Discovery Park Web GIS Based Vegetation Monitoring and Reporting

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Executive Summary

The primary goal of the University of Washington MGIS Discovery Park Capstone Project Group is to provide the Friends of Discovery Park a holistic park-wide management platform per their request and specifications. The Group has taken several complementary approaches toward meeting this goal. Our efforts concentrated in three focal areas: 1. vegetation characterization, 2. land cover and carbon sequestration analysis, and 3. quantifying visitor use across the park. Fundamental work on metrics that are likely to serve multiple queries about the current state of Discovery Park's vegetation, as well as trajectories of vegetation change over time, are deemed substantially important to this effort given the pivotal role vegetation serves in relation to wildlife in general and to most if not all Discovery Park management decisions on key Park related issues. Georeferenced aerial imagery from three distinct years provides a visualization of the change in landscape over time, and the land cover classification conducted on the most recent imagery provides a better sense of the current landscape of the park. The land cover classification also provides a means to better understand the ecosystem services provided by the park in terms of carbon sequestration values. In addition, visitation patterns were analyzed using data output from the Natural Capital Project's InVEST Recreation model to help visualize how human impact differed across the park. Significant variation in visitation patterns were seen, especially within certain types of land cover and vegetation classes. This data can help to inform management decisions that aim to offset human impact on the park environment. Together, these approaches provide a broad view of key elements relating to park management and establish the grounds for future work in this area.

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1. Background and Problem Statement

1.1 Background

Discovery Park in Seattle, Washington is a large urban park, encompassing an approximate area of 534 acres along the northern coastline of the city. The park serves an important role to the city, related to the environmental and social contributions afforded by the park and its varied landscape. The park's role within the larger community of Seattle is to provide an escape from the busyness of the city, and provide the city's inhabitants and visitors an opportunity to be in contact with the wildlife, vegetation, and scenery that the park provides. Nestled within a large, populated, busy urban setting, Discovery Park provides an unparalleled opportunity to experience the serenity and beauty of the natural environment within the limits of one of the United States most populous cities.

The Friends of Discovery Park (FoDP) was established in 1974 as a volunteer based group which serves to defend the integrity of the park and to create, protect, and promote the landscape affordances provided by the park. Specifically, the mission statement for the FoDP reads as follows: "Our purpose is to defend the integrity of Discovery Park; to create and protect there an open space of quiet and tranquility, a sanctuary where the works of man are minimized, appearing to be affected primarily by the forces of nature, a place which emphasizes its natural environment, broad vistas and unspoiled shorelines; and to promote the development of the Park according to a Master Plan responsive to these goals." (FoDP 2018). In accordance with this mission statement, a Master Plan document for the park was created in 1972, revised in 1974, and updated again in 1986, the latter of which represents to the most recent Master Plan document. The Master Plan serves as a policy document meant to guide decisions regarding development within the park, with an understanding that the park cannot and should not attempt to be a pristine wilderness environment, but rather that the park be managed in a manner which promotes a place of serenity and tranquility for human visitors to the park, as well as maintaining a suitable habitat for the various vegetation and wildlife who call the park home.

1.2 Problem Statement

The Friends of Discovery Park proposes the creation of a web based GIS platform which will ultimately serve as a holistic representation of the various vegetation, wildlife, and human influences which influence one another, both positively and negatively, as a means to better understand the interactions of these variables in relation to the overall goals for the park set out in the Master Plan. The representation of these variables will also serve as a baseline of current conditions within the park, to better serve efforts related to tracking changes in the park over time. This proposed platform will ultimately be developed for use within all city parks of Seattle, with the initial platform focusing on Discovery Park as a test location. Discovery Park was deemed to be a suitable test location due to its varied landscape affordances and engaged organizational stakeholders, with the thought that due to the variability of the landscape affordances the large number of organizational stakeholders, the platform could be more easily incorporated into smaller, less complex (environmentally and organizationally) parks within Seattle. The platform will provide visual and analytical capabilities for the various stakeholders of the park to aid in the coordination and evaluation efforts undertaken by these stakeholders, or any other party who may be responsible for the influence of changes made within the park.

The creation of the proposed platform consists of two major phases of work: 1. Data compilation and database creation 2. Integration of pertinent datasets in a manner which facilitates a holistic analysis of the various entities existing within the park. The platform will aid in addressing the problems which arise from the existence of the large number of organizational stakeholders who all design and implement land management practices in accordance with the values outlined in the Master Plan. The platform proposed to display a representation of the current state of the social and environmental aspects of the park from the full park extent down to areas as small as 50 square feet, as well as providing a means for the stakeholders to create scenarios which can inform how changes in the landscape affect the various relationships between the many entities which make up the park as a whole.

1.3 Project Goals and Objectives

The Friends of Discovery Park provided a detailed set of issues they wish to be addressed through the creation of the proposed platform. Due to the broad and inclusive nature of the proposed platform, the set of issues provided by the FoDP was quite lengthy, and it was determined that a subset of these issues would be focused on for inclusion into this phase of the platform creation and implementation. Three primary objectives were established for inclusion within this project:

1. How does the Discovery Park Master Plan (MP) shape and guide the evolution, usage, and management of the Park?
2. How has management of Discovery park changed in past decades in land use and land cover types?
3. What are the significant landscape affordances provided by Discovery Park?

The first objective speaks to a wide array of entities related to the park, including existing vegetation and wildlife, human visitors to the park, stakeholders who manage lands within the park, and many others, all of which relate to and influence one another. Understanding these relationships and influences is key to understanding how the Master Plan is carried out regarding land management practices enacted as part of the overall plan. The second objective aims at an understanding of how the park has changed over time, as a direct effect of land management plans and implementation associated with the Master Plan. The third objective relates to the current status of the park, addressing the affordance, or benefits, that the landscape of the park provides. The proposed platform aims to include various sets of data which, together, work together to address the core three objectives for the project overall.

Three specific goals were established regarding the data which needs to be included within the platform to best address the three core objectives outlined above. Considering that the current status of the park is a primary aspect of each objective, it was determined that a baseline for vegetation, land cover, landscape affordance, and user visitation data was a necessary first step in the creation of the platform. Establishing a baseline for these aspects of the park is an integral part of tracking change over time, which in turn informs land management practices within the park as they are guided by the Master Plan. In addition to the inclusion of preprocessed, ready to go data made available by the Friends of Discovery Park, it was determined that there were five specific goals to be completed regarding the acquisition, processing, and analysis of data necessary for the base map, listed below.

- Develop a current, accurate vegetation analysis for the park, including identifying dominant and subordinate species for each plant community represented and the creation of moisture and weed index surfaces for the entire park.
- Georeference aerial imagery from various years to visualize change in the park's landscape.
- Create a current land cover classification dataset based off of the 2018 aerial imagery.
- Calculate carbon sequestration values, to represent one aspect of landscape affordances, for the different land cover classes.
- Create a dataset representing the density and locations of visitor usage within the park.

The integration of the results of the aforementioned goals into an interactive platform serves as the primary goal regarding the creation and implementation of the platform. In addition to the objectives and goals outlined above, the Friends of Discovery Park also had a set of objectives they hoped to include within the platform itself. The goals related to the platform itself relate to the manner in which the baseline data, and the relationships between the various datasets, are presented. The longview goal of the platform is very broad and complex, and as a result a subset of goals related to the initial creation and implementation of the platform were created for this particular project. The goals for this iteration of the platform are listed below.

- The platform should provide interactive capabilities, allowing the user to view the various datasets which comprise the basemap at any extent within the park.
- Relevant data should be able to be displayed "on-the-fly", so that the relevant metrics are adjusted as the user scrolls through the map.
- The platform should allow users to create scenarios, where the user can estimate the potential impacts of a particular change in the landscape.
- The platform, overall, should accurately represent and portray the data in a manner which meaningfully considers the Master Plan and the influence the plan has on land management practices.

2. System Resource Requirements

2.1 Data

Initially, data was provided to us in various formats: shapefiles, geodatabases, PNG and JPG files, Excel files, etc. Our group organized this data and integrated them into individually managed file geodatabases, maintained by each group member through the course of their analysis. Regularly sharing of these geodatabases was conducted using Google Drive, and a final integrated file geodatabase was created at the conclusion of this project.

2.2 Hardware and Software

As a group, our work drew heavily on the ESRI suite of software and online tools. Data processing and analysis was conducted largely in ArcGIS Pro. For obtaining visitation data, the Recreation model from Natural Capital Project's InVEST toolset (v. 2.4.4) was used.

For data display and the construction of our platform web app, we drew on ArcGIS Online's web maps and web apps. In our platformweb app, we made particular use of the 'Summary' widget, which was able to allow for on-the-fly display of crucial datasets for the area in the field of view. We also drew on the 'Swipe' widget, which provided the ability to slide between aerial imagery datasets of different dates.

Software Function Capabilities:

- AGOL Web Apps and widgets
- ArcGIS Desktop
- ArcGIS Pro
- MS Excel
- MS Access
- Notepad ++ (used to write html, css, and js code)
- Google Docs
- Google Sheets
- Collector (ESRI app)

Microsoft Access was used to record, archive, calculate, and report key vegetation metrics. Microsoft Excel and Google Sheets were used for creating tables, many of which served as an interface between ArcGIS feature class attribute tables and Microsoft Access. ESRI's Collector software was drawn on for a user-friendly way to define 'areas of interest', sync with an online hosted feature service, which was later drawn on in ArcGIS Pro for analysis. Hardware used was restricted largely to Project Group member personal computers.

2.3 People and Institutions

Garrett Epserum, of Friends of Discovery Park, was a primary contact throughout the quarter, providing us with data, guidance, and feedback on our efforts. A whole host of institutions created datasets that our group drew on in its work. These include but are not limited Earth Economics, Seattle Trails Alliance, Jones & Stokes, and Green Seattle Partnership. These institutions and the individuals within them that created these datasets are part of a system, conceptualized in a wider sense, that made this group work possible.

3. Business Case Evaluation

The relationship between costs and benefits associated with this project provide an important understanding of the overall worth of this undertaking. While the project has been deemed worthwhile enough to initiate the creation of this proposed platform, a business case outline for the project is imperative for a comprehensive understanding of how the costs of the project will provide benefits, and to quantify these costs and benefits in monetary terms. This business case follows methods outlined by Huxhold and Antenucci (Huxhold 1991; Antenucci 1991) which include typologies for costs and benefits, framed within a format which attempts to place a monetary value on both costs and benefits to ultimately compare the two.

The business Case focuses on the work conducted with the InVEST Recreation, Land Cover, and Ecosystem Services Valuation data. Included are five specific benefit types (as outlined by Antenucci et al. (1991) and Huxhold (1991), a break down of expected costs, and an analysis of both of these in relation to one another.

3.1 Benefits

3.1.1 Type 1 Benefits: *Quantifiable efficiencies in current practices, or benefits that reflect improvements to existing practices*

Current guidance from our project sponsor holds that FoDP has spent an average of 8 hours per week across the past 18 months on this particular project. Our sponsor also mentioned that Seattle Parks & Recreation places a $25/hour value on volunteer hours.

To generate a figure for Type 1 benefits, it’s assumed that the platform web app will fulfill the goals of that work and those 8 hours/week will be eliminated, apart from 1.5 hour expected to be spent engaging with our platform web app and updating the geodatabase. This time savings represents a quantifiable savings in cost.

As our sponsor has been in regular contact with us, it’s assumed the current workload has stayed the same through the quarter so far. Our platform web app is estimated to go online in the last week of the quarter, which is when these savings will begin to be realized.

Current weekly hours of work	8
Expected hours of weekly work w/platform web app	1.5
Reduction in hourly work	6.5
Value of work	$25/hr
Savings	$162.5/week

Table 1. Type 1 benefits calculated as reduction in previously worked hours.

3.1.2 Type 2 Benefits: *Quantifiable expanded capabilities, or benefits that offer added capabilities*

In order to calculate Type 2 benefits, the question was asked about how the expanded capabilities of our platform web app compare to a baseline scenario without it.

In line with our sponsor's recommendations, the current value of work was set at $25/hour. For each dataset, a factor was calculated that looked at how improvements in efficiency could act as a multiplier of this value. This increase in work value results in a quantifiable number that can be attached to Type 2 Benefits as they relate to our datasets.

InVest Recreation Data

InVEST Recreation data represents the concentration of photo-user-days, calculated as the number of geotagged photos within a predefined sized grid cell per year. It represents a proxy for human visitation.

An estimated 594% increase in efficiency was calculated for efforts guided by the InVEST Recreation data, assuming that it is an accurate proxy for visitation. This was calculated with the assumption that the InVEST Recreation data allows for maximally efficient targeting of park areas to help counter human impact. The InVEST Recreation data informed scenario was compared to a scenario where the same expected amount of effort was applied to only areas within a 200 ft. buffer of trails in the park.

Trails were previously considered the main proxy for human impact, and the following attempts to calculate improvements to that proxy by instead drawing on InVEST Recreation data.

This figure of photo-user-days is used here as a proxy for work applied towards areas impacted by humans, and thus, one photo-user day can be considered to be equivalent to one "photo-user-day of work".

The sum amount of average annual photo-user-days across the park was calculated to be 241.3 photo-user-days. This total was then divided by the number of grid cells located within 200-ft buffer zones of trails to generate a mean figure of 0.0285 photo-user-days of work per grid cell. The assumption here is that under the baseline scenario, work would be restricted to around trails and would equally target these areas.

Under the InVEST Recreation guided scenario, a maximally efficient amount of work is associated with the total of 241.3 photo-user-days. Any difference in the baseline scenario's allocation of 0.0285 photo-user-days of work/grid cell from the InVEST Recreation distribution of photo-user-days represents a loss of some sort.

Any grid cells with more than 0.0285 photo-user-days would have 'wasted' amounts of work, where excess work is not needed, while any grid cells with values lower than 0.0285 photo-user-days represent areas where not enough work is being focused.

For grid cells with a greater amount of photo-user-days than 0.0285, only 0.0285 'photo-user-work-days' were recorded as being effectively applied. The assumption is that only 0.0285 of photo-user-days of work was required. For grid cells with lower values, only the grid cell value was counted as effective work, assuming that 0.0285 photo-user-days of work was too much work and only the grid cell's photo-user-day value of work was required.

This sum difference of effective work calculated to be 40.6 photo-user-days, which when compared to the total of 241.3 days of efficiently applied photo-user days of work under our ideal scenario informed by InVEST Recreation data, results in an estimated 594% increase in efficiency, as shown in Table 2.

This would result in an value efficiency of improvement of $1204, with the assumption that FoDP continues its work level of 8 hrs/week while fully implementing our platform.

Ecosystem Services Data

In order to calculate the efficiency improvements, a similar analysis was conducted on ecosystem services data as provided by Earth Economics. While both high and low estimates on ecosystem service values were provided, the high range of the estimates were used here, as recommended in the analysis notes.

Due to the low number of land use categories and the simplicity of the calculations, this analysis was conducted in Microsoft Excel.

The total ecosystem services were calculated across all land cover types that had associated ecosystem services data. This resulting value was then divided by the respective acreage of these land cover types to provide a park-wide mean ecosystem services value of $3312.65/acre.

The mean absolute difference (MAD), a measure of dispersion around the mean less susceptible to bias from extreme values than the standard deviation, was then used to calculate the level of average difference. With this measure, the absolute difference in ecosystem service value/acre is determined and then averaged across all land cover types.

The resulting mean annual difference was found to be equal to $4570.31/acre, or roughly 1.38 times the park-wide average value of $3312.65/acre.

This mean annual difference represents room for improvements towards an adaptive management approach that considers ecosystem service differences, compared to an ecosystem service blind approach. In short, variability equals room for improvement. Thus the mean annual difference is an apt measure to use in determining improvements in efficiency using the Earth Economics dataset.

Combining the two net weekly gains from the InVEST Recreation model data and the ecosystem services data from Earth Economics, use of our platform web app would result in an estimated net weekly gain of ***$1480*** through improved efficiency.

	InVEST Recreation data	Earth Economics ecosystem services data
Percent efficiency improvement	594%	138%
Current weekly hours of work	8	8
Pre-improvement value of work	$25	$25
Post-improvement value of work	$173.50 ($25 + 594% improvement)	$59.50 ($25 + 138% improvement)
Net gain per hour	$150.50	$34.50
Net weekly gain if work maintained at current rate	$1204	$276

Total efficiency gain	$1480/week

Table 2. Efficiency calculations relating to each dataset.

3.1.3 Type 3: *Quantifiable unpredictable events or benefits that result from unpredictable events*

Our project sponsor pointed to some major park events for which our platform web app could have proven useful. The most notable and impactful was the West Point Treatment Disaster which occurred early in 2017, which is focused on in this Business Case. Additional events were sought out for analysis, but due to a lack of data could not be adequately quantified.

West Point Analysis

The most notable past event was the West Point sewage treatment disaster which began on February 9th and dumped 244 million gallons of raw sewage into the Puget Sound, directly adjacent to the park. While according to a study by the King County Wastewater Treatment division, the impacts were limited to water on adjacent beach for a few days (Stark, Jaeger, Eash-Loucks, Lafer, & Nairn, 2018), it is likely that the impact extended to human appreciation of the park (see Type 4 benefits).

Ecosystem services of the beach could have been affected, but the lack of data in the aforementioned study limits relating to ecosystem services prohibits those calculations calculation. Additionally, the ecosystem services as calculated by the Earth Economics data for the “Beach” land cover category is equal to $0.

In our calculations, it is assumed that visitation to beach areas was impacted severely by the presence of nearby leaking raw sewage from the West Point Treatment Facility. This reduction is assumed to be 90%.

Based on the calculations using the “Summarize Within” and “Summary Statistics tools” in ArcGIS Pro, the InVEST Recreation data was drawn upon to examine the number of photo-user-days found within areas classified as “Beach” in the Earth Economics dataset in comparison with the park-wide totals. Roughly 7.4% of all photo-user-days were found within the Beach layer, providing a multiplier that can be applied to the Type 4 benefits. Multiplying this number by the total duration of disruption provides an overall total of disruption in benefits for this event.

Percent photo-user-days in “Beach” zone	7.4%
Weekly value of Type 4 benefits of Discovery Park	$523

Time from start of leakage event to final compliance with National Pollutant Discharge Elimination System standards	February 9 to May 10th (12.86 weeks)
Estimated value disruption of Type 4 benefits	($523 x 7.4% PUDs in "Beach zone" x 90% disruption x 12.86 weeks) = $447.94
Rate of such disasters based on lifetime of West Point plant	(52 years between 2018 and 1966) 1 event per 2704 weeks
Estimated amelioration of impact based on platform web app	33%
Total weekly improvement in impact	$0.05

Table 3. Calculation of Type 3 Benefits for Discovery Park.

While such events are unpredictable, to generate a weekly number, this must be compared across some type of time scale. To generate this, a rate of 'major leakage events per week' was generated, based on the number of such events that have occurred since the West Point Treatment Plant's dedication in 1966 ("The West Point Treatment Plant – Friends of Discovery Park," 2018).

This number was then multiplied by a subjective estimated 'amelioration of impact percentage', which represents the ability of our platform web app to offset the impacts. While our platform web app cannot prevent such events, it can highlight the impact of such events by providing a geographic context in terms of the values of park visitation data, and showing the close proximity and connections between Discovery Park and the treatment plant.

This resulted in a quite minimal weekly improvement of $0.05 per week, likely reflecting the low calculated rate of such events at the West Point Treatment Plant (1 event per 52 years).

3.1.4 Type 4: *Intangible benefits*

Intangible Value of Park as Green Space

As the largest park in Seattle, Discovery Park holds a great deal of value in a domain that is hard to put into numbers: its intangible value to the community as a green space and as an area for exploration and appreciation of the natural world in a highly urbanized area.

In order to provide a number for this metric, the following calculation was made, making some significant assumptions.

The total land value of all land parcels in Discovery Park equals $541,917,400. Assuming that the aforementioned benefits since the park's dedication in 1973 surpasses this land value and that this why the park has been maintained by the city instead of developed, this means that whatever percentage that this platform web app enhances the intangible value of the park should be calculable, at least with a lower bound.

Assuming that our deliverables (web apps and geodatabase), enhance the intangible value of the park by 0.1%, this would roughly equal $541,917.40 in value. To provide a rate to that value, this figure was divided by the number of weeks since the park's founding, resulting in a value figure of $523/week. The assumption that our platform web app will improve this intangible value by 0.1% is a large one. However, it seems in our subjective opinion that the work of Friends of Discovery Park, along with the efficiency improvements in our platform web app, should be able to reach at least 0.1% improvement seems justified.

3.2 Costs

3.2.1 Capital Costs

Implementation and Database Construction & Management

Implementation here is understood as work spent on producing deliverables, namely our geodatabase and our web app tools that allow for interaction with our datasets and analysis results.

Database costs were largely limited to work searching for useful data, quality checking and organizing that data within our own file geodatabases. Additional work focused on integrating analytical tools within our file geodatabase in a Toolbox. At the end of the quarter, significant work went into merging our group's file geodatabase into one final deliverable.

Week	Adam's Hours (Database)	Warren's Hours (Database)	Adam's Hours (Implementation)	Warren's Hours (Implementation)	Total Hours
Week 1	0	0	6	6	12
Week 2	3	1	14	14	32
Week 3	2	4	12	12	30
Week 4	6	5	13	13	37

Week 5	3	6	15	15	39
Week 6	2	3	14	14	33
Week 7	2	6	8	8	24
Week 8	4	2	6	6	18
Week 9	0	1	4	4	9
		Total hours:			234
		Hourly rate			**$28.68***
		Total:			*$6,711.12*

Table 4. Hours worked on database construction and implementation, each week.
**Hourly rate based on average salary of a GIS Analyst ("GIS Analyst Salaries in the United States | Indeed.com," 2018)*

Hardware and Software

Hardware and software costs were rather limited, given the free non-profit account that Friends of Discovery Park has been granted through ESRI. Additionally, our work involved time spent on our personal computers, meaning the only real costs involving hardware was the depreciation of our computers' value.

Hours worked per week using computer	26 hours*
Computer value	$1200**
Estimated mean life of computer in hours	5840 hours (4 hrs/day for 4 years)
Weekly cost of computer usage	$5.34

Quarter-wide cost of computer usage	$48.06

Table 5. Calculation of hardware costs.
**Based on average weekly computer using across Weeks 1-9 for Adam and Warren*
****Estimation based on approximate cost of Lenovo laptops owned and used by Adam Peterson and Warren Rich*

3.2.2 Operating Costs

Personnel

Some work will be required to run the platform after its implementation, namely interaction with it to provide desired information, training users in its use, and by interacting with our geodatabase deliverable by performing analysis in ArcGIS Pro with included tools. This is currently estimated at 1 hour per week.

Maintenance fees

Friends of Discovery Park's non-profit ESRI account provides free access to ArcGIS Pro and many online resources, resulting in no maintenance costs for most elements. Costs may be incurred as a result of placing web apps on the FoDP website, if FoDP chooses to make public display an option. That will require future testing and determination.

Maintenance will be required to keep the datasets in the geodatabase up-to-date as new datasets emerge. This work is estimated at an average of 0.5 hr/week, with a resulting weekly cost of **$12.50**, although in reality, time expenditure in this area will likely be variable throughout the year as new data becomes available.

More importantly, it is assumed that Friends of Discovery Park will manage its use of service credits and remain within its annual allocation of 200 service credits. Layers within our current platform web app deliverable will take up more than this amount, so some functionality will need to be reduced to stay within current credit limits. These are spelled out below, and FoDP has the choice to maintain which resources it feels are most useful and/or whether to purchase additional service credits for its account.

Layer	File size on AGOL account (MB)	Service credits/month	Service credits/week
49 sq ft grid	351	84.24	19.44
500 sq ft hexbins	35	8.4	1.94
DP_2018_georef	4,791	5.75	1.33
Forested_2018	11	2.64	0.61

LandCover_2018_multipart	10	2.4	0.55
EE_PUDs_by_land_cover	4	0.96	0.22
DiscoveryParkLC_EE	4	0.96	0.22
DP_1990_aerial_Clip	796	0.96	0.22
1968 Aerial Imagery	609	0.73	0.17
DPVeg_PUDs_by_vegetation_class	0.344	0.08	0.02

Table 6. Service credit usage by largest layers on FoDP ArcGIS Online account, calculated using ArcGIS Online service credit rates.

Utilities, Supplies & Other

Based on the relatively cheap price of electricity in Washington state of $0.096/kWh ("Electricity data browser - Average retail price of electricity," n.d.), along with the minimal use of electricity to run the computers conducting this analysis, the price of per week was judged to be <$0.01 and thus negligible in our final analysis.

3.3 Benefit-Cost Analysis

Cost Savings Table

	Wk. 1	**Wk. 2**	**Wk. 3**	**Wk. 4**	**Wk. 5**	**Wk. 6**	**Wk. 7**	**Wk. 8**	**Wk. 9**	**Wk. 10**	**Wk. 11**	**Wk. 12**
Benefits												
Type 1*	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$163**	**$163**	**$163**	**$163**
Type 2*	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$1480**	**$1480**	**$1480**	**$1480**
Type 3*	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0.05**	**$0.05**	**$0.05**	**$0.05**
Type 4*	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$523**	**$523**	**$523**	**$523**

Type 5	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Total Benefits	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$2166**	**$2166**	**$2166**	**$2166**
Costs												
Capital Costs												
Database	**$0**	**$115**	**$172**	**$315**	**$258**	**$143**	**$229**	**$172**	**$29**	**$0**	**$0**	**$0**
Hardware and Software	**$5**	**$5**	**$5**	**$5**	**$5**	**$5**	**$5**	**$5**	**$5**	**$0**	**$0**	**$0**
Implementation	**$344**	**$803**	**$688**	**$746**	**$860**	**$803**	**$459**	**$344**	**$229**	**$0**	**$0**	**$0**
Operating Costs*												
Personnel	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$25**	**$25**	**$25**	**$25**
Overhead	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**N/A**	**N/A**	**N/A**	**N/A**
Maintenance fees	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$13**	**$13**	**$13**	**$13**
Utilities, Supplied & Other	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**~$0**	**~$0**	**~$0**	**~$0**
Total Costs	**$349**	**$923**	**$865**	**$1066**	**$1123**	**$951**	**$693**	**$521**	**$301**	**$38**	**$38**	**$38**
Benefit-Cost Balance	**$349**	**$923**	**$865**	**$1066**	**$1123**	**$951**	**$693**	**$521**	**$1865**	**$2128**	**$2128**	**$2128**
Cumulative Balance	**$349**	**$1272**	**$2137**	**$3203**	**$4326**	**$5277**	**$5970**	**$6491**	**$4626**	**$2498**	**$370**	**$1758**

Table 7. Cost savings table by week across quarter.

