Discovery Park Web GIS
Vegetation Monitoring and Reporting

John Marshall
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Background and Problem Statement

1.1 Background

Discovery Park in Seattle, Washington is a large urban park encompassing an approximate area of 500-acres along the northern coastline of the city. The park provides 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 and 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."*

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 to represent the contribution Discovery Park makes to the regions ecosystem services. If successful, this platform will be further developed and proposed for use within all Seattle city parks. Discovery Park is deemed to be a suitable pilot test location due to its diverse landscape and engaged organizational stakeholders.

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 ecosystem services the park provides. The platform will aid in addressing the problems which arise from the proximity of the park to a large urban area and the diversity of uses impacting the parks natural environments.

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 time constraints and resource limitations, it was determined that a subset of these issues would be focused on for inclusion into this phase of the platform creation and implementation. Based on a 2001 vegetation sampling effort, three primary objectives were established for inclusion within this project:

- Calculate and map plant indicator soil moisture indexes in Discovery Park;
- Calculate and map plant community weed indexes in Discovery Park; and
- Conduct a vegetation analysis for the park, including identifying dominant and subordinate species for each plant community represented.

2. System Resource Requirements

2.1 Data

Initially, data was provided in various formats: shapefiles, geodatabases, PNG and JPG files, Excel files, etc. The data were organized and integrated into a Microsoft Access database and a file geodatabase.

2.2 Hardware and Software

This project drew heavily on the ESRI suite of software and online tools. Data processing and analysis was conducted largely in ArcGIS Desktop.

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)

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.

3. Business Case Evaluation

3.1 Proposed Business Case for Discovery Park MGIS Capstone-2018

Benefits

Vegetation Monitoring and Reporting. 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. Additionally, this work recognizes that 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.

Type 1 Benefits (Quantifiable efficiencies in current practice):

The vegetation mapping component of this Capstone Project has three primary tasks:

1. Develop a weed index metric for Discovery Park, interpolate and map its predicted surface and overall average intensity over the vegetation layer of the entire park;
2. Develop a moisture index metric for Discovery Park, interpolate and map its predicted surface and overall average intensity over the vegetation layer of the entire park;
3. Improve the completeness of coverage, topological continuity, and accuracy of representation of the sampled plant community associations in Discovery Park.

From the perspective of Seattle Parks Department (a primary target beneficiary of the 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, another 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.

Type 2 Benefits (Quantifiable expanded or added capabilities):

The Microsoft Access Database created to track weed and moisture indexes, while crude in its present form, nevertheless allows for fast and efficient creation, update, and deletion of relevant data as well as a multitude of useful query operations. For example, using this crude workhorse 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 and never skip a beat as all the updated changes would instantaneously manifest in the calculated fields and display in the ongoing tracking report, for individual sample locations and the aggregated overall park condition relative to the weed index metric (measures how resilient current (date sampled) native vegetation is to nonnative species incursions).

While it is out of the scope of this immediate Capstone Project, this database should eventually migrate into a Microsoft SQL Server database in a web-based MVC application connected to an SDE, making this data accessible and manageable from multiple locations throughout an enterprise system that includes field monitoring and tracking, desktop / web interface retrieval and reporting. It would likely 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.

Type 3 Benefits (Quantifiable, unpredictable events):

On February 9, 2017, the West Point Wastewater Treatment Plant near the western border of Discovery Park underwent a catastrophic mechanical failure during a record breaking storm event resulting in 260-million gallons of untreated effluent to overflow into the Puget Sound as well as several smaller spillages in the following weeks as heavy rains continued to fall.

The proximity of Discovery Park to this wastewater treatment facility is inherently a high risk venture. There should never be a question whether this kind of failure will reoccur, it will. It’s just a matter of time. And when it does, just as it did in February of 2017, many of the ecosystem services Discovery Park supports will be significantly impaired by the event.

The error in this case was not the site selection for the park, but rather the site selection for the wastewater treatment facility. Ideally it should be moved to an area where there are less conflicting public trust resources, not an easy place to find along the Puget Sound shoreline.

At least for the foreseeable future it is here to stay and per that reality future park planning should give deference to what possible contingencies can be called into action the next time a failure occurs. Events like this are often considered unpredictable when in fact that is not the case. The problem is that we rarely learn enough from past events to adequately prepare for their future counterparts.

Fortunately Discovery Park is not at the receiving end of the outfall pipe but wildlife and humans may permeate in and out of that western border potentially putting themselves in harm’s way. For wildlife perhaps some sort of benign net traps frequently checked and / or loud noise makers causing avoidance behavior could help mitigate some of their exposure. For people, it requires adequate signage and routine staff check-ins to make sure people are following the proper safety rules in the area. OSHA rules at the plant itself should also be strictly enforced. All of these and other potential contingency measure are easily quantifiable in anticipated dollar expenditures.

Type 4 Benefits (Intangible benefits related to intangible [less tangible] advantages):

My recent work on this database reminded me of something that I had not thought about in a while. And that is how much I love to walk outside in the wild areas and enjoy their natural beauty and splendor. How could working with widgets, SQL script, and entering data accomplish that? Well, it so happens that all the plants populating and informing this database are plants I have been out walking next to for my entire life. It was almost like virtually visiting with old friends, resulting in a difficult to describe sense of appreciation and wellbeing.

Further, knowing this work will add to the protection and preservation of these species for future generations, goes directly to a sense of accomplishment and satisfaction. Which actually brings me my main point, this project is contributing to the opportunity for countless others and those who are not even born yet to have this same connection with the natural world, a priceless commodity wouldn't you say? While some may argue this is an intangible aspect of the human condition, I beg to differ. It is as real and solid to me as any type of currency or material possession.

Type 5 Benefits (Quantifiable sale of information):

All information should be made open source, especially if generated by a public facility. The same can be said for private non-profit organizations with a stewardship mission.

Costs

Capital Expenditures on Database Design and Development:

The building of any database, spatial or non-spatial, if done correctly requires an incredible amount of work in pre-planning design and organization, researching the 'business or organization' needs of the future users, actual reiterative trial and error construction, and ongoing operations and maintenance. And after the database is completed and open for business, that's when the real work begins, managing, cleaning, and updating the data. If done poorly, it makes the work environment very difficult and frustrating to navigate but if done correctly, a very smooth and efficient well-oiled workplace ensues. Poor database design, construction, and maintenance results in high costs. Good database design, construction, and maintenance results in high savings. And if a database has a public interface, then the image of the organization in charge of the database is reflected by the public experience regarding that interaction!

Capital Expenditures on Hardware and Software:

These costs are highly correlated with periodical upgrades of obsolete technology, including but not necessarily limited to laptop/desktop computers, GPS devices, handheld recorders, unmanned aerial vehicles, LiDAR, digital cameras, cell phones, VR devices, etc.

Capital Expenditures on Implementation:

These costs are likely to include such things as GIS-service fees, employee salaries and benefits, employee travel and training, telephone coverage, etc. To date, most of the time has been spent on the database development and data entry but a fair amount of time has also been spent in ArcMap and ArcGIS Pro projects, building file geodatabases, writing status reports, workflows, as well as ArcGIS online (AGOL) research with different web applications. There has also been some effort into learning more about the utility and practicality of developing with ESRI code snippets.

Benefit-Cost Analysis

So far, we have devoted or discussion to the benefits and costs associated with the Discovery Park MGIS Capstone Project to a series of more-or-less conceptual discussions. But how do these concepts translate into a dollar based currency? This section of the report attempts to draw those connecting lines

BUDGET TOTALS	ESTIMATED	ACTUAL	DIFFERENCE
Income	1,650.00	1,825.00	175.00
Expenses	2,010.00	1,992.24	17.76
Balance (Income minus Expenses)	(360.0)	(167.24)	192.76

Figure 1. Benefit / Cost Balance Discovery Park MGIS Capstone Project 2018.

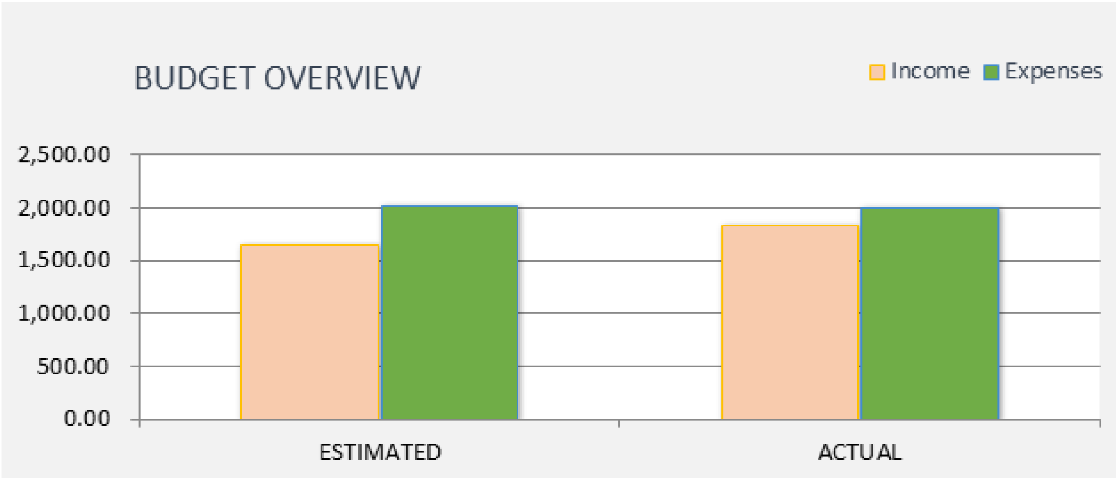

Figure 2. Budget Overview.

between concepts and line item budget items.

