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LONG-RANGE URBAN AIR MOBILITY LAND-USE PLANNING FOR VERTIPORTS

Prepared For:

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RESEARCH
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Urban Air Mobility (UAM) is a rapidly developing industry that highlights tremendous growth opportunities and a major shift in the delivery mode of services and products. This project focuses on a vital step towards the integration of UAM: the siting of vertiports based on their impact on the surrounding community. The identification of potentially suitable sites offers a spatially explicit visualization to facilitate discussion of the future of UAM-focused infrastructure. This project uses a combination of geospatial analysis techniques to determine the suitability of the site across the Wasatch Front for vertiport development. Suitability is a theoretical potential for a given area (or parcel) to support vertiport activities. We define suitability consisting of five categories: the built environment, natural environment, regulatory requirements, technological limitations, and community social values. This report provides details about how these five elements are included in a final suitability map for the region. Feasibility is not considered in this process; neither are land value and access to utility infrastructure which will be elemental for the deployment of UAM infrastructure. Conceptual and procedural frameworks detail the authors' underlying processes used to complete the analyses. Our tools and maps can allow developers and planners to converse about land-use decisions that could influence UAM operations. Further, the geospatial tool is customizable and freely available, allowing communities to adapt for their specific circumstances.</td></tr>
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UNIT CONVERSION FACTORS

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. (Adapted from FHWA report template, Revised March 2003)

LIST OF ACRONYMS AND DEFINITIONS

FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
UAM	Urban Air Mobility
UAS	Uncrewed Aircraft System
sUAS	Small Uncrewed Aircraft System
UAV	Uncrewed Aerial Vehicle
UDOT	Utah Department of Transportation
UGRC	Utah Geospatial Resource Center
WFRC	Wasatch Front Regional Council

Conceptual Framework Definitions *(refer to Section 2.2)*

Dimension:	One the main five categories used to sort variables
Category:	One of eighteen subcategories to further sort variables
Vertiport:	A facility designed to be used by UAV for landings and take offs
Use Case:	The task that UAV will fulfill

EXECUTIVE SUMMARY

Urban Air Mobility (UAM) is a rapidly developing industry that highlights unique planning opportunities and a shift in the delivery mode of services and products. This project focuses on a vital step towards the integration of UAM: the siting of vertiports. The identification of potentially suitable sites offers a spatially explicit visualization to facilitate discussion of the future of UAM-focused infrastructure. While early in its development, our tools and maps can allow developers and planners to converse about land-use decisions that could influence UAM operations. Further, the geospatial tool is customizable and freely available, allowing communities to adapt for their specific circumstances.

This project uses a combination of geospatial analysis techniques to determine the suitability of sites across the Wasatch Front for vertiport development. Suitability is a theoretical potential for a given area (or parcel) to support vertiport activities. We define suitability consisting of five categories: the built environment, natural environment, regulatory requirements, technological limitations, and community social values. This report provides details about how these five elements are included in a final suitability map for the region. Additionally, a capability analysis is supplied to quickly determine if a site can host a vertiport without restrictions such as lakes, roadways, or areas of safety concern. The primary output, the suitability analyses, introduces nuance to the capability by layering scored zones tied to community elements. These scores are split into five categories. These five categories consist of a variety of elements, each element is thus assigned a suitable score of: -1, 0, or 1. All elements are combined and summed for final suitability for every capable parcel within the region. A full table of the spatial criterion for both analyses is viable in appendix B. Due to the large size of the region, example sites are selected to display the analyses generated. Capability, suitability, and parcel suitability maps are shown for Sugarhouse, Salt Lake City, Ogden, and Layton. A full explorable map and map tour are available on the story map developed for this project[1]. Data can be downloaded through the Visualization, Instrumentation and Virtual Interactive Design Laboratory website[2] of Utah State University.

[1] https://storymaps.arcgis.com/stories/a5e89074c5f74cbb94e3f14850b694c2
[2] https://laep.usu.edu/vivid/projects/03_faculty/expertise/urban_air_landuse

PREFACE

This report is being delivered as part of the fulfillment from the UDOT UTRAC project "Long-Range Urban Air Mobility Land-Use Planning for Vertiports" funded from 2020-2022. The work produced in this document is also related to co-author Hall's Master's Thesis (to be published in summer 2022), with shared context, and some overlap with results and text.

All analyses and results are derived from data downloaded in the fall of 2021.

1.0 INTRODUCTION

1.1 Problem Statement

Urban Air Mobility (UAM) is a rapidly developing industry that highlights tremendous growth opportunities and a major shift in the delivery mode of services and products. UAM encompasses multiple benefits and use cases: improving emergency and natural disaster response, facilitating commercial package delivery, and in the long run, integrating with existing transportation and commuter systems (e.g., air taxies). For this project, the use case is on commercial to residential package delivery via drones, with a specific focus on the land-use implications of UAS facilitated delivery. This is one of the first publicly funded projects that aims to identify planning implications of this transportation land-use issue. Currently, there is no comprehensive understanding of the ramifications of our use case on existing transportation, land use, and other infrastructure, making this project unique and groundbreaking.

Integration of UAM requires the development of specific infrastructure known as vertiports, centers that facilitate ground-based interaction with Uncrewed Aerial Systems (UAS). The driving question for this project is - where should vertiports be located? Currently, there is no specific zoning designation for UAM. The existing aeronautic infrastructure has traditionally been oriented toward larger aircraft and for servicing macro-scale industrial and commercial needs. UAM integration represents a shift in scale to micro-level, highly distributed infrastructure with substantially different needs than traditional air-based transportation. These differences include access to electrical grids, higher density of vehicles, reduced land use, sensitivity to microclimate, and concerns over security and safety where vertiports need to be located within developed areas (e.g., residential, commercial, public, industrial). While much research has focused on the optimization and logistics of UAM-based transportation, this project aims to address social aspects of UAM-based transportation through the lens of land-use planning.

1.2 Objectives

This research project has two objectives. The first objective is to develop a structured framework to characterize the legal, infrastructural, and logistical demands and supplies that can be used to visualize ideal locations of vertiports. The second objective of this research project is to develop a geospatial tool and related maps to enable planners to identify a range of suitability for UAM sites, as well as information that explains implications, opportunities, and challenges about implementing vertiports.

1.3 Scope

The proposed research is the first of any open-source geospatial model that will evaluate the role that UAM has on land-use planning, existing infrastructure and transportation networks. Our research will provide government agencies in Utah (e.g., UDOT, MPOs, cities and counties) with a map to facilitate discussions about long-term UAM planning issues, as well as to promote the research issues and gaps in the literature surrounding UAM-based land-use planning. The regional scope of the project will be within the northern Wasatch Front (Davis, Salt Lake, Weber, and Box Elder (partially for the Brigham City area) counties), the primary regions managed by the Wasatch Front Regional Council (WFRC) Metropolitan Planning Organization (MPO).

While there are many potential uses for UAS, a singular use case was determined for the scope of this project. Use cases were compared by their societal need, the timeliness of the need, the availability of supporting literature, and the need for urban planning. Emergency management, for example, has a high societal need but also typically uses pop-up temporary take-off and landing zones.

In the creation of this model, certain assumptions were made. Current infrastructure such as existing structures or access to utilities is largely ignored. Under advisement from the TAC, current flight ceilings under Part 107 that could restrict the integration of UAV are also largely ignored. Certain community elements such as schools, hospitals, and urgent care centers are removed in the interest of public safety. This model is targeted at vertiport locations serving vehicles capable of vertical takeoff and landing (VTOL).

Other industries such as healthcare may establish their own UAS networks with private vertiports. For the safety and security of other industries, certain areas, such as hospitals, are limited. This model exclusively plans for vertiports in residential areas for the delivery of small goods such as food, medicine, and small packages. The results of this study do not recommend or eliminate locations of other vertiport use types. It is important to consider the hierarchy of uses when planning a vertiport, however current conditions and planning climates do not allow for this level of analysis.

1.4 Outline of Report

Chapter 2 details the underlying concepts and procedures that are combined to create the analyses in this project. Chapter 3 explains the individual analyses in depth to the specific details within the capability and suitability analyses. Chapter 4 shows the results produced from the prior stages. Chapter 5 concludes the report with the final summaries, recommendations, and implementation strategies. Appendix A details the processes used to find, store, and prepare all data used in this analysis. Appendix B holds all the individual suitability and capability criteria, and key generated datasets.

2.0 FRAMEWORK DEVELOPMENT AND SPATIAL CRITERIA

2.1 Overview

This report focuses on the development of a framework for evaluating the placement and implications of vertiports in communities. This section highlights two different frameworks used in this study: the conceptual framework and process framework. The conceptual framework identifies the key dimensions and categories used to identify suitable locations for vertiports. The process framework identifies the technical steps used to accomplish the results.

2.2 Conceptual Framework

The conceptual framework details the underlying processes used in the selection of spatial criteria, as well as recommended aspects to consider in future iteration or adaptations. The framework shown in Figure 2-1 guides the development towards the defined goal and organizes research tasks and goals (Jabareen, 2009). This framework operates under the assumption that the area and case for which small Uncrewed Aerial Systems (sUAS) are being used have already been determined. It does not include the process used by the researchers to achieve the results. Instead, it displays the broad concepts and their interplay to create the results and guides the development towards the defined goal and organizes research tasks and goals. For the optimal siting of vertiports to directly support the use of sUAS for deliveries in residential centers, this project identifies potential subsets of existing community elements that may affect sUAS and what sUAS itself affects, considering many distinct aspects of existing urban and rural fabrics. Then, dimensions were determined through the similarity of the potential subsets. This framework includes the clustered variable categories found in a community that all contribute to a site's suitability for vertiport placement. These dimensions are built environment, natural environment, regulatory requirements, technology, and value-based dimensions. The dimensions were created through a review of literature, advice from the TAC members, team conversations, and iterative processes.

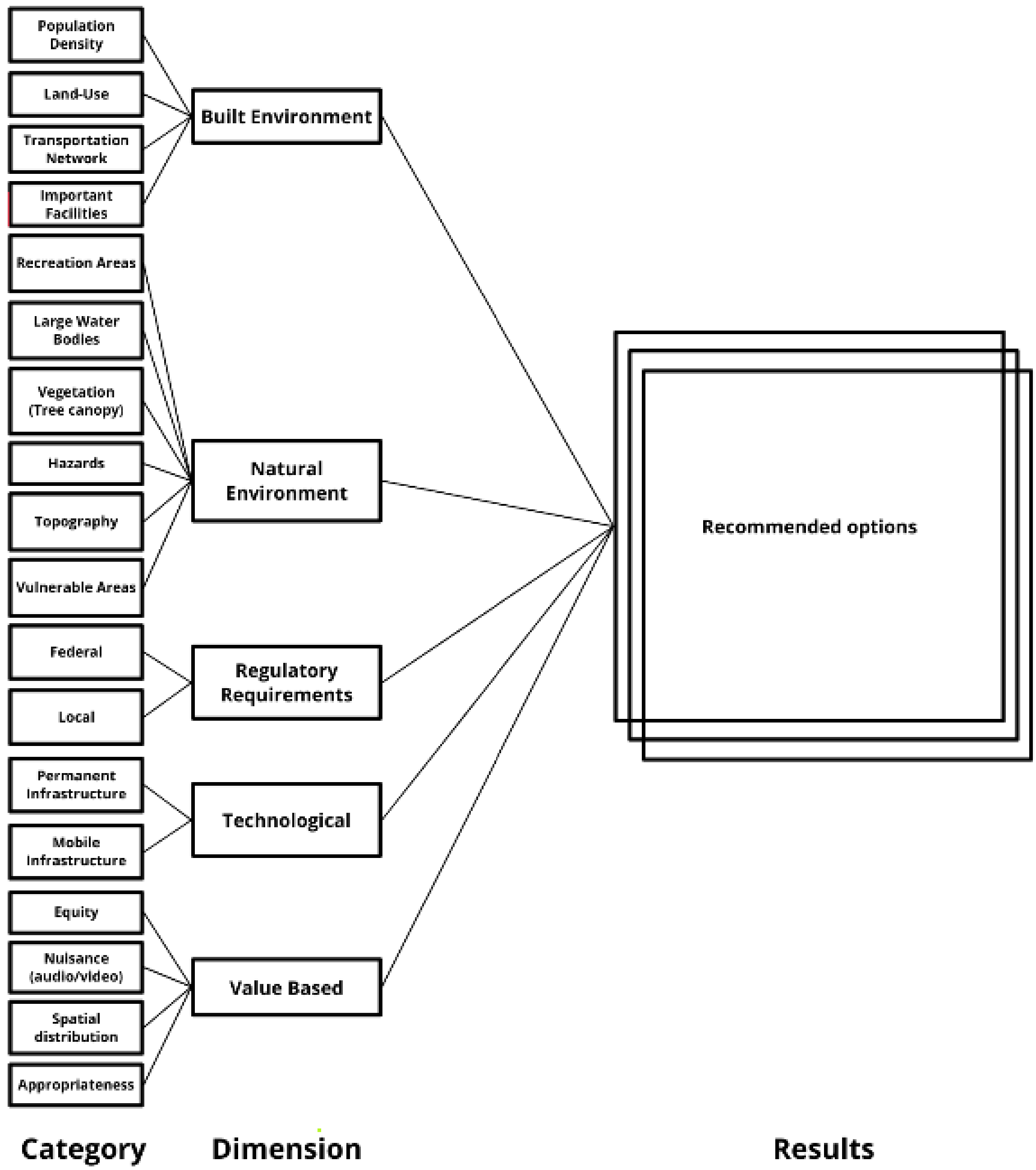

Figure 2-1 Conceptual Framework Diagram

These dimensions are *natural environment*, *regulatory requirements, built environment, technology,* and *value-based* dimensions.

2.2.1 Built Environment

The built environment examines existing physical elements constructed for societal use. This dimension includes the categories *land usage, transportation networks, important facilities, and population density*. Land usage accounts for the current use of the land such as commercial and residential areas or municipal parks. This also accounts for buffers around sensitive areas. Transportation networks encompass all existing or planned roadways, sidewalks, air traffic patterns and the like. Important facilities include all areas we would like to encourage or exclude, such as schools, libraries, and prisons. Population density affects the size or density of proposed vertiports.

2.2.2 Natural Environment

Natural environment recognizes naturally occurring natural environment hazards that may pose a risk to UAS, or vice versa. It includes *recreational areas, large water bodies, vegetation, environmental hazards, topography, and vulnerable areas*. Extreme topography would provide unnecessary difficulty and expanded flight times that are not necessary for our use case. Dense vegetation makes piloting and landing UAS difficult. Large water bodies present sinking hazards toward UAS. These all can limit UAS development and usage. UAS in turn can be seen as a risk to recreation areas and vulnerable environments.

2.2.3 Regulatory Requirements

Regulatory requirements address all possible regulatory or legal bodies with potential control or limitations over UAS in the project area. For the purposes of this study, they have been divided into *air, land, and water-based regulations*. These can be large federal bodies such as the FAA, local government controls, nearby military bases, or airports. This study includes all potential regulations for ground or air. All legal requirements will take precedence in this study.

2.2.4 Technological

Technological encompasses the needs and limitations of UAS under *current technological conditions and established infrastructure*. Flight range, speed, and time are all factors that can be easily changed through innovation or outside factors. This study will be done at typically expected UAS capacity at the time of the study, but the authors recognize that these rulesets will change.

2.2.5 Value Based

These factors are all based on normative values and include *social acceptance, equity, audible and visual nuisance potential, prioritization*, and *safety*. As a disruptive technology with market needs as a major driving factor, UAS have the potential to primarily be integrated in wealthy areas. By placing equity as a prime driver, we instead bring an equity-focused resource to communities. Walkability describes the distance to and potential hazards to the vertiport on foot. Walkability directly impacts the success of sustainable residential community centers. UAS also have the potential to be a visual and audible nuisance.

2.3 Procedural Framework

The procedural framework (Figure 2-2) illustrates the process used by researchers for the duration of this project. The model begins with **constraint identification** that defines the area of interest and use case. The area of interest defines the geographical boundaries the model will operate within. All bodies with regulatory power need to be identified in this region. The use case also must be identified before proceeding to the next stage of the model. The use case describes to a task what the sUAS will be completing. This purpose can affect the size, number of, and needs of the vertiports in the area of interest.

The use case is based on four distinct factors: timeliness, market demand, planning need, and technological ability. Timeliness addresses the legal and cultural constraints at the time. Market demand examines who will be using sUAS, and how popular it will be. Planning needs considers whether this use case will require the need for urban planning. Technological ability determines if the current state of sUAS technology can support the use case in the research area.

Once the area of interest and use case are determined, the constraints used by the model must be identified and delineated in the data prep stage. Here data representing a variety of community elements are first gathered, organized into a database, and combined with geospatially explicit rules in ArcGIS Pro to create the spatial criteria under each category and dimension grouping. These groupings are aimed to capture both how the sUAS may affect an environment, or how an environment can affect sUAS. A single community element can appear in more than one criterion, take for example how built-environment and value-based rulesets will view elements such as schools differently. Built environment sees an already developed community center thoroughly distributed throughout communities that has plenty of open space. Value based recognizes the distraction and safety risks, as well as the site being generally inappropriate for use. The spatial criterion creation and the analysis phase are further explained ahead. At every phase of this process, and once the final results are generated the map is reviewed and adjusted as needed to ensure the correct balance and weighting is maintained. These spatial criteria will be provided in an appendix B.

