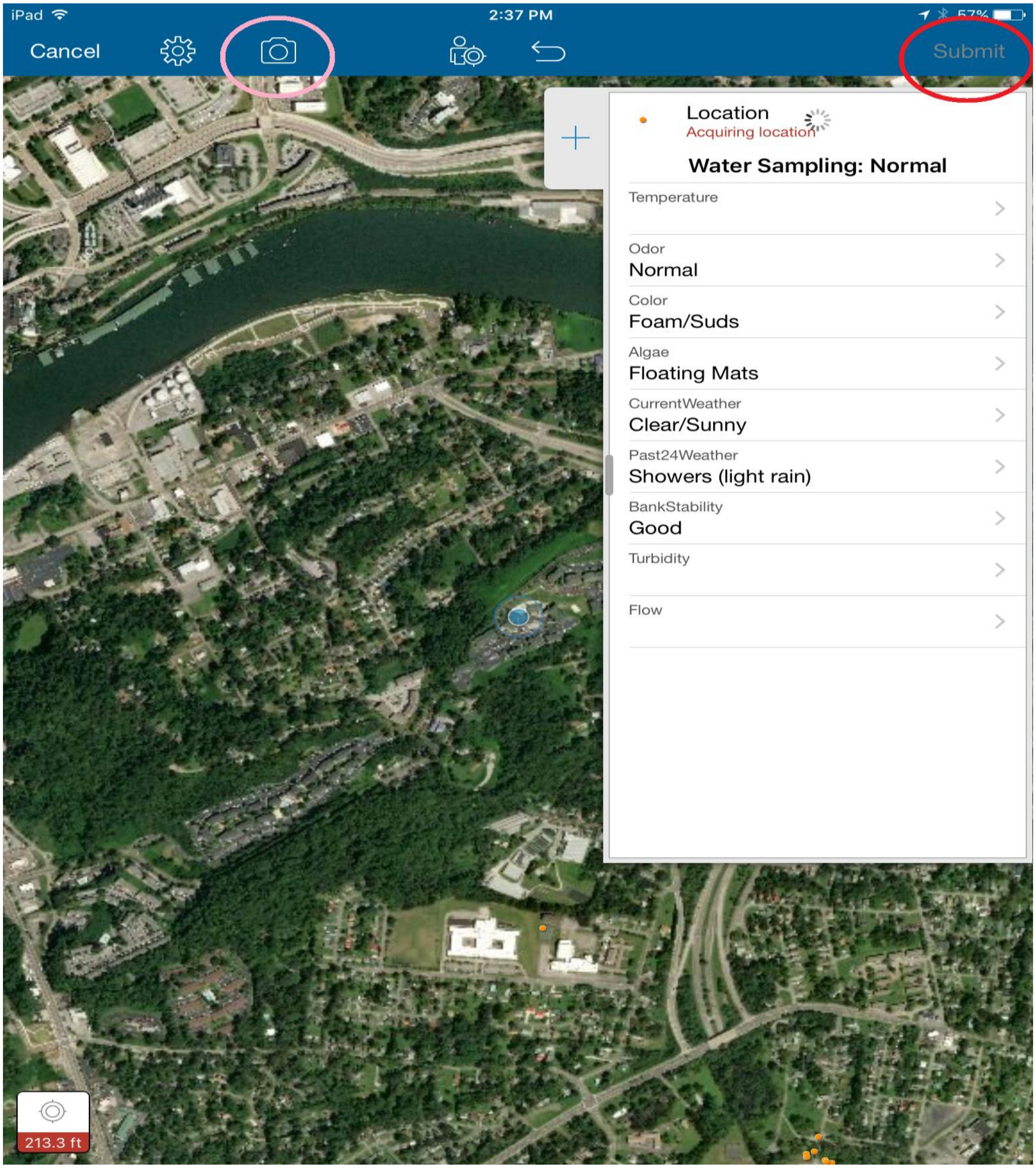
- Clicking the plus sign will activate the feature class selection panel. The feature class used in this stream walk assessment was titled “Water Sampling”. Click on “Water Sampling” to proceed to the next step and begin logging data about your current location.