**Benefits and Operating Costs are not expected to accrue until Week 9, when platform is expected to be deployed*

Payback Chart

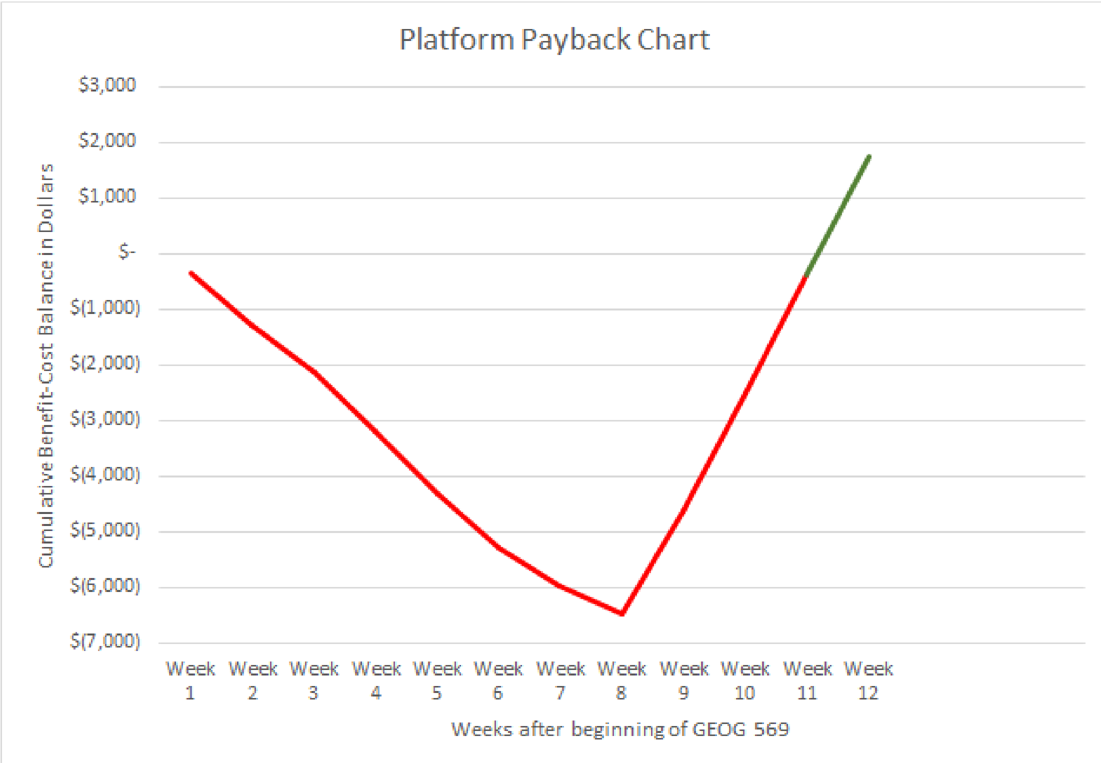


Figure 1. Payback chart for group platform web app over twelve weeks.

Baseline Comparison Chart

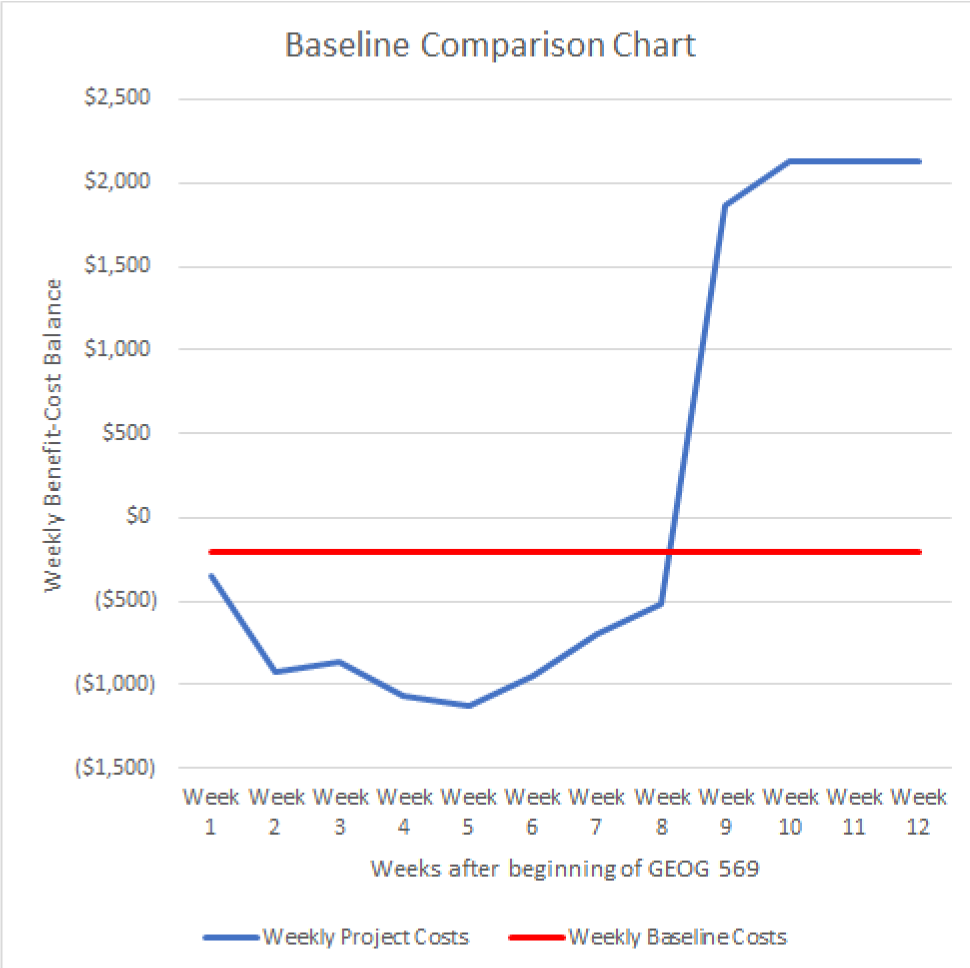


Figure 2. Baseline comparison chart between weekly benefit-cost balance of baseline versus platform web app approaches.

3.4 Discussion

The costs/benefits analysis conducted for the Discovery Park Web GIS Based Vegetation Monitoring and Reporting project resulted in the identification of many benefits associated with the costs of implementing this proposed platform web app. Perhaps the most readily visible takeaway from our benefit-cost analysis was the delay in payoff associated with our project's platform web app. While the project was still in development, there was a distinct investment of time and computer resources before it was fully functional and benefits began to be realized.

However, based on our estimations, the payoff occurs quite rapidly after our estimated time of platform web app deployment in week 9. By week 12, the cumulative balance is positive and begins to grow by a steady $2128 per week.

We feel work shows that our project is worthwhile and given the rapid payback and continued accumulation of benefits after the project completion, it offers substantial benefits to our sponsor.

Platform B

Business Case elements relating to the construction of Platform B and associated work items such as, but not necessarily limited to, a Microsoft Access Database, Discovery Park vegetation feature class, a moisture index raster surface layer and weed index raster surface layer are provided along with a supporting ecosystem services focal document titled: 'Proposed Business Case for Discovery Park MGIS Capstone-2018', including a supplemental appendix. These Discovery Park MGIS Capstone 2018 deliverables are included contemporaneously with this report and other Project Team deliverables as per partial fulfillment of the MGIS Program in preparation for submittal to the University of Washington Geography MGIS Program Director and to the Project Sponsors (Friends of Discovery Park) no later than 5:00 PM PDT on August 17, 2018.

4. Data Development

4.1. Performing Data Acquisition

4.1.1 Data Source Steps

Our initial steps in acquiring data occurred during an initial phone call with our project sponsor. We were provided with links to existing data compiled by FoDP, as well as a follow-up list of additional data resources (see Appendix A). We contacted many of these organizations for data, and this provided our group with additional datasets used in our analysis. We also looked for additional resources from other organizations not listed in Appendix A.

Data was acquired from a wide array of formats and varying degrees of organization. This will be discussed in more detail in the fourth main section of this report. Overall, we've gained key information and data from many different sources.

4.1.2 Data Acquisition Constraints

Our group faced two main constraints throughout the quarter, in regard to data acquisition. First, the time constraints of our class schedule and time requirements for class activities prevented exhaustive acquisition and screening of data. Second, organizations who we contacted for data were not always able to spend the time necessary to fully meet our requests.

4.2 A Logical Schema for Discovery Park Geodatabase

Phase one of our logical schema development involved integrating datasets from organizational resources into an organized geodatabase (See Appendix 1). At a minimum the database will be normalized to the third normal form (Codd 1990). In other words (Hernandez 2013):

"Each table in the database will contain a field that uniquely identifies each of its records and subsequent fields that have high fidelity to the entities each respective table represents'.

As data were acquired, they were screened for quality before being integrated into the file geodatabase.

Feature Dataset	**Feature Class/Raster Name**	**Spatial Object Type**	**Description**	**Source**
Boundary	DPBoundary	Polygon	Discovery Park Boundary	Seattle Parks Department
Boundary	DPArea_Land	Polygon	Dissolved all land portions of Discovery Park polygons	Seattle Parks and Recreation
Boundary	DPMngmtZones	Polygon	Management zones for Discovery Park	Seattle Parks and Recreation
DataGrid	DataGrid_500sqft_hexbins	Polygon	A series of hexbins, each 500 sq ft in size, containing key datasets for display in platform web app	Geoprocessed
DataGrid	DataGrids_49sqft	Polygon	A series of square grids, each 49 sq ft in size, containing key datasets for display in platform web app	Geoprocessed
Hydrology	Streams	Line	Discovery Park Streams	USGS NHD
Land_Cover	EarthEconomics_LandCover	Polygon	Land Cover as determined by 2011 Earth Economics work	Earth Economics
Land_Cover	Land_Cover_2018_1	Polygon	Land Cover types derived from 2018 aerial imagery, provided by FoDP	Geoprocessed
Trails	DPTrails	Line	Discovery Park Trails	Seattle Trails Alliance
Vegetation	DPF2001_169SP_Areas	Polygon	37.2-foot radius vegetation sample plot boundaries	Geoprocessed

Vegetation	DPF2001_169SPs	Point	2001 vegetation sample plot centers	ICF
Vegetation	DPVegZones	Polygon	Modified ICF potential vegetation layer / re-digitized informed by ICF 2001 sample plot data	ICF - Edited / Geoprocessed
Visitation	Recreation	Polygon	Square polygons representing photo-user-days, derived from geotagged Flickr photos	Natural Capital Project, Recreation Model (InVEST v. 3.4.4)
Wildlife	DP2016_BirdData	Point	Discovery Park Bird survey observation point centers	Seattle Audubon Society; derived from Table with Add XY Point tool
Wildlife	DP2016_BirdObsArea	Polygon	Discovery Park Bird survey data 50-meter radius bird observation area boundaries	Geoprocessed
N/A	DP1946_Imagery_Georef	Raster	Imagery of Discovery Park circa 1946	FoDP
N/A	DP1968_Imagery_Georef	Raster	Imagery of Discovery Park circa 1968	FoDP; WAGDA
N/A	DP1990_Imagery_Georef	Raster	Imagery of Discovery Park circa 1990	FoDP; WAGDA
N/A	DP2018_Imagery_Georef	Raster	Imagery of Discovery Park circa 2018	FoDP
N/A	DP_MIWI_SurfaceData	Raster	IDW Interpolation of M Access calculated 2001 Sample Plot Moisture Indexes	Geoprocessed
N/A	DP_WISurface2001_Clip	Raster	IDW Interpolation of M Access calculated 2001 Sample Plot Weed Indexes	Geoprocessed
N/A	DPMainVeg2001	Table	ICF Excel Spreadsheet	Imported to GDB and assigned ObjectID
N/A	LandCover2018	Raster	Derived from 2018 aerial imagery layer	Geoprocessed
N/A	T10tet414782	Raster	2002 Discovery Park Aerial Imagery UTM Zone 10 North	Washington State Geospatial Data Archive
N/A	T10tet429767	Raster	2002 Discovery Park Aerial Imagery	Washington State Geospatial Data Archive

			UTM Zone 10 North	
N/A	T10tet4297 82	Raster	2002 Discovery Park Aerial Imagery UTM Zone 10 North	Washington State Geospatial Data Archive
N/A	T10tet4447 67	Raster	2002 Discovery Park Aerial Imagery UTM Zone 10 North	Washington State Geospatial Data Archive
N/A	T10tet4447 82	Raster	2002 Discovery Park Aerial Imagery UTM Zone 10 North	Washington State Geospatial Data Archive

Table 8. Logical Schema.

Projection: NAD_1983_HARN_StatePlane_Washington_North_FIPS_4601_Feet (EPSG: 2926)

The logical schema above provides a description of our database structures (e.g., feature datasets, feature classes, raster datasets, etc.). Data have been organized thematically and all raster data is deemed appropriate to help meet our project objectives. Conforming existing data and creating new data to meet our project objectives have entailed a wide variety of data naming convention modifications, schema design changes, additional metadata documentation, etc.

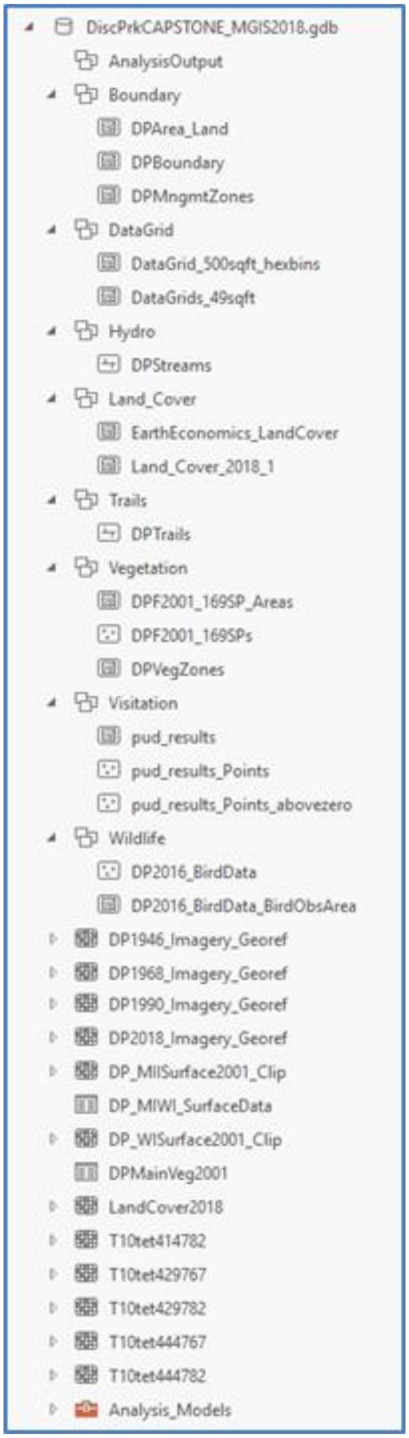


Figure 3. File Geodatabase Thematic and Organization Structure or Schema.

4.3 Data Quality Descriptions

Aerial Imagery

The aerial imagery varies in accuracy based on the year of the imagery, as well as the technology used to create the imagery (i.e. satellite, airplane, drone, etc.). Currently, three different aerial images are being used, including one from 1968, one from 1990, and one from 2018. Each of these contain a different resolution, in the form of pixel size. A common coordinate system regulates the measurement of the pixel size. The 1968 imagery pixels measure 3.16 x 3.16 meters, the 1990 pixels 1.48 x 1.49 meters, and the 2018 0.39 x 0.39 meters. Variance in resolution is expected in aerial imagery, particularly with imagery taken from different time periods. The intended use for this data is to visually display the changes which have occurred in the park, in relation to vegetation, buildings, impervious surfaces, etc., as a result of the efforts which have been undertaken within the park as part of the land management plans. All imagery was provided by the Friends of Discovery Park .

Derived Land Cover

Land cover data is derived from the classification of the aerial imagery outlined above. At this point in time, no existing datasets which provide a high enough resolution for Discovery Park have been identified, therefore it has become a primary task of this project to create the data, as the change in land cover within the Park over time is an important aspect of this project. Due to the nature of creating datasets from scratch through the image classification process, filtering the output datasets for data quality was very important for these particular datasets.

Upon consulting the Data-Quality Filter Matrix found in Paradis and Beard's article, it was determined that locational accuracy, thematic accuracy, locational consistency, and thematic consistency are the most important aspects of data quality to consider regarding the derived land use datasets. Temporal characteristics are explicit in the year the imagery comes from, as does lineage, and resolution is explicit for each image and not up for interpretation. Resolution will matter further down the line regarding analyses of the land cover, but for the creation of the data it is not as important. The image classification process is an iterative one, with each result being subjected to the pertinent aspects of the Data-Quality Filter Matrix. Many derived datasets were discarded through this process, and ultimately it was decided that less land cover classes should be used to create the highest quality dataset which best suits the needs for this type of dataset. Ultimately, four classes were decided on: barren/developed, mixed forest, shrubland, and grassland. Simplifying the process to four classes resulted in much higher quality data products, and this process was determined to provide the most accurate and consistent results.

Visitation Data

The Visitation data are as accurate as the devices that geotagged and timestamped the Flickr photos that feed into the Recreation model. Thus, in terms of the quality attributes of accuracy and resolution, there is some ambiguity about how accurate the input data are in terms of location (as we will be using the annual averages, issues of temporal accuracy are less crucial). The intended use of this data is to provide a measure of off-path traffic, a metric we currently lack data for and that provides a unique look at off-path human impact, and concentration of visitors within the park, taken with the understanding that this metric may be biased based on an areas photogenicity.

The aggregation into a grid size larger than the usual error of many mobile devices (50 ft.) should help compensate for this uncertainty to some degree, and future work will focus on aggregating this data into larger zones (e.g. path buffer zones). In future processing and analysis of this dataset, anything requiring fine-scale precision will avoid use of this dataset.

AOI Layer

This layer is created by the user for the purposes of conducting analysis. Data quality depends on the accuracy of the user in tracing out the area they intend and the quality of the basemap.

5. Workflow Implementation

As part of the initial scope of work, a set of goals/objectives were outlined for this project based on the desires of the project sponsor in conjunction with ideas from group members, with consideration of what our group deemed to be feasible given our skill sets, technology capability/availability, and the time constraints of the project. The specific work activities do not necessarily each meet a single objective, as certain goals/objectives are broad and need to be addressed by multiple activities, while other work activities may address more than one goal/objective.

Following the establishment of goals and objectives for the project and the acquisition of the necessary data to address these goals and objectives, a workflow implementation plan was established to efficiently and accurately process and analyze the necessary data for inclusion within the proposed platform. The workflow focuses on four specific issues focused on during the project, including the establishment of an up to date vegetation baseline for the park, georeferencing of the three aerial images, current land cover status and associated carbon sequestration values in the park, and park visitation data in relation to the vegetation and land cover within the park, as well as addressing the workflow for the proper integration of this data into the platform in a manner which aids in the interactivity and holistic nature of the platform. The following section will outline, in detail, the steps taken to process and analyze the data for each of the three specific issues which serve to address the project goals and objectives.

5.1 Calculating Discovery Park Weed and Moisture Index Metrics

5.1.1 Vegetation Mapping Workflow

Initially, the only vegetation information received from the Project Sponsors was a vegetation dominant plant community polygon shapefile and a pdf file containing a vegetation report conducted by Jones&Stokes in 2002, with several key appendices missing. Follow up questions to the Project Sponsors led to contacting Jon Walker at ICF who had inherited all the raw data from the Jones&Stokes study. Mr. Walker sent over the missing appendices and the raw data in a variety of formats including but not limited to Excel spreadsheets, shapefiles, pdf documents, and several others. Two pieces of data that eventually became the most useful included an Excel spreadsheet with all the plant species recorded in a 2001 Jones&Stokes field sampling effort, along with their associated attribute data, and a point shapefile containing all but 23 of the 2001 sample plots.

Eventually, with a considerable amount of data cleaning and after assigning the table a unique identifier ObjectID key, the use of the relates operation was enabled by keying in on the sample plot number fields in the two datasets. From there it became largely a workflow (Figure 4) and a data management issue. There are 146 sample plots in the sample plot point feature class with a one-to-many relationship to over 2000 plant species data records in the 'cleaned' version of the relates table.

Existing and new data, were entered into a minimalist workhorse Microsoft Access database created to manage several unique data management tasks. Figure 5 displays the database's entity relationships. Using the 2001 Jones&Stokes raw data, focus was centered mainly on two fields in the original Excel spreadsheet, species and percent cover. In addition, each species was assigned two new attributes not in the original table, 'moisture index' (Frenkel and Streatfield 1997)(Corps of Engineers 1987) and 'weed index' (Marshall 2010).[1] A species table was created in the database and populated with Discovery Park plant species which were in turn assigned 'moisture ' and 'weed' indexes

[1] Sample Plot moisture indexes represent the aggregate tolerances of plants in the sample to low oxygen in their root zones due to water saturation. A range between 1 to 5 indicates high tolerance to low tolerance respectively. Sample Plot weed indexes give native species a numeric rank of 1, nonnative noninvasive species a numeric rank of 3, and an invasive plant species a numeric rank of 5. Aggregated sample plot weed index scores close to one indicate low weed influence and weed index scores close to 5 indicate high weed influence.

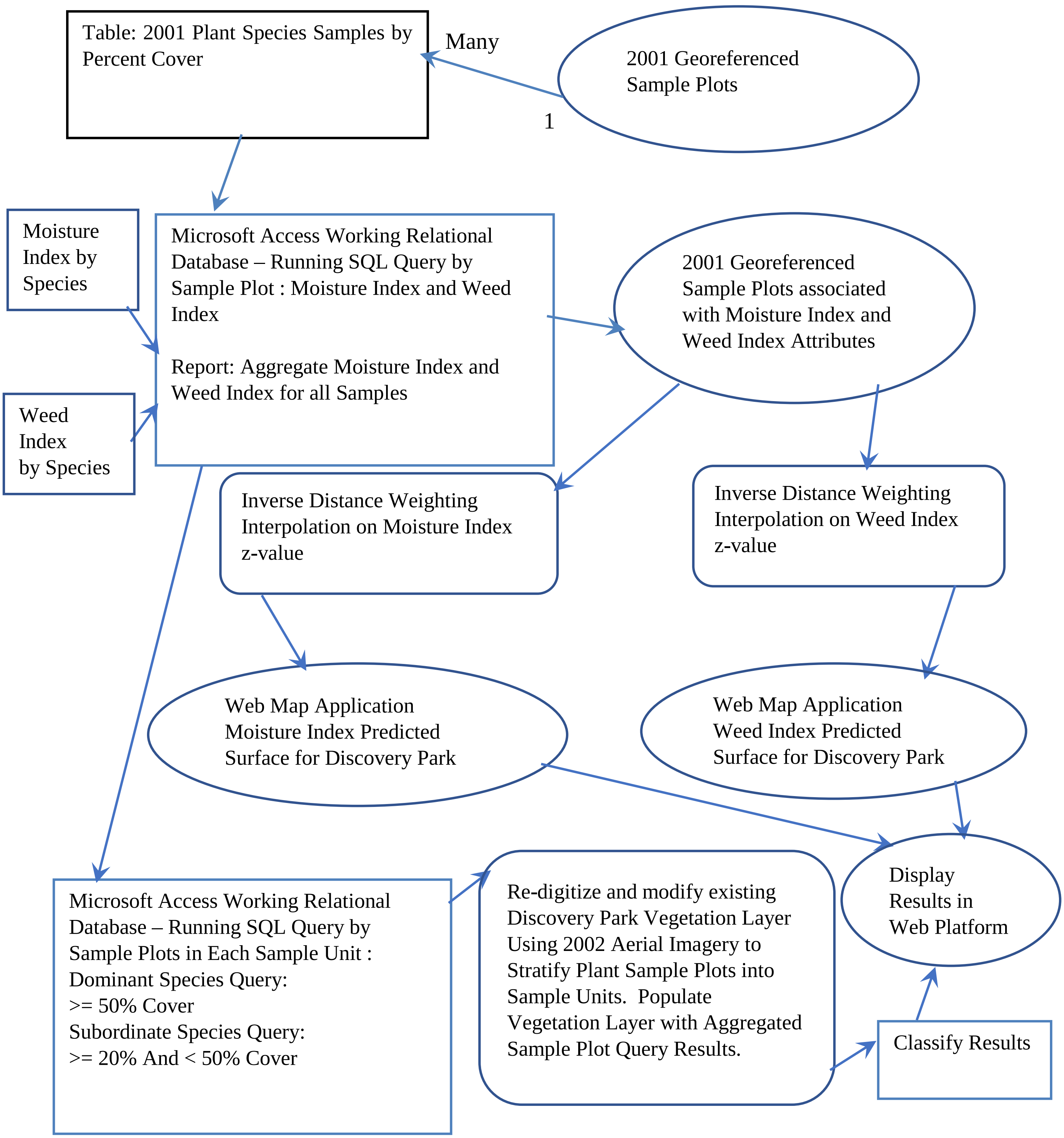


Figure 4. Workflow Diagram for Deriving and Mapping Predictive Weed and Plant Moisture Index Surfaces and Plant Community Feature Class for Discovery Park.

