Navigating Cornell's Waste Data Management

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I. Project Introduction

This document helps waste data trackers and Cornell R5 Operations to navigate Cornell's waste data management system with the goal of increasing the awareness of sustainability innovations across the campus. In particular, the report is designed for both the related departments and the class of ENGRC 3500 as the final project. We begin with an introduction to our project.

A. Primitive Tools Limit Modern Waste Tracking Solutions

Waste data management at Cornell University is currently inefficient. Since the early 1990s, Cornell R5 Operations team has used a simple Excel spreadsheet for tracking tons of waste processed, with inputs being reported via notes on scrap paper at the end of each facility worker's shift. This spreadsheet is disorganized with some inconsistent measurements, which in turn creates difficulty in visualizing, analyzing, and sharing the data with stakeholders. Easing these difficulties can allow for the development of strategies to optimize many waste management processes for Cornell R5 Operations. As an emphasis to our problem statement, we will provide a brief overview of collegiate waste management in the following section.

B. A Brief History of Collegiate Waste Tracking

People are becoming more environmentally conscious and are factoring in waste production and/or eco-friendliness when making decisions as a consumer [1]. Unfortunately, even as younger generations become increasingly involved in sustainability efforts, large colleges and universities still can account for over 20,000 tons of solid waste per academic year [2]. Research even shows that marketing as eco-friendly directly and indirectly boosts a brand's image, and in turn the purchasing intentions of consumers are higher [3]. With this rise in popularity comes the need to properly identify which institutions are actually eco-friendly and produce little waste.

Some efforts to certify universities have already been made. These certifications have been created to identify levels of waste management and are being used to distinguish universities from one another. The Atlas Zero Waste Certification is used to create "a high-level standard for a zero waste campus" [4], and it distinguishes college campuses into four categories: bronze, silver, gold, and platinum. Universities are given scorecards to show which areas need more attention. For example, the University of South Dakota has a score of 41.1% for purchasing and policies, but only a score of 11.4% in compost/recycling systems [5]. Information for these scores are gathered through interviews with "campus stakeholders, compiling campus resources and policies," and "waste and material management reports" [4]. After gathering the information, universities are scored using a checklist created by Atlas. Therefore, a university must have data available for analysis to be certified in any way. However, reporting data has become a big problem as not all universities, including Cornell University, have inefficient waste data management systems.

Scholarly research showcases this difficulty in finding a sufficient waste management system that can track and utilize all types of waste [6]. Two published waste studies, however, have focused on reducing consumer-level instead of community-level waste [7][8]. Although the two articles address different communities, both are within a large university. For example, on-campus dining facilities may make up a large source of regional food waste, with approximately

19.4 million students enrolled in more than 5300 colleges or universities in the fall of 2020 [9]. Considering that most students consume more than one meal per day, managing and reducing this huge amount of waste can be a university-level priority. Other than food waste, recyclable rubbish and e-waste are also important aspects that need to be considered, because given the volumes of e-waste being generated and the content of both toxic and valuable, recyclable materials in them, it's hard to keep track of the waste management [10]. In summary, sustainability on college campuses is an epitome of sustainability awareness on a larger scale. The problem is un-neglectable and imperative to be solved. In order to better understand and resolve the problem, we have conducted some research on the organization in charge of Cornell waste tracking and managing: the R5 Operations.

C. Introduction to Cornell R5 Operations

Cornell R5 Operations is a small, one-person team consisting of Chris Mott. The R5 stands for respect, rethink, reduce, reuse, and recycle [11]. It is a division of the Cornell Facilities and Campus Services Department (FCS) that intends to promote sustainable practices across the campus. Their waste data management system, however, based on our evaluation, and in comparison to peer institutions, is currently insufficient [12][13]. As mentioned in the problem statement, the Cornell R5 Operations team has used a simple Microsoft Excel spreadsheet for tracking quantities of waste processed at Cornell for almost 30 years. It was effective at the beginning, but as the data has grown in quantity and complexity, the spreadsheet has become disorganized and ineffective due to inconsistent measurements and null inputs (see Figure 1), externalities of a non-standardized submission process. This disorganization has created an unnecessary level of difficulty for R5 Operations in their analysis, preventing R5 from better utilizing time and resources elsewhere.

	A	J	K	L	M	N
1		2017	2018	2019	2020	2021 Totals
2			Green Fence Up		Year of COVID	COVID Take 2
3	Refrigerated Units (# units)	480	477	468	243	530
4	Film (tons)	3.45	0	0	0	0
5	Rigid Plastics (tons)	1.04	0	0	0	0
6	Electronics (tons)	102.0725	106.3915	50.26	53.4215	95.893
7	Lamps (tons) - Ithaca campus	9.1575	16.0695	8.6295	5.846	6.647
8	Pesticide Containers	0	0	0	0	0
9	PCB Ballasts	0.3485	0.8665	0	0.501	0.016
10	Mercury Containing Devices	0.0165	0.065	0.018	0.0025	0.015
11	Scrap Metal - various metals	0	0	16	7.0085	0.3075
12	Scrap Metal - tin/steel	308.5105	360.0485	286.4	197.7146	277.6485
13	Scrap Metal - Total	308.5105	360.0485	302.4	204.7231	277.956
14	Batteries	14.579	10.281765	11.9195	2.7355	10.933
15	Single Stream - Regular	1331.63	1100.57	1099.39	473.04	785.91
16	Dump & Bail Cardboard	0.68		0.86	0	0
17	Dump & Bail mixed paper	0			0	0
18	Shredded Paper	0	0	0	0	21.85
19	Total "single stream"	1332.31	1100.57	1100.25	473.04	785.91
20	Shredded Paper	94.172	42.29	87.3	21.85	43.65
21	Food Compost	781.6	823.8	848.8	365.2	543.5
22	Farm Compost	2622.66	2878.6	3489.61	2983.15	3377.85
23	Total Compost	3404.26	3702.4	4338.41	3348.35	3921.35
24	Oil	11.2655	12.276	12.164	11.5455	3.500075
25	Dining Oil	8.5595	61.05		14.84325	0
26	Antifreeze	8.9177	0	2.763	0.394825	2.55475
27	Yard Waste (grounds/plantations)	1504.675	540.625	531.25	500	478.125
28	Wood (R5)	12	20.8	12	12	12
29	Mattesses	0	0.55	0	0	0
30	Tires	8.02	26.75	21.67	4.65	29.48
31	Reuse (Other than STACS)	7.46		71	0	3.53
32	STACS	98.1995	55.6975	30.8215	13.3635	12.4155
33	Diversion Total	6929.0137	6056.731265	#VALUE!	4667.266675	5683.975325
34	Landfill - Statler					
35	Landfill - R5	1878.12	1923.03	2034.35	1256.7	1680.63

Annual Totals (2) | Sheet3 | Annual Totals | Dining Oil Recycle | Electronics | STACS | Glycol Recycle | Steel&Tin Recycle | Other Metal Recycle | Wood

FIG. 1. DINING OIL RECYCLE SHEET IN CORNELL R5 OPERATIONS WASTE SPREADSHEET

Given the nature of it, such data is not only of interest to CSO, R5 Operations, and our Sustainability Team, but also to various other groups of Cornell affiliates, such as students, organizations, or researchers who wish to use their platform and abilities to help Cornell become more sustainable. For this reason, FCS already provides and operates an up-to-the-minute, public access dashboard that provides segmented energy demand data collected from across the Ithaca Campus. Easing the aforementioned difficulties can allow for a more informed development of strategies to optimize waste management processes for Cornell R5 Operations, as well as promote awareness of R5 Operations to the Cornell community.

As a result of the increasing urgency surrounding proper environmental stewardship, as well as concerns about sustainability and resource inefficiency at Cornell, we aim to spread the awareness of the CSO and related sustainability innovations across the campus. We also aim to create a more systemic, comprehensive, and user-friendly way for Cornell R5 Operations to manage landfill waste, as well as standardize the process for collecting and recording quantities of waste streams across Cornell's Ithaca campus.

D. Project Constraints and Scope

Cornell R5 Operations would prefer not to have monetary costs on this project but would be willing to pay a small fee for a data storage service. The current data contains several

inconsistencies that will need to be addressed with R5 Operations or the organizations that submit waste data to R5 Operations before their transfer into a data storage service.
This project will address the standardization of waste data submissions to R5 Operations and will propose a solution to the organization of the waste tracking database in the form of a functioning prototype using pieces of the original data. A fully implemented cloud-based solution is beyond the scope of the project and will require further work with both Cornell IT and Cornell R5 Operations.

II. GETTING READY WITH THE NEW SYSTEM

Within the design of our project, we revamped the entire waste data management system, meaning that everyone involved with the previous system must now be trained to properly utilize the updated one. To specify, we divided our directions for two separate user experiences:

- A. Instructions for Submitting Waste Data: Individuals who will be collecting and submitting waste data.
- B. Instructions for Analyzing Data Using AWS: Staff from CSO and R5 who will be in charge of tracking, analyzing, and presenting data.

A. Instructions for Submitting Waste Data

This section of the user document is intended only for waste data submitters. If you are looking for section B. Instructions for Analyzing Data Using AWS, go directly there.

1) Getting Started with Submission Types: The waste data submitters can be any authorized and verified member of the Cornell community. Anyone from our community who is interested in waste tracking and garbage recycling should feel free to contact the CSO & R5 office for further information. The task for waste data submitters is to collect waste data points from around campus and properly submit them to R5 Operations. For the efficiency and convenience of the users, we have designed two different types of submission approaches, allowing FCS the opportunity to test both submission methods and determine which is best suited for their purposes:

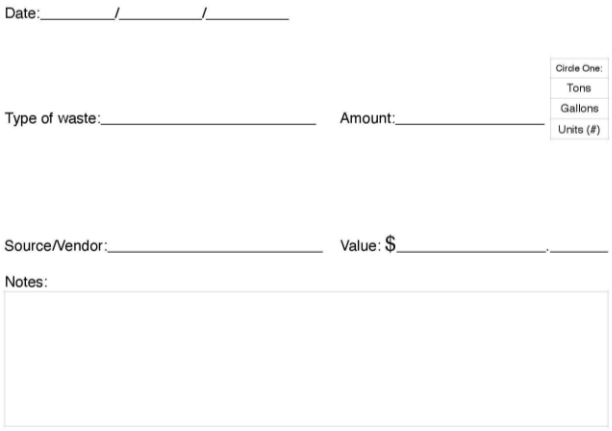
- **Paper Form Submission:** A waste collection form template will be provided for submitters to download, print, and fill in. There will also be some printed copies for submitters without access to printers to pick up at the R5 Operations Office.
- **Digital Submission:** A digital form is also created and provided by our team as the supplement to the paper submission form. We created this using Google Form.

Please note that the submitter needs to decide which submission form to use. If both are submitted for a single submission, only one will be accepted and recorded.
After carefully reviewing the original disorganized waste tracking form, our team has found several aspects to be indispensable for every data recording, shown in Table I.

TABLE 1
IMPORTANT KEY ELEMENTS OF THE WASTE TRACKING FORM

Observation Notes of the Current Waste Tracking Form			
No.	Elements	Description & Notes	Frequency of Appearance
1	Waste Types	The type of certain waste that needs to be reported, including but not limited to construction and demolition waste, agricultural waste, and household waste. Note that hazardous waste is not included and will not be accepted. For hazardous wastes, including but not limited to: chemical, radiological and regulated medical wastes, contact Cornell EHS Laboratory & Research Safety Group for further technical support and compliance assistance.	High
2	Measure	The measurement unit in the original form was inconsistent, creating a high level of confusion and disorganization. The unit section in this form needs to be standardized. All estimations need to be converted to kilograms or tons, if possible. For other types of waste that don't have an applicable weight unit (e.g. volume), the submitter can use gallons or liters as measurement standards.	High
3	Date	The submission date in *mm/dd/yy* format. Note this is the date of submission, not the date of form-filling, if those dates were to differ.	High
4	Source or Vendor	Wastes can be generated from various sources. This can include trash or garbage from households, classrooms, offices, marketplaces, restaurants and other public places. In this case, the submitter should specify the exact location, i.e. Hollister Hall.	High
5	Value	The market value of waste generated. If not specified, use estimations with proof. Note that all calculations and estimations need to be in US Dollars.	Moderate
6	Notes	Any additional information about the waste generated. Can be used to address concerns, suggestions, and questions. Further information would be helpful to the waste tracking but not required. This will add more flexibility to the system.	Low - Moderate

2) Paper Form: We then created an initial draft of the waste tracking paper form (see Figure 2). This form provided us insights about how our final draft should be designed and organized.