Revenue Sources

The nature of the MGIS Discovery Park Capstone project is to help the Discovery Park stakeholders, including the Friends of Discovery Park, to better navigate technologies that will empower their effectiveness at protecting and managing Discovery Park ecosystem services for current and future generations, the hallmark of natural resource sustainability. There are a number of people and like-minded organizations in this Puget Sound region who share common goals and objectives. Many of them are potential revenue sources for projects like this one.

REVENUE SOURCES	ESTIMATED	ACTUAL	DIFFERENCE
Puget Sound Partnership Grant	400.00	450.00	50.00
Stakeholder Donations	250.00	300.00	50.00
City of Seattle Parks Fund	500.00	450.00	(50.00)
Voluntary Conservation Credit Sales	250.00	325.00	75.00
Park Savings Per Efficiency	250.00	300.00	50.00
Total Income	1,650.00	1,825.00	175.00

Figure 3. Revenue Sources.

Part of the project assignment has been to outline a path showing how people and organizations might be approached for assistance toward a common cause, and what that assistance might look like in 1-year funded extension of the initial MGIS Capstone Project. A prerequisite to that objective entails a benefit /

cost analysis of the anticipated completed Project (see Figures 1 and 2). With that said, please bear in mind this is a hypothetical representation presented for illustration purposes only.

Puget Sound Partnership Grant. In this hypothetical scenario, a 3-person Project Team has found a way to be employed part-time as staff members of the Friends of Discovery Park (FoDP) organization using funding from a Puget Sound Partnership Grant. The Project Team applied for the grant in the name of the FoDP, who subsequently received a 24,000 dollar grant award to partially cover the project expenses over a one-year period (see first income line item in Figure 3). With the help of the FoDP, the Team identified and secured three supplemental sources of income to help support their extended Program.

Stakeholder Donations. As a private for non-profit 501c3 organization, FoDP receives monthly voluntary donations from its members. Through a unanimous vote the FoDP steering committee dedicated 300 dollars a week towards the support of a 1-year extended Project (see Figure 3, line item 2).

City of Seattle Parks Fund. In addition, the FoDP chairman requested and was awarded 450 dollars a week toward funding the project from the Seattle Parks Fund (see Figure 3, line item Seattle Parks Fund money was contingent on a prepared demonstration to the Seattle City Parks Board of Commissioners that the initial Capstone Project deliverables will generate Seattle Park operation and management cost efficiencies, saving the parks from significant revenue obligations in the foreseeable future. Part of this decision was contingent on the Project Team demonstrating the deliverables provided by the initial Discovery Park Capstone effort were exportable to other Seattle City Parks.

Voluntary Conservation Credit Sales. One of the initial MGIS Capstone Project deliverables was the creation of an online virtual voluntary credit exchange system that allows public citizens to buy Discovery Park generated ecosystem service credits (identified and monetized by the Team's web application) in exchange for a memorialized certificate of transaction per the online code-first database created specifically for the virtual credit exchange. The revenue source became so reliable the Seattle City Parks Department allowed up to 325 dollars a week from the credit sales to be dedicated to the Team's 1-year extended Capstone Project (see Figure 3, line item 4).

Park Savings by Efficiency. After the Team's group presentation of their initial MGIS Capstone Project was completed, and all the deliverables were made available to the FoDP and their stakeholders, several Seattle City Park managers reviewed copies of the work and determined the Capstone Team had significantly undervalued the cost savings they would accrue through the use of their deliverables if they were deployed to their parks. Recognizing that such a deployment would be significantly expedited by funding of the 1-year extended Capstone Project, they were able to use funds from the individual park budgets to collectively dedicate up to 300 dollars a week to fund the Team's 1-year extended Capstone Project under a budget line item called 'Park Savings Per Efficiency' (see Figure 3, line item 5).

Grantee Expenses

Wages. The Project Team estimated that on an average all three people would collectively work about 37-hours a week on the 1-year extended Capstone Project and applied an hourly wage estimate for a 'typical' GIS Analyst at $28.68 per hour (see Figure 4, line item 1).

Employee Benefits. The FoDP insisted that the Project also receive about $135 per week toward paying for limited duration sick leave and a minimal basic health insurance package in case one or more of us might need to take advantage of such coverage over the course of our 1- year extended Project (see Figure 4, line item 2).

Conferences/Training. Several of the tasks the team will be taking on are highly technical specialized database and web application related code development workflows. To-date, each Team member has limited exposures to these technologies and recognize additional specialized training targeted toward specific project objectives would ultimately make for more efficient and more productive employees. The immediate supervisor at the FoDP agreed and provided a budget for about 75-dollars a week to be set aside for the extended Project related training and conferences (see Figure 4, line item 3).

Operating Expenses

Travel. Travel expenses may include vehicle rental, mileage, and gas to training or conferences, meetings with park managers and stakeholder groups, as well as potential field work.

Per Diem. Per diem costs would include room rentals and meals while traveling.

Office Supplies. Basic pen and notepads plus thumb drives, external hard drives, and other related accessories are covered under office supplies costs.

Grantee Expenses	Estimated	Actual	Difference
Wages	1,000.00	987.86	12.14
Employee benefits	150.00	135.00	15.00
Conferences / Training	100.00	75.00	25.00
Total Grantee Expenses	1,250.00	1,197.86	52.14
Total Operating Expenses	760.00	794.38	(34.38)

Figure 4. Grantee Expenses

Taxes. Taxes levied on employee purchases are covered under this line item.

GIS Services. This line item covers such expenditures a streaming GIS related services, AGOL credit expenditures, annual enterprise licensing fees, etc.

Telephone/Internet. Telephone and internet installation and service fees are covered under this line item.

Collectively each of the above budget line item costs represent the exchange value of the extended Project deliverables to the employers and revenue source organizations listed above.

It is beyond the scope of this document to provide a detailed workflow displaying the monetary values of each of the extended Project's anticipated deliverables, but one example (a weed surface index) is presented in Figure 6 to illustrate its potential monetary value in the context of an ecosystem service credit/debit market exchange transaction.[1] In this following scenario, performance penalties are proportionally levied against acreage encumbered with higher weed indexes and thereby limiting the credit sales potential at a wet-prairie mitigation bank, giving the mitigation bank sponsor a financial incentive to reduce or eliminate the weed problem.

Operating Expenses	Estimated	Actual	Difference
Travel	60.00	75.00	(15.00)
Per Diem	50.00	49.25	0.75
Office Supplies	30.00	35.78	(5.78)
Telephone/Internet	450.00	475.00	(25.00)
Taxes	120.00	110.00	10.00
GIS Services	50.00	49.35	0.65
Total Operating Expenses	760.00	794.38	(34.38)

Figure 5. Operating Expenses.

[1] Note this hypothetical scenario could represent a weed index related performance measure threshold range for both market debit/credit driven exchanges and volunteer credit sale exchanges.

Hypothetical Wetland Mitigation Bank Management Unit A Credit Release Based on One Component (Weed Index 1 = low, 2 = med. low, 3 = med. high, 4 = high) of Vegetation Performance - based on assumption of Credit Value at $75,000.00

WeedClass	WIndexRange	Acres	PotCredits	Penalty	AvaiCredits	CreditValue
1	1 – 2	18.91	9.455	0	9.455	$709,125.00
2	2 – 3	11.14	5.57	0.25	4.1775	$313,312.50
3	3 – 4	3.56	1.78	0.50	0.89	$66,750.00
4	4 – 5	0.71	0.355	0.75	0.08875	$6,656.25
Total		34.32	17.16		14.61	$1,095,843.75

Figure 6. Hypothetical Weed Index Informed Mitigation Bank Performance Penalties.

17.16 x $75,000 = $1,287,000. $1,287,000 - $1,095,843.75 ~ $191,155.00 incentive to address the weed issues.

Feasibility of Seattle City Parks Participation in an Ecosystem Service Market Exchange as Credit Seller and / or as Credit Buyer.

As a public land and open space manager, the City of Seattle Parks Department is already an ecosystem service provider (e.g., carbon sequestration, fish and wildlife habitat, water quality, and many more) through its stewardship and management of City Parks like Discovery Park.