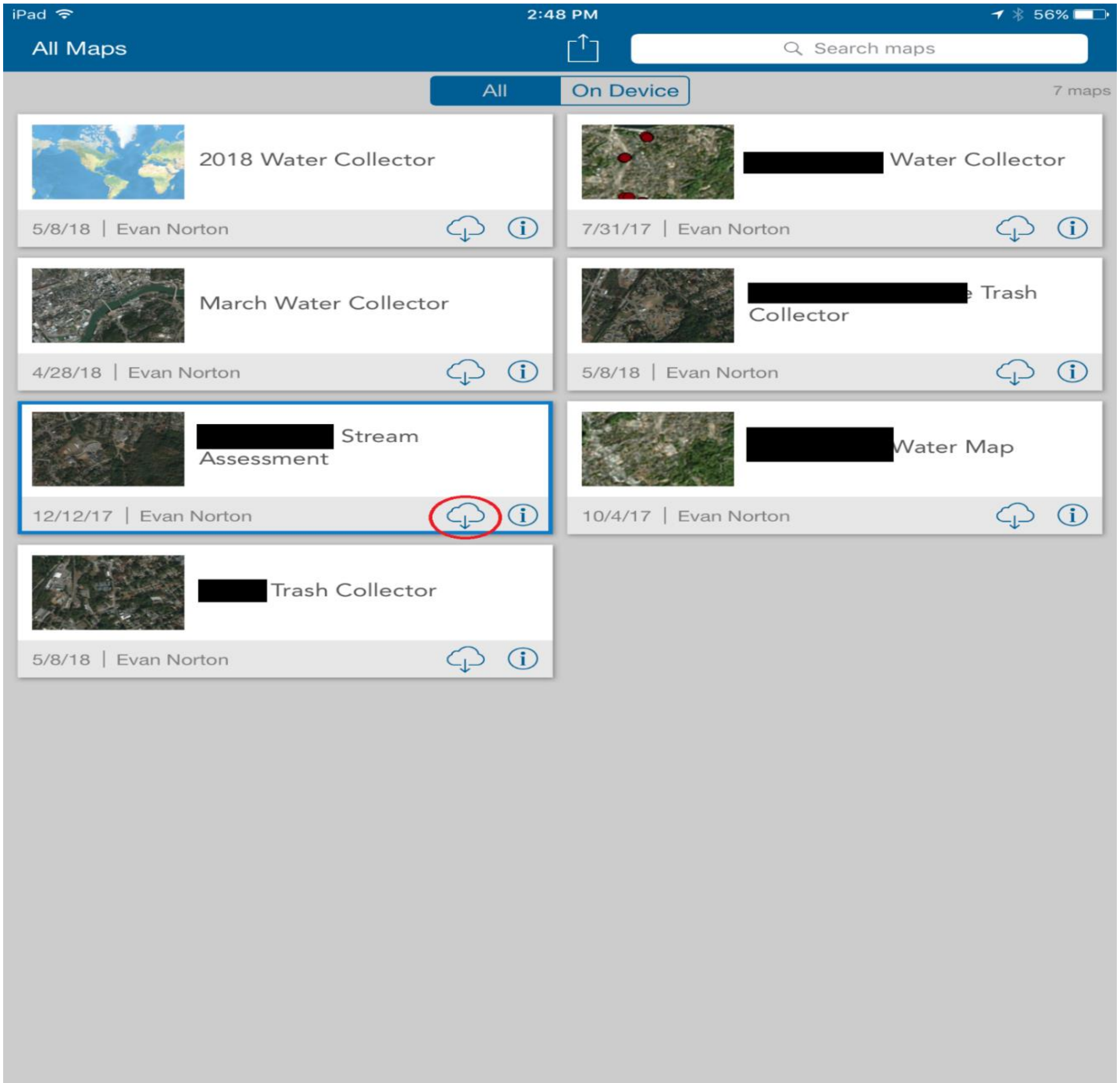
- Your next step is to select which attribute about your location you would like to record first. By clicking/tapping any of the items on the sidebar, you will be able to log information pertaining to the selected attribute. See next page for an example. (Due to changes in itinerary for stream walk day, temperature, turbidity, and flow were not measured during the activity.)