Date:_____/_____/_____

Type of waste:_____ Amount:_____

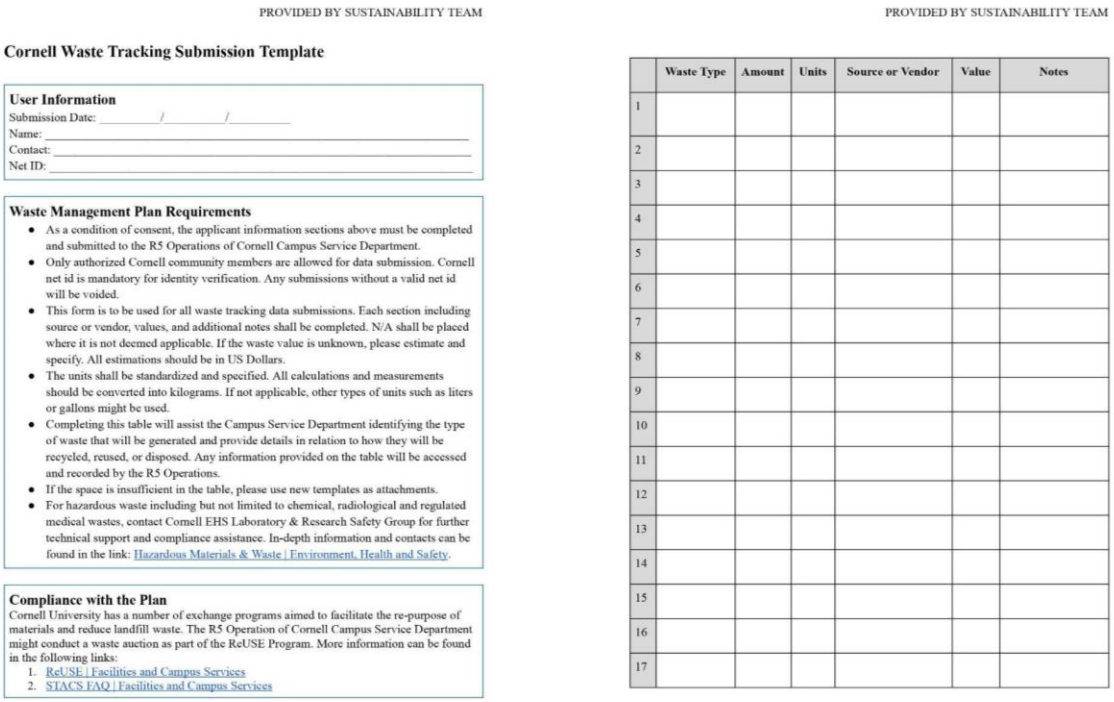
Circle One:
Tons
Gallons
Units (#)

Source/Vendor:_____ Value: $_____._____

Notes:

FIG. 2. INITIAL DRAFT OF PAPER FORM FOR WASTE TRACKING

Based on that initial draft and subsequent user feedback, we updated the form to be more user-oriented and versatile, with supplemental instructions specified and additional information hyperlinked at the end of the template. Figure 3 provides a preview of the paper form.


PROVIDED BY SUSTAINABILITY TEAM

Cornell Waste Tracking Submission Template

User Information
Submission Date: _____/_____/_____
Name: _____
Contact: _____
Net ID: _____

Waste Management Plan Requirements

- As a condition of consent, the applicant information sections above must be completed and submitted to the R5 Operations of Cornell Campus Service Department.
- Only authorized Cornell community members are allowed for data submission. Cornell net id is mandatory for identity verification. Any submissions without a valid net id will be voided.
- This form is to be used for all waste tracking data submissions. Each section including source or vendor, values, and additional notes shall be completed. N/A shall be placed where it is not deemed applicable. If the waste value is unknown, please estimate and specify. All estimations should be in US Dollars.
- The units shall be standardized and specified. All calculations and measurements should be converted into kilograms. If not applicable, other types of units such as liters or gallons might be used.
- Completing this table will assist the Campus Service Department identifying the type of waste that will be generated and provide details in relation to how they will be recycled, reused, or disposed. Any information provided on the table will be accessed and recorded by the R5 Operations.
- If the space is insufficient in the table, please use new templates as attachments.
- For hazardous waste including but not limited to chemical, radiological and regulated medical wastes, contact Cornell EHS Laboratory & Research Safety Group for further technical support and compliance assistance. In-depth information and contacts can be found in the link: Hazardous Materials & Waste | Environment, Health and Safety.

Compliance with the Plan
Cornell University has a number of exchange programs aimed to facilitate the re-purpose of materials and reduce landfill waste. The R5 Operation of Cornell Campus Service Department might conduct a waste auction as part of the ReUSE Program. More information can be found in the following links:

1. ReUSE | Facilities and Campus Services
2. STACS FAQ | Facilities and Campus Services

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	Waste Type	Amount	Units	Source or Vendor	Value	Notes
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						

FIG. 3. PAPER WASTE COLLECTION FORM PREVIEW

We created the Cornell Waste Tracking Submission Template (see Appendix A). Users can download and print it. Any suggestions for revisions are welcomed and strongly encouraged.

3) Proposed Instructions for Paper Form Submission: Users looking to submit the paper form of the waste data tracking sheet need to complete the following steps:

1. Carefully read through the Waste Management Plan Requirements and Compliance with the Plan sections of the template provided in Appendix A. If there is any uncertainty or confusion, do not proceed. The submitter should directly contact the CSO and R5 Operations office using the contact information attached.
2. Fill in the applicant information section of the waste management plan template. This is a very important step because only authorized Cornell community members are allowed for data submission. If any of the applicant information is incomplete, the office would not be able to verify the identity, and the submissions will be voided. Again, if there is any problem, do not hesitate to contact the office.
3. Fill in the waste data. All measurements, estimations, and calculations should be converted to standardized units.
4. Send the standardized file to R5 Operations, who will upload the files to Amazon AWS.

4) Digital Form: We understand that not every individual has access to physical copies of the submission form. For the convenience of users, we also created a Waste Management Digital Form Template using Google Forms, which requires users to login with their Cornell email for a successful submission. Figure 4 below provides a preview of the digital form. The form is laid out in one web page, with information submission below the Waste Management Plan Requirements and Compliance with the Plan sections.

We invite CSO, R5, and other interested stakeholders to review the Waste Management Digital Form Template. Any suggestions for revisions are welcomed and strongly encouraged.

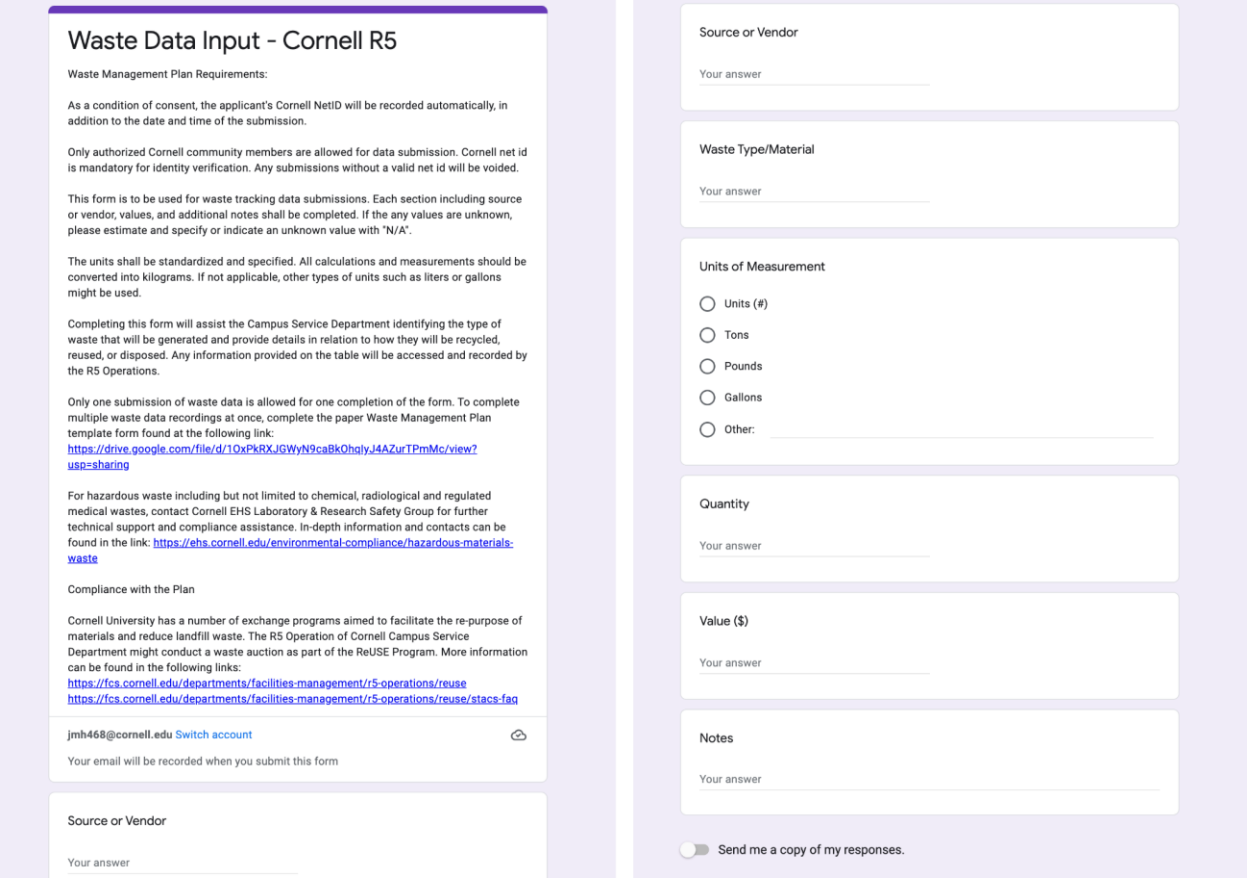

FIG. 4. DIGITAL WASTE COLLECTION FORM PREVIEW

5) Proposed Instructions for Digital Form Submission: Users looking to submit the electronic form of the waste data tracking sheet need to complete the following steps:

1. Carefully read through the Waste Management Plan Requirements and Compliance with the Plan sections of the form. This part is included in both templates and requires careful reading.
2. If there is any uncertainty or confusion, do not proceed. The submitter should directly contact the CSO and R5 Operations office using the contact information attached. Please note that contact information is taken automatically through your Cornell NetID after completion of the form.
3. Fill in the waste data. All measurements, estimations, and calculations should be converted to standardized units. The form is limited to one waste submission per completion of the form, so multiple recordings will require separate completions of the form.
4. The information from the completed form will be sent automatically to R5 Operations. The office will then upload the spreadsheet to Amazon AWS. Please note that an email confirmation of your completion of the form may be sent to your Cornell email address through Google Forms.
5. If an error is present in your submission, it can be edited after submitting the form through the email received by Google Forms. If the information is edited in this way, you must contact the R5 Operations office to notify them of the change.

