Using GIS Overlays as Decision Support Tool in Private Residential Redevelopment Projects

A Master of Science in Geography/Applied Geospatial Sciences Practicum

Northern Arizona University

Flagstaff, Arizona, USA

Advisor: *Dr. Rebecca Dawn Hawley*, Professor

NAU Professor Committee Members:

Dr. Jessica Barnes, Associate Teaching Professor

Dr. Ruihong Huang, Associate Professor

Melissa Rodriguez

mar474@nau.edu

1. Abstract:

This practicum project will explore a small-scale redevelopment project in Tempe, Arizona, and the use of GIS to convert professional drawings into GIS overlays into QGIS overlays for better project management. The practicum will look at the existing use of GIS applications for decision support, the review of the current permit process, and the use of QGIS to turn professional drawings into intelligent data to aid in the construction process. The aim is to showcase the need for GIS data application in diverse construction projects for better project, resource, and time management.

2. Table of Content

1. Abstract …… 1
2. Table of Content …… 2
3. Overview …… 3
4. Introduction …… 4
4.1 Practicum Statement …… 6
4.2 Practicum Objectives …… 7
4.3 Project Site …… 7
5. Literature Review …… 8
5.1 Review and Evaluate Current GIS Processes …… 8
5.2 The importance of Data Analysis …… 8
5.3 The Importance of Private GIS Projects …… 10
6. Methodologies …… 15
6.1 Academic Review …… 15
6.2 Field Observations and Training …… 15
6.3 Methodology Process …… 16
6.3.1 Data Set Flow Process …… 16
6.4 Practical Application …… 16
6.5 Timeline …… 20
6.6 Data Capture …… 21
6.6.1 Reviewing Current City Entitlement and Planning Processes …… 21
6.6.2 Permit Process …… 22
6.6.3 Project Site and Scope …… 25
6.6.4 Initial Project Implementation …… 26
6.6.5 Revised Project Implementation …… 29
6.6.6 Field Data Capture and Methodology …… 31
7. Findings …… 35
7.1 QGIS Data Overlays …… 35
7.2 Risk Mitigation …… 42
7.3 Future of GIS in Small Construction Projects …… 45
8. Appendices …… 47
8.1 Appendix A: Lists of Pictures …… 48
8.2 Appendix B: Project Team …… 49
8.3 Appendix C: Data Dictionary …… 50
8.4 Appendix D: Acknowledgment: …… 51
8.5 Appendix E: References: …… 52

3. Overview

This practicum looks at the current need for GIS in urban planning, specifically in private residential construction small-scale projects. Existing studies of GIS in the construction field look at using data as a decision-support tool. GIS data is used for construction projects in large-scale redevelopment efforts with local municipalities. This data, which cities have long collected for redevelopment projects, can help managers evaluate residential projects' viability. However, research and evaluation in private projects are minimal. This practicum will look at how zoning data and site analysis data, such as 3D models alongside city design guidelines, can aid construction decisions in real-time.

The project to be explored in this practicum is a small-scale construction addition qualified as eight hundred square feet of office and community space for the Vedanta Center in Tempe, Arizona. The clients later chose to add a six-hundred-square-foot parking lot, which increased the professional services needed to meet city approval. This add-on translates into the investment of GIS equipment to collect, translate, and overlay the newly captured data. The additional work required using GIS-specialized staff to help the civil and architectural teams to help interpret and meet the city requirements. This document will walk us through these set processes and the use of integrating GIS into professional services beyond the civil engineering's smaller scale project prevue.

This practicum will preview the need for GIS practices in diverse construction projects and the ease of access utilization can be. Alongside the exploration of the value of making geospatial practices commonplace in data collecting, processing, and presentation of project data to aid in the city design review process.

4. Introduction

Why is city zoning necessary? Zoning is a tool most cities use to govern land use within the municipal boundary based on a comprehensive plan. Municipalities use developmental impact studies to implement base zoning codes and laws. Factors, including the community vision, surrounding cityscape, open spaces, and the street, are considered in implementing these zoning codes. These codes are pivotal in a city's growth, form, and resilience rating. They, therefore, need to be carefully studied and utilized for the success of our communities. Despite a common layperson misconception that zoning only pertains to city officials or project developers, zoning affects every resident in every City. The zoning laws outlined by local municipalities determine what gets built where. For this reason, city stakeholders comprising of residents, city staff, and private and public business members must work together to benefit the community. Only through working together will communities genuinely grow and prosper inclusively.

The City and community members can work together through revitalization efforts. Some areas have aged well with time, while others have not. These now neglected and derelict neighborhoods are still home to residents with old ties to the community. Across the United States, local communities are partnering with private agencies and public officials to revitalize their cities (Beider, Levy & Popkin, 2009). While city stakeholders, community leaders, and developers must consider all residents when creating redevelopment efforts, a lack of representation is a widespread problem. As revitalization efforts expand due to new industries replacing existing ones, disadvantaged community members face further exclusion when new people move in to work the new jobs outbidding preexisting residents. These new industries and jobs infuse new money into the area, allowing new residents to price out existing low and middle-income residents, the elderly, and people with disabilities on limited housing (NLIHC, 2019). These redevelopment projects further create hardships for displaced people, leading to increased issues of housing disparities. A PolicyLink study indicated that vulnerable populations impacted by a lack of affordable housing caused by gentrification typically have a shorter life expectancy, higher cancer rates, a high incidence of diabetes, and exposure to hazardous substances. These increased health risks are directly tied to the lack of access to safe and clean residents (PolicyLink, 2002). In the practice of gentrification, rehabilitation revitalizes the community, but often at a cost too high for the existing residents. The residents who reap the benefits of gentrification are those moving in, which displaces existing residents (Frankl, 2021).

Given that the issue of affordable housing is rampant, project stakeholders and community advocates must explore projects that better inclusively serve the community at large. As cities complete these redevelopment projects around the nation, geospatial data and analysis are becoming more commonplace. This data helps to understand what is needed and where—such as in the site selection of the Jawaharlal Nehru Government Engineering College Sundernagar in India. Initial site selection planning and analysis called for constructing a workshop in a location that would require topological reconfiguration of the site. This reconfiguration did not consider the function of the workshop and the heavy machinery, which posed safety concerns to the site's topological integrity. This spatial analysis allowed the project managers to consider additional project factors and redesign the project while the project was still in the development stages (Kumar & Bansal, 2016). Despite these benefits, many small private projects do not incorporate GIS data and work with potentially problematic design vision as their driving force.

Small-scale construction is defined as the working construction or repair of facilities where the total surface area of the disturbed environment is under 10,000 square feet and less than $200,000 in total cost (USAID, 2013). Where single-family construction is defined as "fully detached, semidetached (semi-attached, side-by-side), rowhouses, and townhouses. In the case of attached units, each must be separated from the adjacent unit by a ground-to-roof wall to be classified as a single-family structure" (U.S Census, 2021). These types of projects have been slow to take advantage of the geospatial data. A 2020 study funded by ESRI and Autodesk found that the biggest challenge reported by GIS users is the lack of interoperability with other tools and the lack of staff with GIS knowledge. However, the study also found that GIS is growing in the construction industry as design and construction companies increasingly take advantage of datasets (Business Wire 2020). This small-scale use contrasts with commercial, mixed-use, and multi-family projects due to significantly deeper financial means, allowing greater access to existing data and GIS personnel. This current niche access is where we can work to improve spatial data incorporation and implementation. Geospatial analytics can aid public and private sector projects using data collected and stored by local city entities. Showcasing that smaller outfits can benefit from the data and do so at an affordable price. The first step is to understand the value and therefore value the data and the costs.

4.1.Practicum Statement:

This practicum explores the need for GIS practices in all urban development efforts, including small private projects. Alongside the exploration of the value of making geospatial practices commonplace in data collecting, processing, and presentation of project data to aid in the city design review process.

4.2. Practicum Objectives

- **Objective 1:** Review and evaluate current GIS processes and utilization in the construction industry.
  - This objective is explored in existing literature and case studies of the utilization of GIS in the construction industry.
- **Objective 2:** Review current city zoning and planning processes identified as a silo and compare them to geospatial data sets identified as collaborative data.
  - This objective is accomplished by reviewing the project's needs as a small-scale redevelopment effort.
- **Objective 3:** Use open-source software QGIS to showcase how user-centric GIS data levels the playing field for consumers to participate and collaborate.
  - This objective is accomplished by reviewing project data and deliverables to be used in the project design review process for city review and approval.

4.3. Project Site

This practicum reviews a small-scale redevelopment project and explores the need for GIS data collection to analyze the City's preliminary design process. The practicum will examine the existing city process, revitalization needs, current zoning, and demographic data.

Figure 1: Project Site
Ramakrishna Vedanta Ashrama Phoenix Temple

1138 E Henry St, Tempe, AZ 85281

This analysis allows the project client to incorporate vital needs into the City's design process. Thus, allowing for a streamlined design review process with the City.

The Tempe project consists of two parts. The first part is an eight-hundred-square-foot addition to an existing dwelling that is changing from a private residence to a temple of worship. The second portion of the project is converting the adjacent empty lot into a parking lot, complete with all the landscaping, civil, pavement, and handicap requirements needed to meet the City's design requirements.

5. Literary Review

5.1. Review and Evaluate Current GIS processes

Since its inception in the 1960s, geospatial data has become integral to dozens of fields. Geospatial science initially helped land-use planners and land resource managers make informed decisions. This objective is still in use across professions and applications, but does it have even more significant potential? Ayman M. Nour, Associate Professor of Architecture at Helwan University, Egypt, asked this question in his 2011 paper, *The Potential of GIS Tools in Strategic Urban Planning Process: as an Approach for Sustainable Development in Egypt*. Professor Nour starts his research by making an innocent yet essential observation, "as GIS use becomes more widespread, GIS advocates make up less of the market (Nour, 201: 284). This statement is essential given that while GIS tools are becoming more accessible and valuable, their utilization is adversely falling. For this reason, continuing to advocate and incorporate GIS data for real-time decision support is essential.

5.2. *The Importance of Data Analysis*

Whether publicly or privately funded, or for residential or commercial projects, construction costs are hundreds of thousands of dollars, if not millions. In addition to the time needed for preliminary project planning, stakeholders must consider if the project will be feasible within the scope, budget, and timeline. These project elements are vital to construction planning and methodologies. They, alongside the application of GIS tools, become real-time decision data.

As stated by Professor Nour, "GIS aids in public policy decisions for a more effective allocation of resources for community and economic development. Due to the nature of spatial analysis and its role in proposed construction projects and models, GIS provides a means of testing alternative projects" (Nour, 2011: 285). These alternative models create project data, which becomes information and knowledge. This knowledge is essential to project, and city stakeholders as different data-driven scenarios showcase real-world practical applications. This real-time knowledge allows for strategic planning based on real-time data instead of theoretical, showcasing the impacted budget, schedule, and scope in real-time. This strategic planning allows for clarification and understanding of short- and long-term goals, including scenario-based tasks creation based on analysis of the project's strengths and weaknesses. This approach creates an evaluation of the benefits and concerns of said project. In turn, it allows for adding or subtracting design and project elements as the project data and model begin to take design shape and identify concerns.