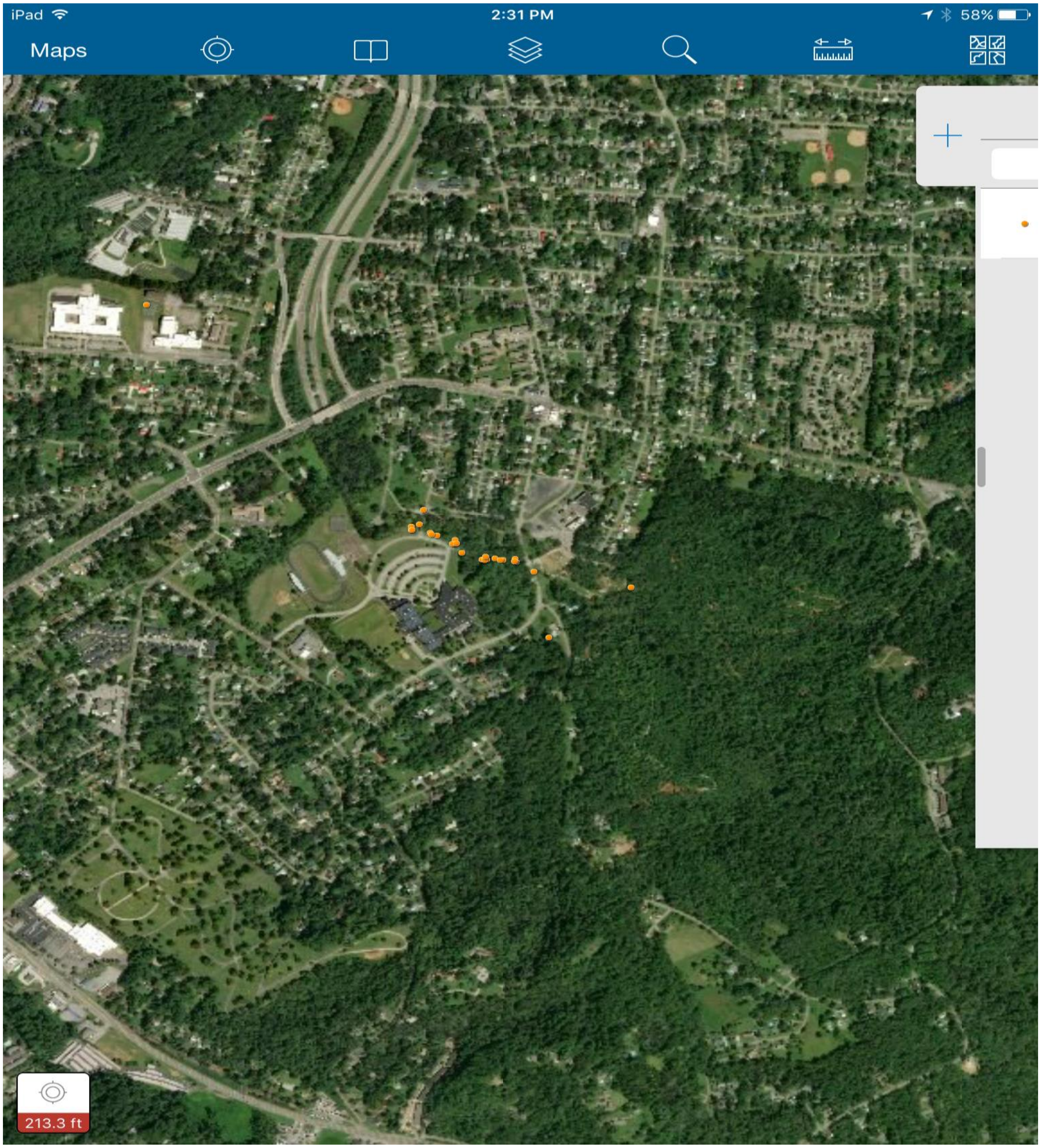
- The attributes logged during this stream walk all presented drop-down options when selected. For example, by choosing to log observations about the stream's odor, the user is presented with the following options to choose from.
- (Notice our location accuracy has improved as our location becomes available to more GPS satellites.)



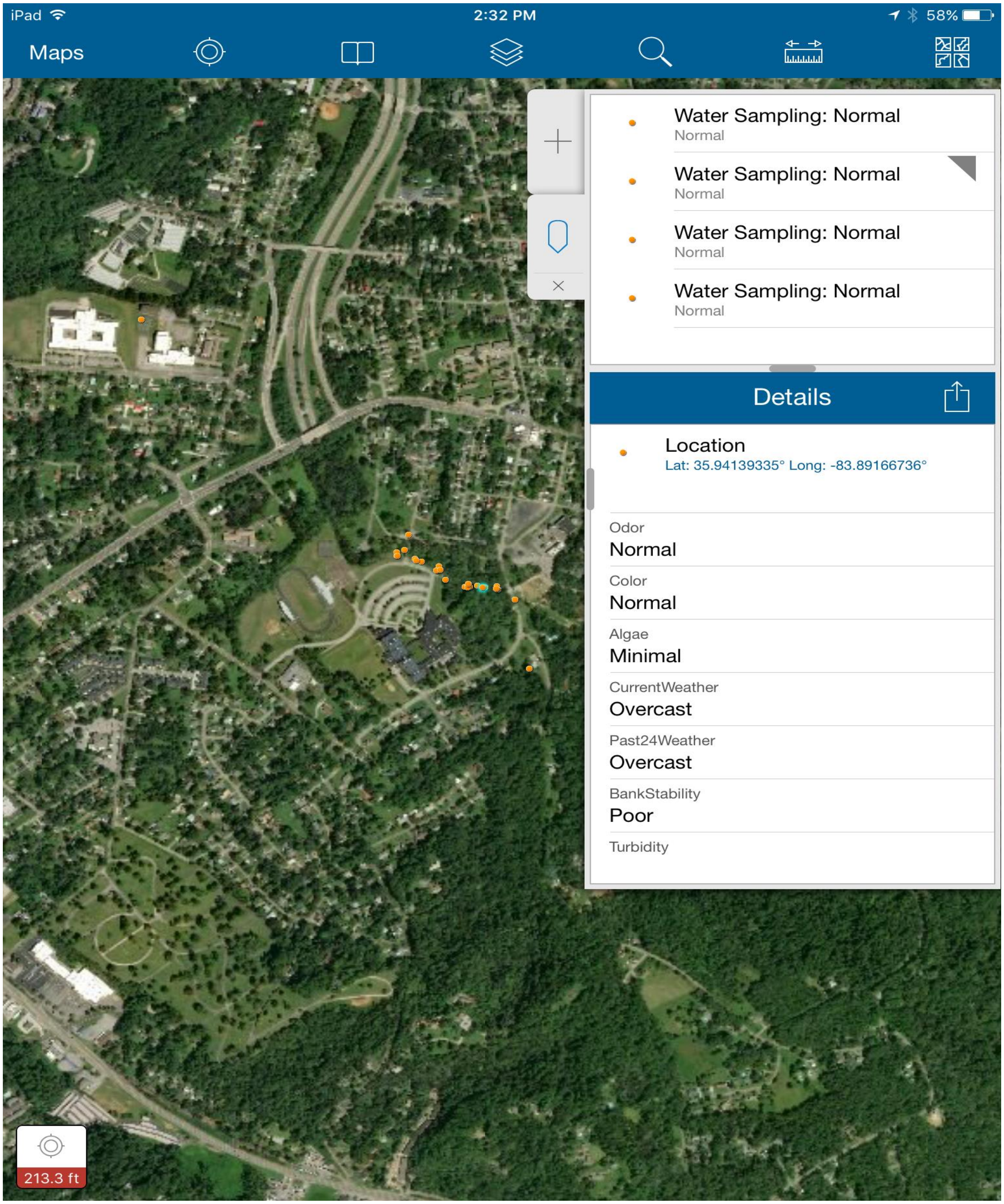
- After all desired attributes have been logged, click on the “Submit” option indicated by the red circle to upload your data to your map
- Notice the pink circle around the camera icon: this icon allows the user to take photos of the location they are documenting to attach to the data point they are about to create