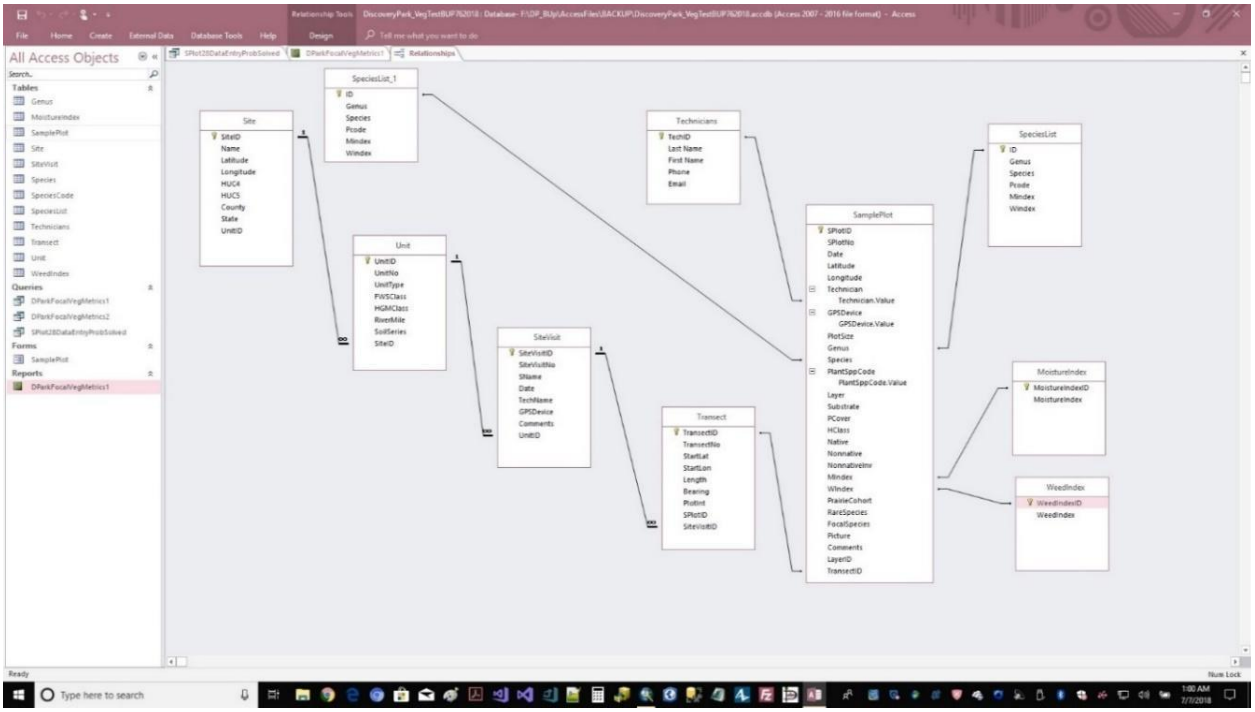
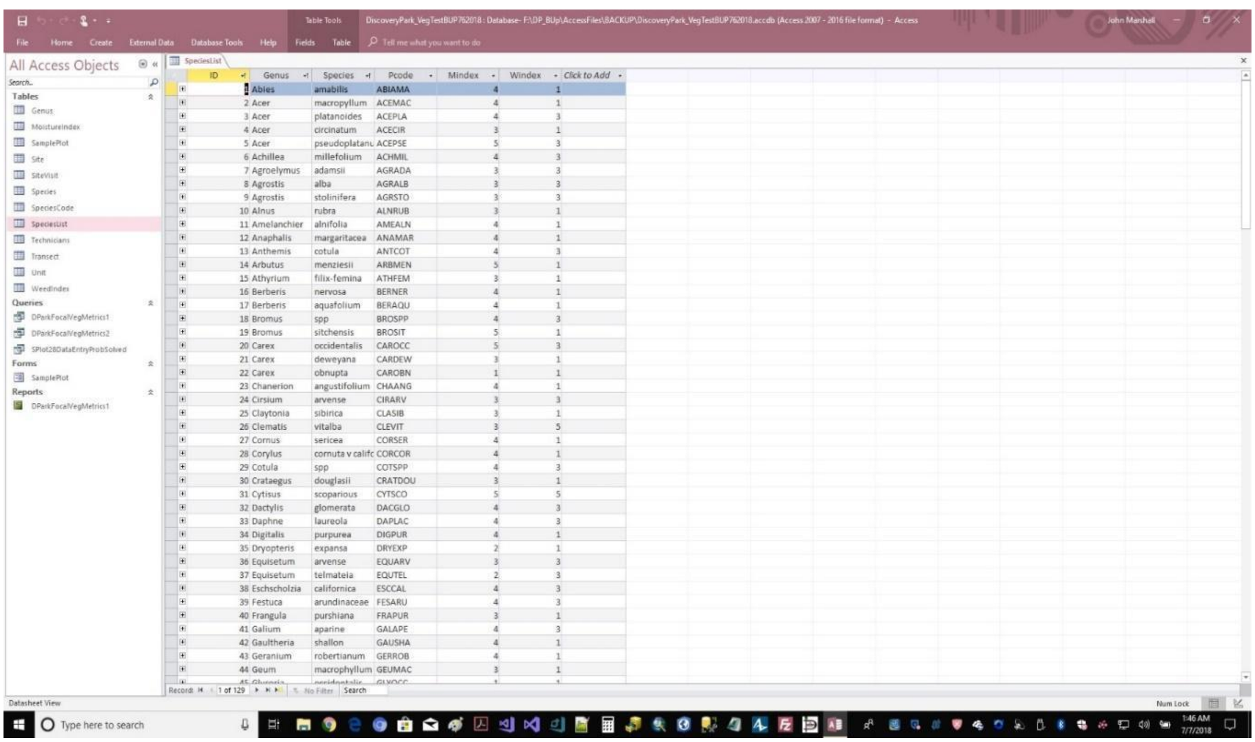


Figure 5. Discovery Park Plant Database Entity Relationships.



ID	Genus	Species	Pcode	Mindex	Windex	Click to Add
1	Abies	amabilis	ABIAMA	4	1	
2	Acer	macropyllum	ACEMAC	4	1	
3	Acer	platanoides	ACEPLA	4	3	
4	Acer	circinatum	ACECIR	3	1	
5	Acer	pseudoplatanu	ACEPSE	5	3	
6	Achillea	millefolium	ACHMIL	4	3	
7	Agroelymus	adamsii	AGRADA	3	3	
8	Agrostis	alba	AGRALB	3	3	
9	Agrostis	stolinifera	AGRSTO	3	3	
10	Alnus	rubra	ALNRUB	3	1	
11	Amelanchier	alnifolia	AMEALN	4	1	
12	Anaphalis	margaritacea	ANAMAR	4	1	
13	Anthemis	cotula	ANTCOT	4	3	
14	Arbutus	menziesii	ARBMEN	5	1	
15	Athyrium	filix-femina	ATHFEM	3	1	
16	Berberis	nervosa	BERNER	4	1	
17	Berberis	aquafolium	BERAQU	4	1	
18	Bromus	spp	BROSPP	4	3	
19	Bromus	sitchensis	BROSIT	5	1	
20	Carex	occidentalis	CAROCC	5	3	
21	Carex	deweyana	CARDEW	3	1	
22	Carex	obnupta	CAROBN	1	1	
23	Chanerion	angustifolium	CHAANG	4	1	
24	Cirsium	arvense	CIRARV	3	3	
25	Claytonia	sibirica	CLASIB	3	1	
26	Clematis	vitalba	CLEVIT	3	5	
27	Cornus	sericea	CORSER	4	1	
28	Corylus	cornuta v califc	CORCOR	4	1	
29	Cotula	spp	COTSPP	4	3	
30	Crataegus	douglasii	CRATDOU	3	1	
31	Cytisus	scoparious	CYTSCO	5	5	
32	Dactylis	glomerata	DACGLO	4	3	
33	Daphne	laureola	DAPLAC	4	3	
34	Digitalis	purpurea	DIGPUR	4	1	
35	Dryopteris	expansa	DRYEXP	2	1	
36	Equisetum	arvense	EQUARV	3	3	
37	Equisetum	telmateia	EQUTEL	2	3	
38	Eschscholzia	californica	ESCCAL	4	3	
39	Festuca	arundinaceae	FESARU	4	3	
40	Frangula	purshiana	FRAPUR	3	1	
41	Galium	aparine	GALAPE	4	3	
42	Gaultheria	shallon	GAUSHA	4	1	
43	Geranium	robertianum	GERROB	4	1	
44	Geum	macrophyllum	GEUMAC	3	1	

Figure 6. Example of Discovery Park Plant Species Moisture Index and Weed Index Metrics.

as attributes (Figure 6).[2] This table was then made into an operational 'pick-list' in the sample plot (Figure 7) table, a function that was automatically transferred to the data entry form (Figure 8) at the instance it was created

After entering 169 sample plots and over 2000 related recorded plant species into the database, query creation and report generation began. The first query needed was to generate a moisture index and weed index grouped by each of the 169 sample plots. This is the SQL script that ran the query (see Figure 9 to view query outcome):

> *SELECT SamplePlot.SPlotNo, Sum(SamplePlot.PCover) AS PCoverTotal,*
> *Sum([PCover]*[MIndex]) AS MoistureIndexTotal, Sum([PCover]*[WIndex]) AS WeedIndTotal,*
> *([MoistureIndexTotal]/[PCoverTotal]) AS SPMoistureIndex, ([WeedIndTotal]/[PCoverTotal])*
> *AS SPWeedIndex, SamplePlot.Latitude, SamplePlot.Longitude*
> *FROM SamplePlot*
> *GROUP BY SamplePlot.SPlotNo, SamplePlot.Latitude, SamplePlot.Longitude;*

Given the project extrapolation aspirations of Friends of Discovery Park, an assumption was made that Seattle Parks Department and others may want to compare these metrics in an aggregate form between different parks in the City or in different time frames for the same park. To help get started in that direction, a Microsoft Access running tally report of the average of the vegetation sample plot moisture and weed indexes for all the sample plots entered into the database (see Figure 10) was created. These metrics represent the 2001 average vegetation moisture index and weed index for Discovery Park, subject to comparisons with outcomes informed by more recent data for Discovery Park and potentially with other parks where like metrics have been calculated.

A subsequent query of the georeferenced sample plots now containing moisture and weed index attribute data was exported to Excel and added to ArcMap where the AddXY data tool was used to create an event which was in turn exported to a new vegetation sample plots point feature class. The Inverse distance weighting (IDW) tool in Spatial Analyst was then used to interpolate the weed and vegetation moisture indexes respectively to provide subsequent predictive surfaces for Discovery Park (Figures 21 and 22). IDW works on the assumption that things that are closer to one another are more alike than those that are farther apart (Tobler 1970). A mathematical algorithm is used to 'predict' values between points of known values (in this case moisture and weed index informed sample plots), also called z-values (Bolstad 2008). It assumes each known point has a local influence on surrounding values that decreases with distance, creates a raster grid containing the known and predicted values, and assigns those georeferenced values to each of the corresponding raster grid cells or pixels. The raster grid becomes a "surface

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[2] The following were moisture and weed index verification sources:
US Army Corps of Engineers - Wetland Indicator Plant List
http://wetland-plants.usace.army.mil/nwpl_static/species/species.html?DET=001100#
US Department of Agriculture - Natural Resource Conservation Service Plant Database
https://plants.sc.egov.usda.gov/java/

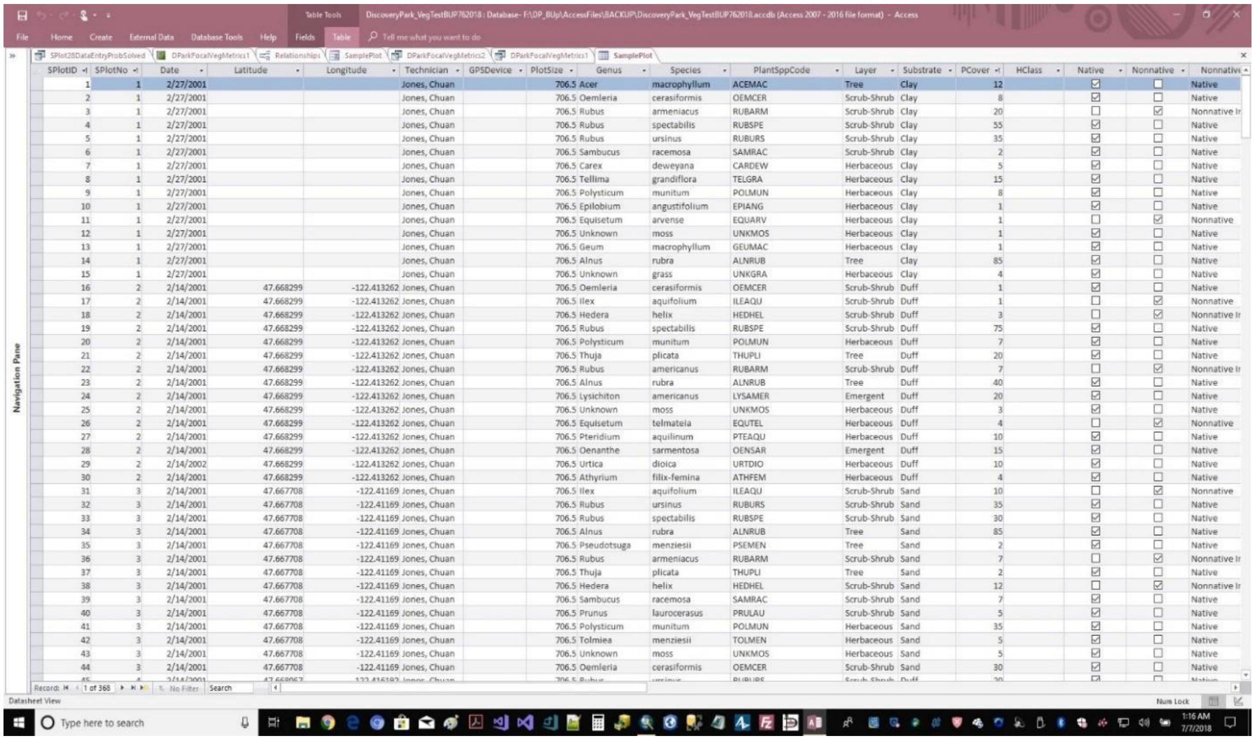


Figure 7. Discovery Park Plant Database Sample Plot Table.

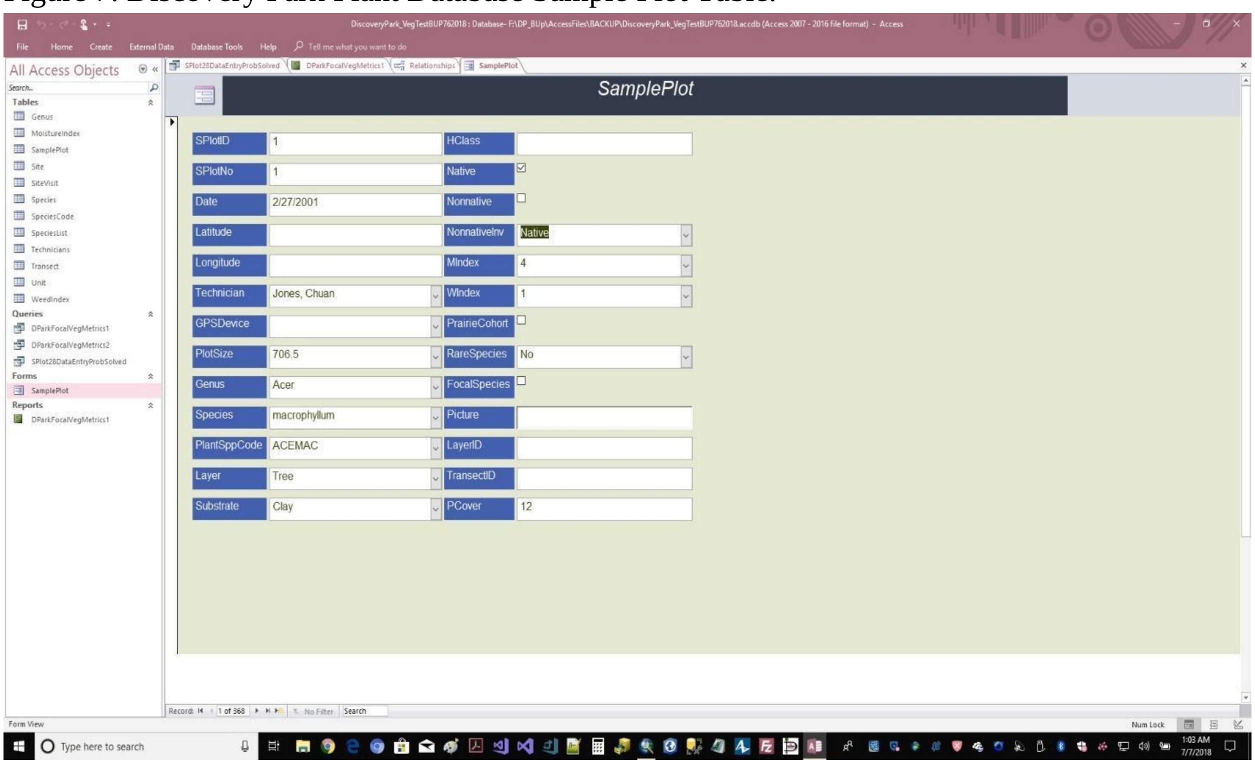
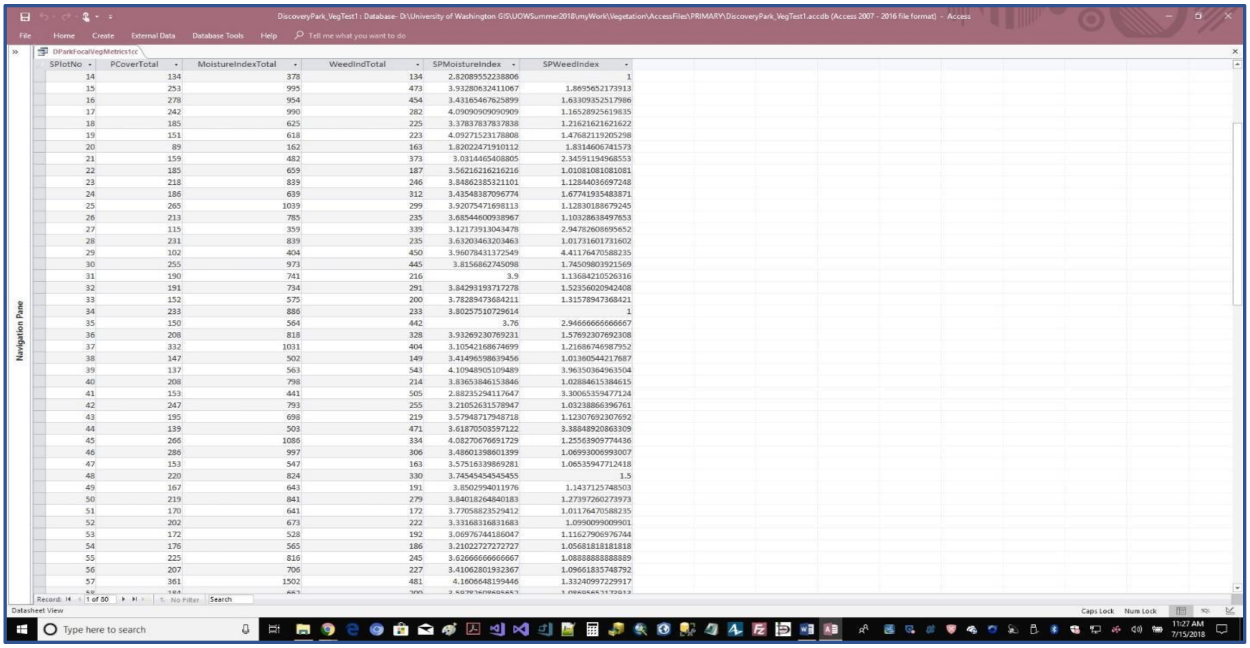


Figure 8. Discovery Park Plant Database Data Entry Form.



SPlotNo	PCoverTotal	MoistureIndexTotal	WeedIndTotal	SPMoistureIndex	SPWeedIndex
14	134	378	134	2.82089552238806	1
15	253	995	473	3.93280632411067	1.8695652173913
16	278	954	454	3.43165467625899	1.63309352517986
17	242	990	282	4.09090909090909	1.16528925619835
18	185	625	225	3.37837837837838	1.21621621621622
19	151	618	223	4.09271523178808	1.47682119205298
20	89	162	163	1.82022471910112	1.8314606741573
21	159	482	373	3.0314465408805	2.34591194968553
22	185	659	187	3.56216216216216	1.01081081081081
23	218	839	246	3.84862385321101	1.12844036697248
24	186	639	312	3.43548387096774	1.67741935483871
25	265	1039	299	3.92075471698113	1.12830188679245
26	213	785	235	3.68544600938967	1.10328638497653
27	115	359	339	3.12173913043478	2.94782608695652
28	231	839	235	3.63203463203463	1.01731601731602
29	102	404	450	3.96078431372549	4.41176470588235
30	255	973	445	3.8156862745098	1.74509803921569
31	190	741	216	3.9	1.13684210526316
32	191	734	291	3.84293193717278	1.52356020942408
33	152	575	200	3.78289473684211	1.31578947368421
34	233	886	233	3.80257510729614	1
35	150	564	442	3.76	2.94666666666667
36	208	818	328	3.93269230769231	1.57692307692308
37	332	1031	404	3.10542168674699	1.21686746987952
38	147	502	149	3.41496598639456	1.01360544217687
39	137	563	543	4.10948905109489	3.96350364963504
40	208	798	214	3.83653846153846	1.02884615384615
41	153	441	505	2.88235294117647	3.30065359477124
42	247	793	255	3.21052631578947	1.03238866396761
43	195	698	219	3.57948717948718	1.12307692307692
44	139	503	471	3.61870503597122	3.38848920863309
45	266	1086	334	4.08270676691729	1.25563909774436
46	286	997	306	3.48601398601399	1.06993006993007
47	153	547	163	3.57516339869281	1.06535947712418
48	220	824	330	3.74545454545455	1.5
49	167	643	191	3.8502994011976	1.1437125748503
50	219	841	279	3.84018264840183	1.27397260273973
51	170	641	172	3.77058823529412	1.01176470588235
52	202	673	222	3.33168316831683	1.0990099009901
53	172	528	192	3.06976744186047	1.11627906976744
54	176	565	186	3.21022727272727	1.05681818181818
55	225	816	245	3.62666666666667	1.08888888888889
56	207	706	227	3.41062801932367	1.09661835748792
57	361	1502	481	4.1606648199446	1.33240997229917

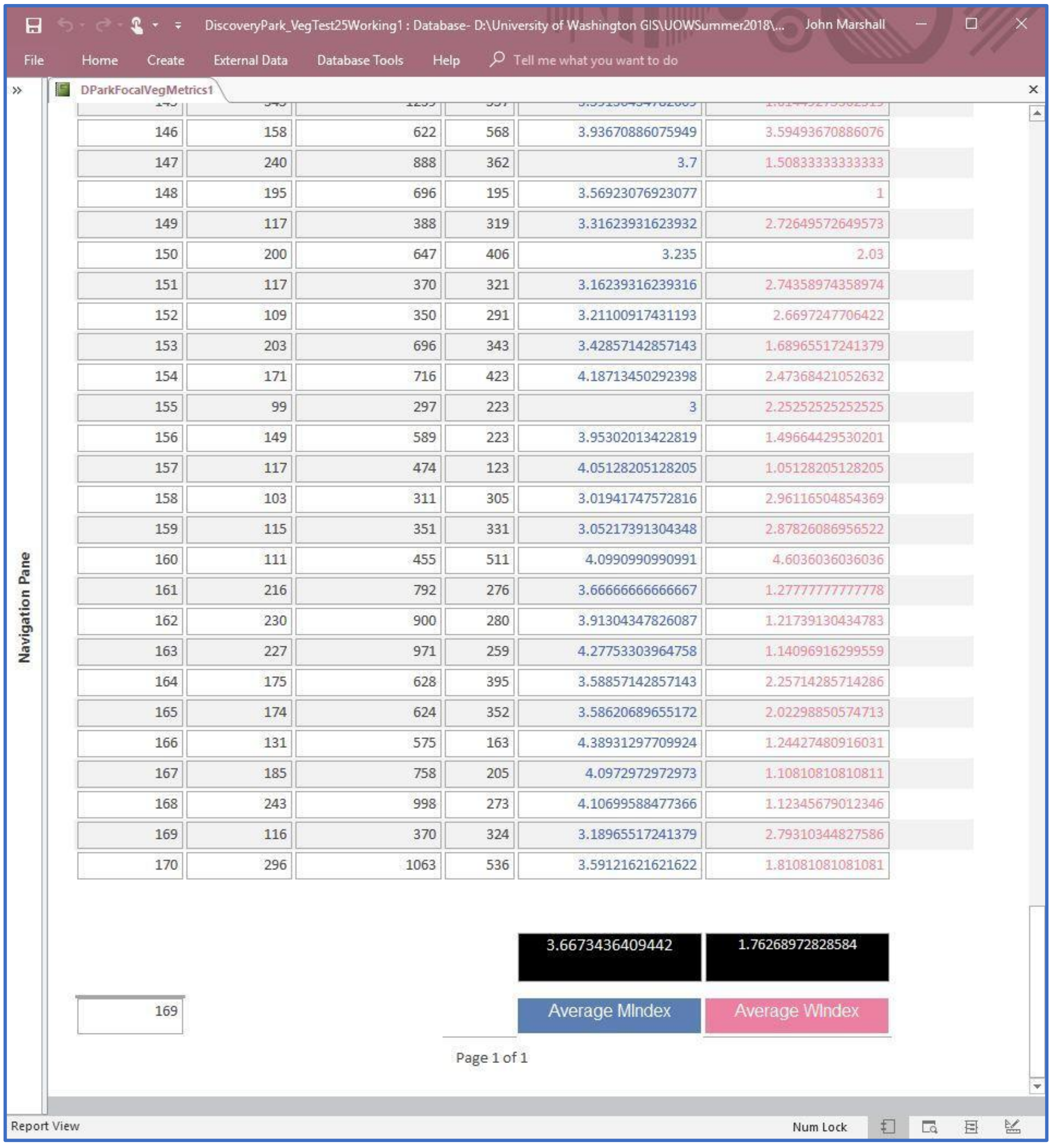
Figure 9. Discovery Park Moisture Index and Weed Index Query Grouped by Sample Plot.

representation” of the predicted spatial distribution of those values (final map representations of these surfaces are on pages 43 and 44 in the Results section of this report).

5.1.2 Mapping Discovery Park Plant Community Associations

The first step in mapping Discovery Park plant community associations (Daubenmire 1968) (Braun-Blanquet et al 1932) was to begin editing the existing vegetation layer provided by FoDP and ICF. The source of the layer was assumed to be the field team that produced the 2002 Jones&Stokes report and the 2001 field sample plot data. The only problem with the layer known at the onset was that it was missing large sections near the center and around the edges of the Park and the boundaries between plant community polygons had numerous gaps and other topological errors.