With an overwhelming portion of the world's population facing overcrowding and housing concerns, making better decisions streamlined by identifying issues and combining planning and design systems is essential. GIS data tools aid in modeling and developing a project's design by addressing fundamental questions to guide the design process. To begin a project, stakeholders must use GIS to review land use data, existing structures, construction materials, zoning ordinances, land ownership, and infrastructure needs.

The Egyptian state is attempting to capture its growth potential by utilizing GIS data analysis to provide a snapshot of its current needs. City officials obtain evidence in a detailed feasibility study to understand what and where public works projects are needed. This, "Strategic planning for the development of the City is a structured decision [that] focuses on the major issues and how to solve them. Based on monitoring and analyzing the current situation, identifying stakeholders and how to work with them, identifying and defining the vision and translating them into long-term goals, short-term objectives, and activities, achieved these goals and identifying means to contribute to and preparation of detailed action plans for implementation of the planned implementation mechanisms" (Nour, 2011: 291). This action plan and the implemented methodologies allow for a clear and precise systematic approach to address problems and identify potential solutions. The existing utilization of geospatial data has shown success with large-scale public projects. However, the general use of the data and its corresponding analytical findings remains very limited in private and small-scale projects.

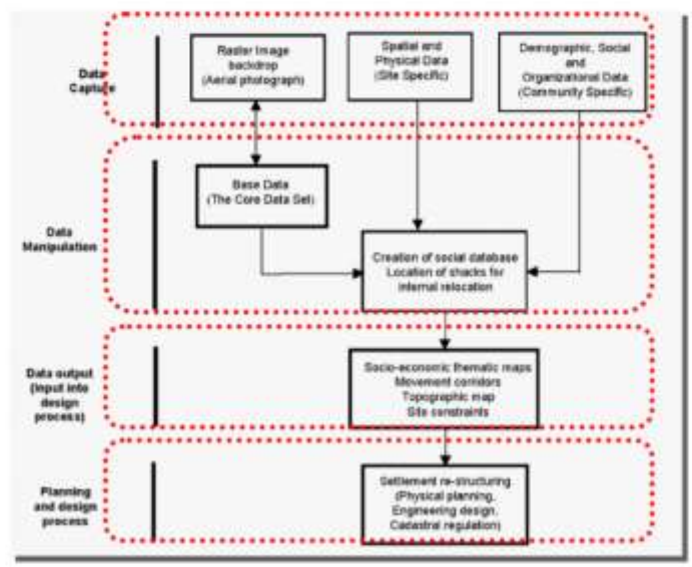


Figure 3: data flow diagram for informal settlement strategic planning.
Source: (Abbott, 2001).

Figure 2 Data Flow Diagram for Egypt's Strategic Planning

5.3. The Importance of Private GIS Projects

Large multiple multifaceted projects such as city infrastructure projects have the purview of more data analytics to consider. However, the scale of a project does not necessarily mean it will or will not create a community impact. Small or privately funded projects can also have a role in the overall look and feel of the City's short- and long-term livability plans. Private projects "are projects of every type that are owned, controlled, or commissioned by a private party. Private parties include individuals, homeowners, corporations, other business entities, non-profit associations, privately funded schools, hospitals, and publicly traded companies" (Levelset, 2021). Regardless of the type or scale of a project, the existing public facilities and neighboring construction elements will influence the site. For this factor alone, planning for a construction project should never be done in isolation without considering the immediate surroundings. Therefore, geospatial exploration is needed. In the pre-construction planning (PCP) phase, project managers recognize that regulatory requirements, site constructions, design planning, site layout planning, and resource planning are vital in the construction process. However, GIS incorporation into these steps and processes is currently limited. Each stage plays a role in the project's time, budget, and scope. Bansal (2015) explored how site layout planning is a common area of project delays, cost overruns, and site congestion. Bansal's study found that incorporating GIS to develop an automated site layout for laying temporary facilities close to their supporting activities reduced travel time. Reviewing GIS data allowed the project team members to utilize the site's geospatial data. The team incorporated a database management system to integrate the information required to find the optimal locations of various temporary facilities to aid the project's efficiencies (Bansal, 2015). Project management elements such as delays, material waste, and resource management are arguably more sensitive with a private small project basis. However, small-scale projects do not get the time and preparation that would help mitigate these critical elements.

Furthermore, the use of GIS in large-scale residential projects is also uncommon, if not virtually absent. Except for sales platforms looking to showcase this critical need in construction projects. However, even these applications, such as ArcGIS CityEngine, look at a macro scale instead of the micro-scale of private residential redevelopment projects (ESRI, 2020).

The use of GIS tools in private construction projects is typically minimal, if not absent altogether, due to the narrow understanding of geospatial data's potential and the current feasibility. City agencies across the United States and the World have entire GIS departments dedicated to the modeling and strategic planning of city development, redevelopment, and large-scale construction projects. However, the private sector is slow to join this data-collecting mindset. As the industry moves away from data collecting and towards data analytics, the opportunity for project modeling and evaluation is ripe for becoming commonplace. Nour's Cario case study demonstrated that incorporating GIS analytics into their mass infrastructure project helped give their stakeholders a clear, shared set of goals, tasks, and obstacles. Incorporating data analysis in the pre-construction planning phase of small-scale projects can wield the same shared vision among project stakeholders. A shared vision will also allow the city design review team to understand the project's scope better to either approve or deny the project. This quicker turnaround time help keeps projects moving forward for the owner and the design review process moving forward for the City.

This utilization of GIS in construction projects holds a critical role. Petimani, Awati, and J.V (2019) explore the central importance by showcasing that a solid geospatial system is needed for the project's database to integrate project-generated satellite imaging data. This process allows GIS to provide visual progress of the project (p. 2995). This imagery data is vital as it allows for visual inspection, reinspection, and overall project review, which helps mitigate scheduling conflicts. The GIS data integration allows for real-time collaboration between schedules and linking different activities. It gives project managers the ability to visualize the project at all levels. While GIS data capture and analytics can be very niche, the practical data output produced by GIS is easily digestible by non-GIS professionals. By creating a visual component of the project, issues such as scheduling, safety, and staging, can be identified and mitigated. Thus, keeping project risks and costs mindful and at the forefront of the management of the project. This practical scheduling approach is demonstrated by developing an integration schedule with 3D construction plans in the GIS model to create a 4D schedule. This process involves:

1. The collection of 2D plans using programs such as CAD.
2. The creation of a work breakdown structure (WBS) to define project tasks.
3. The integration of CAD files into the GIS application.
4. The creation of shapefiles for georeferencing.
5. The preparation of the schedule of the tasks outlined in the WBS.

These initial steps are essential as they layout the project's parameters and allow the 3D simulation to have real-time data linked. Real-time data in architectural plans imported and georeferenced to a job site sets the groundwork for identifying tasks needed for the project. The G+1 project explored in the case study identified the very commonplace stages of foundation work, pedestal work, wall work, and roof work, to list a few. These stages were identified and created for each level of the project. This identification is critical for the 4D schedule to manage the project schedule adequately—these steps incorporated using the GIS software ArcGIS stitch together the multiple layers and components. The final product, the 4D simulation, allows any user to visualize the project from preparation to completion good visual of the construction work and its progress. "The linking between the activities scheduled and drawings in GIS helps identify steps in construction and the findings of errors logically that arrives in [the] schedule project. This 4D output helps the project manager monitor the construction site to take hold of the work progress and keep up-to-date data about the project progress" (Petimani, Awati & J.V, 2019).

Not only do GIS applications play a role in the forward planning of projects, but GIS also plays a role in project management. Patel et al. (2017) explored how GIS programs are not only about geolocation data but how physical location data can be used to model operational needs in various industries. Managing any project can be difficult and has only been made worse by global supply issues and delays. Turning static data into dynamic visuals and models can help even inexperienced technological or operational stakeholders. The construction industry and its projects change minute-to-minutely, yet the operation systems remain static. The data from the system require a re-download and a recompilation every time new information is needed. This process is time-consuming and often not value-added due to the quick pace at which data becomes outdated. However, with the use of a GIS system, as the project changes, so does the model and the information readily available to the field and executive team members. We see this by drawing a small residential bungalow in Auto CAD, which integrates with M.S. Project. M.S. Project contains the project data, such as schedule delays, personnel time clocks, or installation data imported into the model to keep track of changes in real-time. This application of real-time field data presented in a digestible presentation for operation needs allows departments and different taskmasters to share information. Coordinating all facets of the business and departments is essential to operational success and a proper understanding of all business needs. This coordination allows team members without technical knowledge to quickly understand the project's progress (Patel, et al., 2017).

6. Methodologies

6.1. Academic Research

Practicum research was conducted with the literary review with graduate courses in the geospatial program at Northern Arizona University, specifically the Planning and Recreation courses. These courses emphasized the dynamic relationship between urban development and geospatial data. These literary reviews allow for exploring existing research, datasets, and implementation of geospatial data within urban redevelopment efforts. These courses included:

- GSP 531Map Design and GIS
- GSP 532 Community and Urban GIS
- GSP 521 Planning Law and Ethics
- GSP 545 Communities and Public Health
- GSP 697 Independent Study
- GSP 599 Contemporary Developments
- GSP 501 Communities & Public Planning

6.2. Field Observations and Training

Research began while observing real-world equipment demonstrations conducted by Faro Technologies and Allen Instruments, a value-added reseller for Trimble. Further research and interviews with the principles of each professional service/discipline as well small-scale private homebuilding organization. Additionally, field observations and data collection were created in collaboration with an academic geospatial team from the University of Southern California to create a GIS dataset at the Cataline facility. This data was compiled into a GIS dataset for database creation for prospective clients—these data models allowed for real-time decision support and simulations for various clients, industries, and applications.

6.3. Methodology Process

6.3.1 Data Set Flow Process

- Field data collected data set converted to CAD file
  - Google Maps through QGIS will be used as part of the background to base map.
  - Civil engineering will include Grading and Drainage as overlay *UtilityPlanOverLay*
  - Drafting/GIS team will provide field data sets *GeoPoints* overlay.
  - Architectural will include new structures and pathways as overlay *Parking*
  - Landscaping Architecture data sets will be overlay *Landscape*
- CAD file used as main overlays for all professional services: Add image backgrounds, and individual data sets as a support data set for build out.
- Outputs will include all PDF files per discipline for city to review for permit.

6.4. Practical Application

This practicum is conducted in partnership with the design consulting firm Virtual Space to utilize a practical application to a real-world project. This practicum involves working with eight support engineers representing the client/owner. Additionally, six team members representing the city will use GIS to provide data analytics as part of a decision-support process. QGIS is one tool that processes data collected by the data collector handhelds. One of the main benefits of using QGIS is organizing, managing, and distributing documentation to the team members via a database. QGIS is an open-source program that allows entry into the program utilization with limited program training. While industry standard ArcMap is an extremely robust program that is more than capable programs of any nature, the sheer ability of such an industry titan can create barrier of entry, with its very technical user interface and costly license. QGIS being an open-source application allows for the sharing of the overlays in QGIS via a zip file package or converted into PDF as needed. This database repository will be a central bin of information where all participants can review and manage the documentation over the cloud. Using QGIS to review 3D models during the prelim site review process is extremely helpful to the owners. It can represent simulations of the terrain, utilities, and conditions that may impact the project. For this practicum, Leica handheld data capture devices and Carlson tablets were used to capture data and review the level of precision. This data will be part of the new GIS data set.