- **This step is only necessary if you do not have internet access while in the field!**
- If no internet access if available at your study site, all app users can upload their collective points to the web map upon connecting to the internet. To do so:
  - Return to list of maps available for account
  - Click the Cloud icon indicated by the red circle (the number of points available to upload will be listed in red beside the icon)
- Upon reopening the web map, the points collected by all app users will be available to view on your device.

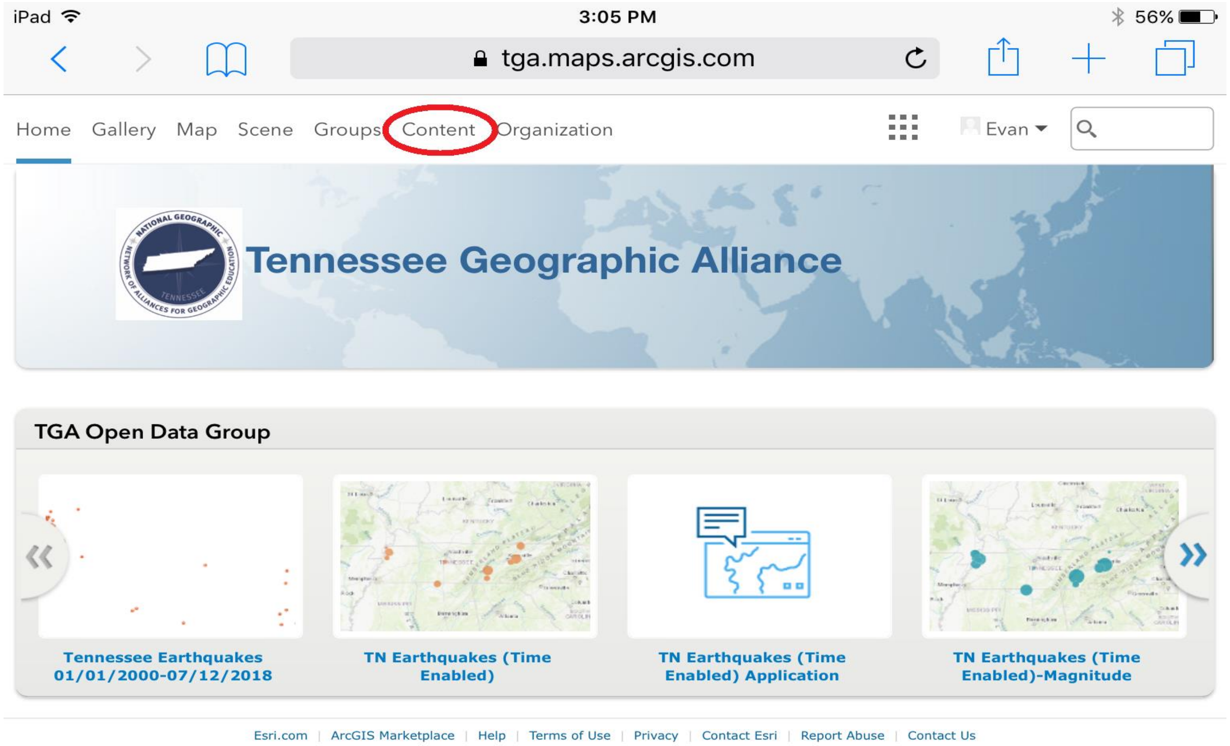


- After submitting all desired points and connecting to internet access, all points collected will be visible on your map.