Since the sample plot data intended to inform the vegetation layer plant community polygons were collected in 2001, aerial imagery from 2002 for the same area were acquired from the Washington State Geospatial Data Archive in order to use aerial photo interpretation as a means to help stratify vegetation signatures on the imagery representing the area at the time the samples were collected. This ‘after-the-fact’ stratification process was used to guide the creation of new plant community sample unit polygons and the delineation of the topologically challenged borders of original polygons during the editing sessions. Once the vegetation layer editing was completed, the 2001 sample plots were added as an overlay. The following fields were added to the attribute table of the vegetation layer:



146	158	622	568	3.93670886075949	3.59493670886076
147	240	888	362	3.7	1.50833333333333
148	195	696	195	3.56923076923077	1
149	117	388	319	3.31623931623932	2.72649572649573
150	200	647	406	3.235	2.03
151	117	370	321	3.16239316239316	2.74358974358974
152	109	350	291	3.21100917431193	2.6697247706422
153	203	696	343	3.42857142857143	1.68965517241379
154	171	716	423	4.18713450292398	2.47368421052632
155	99	297	223	3	2.25252525252525
156	149	589	223	3.95302013422819	1.49664429530201
157	117	474	123	4.05128205128205	1.05128205128205
158	103	311	305	3.01941747572816	2.96116504854369
159	115	351	331	3.05217391304348	2.87826086956522
160	111	455	511	4.0990990990991	4.6036036036036
161	216	792	276	3.66666666666667	1.27777777777778
162	230	900	280	3.91304347826087	1.21739130434783
163	227	971	259	4.27753303964758	1.14096916299559
164	175	628	395	3.58857142857143	2.25714285714286
165	174	624	352	3.58620689655172	2.02298850574713
166	131	575	163	4.38931297709924	1.24427480916031
167	185	758	205	4.0972972972973	1.10810810810811
168	243	998	273	4.10699588477366	1.12345679012346
169	116	370	324	3.18965517241379	2.79310344827586
170	296	1063	536	3.59121621621622	1.81081081081081
169				3.6673436409442	1.76268972828584
				Average MIndex	Average WIndex

Figure 10. Microsoft Access Database Report Calculating Average 2001 Plant Sample Plot Moisture and Weed Indexes.

- SampleA
- SampleB
- SampleC
- SampleD
- SampleE
- SampleF
- SampleG
- SampUnitNo

Using the field calculator, each of the polygons were considered as sample units and were assigned a sample unit number (integer data type) in the field 'SampUnitNo'. Then with the sample plot overlay as a guide, for each polygon with one or more sample plots 'contained' by it borders, the corresponding sample plot numbers were assigned to records in the fields 'SampleA', 'SampleB', 'SampleC', etc.

```
SELECT SamplePlot.SPlotNo, SamplePlot.Genus, SamplePlot.Species, SamplePlot.PCover
FROM SamplePlot
WHERE (((SamplePlot.SPlotNo)=8) AND ((SamplePlot.PCover)>=50));
```

SUnit105_Sample8

SPlotNo	Genus	Species	PCover
8	Acer	macrophyllum	90
8	Hedera	helix	65
*			

Figure 11. Sample Unit 105 Dominant Species Query in Sample 8.

The attribute table for the vegetation layer was reproduced as a table in the Microsoft Access database using several steps:

1. The vegetation feature class in the file geodatabase was exported as a shapefile;
2. An empty Microsoft Excel worksheet was created;
3. From windows explorer the dbf file in the shapefile was dragged and dropped into the Excel worksheet;
4. The Excel worksheet was then imported as a table into the Microsoft Access database.

Once the vegetation layer attribute table was in the Microsoft Access database, dominance and subordinate queries were run on the sample plot data in each respective sample unit (see examples of SQL queries and their results in Figures 11 and 12) , the results of each query were stored in the imported Microsoft Access database table under the field titled: 'FULL_LATIN' in the format of dominant/ subordinate (see examples in Figure 13). If there were no sample plots in a given sample unit, a 'No Sample Data' term was typed in. In cases where there were two or more samples in a sample unit, if any of the sample plots returned dominants they were considered as dominants for the sample unit. Once a species was considered a dominant in a sample unit it was not also considered a subordinate, even if it was returned on subordinate queries for the same sample unit. The order of listing a dominant or subordinate was biased by the highest percent cover and stand structural type. In other words trees were listed before shrubs, and shrubs before herbaceous species.

SELECT SamplePlot.SPlotNo, SamplePlot.Genus, SamplePlot.Species, SamplePlot.PCover FROM SamplePlot WHERE (((SamplePlot.SPlotNo)=8) AND ((SamplePlot.PCover)>=20 And (SamplePlot.PCover)<50));

SUnit105_Sample8

SPlotNo	Genus	Species	PCover
8	Holodiscus	discolor	20
8	Polysticum	munitum	35

Figure 12. Sample Unit 105 Subordinate Species Query in Sample 8.

DP_VegSampleUnits_SP2001

SampUnitNo	FULL_LATIN
1	No dominants/Cytisus scoparius-Agrostis alba-Poa spp
2	Cytisus scoparius-Agrostis alba/No subordinates
3	No Sample Data
4	Alnus ruba-Rubus spectabilis/No subordinates
5	Acer macrophyllum/Oemleria cerasiformis-Rubus ursinus-Robinia pseudocacia-Agrostis alba
6	No dominants/Pseudotsuga menziesii-Acer macrophyllum-Alnus rubra
7	No Sample Data
8	No Sample Data
9	No Sample Data

Figure 13. Populating Sample Units with Dominant and Subordinate Plant Species Associations.

The next step was to add two more fields to the attribute table of the vegetation feature class:

- DominantSpecies
- SubordinateSpecies

Then each record (sample unit) in the vegetation feature class was populated in the appropriate field with the corresponding results from the Microsoft Access queries discussed above (Figure 14). Now it was possible to classify and spatially represent the diversity of dominant and subordinate plant associations at Discovery Park in the areas represented by sample plot data.

During the course of working on topological errors and cross-referencing the sample unit data to the sample plot data, it became very clear that the original vegetation layer undergoing modification had not used the 2001 sample plot data to inform its plant community designations. In fact the designations given for the same geographic areas were those you would expect to characterize old growth coniferous

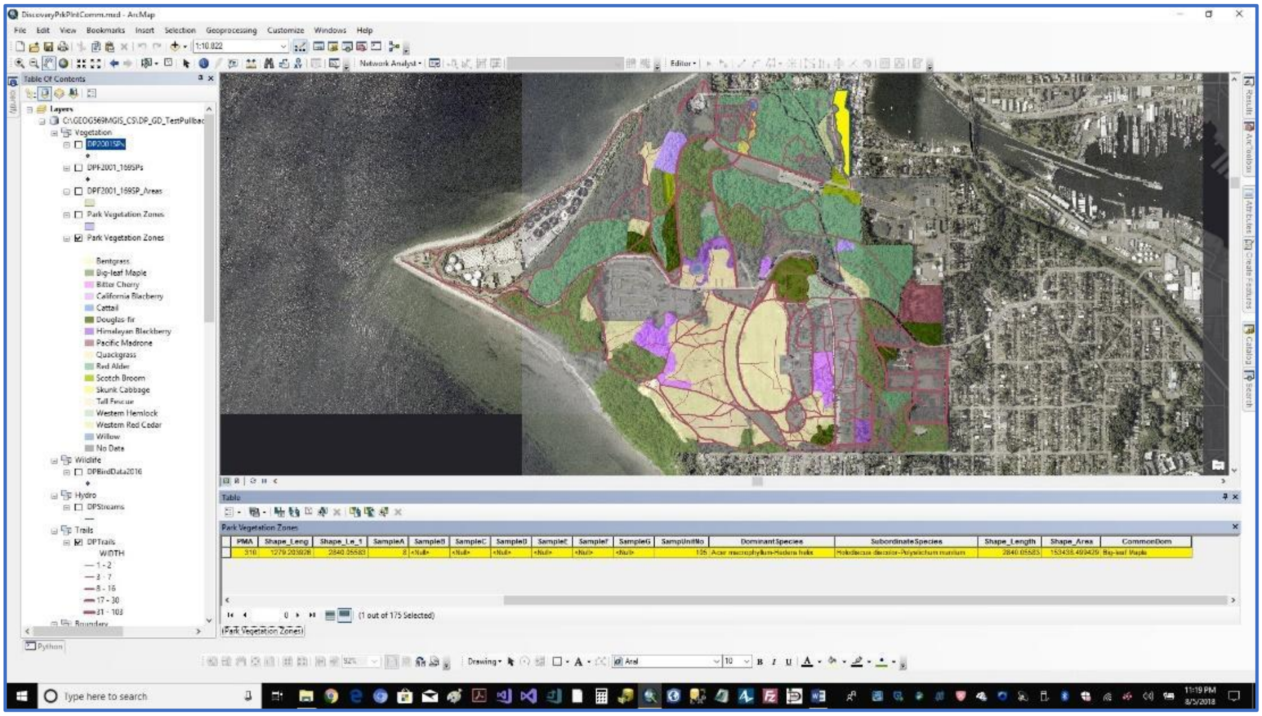


Figure 14. Vegetation Layer Feature Class Attribute Table Records Populated with Query Results.

forests. The jury is still out as to how this discrepancy came to be but one working theory is that the layer came from Green Seattle Partnership who have a mission to reforest much of the public land in and around the Seattle area. It is possible this layer was originally intended to depict vegetation potential and never meant to be a representative of existing vegetation.

When using this data to create maps and web map applications, it became apparent while the dominant and subordinate classifications offered rich and detailed representations of the vegetation, they also made for busy and difficult to interpret map legends. So a final field called ‘CommonDom’ was added to the vegetation layer attribute table and it was populated by the single leading dominant plant in each record’s list of dominants by its common name instead of its scientific name (A final map representation of the plant community classification (Figure 23) can be found on page 45 in the Results section of this report).

5.1.3 Platform B

The final task of this vegetation monitoring and mapping work task is to encapsulate the data and its data derived products in a platform that allows our project sponsors to interact with and better understand the context of the data used as well as their related outcomes in the Results section of this report. A web page based platform ‘Platform B’ (Figure 15) is used to accomplish this. This ‘working’ platform is comprised of the following:

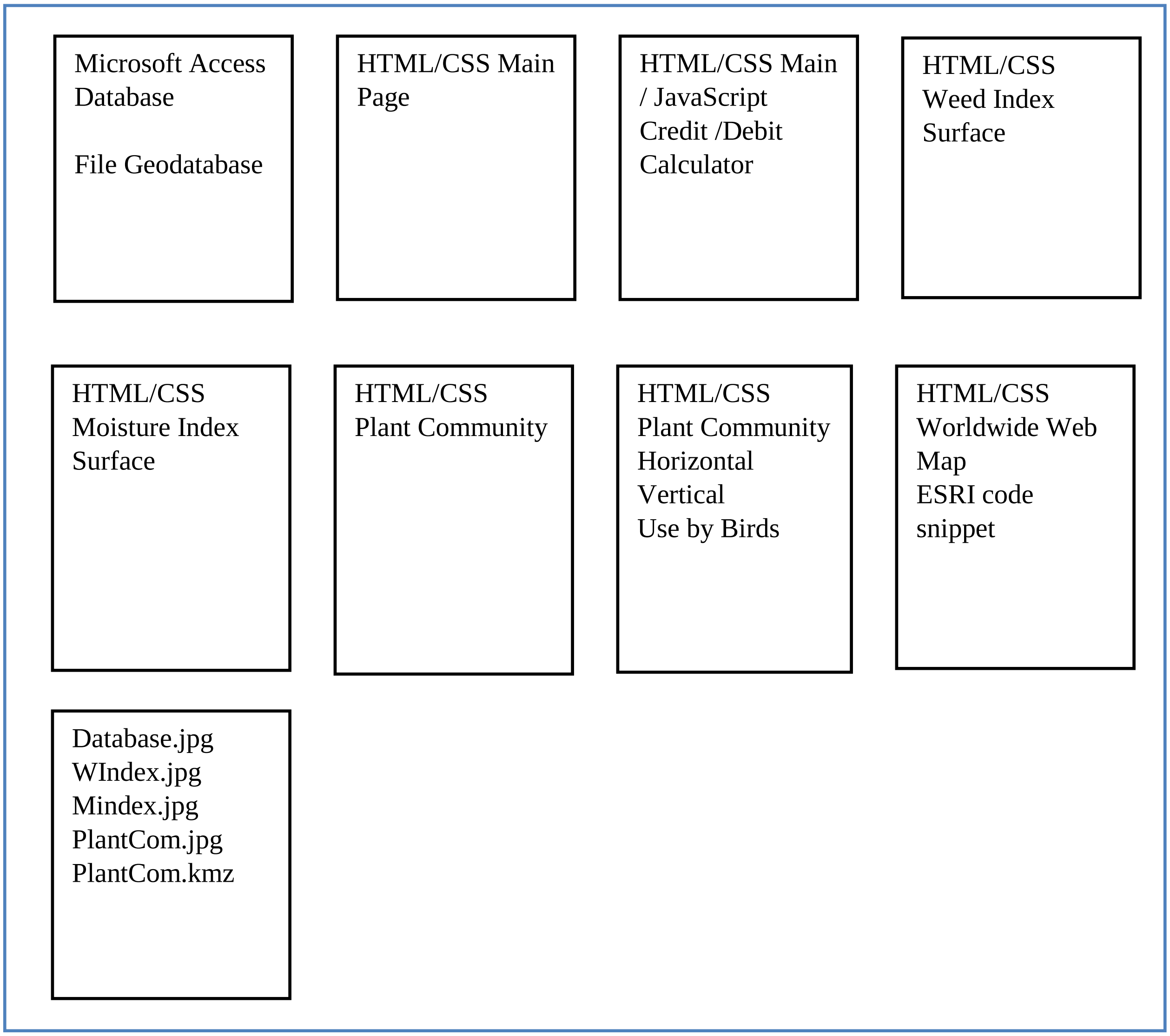


Figure 15. Working Non-hosted Multi-HTML / CSS / Java Script Web Page Platform B.[3]

- Microsoft Access Discovery Park vegetation database with tables, forms, reports, and attribute queries managing 169 sample plots related to over 2000 species records and over 170 dominant and subordinate vegetation sample unit polygons.
- Supporting File geodatabase for:
    - 2001 vegetation sample point feature class with moisture index and weed index fields populated
    - A 2001 moisture index raster surface for Discovery Park
    - A 2001 weed index raster surface for Discovery Park

[3] Platform B is intended solely for the convenience of our sponsors to have a centralized option for internally viewing and analyzing our collective project content in relation to their intended contexts. It is not intended as a web platform that would be directly hosted in its current stage of development. While our content is at a stage where it can be openly shared and discussed among stakeholders, we recommend this Platform B be limited to FoDP core member use.

    - A 2001 plant community feature class for Discovery Park
    - A 2016 bird observation feature class for Discovery Park
- Multi-html / javascript web pages currently non-hosted locally providing browsers interlinked access to, a credit / debit calculator for ecosystem services, instances of the above gdb content plus kmz / Google Earth instances of the plant community data, AGOL web map applications of the weed and moisture index surfaces, an ESRI code base web map service viewable at multiple scales at efficient rendering speeds for the entire planet, links to download or print selected Discovery Park ecosystem services related maps, and text and tables helping users to understand the context of the content they are viewing.

5.2 Historical Landscape Change

How have reforestation efforts, as part of the park Master Plan, changed the landscape of the park over time?
<u>Workflow Activity: Acquisition and georeferencing of various temporal aerial imagery, followed by land use classification of each image</u>

To visually display the ways land management efforts have affected the landscape of the park, aerial imagery has been acquired and georeferenced for three specific years representing various stages of land management efforts within the park. These include aerial imagery from 1968, 1990, and 2018. Imagery from 1946 is also included in the database, however the quality of the imagery is somewhat poor and therefore is not included within the final platform. Alone, these georeferenced images provide a visual comparison analysis, however image classification necessary to provide a quantitative metric of change.

For the purposes of this project, each image will be classified into four land cover categories: Barren/Developed, Mixed Forest, Shrubland, and Grassland. The image classification process was conducted within ArcGIS Pro, using the set of Classification Tools provided within the ESRI based software. The classification process initially involved creating training samples, utilizing the Training Samples Manager, which involves drawing polygons around locations throughout the aerial imagery which represent the four land cover classes. The training samples were then used within the Classify tool, utilizing the Support Vector Machine Classifier. A segmented image was deemed necessary for the 2018 aerial imagery due to its high resolution, however this step was determined to not be necessary for the 1990 and 1968 imagery. The results of the image classification process were then further processed to group together 'stray' pixels which were inaccurately classified, as well as to smooth out the edges of the raster. This was accomplished using Focal Statistics tool (Image Analyst Extension) using a 7 x 7 pixel setting, followed by a Boundary Clean tool (Spatial Analyst), respectively. Following these steps, a visual inspection for each image classification was conducted to identify locations which appear to have been inaccurately classified, with each of these locations manually changed to the correct classification.

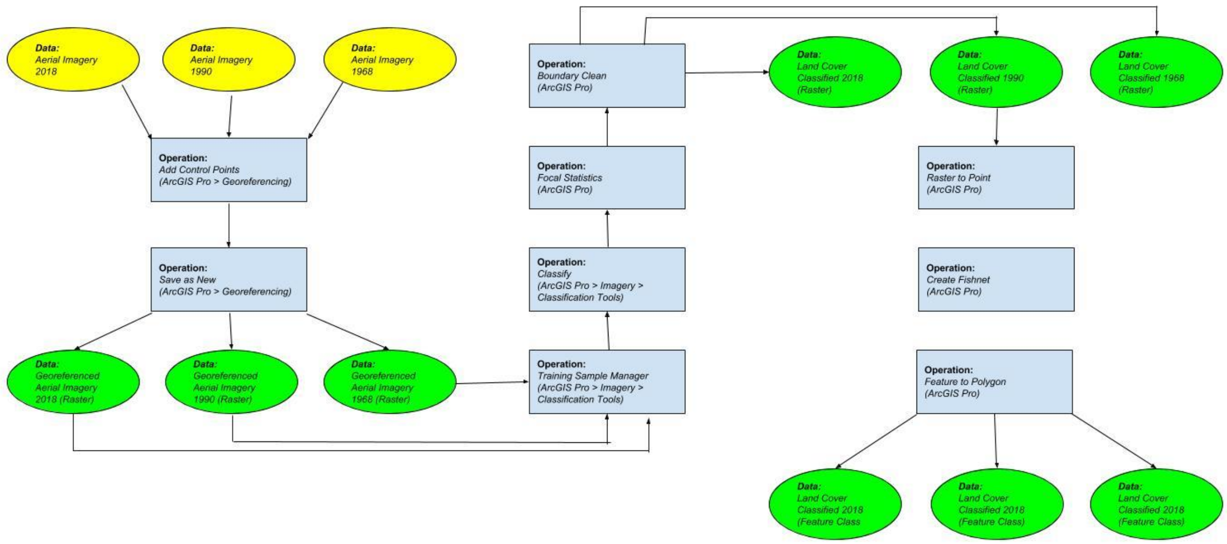


Figure 16. Diagrams displaying the workflow for georeferencing aerial imagery, classifying into four land cover classes, and converting to a feature class.

At the time of this report, only the 2018 image was able to be classified into the four land cover classes described above. Further work should prioritize the classification the 1990 and 1968 imagery to provide a more thorough analysis providing metric representing the change in land cover over time.

5.3 Ecosystem Service Evaluation

Project Objective: Calculate carbon sequestration values, to represent one aspect of landscape affordances, for the different land cover classes.

To convert raster cell to an individual polygon, the Raster to Point conversion tool is used. Each point retains the value associated with the raster cells. A polyline grid is then created using the Create Fishnet tool, using the extent of the raster for the boundaries and a predetermined cell size. Because the goal is to perform this process on the 1968, 1990, and 2018 land cover rasters, and to maintain the same cell size for each, the cell size of 49 sq ft from the 1968 imagery is being used. The fishnet is then converted into a polygon feature class, using the Polyline to Polygon tool, which also retains the values of the raster which indicates the land cover type for each polygon created within the new feature class. The Spatial Join tool was then used to aggregate the numerous points and associated values into the new feature class. The merge rule of "Majority" was used, which assigns each polygon the most commonly occurring land cover value, resulting in a land cover feature class.

With the feature class representation of the land cover data created, Earth Economics data regarding high and low carbon sequestration value for each land cover type is then added. Because the Earth Economics data is valued on a per acre basis, a field for Acres is added, and then calculated using Calculate Geometry. A new field for high carbon sequestration value and a field for low carbon sequestration was then created and populated by multiplying the Acres field by the Earth Economics carbon sequestration values for each land cover class.

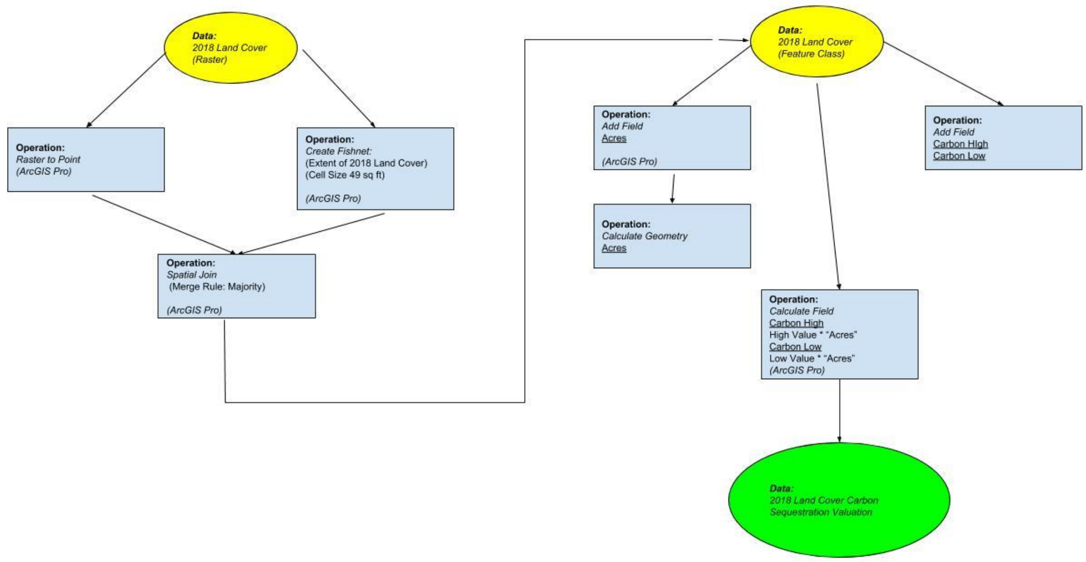


Figure 17. Diagram outlining the workflow for converting Land Cover 2018 to a feature class, followed by including carbon sequestration valuation attributes in new feature class.

5.4 Visitation Data

Project objective: Create a dataset representing the density and locations of visitor usage within the park.

A number of analyses were conducted with the aim of answering key questions related to human impact on the park, largely drawing on InVEST Recreation data, in combination with datasets relating to land cover and vegetation type.

5.4.1 Analysis of Photo-User-Days within Discovery Park

In order to provide a data-based view of off-trail visitation within the park, the Natural Capital Project's Recreation Model was used to provide information on where visitors have taken photos in the park. This analysis takes on the Recreation model's key assumption that photography acts as a proxy for levels of visitation, and this limitation should be kept in mind when interpreting the results of this analysis.

The following workflow was developed which draws on the Recreation tool in the InVEST 3.4.4 toolset and tools present in ArcGIS Pro. The mode's photo-user-day data, calculated from the number of geotagged Flickr photos, has been summarized within concentric buffers to provide relevant statistics about the levels of human activity as it relates to distance from established trails.

This provides both a look at the average photo-user-days within each distance zones from the park, as well as the total amount of photo-user-days within each zone. Since each distance zone varies widely in area, with the nearest 200-ft zone occupying a majority of the park's area, this provides both an absolute and area-adjusted measure of photo-user-days.

Figure 18. Operations flow diagram for buffer and Euclidean distance analysis. Input data shown here in yellow, output data products shown here in green.

Another analysis was run to calculate the relationship between distance from trails to the number of photo-user-days. The goal of this analysis was to determine if the *amount* of visitation was in some way linked to an area's *distance* from park trails. This helps to clarify the nature of human traffic within the park by determining whether visitation of off-trail areas is distinctly more, less, or equally intense compared to on- or near-trail areas. To assist with this analysis, an output CSV file is generated which can be opened in a spreadsheet program for further examination.