Additionally, a drone will be used for fly-over data capture. The multiple data levels will allow participants to discuss essential utilities, setbacks, access, traffic flow, landscaping, and other technical conditions. GIS can now be used to create the documentation needed to complete the permit. Standardizing the documentation process with QGIS will create the overlays to aid the city submittal documents. The documentation will be converted from raw data into finished data, defined as PDF files, images, text, video, and other formats used in the practicum.
These data sets were completed using the Trimble Nomad and Trimble Total Station to capture the cut sections/profiles. These new layers were able to precisely define the areas of total square footage, paths of travel for traffic, rain runoff, and covered empty areas with new landscaping

The methodologies will be used in the practicum to look at data to determine what design elements are needed and if these elements are viable for the project. The project of study, the "Temple," in which the practice of using GIS data capture to aid in city design review was conducted in the following two-step process:

Phase One: Structural Review:

- Surveying *Team:* Provided typical land map overlay using raw data shot from a total station and converted directly to CAD style program.
- Civil Engineering: Using the survey data set as an Elevation overlay, the civil now shot its points defined as:
    - Contours
    - Elevations
    - Utilities

This information allowed for the creation of a drainage plan defined as Drainage_overlay

- Landscaping: The landscape architect used the overlays provided by the civil survey to produce the types of the landscaping plan, Landscape_overlay.

After an extensive review by the City, the corrections identified that a more detailed set of data sets would need to take place and thus created a significant change order for the client as additional expenses for GIS services were now needed. The new data sets are comprised of the following:

- Revised elevation scans compiled into elevation2_overlay
- New profile diagram for drainage to include the overall landscape.
- Coverage was completed by two new data sets defined as architectural data paths identifying areas specifically for
    - ADA Parking
    - Drainage wells
    - Egress and ingress access
    - Utility easements

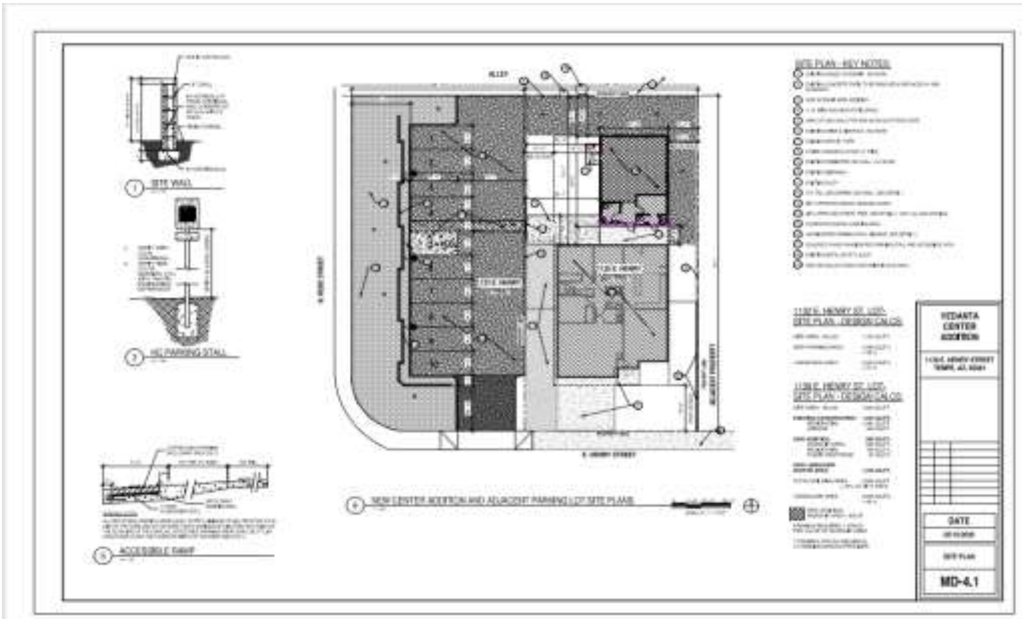


Figure 3 Initial Civil Engineering Plans

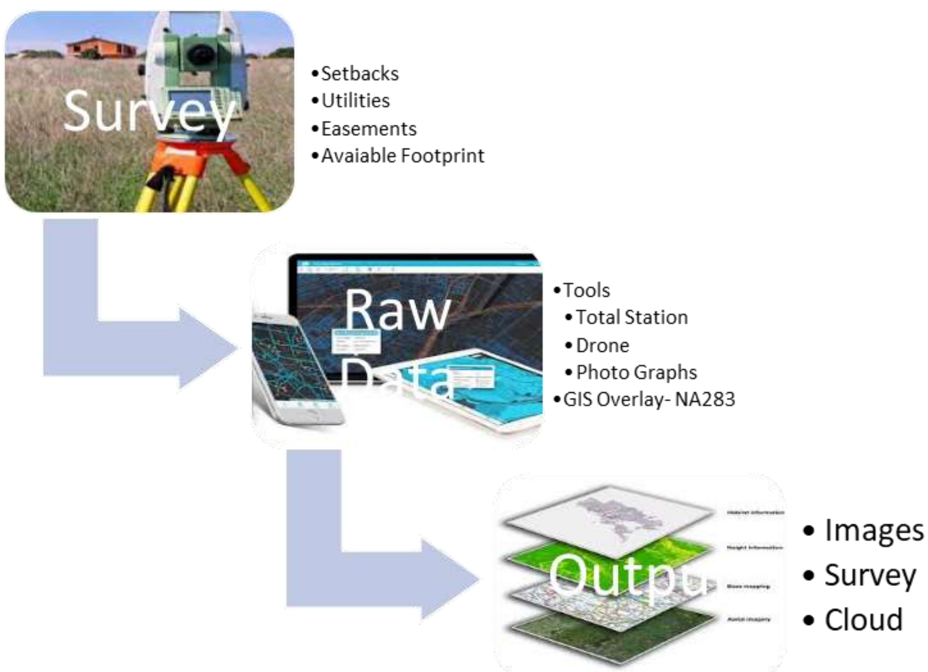


Figure 4 Data Capture Methodology

6.5. Timeline

- August 2016
  - Prelim Design Meeting for The First Part Of The Design
  - Prelim Field Data Collecting: Physical Measurements and City Due Diligence
  - Prelim Design and Budget Approvals to Proceed
- August 2018
  - Contract Architect to Begin Production Drawings
  - Secondary Field Data Collecting
- October 2018
  - Lot Survey: New Data Collecting Contours, Property Boundaries, and Easements
- January 2019
  - Contract Support Engineers to Complement Architectural Set
  - Mechanical/Electrical/Geo Technical and Civil Engineering
  - Third Set of Data Collecting Based Off of Tiered GIS Overlays from Previous Data Collecting
- January 2020
  - Original Project Completed and Submitted to City of Tempe for Project Review
- March 2020
  - First Set of Redline Corrections: Clarification on All Disciplines Overlays
- August 2020
  - Resubmittal With Additional Landscaping Included

- January 2021
  - Preliminary Design Approvals with Conditions for Infrastructure. This Requires an Architect and Redesign Civil Grading and Drainage Plan
  - A Total Of 6 Meetings with the City on Final Cuts Due to Infrastructure Specifications, In Alley, New Grading and Drainage Requirements, and Lighting Requirements
- December 2022
  - City Of Tempe Issues Building Permit
- Aug 2022
  - General Contractor Signs Formal Contract to Begin Construction
- October 2022
  - Field Change Order Due to Field Conditions That Do not Reflect On The Approved Set
  - Revised Field Data Collecting to Verify All Site Objects And Field Measurements To Match Field Conditions

6.6. Data Capture

6.6.1. *Reviewing Current City Entitlement and Planning Processes*

Figure 5: Map of Zip Code 85281

The zip code 85281 is in Tempe, Arizona, in the United States, in the greater Phoenix Metro area. Scottsdale surrounds the area to the North, Mesa to the East, and Phoenix to the West. While Tempe is most notable for being the home of Arizona State University, Tempe is a thriving city. The area and the rest of the Phoenix area have seen significant population growth over the past decade. The area's demographics consist of 55.62% White, 23.98% Hispanic, and only .2% identifying as Other (ZipDateMaps, 2022). The local public services are governed by the City of Tempe, which oversees zoning, building codes, and municipal construction applications. Tempe utilizes a ten-year General Plan to guide the development, land use, neighborhood use, and human service annuities that will be approved and developed within their jurisdiction. One of the current goals for the 2040 General Plan is to develop the City in such a way that allows residents to be able to meet their needs within a twenty-minute travel radius for its residents. One such strategy to accomplish this

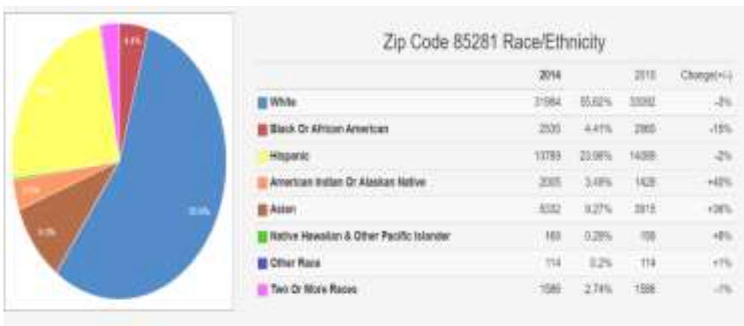


Figure 6: Zip Code 85281 Race/Ethnicity Demographics


Figure 7: Zoning and Overlay Districts Map

goal is to recognize and identify locations for social institutions which play a vital role in our neighborhoods (City of Tempe General Plan 2040). With that forward need in mind, the owners of 1132 and 1138 E Henry Street desired to turn an existing private residence into a worship center. The site location, -111.92, 33.44, currently houses a vacant lot and a single-family residence. The neighborhood is currently zoned for multi-family residents, with the project calling for a rezoning of a commercial classification.