Both the City of Seattle and its Parks Department are also developers that on occasion have an adverse impact on a number of ecosystem services. When these adverse impacts are regulated by Federal, State, and local government law, the City may be required to provide compensatory actions to offset their adverse impacts. In these instances, the City is automatically required to be engaged in one or more ecosystem service trade transactions that invoke considerable financial costs. The question is, could the City of Seattle better manage these costs while simultaneously aiding in the recovery of city-wide and regional ecosystem services by becoming more proactively involved in ecosystem service trade markets?

The answer requires a feasibility study that is beyond the scope of this paper. But at the outset, such a venture would require a considerable effort (see Appendix C) and commitment of taxpayer funded resources and that there are at least two looming issues that should be addressed relatively early in the analyses:

1. In instances where the City of Seattle may find it is a regulatory authority with oversight influence over itself, can a protocol be followed that assures there are no legal conflicts of interest associated with these cases?

2. Can the City of Seattle effectively demonstrate that any credits it may accrue as an ecosystem service provider, and that would ultimately be traded against debits incurred by either City projects or other third party developers, would reflect mitigation efforts that increase the baseline of ecosystem service above and beyond that which would normally be expected of existing City operations and maintenance without a banking program?

Another alternative for the City of Seattle to consider is that there are what are called voluntary ecosystem markets. This basically means that there are likely opportunities through public messaging to persuade people that voluntary donations to the City for ecosystem services already rendered can help ensure their continued availability into the foreseeable future.

There are precedents for establishing public mitigation banks represented by a number of state transportation departments, cities like Eugene, Oregon, certain ports, etc. Often, they are single user banks in that they are dedicated to off-setting only their own project related debits. But Public banks may also trade with third-parties as well. A review of Appendix C should assist anyone who wishes to look into this further toward finding relevant answers directly and / or contacts who can answer questions and discuss specific concerns.

4. Data Development

4.1. Performing Data Acquisition

4.1.1 Data Source Steps

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.

4.2 A Logical Schema for Discovery Park Geodatabase

Phase one of the logical schema development involved integrating datasets from organizational resources into an organized geodatabase (See Table 1 and Figure 7). At a minimum the database was normalized to the third normal form (Codd 1990). In other words (Hernandez 2013):

"Each table in the database contains 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.

Table 1. Logical Schema.

Feature Dataset	**Feature Class/ Raster**	**Spatial Object Type**	**Description**	**Source**
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	ICF - Edited / Geoprocessed
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	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	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 UTM Zone 10 North	Washington State Geospatial Data Archive
N/A	T10tet429782	Raster	2002 Discovery Park Aerial Imagery UTM Zone 10 North	Washington State Geospatial Data Archive
N/A	T10tet444767	Raster	2002 Discovery Park Aerial Imagery UTM Zone 10 North	Washington State Geospatial Data Archive
N/A	T10tet444782	Raster	2002 Discovery Park Aerial Imagery UTM Zone 10 North	Washington State Geospatial Data Archive

Projection: NAD_1983_HARN_StatePlane_Washington_North_FIPS_4601_Feet (EPSG: 2926)

The logical schema above provides a description of the 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 the project objectives. Conforming existing data and creating new data to meet project objectives required a wide variety of data naming convention modifications, schema design changes, additional metadata documentation, etc.

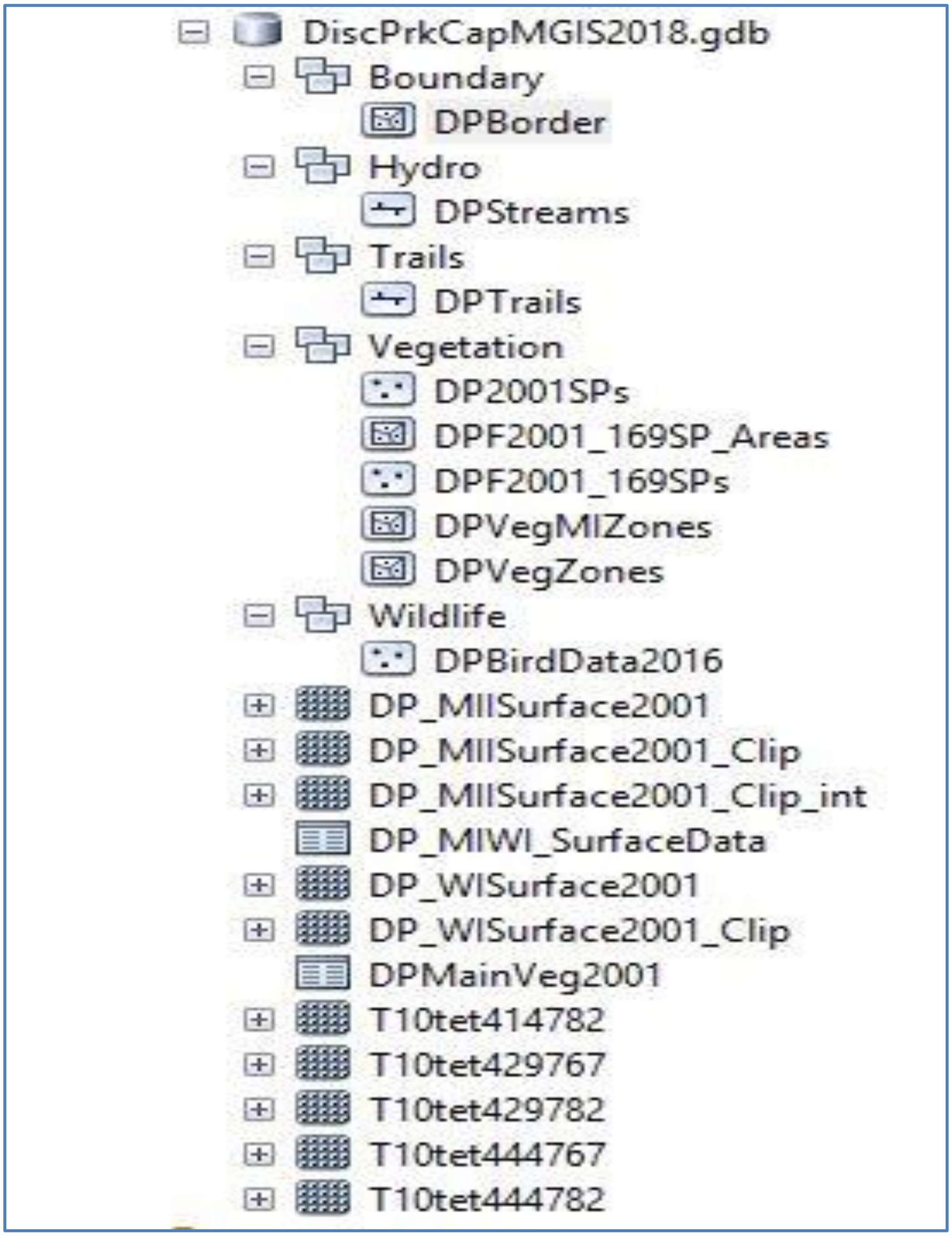

Figure 7. File Geodatabase Thematic and Organization Structure or Schema.

5. Workflow

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 8) 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 9 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).[2] A species table was created in the database and populated with Discovery Park plant species which were in turn assigned 'moisture ' and 'weed' indexes as attributes (Figure 10).[3] This table was then made into an operational 'pick-list' in the sample plot (Figure 11) table, a function that was automatically transferred to the data entry form (Figure 12) at the instance it was created.

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[2] 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.