5.4.2 Analysis of Visitation by Land Cover and Vegetation Types

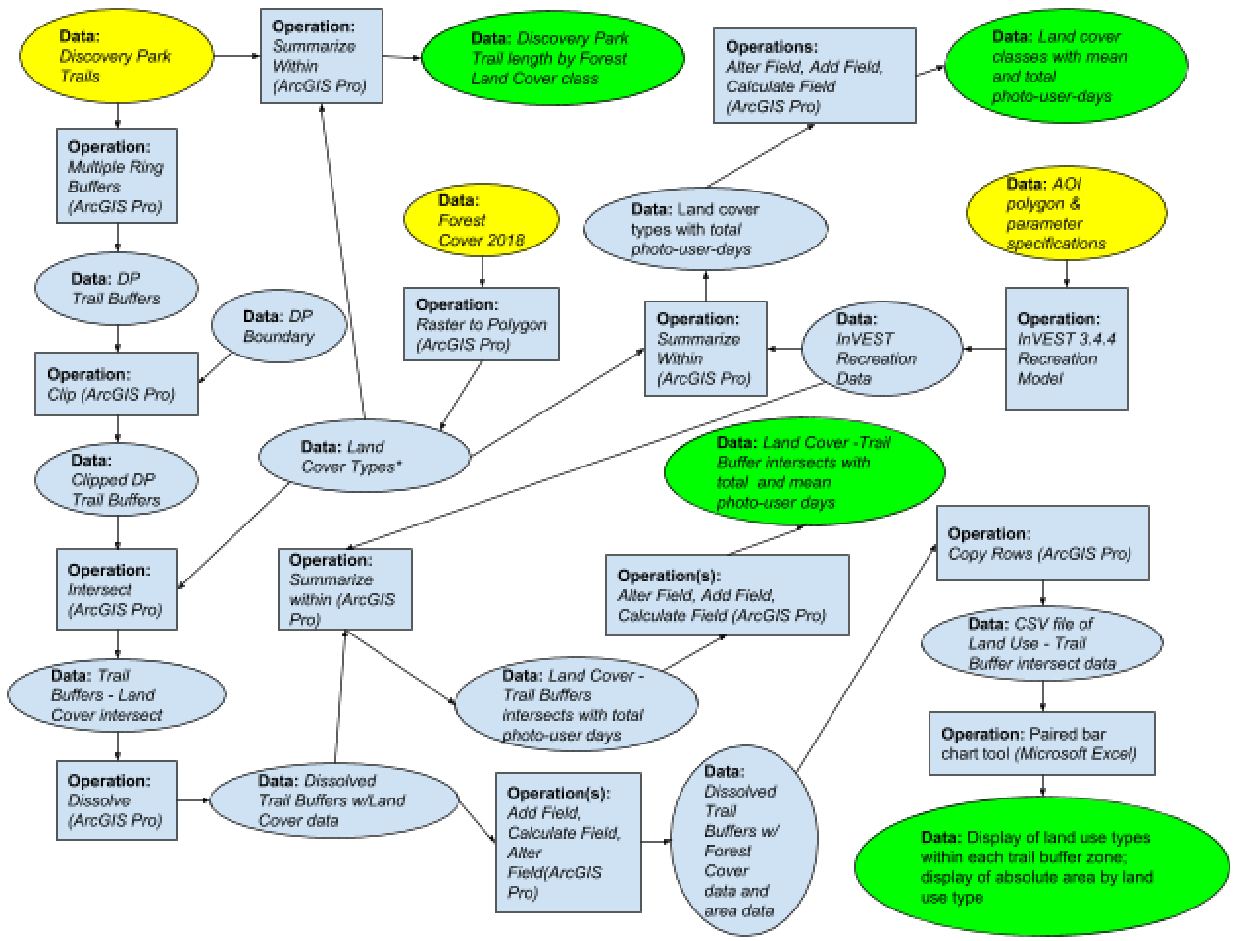


Figure 19. Operations flow diagram for land classification zone/ analyses. Input data shown in yellow, output data products shown in green.

The second part of this work activity centers around analyses of trails and InVEST photo-user-day data in the context of three types of land classification. This generalized analysis was repeated for three types of land classification: Earth Economics land cover zones, and the land cover and vegetation class zones mentioned in the previous sections of this chapter.

The first two analyses look at the mean and total photo-user-days found within each zone and the length of park trails within each. These two simple analyses will help provide two important sets of figures showing whether non-forested or forested areas appear to face the greatest amount of human impact.

The next analysis looks at the intersection of land classifications and how that relates to photo-user-day data. Are certain types of land more likely to be visited by those venturing off-trail than other areas? Are trails (and the directly adjacent areas) that go through certain land types more likely to see visitors than trails that traverse other types? This analysis will help provide answers to such questions.

The final analysis measures the proportion and absolute areas of land classification types within each trail buffer zone. Following the assumption that trails represent areas of human impact, this helps to tell us which zone is receiving most of that impact.

5.5 Collector-based CRUD Interface Workflow

A processing model was setup in ArcGIS Pro's ModelBuilder in order to create a tool that properly sums all ecosystem services specified for the "AOI" layer generated in ESRI's Collector app, allowing for interactive processing capabilities.

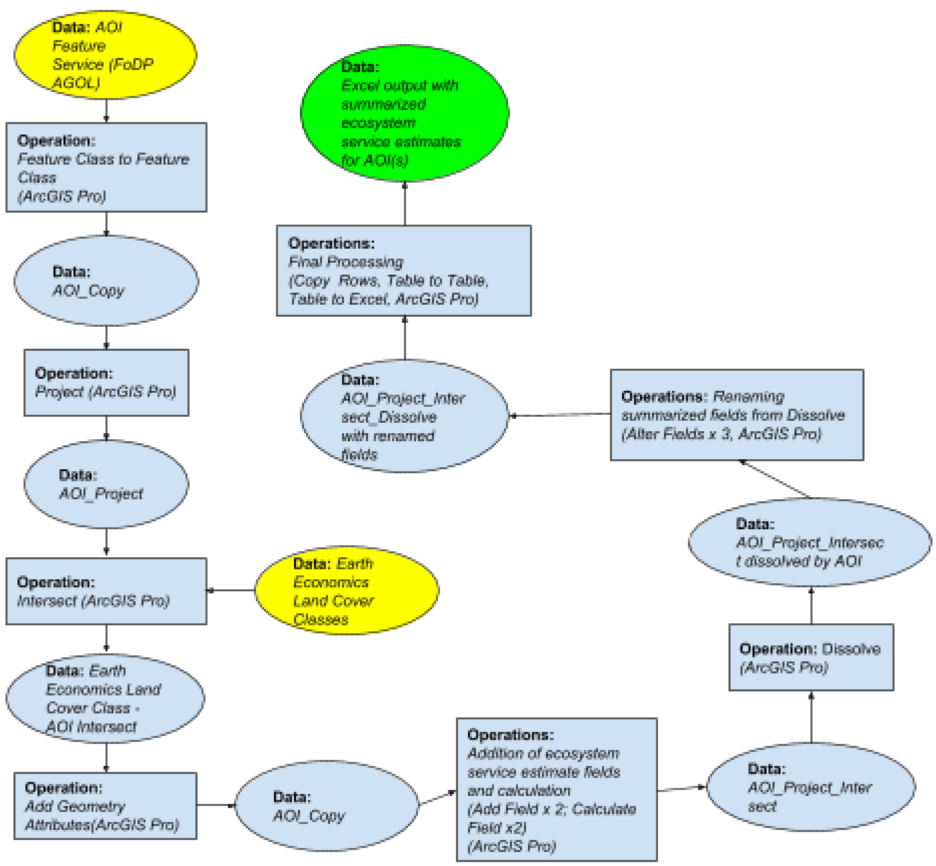


Figure 20. Workflow diagram for Ecosystem Services Evaluation tool.

This analysis is done by running an Intersect between AOIs and land cover classes from Earth Economics, then dissolving the data by each AOI to provide an AOI-wide summary of all ecosystem services. This is then output in an Excel document to the path desired by the user.

5.6 Platform Web App (Platform A)

Introduction of our data and analysis results into a final web app platform, referred to as "Platform A", for data display involved careful work turning our feature and raster datasets into feature services and tile layers, respectively.

All feature classes were uploaded to FoDP's ArcGIS Online account using the "Share as Web Layer" tool in ArcGIS Pro. Rasters, particularly aerial imagery, were uploaded also using the "Share as Web Layer" tool, with the setting of 'Cache locally'. This allowed us to avoid the significant costs associated with online tile service generation by conducting this work locally, and we were able to upload three highly detailed aerial imagery datasets to Platform A as a result.

Crucial datasets, such as Carbon sequestration estimates, photo-user-days, and moisture and weed indices were appended to a hexbin layer, drawing on two of ArcGIS's tools: 'Summarize Within' and 'Spatial Join'. The values of the included datasets were either summed or averaged within the hexbin feature class, based on the type of data represented. For instance, photo-user days and carbon sequestration represent values which needed to be summarized to account for the total values of each within the hexbin polygons, while moisture and weed index values were averaged to best represent the average value of each within the hexbin polygons. These values were then joined to a common layer, which was given null symbology, allowing for faster loading in the web map.

Each hexbin was 500 sq. ft. in size and provided sufficient resolution for proper display of our data in the 'Summary' widget, available for web apps on ArcGIS Online. An additional, higher resolution square, 50 square feet polygon feature class was also created the same. This dataset is not currently used within Platform A, but is available should the user require this data at a higher resolution.

5.7 Initial Goals versus Realized Workflow

In our group's initial workflow, we set out an optimistic vision to analyze both the effects of humans, but also cyclists and off-leash pets on a wide range of elements of the park environment.

Due to data and time restrictions, we focused our efforts largely on our two best measures of human impact - trails and visitation data - on the best measures we had on components of the park environment: land value ratings tied to park land cover data.

Unfortunately, the limitations of our data resources meant we were unable to answer certain initially formulated need-to-know questions, namely:

"***What are the impacts of cyclists on vegetation within Discovery Park?"*** and ***"What are the impacts of pets on birds and vegetation within the park?"***

However, in the process of this project, we built the basis for future work in this area by drawing on the most complete datasets available to our group.

6. Results

6.1 Weed Index Surface

Sample Plot weed indexes give native species a numeric rank of 1, a nonnative non-invasive species a numeric rank of 3, and an invasive plant species numeric rank of 5. The percent cover of each species in a sample plot is multiplied by their respective weed indexes to derive a weighted percent cover. Both the percent cover and weighted percent cover columns are totaled. Then the total weighted percent cover is divided by the total unweighted percent cover. For example, a sample plot with a weighted percent cover of 270 and an unweighted percent cover of 220, would have a sample plot weed index of 1.23 (270 / 220). A Microsoft Access database was used to calculate and query the weed index for each 2001 plant sample plot and to average all the samples to derive the Discovery Park 2001 average weed index (Figure 21) of 1.76.[4] This index provides a gauge of the resilience of Discovery Park native species in relative to the encroachment on their habitat by exotic species.

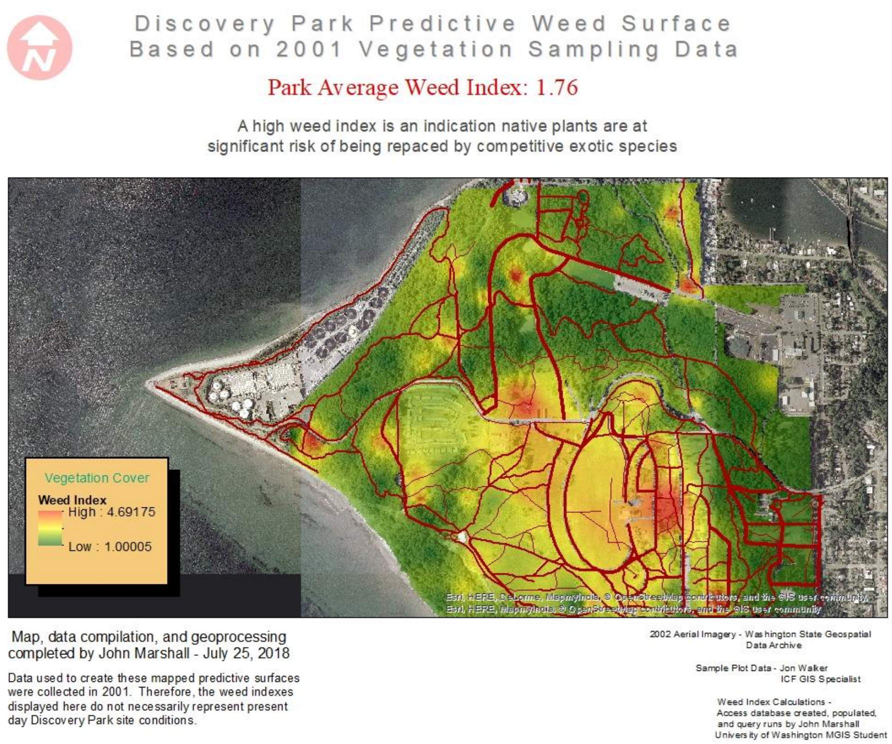


Figure 21. Dominant Discovery Park Weed Index Surface based on 2001 Vegetation Sample Plot Data.

[4] It should be noted that the Microsoft Access database averages the weed indexes of all of the 169 sample plots where plant data was recorded in 2001. But 23 sample plots were not georeferenced. So the weed index surface illustrated in Figure 21 was only informed by 146 sample plots.

6.2 Moisture Index Surface

Sample Plot moisture indexes give an obligate wetland species a numeric rank of 1, a facultative-wet wetland species a numeric rank of 2, a facultative wetland species numeric rank of 3, a facultative-upland species a numeric rank of 4, and an upland species a numeric rank of 5. Aggregated plant sample plot moisture index scores close to one indicate hydrophytic plants adapted to low oxygen in their root zones typically due to saturation by a high water table. Scores closer to 5 indicate plants with low tolerance to low oxygen from high water and that are typically found in much dryer site conditions.

The percent cover of each species in a sample plot is multiplied by their respective moisture indexes to derive a weighted percent cover. Both the percent cover and weighted percent cover columns are totaled. Then the total weighted percent cover is divided by the total unweighted percent cover. For example, a sample plot with a weighted percent cover of 625 and an unweighted percent cover of 220 would have a sample plot moisture index of 2.84 (625 / 220). A Microsoft Access database was used to calculate and query the moisture index for each 2001 plant sample plot and to average all the samples to derive the Discovery Park 2001 average moisture index (Figure 22) of 3.67.[5]

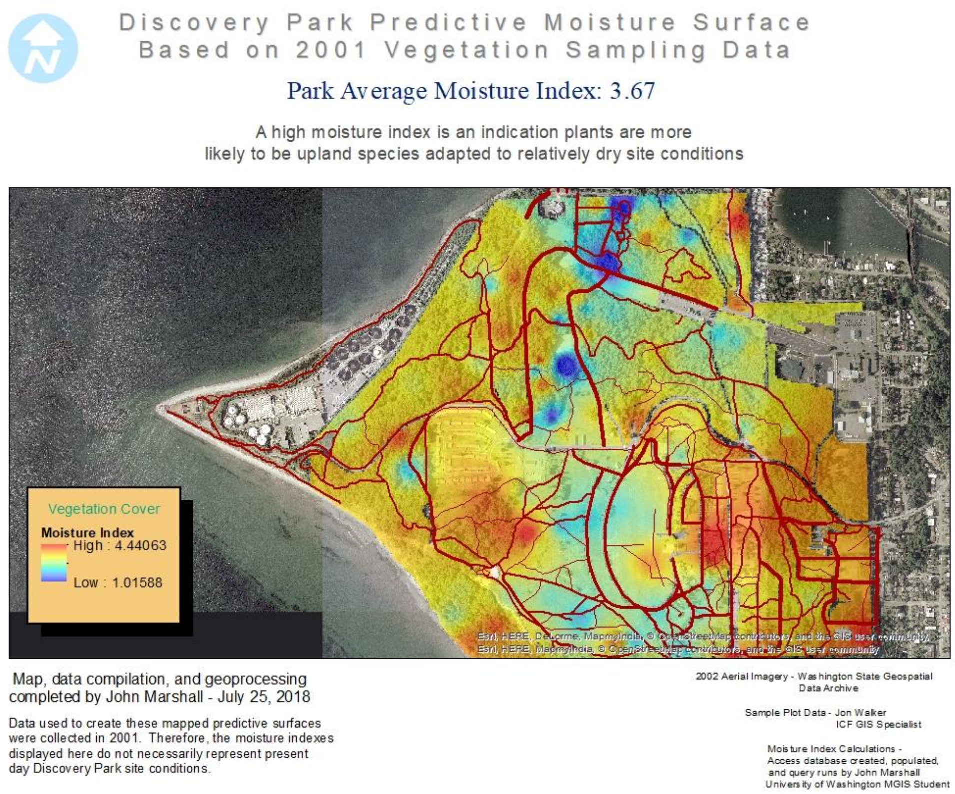


Figure 22. Dominant Discovery Park Vegetation Moisture Index Surface based on 2001 Vegetation Sample Plot Data.

5 It should be noted that the Microsoft Access database averages the moisture indexes of all of the 169 sample plots where plant data was recorded in 2001. But 23 sample plots were not georeferenced. So the moisture index surface illustrated in Figures 22 was only informed by 146 sample plots.

6.3 Plant Communities

The 2001 vegetation sample plots were grouped by stratified plant cover based on 2002 aerial photo interpretation. If any species in a sample plot inside a stratified sample unit polygon was returned in a query of >= 50% areal cover, it was assigned a status of a dominant species in that sample unit polygon. If any species in a sample inside a stratified sample unit polygon was returned in a query of >= 20% And <50% areal cover, it was assigned the status of a subordinate species in that sample unit polygon. However, a simpler more generalized field was used to display plant communities in this map. The criteria were the highest percent cover by dominant species present with ties going to the superior structural type (e.g., trees over shrubs and shrubs over herbaceous or emergent plants). In this category the common name was used instead of the scientific name. Unfortunately out of the 526-acres of vegetated area covered by the sample units, 171-acres (about 33%) were not sampled. These areas were given a designation of ‘no data’.

The plant communities sampled are represented by mixed deciduous and coniferous forest (Figure 23). While isolated areas are dominated by conifers, the majority of the 2001 sampled area is dominated by native deciduous trees (mostly by Big-leaf maple and Red alder) and nonnative grassland.

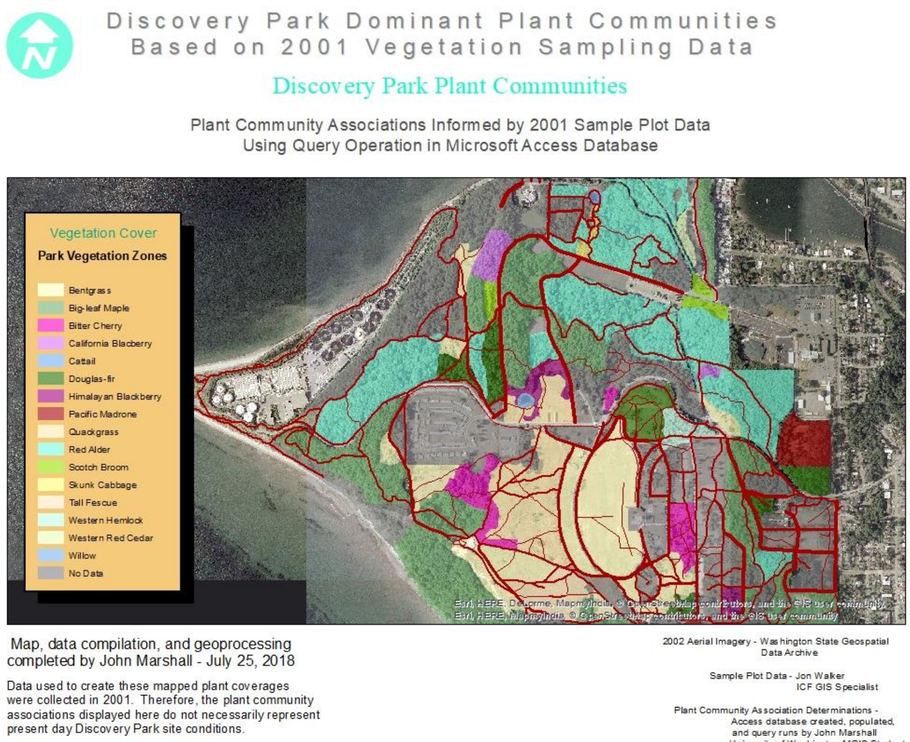


Figure 23. Discovery Park Plant Communities Based on 2001 Sample Plot Data.[6]

[6] While great effort was taken to resolve topology errors in this layer, a significant amount of error resolution work remains undone. Basically, this can be contributed to competing work priorities and limited time.

6.4 Plant Community Use by Birds (Horizontal)

The 2016 Seattle Audubon bird observation data (50-meter radius observation areas) are added as a GIS layer over horizontally stratified (Odum 1959) Discovery Park plant community polygons informed by 2001 vegetation field sample plot data (Figure 24). Initial anecdotal queries reveal indications that birds with specialized habitat requirements are recorded in their expected habitat types, such as savanna sparrows in open grasslands.

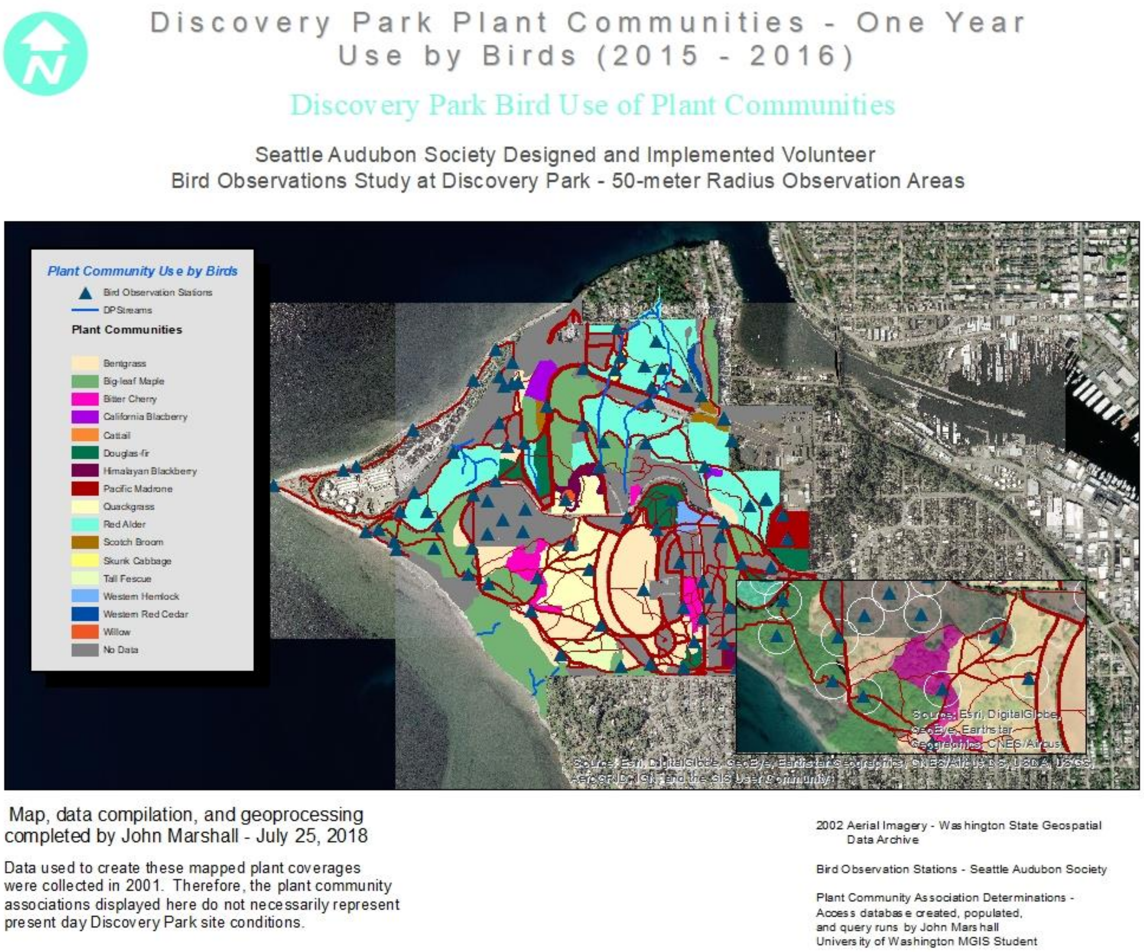


Figure 24. Horizontal Use of Plant Community Structure by Birds.[7]

[7] Due to project time constraints and a concern there were insufficient data to proceed with further analyses, there were no attempts to do correlations of species observations with plant community types. But because there was anecdotal evidence of correlation and because the authors of this report consider this a candidate area for future work effort concentration, this overlay display of the datasets is included in the Results section of this report.

6.5 Plant Community Use by Birds (Vertical)

In 2008, Manares et al reported the following:

> *"In studies in which landscape level forest structure was found to be more predictive of bird occurrence than stand level forest structure, a mismatch between extent of bird and vegetation sampling may have influenced conclusions. The role of stand-level structure in providing habitat may therefore have been underestimated. This finding has important implications for conservation planning because it means that the structural conditions (e.g., successional or stand development stage) within a forest reserve or land management unit can influence its suitability for different organisms. Regional or landscape scale conservation planning based on assessment of cover type alone, therefore, may be insufficient to capture important habitat relationships occurring at fine scales. Information at both scales, if available, is relevant and desirable based on our results."*

Vertical stratification of forest vegetation has been characterized in the literature for quite some time (Odum 1959). A vegetation structural index (Figure 25) illustrates one alternative means of objectively quantifying this phenomena when observing and documenting how wildlife (emphasis on birds) respond and or possibly even contribute to vegetation structure.

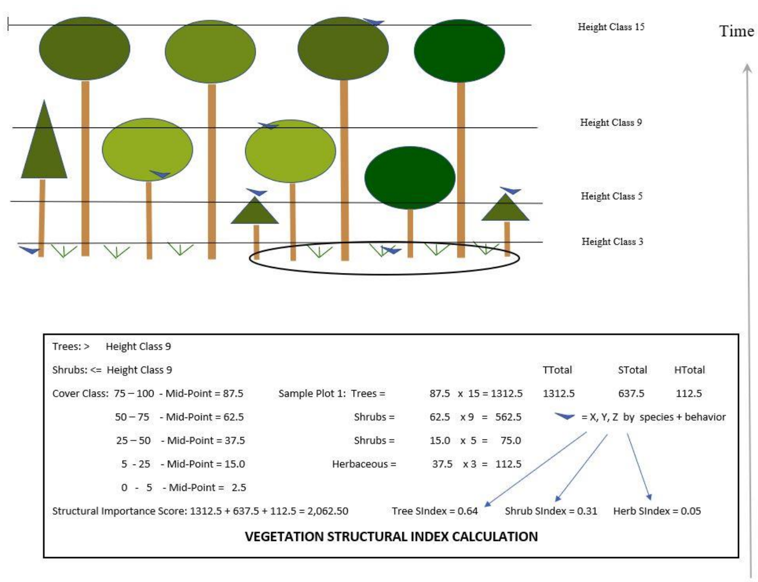


Figure 25. Vertical Use of Plant Community Structure Use by Birds as a Structural Plant Community Index.[8]

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[8] Due to project time constraints and a concern there were insufficient data to proceed with further analyses, there were no attempts to do correlations of species observations with vertical plant community structure. But because the author's review of the literature on this subject gave weight to considering this as a candidate area for future work effort concentration, this diagram of a vegetation structural index is included in the Results section of this report.

6.6 Land Cover Analysis and Associated Carbon Sequestration Valuation

Land cover classification of the 2018 georeferenced aerial imagery allowed for the analysis of four distinct types of land cover classes which currently exist within the park, as well as the associated carbon sequestration values associated with these land cover types. The scope of this project only allowed for a simplified land cover classification, with only four classes being used. These four classes (Barren/Developed, Mixed Forest, Shrubland, and Grassland) do, however, represent the land cover classes which have experienced the most change due to rehabilitation efforts undertaken within the park. In addition, these four land cover classes provide the majority of the carbon sequestration ecosystem services within the park. Overall, this land cover classification analysis indicates that at the time the 2018 aerial imagery was recorded, the park is comprised of approximately 45 acres of developed/barren land, 80 acres of shrubland, 87 acres of grassland, and 346 acres of forest.