6.6.2 Permit Process

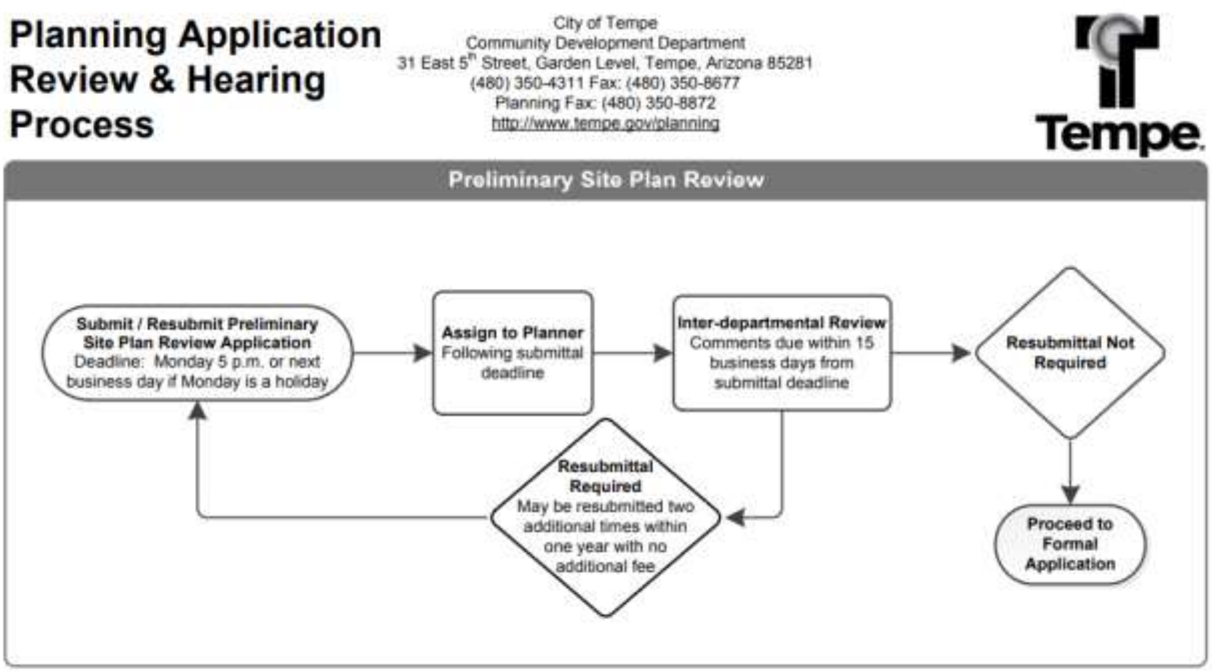


Figure 8 Preliminary Site Review Process

- Step#1: Civil Survey team shoots raw data points via total station and converts the data sets to a CAD file.
- Step#2: CAD file is shared to the Architect/Drafting and Civil Engineer to add their own overlays.

- Step#3: Field data points are shot using, drone, Leica and Trimble Nomad to incorporate existing structures and conditions.
- Step#4: Data is converted to CAD file data as a new overlay for architect and support engineers to use to add their own data.
- Step#5: Civil data set and architectural data sets are reviewed by submitting to city as a prelim site design process.
- Step#6: The City of Tempe creates a team representing each section that is part of the city permit process. The review the new PDF data set and return to client with corrections as red lines.
- Step#7: The architectural team will distribute back all PDF corrections redlines for support teams to update and revise the data sets.
- Step#8: The field team may need to go back and reshoot or verify city of Tempe questions pertaining to existing preconditions for more clarification.
- Step#9: One all data sets have been reviewed by the professional services and updated data sets to meet the city of Tempe corrections. The revised plans are resubmitted for prelim design approval.
- Step#10: Once the prelim site has been approved, we now move into Grading and drainage city process and building process The project files (PDF) are submitted for the individual components to be reviewed for permit.
- Step#11: The City will review and add their G&D comments as part of a separate review for permit process and approvals. The new added services will be to add the following items to the project:

- Landscaping
- Lighting
- Revised and more detailed drainage
- Parking lot calculations and design
- The architectural review process will be reviewed and will need to add the following services:
  - Fire life safety sprinkler systems
  - Handicap ramp and parking

➢ Step#12: Once these revisions have been completed and new professional services have provided their new documents as part of the support package. The new data set will be ready for resubmittal number 3. The client will need to pay additional fees for added city services based on the last submission.

➢ Step#13: The city issues Architectural set building approval.

➢ Step#14: The civil engineer needs to coordinate with landscape team and lighting consultants to add their new data sets addressing the last city revised corrections set of red lines.

➢ Step#15: Civil engineer is now approved with provisions(conditions).

➢ Step#16: Once client pays for permit fees, the city issues permit.

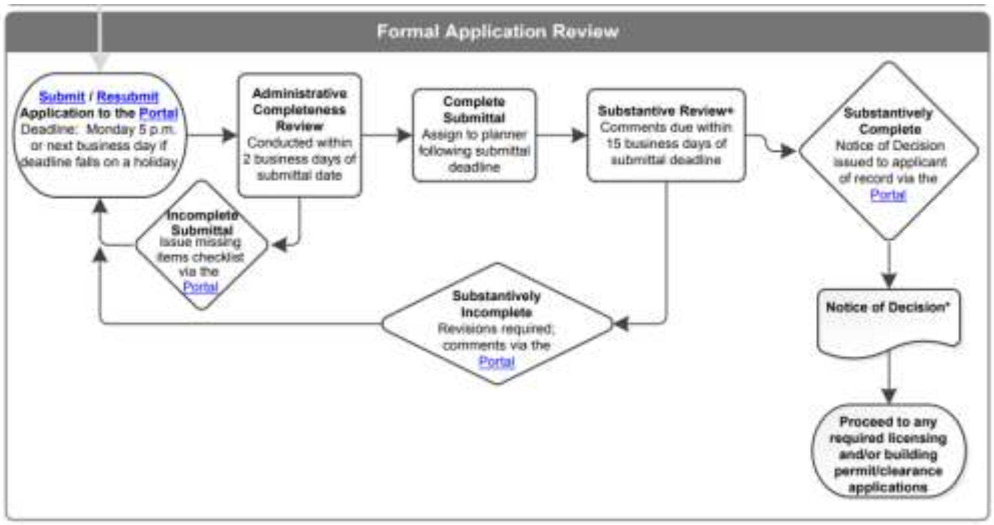


Figure 9 City of Tempe Formal Application Process

Figure 10 City of Tempe Permit Issued

6.6.3. Project Site and Scope

This practicum study site, The Vedanta Center Addition project, calls for adding 800 square feet to the existing structure, currently 2,045 square feet. The initial project conception began in 2020, with the initial design process beginning in the spring of 2021. However, the project saw a ten-month delay due to the new data needed to comply with city ordinances. The City of Tempe plan requirements must include:

- Details of All Planning Conditions of Approvals
- Equipment Screening Details
- Photometric plans a 50% screened landscape plan
- Zoning & Development Code security requirements
- Landscape plans, including vegetation details
- Parking details, including islands

Figure 11: Project Site: Vacant Lot and Existing Structure

6.6.4. Initial Project Implementation

The design process began with collecting site data to process into a CAD file for review by the engineering team, who looked at the existing and after conditions of the land. Different teams provided the original data collecting:

- Landscape architect, architect, and the drafting field team.
- The results were as follows:
- Land survey data set: Physical data collecting
- Architect scaled CAD file (based on field data collecting team)
- Drafting field data set: Physical data collecting
- Landscape architect boundary conditions (based on Survey drawings)

The professional process consists of the following processes that walk the client through each data set process to provide the support document needed for city submittal.

- Step#1: Data collecting process, which requires physical field measurements.

- Step#2: Once the data is collected, it is converted into an electronic format for the support engineers to begin the design process.
- Step#3: The support engineers and architect design the new conditions based on the field data sets.
- Step#4: The client approves a complete set of drawings and submitted to the city for plan review.

This original city process took 18 months of review to obtain approval on a final construction plan set. After that initial approval, the general contractor discovered that the permitted construction plans were either missing information or had misinterpreted information that questioned field conditions. This discrepancy resulted in re-visiting the site and field, capturing a new set of data sets to clarify the issues. Had the project been approached from a geospatial standpoint at the being, the professional drawings would have been interconnected and allowed for a nine-month reduction in city revisions. While the cost to implement a GIS analysis would have ended up costing the same as additional professional services, the project progression would have been linear and forward moving.

The first set of issues the project ran into was the call for the civil engineering team to provide more details about preexisting conditions. While initial site planning and city submittals called for a simple grade-driven slope drainage plan, the city redlined additional runoff from the adjacent rear lot. The concern of elevation differences between the north side of the property, and the south side of Henry Street, could pose a flood issue despite Tempe's typically dry climate. The City's redlined questions impacted the location and design of the entrance and exit needed on Henry Street and the rear alley, respectively. The civil engineer provided a new map identifying the 500-year and 200-year flood with new elevations on how the water would move to areas defined as water wells. The second set of plans was called to show how the existing grade would need to be paved to meet the existing rear alley level that will become a part of the new parking lot. In order to complete the (3) new plans within the civil drawings, the engineer needed to send a team for more detailed data collecting of elevation points and the water path of travel to the water wells. The second plan used was a property profile (section) demonstrating the high points and the difference in elevation where the water wells will be located and their depth to meet the code requirements. These plans would allow the client, the architect, the project manager, and the civil engineer to understand the City's concerns and elevate a revised project design to meet the requirements needed for the project site.

City design review can require several rounds of revisions and may or may not call for out-of-the-ordinary requirements to be included in the design. The project team was not expecting that the City of Tempe would require drainage consideration for the 500-year plan due to the average of nine inches the City gets against the national average of 38 inches. This extra consideration caused the incorporation of two stormwater drainage wells on both sides of the property to handle the stormwater pouring onto the new pavement parking lot. These new considerations cost the project three months of revisions, an additional $2,000 in engineering fees, and an additional $20,000 in construction costs to incorporate the additional city requirements. These were not considerations that the client had not been expecting in the form of time or money. These types of delays and revisions are not uncommon in redevelopment efforts and have been known to derail projects due to scope and budget creep. Another consideration project managers must also consider the client's ability to gauge and understand the full extent of the requirements. Private residents undertake many residential projects, not in the construction industry. Therefore, they rely on their project team to manage the project. It can be very easy for clients to experience project creep without genuinely understanding the rationale behind it, but rather trust in the information the hired professionals are giving them. Projects funded by non-industry professionals are becoming more commonplace, which is why traditional project management and documentation are outdated in today's technological world. The client relies on the project manager and the various engineers to communicate with one another to piece the various elements together, which left the client in the dark about project status, revisions, and cost increase throughout the building permit stages of this project.

4.6.5. Revised Project Implementation

One issue that hinders non-technological stakeholders is how documentation is issued and how the field data-collecting process and data types are standardized. Once data has been collected, it needs to be converted into a standard electronic format that all participants can use. One type of field data-collecting process is where a handheld device is used to capture points using a base image of the project site. The data set is then converted into an electronic CAD file that will be used as a project overlay. A second field data collecting process is to confirm elevation points off of critical landmarks to confirm the difference in terrain slopes and differences that impacts the ingress and egress of the property line. These two data capture techniques are utilized in the Temple project to address the rear north alley and front south access. From provided site data, the rear alley center line is to have a 50'0" distance into the proposed parking lot. The south side main entrance off Henry Street is to have a center line into the street also at 50'0" towards the proposed lot. These elements became a priority due to the City's comments, leading to the following questions:

- Why did the general contractor question the second access requirement only after the initial design review submittal? Despite the City of Tempe's standard parking lot requirements, including ingress and egress access. This afterthought required a second round of professional services after the initial approval.

- Secondly, what are the legal and financial implications of the additional required professional services?

From this next round of design requirements, it was determined that GIS data sets collected would demonstrate the elevation points and would be compared to the civil engineer plans on grading, water retention areas, and parking grading. This data set is then utilized to create an overlay, which can be turned off and on. This ability allows for the City to review each overlay data sets as it pertains to existing conditions, field measurements, code requirements, lot boundary guidelines, contours of the existing site plan for grading and drainage, architectural egress and ingress, ADA handicap parking and accessory parking for bikes and motorcycles.