[3] 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/

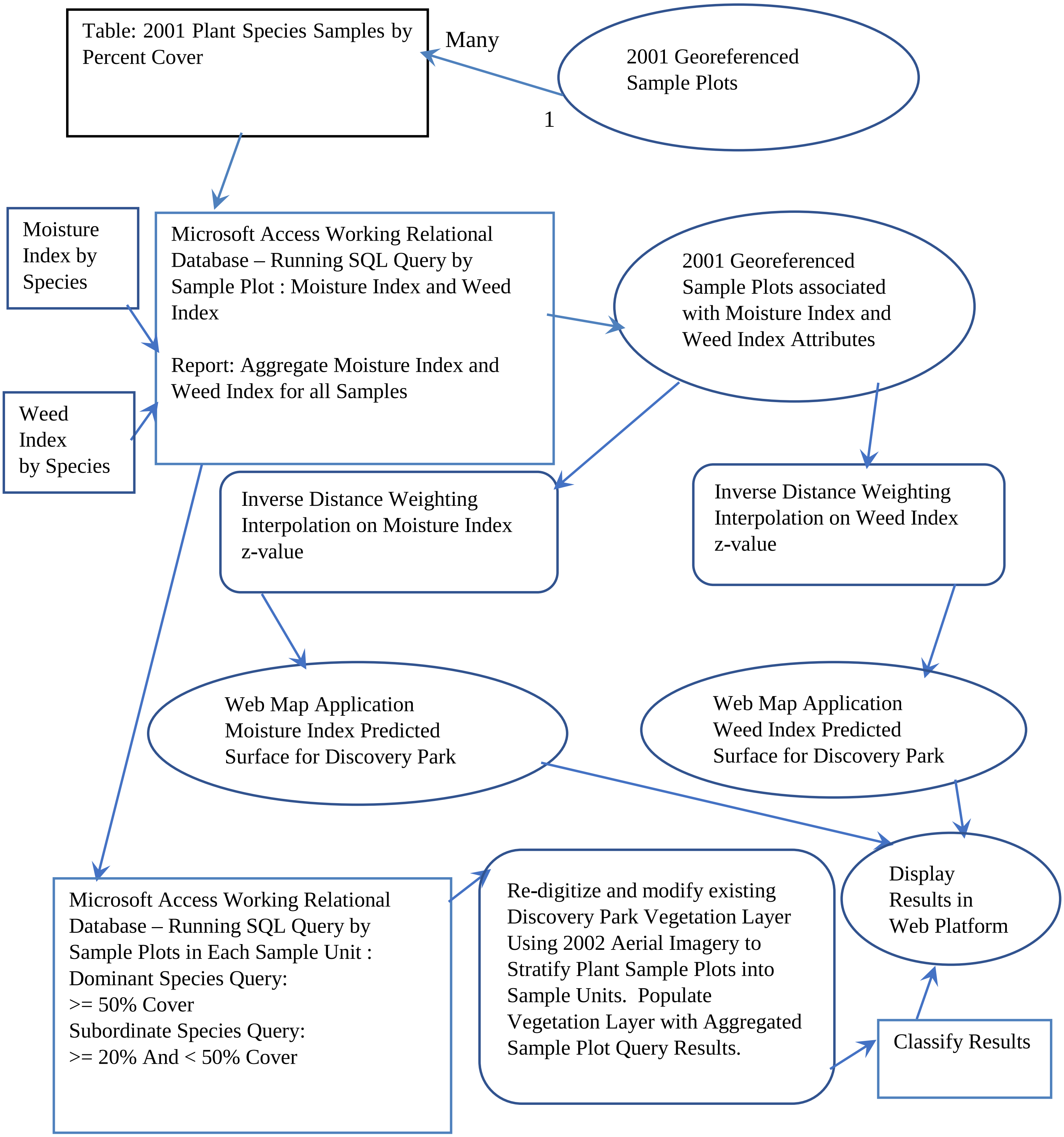


Figure 8. Workflow Diagram for Deriving and Mapping Predictive Weed and Plant Moisture Index Surfaces and Plant Community Feature Class for Discovery Park.

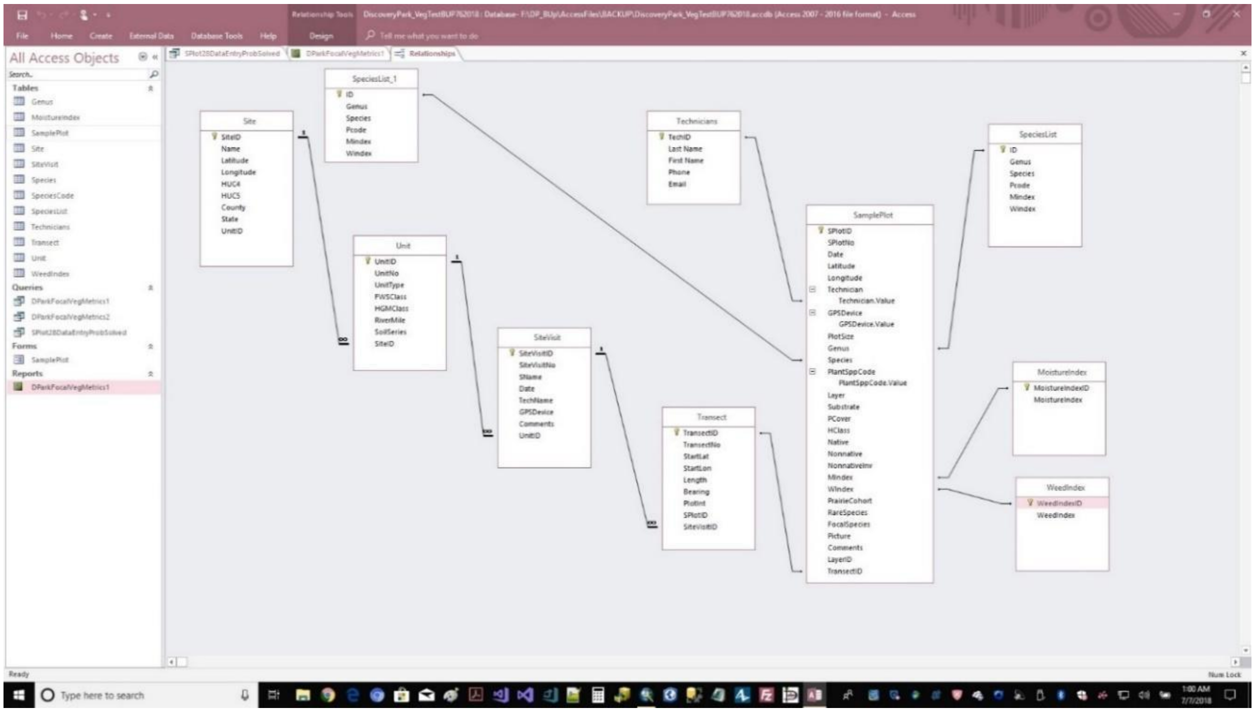
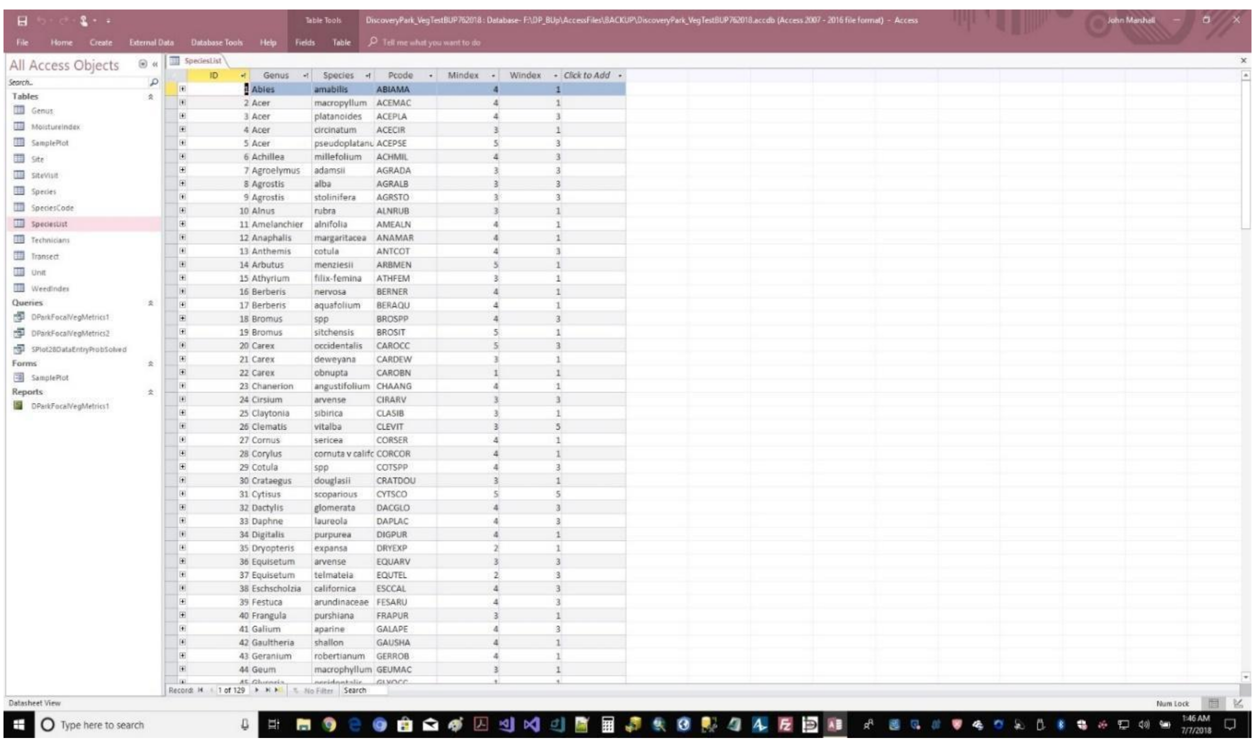


Figure 9. Discovery Park Plant Database Entity Relationships.



ID	Genus	Species	Pcode	Mindex	Windex
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 10. Example of Discovery Park Plant Species Moisture Index and Weed Index Metrics.