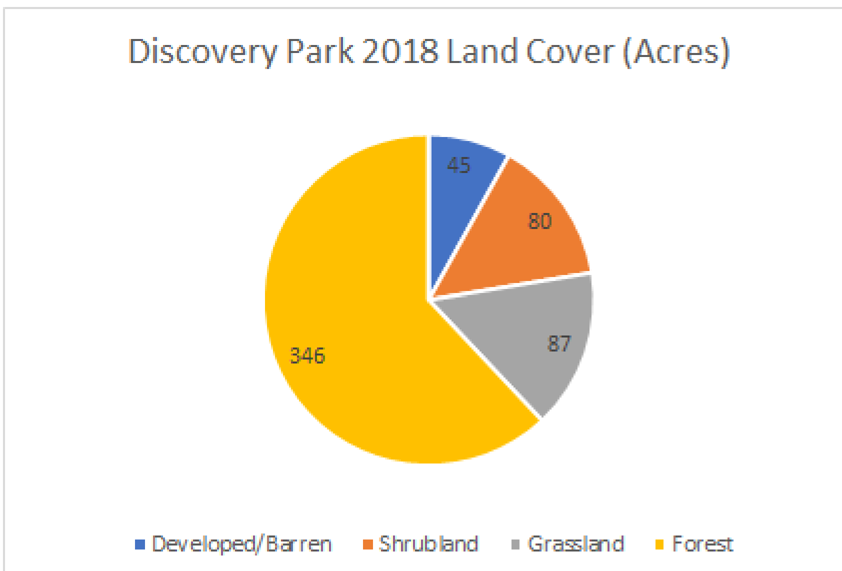

Figure 26. Acreage for the four land cover classes, based off of the 2018 aerial imagery.

A comparison of the total area for each land cover class to the National Land Cover Dataset from 2011 (NLCD 2011) indicates that the park has increased on forested and grassland land cover since 2011, and decreased in shrubland land cover. A detailed comparison of the change in developed/barren land cover is not currently available based on the NLCD 2011 data and the land cover derived from the 2018 imagery. In terms of forested area, in 2011 Discovery Park contained a total of 288 acres, while the 2018 data indicates a total area of 346 acres, an approximate 20% increase. In terms of grassland, the 2011 data indicates a total area of 83 acres of grassland, while the 2018 data indicates a total of 87 acres, an approximate 5% increase. Shrubland appears to have declined from 120 acres in 2011 to 80 acres in 2018, a decrease of approximately 33%.

Land Cover Type	2011 (Acres)	2018 (Acres)	% Change
Forested	288	346	+20%
Grassland	83	87	+5%
Shrubland	120	80	-33%

Table 9. Table displaying the change in land cover (Acres and Percent) from 2011 to 2018 within Discovery Park.

+

The carbon sequestration data was referenced from an analysis conducted by Earth Economics for Discovery Park. This analysis utilized land cover data from 2011 (NLCD 2011), and because the land cover of the park has changed from 2011 to 2018, the 2018 carbon sequestration analysis was deemed a worthy endeavour. The carbon sequestration analysis of the 2018 land cover data indicates that in its current state, Discovery Park holds an annual carbon sequestration value as high as $178,102 and as low as $43,002. These values are subject to change depending on the change in land over within the park over the course of time.

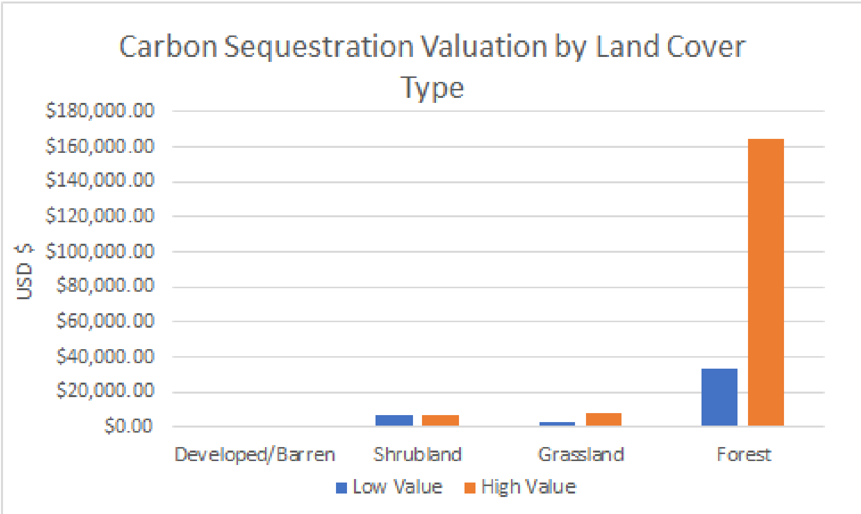

Figure 27. Carbon sequestration values, high and low, for each land cover class.

6.7 Visitation Analysis Tools

Each analysis was formulated as a tool in ArcGIS ModelBuilder and included in a common toolset in our group's file geodatabase deliverable. This allows the analyses to be re-run in the future should more up-to-date datasets be acquired. Additionally, the models exist as a form of documentation of the process used to generate these results.

The results here represent the outputs of these tools. Due to the large number of outputs from the analysis models, only the main core of outputs for each analysis are included here for discussion. Instead of representation in static maps, output from these models are included in our group's Platform Web App for interactive display.

6.7.1 Land Cover from 2018 Aerial Imagery

Using the most recent land cover dataset, derived from 2018 aerial imagery, photo-user-days were summed into four categories, shown in Figure 28. While this classification system is somewhat less specialized than the Earth Economics land cover classes, which were generated in 2011, it is the most up-to-date, based on 2018 aerial imagery.

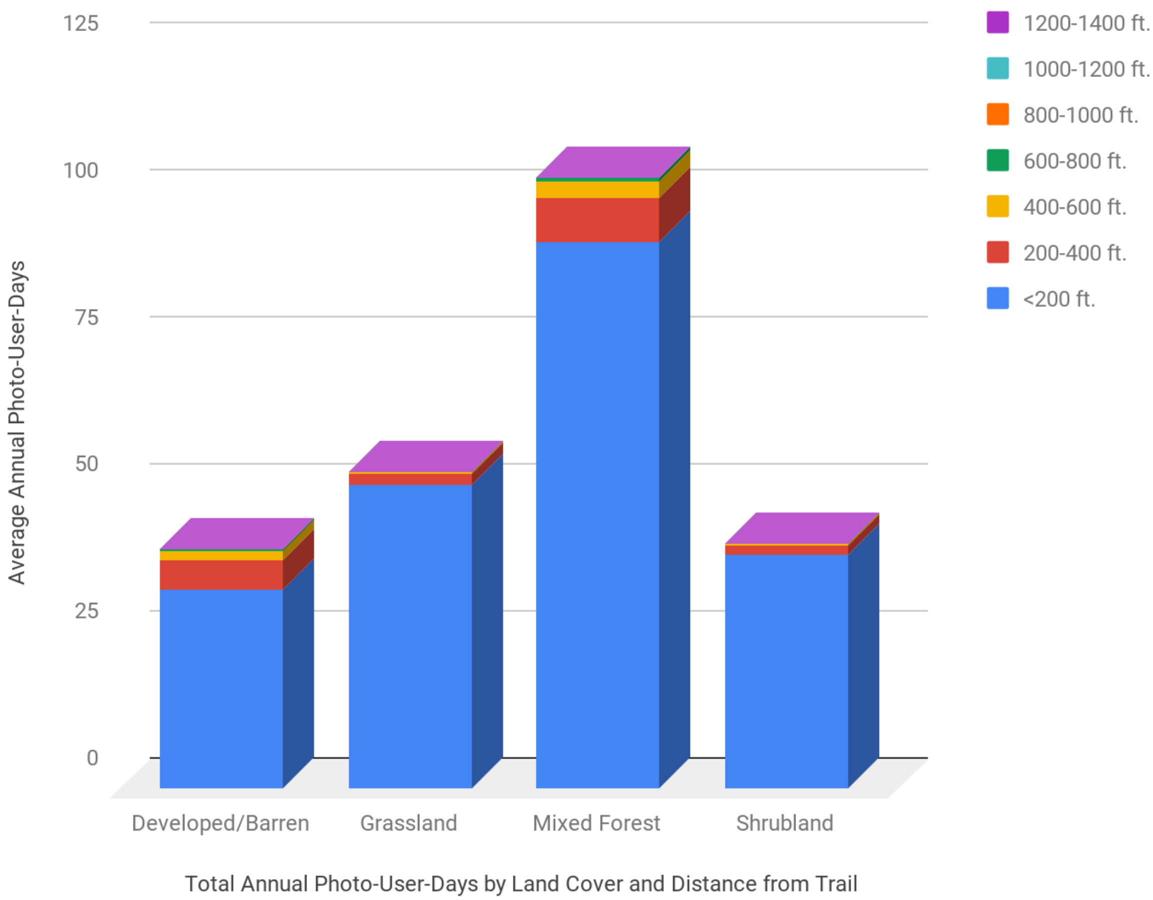

Figure 28. Total Annual Photo-User-Days by Land Cover and Distance from Trail.

By far, areas classified in "Mixed Forest' accumulated the highest overall number of photo-user-days. As all forested areas in the park are grouped within this category, the high number of photo-user-days likely reflects the large proportional area that forests have within Discovery Park.

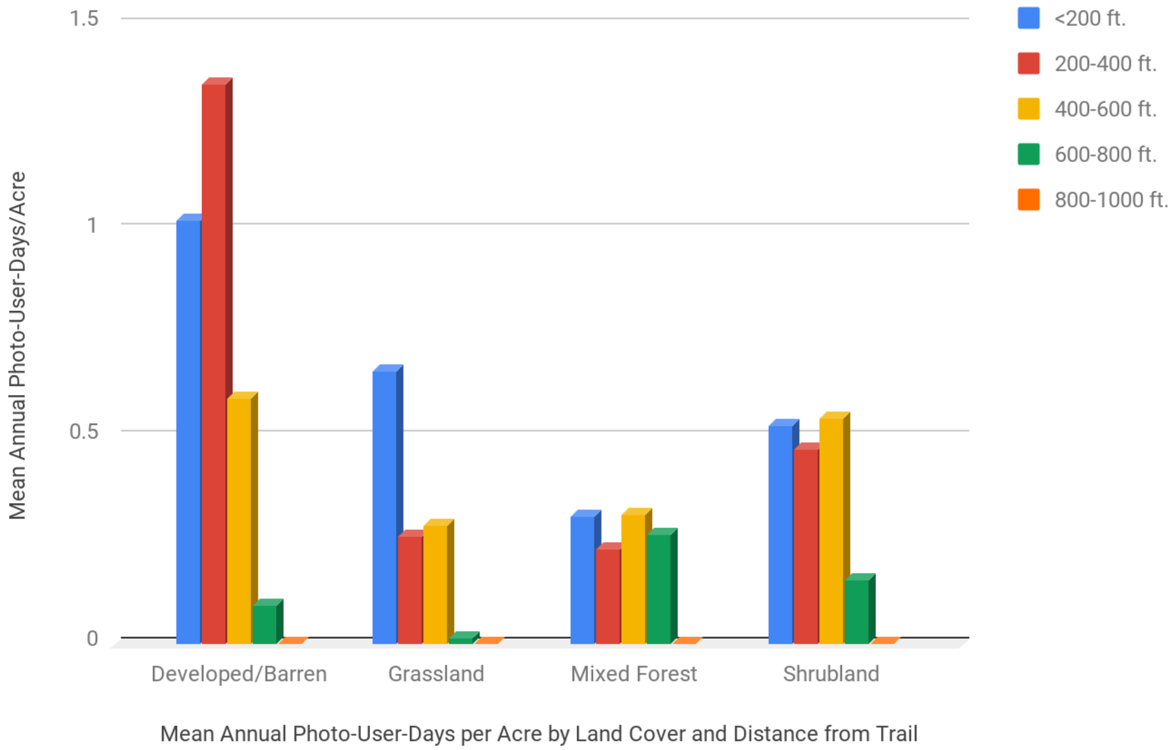

Figure 29. Mean Annual Photo-User-Days per Acre by Land Cover and Distance from Trail.

On an area-corrected basis, the Developed/Barren class stands out as having the highest visitation rate of all four classes. Interestingly, areas further away from the trails (200-400 ft. zone) have the highest rate of visitation. This might reflect the high rate of visitation that occurs along beach areas, which is included in this category.

Interestingly, when grouped by type, the impact on Mixed Forest looks relatively light and evenly balanced by distance.

6.7.2 Earth Economics Land Cover

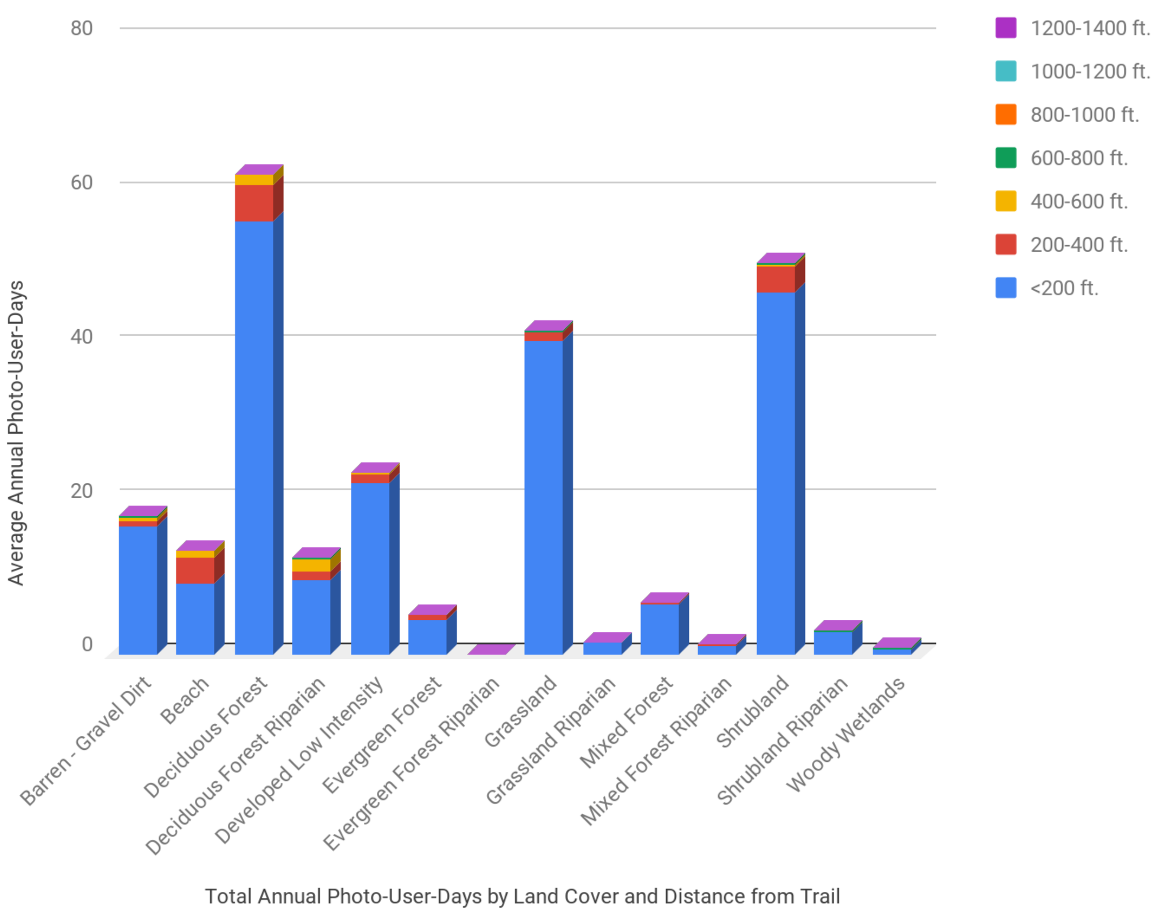

Figure 30. Total Annual Photo-User-Days by Earth Economics Land Cover and Distance from Trail.

In absolute terms, many land cover types bear more of the brunt of visitation, namely Deciduous Forest, Grassland, and Shrubland. It is important to note that these land cover types are more greatly represented in terms of area, which contributes to the greater absolute figures. Some areas, such as Barren - Gravel Dirt and Developed Low Intensity, are next down in levels of visitation, likely reflecting human activity in these areas showing anthropogenic activity.

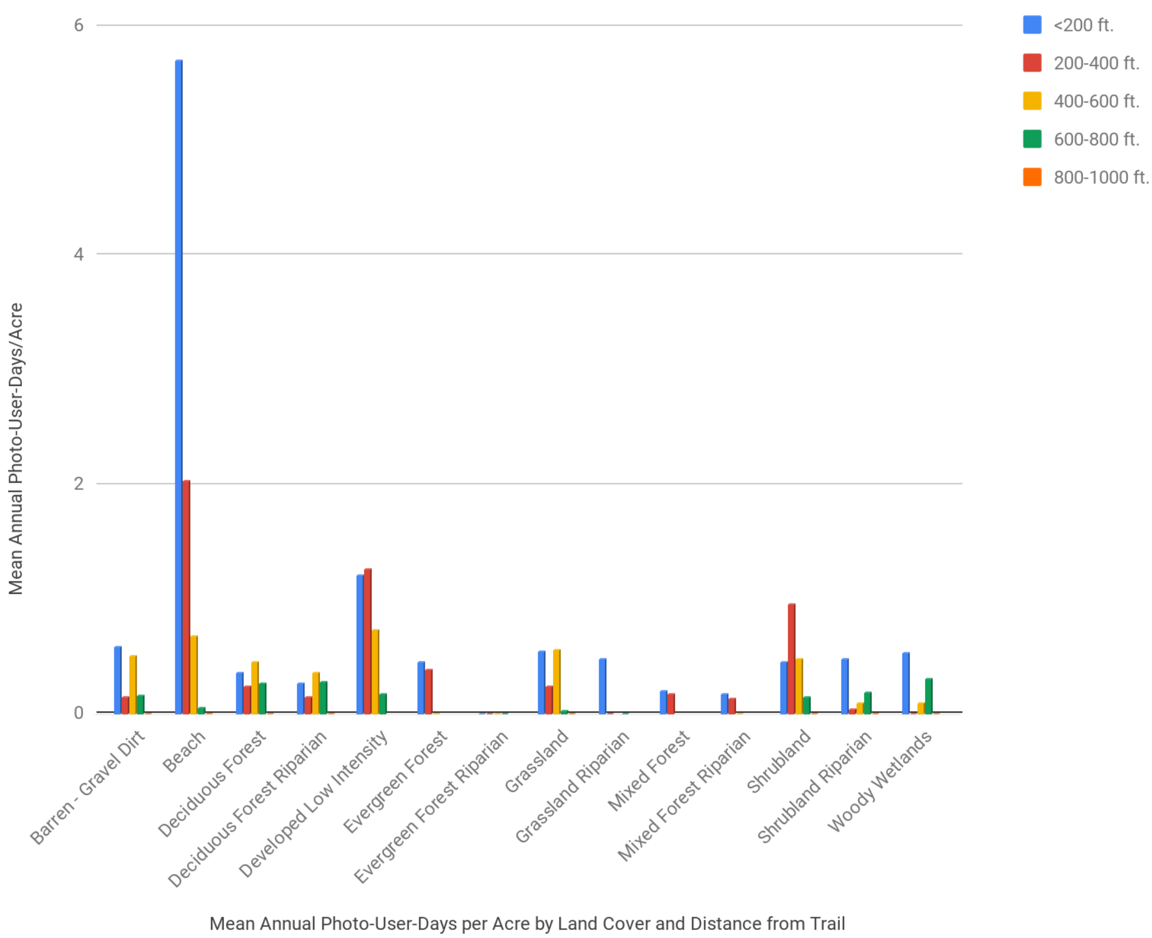

Figure 31. Mean Annual Photo-User-Days per Acre by Earth Economics Land Cover and Distance from Trail.

When compared on an area-adjusted basis, the Beach land cover zone stands out as by far the most visited land cover type. This indicates that the Beach land cover zone is a particular draw to park visitors and may be significantly more impacted than other land cover types in terms of human impact.

Other types with greater than average visitation rates include Developed Low Intensity and Shrubland, although these are not comparable with the rate of visitation seen in the Beach land cover zone. Interestingly, there is a trend for Riparian versions of land cover zones to have lower levels of overall visitation, which is noteworthy, given the generally higher level of ecosystem services that riparian areas provide.

6.7.3 Vegetation Class

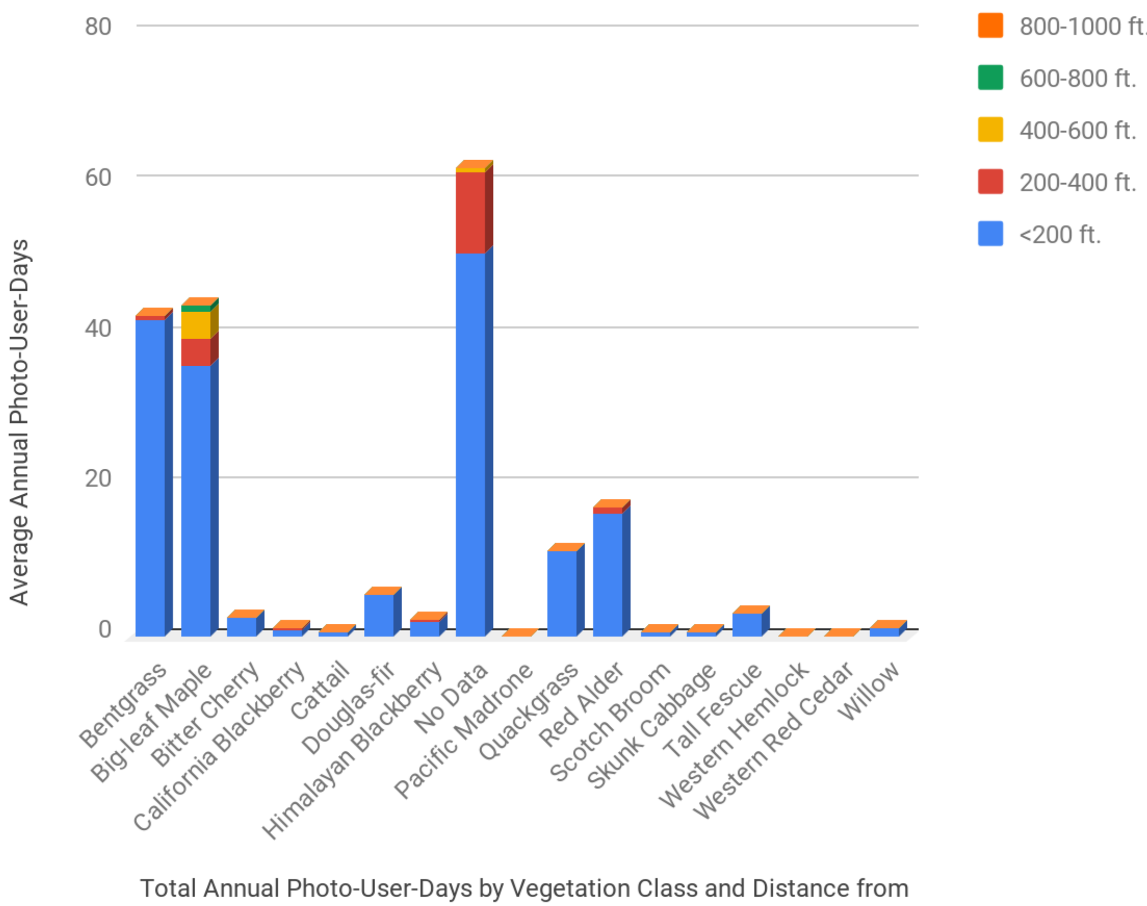

Figure 32. Total Annual Photo-User-Days by Vegetation Class and Distance from Trail.

In absolute terms, the most represented vegetation class was areas with no data, followed by Big-leaf maple and Bentgrass. Many vegetation classes were predominantly or solely present within <200 ft. of a trail, which could mean that these vegetation types were found relatively close to trails.

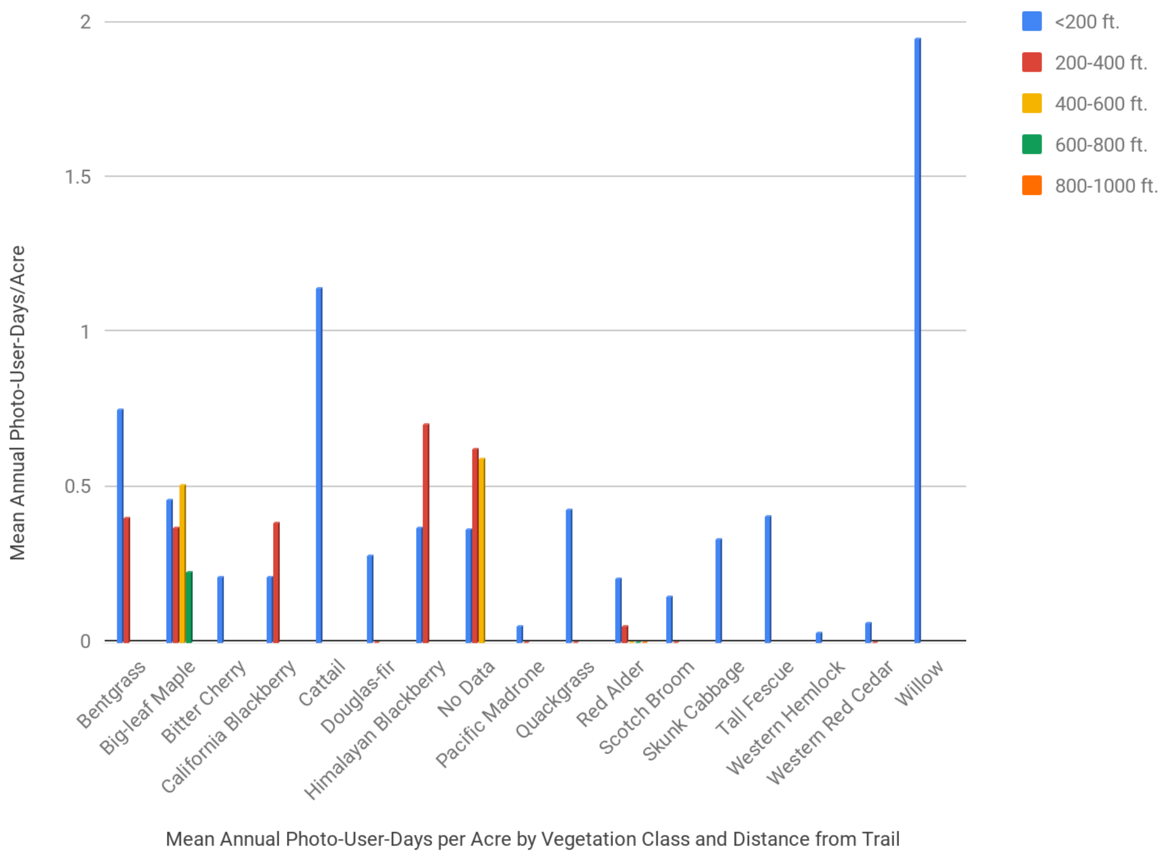

Figure 33. Mean Annual Photo-User-Days per Acre by Vegetation Class and Distance from Trail.