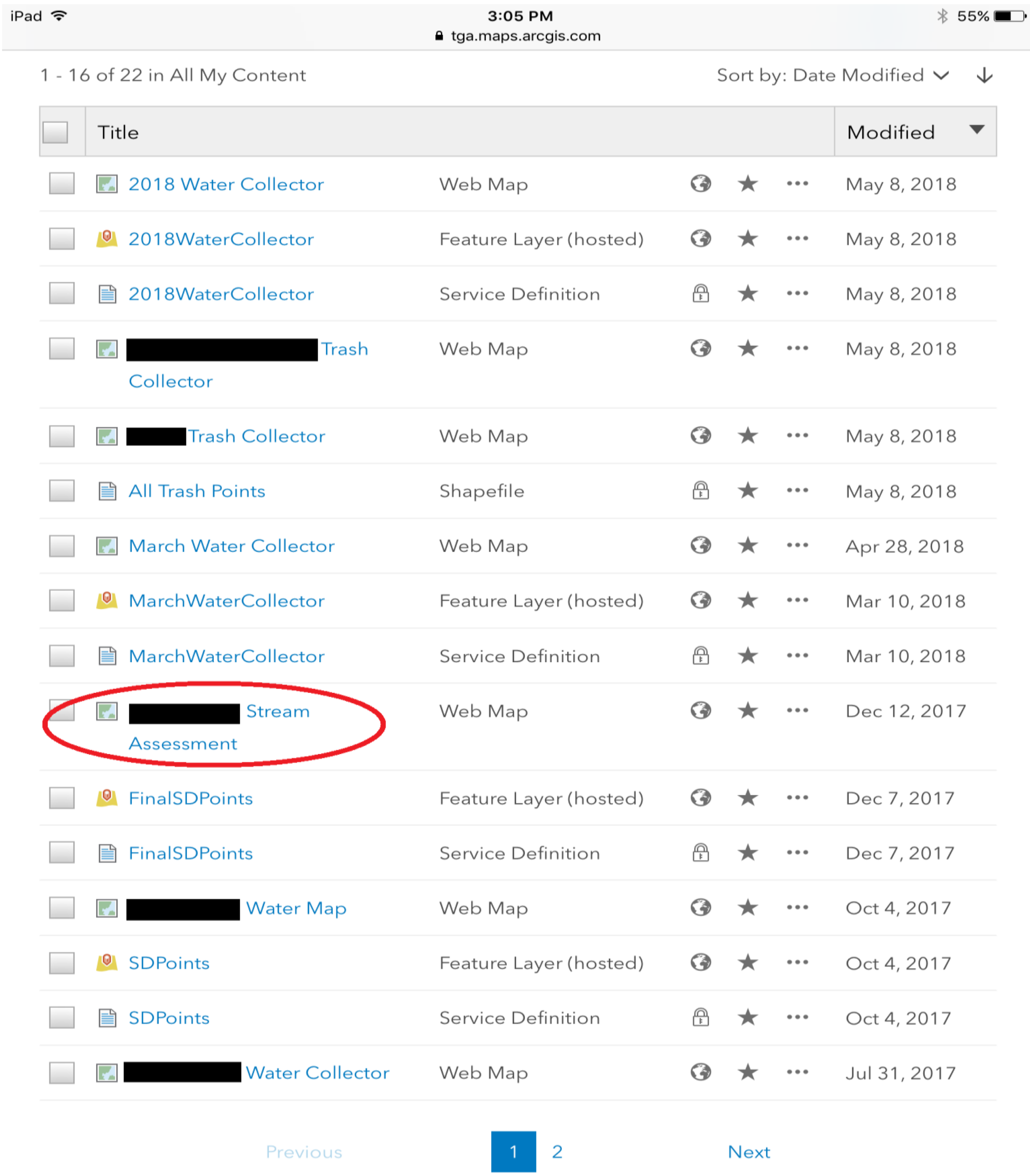


- By tapping on any of these points, you are able to review and compare the data logged at that location.