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 13 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 14) 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 20 and 21). 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 representation” of the predicted spatial distribution of those values. Final map representations of these surfaces are on pages 26 and 27 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

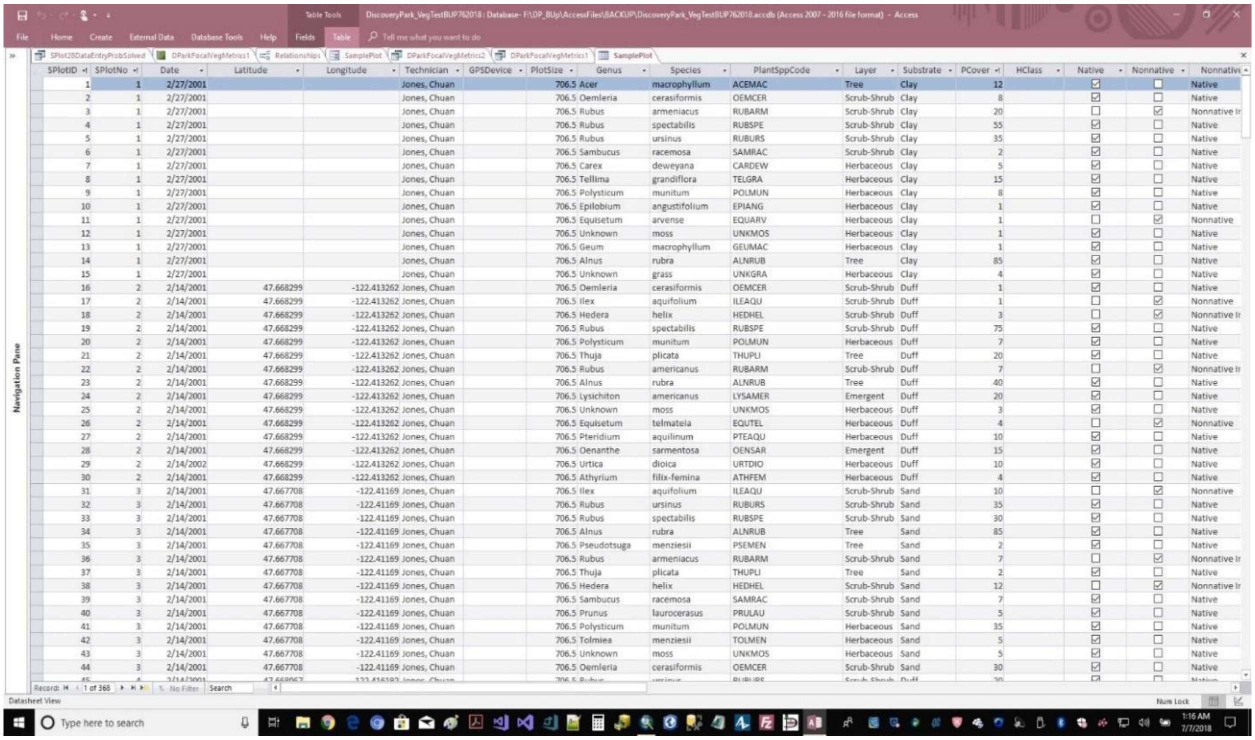


Figure 11. Discovery Park Plant Database Sample Plot Table.

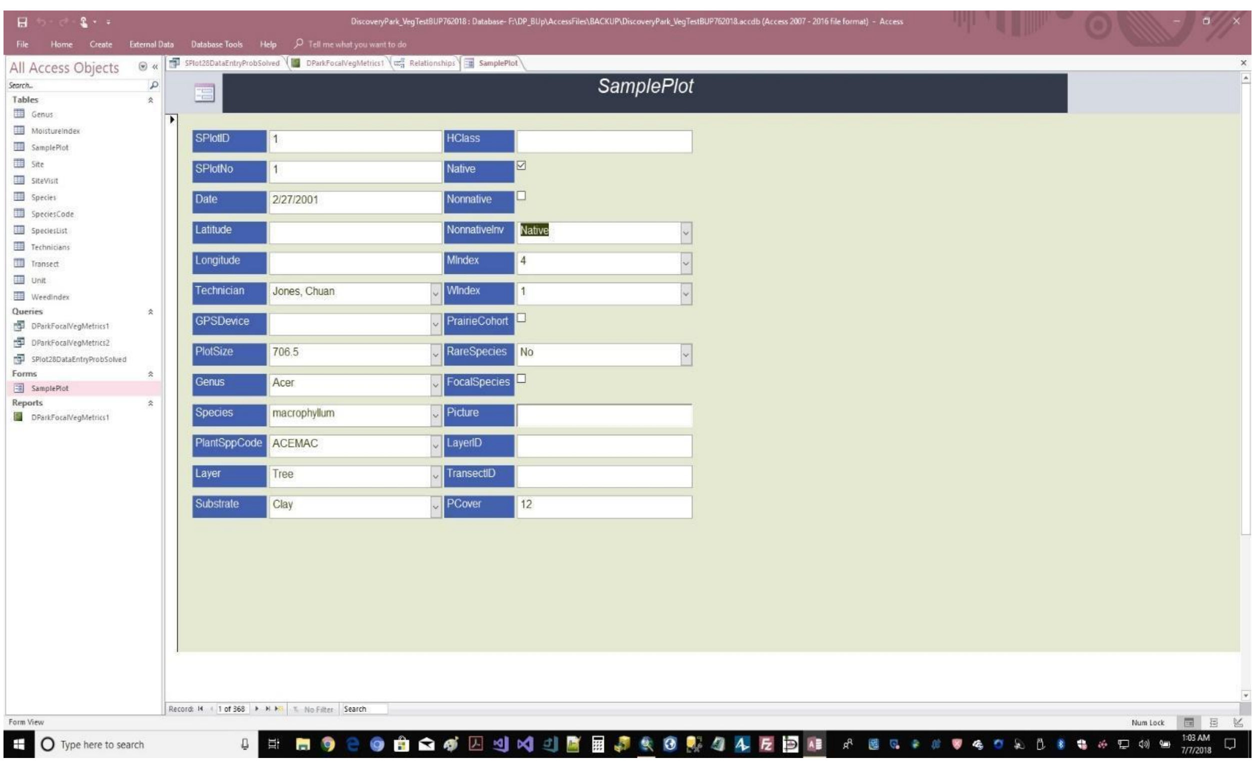
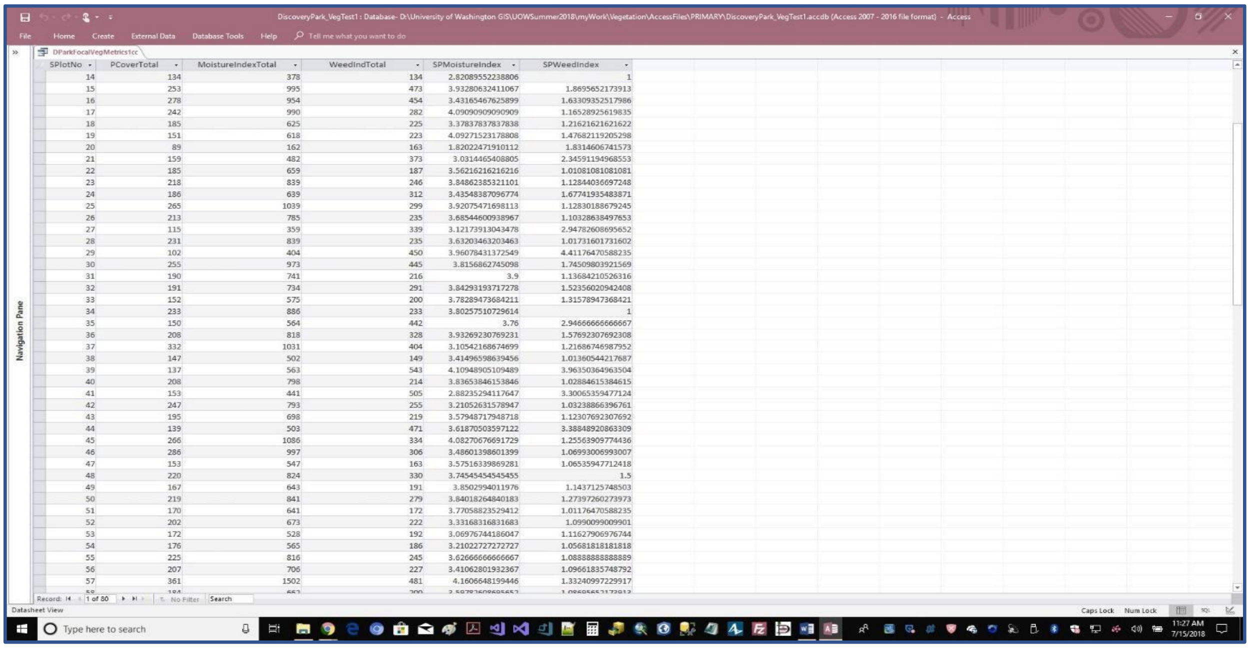


Figure 12. Discovery Park Plant Database Data Entry Form.