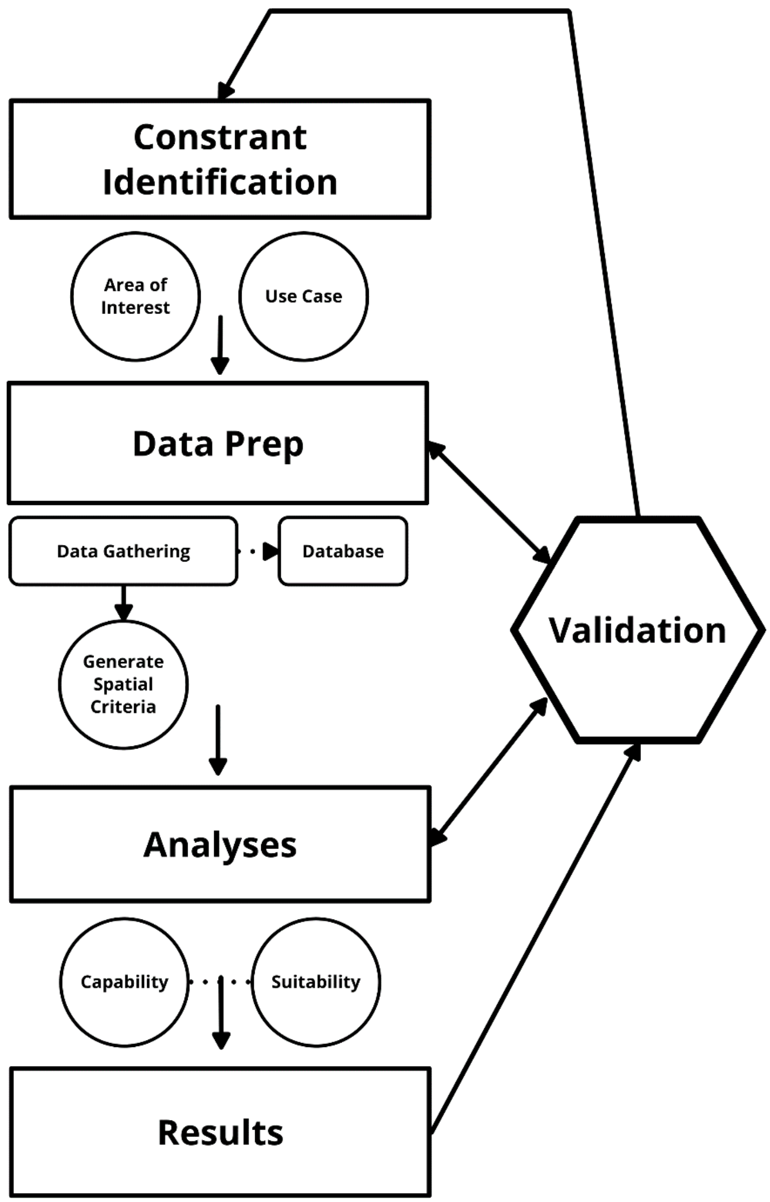

Figure 2-2 – Procedural Framework Diagram

2.4 Spatial Criteria

Before any analysis can be created, all potentially applicable data was found and saved. This includes geographically linked data regarding community elements such as existing land uses and types, community amenities, historical sites, natural hazards, water bodies, etc. All data was found online through sources such as the UGRC, WFRC data services, and individually from each county. All of the data besides parcel ownership is also open access and freely available. Once found, the metadata for each set was then saved to a data dictionary spreadsheet. The data was then prepped by clipping it to the site, and ensuring it was all in the same projection. All spatial criteria are stored in a spatial criteria library, similar to the data dictionary. The following diagrams illustrate some of the spatial typology used to delineate rulesets for a variety of different spatial analyses. For each of these figures white represents the area to be scored.

Figure 2-3 Field

Here is when the area of the spatial element is used for the scoring area.

Figure 2-4 Field Buffer

A field buffer expands the section area while keeping the original area. This is used for areas that have a larger impact than just their boundary.

Figure 2-5 Delayed Buffer

This rule is used for areas that are popular but may have other concerns such as a school. This rule selects the area surrounding an element without including it.

3.0 GEOSPATIAL MODELS

A geospatial model is a pre-programmed GIS process we created in ESRI's ModelBuilder. This process applies various analyses to spatially explicit data to delineate new relationships and patterns. For the purposes of this study, we use geospatial modeling to establish relationships between community elements and sUAS using positive and negative integer values. In this project both capability models and suitability models are implemented to determine the appropriateness of the site (Figure 3-1).

When the suitability and capability models are combined the final dataset creates a scoring for every capable location in the Wasatch Front. Specific maps that simplify or highlight information for planning purposes as requested by the TAC, and a shareable toolbox for other planners to use in the future are also available. This section provides further details of how the two different analyses were produced. Given the spatial extent and complexity of the maps, the results in this report are simplified (while a full web version is available), showing the average suitability of each parcel.

Capability

- Yes/No: Can a UAV land here?
- Does not consider feasibility of that landing
- Used to quickly rule out areas
- Exceptions for safety and higher priority uses

Suitability

- Uses community elements through multiples lenses such as value based or regulatory requirements to create spatially explicit rules
- Uses a scalable positive-negative scoring system to create final suitability map

Figure 3-1 Capability & Suitability Comparison

3.1 Capability

The first of two analysis models created for this modeling project is known as capability. Capability is used to quickly rule out areas that cannot be used for vertiport development or areas of safety concern or higher priority usage. The capability analysis map was developed by finding and identifying all community elements hostile to vertiport integration such as roadways, lakes, and steep slopes. Some capability decisions are made for safety, such as the exclusion of all school grounds, and to give way to higher priority uses by excluding hospitals from vertiport capability. These are removed either by land ownership in the instance of built facilities, the elements' own boundaries (e.g. lakes, or river buffers) and roadways buffers. The capability analysis uses the following equation:

$$capability_{pixel} = \left(\bigcup_{i=1}^{n} C_{area_i}\right) * \left(\prod_{j=1}^{m} C_{pixel_j}\right)$$

Where: *pixel* = a single raster pixel, *C* = criteria variable (e.g., spatial data layers shown in Table 3.1), *n* = number of criteria, *area* = vector boundary, *i*,*j* = starting criteria. Further, where the union of all vector-based capable areas multiplied by the product of all raster-based capability creates the final capability analysis.

Table 3.1 Capability Criterion

Community Element	Rule	Selector
Conservation Easements	Field	
Electrical Lines	Buffer	50ft
Dams	Buffer	50ft
Railroads	Buffer	50ft
Streams	Buffer	15ft
Roads with speed limit >=65	Buffer	100ft
Roads with speed limit <65	Buffer	50ft
Minor Water	Buffer	50ft
Major Water	Buffer	100ft
Land Ownership BLM DNR DOD SITLA USFS UFWS	Field	
Solid Waste Facilities	Field	
Hospitals	Field	
Child Care Facilities	Field	
Power Plants	Field	

Community Element	Rule	Selector
Private Schools	Field	
Public Schools	Field	
Correctional Facilities	Buffer	500ft
Urgent Care	Field	
Airport	Field	
Slope	Field	10%

3.2 Suitability

The suitability analysis introduces nuance into the decision-making process when identifying vertiport locations by looking at the compatibility of neighboring community elements. The suitability analysis is created by layering community elements and their connected score, tallying the final scores to create the complete suitability analysis. This is completed by pairing each community element with each dimension and determining if that combination has an effect on vertiport suitability. For example, the location of an apartment complex currently has no impact on the regulatory side of sUAS. The location of a cemetery does have an impact on the value-based dimension. If the combination is found to have an impact, the pairing then moves forward and is assigned a spatially explicit rule, creating a spatial criterion. In this model, that rule is either a field, straight buffer, or a delayed buffer. A field is the exact shape of the element in question with no extension, or the parcel ownership associated with the element. A straight buffer holds a single value across a certain diameter surrounding the community element in question. A delayed buffer is used when the element itself is incompatible with vertiport integration but has other properties that support a vertiport in proximity, such as a school which is deemed incapable due to safety but is also a popular and commonly visited community element. For example, areas directly surrounding a school hold a lower value, but immediate connections are given a higher value.

Rules are then organized by their respective dimensions, either built environment, natural environment, regulatory requirements, or value based. The technological factor is not compared at this time because there is no way to know which specific sUAS will be used, or the infrastructural needs (amount of electricity, access to water, etc.) of the vertiport. Future iterations may include this when such data becomes available. The score for each dimension is tallied with the respective spatial criteria and combined into a single GIS layer. Each dimension layer is then compiled, and the final score calculated. All GIS processes are run through and documented by ModelBuilder in ArcGIS Pro. The suitability analysis uses the following equation.

$$suitability_{pixel} = \left(\sum_{i=1}^{n} S_i * W_i\right) * capability_{pixel}$$

Where *S* = spatial variable (see Table 3.2), *W* = weight, *n* = the total number of S, and *i* = rating (value, etc.).

Table 3.2 Suitability Criterion

Community Element	Dimension	Rule	Score	Criteria
Historic District	Built Others	Field	-1	
Land Ownership	Built Others	Selected Field	1	Privately Owned Land
	Natural Environment	Buffer	-1	Parks and Recreation
	Natural Environment	Buffer	-1	State Parks and Recreation
	Natural Environment	Buffer	-1	BLM, DNR, USFS, USFWS
Parks	Built Others	Field	1	
FrontRunner Stations	Built Others	Buffer	1	
TRAX Stations	Built Others	Buffer	1	
Law Enforcement	Built Point	Buffer	-1	
	Value-Based	Field Buffer	-1	
Libraries	Built Point	Buffer	1	
	Value-Based	Field Buffer	1	
Community Services	Built Point	Buffer	1	
	Value-Based	Field Buffer	1	
Community Centers	Built Point	Buffer	1	
	Value-Based	Field Buffer	1	
Cemeteries	Built Point	Buffer	-1	
	Value-Based	Field Buffer	-1	
Retail Centers	Built Point	Buffer	1	
	Value-Based	Field Buffer	1	
Public Schools	Built Point	Buffer	1	
Private Schools	Built Point	Buffer	1	
Grocery Stores	Built Point	Buffer	1	
	Value-Based	Field Buffer	1	
Fire Stations	Built Point	Buffer	-1	

Community Element	Dimension	Rule	Score	Criteria
	Value-Based	Field Buffer	-1	
Child Care	Built Point	Buffer	1	
	Value-Based	Field Buffer	-1	
Churches	Built Point	Buffer	-1	
	Value-Based	Field Buffer	-1	
Correctional Facilities	Built Point	Buffer	-1	
	Value-Based	Field Buffer	-1	
Urgent Care Centers	Built Point	Buffer	-1	
Streams	Natural Environment	Buffer	-1	Minor
		Buffer	-1	Major
Floodplains	Natural Environment	Field	-1	A, Ae, Ve
Lakes	Natural Environment	Buffer	-1	Not Internment
Conservation Easements	Natural Environment	Buffer	-1	
Wetlands	Natural Environment	Buffer	-1	
Dams	Natural Environment	Buffer	-1	
Airports	Regulatory	Buffer	-1	
Hospitals	Natural Environment	Buffer	-1	
Monuments and Markers	Value-Based	Buffer	-1	

3.3 Parcel Suitability

To better optimize the map to be respectful of parcel and jurisdictional boundaries, the resulting suitability scores were simplified in a parcel suitability analysis. This analysis is based on the following equation:

$$suitability_{parcel} = median(suitability_{pixel})$$

Where suitability-parcel is the median of all suitable pixels in the bounds of a parcel ignoring null values.

Parcels with a score of <1 are considered unsuitable. Parcels with a score of 0-1 are deemed neutral, as nothing sways the site towards or away from vertiport development. Parcels with a score of two are classified as possible, as they are suitable for development, but not a strong contender. A score of three or four are suitable, and any value over four is highly suitable. Still, these are relative values and not to be used without further investigation of the feasibility of the site.

The capacity of a vertiport is based on the safety buffer per landing site, site amenities, and walkways when needed. As such the equation is:

$$(a^2)x + (b * c)y + (5 * ax) = \text{minimum square footage}$$

Where x = number of vertiports, y = number of amenity boxes, a = 5x the largest recommended vehicle width, b and c both equal the dimensions of an amenity box, and the final step is only used when a walkway is desired. A minimum vertiport size was determined using a safety buffer of 2.5 vehicle lengths, assuming a maximum of a 5’ wide sUAS. In the model, vertiport capacity is sorted by minimum number of vertiports the site can hold. Such capacities are sorted into categories based on the minimum number of potential vertiports based on the area of the site. These classifications include inadequate, single, double, medium, and large. Inadequate parcels are less than 750 sq feet, and sometimes represented as parcels segments to identify ownership in a multi-story building. Single vertiport slots are between 751 and 1499 square feet, enough room to hold a single vertiport and some amenities as needed. Double vertiports are between 1500 and 2874 square feet, enough room to hold two vertiports and a walkway between them. Medium slots can hold a minimum of four vertiports, adequate walkways, and extra space for amenities such as benches, trash cans, or bus shelters. These areas are at most 5624 square feet in area. As such capacity numbers would indicate a high level of community use, some amenities are recommended to be included at the area. Large vertiport classifications indicate areas that can hold a minimum of 8 vertiports, adequate walkways, and amenities on-site. Such parcels could also include other site uses, such as storefronts, parks, or other large community elements. Due to variations in site dimensions, these are not guaranteed capacity numbers at each site, and should be used only for guidance, not final selection.

4.0 DASHBOARD AND VISUALIZATIONS

Note 1: A story map has been developed in conjunction with this report to further describe and show the analyses. It can be found here: https://storymaps.arcgis.com/stories/a5e89074c5f74cbb94e3f14850b694c2

Note 2: All analyses and results are derived from data downloaded in the fall of 2021.

4.1 Overview

Due to the large site size, sample areas have been identified to provide imagery across different community types and locations in the Wasatch Front. Locations include: Sugarhouse neighborhood in Salt Lake City, Layton City, and Ogden City. A map highlighting these locations is provided, followed by sample imagery for capability, suitability, and parcel suitability for each site. For capability, all areas colored green are deemed capable for the remaining analyses. Both suitability and parcel suitability are shaded using an orange-to-green scale, with orange being unsuitable and dark green being highly suitable for vertiport development. Suitability and Parcel Suitability have differing color scales, as the value range for parcel suitability is smaller when capability is included, removing the least suitable areas from inclusion.

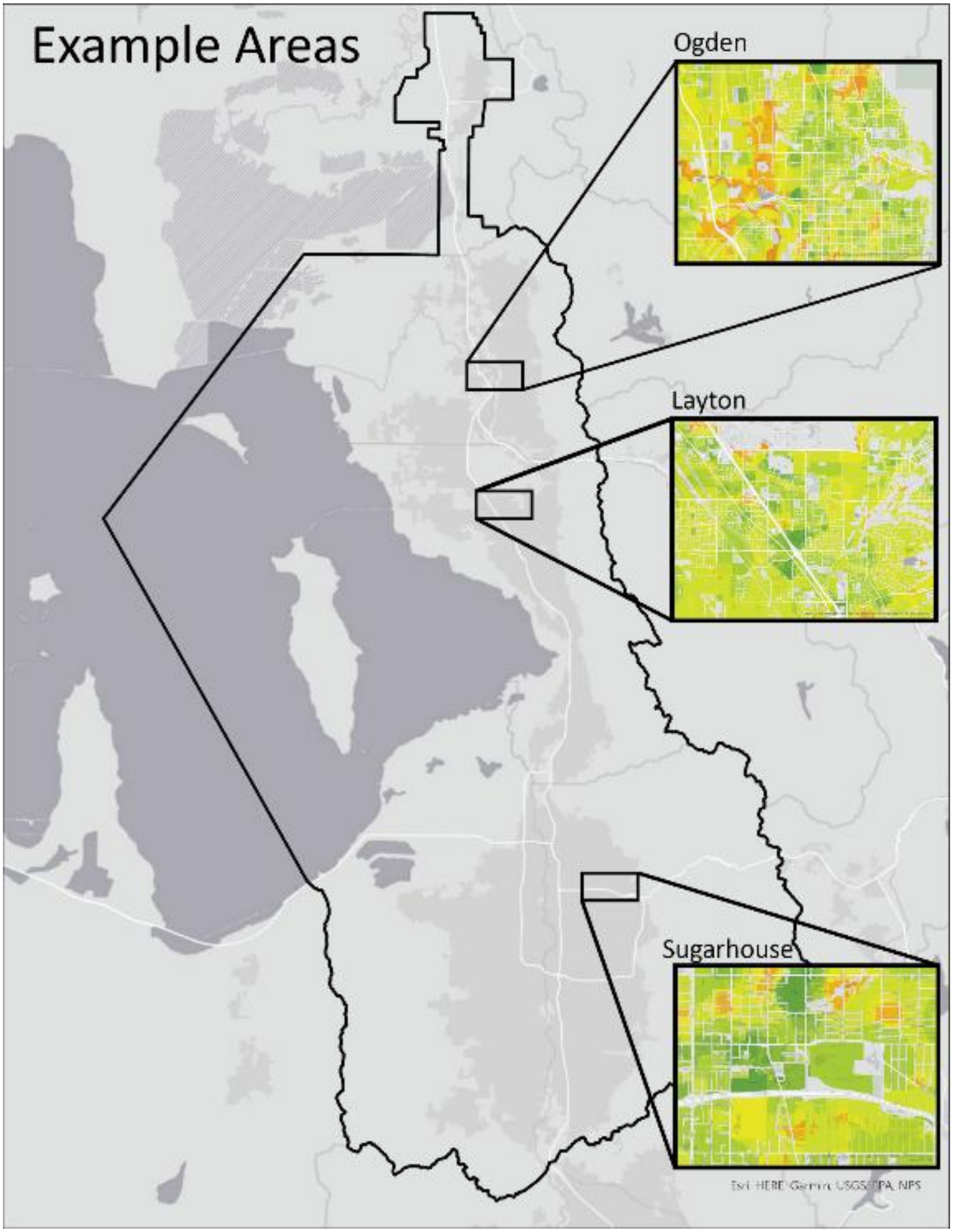

Figure 4-1: Sample Area Map

Due to large size of the test region, three example areas have been chosen in Ogden, Layton, and the Sugarhouse neighborhood of Salt Lake City. This shows the placement of each sample site and the final image for each within the boundaries of the WFRC.