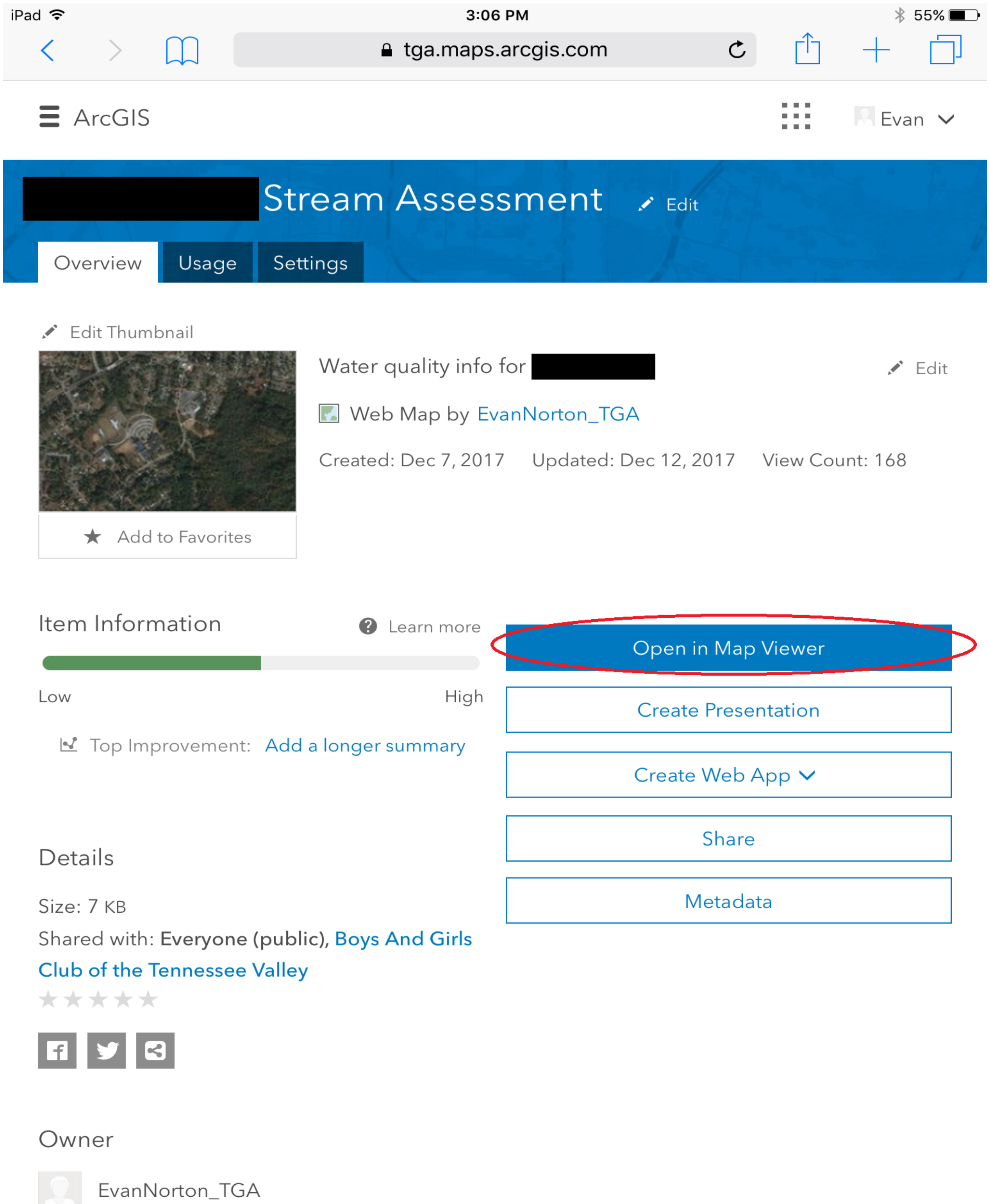
- To view your collected dataset from a laptop or desktop computer, go to www.arcgis.com.
  - Select “Sign In” and sign in using the credentials using the same credential used to sign in to the Collector for ArcGIS app.