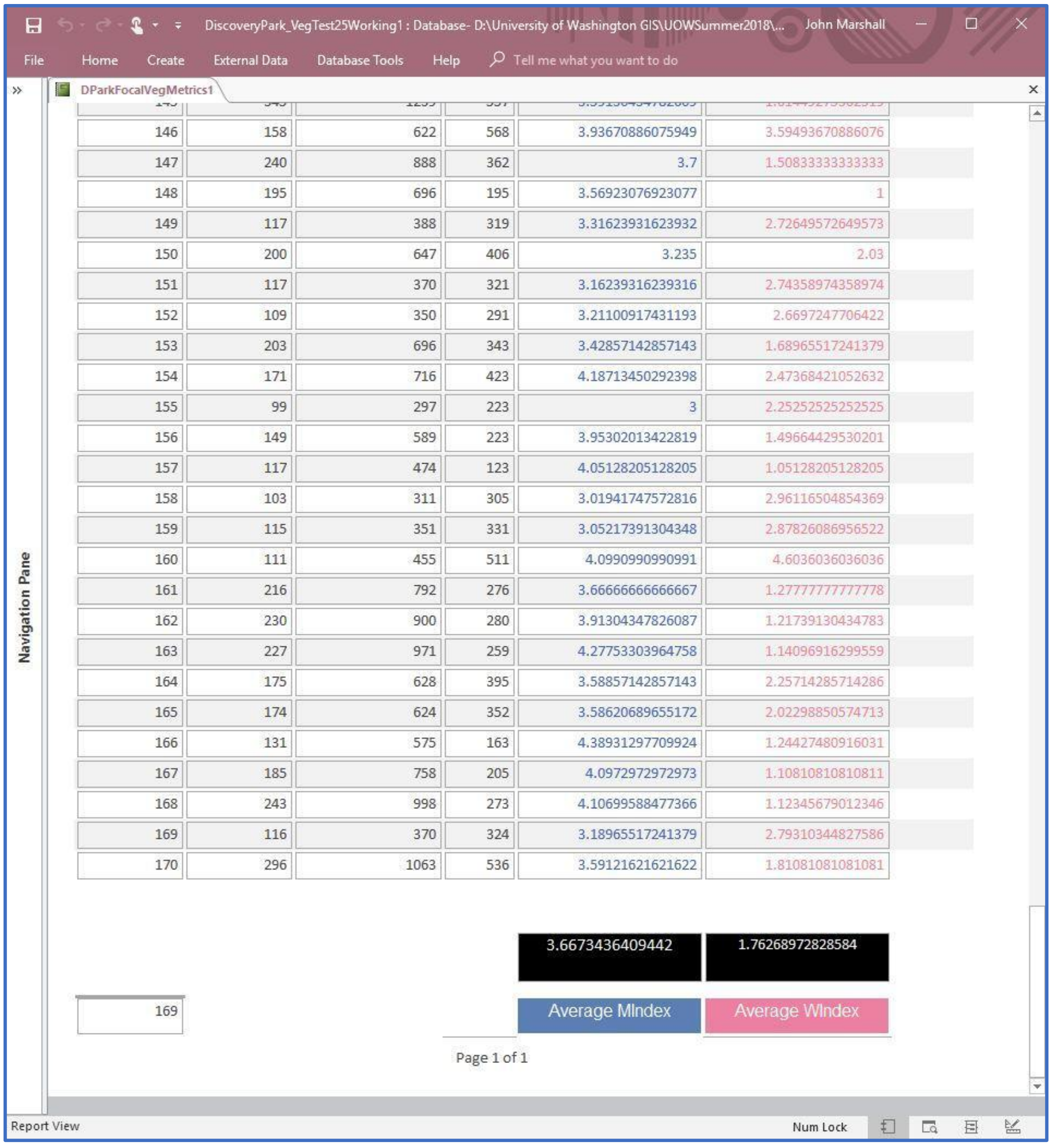
SPlotNo	PCoverTotal	MoistureIndexTotal	WeedIndTotal	SPMoistureIndex	SPWeedIndex
14	134	378	134	2.82089552238806	1
15	253	995	473	3.93280632411067	1.8695652173913
16	278	954	454	3.43165467625899	1.63309352517986
17	242	990	282	4.09090909090909	1.16528925619835
18	185	625	225	3.37837837837838	1.21621621621622
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 13. Discovery Park Moisture Index and Weed Index Query Grouped by 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:

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



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

				3.6673436409442	1.76268972828584
169				Average MIndex	Average WIndex

Page 1 of 1

Figure 14. Microsoft Access Database Report Calculating Average 2001 Plant Sample Plot Moisture and Weed Indexes.

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.