4.2 Capability Maps

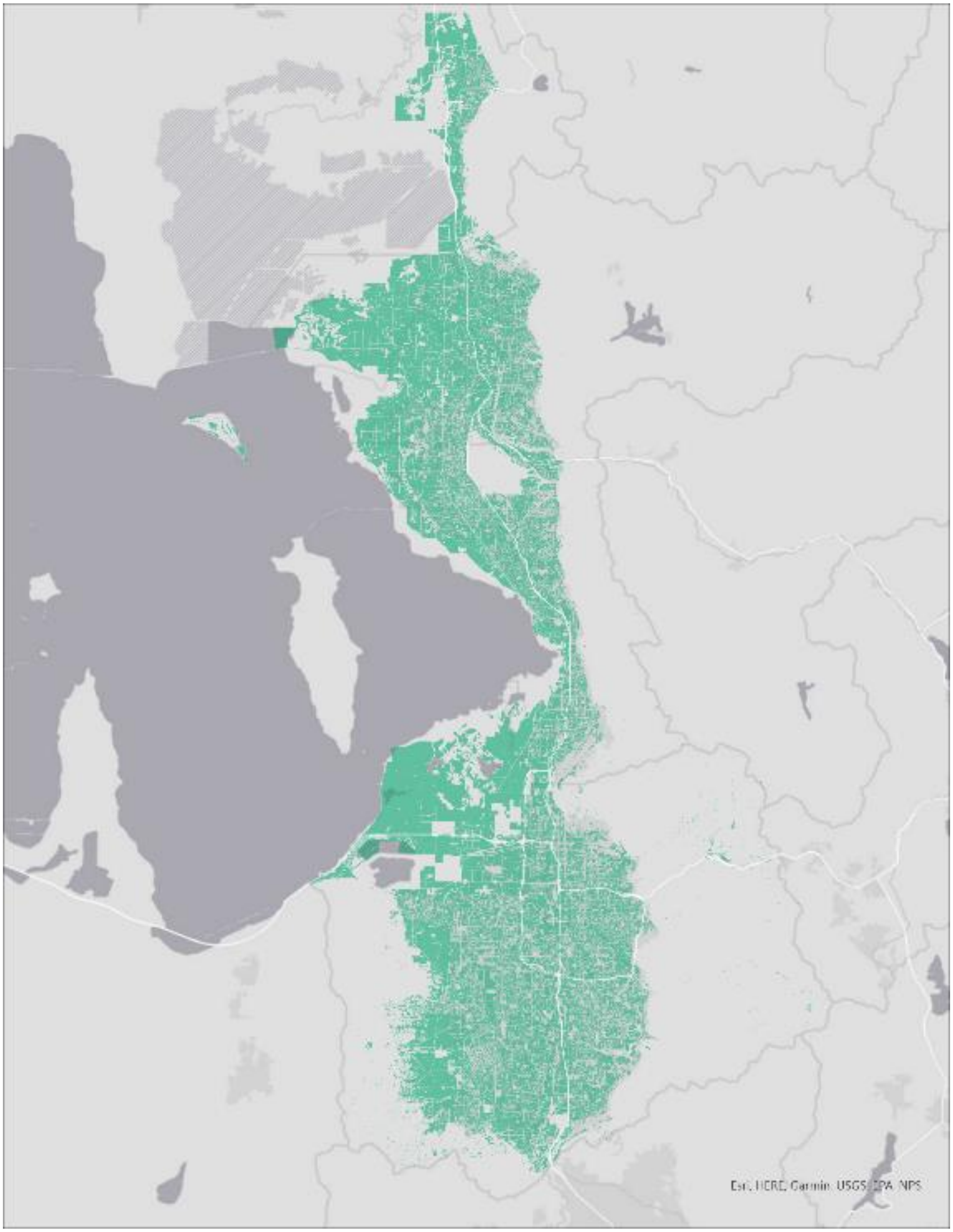

Figure 4-2: The capability analysis for the entire WFRC

All areas that are green are deemed capable.

Figure 4-3**: The capability analysis for Sugarhouse**

All areas in green are deemed capable. Primary reason for incapability in this area are roadways, schools, and slope surrounding waterbodies.

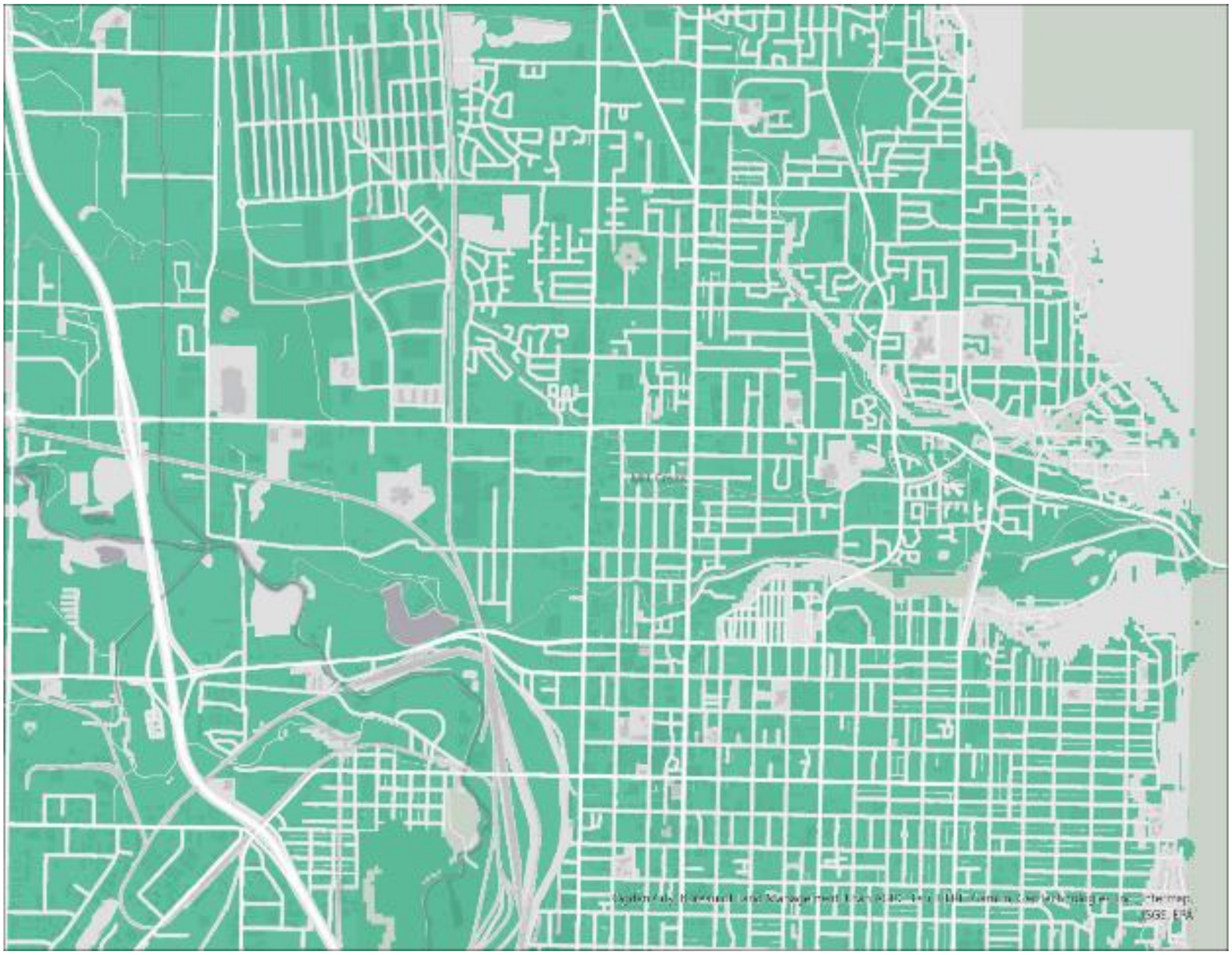

Figure 4-4: The capability analysis for Ogden

All areas in green are deemed capable. In this area, the primary reason for incapability is roadways, schools, and slope.

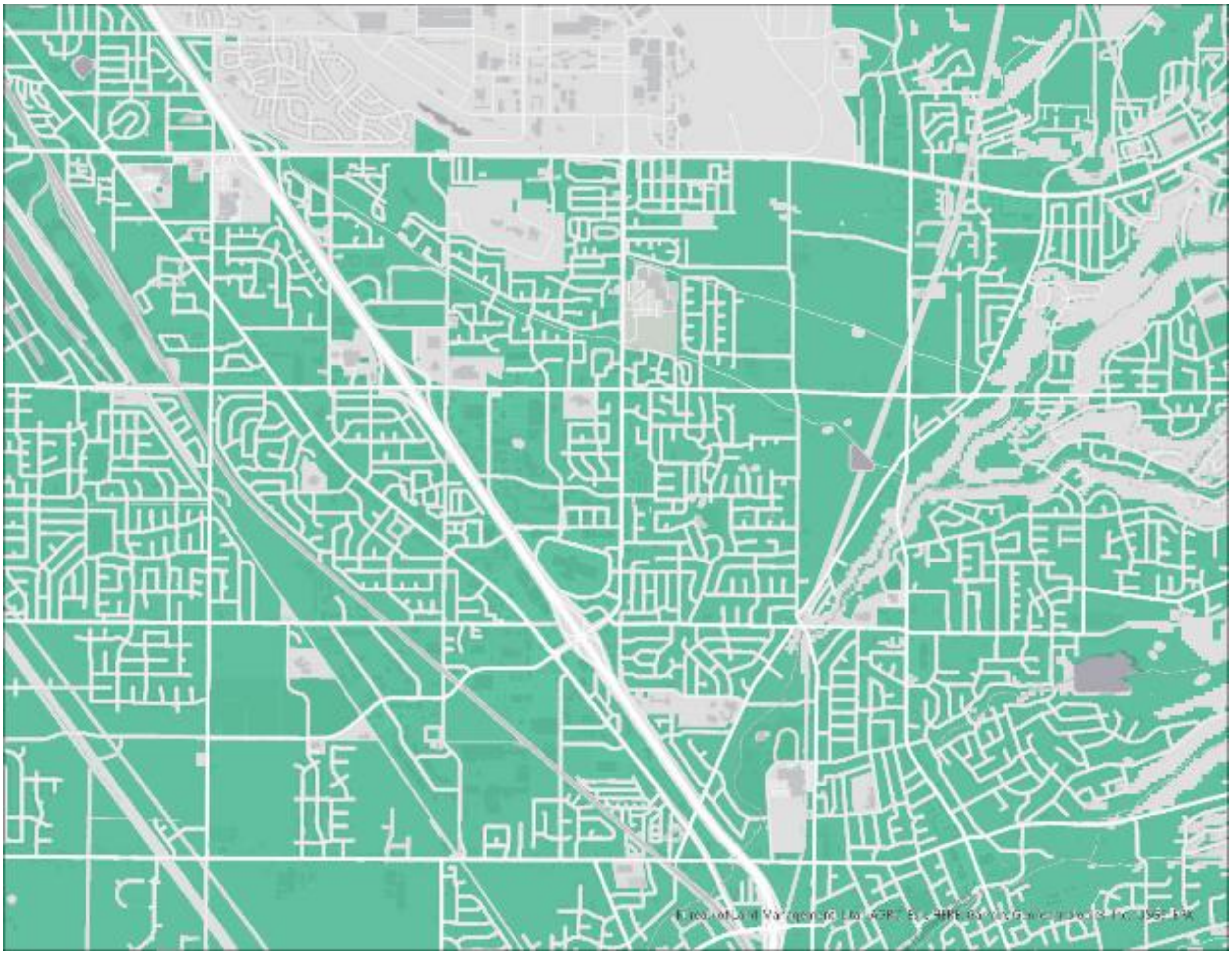

Figure 4-5: The capability analysis for Layton

All areas in green are deemed capable. This area shares the primary incapability of roadways and slope, but also features Hill Air Force Base at the top of the map.

4.3 Suitability Maps

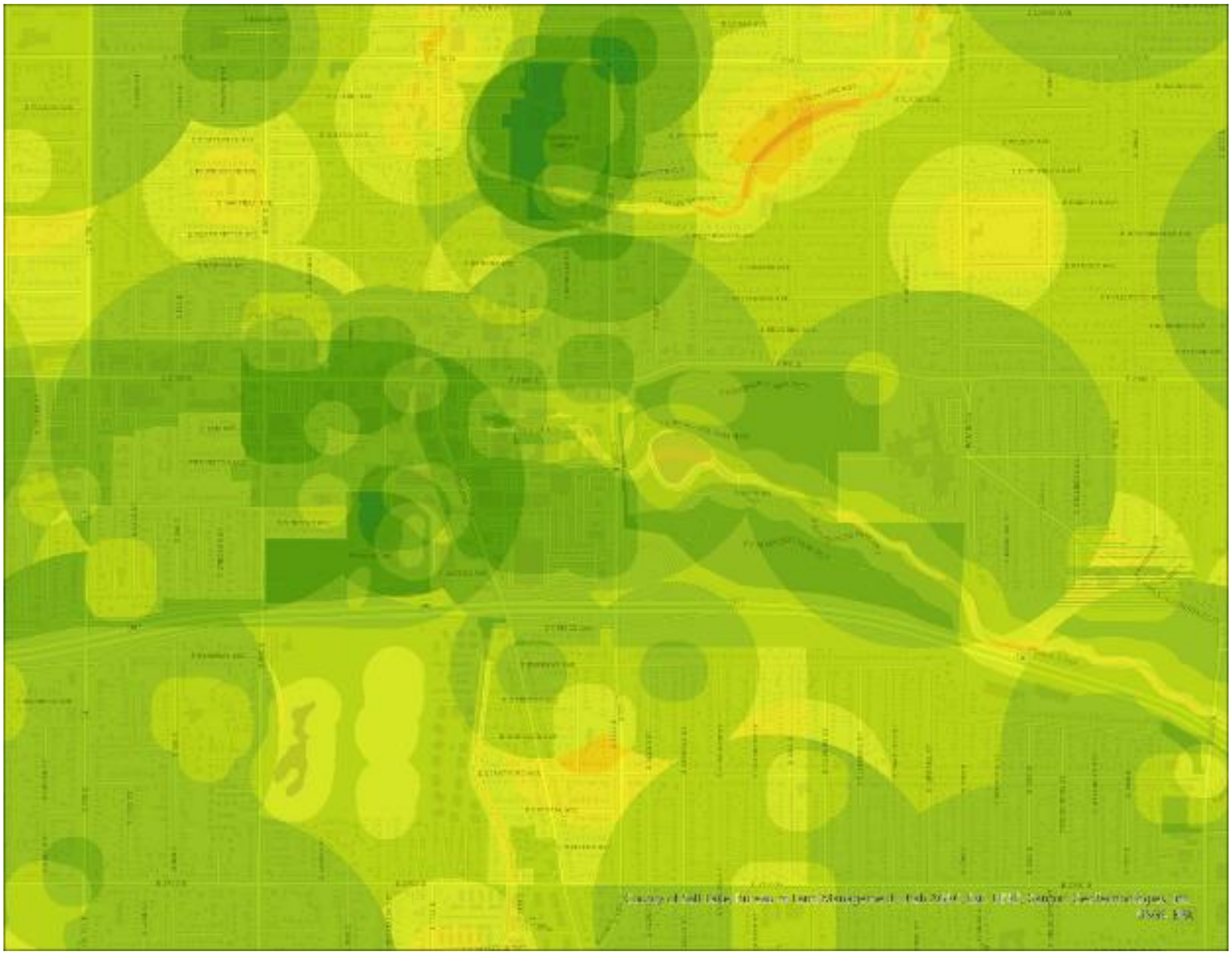

Figure 4-6: The suitability analysis for Sugarhouse

Areas in red have poor suitability, and green have high suitability. Here we see higher suitability in commercially dense areas and educational centers. Areas of lower suitability are generally due to schools, water features, and some reduced suitability in residential areas.

Figure 4-7: The suitability analysis for Layton

Areas in red have poor suitability, and green have high suitability. This map shows the higher suitability at existing commercial centers, reduced suitability in the surrounding residential areas, and unsuitability at Hill Air Force Base.

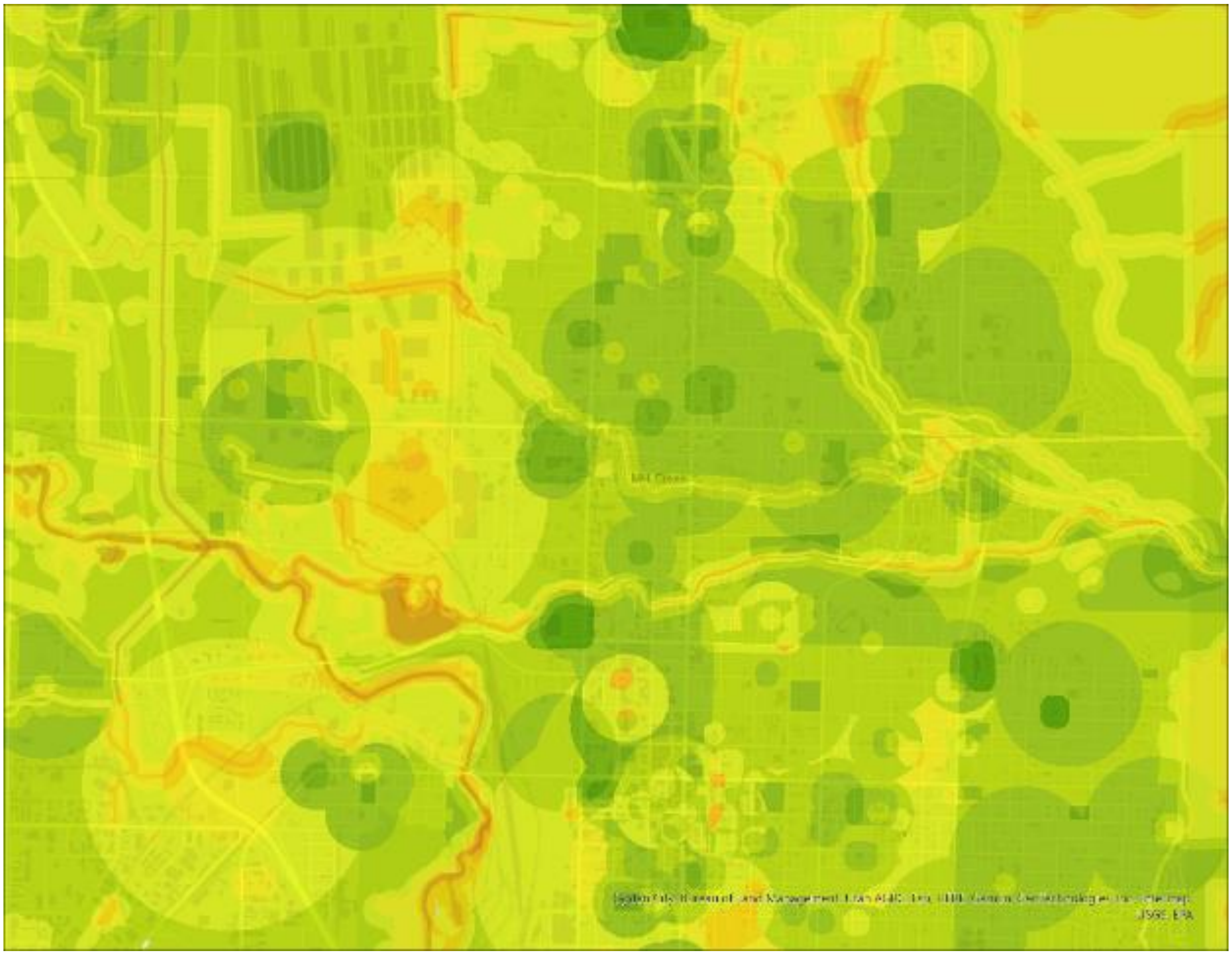

Figure 4-8: The suitability analysis for Ogden

Areas in red have poor suitability, and green have high suitability. In Ogden, the primary reason for reduced suitability is connection to waterways.