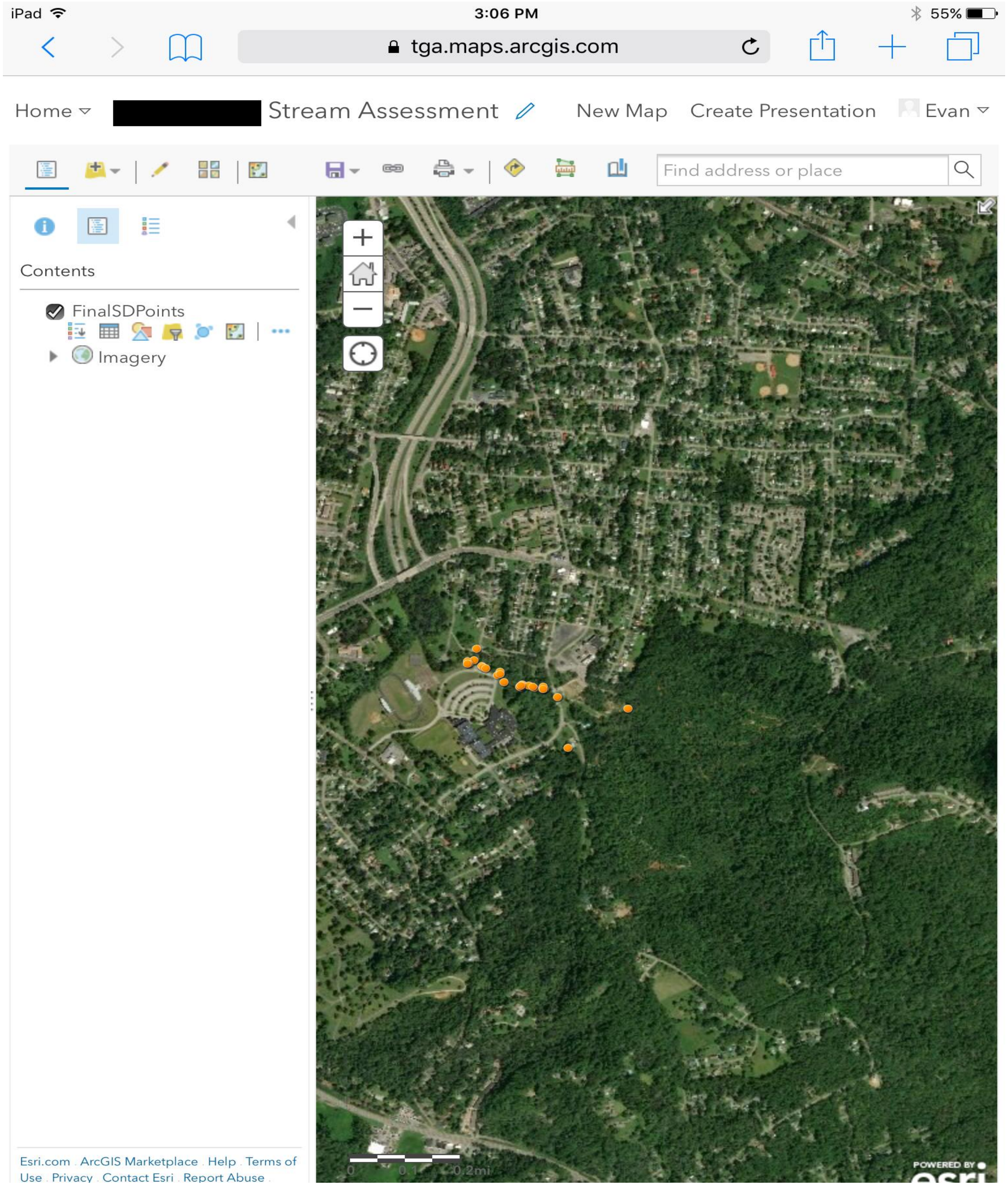
- After logging in, select the "Content" option at the top of the screen to view content associated with your account.



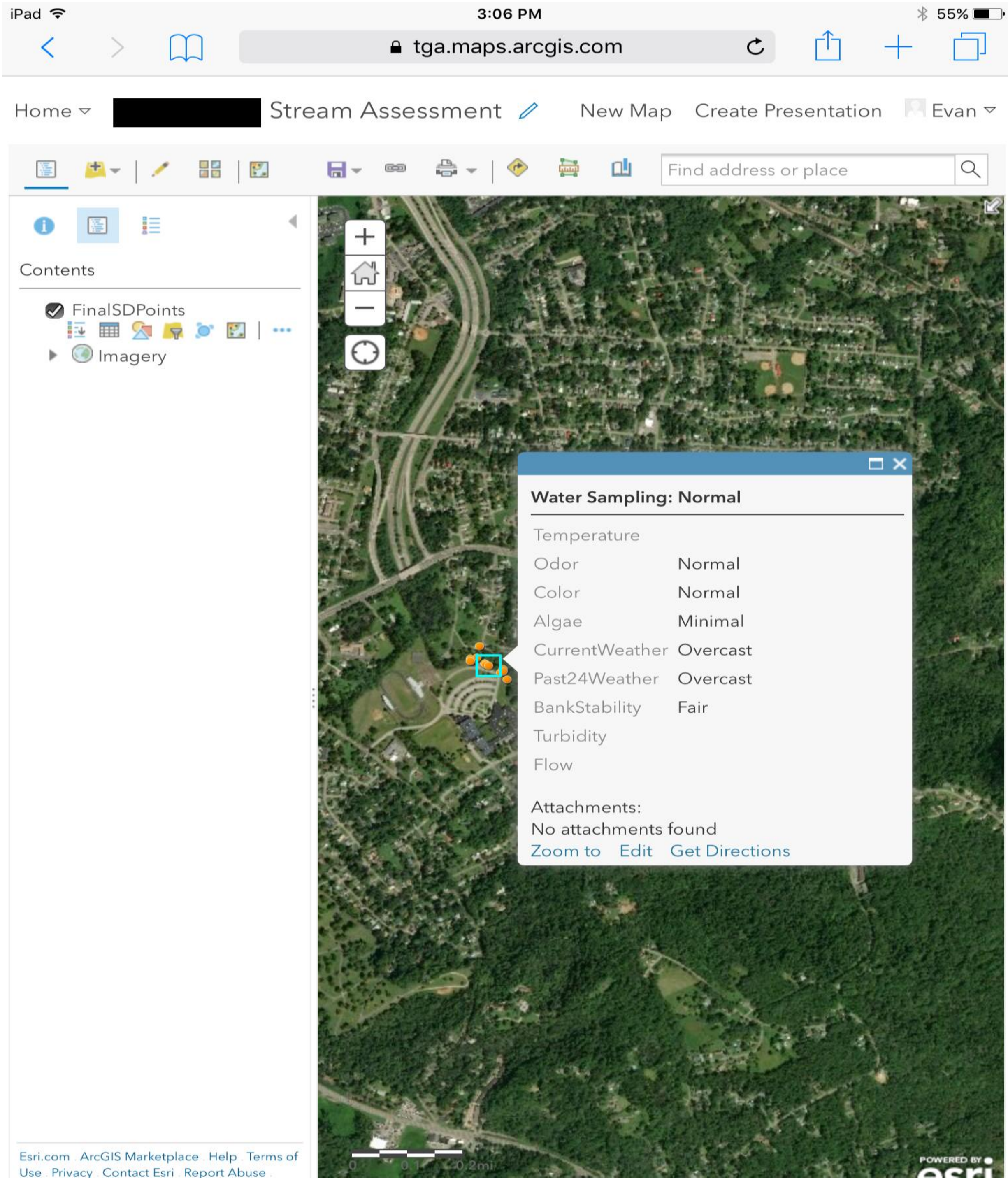
- You are now viewing all the files associated with your account. Scroll down until you find the web map file that was used to collect data ("XXXXX Stream Assessment"). Click this link to access more options associated with the web map.