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;

```
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 15. Sample Unit 105 Dominant Species Query in Sample 8.

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

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

SUnit105_Sample8

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

Figure 16. Sample Unit 105 Subordinate Species Query in Sample 8.

results in Figures 15 and 16) , 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 17).

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.

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 17. 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 18). 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 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 22) can be found on page 28 in the Results section of this report.

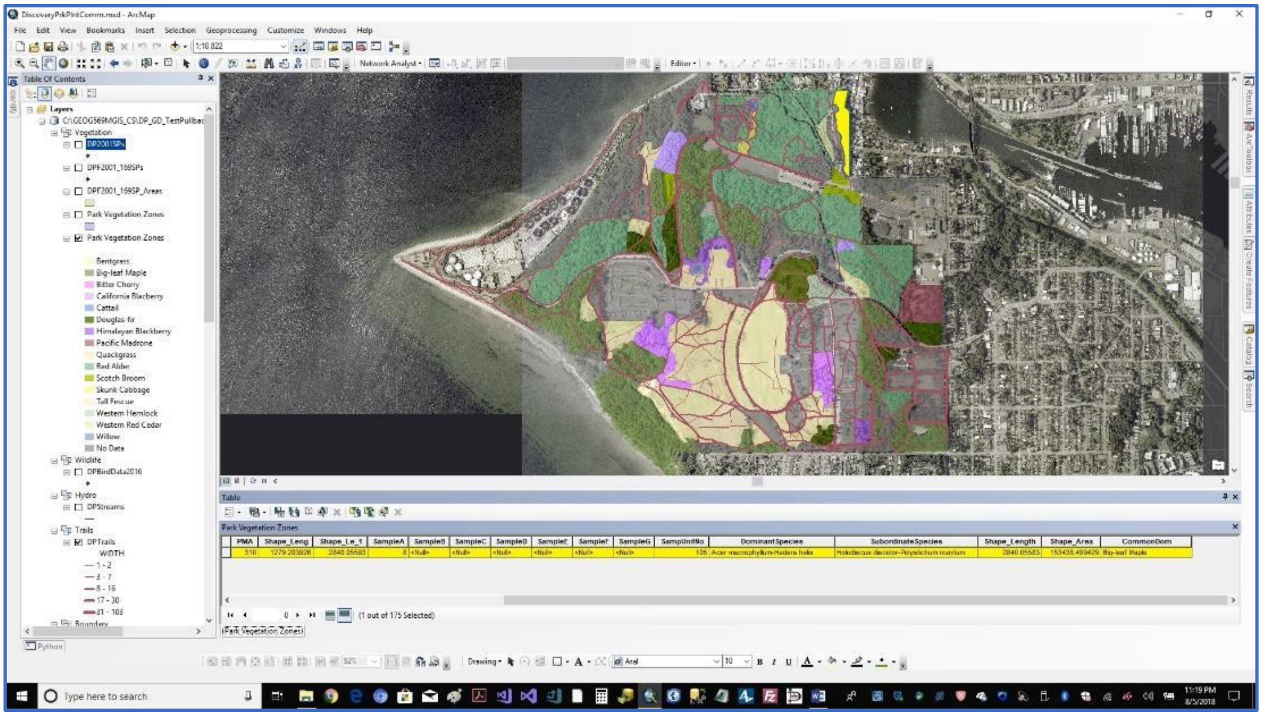


Figure 18. Vegetation Layer Feature Class Attribute Table Records Populated with Query Results.

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 the 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 19) is used to accomplish this. This ‘working’ platform is comprised of the following:

- 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
  - A 2001 plant community feature class for Discovery Park
  - A 2016 bird observation feature class for Discovery Park

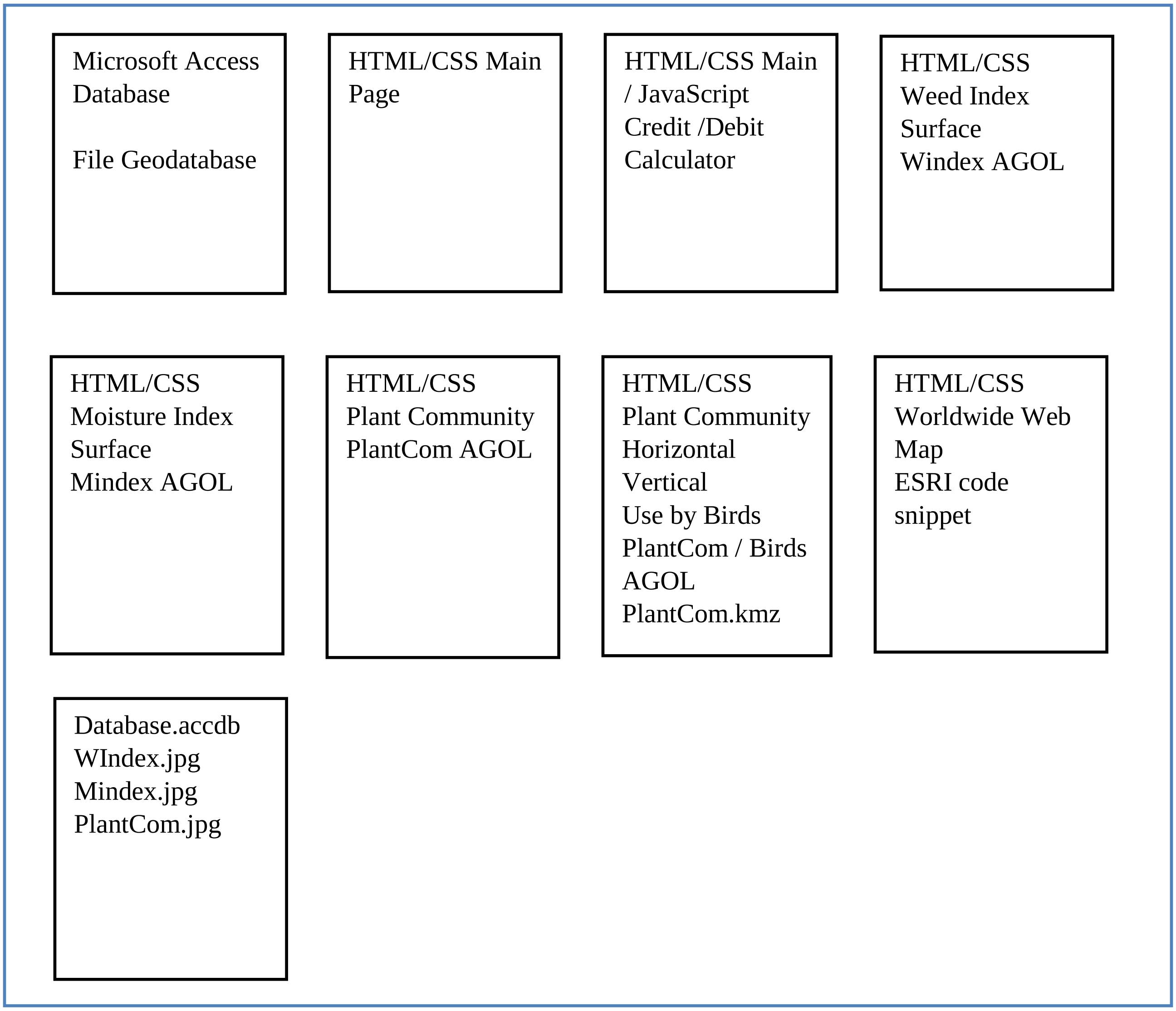


Figure 19. Working Non-hosted Multi-HTML / CSS / Java Script Web Page Platform B.[4]

- Multi-html / java Script 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.

[4] Platform B is intended solely for the convenience of the sponsors to have a centralized option for internally viewing and analyzing the 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 the content is at a stage where it can be openly shared and discussed among stakeholders, it is recommended that this Platform B be limited to FoDP core member use.