B. Instructions for Analyzing Data Using AWS

This section of the user document is intended only for members of Cornell's Sustainability Office and Cornell R5 Operations. Here we will cover how to get started with AWS, transfer existing data into AWS, and use AWS to create visuals for reports and/or analysis. If you are not a member of one of these departments, you will be unable to access the centralized AWS system this section covers.

1) Initial Setup Procedure: Before we explain how to use AWS to analyze data, we must first explain how to access the waste data management system and properly set up the system using the existing excel spreadsheet.

a) Getting an AWS Account: In order to use the waste data management system that we are proposing, users need to have a pre-existing AWS account set up. Since this section of the user document is intended only for authorized Cornell employees, users without an AWS account must set up a brief meeting with Cornell's IT Department in order to set up a secure account.

b) Logging into AWS: We worked with Cornell's IT Department to help set up a secure login page for the new waste data management system. In order to access the system, please make sure you have already completed step *a* above on getting an AWS account.

1. Go to the AWS QuickSight home page.
3. Enter your QuickSight account name.
4. Enter your Cornell email address and password.
    a. You will be redirected to Cornell's Two-Step Login.

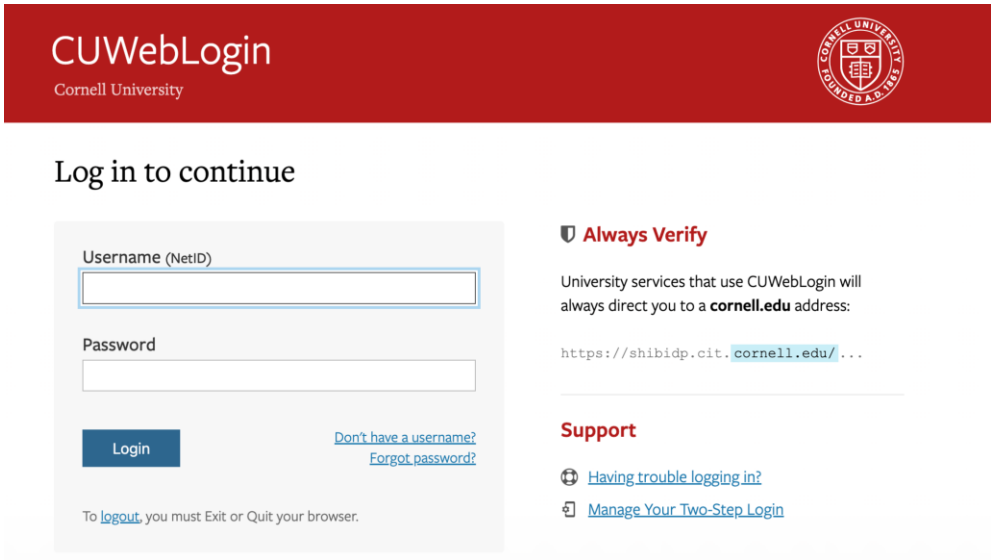

FIG. 5. CORNELL'S TWO-STEP LOGIN

5. Login using Cornell's Authentication System.
6. If unable to login, contact Cornell's IT Department.

c) Migrating the Existing Spreadsheet to AWS: We have created this user document to attempt to redesign and modernize Cornell's waste tracking system. However, the scope and timeline of our project prevents us from fully implementing a complete solution. In other words, we haven't created a centralized system or uploaded the existing spreadsheet to AWS. Once a centralized system is created, you can use the following instructions to transfer data from the spreadsheets to AWS:

1. Go to the AWS QuickSight home page.
2. Login using Cornell's Authentication System. You can refer to the b) Logging into AWS instructions above if you forgot how to access the system.
3. Once logged in, you will be in the "Analysis" Tab. You want to switch to the "Datasets" Tab. Switch by clicking the "Datasets" button on the left hand side of your screen. Confirm you are on the "Datasets" Tab.
    - The "Datasets" section on the left hand side will be highlighted.
    - On the top of the page, it will say "Datasets."

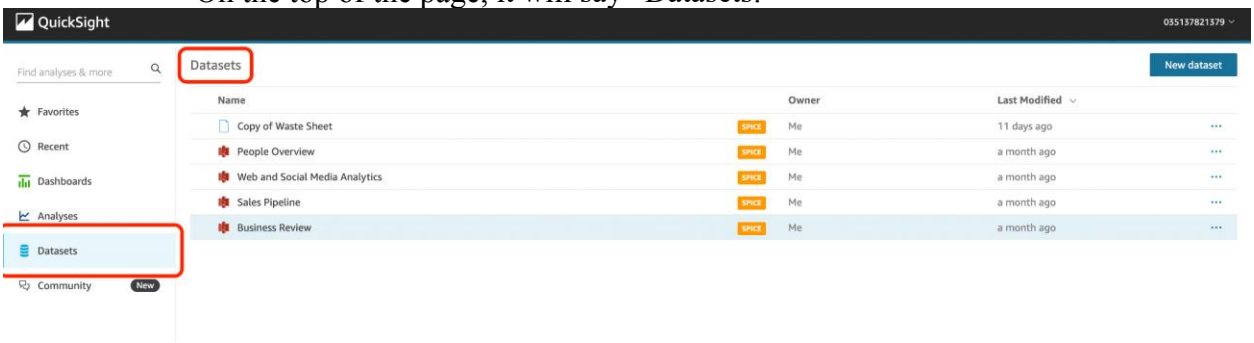

FIG. 6. AWS QUICKSIGHT DATASETS PAGE

4. Once on this page, you can select an existing dataset that you'd like to edit or review. This section assumes that you want to transfer over existing data, so click the "New dataset" button on the top right.

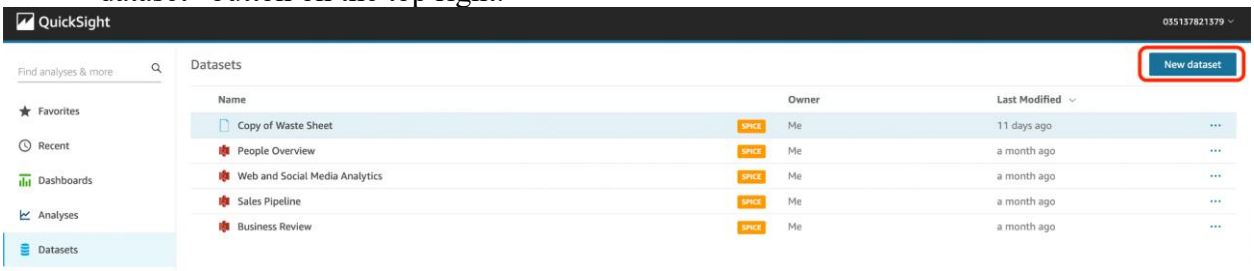

FIG. 7. AWS QUICKSIGHT NEW DATASET BUTTON

5. On this page you will be prompted to select what type of dataset you want. You have the option to login to other platforms, like Salesforce, to extract datasets, create new datasets through different data sources, like MySQL, or upload an existing file from your computer. To upload the existing excel spreadsheet, click on the “Upload a file” button.

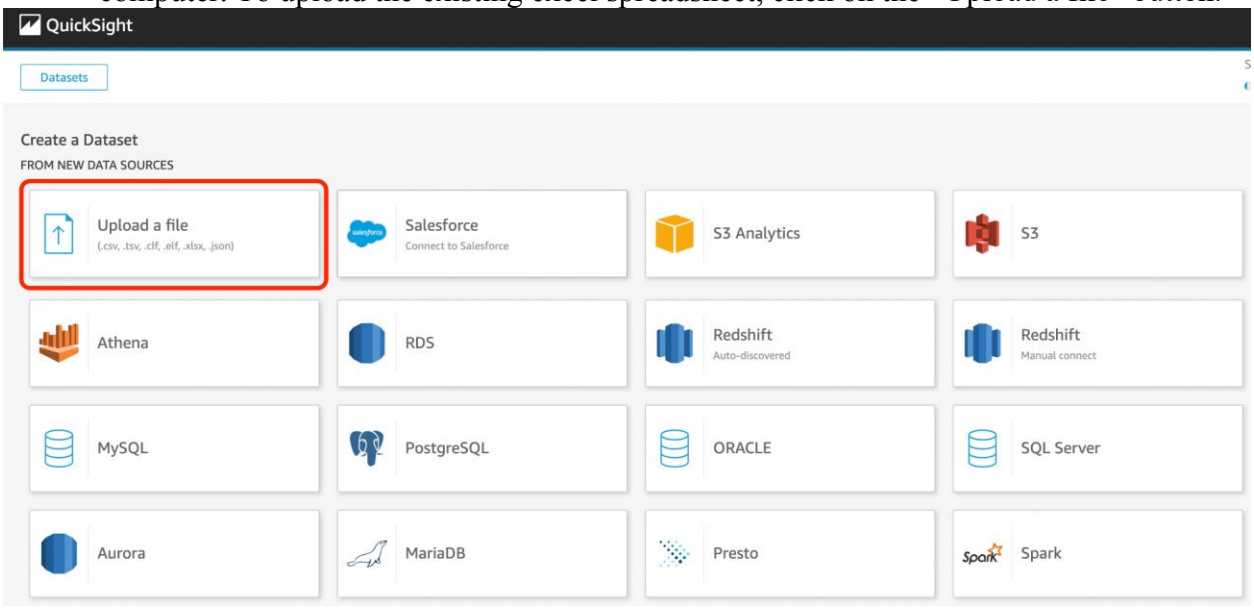

FIG. 8. AWS QUICKSIGHT UPLOAD A FILE BUTTON

6. Your device’s storage navigator will then appear as a pop-up on your screen. Find the file on your device that you wish to upload, and then click the “Open” button on the pop-up.

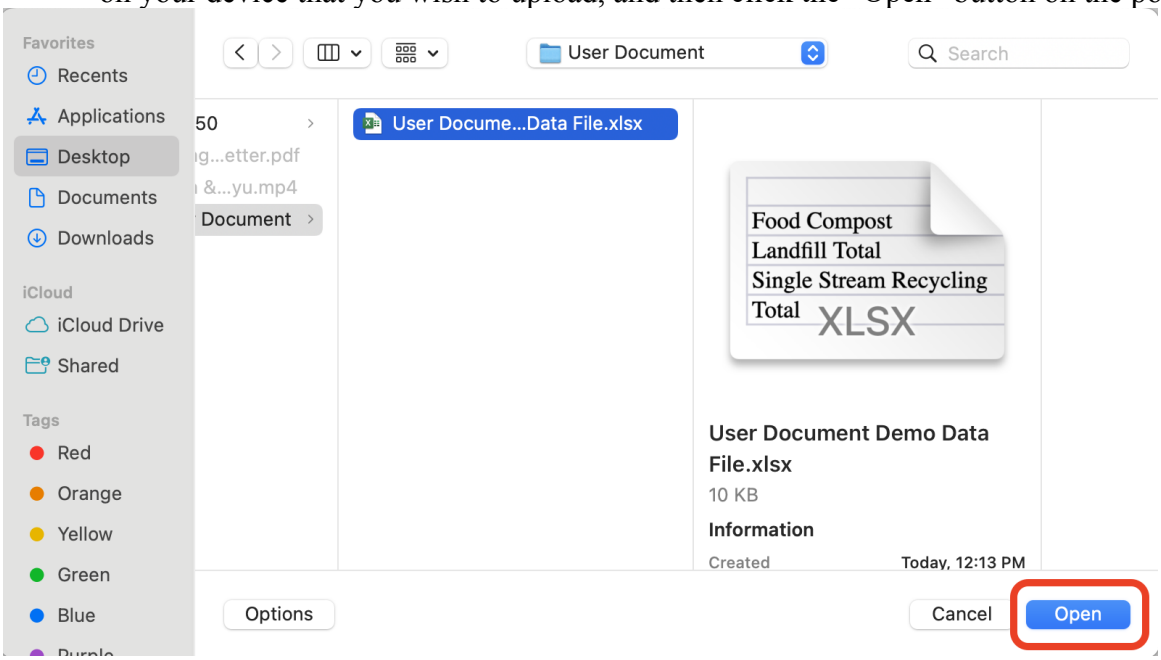

FIG. 9. AWS QUICKSIGHT FILE OPEN BUTTON

7. The Excel spreadsheet currently used for waste data management contains multiple sheets, so a demo file with two sheets is shown here. After opening the file, AWS will scan it and ask you which sheet you would like to import. AWS will not allow you to upload both at once. This is preferable because it keeps the sheets separate, but all in one central location. Select the sheet you would like to upload and click the "Select" button.
    - The selected sheet will have a blue dot on its left and be highlighted with a light gray background.