4.4 Parcel Suitability Maps

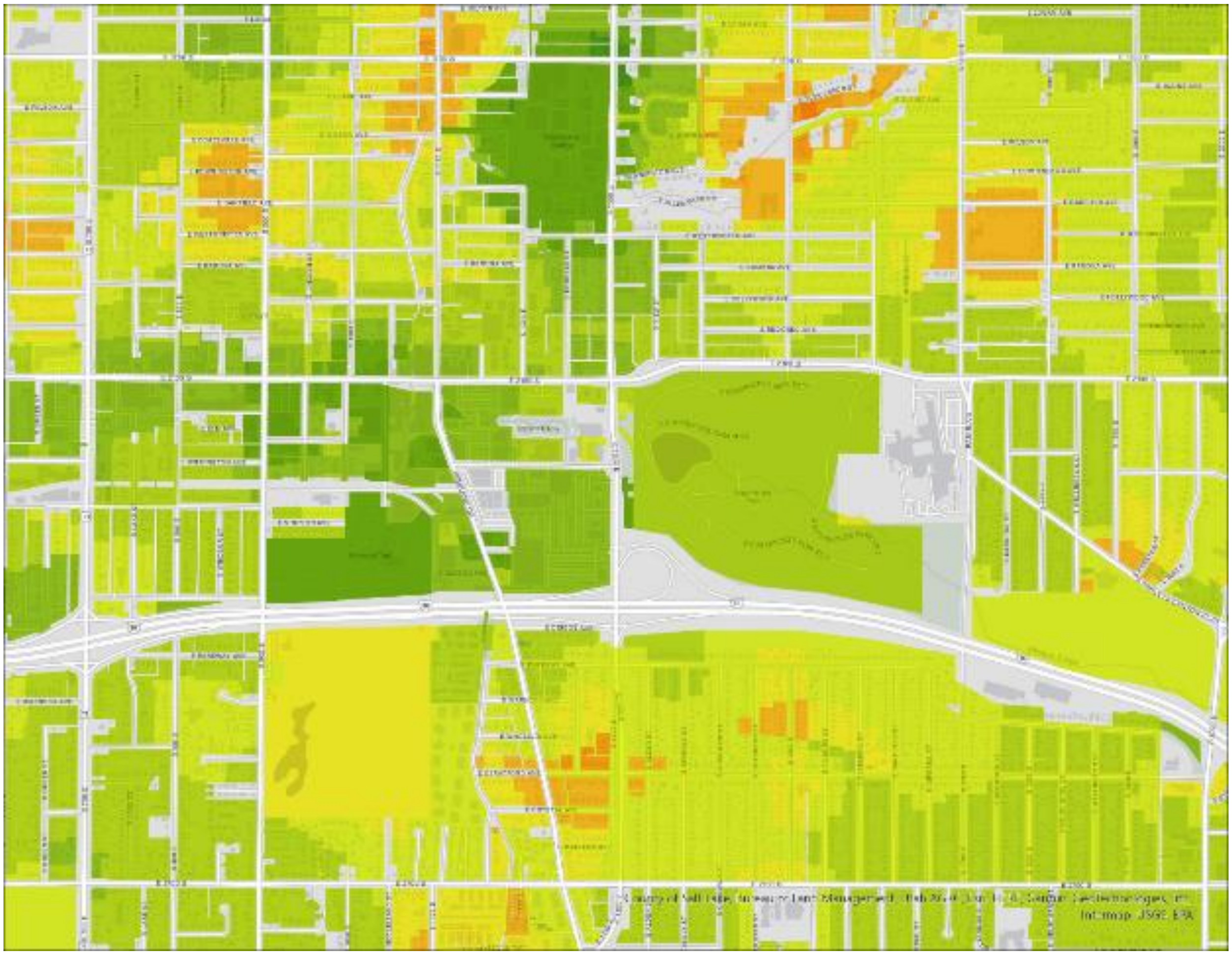

Figure 4-9: The parcel analysis for Sugarhouse

Areas in red have poor suitability, and green have high suitability. Areas with no color overlay are incapable. The combination of the analyses and simplification into parcel data reduces the range of values, giving areas accurate color range representation. Here we still see a focus on commercial and education centers, with the loss of K-12 school properties, areas of high slope, or parcels that were mostly water. The simplification process does contain loss, so capability must be included in any final analyses.

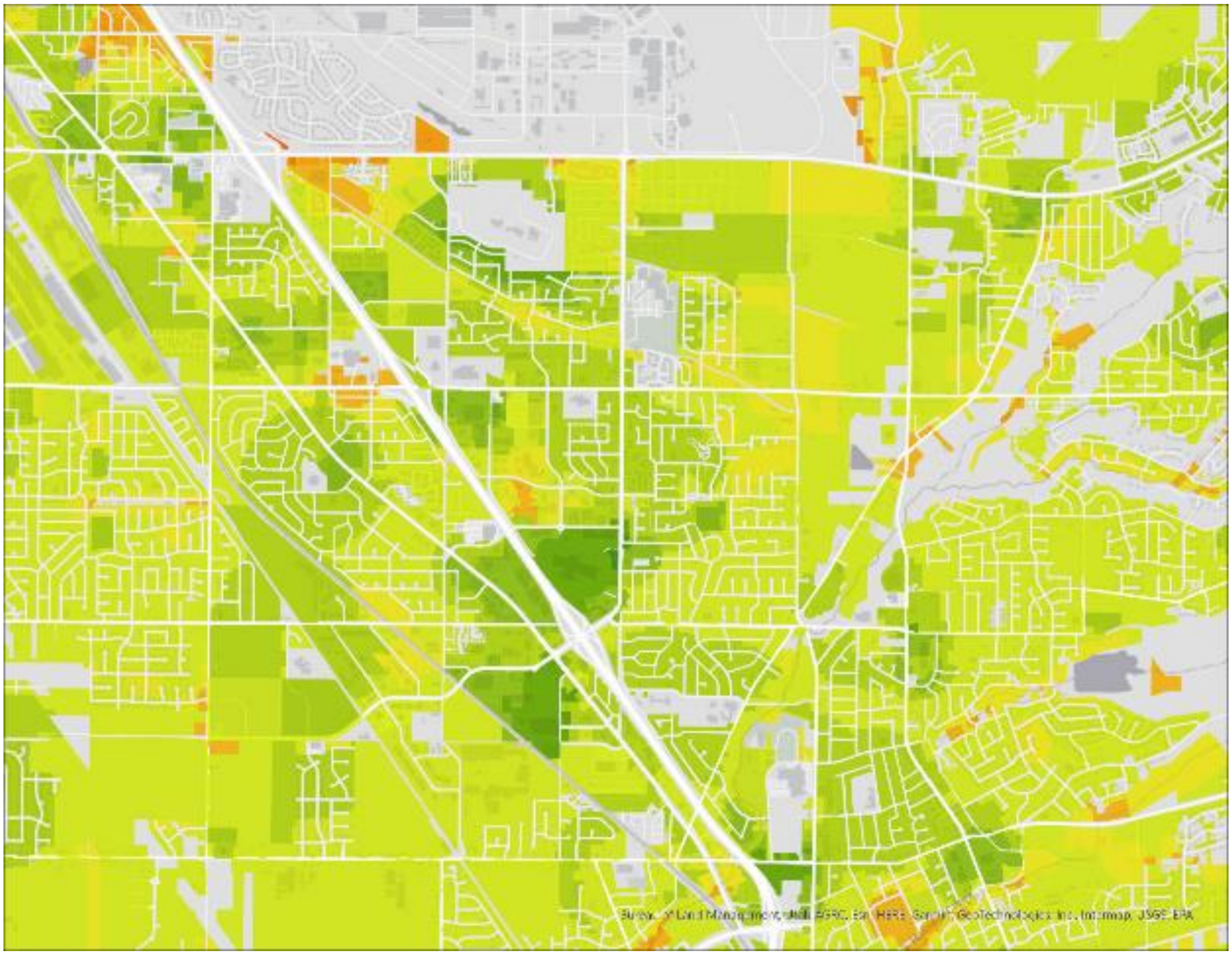

Figure 4-10: The parcel analysis for Layton

Areas in red have poor suitability, and green have high suitability. Areas with no color overlay are incapable. Here we see low suitability in residential areas, high suitability in retail centers, and Hill Air Force Base is incapable bounded by lower suitability.

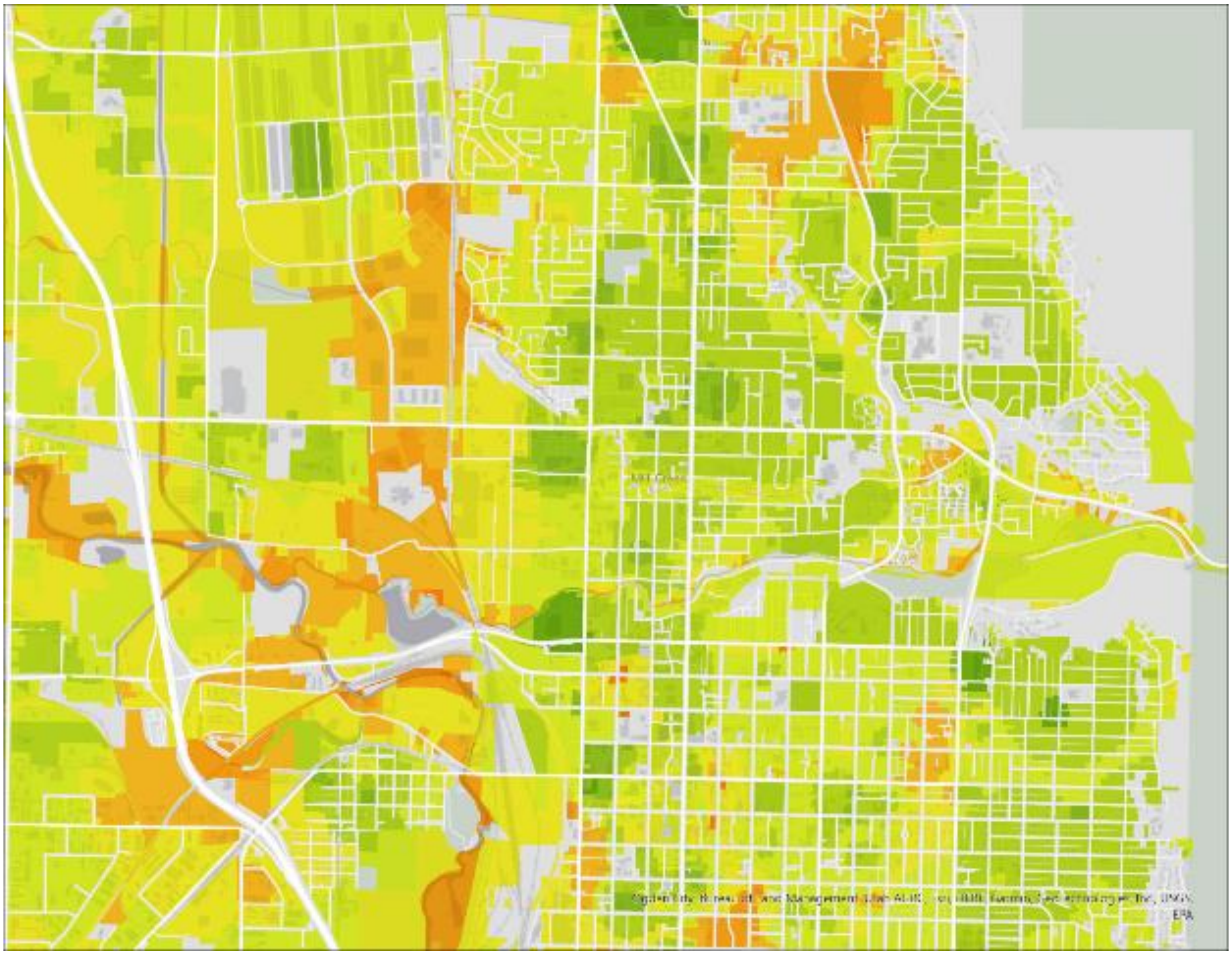

Figure 4-11: The parcel analysis for Ogden

Areas in red have poor suitability, and green have high suitability. Areas with no color overlay are incapable. In Ogden, we see large areas of unsuitability near waterways and pockets of suitability around community centers such as commercial districts and schools.

4.5 Parcel-Level Suitability Statistics

Across the entire site, there are 494,312 capable parcels. The figure below shows the number of parcels in each suitability class for the entire site regardless of size class. Over a third of parcels are considered suitable, and nearly half are considered possible with a suitability score of 2. It is very rare to hit high suitability, with a score greater than 4, making up less than 1% of all available parcels.

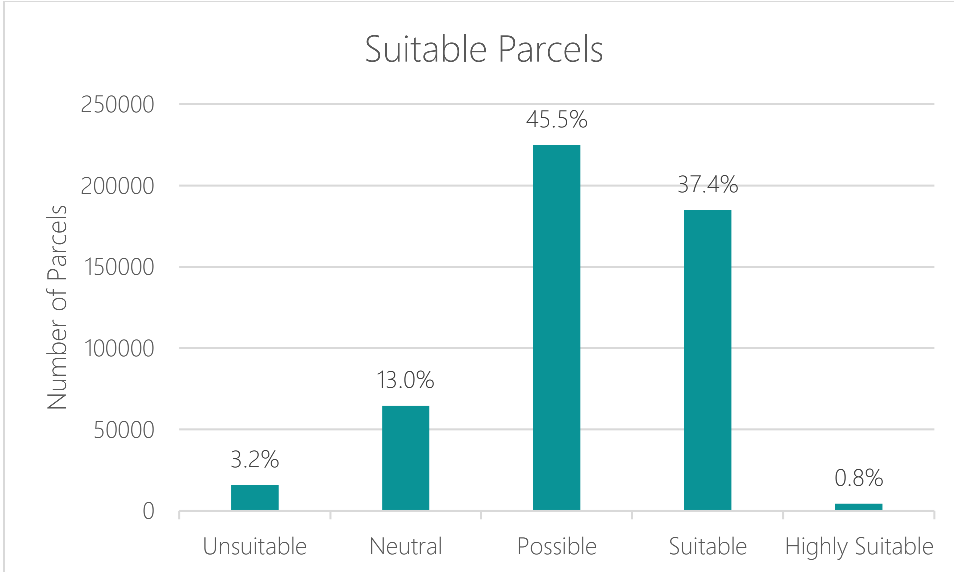

Figure 4-12: Breakdown of all parcels by suitability

The full site analysis encompasses all parcels that have their center within capable areas on the analysis. This includes every capable parcel in the Wasatch Front, regardless of zoning or existing land use. This shows the overall vertiport character of the Wasatch Front. As vertiports are fairly compact compared to other infrastructure, they can easily fold into existing communities. The Wasatch Front has also experienced decades of sprawl-based growth, leading to the majority of parcels being in the large vertiport categorization. Across all size classifications, we see a concentration of vertiports in the possible and suitable categories, showing high potential for vertiports generally across the Wasatch Front.

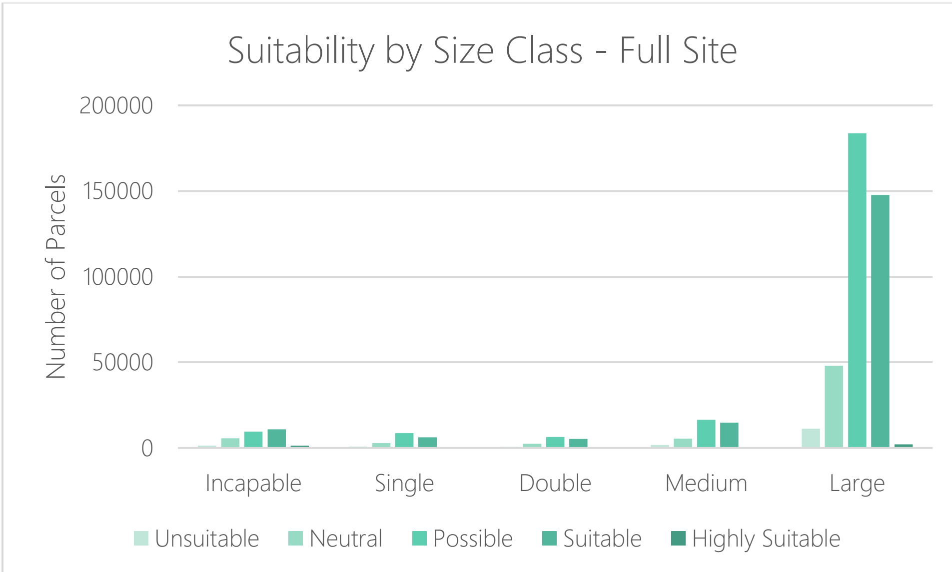

Figure 4-13: A breakdown of all parcels by suitability and capacity

	Full Site				
	Inadequate 0	Single 1	Double 2	Medium 3-4	Large 5+
Unsuitable <1	1,384	762	652	1,775	11,280
Neutral 1	5,618	2,837	2,453	5,535	48,086
Possible 2	9,506	8,644	6,491	16,416	183,652
Suitable 3-4	10,819	6,240	5,383	14,775	147,745
Highly Suitable 5+	1,317	164	147	506	2,125
Total	28,644	18,647	15,126	39,007	392,888
					494,312

Table 4.1 Parcels' Suitability and Capacity *(unit: number of parcels)*

4.6 Focus Area Analyses

Each focus area analysis is provided with a table describing the number of parcels available by suitability and capacity, a chart visualizing that availability, and a suitability map of the selected parcels in Salt Lake City. Focus area analyses were run on vacant parcels, WFRC 2050 centers, parcels proximal to a planned transportation network project, publicly owned parcels, WFRC equity focus areas, residential, and commercial or industrial parcels. Additional data containing the same statistics about every parcel analyzed is also listed.