The overlay was created by using field equipment to capture data which was then converted to electronic CAD files that will allow the support engineers to review preexisting conditions and new proposed finished requirements to meet client requirements and city ordinances. As the main goal is to maximize project resources for a non-technical client, creating documentation for the client and team that was not only digestible but also useful for the design review process was the point of involving GIS processes. It is important to remember that even industry professionals such as the general contractor or city planners, while knowledgeable about construction processes, may not have a proficiency in reading raw data or be prepared to anticipate project needs. This reason is an important reminder that new project requirements should not be driven by past experience but rather be data-driven based on the individual project, its site, and its ultimate purpose. A common understanding must be had among team members as each member brings a different vernacular to the project and different data types. GIS data overlays allow for the marring of the different disciplines for a common understanding. The need for additional requirements and professional services. These additional requirements, costs, and schedule delays gave the client pause on why they were bearing the consciences of an unorganized design process.

6.6.6. Field Data Capture and Methodology

To combat the silos of information obtained by the various project team members, the digital overlays were incorporated to bridge the different project aspects. Specifically looking at the drainage concern raised by the City of Tempe's review, geospatial field equipment was used to create geospatial data to aid in the management of the project.

In aid of the implementation of an irrigation plan, the following equipment was used to data capture the elevation. The project team utilized an AGL 3000s Laser Level Package to calculate the existing grade on the project site. The laser unit utilizes a laser beam from the base station that communicates to a receiver. The receiver is moved around the project site to capture grade data at various locations. The receive is attached to a grade rod that displays measurements in feet. The measurement of each data point is compared to create an overall comparison. The base station was initially set up at Station Location A (33°26'28.87"N, 111°55'15.24"W) in the center of Henry Street. This base location was physically 20'6" from the property line and was set to a baseline height

Figure 12: Laser Level at Base Station B

Figure 13: Laser Receiver Calibration

of 3'3". This baseline point was chosen to match standard civil survey practices. The laser level was set to calibrate upon setting up at a location to begin the grade study. Four points were taken throughout the property to calculate the existing grade of the vacant lot. At each location, the AGL LS 100 laser receiver was attached to the grade rod to determine the grade at each point.

The level and the receiver connect and utilize sound and visual cues to indicate when the receiver was positioned "on ground." These readings allowed for determining the vacant lot's grade and how the grade would play into the drainage plan. Four data points identified as P1 through P4 were captured alongside two base station locations. These measurements were incorporated into Google Earth to obtain the latitude and longitude coordinates needed to create a KML data file, and compared against the surveyor crews data points.

Point	Grade	Latitude and Longitude
Base station A	3'3"	33°26'28.87"N 111°55'15.24"W
Base station B	3'3"	33°26'30.47"N 111°55'15.32"W
P1	3'5"	33°26'29.04"N 111°55'15.26"W
P2	4'3"	33°26'29.27"N 111°55'15.27"W
P3	4'6"	33°26'30.02"N 111°55'15.30"W
P4	4'5"	33°26'30.13"N 111°55'15.31"W

Figure 14: Grade Data Points

Communication between software has been a nightmare as each support engineering crew has its own system. For this problem, it was decided that we would use open-source software that would be able to translate, convert and overlay the data sets from a raw format to a full-functioning overlay.

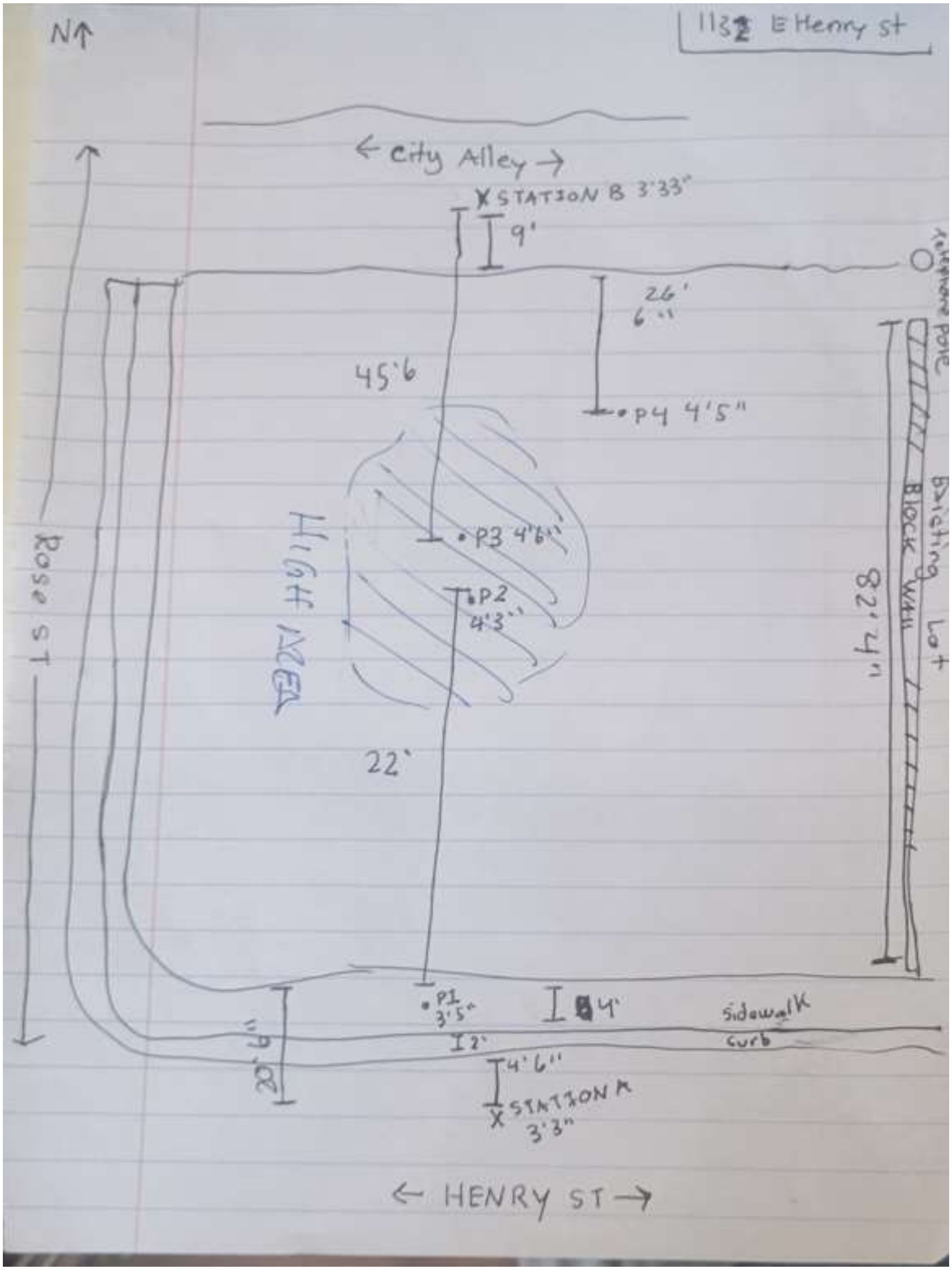


Figure 15: Project Sketch with Grade Data

The need to capture points using Trimble devices would seem an easy feat, but there are several devices from different crews with specifically different calibrations based on the specific discipline. These slight variations can create calibration issues when matching data from different tools and systems. Such considerations are:

- The unit of measurement (meter, submeter, or centimeter) is needed to account for the accuracy of each device
- A standard 12-inch measurement tape measure with and an engineer scale measured in 1/10th of an inch
- An agreed-upon study area and shared paths are needed for each discipline.
- Images from cameras, scanners, and drones unaltered from file transfers or sizing manipulation.
- Scale rulers need to be interchangeable to meet both architectural and civil calculations.

These conversation issues were resolved by agreeing to use GIS overlays as the de facto PDF version. This agreement meant that all equipment was going to be recalibrated and re-shot with the same reference points, field verified measurements, and address the city redlines by using the civil drainage and grading plan, the landscaping plan, the light/electrical plan, and the architectural plan to be merged as a base overlay with sub overlays that would turn off and or on as needed. The same GIS data sets of the lot coverage, setbacks, and utility easements can be married by re-shooting and recalibrating all the data capture equipment. Thus, allowing for a set of GIS points to be retaken with static shots geolocated as one new overlay over an existing site profile to compare before and after results.

7. Findings

7.1. QGIS Data Overlays

The data collected at the Temple project site allows for site review and an ability to review the data to discover areas that may need re-engineering. The data points captured were compiled with the open-source program QGIS. QGIS allowed for importing the grade data points and several professional PDF overlays. This PDF can identify preexisting conditions for the civil engineer and architect to use for the new proposed design. This PDF was created using raster data layers, Parking Overlay, Drainage Overlay, and the 9427_75m DEM raster file. The compiled overlays show that the grade data points fall along an elevation change denoted by the black line on the DEM file. The DEM raster file also allows for the use of the DEM Elevation Profile Tool. This QGIS plugin shows the elevation change and height profile. Initially, graphing the captured data points does support the City's requirement to provide drainage wells at the high points of the lot to aid with the natural drain into the street drainage system. Figure 13 shows the two high points of P2 and P3 at over 12 inches higher than the street and alley's grade.

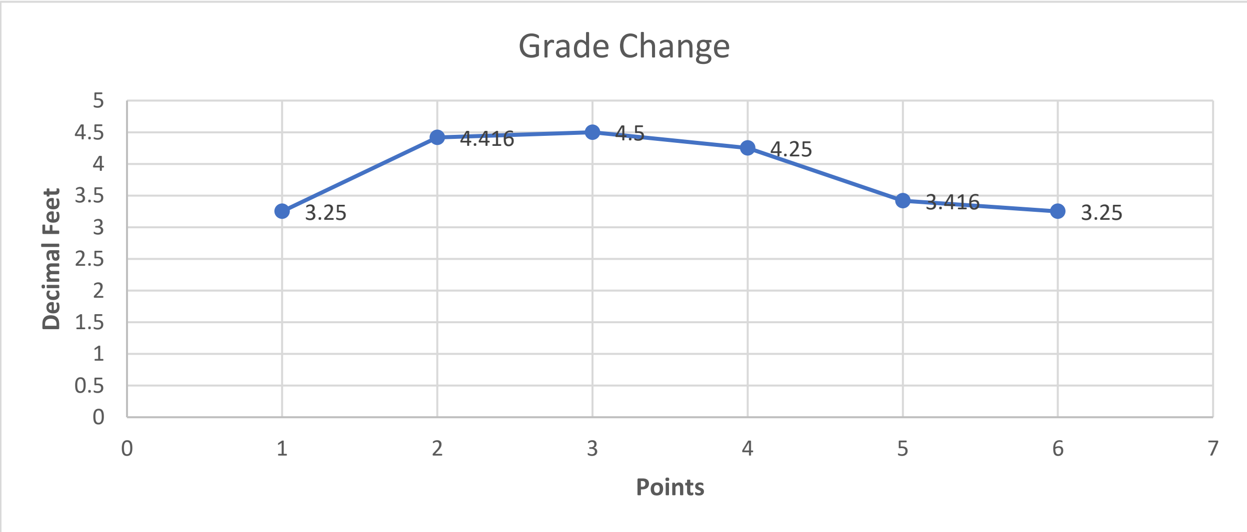


Figure 16: Grade Data Points

This data is mirrored less dramatically with the DEM Elevation Profile Tool, which shows the slight elevation change between the six data points. The difference in appearance is caused by the measurement difference that DEM Elevation Profile Tool utilizes. The Profile Tool graphs changes in feet above sea level, as opposed to the decimal feet calculation used by the field team. As such, the profile tool, which can graph elevation changes in mountain ranges, does not have the same effect of a one-to-two-foot difference around a roughly 6,000-square-foot area of the project site. Nevertheless, when the Profile Tool data range was expanded to capture the neighboring rear lot, the additional data did support the City's concern about drainage flowing from this lot toward the new project. Figure 15 shows the height difference of the lower rear yard, towards the alley, and then the raised center of the project site. This data confirms the need for extra drainage considerations should adverse weather conditions occur.