On a per acre basis, Willow and Cattail vegetation zones stood out as disproportionately visited vegetation classes, all within the <200 ft. buffer zone. Oddly, Big-leaf Maple and Himalayan Blackberries saw their highest rates of vegetation at zones further away from trails, indicating that for these vegetation classes, distance was not necessarily a barrier to visitation. A similar phenomenon was seen for areas with no data regarding vegetation class.

6.7.4 Distance from Trail

An analysis solely examining photo-user-days in terms of distance from trails was undertaken to examine what proportion of visitation occurs in the on- or near-trail area (<200 ft. zone), compared to zones further out (e.g. 200-400 ft., 400-600 ft., etc.). The nearest zone of <200 ft. had by far the largest area across the park, which likely contributed to this zone's large area of total photo-user-days.

Figure 34. Average Annual Photo-User-Days by Distance from Trail.

When standardized by area, as shown in Figure 35, the most proximal zone of <200 ft. still showed the highest rate of visitation, confirming that park trails are a major contributor of human traffic, and by extension, human impact. However, both the 200-400 ft. and 400-600 ft. zones had comparable rates of visitation, indicating that significant *rates* of visitation extend past the most proximal distance zone. Thus, while distance from trails is a contributor to human traffic, walking distances of up to 400 ft. appear not to be a major obstacle for visitors.

Photo-user-days are much reduced for the 600-800 ft zones and beyond; however, it should be noted that as trails intersect much of the park, these more distal zones represent fairly small areas of the park and so these small numbers might reflect other attributes specific to these small areas of the park rather than the direct influence of distance.

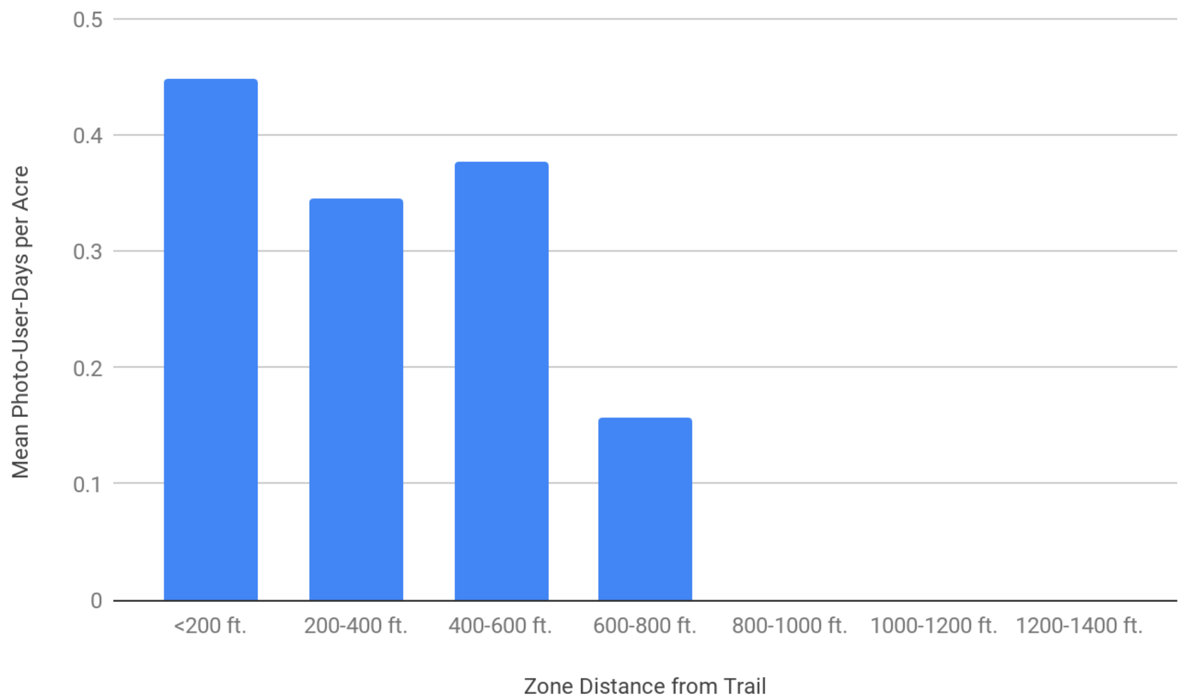

Figure 35. Mean Photo-User-Days per Acre by Distance from Trail.

6.8 Collector-based CRUD Interface

This deliverable provides CRUD (create, read, update, delete) functionality to our group's work. In order to avoid the use of online processing power, which uses a great deal of service credits, a semi-offline arrangement was arranged, drawing both on ESRI's Collector software and the custom processing capabilities in ArcGIS Pro.

Collector was used as a user-friendly interface that is able to directly update an ArcGIS Online hosted feature service that can be drawn upon for analysis in ArcGIS Pro. This feature service, named 'AOI' for area of interest, allows the user to mark out one or more areas of interest (as seen in Figure 36).

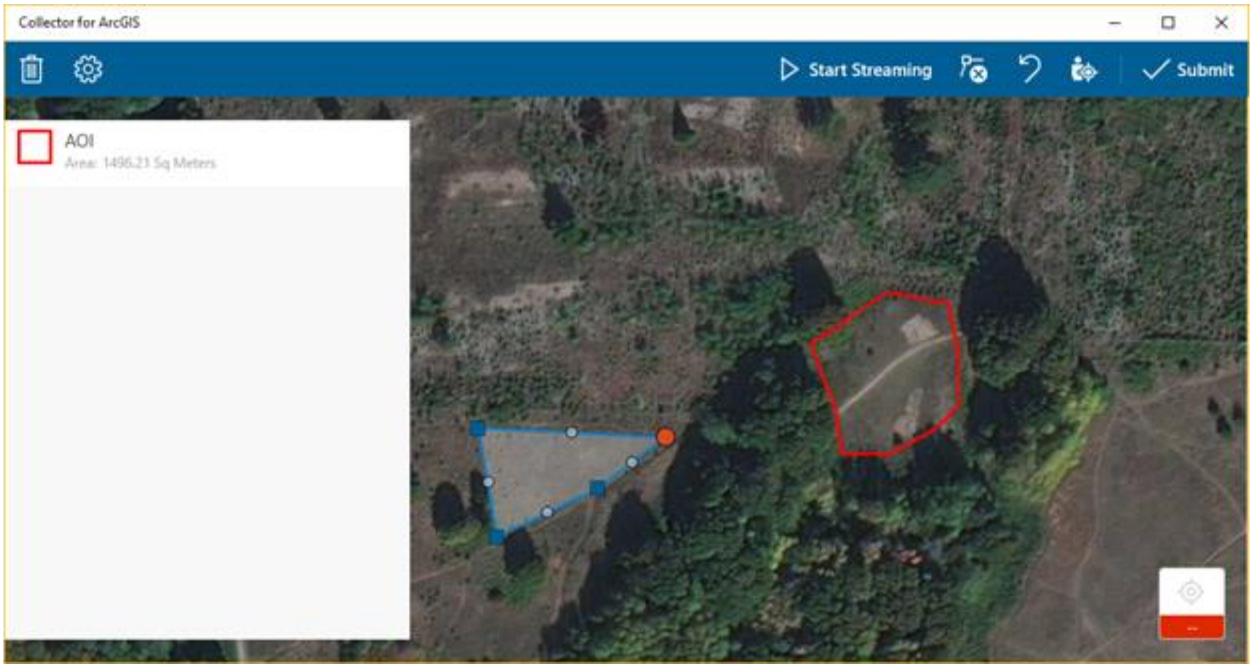

Figure 36. Using ESRI's Collector app to delineate areas of interest for summarizing ecosystem services within Discovery Park.

The syncing of these features to a hosted feature service on ArcGIS Online can be done without any usage of ESRI service credits. The next step of the process involves running a tool named 'Ecosystem Services Evaluation', which was constructed in ArcGIS Pro's ModelBuilder to work with this hosted feature class and calculate ecosystem services within the user-defined areas of interest.

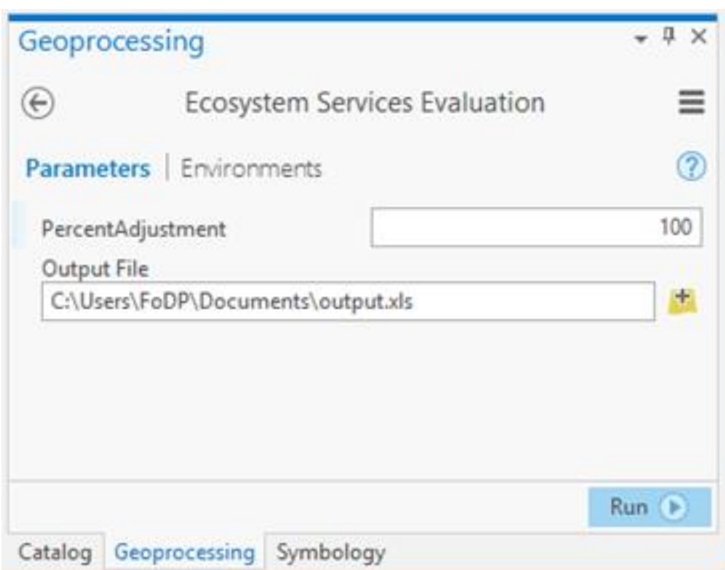

Figure 37. User Interface for ArcGIS Pro Tool.

An additional 'PercentAdjustment' option allows users to simulate increases or decreases in ecosystem services for the defined area.

The output is obtained in an Excel document, showing both high and low estimates of ecosystem services based on Earth Economics data.

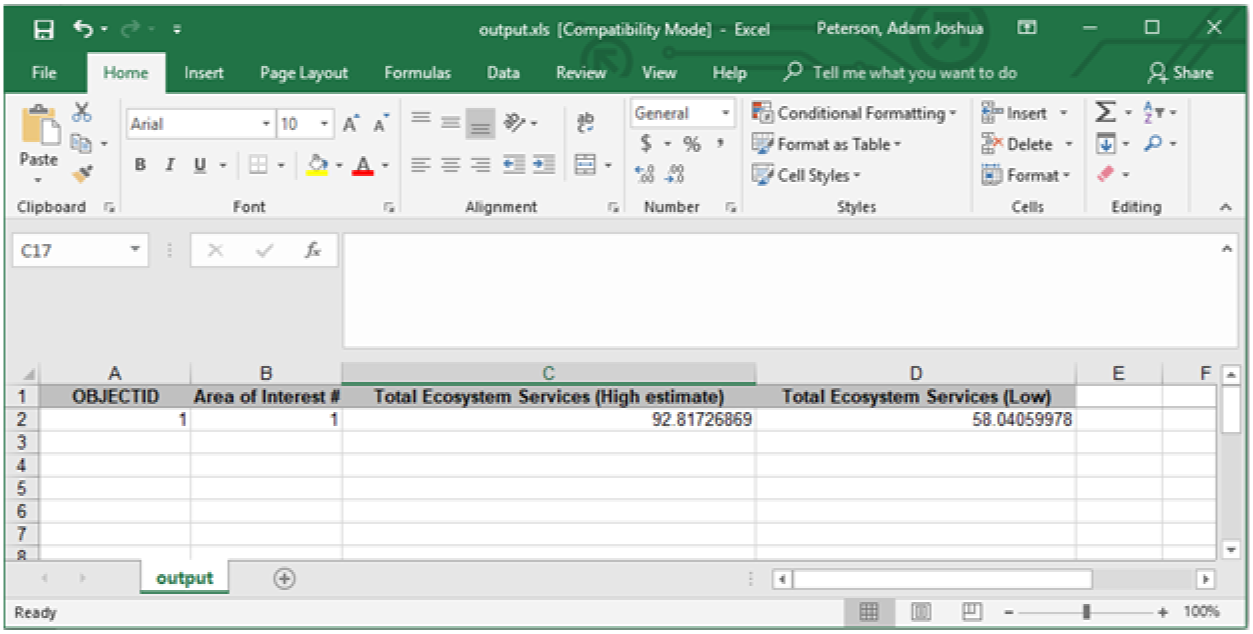

Figure 38. Example Excel Output.

This process uses none of FoDP's annual budget of 200 service credits.

While we were able to find a way to combine the 'Draw' and 'Analysis' widgets in ESRI's web app environment, the credit costs for a similar analysis to the one just outlined were estimated at roughly 18 credits, or nearly 1/10 of FoDP's annual allocated service credit budget. Such a setup is unrealistic for repeated use, and thus this setup provides a cost-appropriate and effective way to provide rapid quantification of ecosystem service analysis within FoDP's current account capabilities.

6.9 Data Organization for On-the-Fly Display of Relevant Data in Web Application

The aforementioned data is organized together within a 500 square feet cell grid, covering the entirety of Discovery Park. Each cell contains attributes related to photo user days, carbon sequestration, land cover type, dominant and subordinate plant species, and moisture and weed indexes. The metric data is adjusted accordingly so that the values are consistent with the size of the grid cells. For example, carbon sequestration is based on a per acre value for each land cover type, therefore the total area of each land cover existing within each grid cell was adjusted accordingly to represent the total carbon sequestration for each 500 square foot grid cell. Photo user days are summed within each grid cell, while the weed and moisture index values are averaged. This grid system, referred to here as a "data grid", enables the web application user to view the included data on an individual cell basis, or, with the help of a widget within the final platform, summaries of the data at any extent from 500 square feet to the entirety of Discovery Park.

The final platform exists as a web application housed on the Friends of Discovery Park ArcGIS Online account. In the current platform state, the 500 sq ft hexbins are not displayed within the web application, but rather serve to provide metric data for use within the Summarize widget (see Figure 39). If a higher resolution is desired, the 49 sq ft grid cell feature class contains the same data as the 500 sq ft hexbin, adjusted appropriately to the smaller size, higher resolution polygons. Due to the nature of the Summarize widget, however, the switch from one feature class to the other must be made by an authorized editor of the web application rather than the map user. In addition to the Summarize widget, the Swipe widget was also applied to view the aerial imagery from different years in comparison to one another, which aids in a visual representation of the changes which have occurred in the park over time (Figure 40).

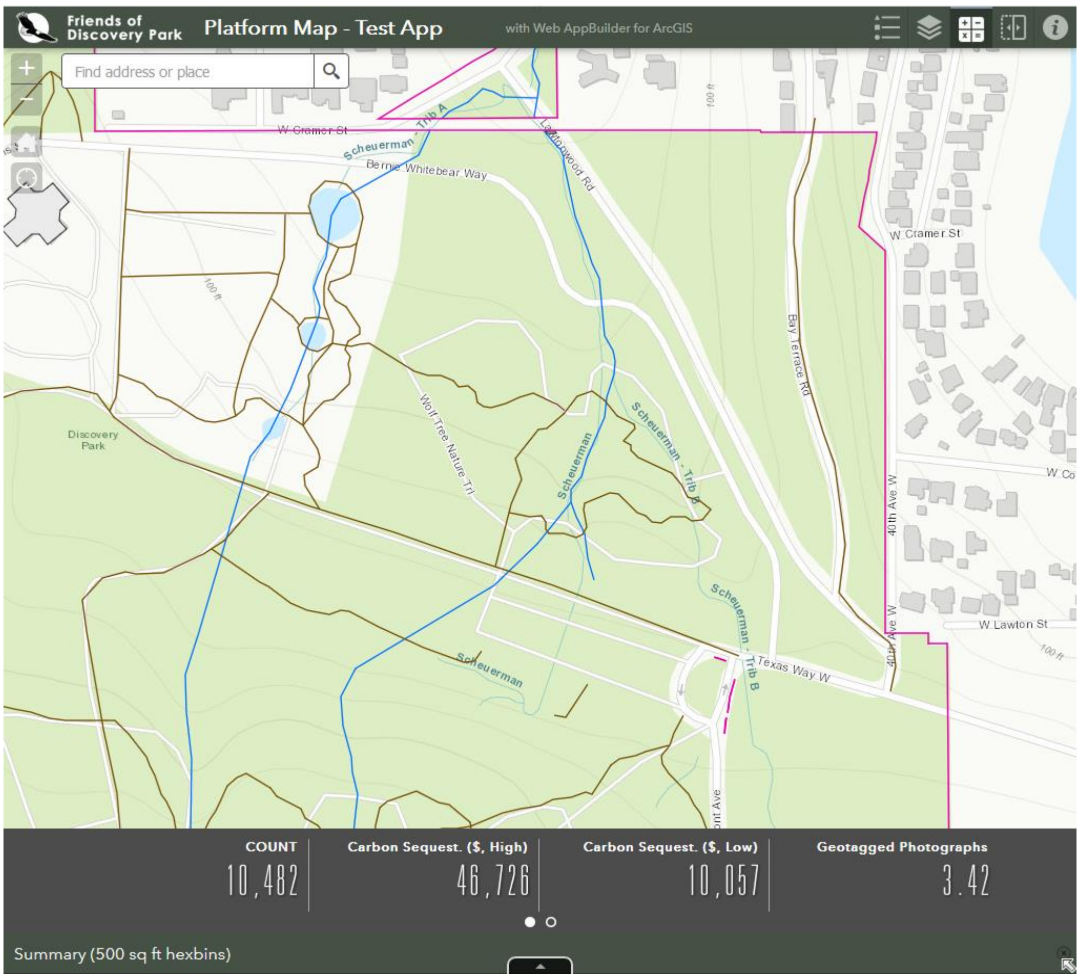

Figure 39. Platform A showing “Summary” widget in action, displaying key data metrics for a section of Discovery Park.

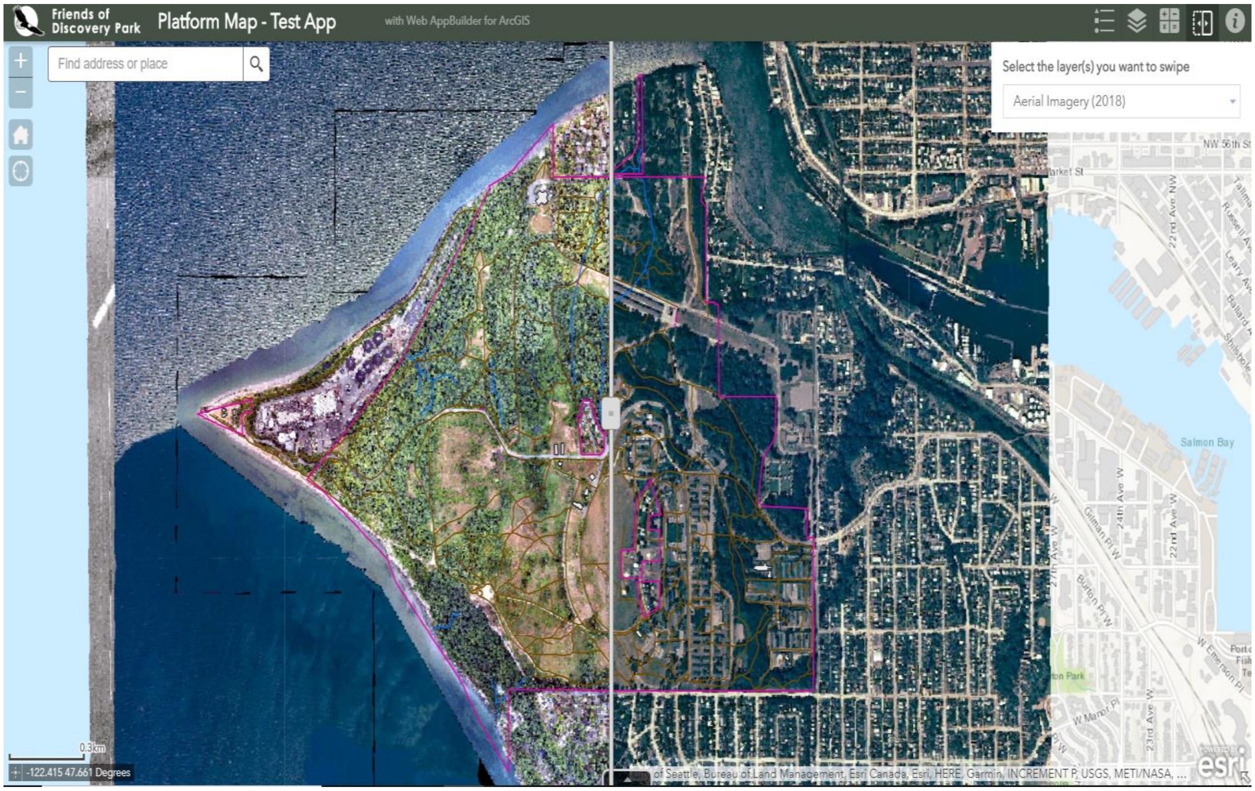

Figure 40. Platform A showing “Swipe” widget in use with historical aerial imagery.

7. Conclusions and Recommendations

7.1 Conclusions

7.1.1 Vegetation Monitoring and Mapping

Fundamental work on metrics that are likely to serve multiple queries about the current state of Discovery Park’s vegetation, as well as trajectories of vegetation change over time, are deemed substantially important and to have a pivotal role in relation to wildlife use in general and to most if not all Discovery Park management decisions on key Park related issues. Additionally, while it is true in-situ use of the Park by Seattle’s citizens and visitors from outside of Seattle can have considerable influence on the Park’s vegetation response, there are also other overarching ambient influences on the Park’s vegetation, including but not necessarily limited to proximity to nonnative horticulturally propagated species subject to dispersal by wind and wildlife and shallow water table responses to local landscape design changes and / or global temperature changes over time. Moreover, it is incumbent on the Park’s information and data stewards to help Park Managers, to the degree possible, distinguish between global, regional, and local factors affecting the Park’s vegetation.

From the perspective of Seattle Parks Department (a primary target beneficiary of this project) the ability to determine and predict the species, locations, and relative intensity of park weed outbreaks can guide decisions on labor and material allocations as well as timing vis a vis other competing expenses, thereby serving to reduce overall costs and result in a significant cost savings.

The ongoing tracking of a vegetation moisture index can help inform park managers in efforts such as wetland inventories, red-flag signals of unanticipated recent local changes in hydrology due to unauthorized and/or unintentional project actions (e.g., miscalculation of culvert elevations in a recent road improvement, side cast fill into wetlands from a new parking lot, lack of follow-up on temporary ditching to reduce flood elevations, miscalculations in stream and wetland restoration actions causing stream channelization and adversely affecting an imperiled species, etc.). This index can be tracked over time and may one day be used regionally to help track moisture regime changes associated with global warming.

Having these metrics and their supporting documentation provides improved assurances that budget requests will be answered with adequate funding to accomplish their targeted management objectives and to minimize a risk of misallocation of financial resources between competing park budgets, an efficiency in its own right.

The recalculation of vegetation plant community associations mapped in the Discovery Park vegetation layer, if properly vetted and validated, may be one of this project's most important contributions to park managers and those with an interest in ensuring long-term sustainable ecosystem services are retained in Discovery Park. It is difficult at best to prescribe or implement any important park management objectives if your vegetation type and location information is misleading or inaccurate. This ranges from everything between anticipating forest insect outbreaks, managing fuels to reduce wildfire risk, and/or making informed decisions on fish and wildlife habitat protection or improvement activities.

As expected, the plant community feature class developed during this project using the 2001 Sample Plot data more-or-less corroborates the 2002 Jones&Stokes report which was based on the same data, both on major plant community dominants and their general locations. The comparison on location is more difficult because the Jones&Stokes spatial representation of the data is more of a coarse diagram than a map.

While working with the 2001 sample plot data several peculiarities stood out. The first were the dates the field sampling occurred, mostly mid to late February and early March 2001. This is likely the least preferred time of year to do botanical field sampling. Few plants are flowering and most of the deciduous species have completely lost their leaves. Second, almost every sample plot contained species proximate to one another typically found in separate geomorphic and hydrologic settings. For example Red alder and salmonberry (commonly in wetland and riparian lowland areas) were frequently found in the same samples as Big-leaf maple and sword-fern (typically found in dryer forested uplands). Next, apparently the same sample size (0.10-acre inside circular plots of 37.2-ft radius) used to sample forest trees was also used to sample shrubs and herbaceous species. The sampling challenges this approach can have were likely exacerbated by the fact the field crews used an absolute cover protocol (Jones&Stokes 2002), sampling down to as low as 1-percent cover.[9] Making these percent cover assignments for herbaceous species at this level of precision using a 0.10-acre sample plot would likely be considered challenging by most botanists.

A relatively common hydrogeomorphic landscape feature in the Pacific Northwest is what has come to be known in the field vernacular as a ‘mosaic’ condition. This is basically a situation where the micro-topography is very hummocky with frequent depressional features interdigitated with higher elevation upland areas (Holland 1996). If this is the case at Discovery Park, it could help explain the high number of 2001 sample plots with species typically adapted to dry conditions mixed in with species typically adapted to wetter conditions. An alternative theory is that the areas being sampled had undergone a recent change in hydrology and the sampling was representing a transition from one moisture regime to another. Or, perhaps due to the time of year sampling took place, there were several mis-identifications of key indicator species giving bias to a moisture regime that was not actually represented.

Probably the most obvious issue with the 2001 vegetation sample data are the large areas, about 33% of Discovery Park, that were not sampled. Appendix B of the 2002 Jones&Stokes report covers the 2001 vegetation sampling protocol but fails to explain why one-third of the park was not included in the sample area. It does inform that the sampling pattern was randomly generated but that alone would not account for the inadequate sample size or the lack of any sample coverage in so large an area.