4.6.1 Vacant Parcels

The parcel map provided by WFRC labels parcels as vacant in lieu of current zoning status. These parcels were selected from all capable parcels with the vacant classification. The figure below shows a breakdown of suitability across each size classification for all capable vacant parcels. This focus area was selected, as development in vacant parcels is often cheaper, less disruptive, and will bring overall improvement to the community it serves. Vacant parcels of all sizes see peaks in possible and suitable categories, showing good potential for development in these vacant parcels.

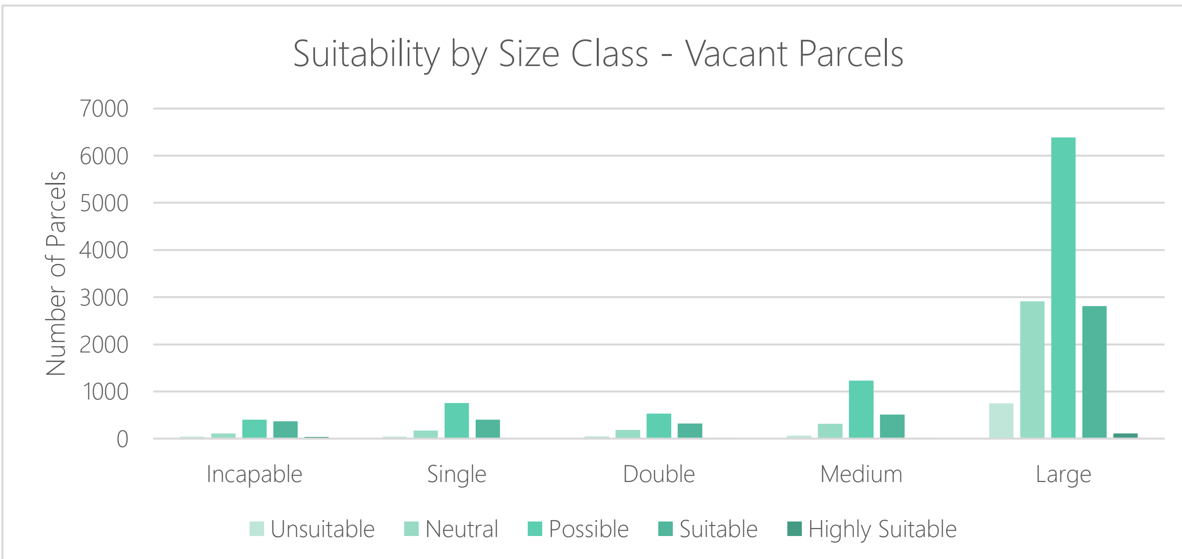

Figure 4-14 A breakdown of all vacant parcels by suitability and capacity

	Vacant Parcel				
	Inadequate 0	Single 1	Double 2	Medium 3-4	Large 5+
Unsuitable <1	42	43	46	65	750
Neutral 1	113	172	186	316	2,915
Possible 2	405	755	528	1,232	6,387
Suitable 3-4	371	401	324	512	2,812
Highly Suitable 5+	35	9	14	15	110
Total	966	1,380	1,098	2,140	12,974
					18,558

Table 3.2 Parcel availability by suitability and capacity classifications

(unit: number of parcels)

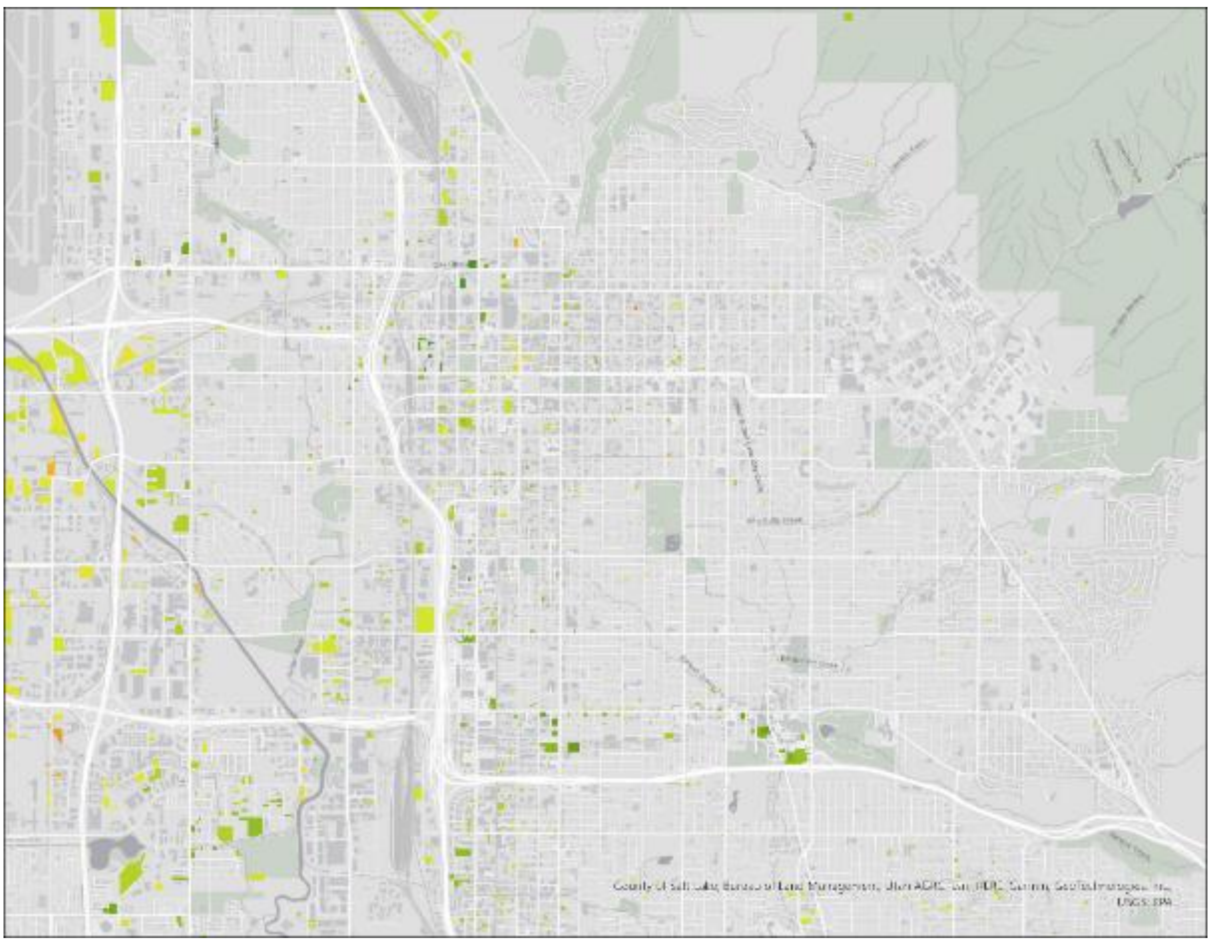

Figure 4-15 Suitability of vacant parcels

4.6.2 WFRC Centers

This focus area selects all capable parcels within WFRC projected regional centers. These are regional centers envisioned in the Wasatch Choice 2050 plan, as created by WFRC with local partners. Development in such parcels directly supports long-range efforts being undertaken by communities at all levels, and directly supports and strengthens such communal centers. Such areas are also expected to be popularly used, and are already a part of many people's daily lives, reducing the change citizens would need to make to use the vertiport. The figure below shows that in comparison to the other focus areas, WFRC centers have a much higher concentration of smaller vertiport classes, as the areas are largely developing or established urban centers.

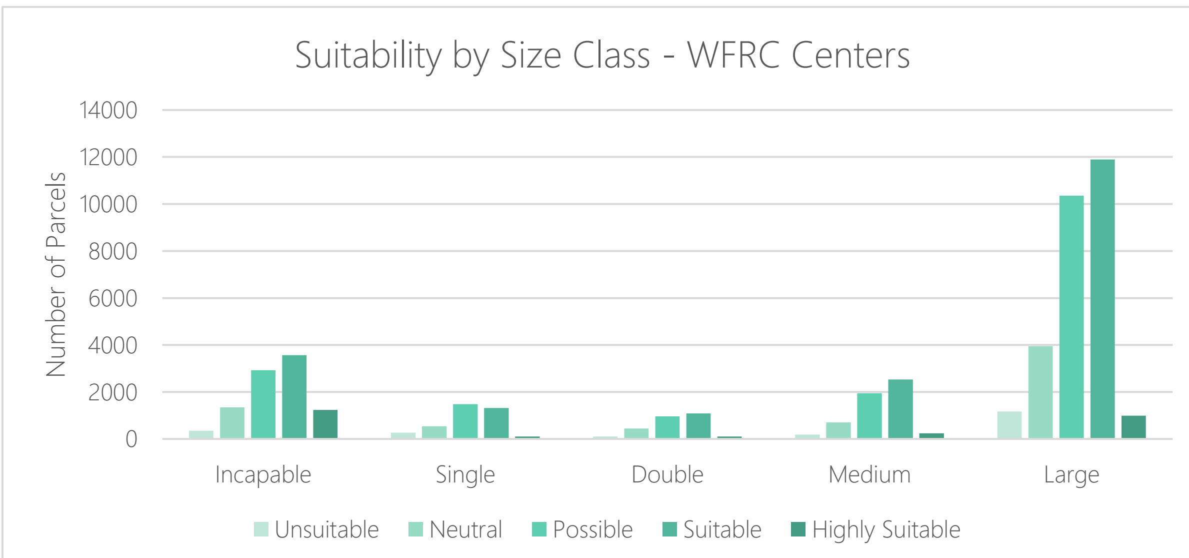

Figure 4-16 A breakdown of all WFRC center parcels by suitability and capacity

	WFRC Centers				
	Inadequate 0	Single 1	Double 2	Medium 3-4	Large 5+
Unsuitable <1	352	272	110	181	1173
Neutral 1	1,339	540	444	707	3,947
Possible 2	2,931	1,475	961	1,943	10,352
Suitable 3-4	3,573	1,311	1,089	2,533	11,899
Highly Suitable 5+	1,234	102	99	244	989
Total	9,429	3,700	2,703	5,608	28,360
					49,800

Table 3.3 Parcel availability by suitability and capacity classifications

(unit: number of parcels)

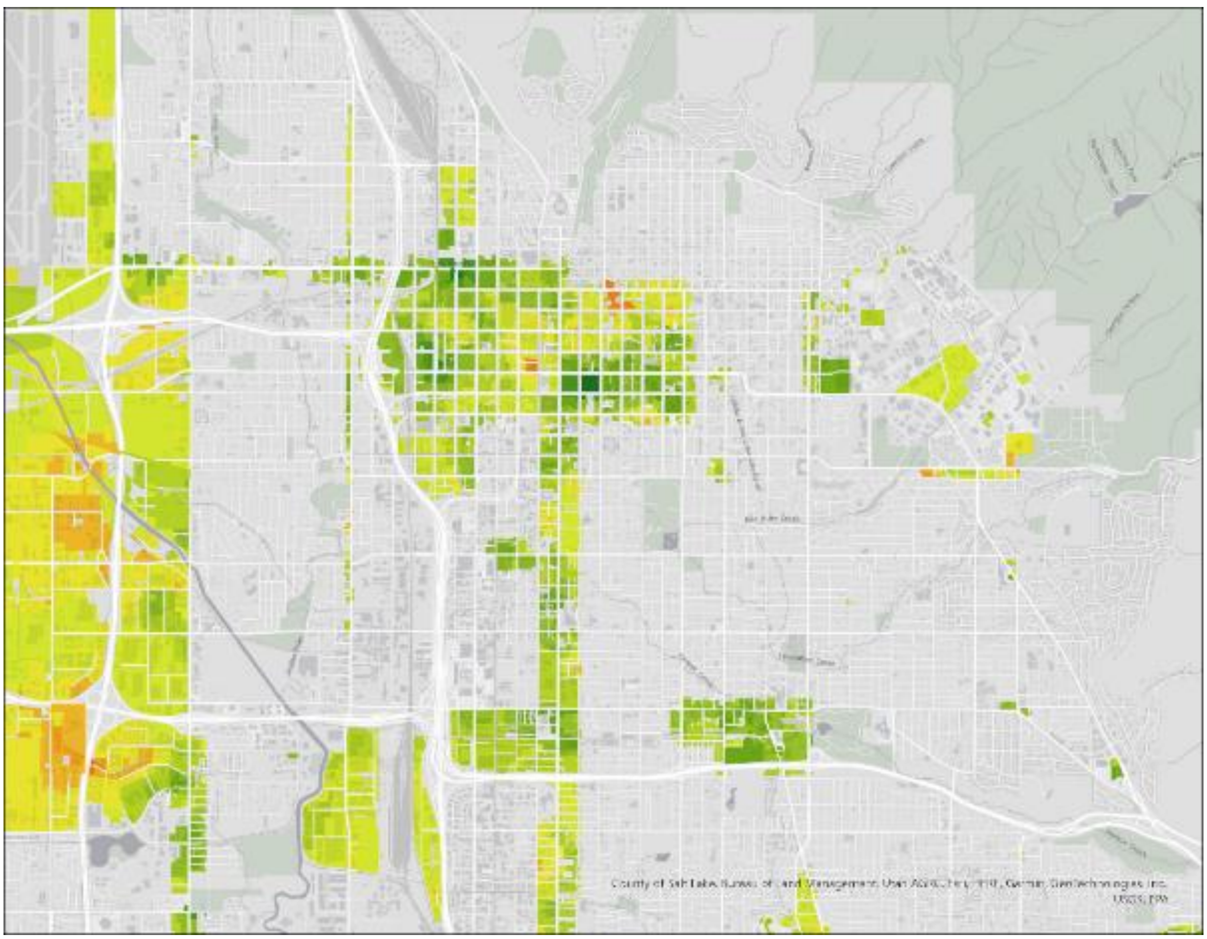

Figure 4-17 Suitability of parcels in WFRC centers

4.6.3 Transportation Planning

This analysis selects all capable parcels within a quarter mile of a planned road, rail, or other transit-oriented project published by WFRC or UDOT. As these areas will already undergo maintenance or development, vertiports can be included in some projects with reduced overall impact. Unfortunately, the data available by UGRC may include roadway maintenance projects that might not be as relevant for nearby development. The authors suggest caution when interpreting these results. Regardless, the data here offer a hint at the potential connections with existing transportation networks in land that is already likely owned by a public body, potentially reducing costs as well. However, the same proximity to major roadways causes the peaks of usable land to be generally less suitable, peaking in the possible category, which is slightly suitable for development. While this is not a hindrance to development, it does not strongly encourage it either.