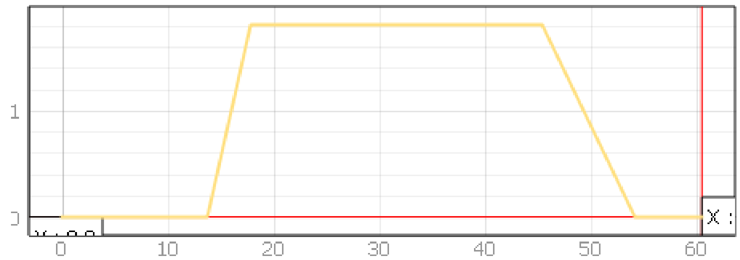


Figure 17: Slope Change of Grade Points graphed by DEM Profile Tool

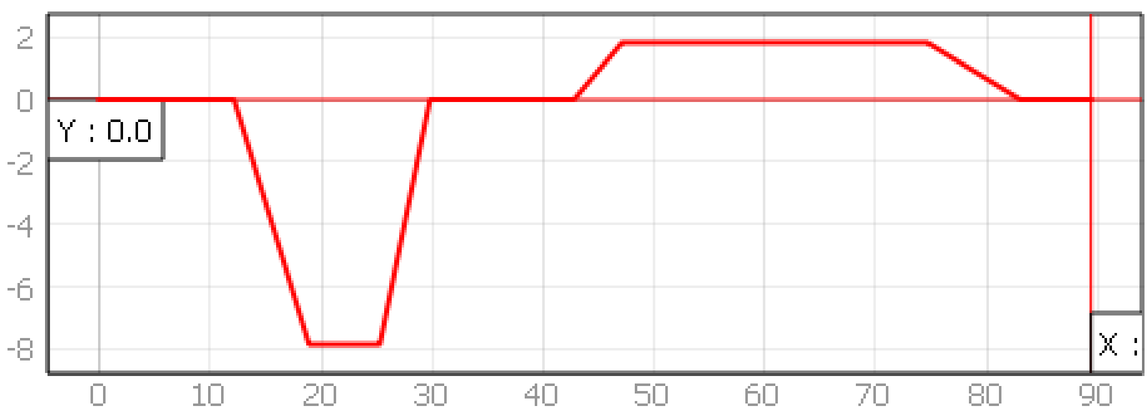


Figure 18: Height of Grade Change graphed by DEM Profile Tool

Figure 19: QGIS Overlays

By standardizing the data collecting method, we were able to create new interactive overlays using GIS backgrounds and toggle between each discipline, creating a decision support process that the City and all participants would be able to use overlays to review the overall project in unison with the other team members. As individual support crews, the overall results would produce a static PDF file with specific data points from said support engineering firm. These data overlays and raster PDF overlays of the drainage, landscape, and parking lot overlays helped the client review the project. These overlays also allowed the project manager to review the project at a 30,000-foot view and incorporate the different team members involved.

These overlays include GeoPoints Points, Landscape Overlay, UtilityPlanOverLay, and Parking Overlay. The Landscape Overlay, UtilityPlanOverLay, and Parking Overlay were provided to the team to incorporate the existing civil plans. These existing plans were geolocated to the site to match each layer to the next. This process is how the on-and-off feature comes into play, as the different stakeholders can review specific elements and how they and adjacent components interact. The ability to see the project piece by piece allows the client to see how new data will interact with their new proposed project. Not only does it give a technical overview, but also a design element to get an understanding of how these construction elements will fit in the existing community. Utilizing overlays that are tied to actual data opens the project dialogue to understanding obstacles, pitfalls, and overall project design. This utilization of GIS overlays allowed the client to visualize the City's grading revisions and why the additional professional services were needed but also opened the question of what else was incorrectly identified.