- Select “Open in Map Viewer” to proceed to the web map.



- We are now viewing the entire dataset of points collected by all users of the app.
- To review individual points, tap on them on the screen.



- By clicking on individual points, one can review the attribute data collected at each specific location. This allows for unlimited dataset access to analyze as the users see fit.

GLOSSARY OF ACRONYMS & TERMS

App: shortened form of the word “application”

ArcCatalog: computer application used to create, organize, and manage geographic information and geodatabases

ArcGIS Online: GIS software that is hosted on the internet for cloud-based geospatial analysis and map production

ArcMap: primary GIS software produced by ESRI

Active Learning: learning activities that require students to engage in the learning process and think about what they are doing

Adventure Learning: concept based around the notion that exploration of geospatial data through a GIS provides students with a “choose-your-own-adventure” style experience with data analysis

Base Map: collection of imagery used as the background of a GIS or mobile GIS app

Database: collection of data that has been electronically organized in a specific manner

Engagement: degree of attention or interest one shows during participation of an activity, lecture, etc.

Feature Class: a collection of common features in a GIS that are similar enough to be displayed using identical symbology

Geodatabase: database that combined GIS data into one large, manipulatable file for further analysis

Geospatial Technology: any technology that utilizes tools to map or analyze data that is specific to a particular location

GIS: acronym standing for “geographic information system”; GIS are systems designed to record, analyze, and manipulate geographic data

iSTEM: Science, Technology, Engineering, and Math (STEM) education that is integrated with technology-based methods

Line: GIS feature class typically representing roads or water features such as streams, rivers, etc.

Point: GIS feature class used to represent data at a specifically defined location (location of a building, water monitoring station, etc.)

Polygon: GIS feature class used to indicate features with defined areas (crop fields, building footprints, etc.)

Scale: The relationship between distances displayed on a map and the same distances in the physical world

STEM: acronym for Science, Technology, Engineering, and Math

Teaching Proxy: a new/unique tool or method utilized by educators in place of a traditional one

Web Map: GIS-based map that is hosted on the internet for the purpose of public viewing, analysis, and contribution

VITA

Evan Norton was raised in Clinton, TN, where he attended and graduated from Clinton High School. During this time, he found his passion for the environment after taking several courses in biological and natural sciences. After graduating in 2011, he attended The University of Tennessee, obtaining a Bachelor of Science degree in 2016 in Environmental Studies, double minoring in Sustainability and Geography. During his last few semesters as an undergraduate, he took courses in the Geography Department. Thanks to these courses, and the excellent professors who taught them, he decided he wanted to pursue an advanced degree in the discipline.

Evan began his Master of Science program in The University of Tennessee's Department of Geography in the Fall of 2016, studying under his academic advisor Dr. Yingkui "Philip" Li. His program of study comprised of a wide variety of environmental science and geographic information system (GIS) related courses, as he sought to blend the two disciplines in some manner for his thesis work. After joining an EPA-funded grant within the Department, he helped in organizing several informal STEM summer science camps and realized that education was the aspect his thesis was missing.

Evan served as a Graduate Teaching Assistant for four semester, having taught lab sections of Landscape & Environmental Change and Climate Change/Climatology two semesters each. He also served as a Graduate Research Assistant for three semesters, working together with the Departments of Environmental Engineering and Social Work on a project to engage local communities in citizen science and teach local youth about local water quality issues and watershed health.

Evan hopes to begin a career that utilizes GIS to help promote sustainability and protect the environment from further degradation. His ultimate goal is to leave the Earth in a better shape than when he was born.