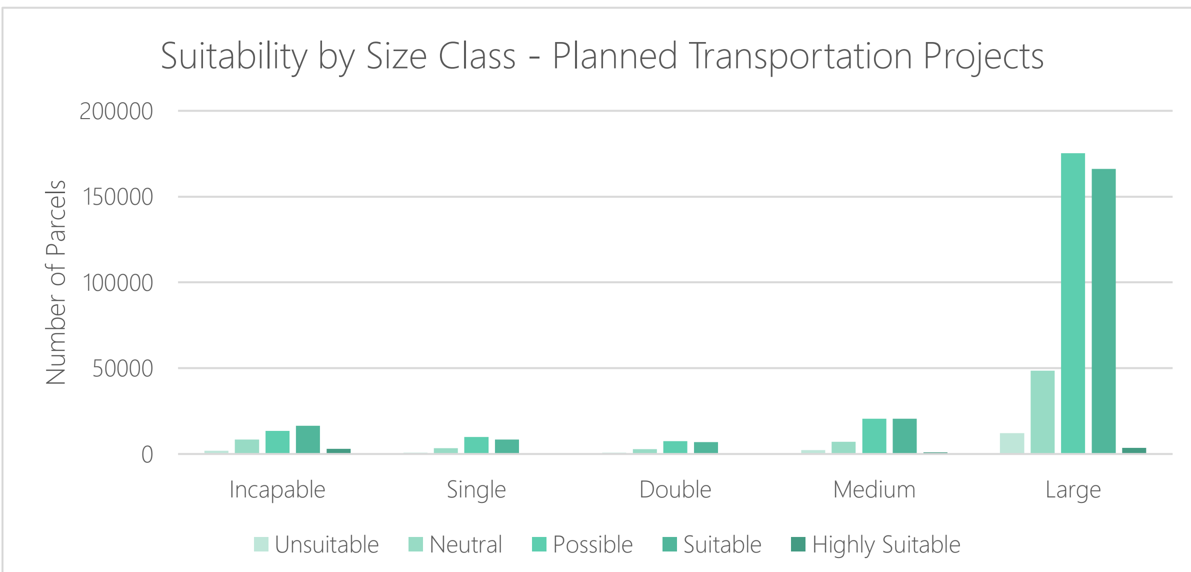

Figure 4-18 A breakdown of all parcels near transportation projects by suitability and capacity

	Transportation Projects				
	Inadequate 0	Single 1	Double 2	Medium 3-4	Large 5+
Unsuitable <1	1,854	803	753	2324	12240
Neutral 1	8413	3347	2797	7215	48497
Possible 2	13410	9956	7546	20575	175215
Suitable 3-4	16407	8498	6929	20547	166172
Highly Suitable 5+	3086	232	231	907	3667
Total	43170	22836	18256	51568	405791
					541621

Table 3.4 Parcel availability by suitability and capacity classifications

(unit: number of parcels)

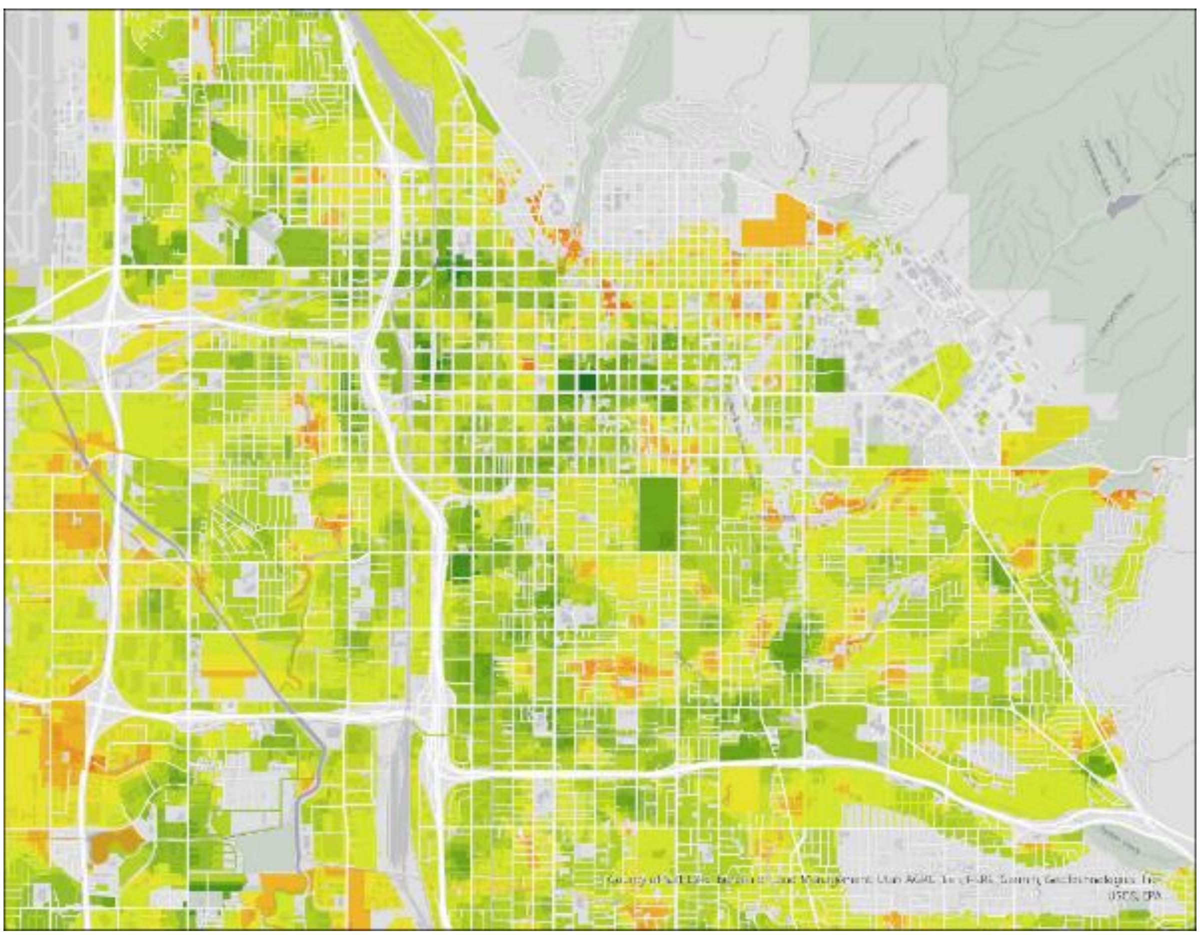

Figure 4-19 Suitability of parcels near a planned transportation project

4.6.4 Publicly Owned Parcels

All capable parcels zoned for government, institutional, or roadway uses are collected in this analysis area. These parcels are already owned by a governing body, reducing overall vertiport development costs if that site is selected. This figure shows a generally lower degree of suitability than other focus areas, likely due to the nature of the site itself. Some municipally run services, such as transfer stations or courts, are not considered suitable for vertiport development. However, there is still a significant portion of vertiports in the suitable category that should be considered.

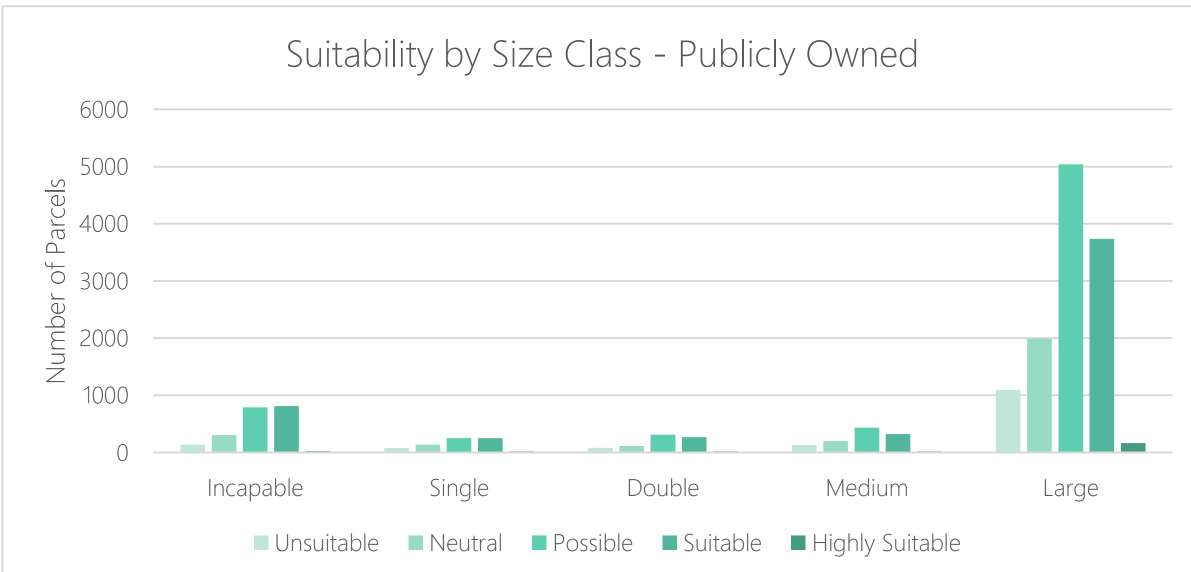

Figure 4-20 A breakdown of all publicly owned parcels by suitability and capacity

	Publicly Owned				
	Inadequate 0	Single 1	Double 2	Medium 3-4	Large 5+
Unsuitable <1	138	77	85	134	1,097
Neutral 1	307	136	118	202	1,992
Possible 2	787	251	313	436	5,038
Suitable 3-4	810	248	267	326	3,741
Highly Suitable 5+	24	20	19	20	167
Total	2,066	732	802	1,118	12,035
					16,753

Table 3.5 Parcel availability by suitability and capacity classifications

(unit: number of parcels)

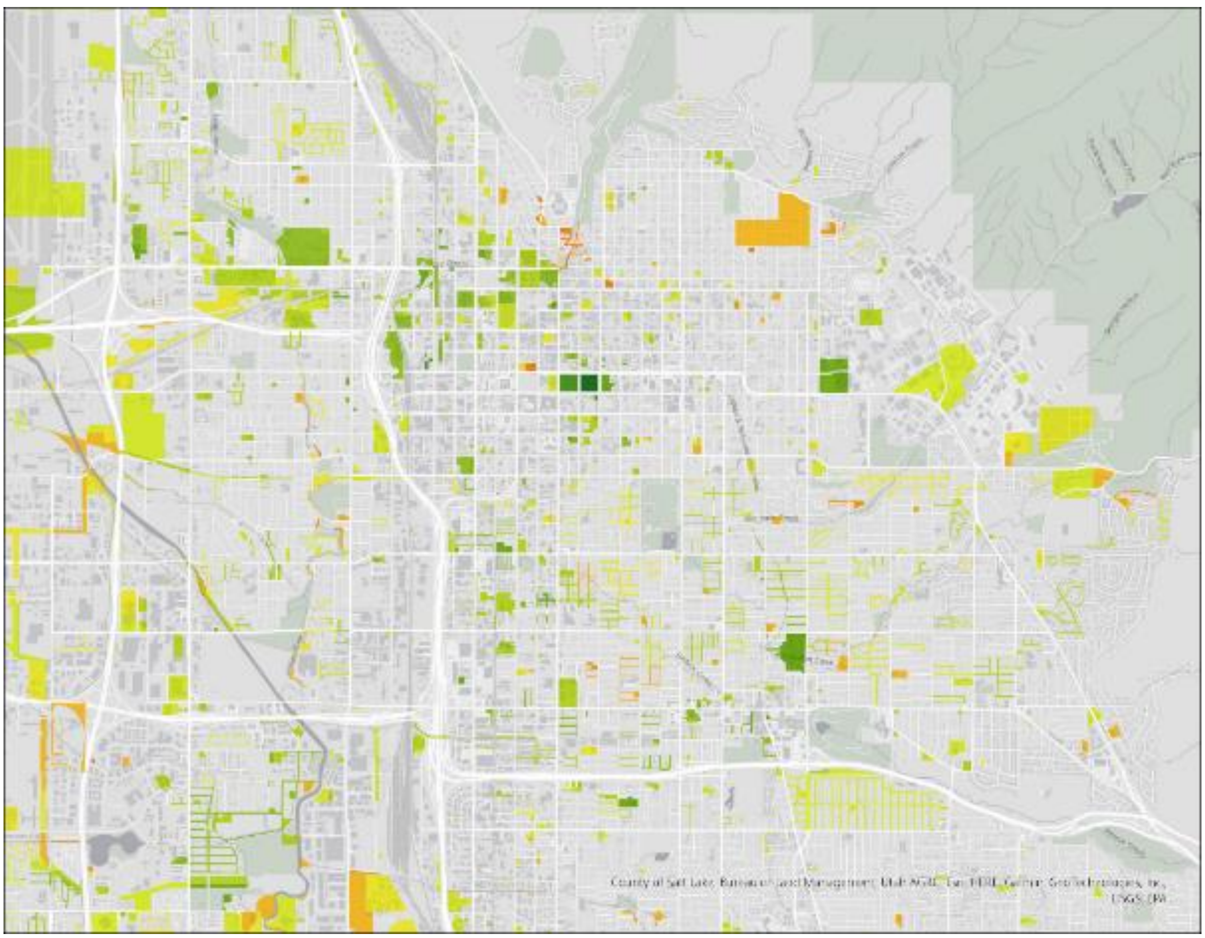

Figure 4-21 Suitability of publicly owned parcels

4.6.5 Equity Focus Areas

WFRC has deemed certain areas as an equity focus area, data on which is freely available through WFRC. These areas have any of the following: greater than 25% of residents are low income, more than 40% of residents are people of color, or more than 10% of households have no private vehicle. All capable parcels that have the equity focus area designation have been included in this focused analysis. As with any new technology, it is fair to expect that UAM will be marketed towards and received by more affluent communities. However, as UAM can deliver key households' goods or medications directly to the consumer with no need for a personal vehicle, this technology can be very useful in such communities as long as they are financially and physically accessible. The equity focus areas in this analysis also show a high ratio of suitable sites compared to the other suitability classes. These areas should be considered fully for their service to the surrounding communities.

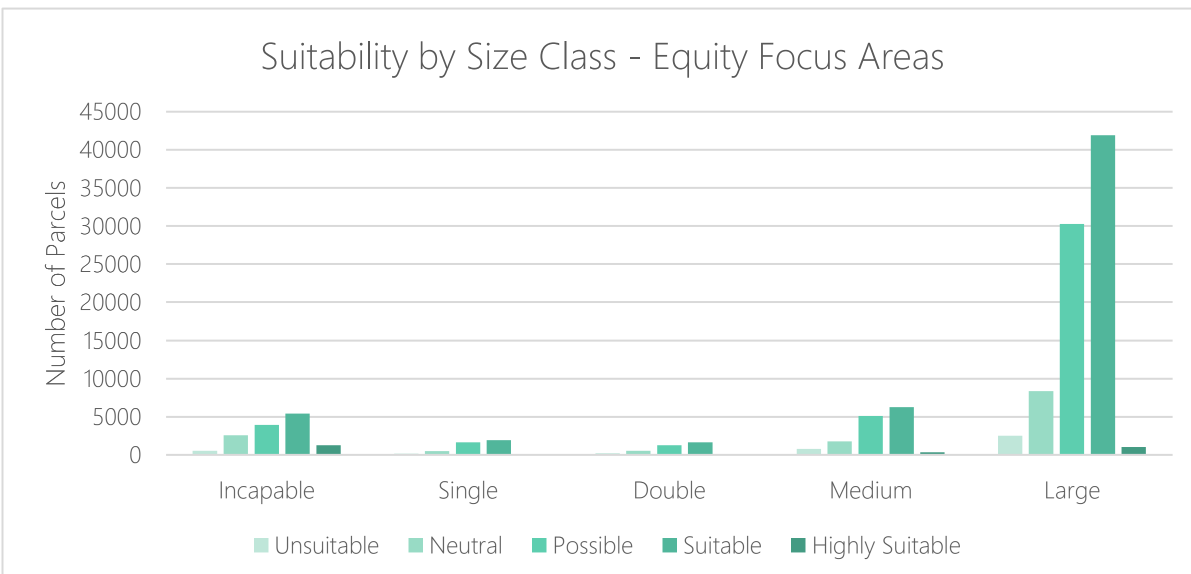

Figure 4-22 A breakdown of all WFRC Equity Focus Area parcels by suitability and capacity

	WFRC Equity Focus Areas				
	Inadequate 0	Single 1	Double 2	Medium 3-4	Large 5+
Unsuitable <1	538	153	187	790	2509
Neutral 1	2,561	501	539	1,764	8,363
Possible 2	3,943	1,620	1,244	5,118	30,248
Suitable 3-4	5,386	1,908	1,608	6,251	41,890
Highly Suitable 5+	1,240	69	58	306	1,053
Total	13,668	4,251	3,636	14,229	84,063
					119,847

Table 3.6 Parcel availability by suitability and capacity classifications

(unit: number of parcels)

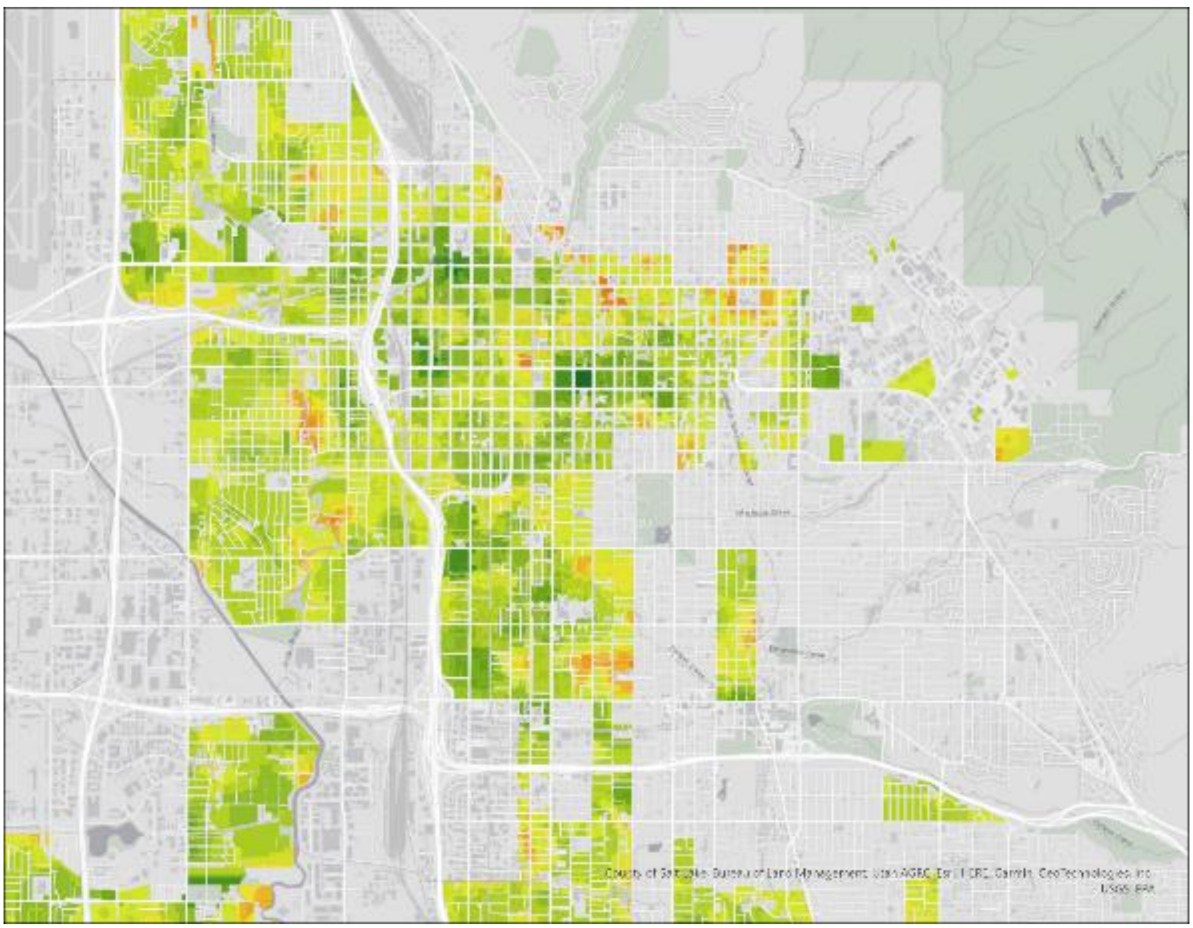

Figure 4-23 Suitability of equity focus areas

4.6.6 Residential Areas

All capable residential parcels, regardless of density, are included in this focus area. As the primary delivery target for this analysis is residential delivery, vertiports will especially need to be built in or near residential areas. As seen in the figure below, residential areas have a comparatively higher proportion of large-class vertiports. Vertiports need to blend into residential communities to provide services easily to residents, which may prove a difficult task. Development goals may adapt and change to many small vertiports of lower suitability to fulfill such a need, similar to community mailboxes.