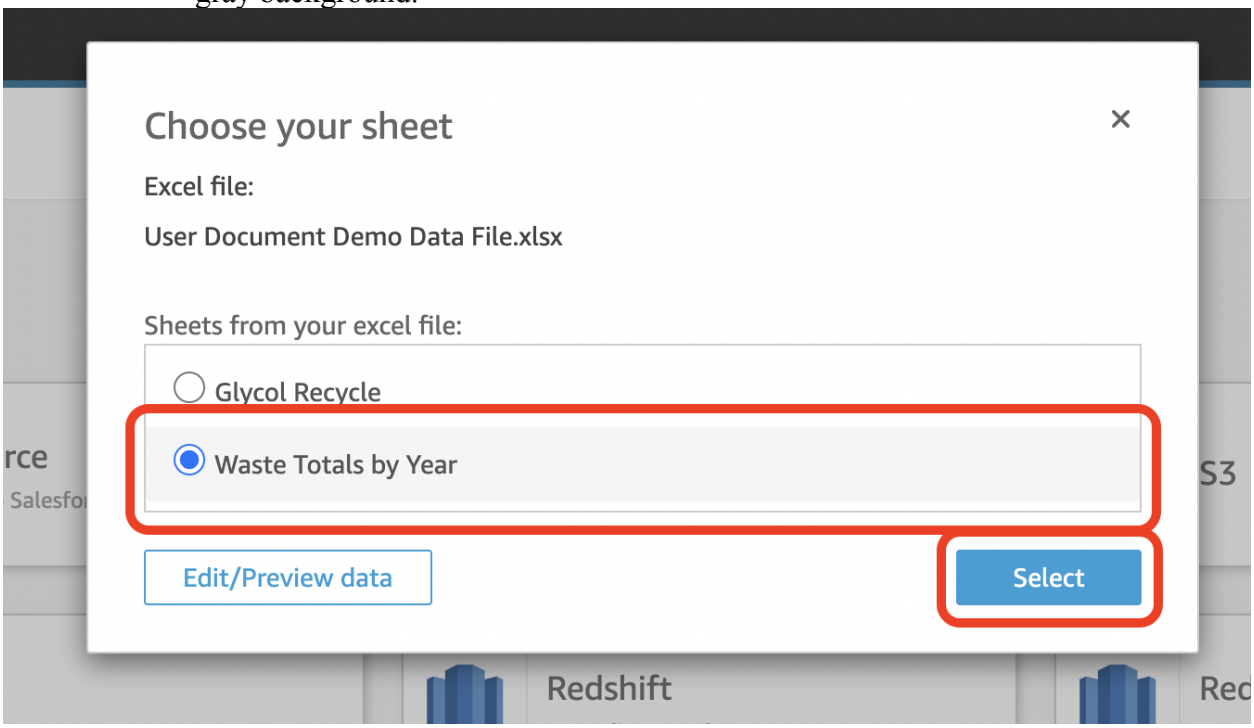

FIG. 10. AWS QUICKSIGHT SHEET SELECT BUTTON

8. After selecting the spreadsheet that you wish to upload, you will be given a preview of your dataset. This pop-up has options to edit import settings or to edit the data. If the dataset is formatted the way you would like it, click the "Next" button.
    - To edit settings, click the button in the lower left corner of the pop-up.
    - To learn more about preparing your data and other possible settings, click the learn more button.

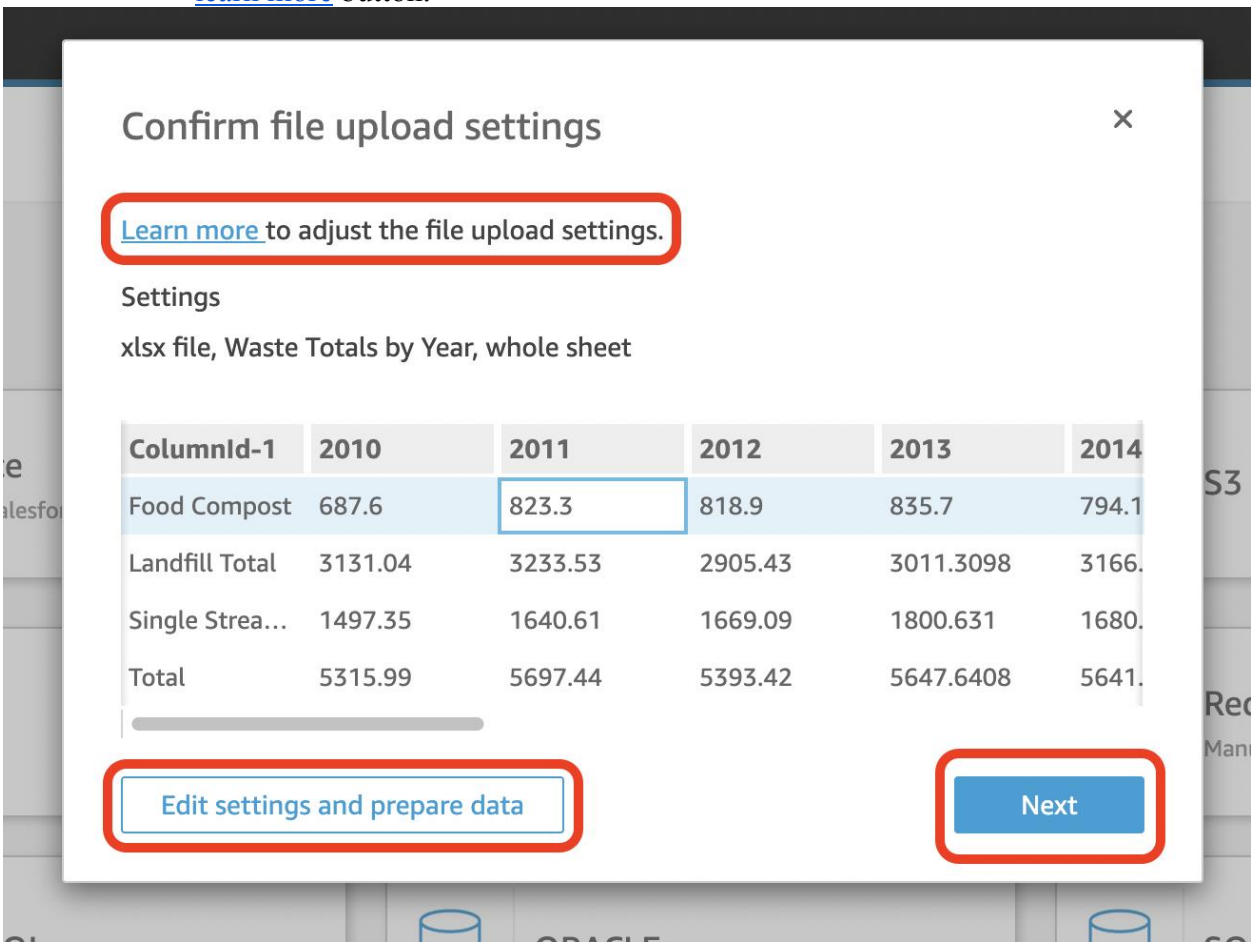

FIG. 11. AWS QUICKSIGHT CONFIRM FILE UPLOAD BUTTONS

9. After you select next, you have to publish your dataset to officially have it in the system. You can do this by clicking the “Visualize” button, which will then open a page where you can begin analyzing your data. If this is what you want then you can skip the next steps and go to the 2) Instructions for Creating Data Analyses (CSO & R5 Operations) section below.
    - If you are not ready to begin analyzing your data, click the “Edit/Preview data” button in the lower left corner.

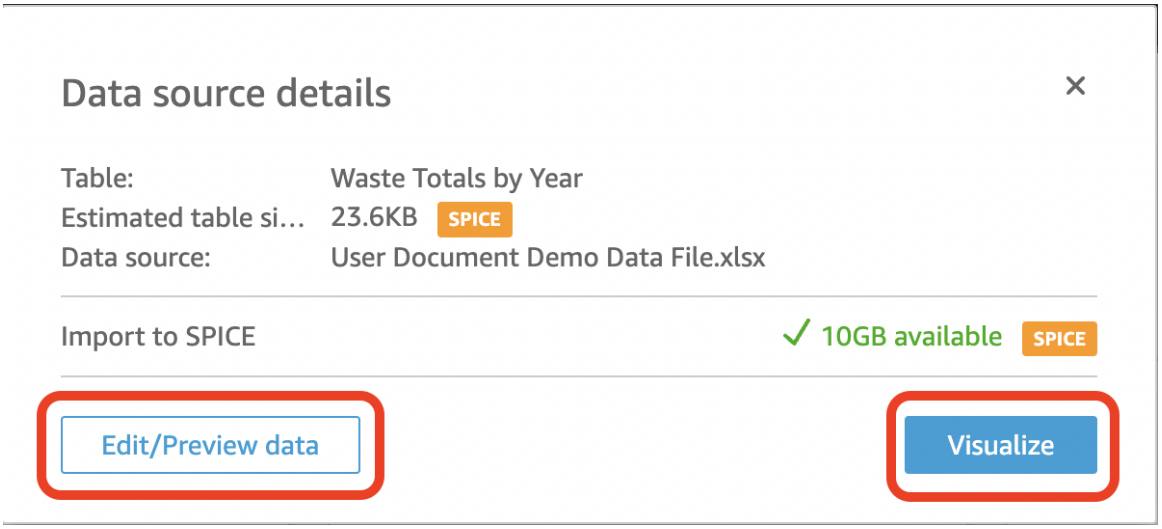

FIG. 12. AWS QUICKSIGHT DATA SOURCE BUTTONS

10. You will now be on a page where you can edit your dataset. If the dataset is how you would like it then you must click the “Save & publish” button in the upper right corner.