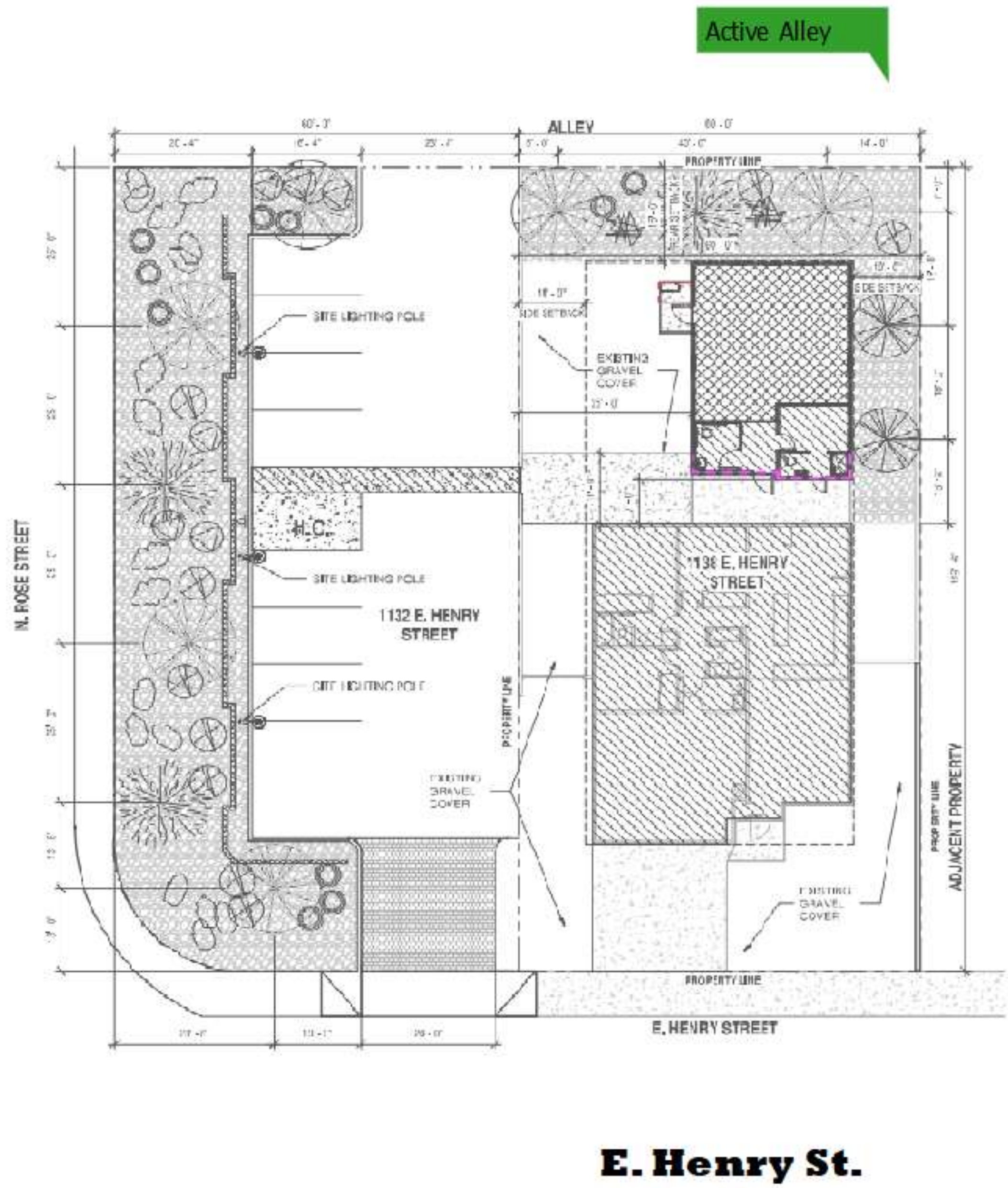


Figure 20: Landscape Overlay

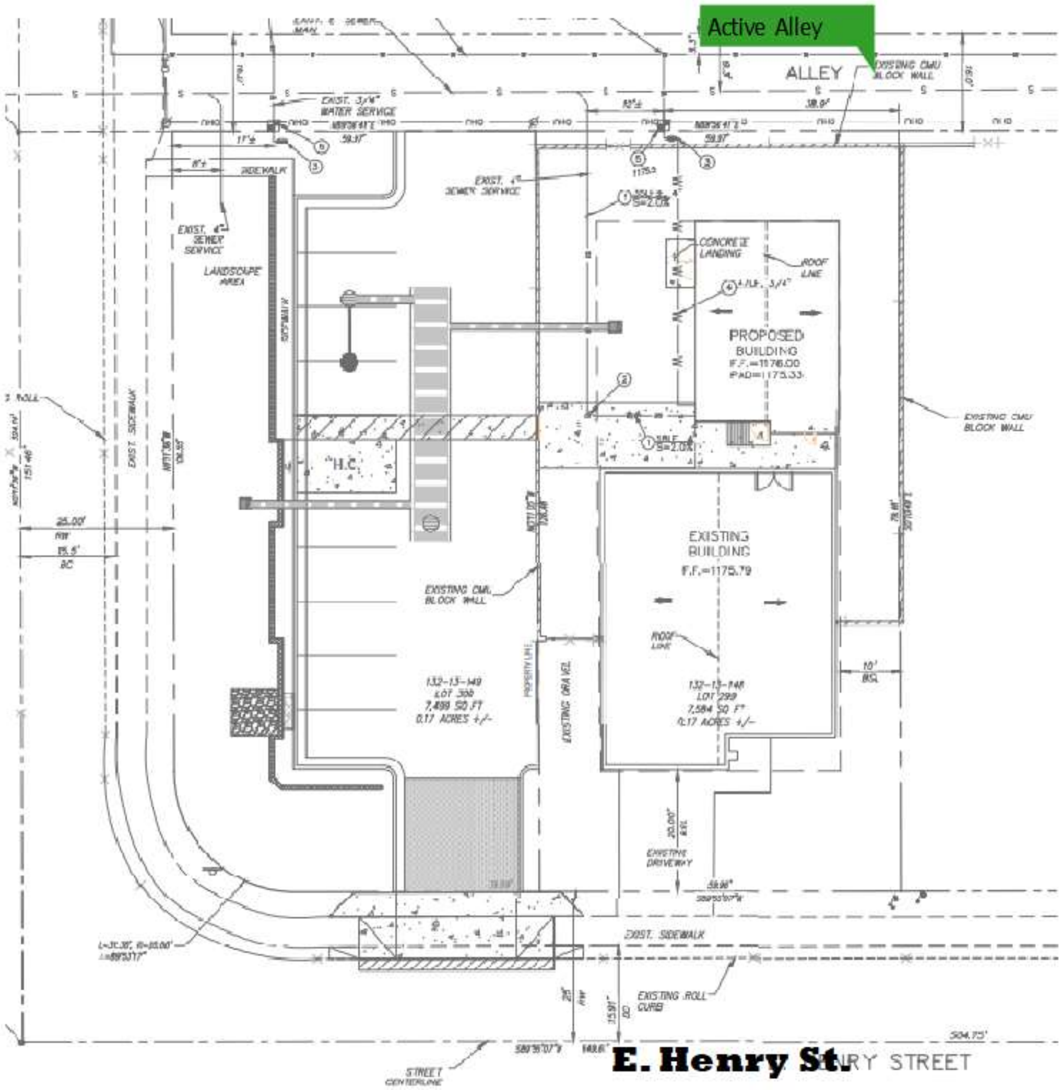


Figure 21:: UtilityPlanOverLay Overlay

Figure 22: Parking Overlay

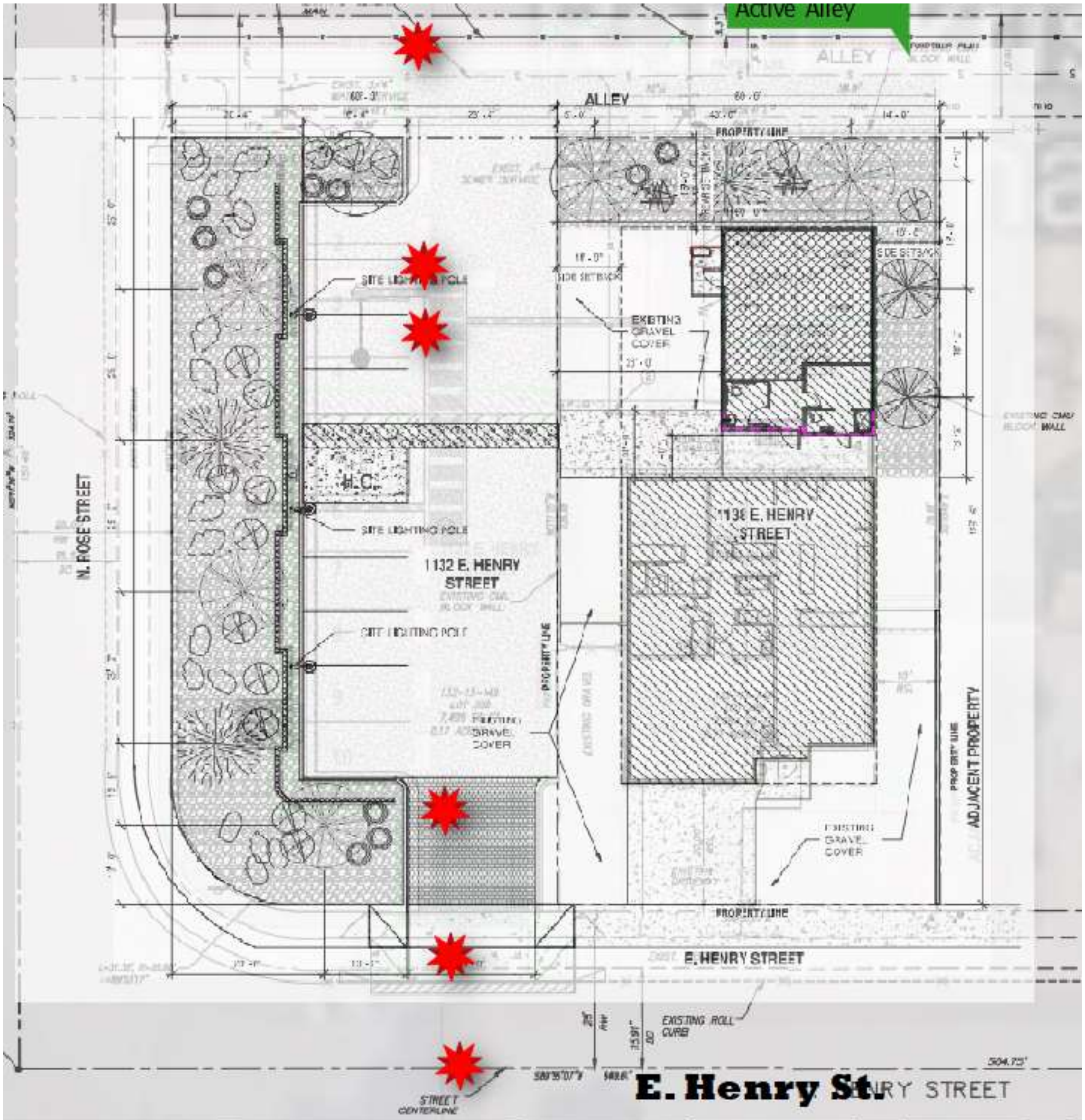


Figure 23: Project Site Overlays

7.2. Risk Mitigation

As experienced by numerous construction projects, what is outlined and approved on plans does not always express actual conditions. With the Temple Project, during the final outcomes of the permit set for this project, the field construction team discovered that the civil drawings were not one hundred percent accurate and thus challenged the actual field measurements and data types called out on the drawings. The importance is that the field data was not appropriately represented by each discipline's field-collecting process, which impacted the actual construction and created unknown variables. The GIS field team was asked to collect specific data points and was explicitly asked to ignore utility landmarks, as the survey had already collected them. These utilities proved very important and were eventually found to be unknown variables. Unknown variables cause project delays until the drawings match the field conditions. Here, projects face schedule delays and scope and budget creep. However, a standardized methodology set of processes for field data collecting can be utilized to eliminate these unknown variables. For example, if we start to review each drawing, we can see that the civil plans are drawn to the world coordinate system (WCS), which is scaled 10 inches to a foot, whereas the architectural drawings are drawn at ¼ of an inch to a foot. Both types of drawings and their respective scales have been utilized for decades. These standard methods and their viability is not being questioned. The question is how we can better work across disciplines for better data collection and interpretation. As we have seen, several essential field data items that impact the construction build process. The following sketch is an example of missed data points and non-defined site elements triggering a significant change order and delaying the project. GIS data collecting was only allowed on a precise basis for this project, and the limitation of the data was evident in the overall project.