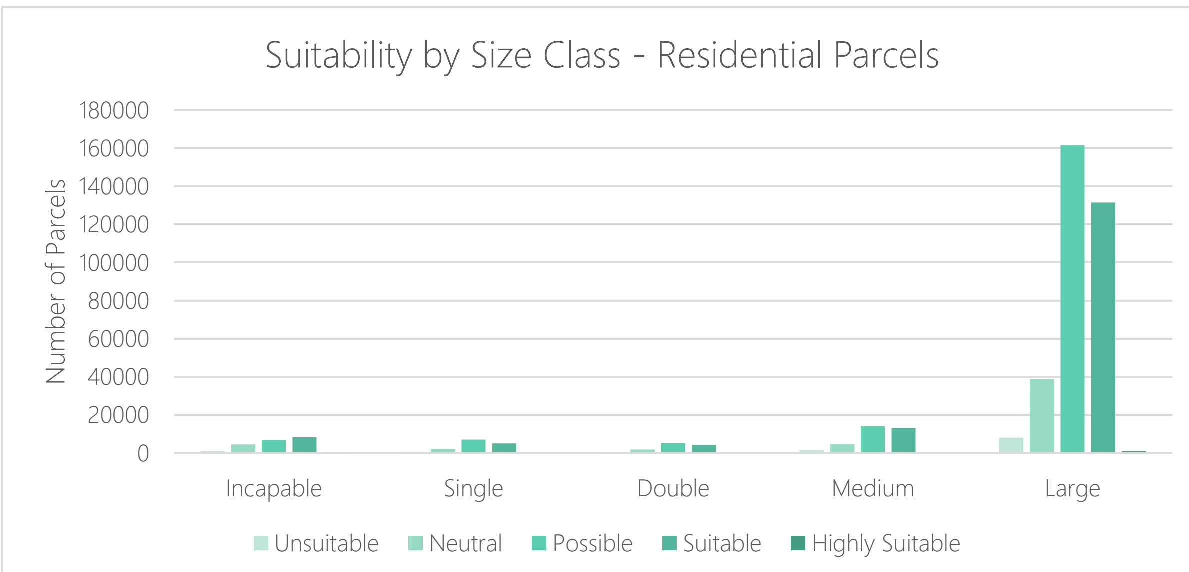

Figure 4-24 A breakdown of all residential parcels by suitability and capacity

	Residential				
	Inadequate 0	Single 1	Double 2	Medium 3-4	Large 5+
Unsuitable <1	946	553	423	1,483	8,086
Neutral 1	4,505	2,194	1,875	4,700	38,683
Possible 2	6,838	6,962	5,176	14,152	161,584
Suitable 3-4	8,126	5,072	4,094	12,997	131,482
Highly Suitable 5+	537	89	73	350	993
Total	20,952	14,870	11,641	33,682	340,828
					421,973

Table 3.7 Parcel availability by suitability and capacity classifications

(unit: number of parcels)

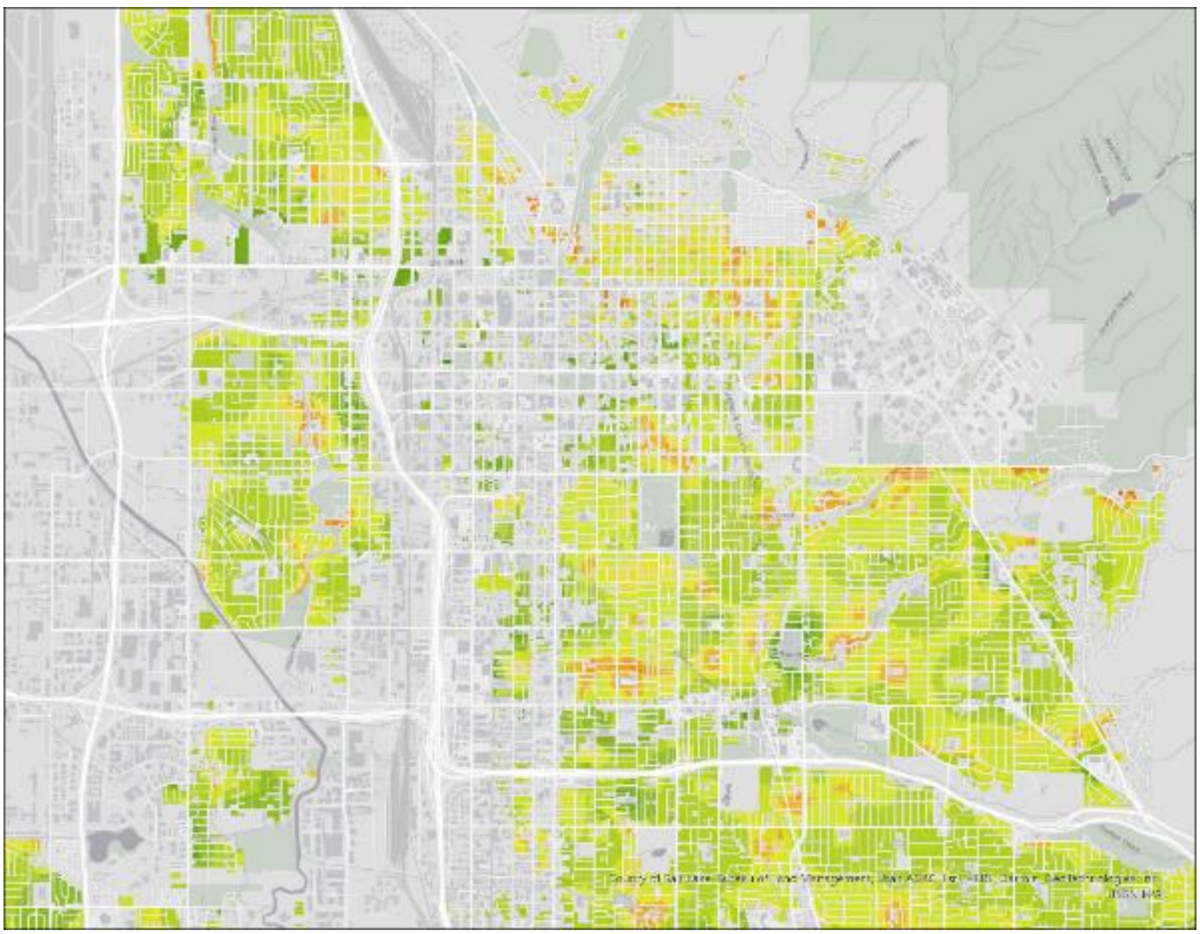

Figure 4-25 Suitability of residential parcels

4.6.7 Commercial & Industrial Areas

Similar delivery-focused industries are typically placed strongly within existing commercial and industrial areas. Many communities may prefer to keep vertiports in these zones as well. Future analyses will need to be run to determine the service area from such a vertiport to determine the feasibility in the community in question. Commercial and industrial appear to have a high proportion of inadequate parcels, however that is due to the minutiae of the data where small, subdivided parcels are used to indicate ownership in a multi-unit building or office. Commercial and industrial areas also show a larger portion of suitable sites, as they can easily blend with communal areas such as retail centers already in use, according to public perceptions.

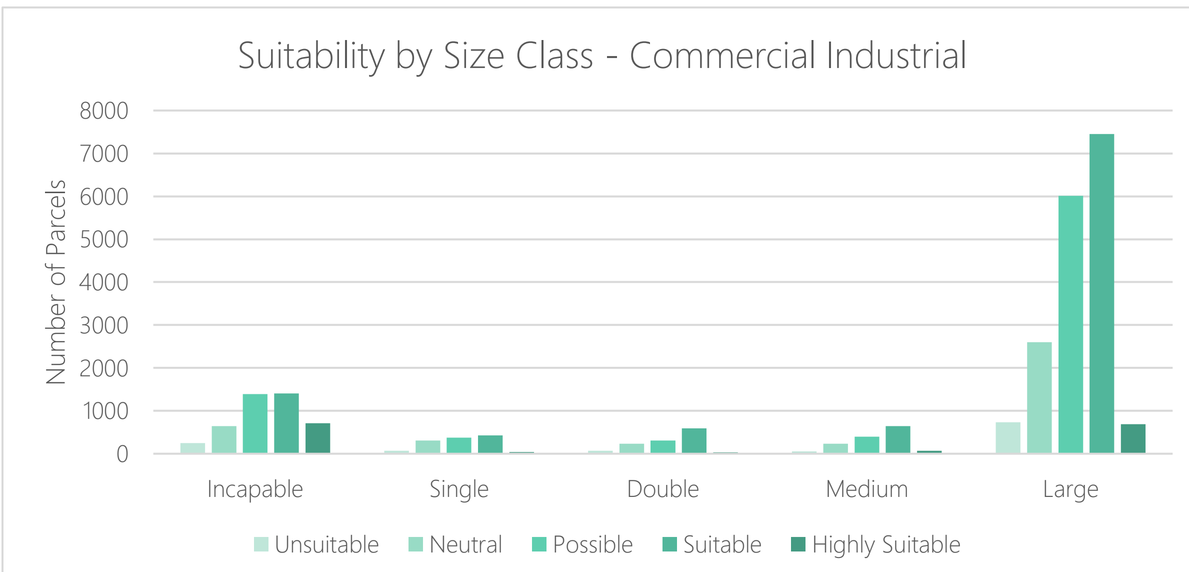

Figure 4-26 A breakdown of all commercial and industrial parcels by suitability and capacity

	Commercial Industrial				
	Inadequate 0	Single 1	Double 2	Medium 3-4	Large 5+
Unsuitable <1	249	69	71	56	735
Neutral 1	645	305	231	233	2,602
Possible 2	1,390	377	311	399	6,010
Suitable 3-4	1,402	425	591	641	7,452
Highly Suitable 5+	714	39	34	71	692
Total	4,400	1,215	1,238	1,400	17,491
					25,744

Table 3.8 Parcel availability by suitability and capacity classifications

(unit: number of parcels)

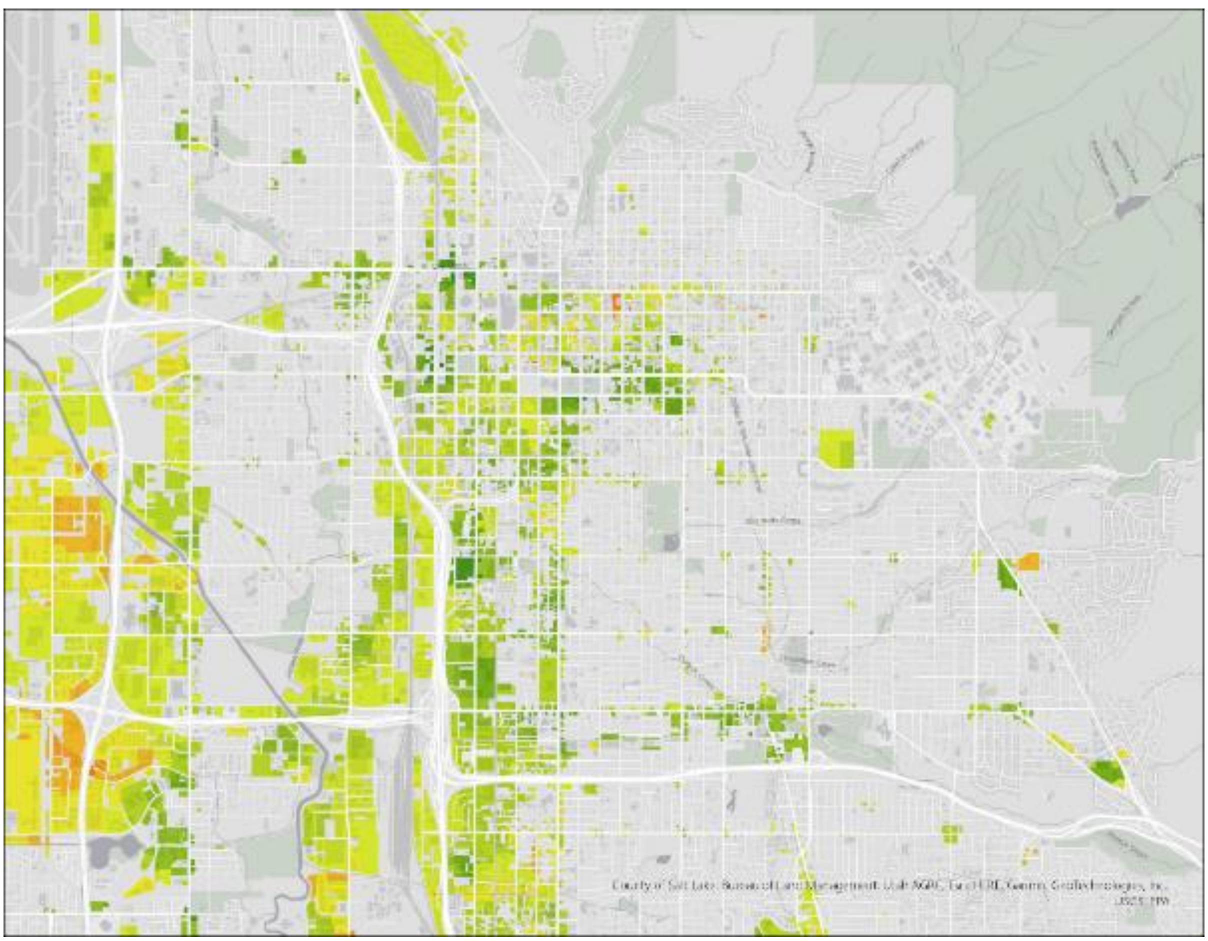

Figure 4-27 Suitability of commercial & industrial parcels

5.0 CONCLUSIONS

5.1 Summary

This pioneering study is among the first of its kind, pursing the impact of an entirely new infrastructure on our communities and recommending options for its optimal development. This tool uses accessible custom-written GIS toolboxes to create capability and suitability analyses for vertiport development across the Wasatch Front. By using the unique approach of evaluating suitability based on the impacts to both communities and sUAS operation, this approach empowers planners and communities facing sUAS integration. While early in its development, this tool will allow developers and planners to converse about land-use decisions that could influence UAM operations. Further, the geospatial tool is customizable and freely available, allowing communities to adapt it for their specific circumstances. Outputs can be simplified to facilitate stakeholder and community member discussions without sacrificing analytical depth in the background.

This tool aims to prepare for an entirely new infrastructure whose impacts are not fully known. Thus, the tool was designed to be simple, flexible, adaptable, and useful. The base methodology is the simple creation of spatial criteria, assignment of a score, and the tally of all variables. In the programming of the tool, each individual spatial criterion is easy to identify, and underlying flow is made obvious for the creation or removal of spatial criteria to suit a community. While weighting is not done in this iteration, the space for its integration has been left at multiple points.

The five dimensions outlined in this work, built environment, natural environment, technological needs, regulatory requirements, and value-based are designed to be encompassing of the most important community elements, when publicly available spatial data are provided, that may impact UAM development. The individual categories within them are provided as guidance only, as the impact of some may be found to be inconsequential while new elements may arise. Future users should look at the area of interest to determine if the categories and values should be changed.

This work aims to begin the vertiport siting process in Utah, assisting existing UAM research and development efforts already occurring in the area. Such work is foundational for future studies, both in and out of the Utah market as it directly supports the creation of quality infrastructure for a community. This work, however, is only a first step as many aspects of UAM integration are still unknown in the public planning realm. This work only creates a suitability analysis and does not include optimal locations to tie in with existing road and pedestrian networks. This analysis also makes no recommendations on the number or density of vertiports, both of which depend on market demands, regulation and technological innovation.

The model was created for a residential use case of sUAS-facilitated package delivery in small areas and using the simple scoring structure, yet it shows high possibility for sUAS and vertiport development across the Wasatch Front. Urban areas see a greater diversity of suitability, and a higher likelihood to reach extremely high suitability, as the areas are already developed, allowing sUAS to better blend with the existing character. Rural and suburban areas still see excellent opportunity for sUAS integration but may see higher communal impacts. Over 38% of capable parcels in the Wasatch Front are deemed suitable or highly suitable. Only 3% of capable parcels are considered unsuitable based on the surrounding community elements, and all remaining sites show as either neutral or slightly suitable for sUAS development. This shows that the Wasatch Front holds good opportunity for sUAS development from a community impact standpoint.

This entire project was completed using ModelBuilder in ArcGIS Pro. This allows complete documentation of the process that was used without a loss of information and creates new toolsets that others can run within ArcGIS Pro. The largest benefit of using ModelBuilder is the ability to preprogram entire analyses, easily allowing single steps to be changed or corrected without having to complete the analysis manually, saving countless hours. This also facilitated a team working on a single project with the sharing of one core geodatabase and several toolboxes in ArcGIS Pro.

Development of UAM through the creation of vertiports and other infrastructural systems is rapidly coming to our communities. While industries and regulatory bodies have been working on these technologies for years, the planning sector has done little to address them. This work gives planning a starting point, identifying the optimal locations for vertiports within the fabric of Wasatch Front communities. By analyzing how the existing community may impact UAM operations, and how they may in turn affect the community, this work brings UAM integration into the planning realm and introduces the topic to regional and local planners, providing the tools to conceptualize their community in the incoming aerial context. The final results of this study will inform more in-depth studies that include existing infrastructural elements as well as partnerships with UAM-focused companies to bring such technologies to the Wasatch Front.

Across the Wasatch Front, this study found significant opportunity for vertiport development. Over a third of parcels in the Wasatch Front are suitable, and only 16% show no propensity for vertiport development of any kind. Furthermore, parcels in WFRC designated centers, near planned transportation projects, and in residential areas are near the 40% suitable level, showing good opportunity for sUAS infrastructure development within our communities, allowing the technology to better integrate into the societal fabric.

5.2 Limitations and Challenges

As the research area is so broad, and the nature of vertiport siting is so closely tied to existing planning systems, the decision was made to use the median value of each parcel for final analyses. Doing so simplifies the full analysis into an understandable format that facilitates discussions in the siting, development, and impact factors of such a project. This also aligns with general systems in place and reduces the complicated analysis into an understandable format. This comes with some drawbacks. The capability analysis was run regardless of parcels, so some incapable areas that were in majority-capable parcels are shown as capable. As such, it is recommended to review the capability of an area when the parcel analysis is being used.