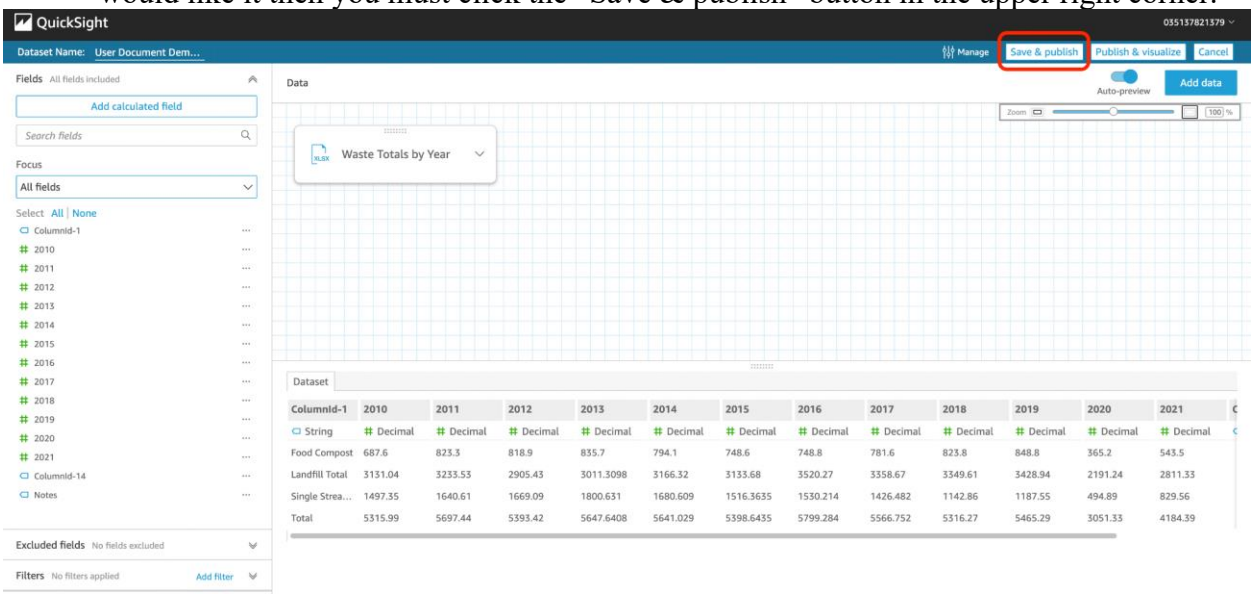

FIG. 13. AWS QUICKSIGHT SAVE & PUBLISH BUTTON

11. You have now successfully uploaded your dataset into AWS. You can continue editing the data on this page, just make sure to save your changes (see Figure 13). For more information on editing/filtering your data, please visit the AWS QuickSight user guide. If you are ready to begin analyzing the data, click the "Publish & visualize" button in the upper right corner and go to the 2) Instructions for Creating Data Analyses (CSO & R5 Operations) section below.

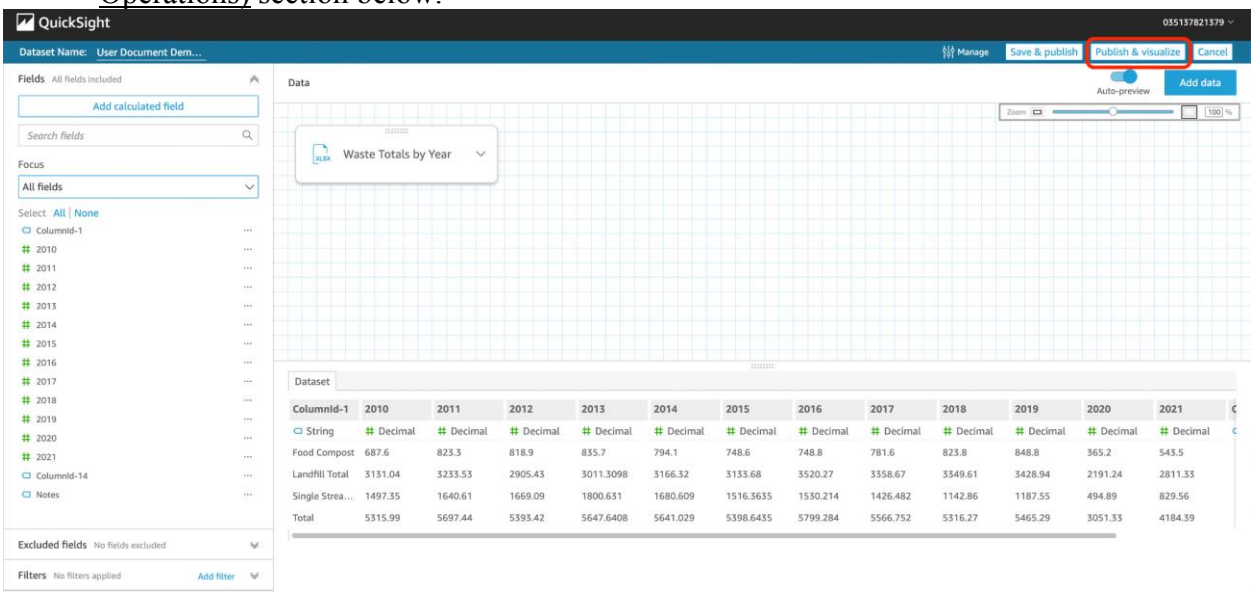

FIG. 14. AWS QUICKSIGHT PUBLISH & VISUALIZE BUTTON

12. If you wish to upload more data, go to the homepage of AWS QuickSight by clicking the "QuickSight" button in the upper left corner and repeat steps 3-11.

2) Instructions for Creating Data Analyses (CSO & R5 Operations): Before attempting to analyze waste data using AWS, please ensure that you have completed all the necessary steps in the 1) Initial Setup Procedure section. At this point you should already have waste data in AWS that is ready to be analyzed. If there is no data in AWS, please refer to the c) Migrating the Existing Spreadsheet to AWS section. Keep in mind that this step is only required if you have data that is not currently in AWS that you would like to transfer over. You are now ready to begin analyzing data using AWS. Go to the AWS QuickSight home page.

2. Login using Cornell's Authentication System. You can refer to the previous b) Logging into AWS section if you forgot how to access the system.
3. Once logged in, make sure you are in the "Analysis" Tab.
    - The "Analysis" section on the left hand side will be highlighted.
    - The top of the page will say "Analyses."

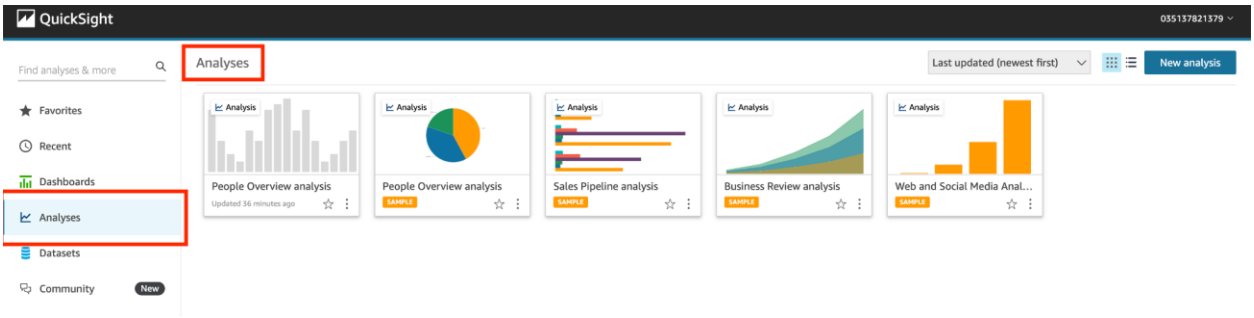

FIG. 15. AWS QUICKSIGHT ANALYSES PAGE

4. Once on this page, you can choose to select an old analysis you have already made.
    - If you want to access an old analysis then this is the final step, simply select an old analysis to view it.
5. If you want to create a new analysis, click the "New analysis" button on the top right of the page.

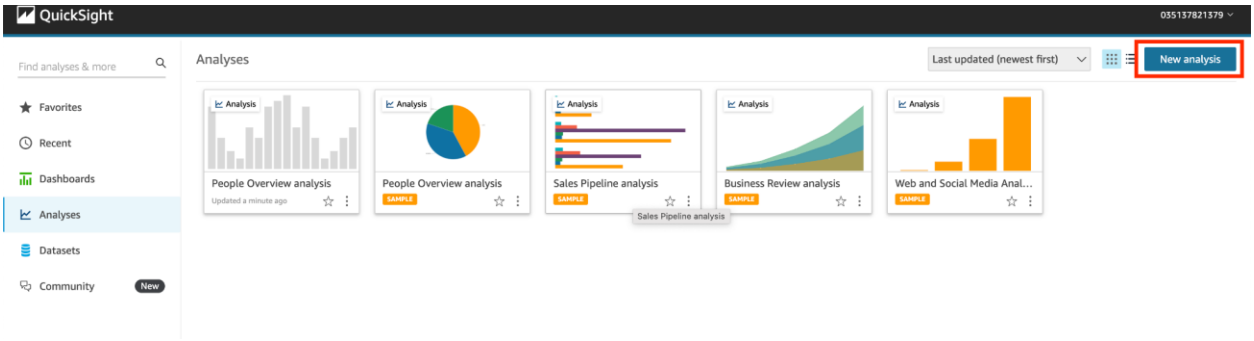

FIG. 16. AWS QUICKSIGHT CREATE ANALYSIS BUTTON

6. On the next page, you will be prompted to choose a dataset.
    - If you do not have an existing dataset, or want to create a new one for analysis, you can do so by clicking the new dataset button on the top left. If you have a new dataset to transfer into AWS, please refer to the c) Migrating the Existing Spreadsheet to AWS section.

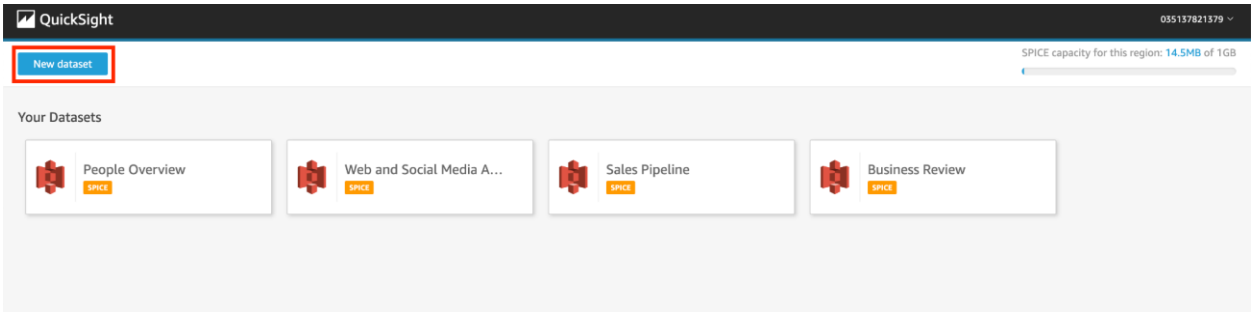

FIG. 17. AWS QUICKSIGHT NEW DATASET BUTTON

7. After selecting your dataset, click the “Create analysis” button in order to begin your analysis. If you selected the wrong dataset by mistake, you can simply click the x button on the top right of the pop-up in order to go back to the dataset selection page.