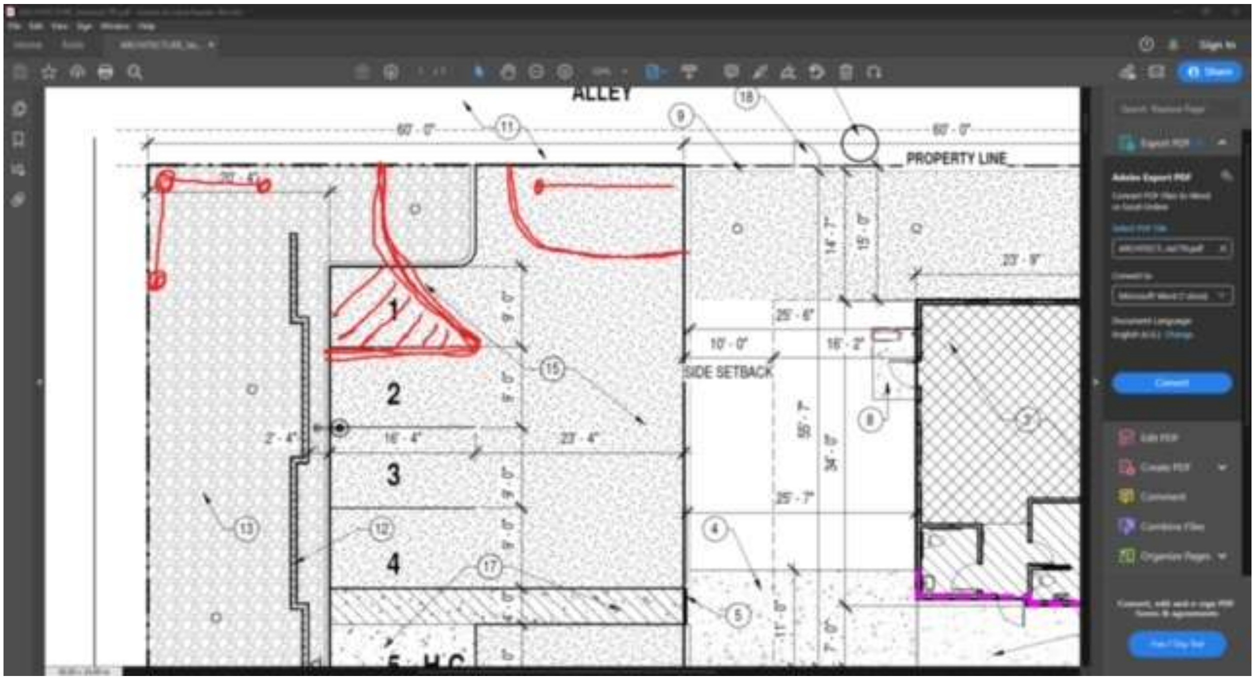


Figure 24: New Parking Recommendations Sketch 1

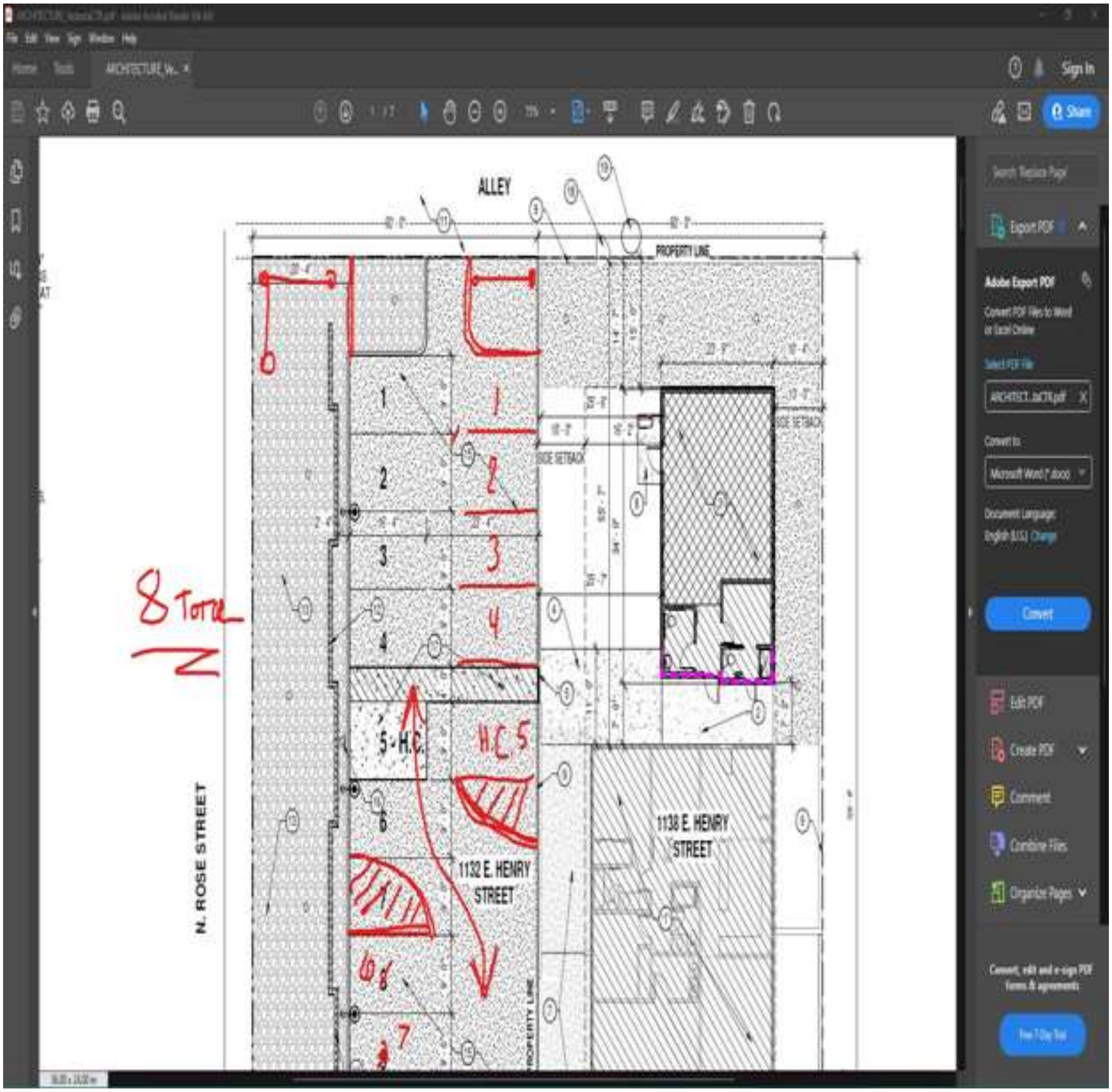


Figure 25: New Parking Recommendations Sketch 2

7.3. Future of GIS in Small-Scale Construction Projects

The number one issue in project management is communication among clients and executives and among the different crews and team members in the field. GIS allows for real-time field data to be captured and level the field to create a common ground. The utilization of GIS data has already been shown to provide cost and time-saving benefits to commercial projects which require multiple regulatory requirements. The ability to review project needs before the start of construction significantly impacts the ability to plan for functionality and space planning.

The Temple project was no different because the task members could not always see what each other was doing. This lack of understanding caused delays and miscommunication between the deliverables and the client's expectations. GIS overlays allowed the team to understand each other's roles, tasks, and relationships between the different trades. While QGIS is open source and there is more robust software, using QGIS on this project showcased the ease of access to tools that have been slow to become mainstream in residential construction projects. This practicum only looked at a small application of the potential usages and benefits of data overlays, but even from this, we can see that data collecting allowed us to anticipate the needs. These needs can easily be demonstrated in a manner easily digested by non-technology personnel and seasoned engineers and managers. Just because the construction industry has tried and true methodologies do not mean there is no room for improvement.

We can see this with the breakdown in communication on the Temple Project with the unaccounted-for utilities, which cost the project time and money. Making GIS commonplace on construction projects has the potential to improve upon these methodologies for the benefit of clients, shareholders, stakeholders, and the public.

GIS is not a new concept, but its mainstream utilization is still in its infancy. In a day in age where, communication is at our fingertips 24/7. Project team members, whether large or small should at any time be able to review the entire project to get a full grasp of their individual role and responsibility for improved project outcomes.

8. Appendices

8.1. Appendix A: Lists of Pictures

- Figure 1: Project Site……………………………………………………………...………7
- Figure 2: Data Flow Diagram for Egypt's Strategic Planning……………….………....10
- Figure 3: Initial Civil Engineering Plans……………………………………………...19
- Figure 4: Data Capture Methodology………………..……....……………………19
- Figure 5: Map of Zip Code 85281 ……………………………………………………19
- Figure 6: Zip Code 85281 Race/Ethnicity Demographics………………………………21
- Figure 7: Zoning and Overlay Districts Map……………………………………………22
- Figure 8: City of Tempe Preliminary Site Review Process……………………………..22
- Figure 9: City of Tempe Formal Application Process…………………………………...25
- Figure 10: City of Tempe Permit Issued…………………………………………….....25
- Figure 11: Project Site: Vacant Lot and Existing Structure……………………………..26
- Figure 12: Laser Level at Base Station B……………………………………………31
- Figure 13: Laser Receiver Calibration……………………………………………...31
- Figure 14: Grade Data Points……………………………………………………………32
- Figure 15: Project Sketch with Grade Data……………………………………………...33
- Figure 16: Grade Data Points……………………………………………………………35
- Figure 17: Slope Change of Grade Points graphed by DEM Profile Tool………………36
- Figure 18: Height of Grade Change graphed by DEM Profile Tool……………………36
- Figure 19: QGIS Overlays ………………………………………………………………37
- Figure 20: Landscape Overlay…………………………...……………………………38
- Figure 21: UtilityPlanOverLay Overlay……………………………………………39
- Figure 22: Parking Overlay……………………………………………………………...40
- Figure 23: Project Site Overlays……………………………...………………...….41
- Figure 24: New Parking Recommendations Sketch 1…………………………………...43
- Figure 25: New Parking Recommendations Sketch 2……………...………………. …..44

8.2. Appendix B: Project Team:

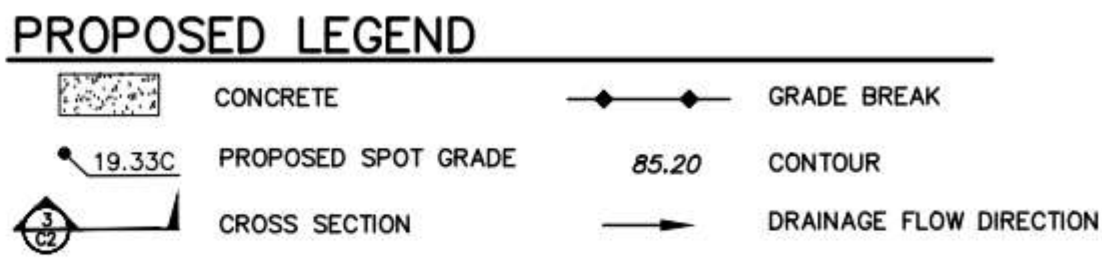
- City of Temp Team
- Survey Team/Civil Engineering: Joseph Burke
- Architect: Wayne Franks
- Structural engineer: Shannon Johnson
- Drafting/GIS consulting firm: Virtual Space
- Mechanical Engineer: Nathan J Pies
- Electrical engineer: Michelle Meisenbach
- Lighting Consultants: Wright Engineering Corporation
- General Contractor: Bonumdc

8.3. Appendix B: Data Dictionary

Data Collecting:

Equipment:	**File Type:**	**Accuracy:**	**Output:**
Total Station	Raw Data:	Engineering Scale 1:1	Tin File/ CAD File
Trimble Nomad 9000	Data Points:	Centimeter Accuracy	Gis File
Drone: (3 Passes Scan)	Scan	Meter Accuracy	Rtl File
Google Aerial:	Download	Scale= 1:1	Obj Image
Leica Disto 8000	Laser Image	Scale =1:1	Jpg Image
Physical Tapes	DeWalt	Scale=1:1	Numeric Output
Samsung 360 Camera	Scan	Nts	Video/Image
AGL 3000s Laser Level Package	Elevation Points	1:01	Numeric Point

Data Legend from Civil Drawings:



8.4. Appendix D: Acknowledgment:

I want to express my sincere thanks and appreciation to the faculty and staff of Northern Arizona University's Department of Geography Planning & Recreation and Graduate College. Thank you to the practicum committee, *Dr. Jessica Barnes*, and *Dr. Ruihong Huang.* Along with *Dr. Erik Schiefer* and *Dr. Alan Lew*. A special thank you to my advisor, *Dr. Rebecca Dawn Hawley*, whose support and encouragement keep this project alive. Additional thanks to the project client, City of Tempe staff members, and the team at Virtual Space for allowing me to explore this project with their team. Lastly, this work is dedicated to Carlos Rodriguez for imparting his lifelong love of learning.

8.5. Appendix E: References:

Bansal, V.K. & Pal, M. (2011). Construction Project s Scheduling Using GIS Tools. The International Journal of Construction Management. 11(1), 1-18).

Beider, H., Levy, D.K. & Popkin, S.J. (2009). Community Revitalization in the United States and the United Kingdom. Retrieved from, https://www.urban.org/sites/default/files/publication/30076/411826-Community-Revitalization-in-the-United-States-and-the-United-Kingdom.PDF

Business Wire. (2020 December 15). Use of GIS Improves Construction Project s and Strengthens Business for Design and Construction Companies. Retrieved from, https://www.businesswire.com/news/home/20201215005299/en/%C2%A0Use-of-GIS-Improves-Construction-Project s-and-Strengthens-Business-for-Design-and-Construction-Companies

ESRI. (2020). ArcGIS CityEngine. Retrieved from, https://www.esri.com/en-us/arcgis/products/arcgis-cityengine/overview

Frankl, F.(2021, September 28). *The real cost of gentrification*. Statesman Association. Retrieved from, https://www.sbstatesman.com/2021/09/28/the-real-cost-of-gentrification/#

Kumar, S. & Bansal, V.K.(2016). *A GIS-based methodology for safe site selection of a building in a hilly region.* Frontiers of Architectural Research, 5(1) 39-51. https://doi.org/10.1016/j.foar.2016.01.001.

Levelset. (2021). Types of Construction Project s & Why They Matter. Retrieved from, https://www.levelset.com/blog/types-of-construction-project s/

National Low Income Housing Coalition. (2019 April 5). Gentrification and Neighborhood Revitalization: WHAT'S THE DIFFERENCE? Retrieved from, https://nlihc.org/resource/gentrification-and-neighborhood-revitalization-whats-difference

Nour, A.N. (2011 February). The Potential of GIS Tools in Strategic Urban Planning Process; as an Approach for Sustainable Development in Egypt. *Journal of Sustainable Development*. 4(1), 284-298.

Patel, K.M, Patel, T.D & Patel, P.J. (2017 September). *Application of GIS in Construction Management*. International Conference On Construction, Real Estate, Infrastructure and Project Management, NICMAR (ICCRIP 2017).

Petimani, V.S., Awati, V., & J.V., Rashmi (2019 July). *Monitoring the Construction Project by 4D Application of GIS. International Journal of Recent Technology and Engineering,* 8(2), 2994-2999.

PolicyLink.(2002). *Reducing Health Disparities Through a Focus on Communities. Retrieved from https://www.policylink.org/sites/default/files /REDUCINGHEALTHDISPARITIES_FINAL.PDF*

USAID. (2014). Sector Environmental Guidelines: Small-Scale Construction. Retrieved from, https://usaidgems.org/Workshops/Jordan2016Materials/Additional%20Materials/SectorEnvironmentalGuidelines_Construction_2014.pdf

U.S. Census Bureau. (2021). New Residential Construction. Retrieved from, https://www.census.gov/construction/nrc/definitions/soc.html