This study is just a first step towards UAM integration and develops some tools for developers to use. Future iterations of this project will need to be built with greater integration into existing infrastructure, such as the power capacity available for vertiport development. A key aspect of how this model theoretically functions is not possible, as the actual infrastructural needs or what craft will be used is not known. Regulatory structures must also change, and vertiports must adapt in turn. Building on this study requires the addition of market studies and sUAS statistics to determine the actual number and density of vertiports needed. From such knowledge this suitability data can be combined into existing transportation networks to identify the optimal sites for actual development.

This project has some limitations, primarily due to issues of data access, such as electrical line access and capacity at potential vertiport sites. As this project was done at such an early stage in vertiport development, the authors designed the spatial model to be flexible and adaptive as collective knowledge of sUAS integration changes and grows. The new or changed data simply must be added to the GIS model and assigned rules for capability and suitability as followed by every other dataset, and then incorporated into the model. The created GIS toolsets can run the entire capability and suitability inputs independently, and with some guidance be derived into parcel suitability and focus area analyses. This same structure also allows variable weighting to be quickly and simply adjusted, both by individual spatial criteria and by dimension.

6.0 REFERENCES

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7.0APPENDIX A: Geospatial Database

7.1 Introduction

In order to conduct the suitability analysis for the location of UAS vertiports, part of the secondary objective of this study, each spatial criterion or "rule set" must have associating geospatial data. Geospatial data is a term used for any data related to a specific location on the Earth's surface. Visual representation of the spatial criteria comes through the analysis of the associated geospatial data. This section discusses 1) where the geospatial data was retrieved from, and 2) how the data was organized.

7.1.1 Data Sources

Almost all the geospatial data used for this research was open-source, accessible data. Datasets were downloaded from 3 main websites, including the Wasatch Front Regional Council Data (WFRC) Portal (https://data.wfrc.org/), the Utah Geospatial Resource Center (UGRC) State Geographic Database (https://gis.utah.gov/data/), and the Federal Aviation Administration (FAA) UAS Data Delivery System (https://udds-faa.opendata.arcgis.com/). Other datasets were received through direct request. The UBCP Airstrip Data was obtained through the Utah Department of Transportation's Clint Harper through a shared drive.

The Wasatch Front Regional Council is responsible for coordinating the transportation planning process for the Wasatch Front. WFRC is "comprised of elected officials from Box Elder, Davis, Morgan, Salt Lake, Tooele, and Weber counties" ("About," n.d.) The roles of the WFRC are to be conveners, (able to collaborate with communities and partners), trusted technical experts, proactive planners, and implementers of visions and plans into action. Data gathered in separate cities, counties, regions, or Metropolitan Planning Organizations (MPOs) covering the WFRC are used for Regional Transportation Plans (RTPs) and Transportation Improvement Programs (TIPs). Much of this data is available on the WFRC Data Portal for public access and use.

The Utah Geospatial Resource Center is the State of Utah's map technology coordination office. The mission of UGRC is "to encourage and facilitate the effective use of geospatial information and technology for Utah" (gis.utah.gov/about/). UGRC strives to make sure coordination among fellow Utah GIS users is effective and efficient. They provide multiple services, including address geocoding services, aerial photography, custom web map apps, LiDAR elevation models, and more. One main role of UGRC is to provide updated spatial data in Utah to the public through the State Geographic Information Database. Data is gathered by different agencies and organizations and is accessible to all.

The Federal Aviation Administration (FAA) is a national organization under the U.S. Department of Transportation. The FAA seeks to "provide the safest, most efficient aerospace system in the world" (faa.org/about/). In order to achieve this goal, spatial data including flight patterns and policies are available on their website. Specific, new data on UAS is also available for download. The FAA is the source for all legal flight restrictions at a federal level.

7.1.2 Data Organization

The full set of data collected for this project is provided in the attached appendix table. Here we provide an abbreviated example of the structure of the data with appropriate commentary. Over 100 datasets were collected, and each dataset falls into one of the different framework categories (Built Environment, Natural Environment, Regulatory Requirements, Value-Based, and Technological).

Datasets were also assigned one of eight separate categories based on similarities to better manipulate the data. These categories are listed as follows: Boundaries (7 datasets), Demographics (10 datasets), Destinations (26 datasets), Hazards (11 datasets and 1 geodatabase), Land Use (13 datasets), Natural Landscape (8 datasets), Transportation (17 datasets), and UAS (3 datasets). Each data was downloaded, extracted, and saved in a file organized in one of the eight geospatial categories listed below.

- **Boundaries:** Datasets in this category include borders around towns, counties, and regions. Examples include Utah MPO Boundaries, WFRC Boundaries.
- **Demographics:** Datasets in this category include structures of populations, including employment, vulnerable communities, and households. Examples include Equity Focus Areas, Access to Opportunities, Job Projections.
- **Destinations:** Datasets in this category include point data of specific locations. Examples include Fire Stations, Schools, Places of Worship.

- **Hazards:** Datasets in this category include any natural or human-caused risks when planning for new development. Examples include Fault Lines, Radioactive Hazard Disposal Sites, Landslides, Solid Waste Facilities.
- **Land Use:** Datasets in this category include how our land is used and what it is used for. These uses could be both natural and human. Examples include Designated Wilderness, Land Parcels, Water-Related Land Use, Electric Transmission.
- **Natural Landscape**: Datasets in this category include the natural environments of the area. Examples include Lakes and Rivers, DEM, Dominant Vegetation.
- **Transportation:** Datasets in this category include any existing or proposed plans for transportation or how to move people. Examples include Sidewalk Inventory, UTA Commuter Rail Stations, Railroads, Airports.
- **UAS:** Datasets in this category include legal and informational data from FAA based on flight information. Examples include UAS Facility Maps, National Security Flight Restrictions.

Listed at the end of the chapter is a table displaying the datasets originally obtained and used in this research project. This table, referred to as the data dictionary, helped to organize all spatial data downloaded and obtained from various websites. This table includes: data title, framework dimension, category, description, data type, date downloaded, and source. Every dataset that was downloaded is listed, although not all of them may have been used. Directly below in Table 7.1 is a sample portion of this data dictionary.

Table 7.1 Data Dictionary Example Table

Data Title	Framework Dimension	Category	Description	Data Type	Date Downloaded	Source
Child Care Centers	Built Environment	Destinations	Preschool, day care, etc.	Point	9/15/2020	WFRC GIS Database
Roadway point projects (2019-2050 RTP)	Built Environment	Transportation	This dataset represents the roadway line projects in the 2019-2050 Regional Transportation Plan	Point	9/16/2020	WFRC GIS Database
Salt Lake County Land Use Parcels	Natural Environment	Land Usage	analysis on parcels within the WFRC MPO area	Polygon	9/16/2020	WFRC GIS Database

7.1.3 Data Manipulation

Once data was gathered, all data needed to be double-checked in case of broken links, projected into a specific coordinate system, and then clipped to the area of interest. All datasets were then projected to the North American Datum 1983 UTM Zone 12N (commonly used for spatial data analyzed in Utah). The projected data was then clipped to the boundaries of the WFRC Metropolitan Planning Organization (MPO).

This process was done using ArcGIS Pro's ModelBuilder in order to create efficiency and iterate the process as more data was found and gathered. Figure 7-1 below shows the model created for projecting the data.

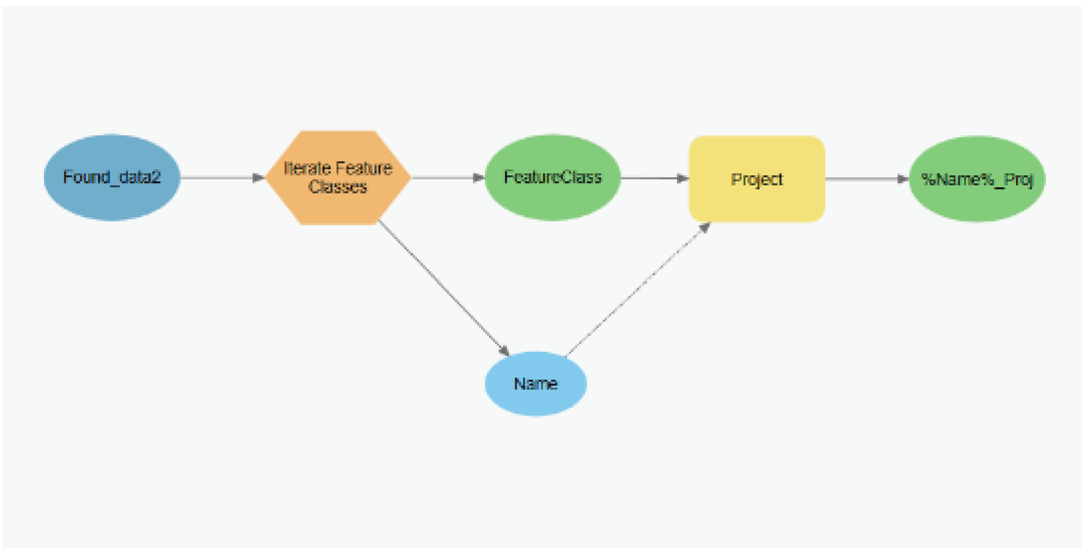

Figure 7-1 ESRI ModelBuilder to Project All Data

This model is organized by connecting the folder where all the data was saved and zipped to an iterator tool, so that the projection process can be done to each dataset in the folder. Once the project tool is used, each data feature class is saved in a new folder. Figure 7-2 displays the model built for clipping the data to the MPO.

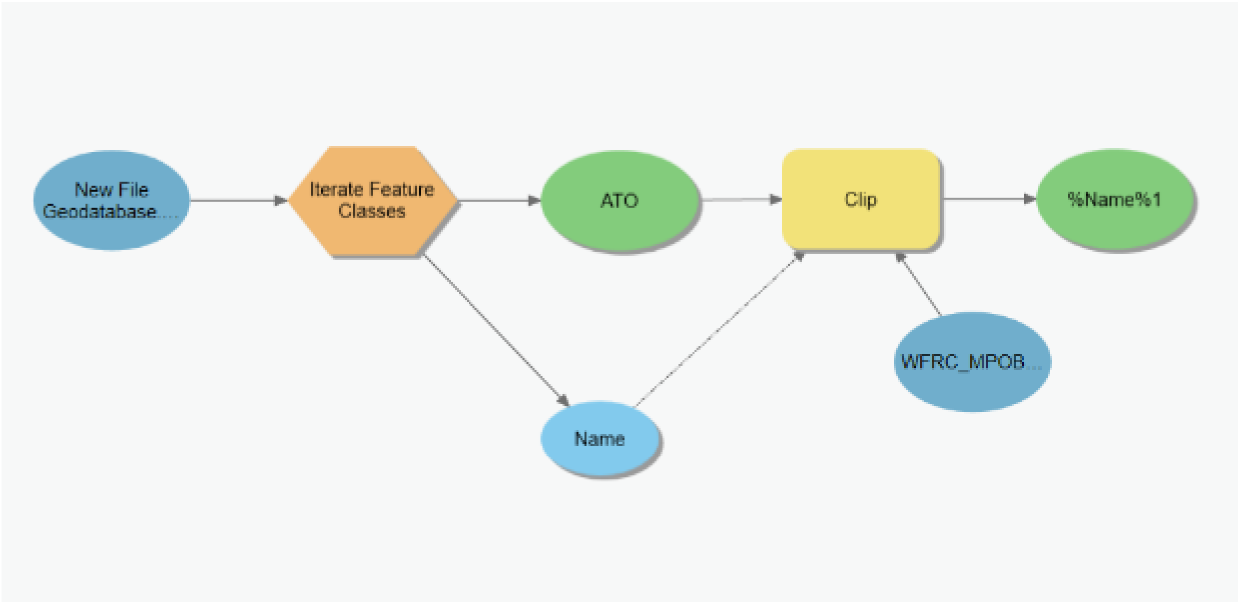

Figure 7-2 ModelBuilder to Clip All Data

This model begins by adding the projected data (now titled new file geodatabase) and iterating it once again. This time the tool used is the “clip” tool, and the WFRC MPO boundary is the clipped area. This produced a new folder of data projected and clipped to the area of focus.

Once all the data downloaded was both projected and clipped, the new data was renamed and organized into each of the 8 categories listed on the data dictionary in a geodatabase. (Note that raster datasets are filed differently from vector feature classes, due to the organization of geodatabases). The final geodatabase contains 115 separate feature classes and 3 raster datasets. The complete size is 1.60 gigabytes.

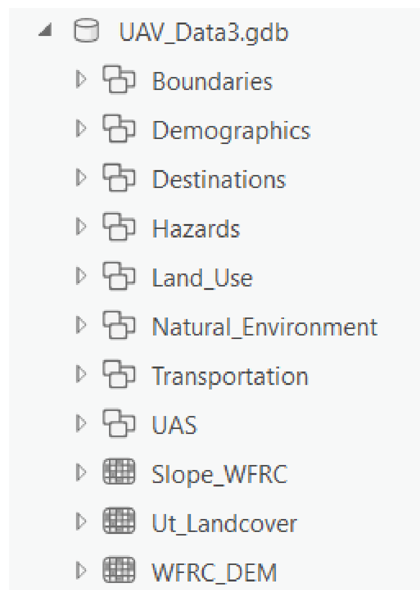

Figure 7-3 Organized Geodatabase Folders

8.0 APPENDIX B: Spatial Criteria and Variables

Story Map: https://storymaps.arcgis.com/stories/a5e89074c5f74cbb94e3f14850b694c2

Community Element	Dimension	Rule	Score	Criteria	Source
Historic District	Built Others	Field	-1		UGRC
	Built Others	Selected Field	1	Privately Owned Land	UGRC
	Natural Environment	Buffer	-1	Parks and Recreation	
	Natural Environment	Buffer	-1	State Parks and Recreation	
Land Ownership	Natural Environment	Buffer	-1	BLM, DNR, USFS, USFWS	
Parks	Built Others	Field	1		UGRC
Frontrunner Stations	Built Others	Buffer	1		UGRC
TRAX Stations	Built Others	Buffer	1		UGRC
	Built Point	Buffer	-1		UGRC
Law Enforcement	Value-Based	Field Buffer	-1		
	Built Point	Buffer	1		UGRC
Libraries	Value-Based	Field Buffer	1		
	Built Point	Buffer	1		WFRC
Community Services	Value-Based	Field Buffer	1		
	Built Point	Buffer	1		WFRC
Community Centers	Value-Based	Field Buffer	1		
	Built Point	Buffer	-1		UGRC
Cemeteries	Value-Based	Field Buffer	-1		
	Built Point	Buffer	1		WFRC
Retail Centers	Value-Based	Field Buffer	1		
Public Schools	Built Point	Buffer	1		WFRC
Private Schools	Built Point	Buffer	1		WFRC
	Built Point	Buffer	1		WFRC
Grocery Stores	Value-Based	Field Buffer	1		
	Built Point	Buffer	-1		UGRC
Fire Stations	Value-Based	Field Buffer	-1		
	Built Point	Buffer	1		WFRC
Child Care	Value-Based	Field Buffer	-1		
	Built Point	Buffer	-1		WFRC
Churches	Value-Based	Field Buffer	-1		
	Built Point	Buffer	-1		UGRC
Correctional Facilities	Value-Based	Field Buffer	-1		

Community Element	Dimension	Rule	Score	Criteria	Source
Urgent Care Centers	Built Point	Buffer	-1		WFRC
		Buffer	-1	Minor	UGRC
Streams	Natural Environment	Buffer	-1	Major	
Floodplains	Natural Environment	Field	-1	A, Ae, Ve	UGRC
Lakes	Natural Environment	Buffer	-1	Not Internment	UGRC
Conservation Easements	Natural Environment	Buffer	-1		UGRC
Wetlands	Natural Environment	Buffer	-1		UGRC
Dams	Natural Environment	Buffer	-1		UGRC
Airports	Regulatory	Buffer	-1		UGRC
Hospitals	Natural Environment	Buffer	-1		WFRC
Monuments And Markers	Value-Based	Buffer	-1		UGRC

Table A.2 Capability Variables

Community Element	Rule	Selector	Source
Conservation Easements	Field		UGRC
Electrical Lines	Buffer	50ft	UGRC
Dams	Buffer	50ft	UGRC
Railroads	Buffer	50ft	UGRC
Streams	Buffer	15ft	UGRC
Roads with speed limit >=65	Buffer	100ft	UGRC
Roads with speed limit <65	Buffer	50ft	UGRC
Minor Water	Buffer	50ft	UGRC
Major Water	Buffer	100ft	UGRC
Land Ownership (BLM, DNR, DOD, SITLA, USFS, UFWS)	Field		UGRC
Solid Waste Facilities	Field		UGRC
Hospitals	Field		WFRC
Child Care Facilities	Field		WFRC
Power Plants	Field		UGRC
Private Schools	Field		WFRC
Public Schools	Field		WFRC
Correctional Facilities	Buffer	500ft	UGRC
Urgent Care	Field		WFRC
Airport	Field		UGRC
Slope	Field	10%	UGRC

A.3 Generated Datasets

Dataset	Components	Method
MasterOwnership	Ownership Data for Salt Lake, Weber, and Davis Counties	Union. Box Elder not included as county would not provide data for free, and suitable workarounds were found
MasterParcel	All Parcels	Union. Add field and calculate to hold all values needed in a single column.
Capability Vector	Entire WFRC, All incapable components	Dissolved WFRC boundary with incapable areas erased
Capability Invert	Inverted capability raster holding only incapable areas	"is null" ran on the capability raster
Suitability Combined Raster	Suitability and Capability	Raster calculator multiplies the rasters where capability is either a 1 or zero.
Zonal Stats Specific		
Parcel Suitability Union	Parcel Suitability for all counties combined, cleaned as needed.	
Parcel LU Merge	WFRC coded land use for each parcel	Spatial join Parcel Suitability Union and WFRC land use
Parcel Land Use	All Parcels with WFRC Land Use Codes with size and suitability classes	Add field and calculate size and suitability classes in Python