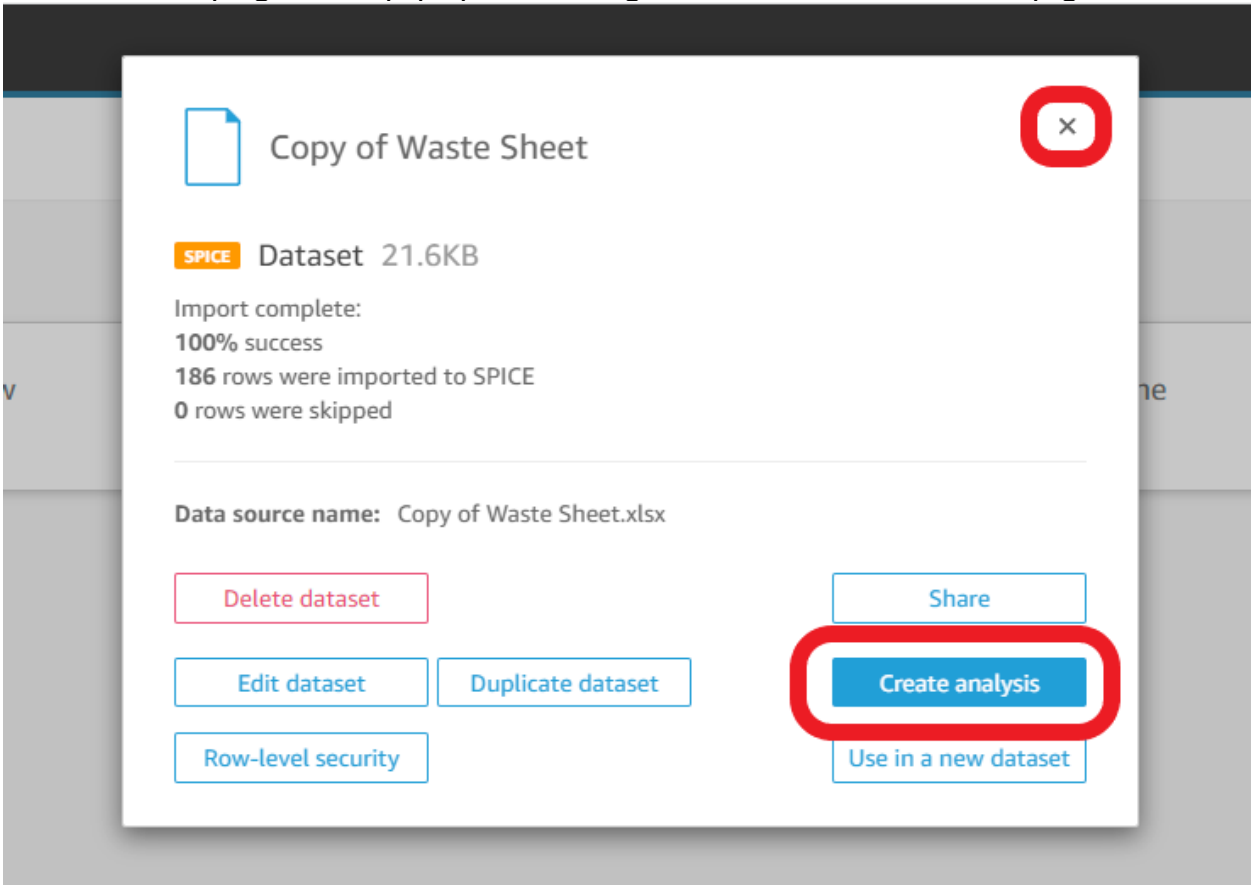

FIG. 18. AWS QUICKSIGHT SELECTED DATASET

8. You can now begin visualizing the dataset through the fields list on the left hand side of the page. This fields list is populated with the column names of the dataset. Select a field that you are interested in. The starter visual is AutoGraph, an analytics tool that will select the best visual available based on the fields you choose. For this demonstration, a field populated with strings ("Service Month") was selected, so it created a bar graph.

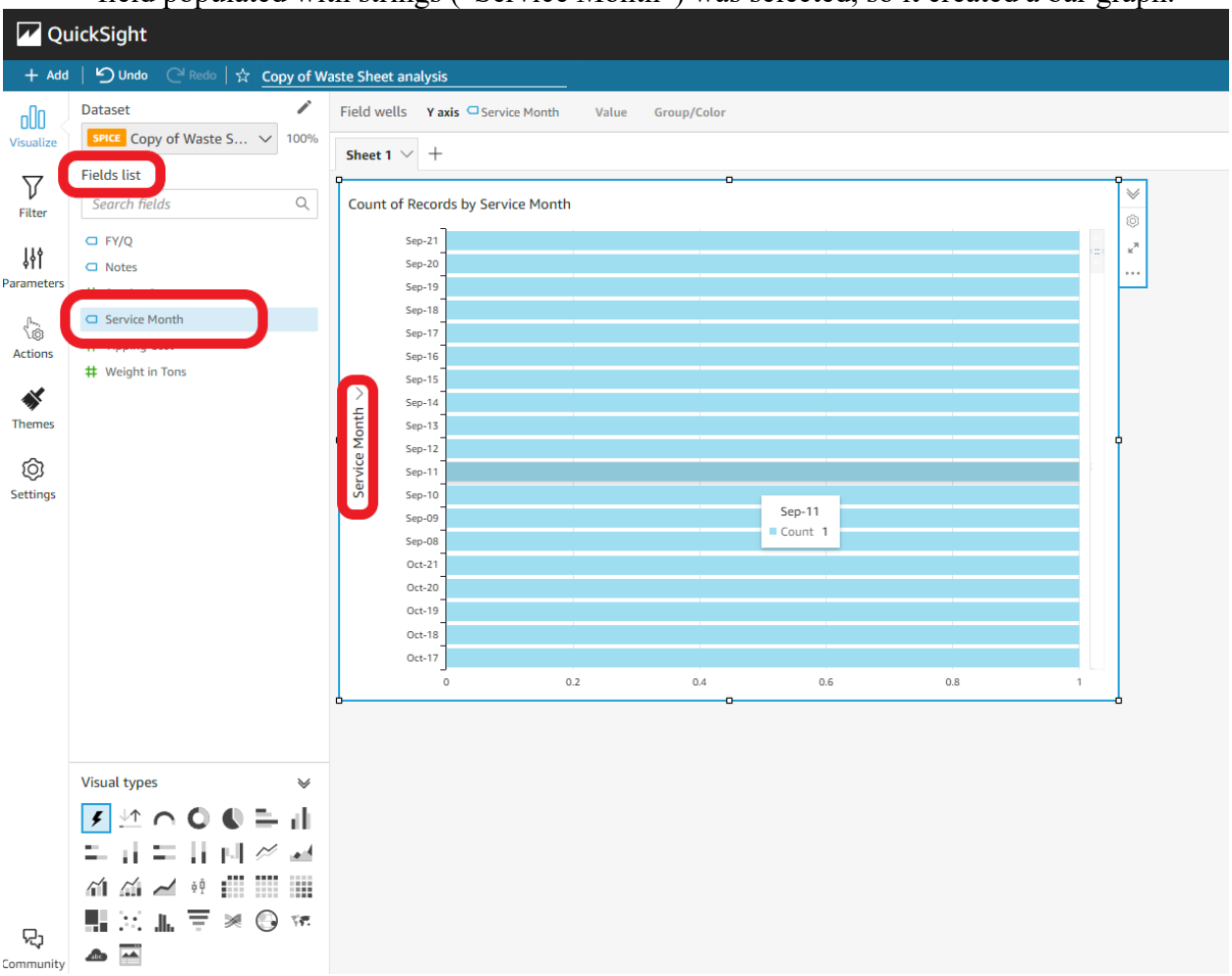

FIG. 19. AWS QUICKSIGHT BAR GRAPH ONE FIELD

9. With only one field selected, the AutoGraph tool will fill in the bar graph's x-axis with a count value. You can replace the count value on the x-axis with another field by clicking the one you want to see there. While you do this, make sure you are currently still selected on the graph you want to add the field to, or a new AutoGraph visual will appear. This demonstration illustrates the "Weight in Tons" field.

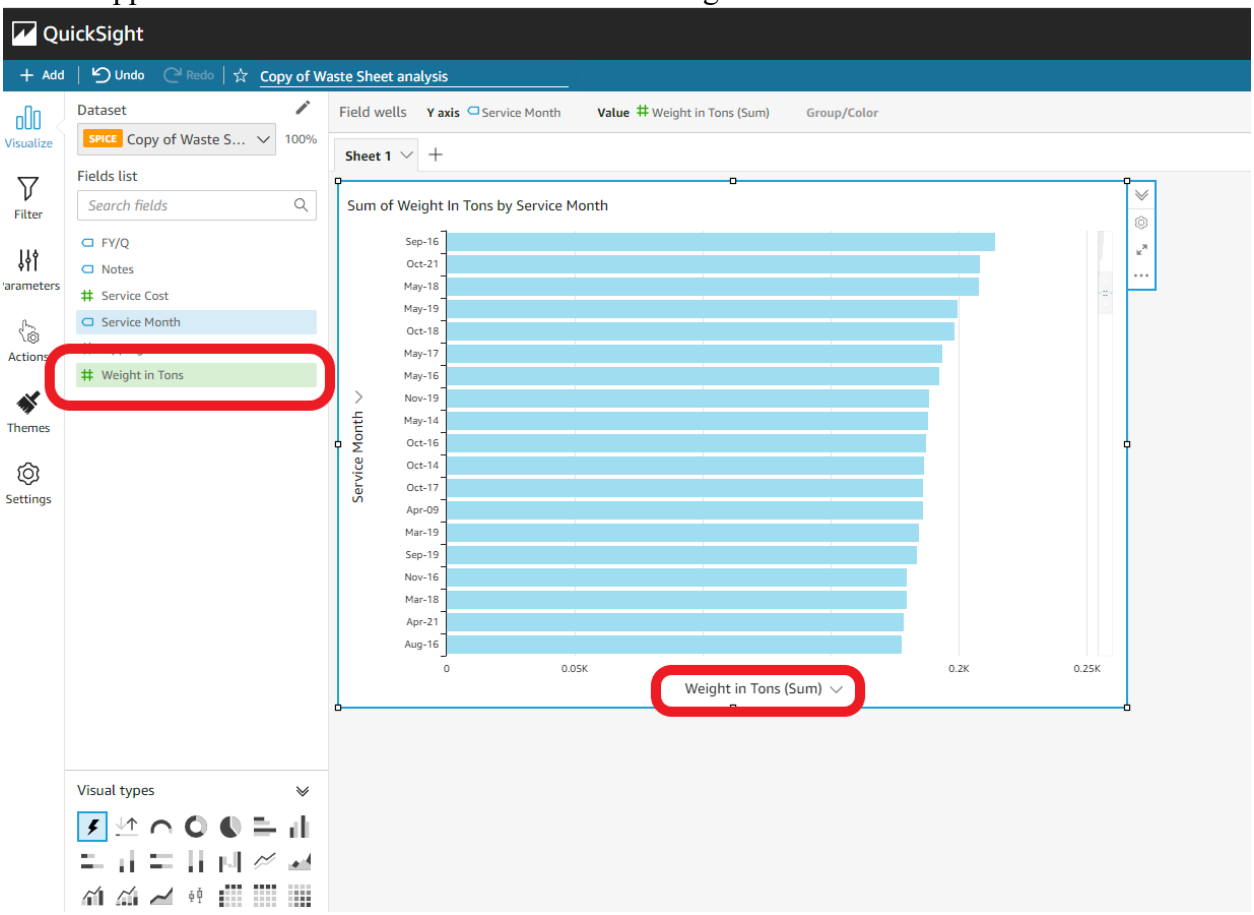

FIG. 20. AWS QUICKSIGHT BAR GRAPH TWO FIELDS

10. If you selected the wrong field or would like to change the one you currently have, simply click the one you no longer want. It will remove it from the visual. You can confirm that it is no longer part of the visual by checking if the field is highlighted on the field list.

11. If you want to create a different visual, you can create a new one by either adding a new sheet (see Figure 21) or by selecting a field while no graph is currently selected (see Figure 22). For this demonstration, a field with numbers was chosen, so the AutoGraph shown in Figure 22 is a sum.