The Microsoft Access Database created to track weed and moisture indexes allows for fast and efficient creation, reading, update, and deletion of relevant data as well as a multitude of useful query operations. For example, using this database, a park manager can instantaneously now know where every documented noxious weed is located in the park within a radius of 30-feet from a known point. If citizens complain the holly in the park should be considered an invasive weed and treated accordingly, the database operator can easily run a query on the holly and make the adjustments in a matter of minutes as all the updated changes instantaneously manifest in the calculated fields and display in the ongoing tracking report.

Finally, almost all of the vegetation documentation and reporting work in this project was devoted to the horizontal distribution of plant species and plant communities and almost no work was done on documenting and monitoring vertical stand structure. The research (Smith et al 2008) indicates this is an important dimension of vegetation that is typically overlooked in terms of its importance to wildlife and numerous other natural resource management and planning considerations.

7.1.2 Land Cover and Carbon Sequestration Analysis

[9]A significant number of the 2001 samples were logged at 0-percent cover which, was probably an interpretation of ‘trace’ occurrence. For this project 0 was changed to 1-percent cover so the species could be used to help inform the index calculations.

The land cover classification and carbon sequestration analysis of the most recent, 2018 aerial imagery of Discovery Park provided an insightful view into the current state of the landscape and one of the many affordances it provides. The land cover classification was simplified into four distinct classes which were deemed necessary for a sufficient carbon sequestration analysis, and while a more robust land cover classification would be even more beneficial, this analysis provides a basic understanding of current state of Discovery Park regarding its land cover. A comparison of the land cover classification from 2011 and 2018 provides a meaningful analysis into the changes which have occurred within the park in those seven years. Forested and grassland areas appear to have increased, while shrubland areas appear to have decrease. At face value, this appears to indicate that reforestation and rehabilitation of developed/barren areas have led to an increase in forest and grassland within the park from 2011 to 2018. The decrease in shrubland may be attributable to an increase in forested areas, with the shrubland areas developing into a more forested land cover.

Carbon sequestration analysis of Discovery Park helps in placing a monetary value on the percentage of each land cover classification. Placing a monetary value on the landscape of Discovery Park is a powerful means of portraying the value, actual and perceived, in terms that most all are familiar with. Due to the difference in resolution between the 2011 and 2018 land cover classifications, it is not currently possible to compare the carbon sequestration valuation between the two time periods. Additionally, the market values of carbon sequestration value per acre change over time, which poses even more difficulty in the comparison of the two carbon sequestration valuation analyses.

The georeferencing of the 2018, 1990, and 1968 provide a visualization of the changes which have occurred in the park over time as part of the efforts undertaken regarding vegetation rehabilitation. Between 1968 and 2018, there is an obvious increase in vegetated areas, particularly within locations which were developed as part of Fort Lawton, where major efforts to revegetate have been focused. Differences between the 1990 and 2018 imagery also indicate a continued effort of vegetation rehabilitation. The 2018 imagery was the only imagery to be subjected to a land cover efforts, the existence of the georeferenced 1990 and 1968 imagery allows for future work to more easily conduct additional land cover classification analyses.

7.1.3 Visitation Analyses and Collector-based CRUD Interface

Photo-user-day data helped provide a comprehensive view of the distribution of human visitation both on trails and beyond. The multiple analyses shown in this report drew on this data and examined it in context of land cover and vegetation classes, providing insight into the relative impacts of visitation on different parts of the landscape. Some areas, such as the Beach land cover zone, and vegetation class zones classified as having Willow and Cattail vegetation showed significant higher rates of human visitation and could be the most impacted across the park landscape.

The Collector-based CRUD Interface provides a workable tool that allows for interactivity paired with geoprocessing capabilities. By combining online elements that do not exhaust service credits, such as Collector, with the local processing power of ArcGIS Pro, this interface provides FoDP with Create/Update/Rename/Delete capabilities in a way that stays within the allowances of their non-profit

ESRI account. This setup can be greatly expanded on in future work, since custom tools can be constructed to act on custom drawn areas of interest.

7.1.4 Platform A - Interactive Web Application

Platform A is the culmination of the aforementioned efforts to collect, process, and analyze relevant environmental and social data about Discovery Park, centralized within a single web mapping application which aims to create a holistic representation of the current state of Discovery Park. Data related to wildlife, vegetation, ecosystem services, visitation, and more were uploaded to the Friends of Discovery Park ArcGIS Online account, and subsequently entered into a web mapping application. This web application allow the user to interactively investigate the location and relationship between various datasets relevant to overall current state of the park.

The most powerful aspect of the web application, arguably, is the various widgets included to allow the user to add/remove data, view total metrics related to vegetation, visitation, and ecosystem services valuation at any extent, interactively compare imagery, and generally gain a better understanding of the current state of the social and environmental aspects of any particular location within the park. The Summarize widget is used within a polygon grid of 500 square feet hexbins, which houses data about the vegetation, carbon sequestration valuation, and visitor usage, with the data adjusted to represent the total or average metrics for each hexbin polygon. If a finer resolution is desired, a 49 square feet polygon feature class was also created to hold the same data adjusted for the smaller size, however it is not currently loaded into the web application as a default layer. Visually, the polygonal hexbin grid is invisible to the user, however selecting a particular location within the park will provide an outline of the hexbin polygon encompassing a 500 square foot area related to the location selected, and a pop-up window will display the relevant data to that location. The Summarize widget works to display the sum and/or average of the data within a small window at the bottom of the map. As the user zooms in or out of the map, the metrics are adjusted to represent the total/average data metrics at any extent above 500 square foot resolution. The Swipe widget allows the user to swipe a sliding bar left and right to visually compare any two of the three aerial images within the map.

7.2 Recommendations

7.2.1 Vegetation Monitoring and Mapping

Due to the peculiarities in the 2001 plant sample plot data noted in the conclusion section above, a field verification site visit is warranted. The primary objective would be to test whether the documented mix of species with distinctly different moisture indexes found in 2001 is present today. This report recommends either a randomly picked subsample of the 2001 sample plots be resampled, preferably sometime in early June to mid-summer, or another more comprehensive vegetation sampling effort be conducted in all the vegetation sample units in the park.

Regarding the larger sampling effort, this data is ultimately necessary to support the fundamental work on metrics that are likely to serve multiple queries about the current state of Discovery Park's vegetation, as well as trajectories of vegetation change over time, which significantly affects decisions about wildlife management and many other key Park related trust responsibilities. Therefore, the larger more comprehensive sampling effort is this report's preferred recommendation.

An iterative stratified random sampling methodology (Mueller-Dombois and Ellenberg 1974), redrawing sample unit boundaries in the field when necessary, using recent high resolution aerial imagery to delineate sample units is recommended. The number of sample units identified and the number of sample plots per unit is highly contingent on the heterogeneity of the areas being sampled. Having said that, the number of sample units would not be expected to be significantly greater than the number used in this project, but the sample number would likely increase by at least 1.33 x 169 ~ 225 sample points. While the distribution of sampling would still be random, stratification by sample unit would ensure each sample unit receives an adequate number of samples based on its size and heterogeneity.

Herbaceous plants are much more sensitive to saturated soil conditions in the shallow root zone than trees or shrubs (Corps of Engineers 1987). Therefore, it may be prudent in future moisture index calculations, except in samples where there are no herbaceous understory species present, to limit the moisture index indicator plants to the herbaceous species in the samples.

This report recommends all existing and future Discovery Park vegetation data be entered into a Microsoft SQL Server database in a web-based MVC application connected to an SDE (or some equivalent hardware/software arrangement), to make this data more accessible and manageable from multiple locations throughout an enterprise system that includes field monitoring and tracking, desktop / web interface retrieval and reporting. It should be accessible at different security levels to park managers and staff at their computer workstations or hand-held devices on an as-needed basis. If properly designed, it could also be used to help make instantaneous connections with the general public and community decision makers, keeping them advised and updated on important changing Park conditions and integrating their input into important decisions.

Regarding questions about how vegetation affects wildlife distribution and behavior in the park, with emphasis on birds, the Friends of Discovery Park should continue cooperative efforts to monitor wildlife use of vegetation horizontally but also consider monitoring vertical use of vegetation by birds and other wildlife. With that in mind, development of a structural vegetation index may provide one more important measure for gauging the overall 'health' or sustainability of the ecosystem services that Discovery Park serves out on a daily basis.

Finally, while it is true in-situ use of the Park by Seattle's citizens and visitors from outside of Seattle can have considerable influence on the Park's vegetation response, there are also other overarching ambient influences on the Park's vegetation, including but not necessarily limited to proximity to nonnative horticulturally propagated species subject to dispersal by wind and wildlife and shallow water table responses to local landscape design changes and / or global temperature changes over time. Moreover, it is incumbent on the Park's information and data stewards to help Park Managers, to the degree possible, distinguish between global, regional, and local factors affecting the Park's vegetation.

7.2.2 Land Cover and Carbon Sequestration Analysis

The land cover classification and carbon sequestration analysis of the 2018 Discovery Park aerial imagery provided a valuable insight into the current status and value of the park's landscape, however there are limitations and caveats to each of these analyses. The land cover classification is a simplified version of the more standard NLCD 2011 classification method, with this classification schema containing only four classes: barren/developed, mixed forest, shrubland, and grassland. While these four classes provide a solid understanding of the current land cover status for the park, a more detailed, intensive classification analysis would undoubtedly be beneficial to a better understanding of the current land cover status for the park. Moving forward, it is recommended that a more complete land cover classification be completed with the 2018 aerial imagery.

Regarding the carbon sequestration valuation, the perceived per acre monetary value assigned to each land cover class is based off of data provided by Earth Economics, who conducted a more robust, complete ecosystem services valuation for the park based off of the NLCD 2011 dataset. The per acre values for mixed forest, shrubland, and grassland were utilized for the 2018 carbon sequestration analysis, however these do not necessarily represent the current market values, but rather the perceived market values for when the Earth Economics analysis was conducted. Utilizing the same values for both analyses provides a baseline for comparing changes in ecosystem services valuation between 2011 and 2018, however the values for the 2018 do not necessarily represent the up to date 2018 market value for carbon sequestration. Moving forward, identifying up to date market values for carbon sequestration would provide a more accurate depiction of the current value for the landscape of Discovery Park.

The 2018 land cover classification provides a representation of the current land cover status for Discovery Park, however without the 1990 and 1968 imagery classified into the same land cover categories as the 2018 imagery, a quantitative analysis of the change in land cover over time for the park is not available. Land cover classification of 1990 and 1968 was not possible given the time constraints for this project, however moving forward the creation of these land cover datasets would provide a valuable means for tracking the changes in the land cover of the park over time related to rehabilitation efforts undertaken within the park as part of the overall land management practices. The 2018 land cover data does, however, provide a baseline for tracking land cover change for the future of the park.

7.2.3 Visitation Analyses and Collector-based CRUD Interface

InVEST Recreation data provided a helpful insight, but given limited usage of Flickr and the current date restriction of InVEST Recreation data (2005-2014), we recommend that additional data sources be sought out as they become available. This data represents a good first step, and it is expected that additional data sources could help illuminate changing visitation patterns in the park. If the InVEST Recreation model allows for more recent data, it is recommended that the monthly visitation attributes be utilized. While not a focus in this project, this could allow for detecting any seasonal changes in visitation across the park.

Regarding the Collector-based CRUD Interface, it appears that FoDP has two choices moving forward involving interactive processing capabilities. The CRUD Interface should allow for similar or greater capabilities to an online processing environment, such as a web app and the capabilities of ArcGIS Enterprise, while exhausting zero service credits. However, it is split between two programs (Collector and ArcGIS Pro) and thus is not seamless and requires some experience with these programs.

The other choice involves investing in annual subscription to a non-profit license of ArcGIS Enterprise, and also setting up an independent server on which to host an enterprise geodatabase. This undertaking exceeded the skills and time resources of our group this quarter, but could be a fruitful future path forward, especially towards creating a web app with on-the-fly processing capabilities.

7.2.4 Platform A - Interactive Web Application

Platform A, in its current state, represents an important step forward in the creation of an interactive web map/application which can provide a holistic representation of the many complex relationships between the various environmental and social aspects of Discovery Park. The platform is, however, far from complete. While the Collector-based CRUD Interface, mentioned above, provides a means for the user to analyse particular locations of the park through the drawing of a polygon, a more integrated tool existing within the platform would be beneficial. Particularly, a means for the user to change certain aspects of a location (vegetation class, land cover, moisture/weed index, etc.) would provide a powerful planning tool for stakeholders regarding how to best manage a particular plot of land based on individual stakeholders land management/land status goals. This type of tool is not currently possible without a GIS server and/or ArcGIS Enterprise license. Should the Friends of Discovery Park build a server and gain access to an ArcGIS Enterprise license, this tool should be a high priority for future work.

Additional analysis elements should also be considered moving forward to further the holistic representation of the park and its many entities. The specific relationship between human interaction with the vegetation and wildlife within the park, specifically, is not currently fully represented within the current platform. With a more fine-grained vegetation analysis, an analysis of the vegetation most impacted by human visitation to the park can be better understood, which is also true of the impacts human visitation has on wildlife, specifically birds, within the park. Further research and higher quality data acquisition of bird and specific vegetation data for the park would undoubtedly provide a better understand of how human visitation impacts the natural environment of the park. The current platform is well established to handle this data if/when it is available, and set up to meaningful display the data within the friendly user interface.

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US Department of Agriculture - Natural Resource Conservation Service Plant Database.

https://plants.sc.egov.usda.gov/java/

9. Technical Appendices

Appendix A. Contacts for data.

Green Seattle Partnerships (GSP)

Andrea Mojzak - Main GSP contact at Forterra, the 5013c partner of Seattle Parks
Knows about Discovery Park restoration projects and associated data
amojzak@forterra.org
206-619-1121
901 5th Ave Suite 2200 Seattle, WA 98164

Jesse Alton - Consultant responsible for GSP Interactive Habitat Map in AGOL
Knows how to filter map to extract Discovery Park data and export to save file but right now the save file is stored on GSP AGOL account and full dataset layers need to be imported into FoDP AGOL.
jesse@pugetsoundgis.com

Markus Rook - markus@pugetsoundgis.com

Seattle Parks and Recreation

Jordan Ng - Seattle PaIS
Provides data for Parks mapping projects and GSP online map.
Jordan.Ng@seattle.gov
206-233-2035

Michael Yadrick - Plant Ecologist
Handles contractors and Natural Area Crew
Should be aware of any vegetation inventory work and VMP
michael.yadrick@seattle.gov
206-615-1056

Eric Sterner - Plant Ecologist
Handles volunteers, CEDAR tracking system for work on GSP sites and plant orders
eric.sterner@seattle.gov
Office: 206-386-1982 Mobile: 206-423-9878

Lisa Ciecko - Plant Ecologist
Handles consultants and mapping/monitoring
Should know about recent plant inventory work
lisa.ciecko@seattle.gov
206-386-1371

Deb Brown McRarry - Urban Forest Manager
Has the Seattle Tree database info among other datasets.
deb.brown@seattle.gov

Jon Jainga - Manager of Plant Ecologists
Person we have been trying to lobby to fund update of 2002 Discovery Park VMP
jon.jainga@seattle.gov

ICF (absorbed Jones & Stoke, VMP authors in 2002)

Jon Walker - GIS specialist
Knows data gathering protocol; for VMP and may have survey point GPS data and imagery for appendices.
jon.walker@icf.com
503-525-6147

EarthCorps - Actively restoring 20+ acres in Discovery Park

Nelson Salisbury - Ecologist and GIS specialist
Did original GSP Interactive Habitat Map
Was once part of 2000 Seattle Urban Nature Project (SUNP) which was absorbed into EarthCorp. The 2000 project mapped invasive coverage in Seattle parks. I have the map for Discovery Park. Did an inventory of Discovery Park and 20+ monitoring plots 2010-2014. Helped create the 20 management zones in the VMP that are used in the GSP online map.
nelson@earthcorps.org
6310 NE 74th St Suite 201E Seattle, WA 98115
206-322-9296 ext 214

Seattle Audubon Society (SAS)

Jenn Lang
Knows bird data and protocols
jenniferl@seattleaudubon.org

Seattle Audubon Society (SAS) (Cont)

Jennifer Lang
Conservation Science Coordinator
Seattle Audubon Society
8050 35th Ave NE, Seattle, WA 98115
(206) 523-8243 ext. 103
jenniferl@seattleaudubon.org
www.seattleaudubon.org

Megan Friesen
Provided us 2016-2017 bird data
meganf@seattleaudubon.org

Toby Ross
Data and GIS specialist
tobyr@seattleaudubon.org

Earth Economics

Matt Van Deren
Provided analysis for six ecosystem services provided by Discovery Park
mvanderen@eartheconomics.org
303-916-8110

107 N Tacoma Ave Tacoma, WA 98403

Seattle Trails Alliance (STA)
Provided us shapefiles and other data for official and social trails in Discovery Park

Brennan and Associates

Jim Brennan - Principal, Landscape architect and planner
Created an extensive trails report for Discovery Park 10 years ago
Provided us a DWG file which I was able to import into ArcMap that shows the layers for their trails report. Working on a plan to re-route South Beach Trail.

Brennan and Associates (Cont)

jim@jabrennan.com
206-583-0620
2701 First Avenue, Suite 510 Seattle, WA 98121

Trust for Public Land (TPL-National - Florida)

Fred Gifford
Offered us access to any of their ArcGIS Online data sets and will provide a one hour consulting call upon request with their GIS specialist
fred.gifford@tpl.org

Kroll Maps

Provided the printed map for Discovery Park for many years.
Has GIS data for Discovery Park
Is updating the map to provide online and in large form at Park kiosks.

Appendix B. Supplementary tables, charts, and reports.

Table 10. Discovery Park Flora Moisture and Weed Indexes.

ID	Genus	Species	Pcode	Mindex	Windex
1	Abies	amabilis	ABIAMA	4	1
126	Abies	grandis	ABIGRA	4	1
2	Acer	macrophyllum	ACEMAC	4	1
3	Acer	platanoides	ACEPLA	4	3
4	Acer	circinatum	ACECIR	3	1
5	Acer	pseudoplatanus	ACEPSE	5	3
6	Achillea	millefolium	ACHMIL	4	3
7	Agroelymus	adamsii	AGRADA	3	3
137	Agropyron	repens	AGRREP	3	3
8	Agrostis	alba	AGRALB	3	3
9	Agrostis	stolonifera	AGRSTO	3	3
10	Alnus	rubra	ALNRUB	3	1
11	Amelanchier	alnifolia	AMEALN	4	1
12	Anaphalis	margaritacea	ANAMAR	4	1

13	Anthemis	cotula	ANTCOT	4	3
152	Anthoxanthum	odoratum	ANTODO	4	3
14	Arbutus	menziesii	ARBMEN	5	1
15	Athyrium	filix-femina	ATHFEM	3	1
16	Berberis	nervosa	BERNER	4	1
17	Berberis	aquifolium	BERAQU	4	1
18	Bromus	spp	BROSPP	4	3
19	Bromus	sitchensis	BROSIT	5	1
20	Cardamine	occidentalis	CAROCC	2	1
21	Carex	deweyana	CARDEW	3	1
22	Carex	obnupta	CAROBN	1	1
128	Carex	densa	CARDEN	2	1
149	Cedrus	deodara	CEDDEO	5	3
23	Chanerion	angustifolium	CHAANG	4	1
24	Cirsium	arvense	CIRARV	3	3
25	Claytonia	sibirica	CLASIB	3	1
26	Clematis	vitalba	CLEVIT	3	5

27	Cornus	sericea	CORSER	2	1
148	Cornus	nuttallii	CORNUT	4	1
28	Corylus	cornuta v californica	CORCOR	4	1
29	Cotula	spp	COTSPP	4	3
30	Crataegus	douglasii	CRATDOU	3	1
31	Cytisus	scoparious	CYTSCO	5	5
32	Dactylis	glomerata	DACGLO	4	3
33	Daphne	laureola	DAPLAU	5	3
34	Digitalis	purpurea	DIGPUR	4	1
35	Dryopteris	expansa	DRYEXP	2	1
151	Elymus	glaucus	ELYGLA	4	1
118	Epilobium	angustifolium	EPIANG	4	1
139	Epilobium	ciliatum	EPICIL	2	1
36	Equisetum	arvense	EQUARV	3	3
37	Equisetum	telmateia	EQUTEL	2	3
38	Eschscholzia	californica	ESCCAL	4	3
39	Festuca	arundinacea	FESARU	3	3

138	Festuca	rubra	FESRUB	3	3
40	Frangula	purshiana	FRAPUR	3	1
41	Galium	aparine	GALAPE	4	3
125	Galium	spp	GALSPP	4	1
42	Gaultheria	shallon	GAUSHA	4	1
43	Geranium	robertianum	GERROB	4	1
44	Geum	macrophyllum	GEUMAC	3	1
45	Glyceria	occidentalis	GLYOCC	1	1
123	Glyceria	elata	GLYELA	2	1
46	Hedera	helix	HEDHEL	5	5
47	Holcus	lanatus	HOLLAN	3	3
48	Holodiscus	discolor	HOLDIS	4	1
49	Hydrangea	arborescens	HYDARB	5	3
136	Hydrophyllum	tenuipes	HYDTEN	3	1
50	Hypochaeris	radicata	HYPRAD	4	5
51	Ilex	aquifolium	ILEAQU	4	3
52	Iris	pseudacorus	IRIPSE	1	5

121	Juncus	effusus	JUNEFF	2	1
133	Juniper	spp	JUNSPP	5	3
53	Lamium	purpureum	LAMPUR	5	3
131	Lathyrus	latifolia	LATLAT	5	3
54	Lonicera	hispidula	LONHIS	4	1
55	Lonicera	ciliosa	LONCIL	4	1
56	Lonicera	hirsuta	LONHIR	5	3
57	Lupinus	rivularis	LUPRIV	3	1
141	Luzula	SPP	LUZSPP	4	1
58	Lysichiton	americanus	LYSAMER	1	1
132	Lysimachia	nummularia	LYSNUM	2	3
59	Maianthemum	stellatum	MAISTE	3	1
60	Malus	fusca	MALFUS	2	1
154	Malus	spp	MALSPP	2	1
61	Mitella	caulescens	MITCAU	3	1
62	Oemleria	cerasiformis	OEMCER	4	1
119	Oenanthe	sarmentosa	OENSAR	1	1

63	Oplopanax	horridus	OPLHOR	2	1
122	Osmorhiza	chilenses	OSMCHI	4	1
64	Phalaris	arundinacea	PHAARU	2	5
65	Physocarpus	capitatus	PHYCAP	2	1
66	Pinus	ponderosa	PIPO	4	1
67	Pinus	contorta	PICO	3	1
146	Pinus	spp	PINSPP	4	3
68	Plantago	lanceolata	PLALAN	4	3
69	Plantago	major	PLAMAJ	3	3
70	Poa	pratensis	POAPRA	3	3
129	Poa	spp	POASPP	4	3
71	Polygonum	cuspidatum	POLCUS	4	5
143	Polypodium	glycyrrhiza	POLGLY	5	1
72	Polystichum	munitum	POLMUN	5	1
73	Populus	balsamifera	POPBAL	3	1
147	Populus	deltoides	POPDEL	3	1
74	Prunella	laciniata	PRULAC	5	1

75	Prunella	vulgaris	PRUVUL	4	3
76	Prunus	laurocerasus	PRULAU	5	3
77	Prunus	lusitanica	PRULUS	5	3
78	Prunus	emarginata	PRUEMA	4	1
79	Pseudotsuga	menziesii	PSEMEN	4	1
80	Pteridium	aquilinum	PTEAQU	4	1
81	Quercus	garryana	QUEGAR	4	1
82	Ranunculus	repens	RANREP	3	3
83	Ribes	sanguineum	RIBSAN	4	1
84	Ribes	lacustre	RIBLAC	3	1
142	Ribes	bracteosum	RIBBRA	3	1
85	Robinia	pseudoacacia	ROBPSE	4	3
86	Rosa	gymnocarpa	ROSGYM	4	1
124	Rosa	spp	ROSSPP	4	1
87	Rubus	ursinus	RUBURS	4	1
88	Rubus	armeniacus	RUBARM	4	5
89	Rubus	spectabilis	RUBSPE	3	1

90	Rubus	leucodermis	RUBLEU	4	3
91	Rubus	spp	RUBSPP	4	3
134	Rubus	parviflorus	RUBPAR	4	1
92	Rumex	acetosella	RUMACE	4	3
127	Rumex	crispus	RUMCRI	3	3
93	Salix	spp	SALSPP	2	1
94	Salix	sitchensis	SALSIT	2	1
95	Salix	scouleriana	SALSCO	2	1
130	Salix	lucida	SALLUC	2	1
144	Salix	alba	SALALB	2	3
96	Sambucus	racemosa	SAMRAC	4	1
145	Schoenoplectus	acutus	SCHACU	1	1
97	Scilla	spp	SCISPP	5	3
140	Scirpus	microcarpus	SCIMIC	1	1
98	Sorbus	aucuparia	SORAUC	3	3
99	Spiraea	douglasii	SPIDOU	2	1
100	Stellaria	media	STEMED	4	3

101	Symphoricarpos	albus	SYMALB	4	1
102	Taraxacum	officinale	TAROFF	4	3
103	Taxus	brevifolia	TAXBRE	4	1
117	Tellima	grandiflora	TELGRA	4	1
155	Thalictrum	occidentale	THAOCC	4	1
104	Thuja	plicata	THUPLI	3	1
105	Thuja	occidentalis	THUOCC	5	3
106	Tolmiea	menziesii	TOLMEN	3	1
107	Trifolium	pratense	TRIPRA	4	3
108	Tsuga	heterophylla	TSUHET	4	1
120	Typha	latifolia	TYPLAT	1	1
109	Unknown	grass	UNKGRA	5	3
110	Unknown	moss	UNKMOS	5	3
111	Urtica	dioica	URTDIO	3	1
112	Vaccinium	parvifolium	VACPAR	4	1
113	Vaccinium	ovatum	VACOVA	4	1
114	Veronica	americana	VERAME	1	1

115	Viburnum	spp	VIBSPP	2	3
150	Viburnum	rhytidophyllum	VIBRHY	5	3
116	Vicia	americana	VICAME	3	3
135	Viola	orbiculata	VIOORB	5	1