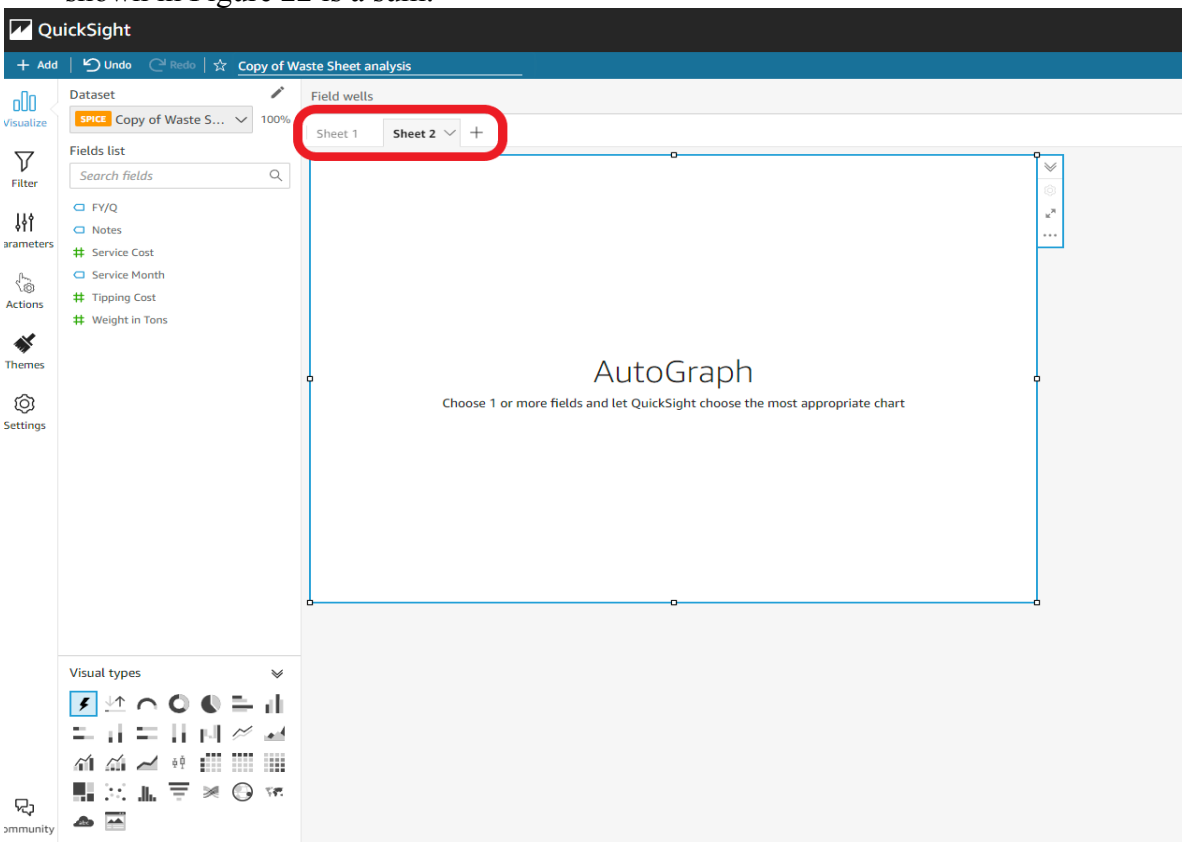

FIG. 21. AWS QUICKSIGHT CREATING A NEW SHEET

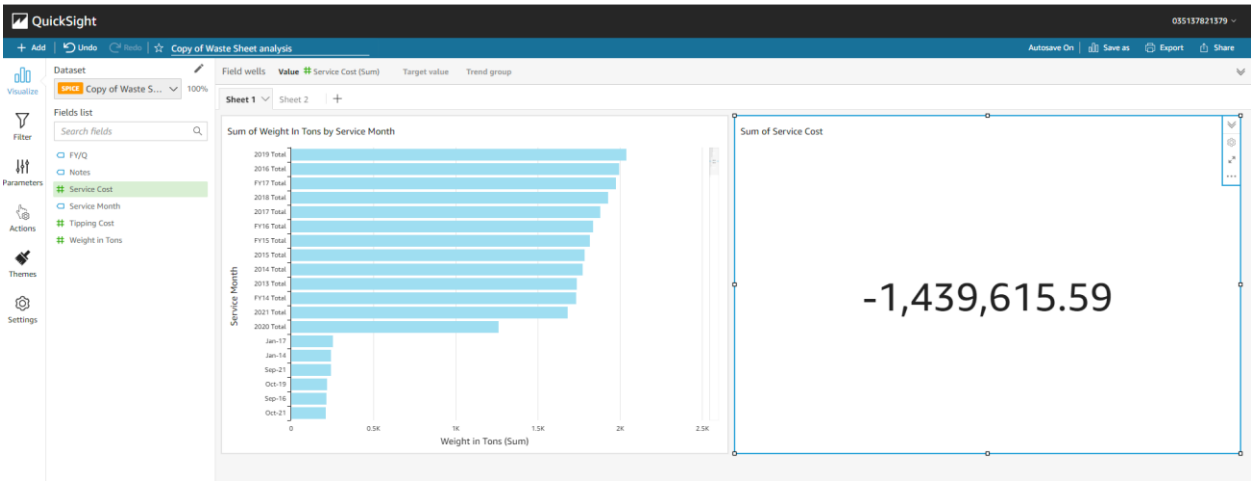

FIG. 22. AWS QUICKSIGHT TWO GRAPHS ON ONE SHEET

12. If you do not want to use AutoGraph, you can select your own visual through the “Visual types” dropdown in the bottom left-hand corner (see Figure 23). AutoGraph is nice because it will always show you something. If you selected a visual that doesn’t have enough information to be constructed, AWS will tell you that. For this demonstration, a pie chart was chosen, and this type of visual needs more than just one field.

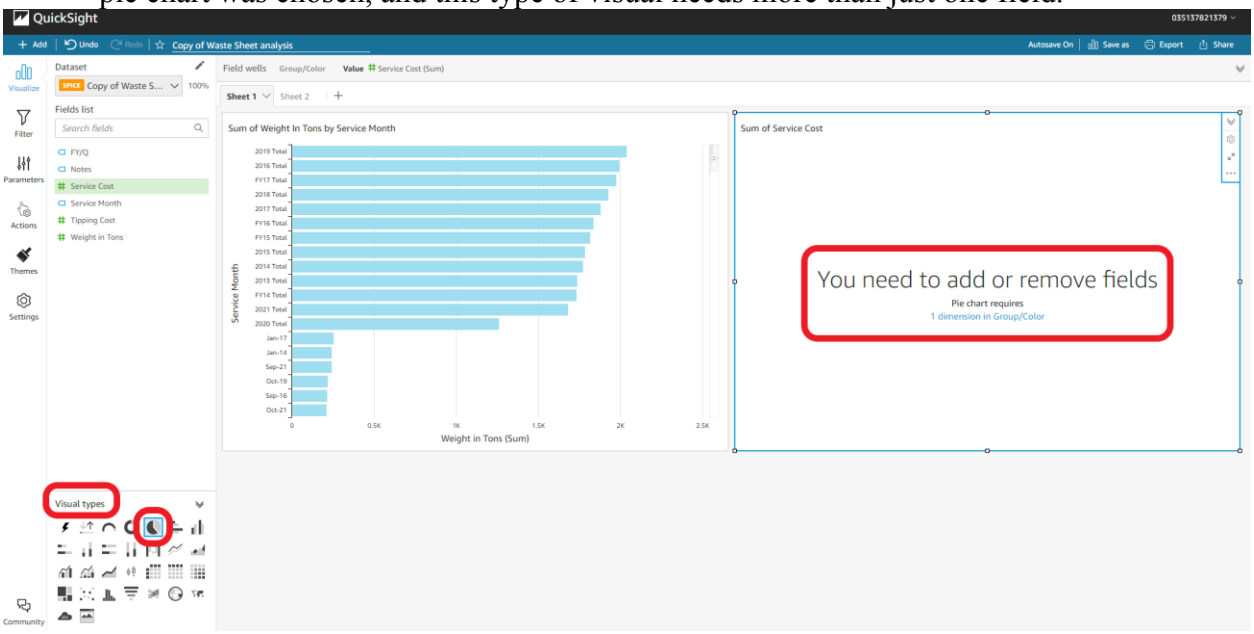

FIG. 23. AWS QUICKSIGHT PIE CHART WITH ONE FIELD & VISUAL TYPES

13. In order to fix this, simply select another field to populate the graph. For this demonstration, the field “FY/Q” is shown.

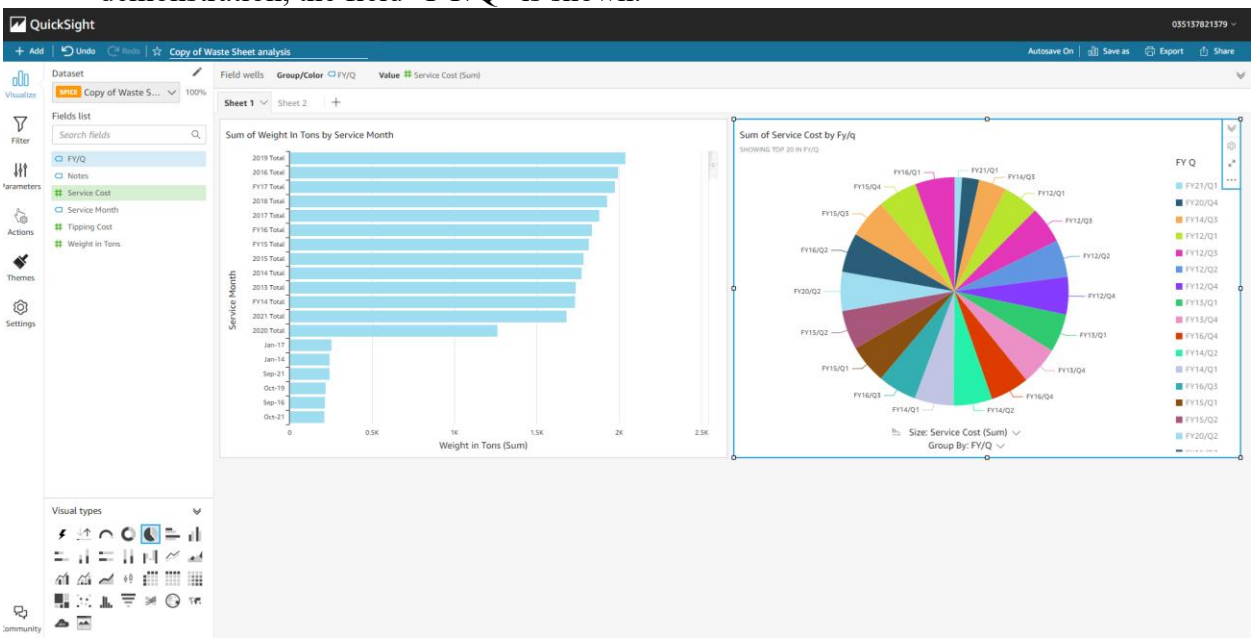

FIG. 24. AWS QUICKSIGHT COMPLETED ANALYSIS

14. You have just created your first visuals based on your data! There are so many things you can do with this analytical tool that we cannot possibly include that in this user document. See AWS's official user guide for further step-by-step instructions on how to use specific features if you'd like to learn more [14].
15. Share results with relevant stakeholders.

3) Use Cases for Analytics/Visuals: Below are several example outputs of QuickSight analytical tools, meant to demonstrate the powerful and informative graphics and reports that can be created by the software. Real data from the existing spreadsheet was uploaded into AWS and used for these use cases.

With the press of a button, users can break down the composition of waste streams! Users can quickly identify the difference in composition of liquid waste streams year over year from Q1 2013 and Q1 2014, and see how even within such a short period of time different chemicals were utilized for campus operations (see Figure 25).

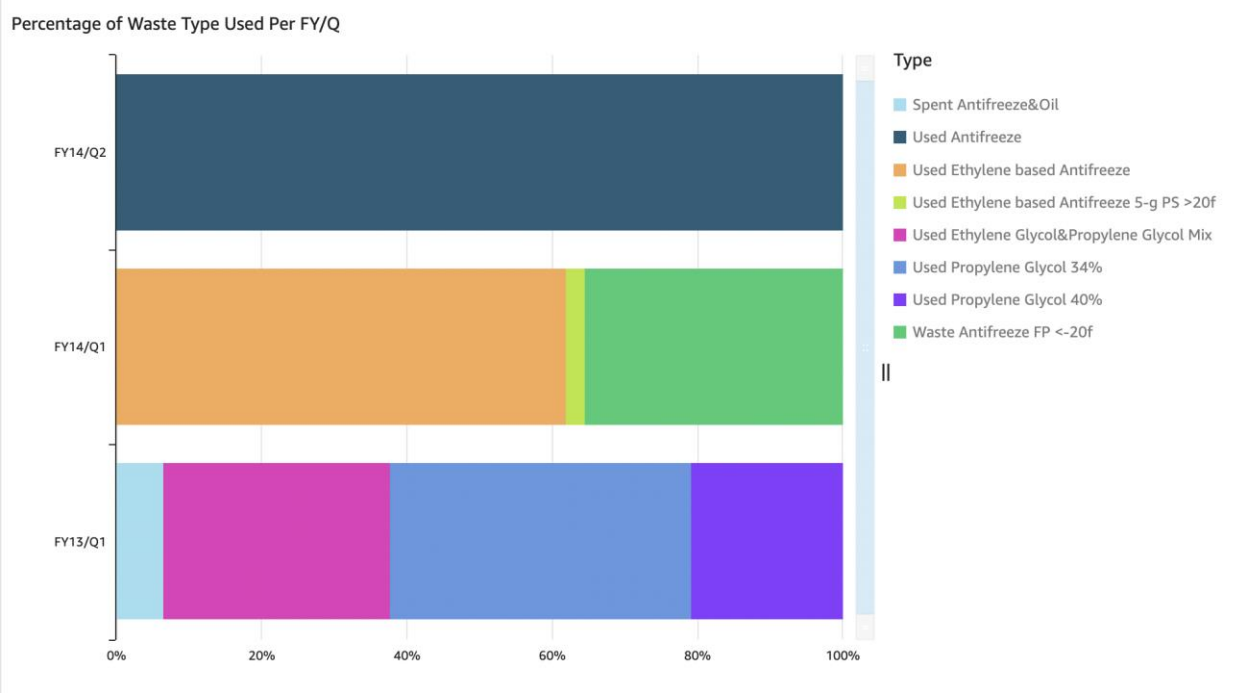

FIG. 25. LIQUID WASTE COMPOSITION BY FISCAL QUARTER

Identification of such trends is important for both fiscal and ecological records, as it can potentially highlight cases of unnecessary consumption or inventory shortages of a particular chemical. For example, if the data set was expanded to encompass a 10 year period and found that Q1 2014 was the only instance where Ethylene based Antifreeze was the most prevalent, this could potentially reveal that quantities of the standard chemicals were insufficient, and proper proportions of cold-resistant chemicals need to be ordered ahead of time going forward. Conversely, if a soil analysis found an alarmingly high presence of Propylene Glycol 34% present on campus, R5 and FCS can quickly go back and see that such chemicals were last disposed of in large quantities in Q1 2013, and as such investigate if proper disposal protocols

were used at that time. Visualizations like this also can reveal unnecessary consumption, and maybe even help inspire researchers at Cornell to focus their attention on creating a more eco-friendly substitute for a chemical solution they wish to replace our usage of.

Long term trends can easily be demonstrated using bar graphs! Users can visualize how many tons of waste ultimately were processed within a given time period, and where it ultimately ended up (see Figure 26). Users can clearly see the impact the Covid-19 pandemic had on campus operations and the significant decrease in waste disposed in 2020, as well as how the data subsequently began trending back towards normal in 2021. Users can see how in a typical year, around 3 times as much waste ends up in landfills than is either recycled or composted, as well as long term trends in overall waste disposed at Cornell. Such findings could potentially even be cited as evidence for why more funding and a greater commitment to recycling and/or composting is necessary at Cornell! With the undergraduate population set to increase over the coming years, such data will be important to see how much the addition of new buildings and undergraduates impact Cornell's environmental footprint. Data can be converted to a per student basis, and then reanalyzed to quantify how much the creation of new "green" buildings, such as Toni Morrison Hall, has improved Cornell's environmental bottom line.

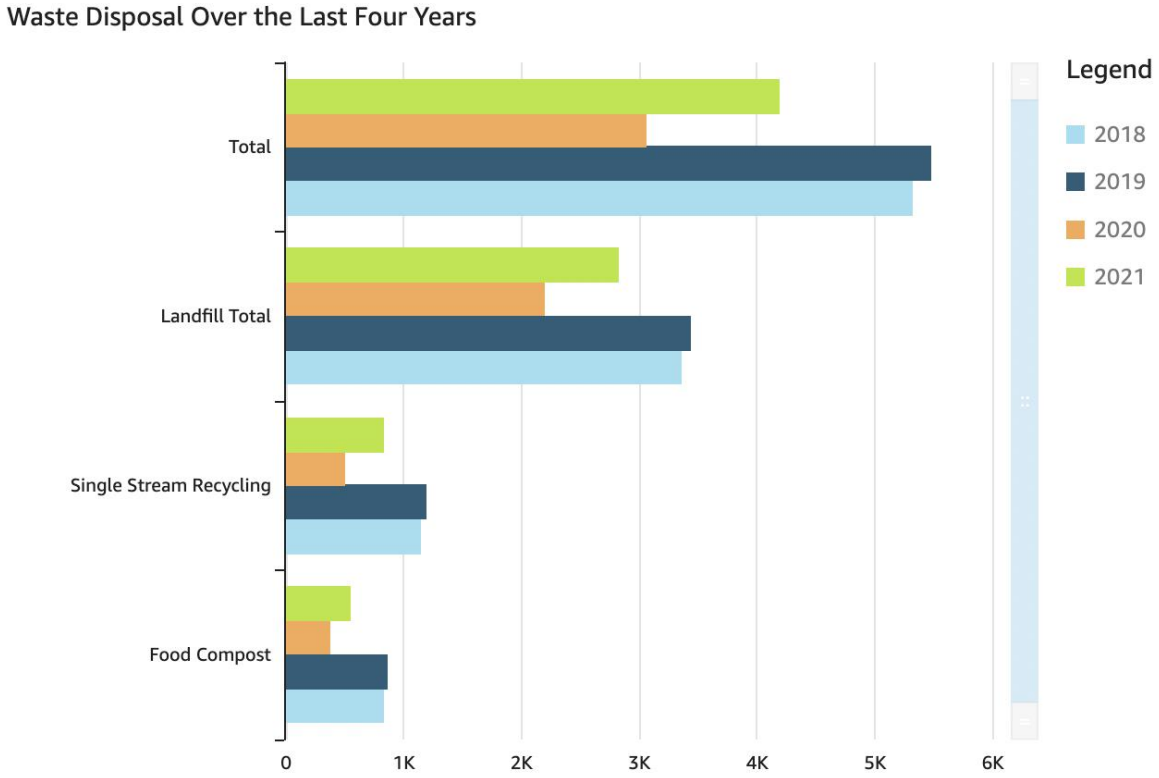

FIG. 26. WASTE DISPOSAL OVER THE LAST FOUR YEARS

III. PROJECT CONCLUSION

The original waste tracking system used by Cornell R5 and CSO contains valuable data for various groups of people across campus, including but not limited to students, researchers, staff,

and other stakeholders. Unfortunately, the lack of standardization and modern technologies have led to inconsistency in measurements, difficulty in visualization, and confusion in data sharing. As Cornell continues to expand in size and more waste streams are introduced, these shortcomings will only be exacerbated and further convolute the existing waste tracking system. The goal of this project was to propose a pathway to resolve these issues through the development of a new waste management system capable of integrating existing data from the original system. Throughout this semester, our team has worked on designing, implementing, and testing the new waste management system, as well as collaborating with the Sustainability Department and R5 Operations. If our project is implemented, we believe that it will catalyze a deeper commitment to sustainability within the Cornell Community and greatly benefit all potential stakeholders and community members while making the system easier to understand and use.

IV. NEXT STEPS

A fully implemented cloud-based solution is far beyond the scope of this project and will require further collaboration with both Cornell IT and Cornell R5 Operations. While we may not be able to fully utilize and implement such changes in their entirety in this semester, we hope that this project can be a worthwhile first step in a long overdue update to our campus-wide waste tracking practices. The next steps for this project will be to set up an official meeting with all stakeholders to discuss details about transferring archived data onto the Amazon AWS, and begin beta testing. Such a discussion should include, but not be limited to: who should have access to AWS and to what extent, creation of a timeline for beta testing and implementation, and how to best merge existing data onto the new platform.

Due to time constraints and scheduling conflicts with stakeholders, to date only minimal user testing has been conducted by R5 and FCS, necessitating an additional round of user testing prior to rolling out a formal round of beta testing. In the meantime, multiple rounds of user testing was successfully conducted on fellow students, but ultimately it is our belief that an additional round of testing with our target audience (FCS) would be greatly beneficial to assessing the feasibility of fully implementing our proposed waste management system. As several of us will be still attending Cornell next year, we anticipate being readily available to help R5 and CSO with a formal implementation if such a resolution is desired. Regardless, we are available to answer any questions about our existing work and assist with further development of this project, if necessary. If there is anything in particular that was omitted from this user document, or would make a significant difference in the waste management improvement project in general, please don’t hesitate to reach out and let us know!

Beyond what is outlined above, we would strongly encourage a promotional campaign for our project to help raise campus-wide awareness of our revamped waste management system, in addition to promoting increased awareness of CSO in general. We envision such a campaign including the creation of original YouTube videos and posters to help reiterate, enforce, and foster the information we are trying to convey by making our campus a living laboratory for sustainability.

V. TEAM MEMBER BIOGRAPHY

Sean Sanchez is an undergraduate senior majoring in Computer Science. He comes from Long Island, New York. Sean hopes revamping the waste management system at Cornell will gather more attention and university-level awareness to campus sustainability. He enjoyed working collaboratively with stakeholders to create the perfect solution.

Cindy Wei is an undergraduate senior majoring in Electrical and Computer Engineering. She comes from Beijing, China. Cindy is passionate about sustainability and believes that an innovated waste management system is a critical step to a sustainable campus. She's grateful to have played a part in optimizing the waste management system for the Cornell Sustainability Office.

Drew Scacchi is an undergraduate junior majoring in Environmental Engineering. He comes from Boston, Massachusetts. Drew is passionate about using technology to help create a more sustainable society going forward and believes that implementing Amazon Web Services into R5 Operations is an excellent example of this. He is excited to see how the new waste management system is ultimately utilized by CSO and R5 Operations.

Jacob Hoglund is an undergraduate senior majoring in Information Science, Systems and Technology. He comes from New York City, New York. Jacob sees the potential benefits of how the original waste collection form can be utilized for the use of the Cornell community. He hopes to bring this experience combined with his background knowledge to create a reliable solution to the problem.

VI. References

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APPENDIX A

CORNELL WASTE TRACKING SUBMISSION TEMPLATE

User Information
Submission Date: _____/_____/_____
Name: _____
Contact: _____
Net ID: _____

Waste Management Plan Requirements

- As a condition of consent, the applicant information sections above must be completed and submitted to the R5 Operations of Cornell Campus Service Department.
- Only authorized Cornell community members are allowed for data submission. Cornell net id is mandatory for identity verification. Any submissions without a valid net id will be voided.
- This form is to be used for all waste tracking data submissions. Each section including source or vendor, values, and additional notes shall be completed. N/A shall be placed where it is not deemed applicable. If the waste value is unknown, please estimate and specify. All estimations should be in US Dollars.
- The units shall be standardized and specified. All calculations and measurements should be converted into kilograms. If not applicable, other types of units such as liters or gallons might be used.
- Completing this table will assist the Campus Service Department identifying the type of waste that will be generated and provide details in relation to how they will be recycled, reused, or disposed. Any information provided on the table will be accessed and recorded by the R5 Operations.
- If the space is insufficient in the table, please use new templates as attachments.
- For hazardous waste including but not limited to chemical, radiological and regulated medical wastes, contact Cornell EHS Laboratory & Research Safety Group for further technical support and compliance assistance. In-depth information and contacts can be found in Hazardous Materials & Waste | Environment, Health and Safety.

Compliance with the Plan

Cornell University has a number of exchange programs aimed to facilitate the re-purpose of materials and reduce landfill waste. The R5 Operation of Cornell Campus Service Department might conduct a waste auction as part of the ReUSE Program. More information can be found in the following links:

1. ReUSE | Facilities and Campus Services
2. STACS FAQ | Facilities and Campus Services

	Waste Type	Amount	Units	Source or Vendor	Value	Notes
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						