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.[5] This index provides a gauge of the resilience of Discovery Park native species relative to the encroachment on their habitat by exotic species.

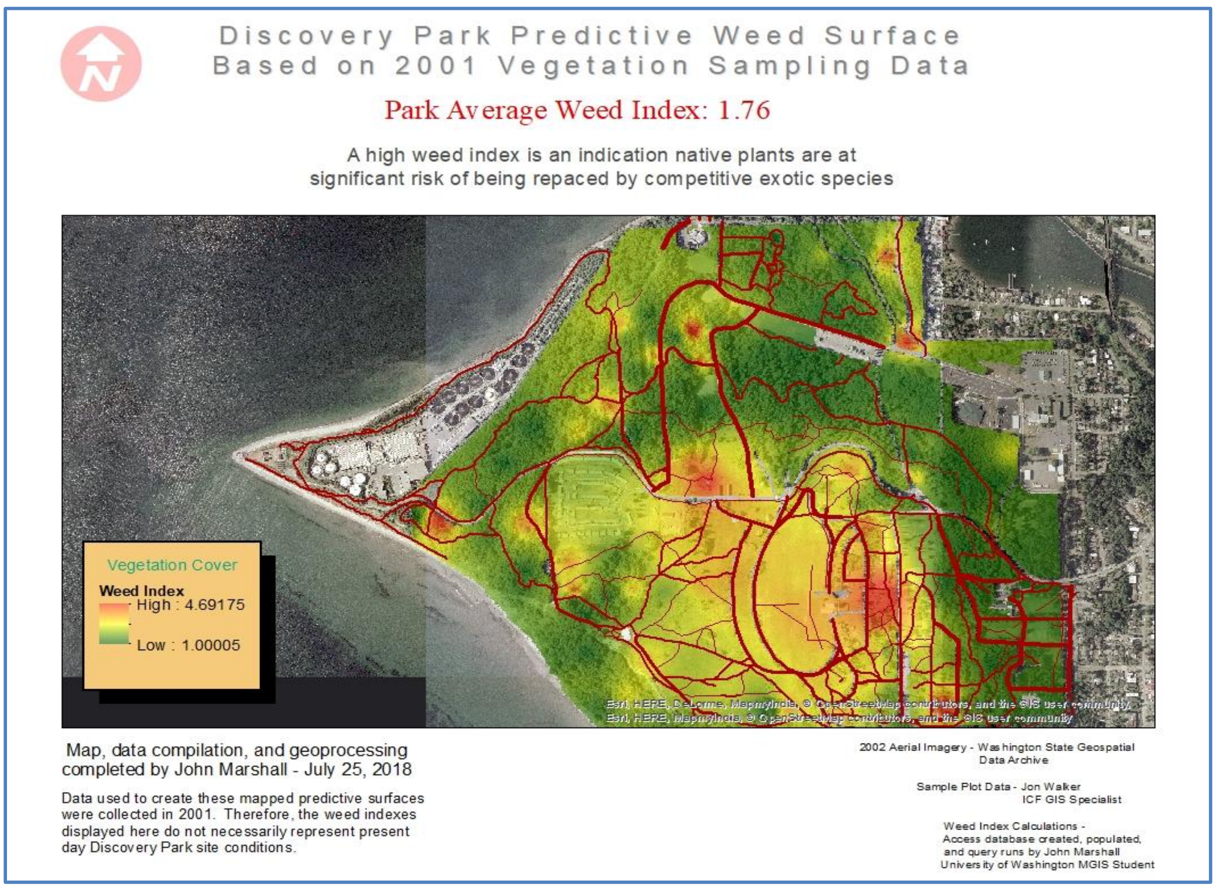


Figure 20. Discovery Park Weed Index Surface based on 2001 Vegetation Sample Plot Data.

[5] 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 20 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.[6]

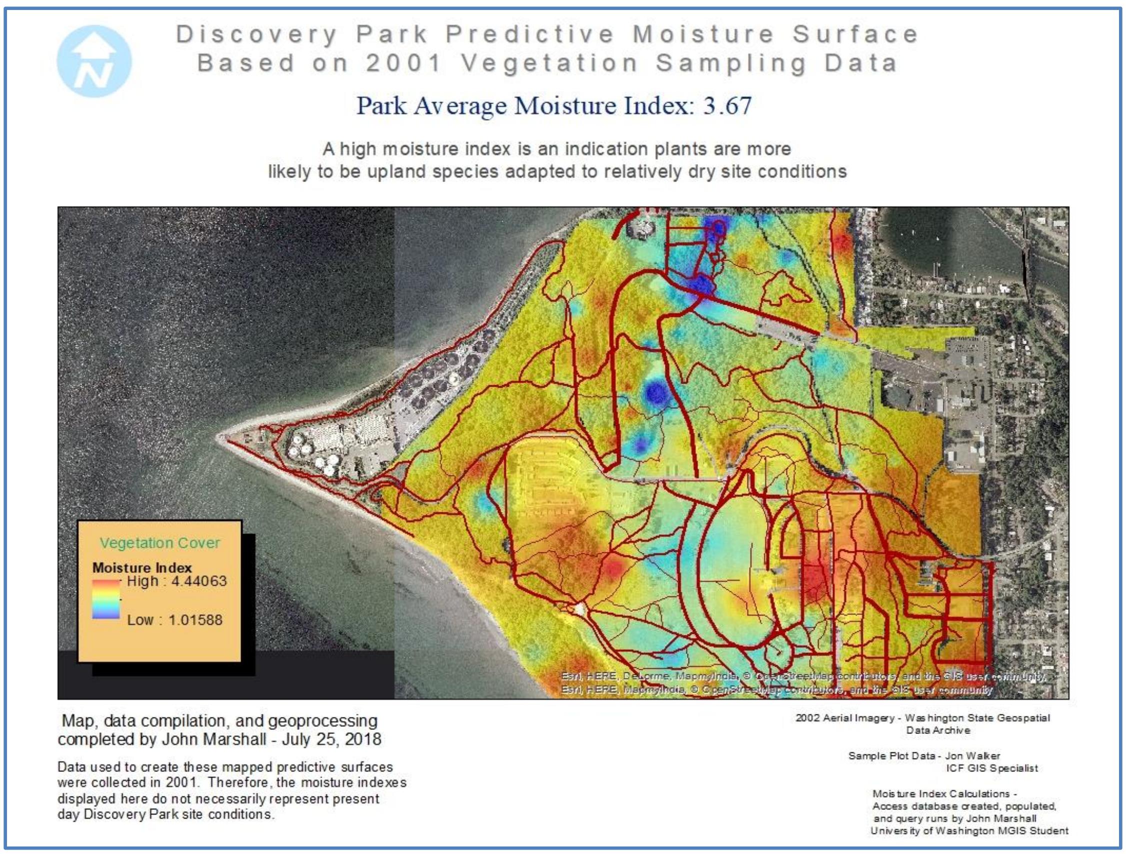


Figure 21. Discovery Park Vegetation Moisture Index Surface based on 2001 Vegetation Sample Plot Data.

[6] 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 21 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.

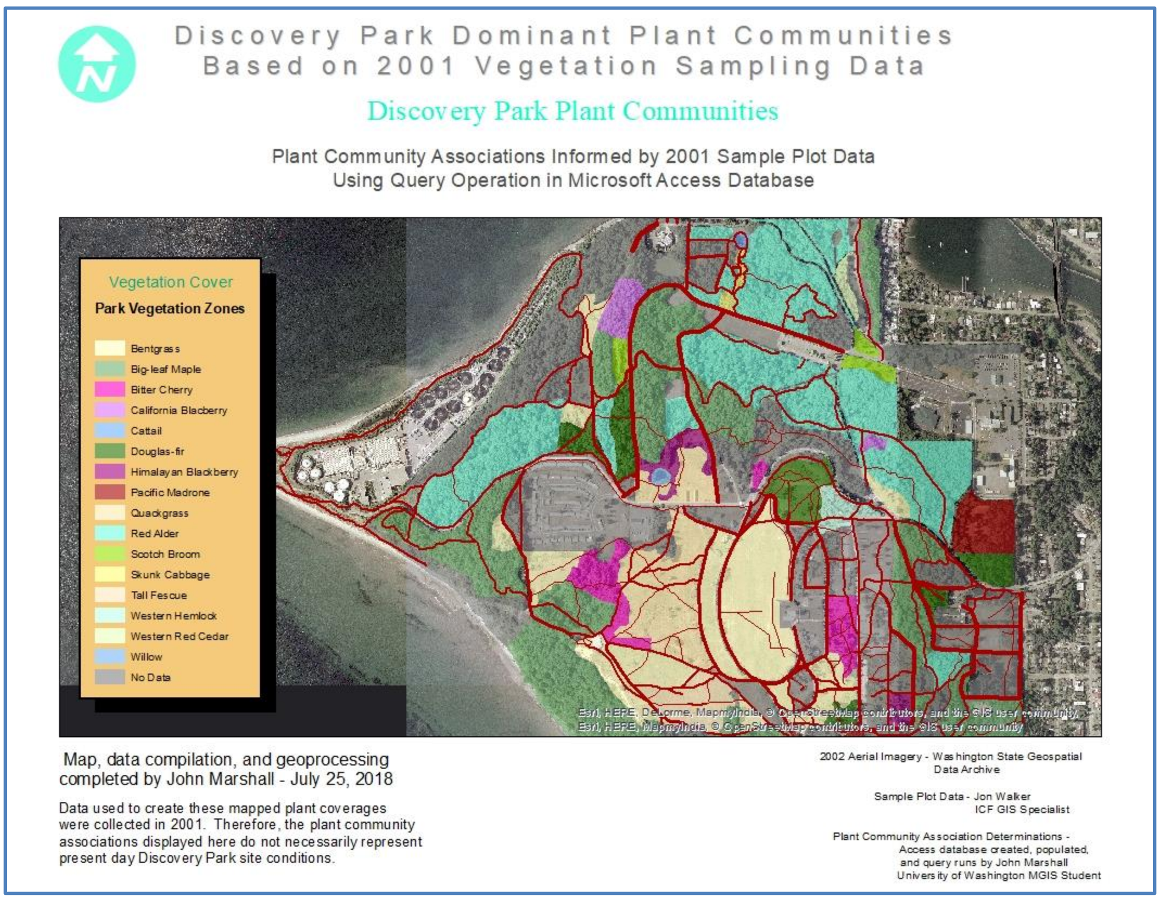


Figure 22. Discovery Park Plant Communities Based on 2001 Sample Plot Data.[7]

[7] 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 attributed 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 23). 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.

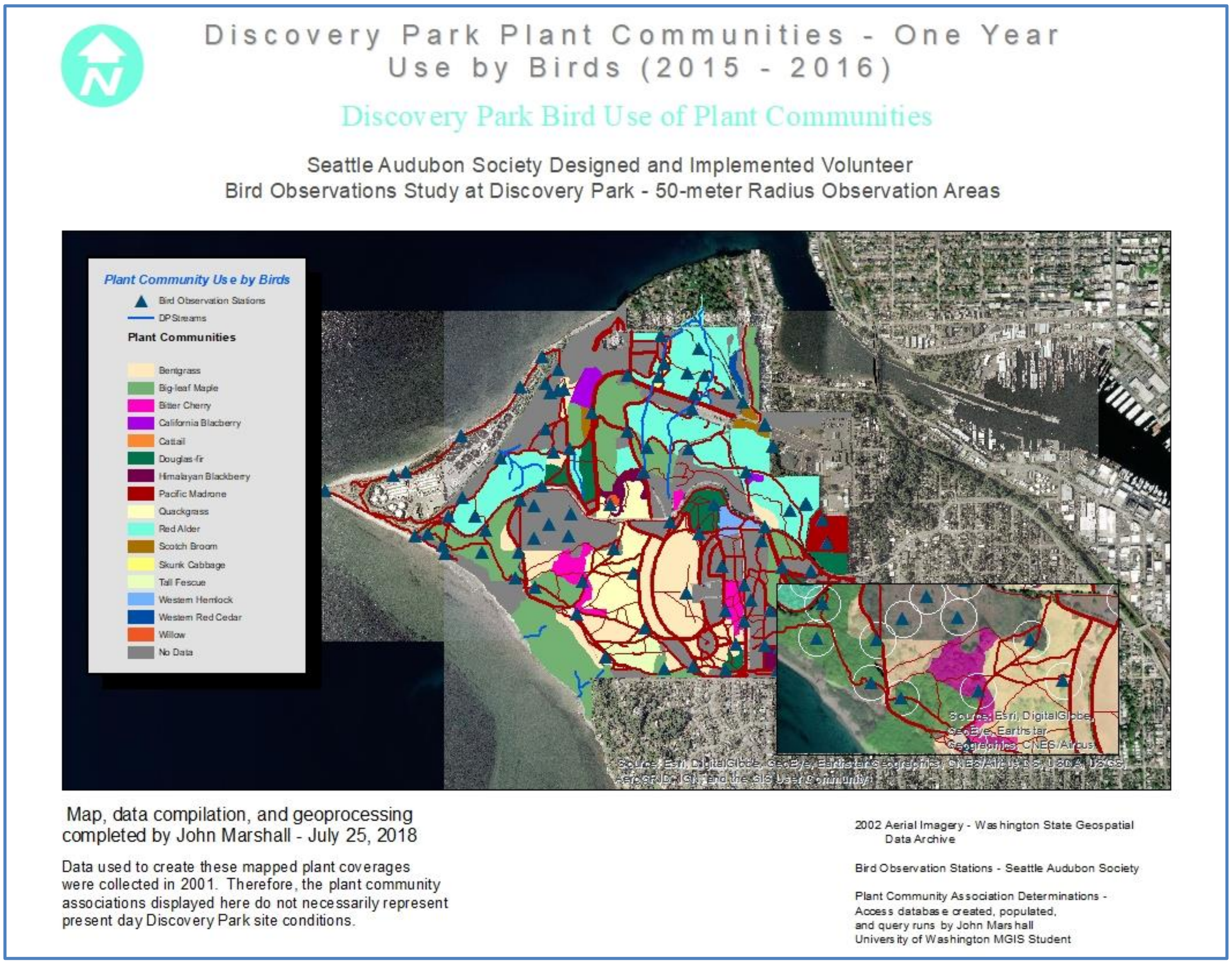


Figure 23. Horizontal Use of Plant Community Structure by Birds.[8]

[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 plant community types. But because there was anecdotal evidence of correlation and because the author of this report considers 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 the results."*

Vertical stratification of forest vegetation has been characterized in the literature for quite some time (Odum 1959). A vegetation structural index (Figure 24) 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.

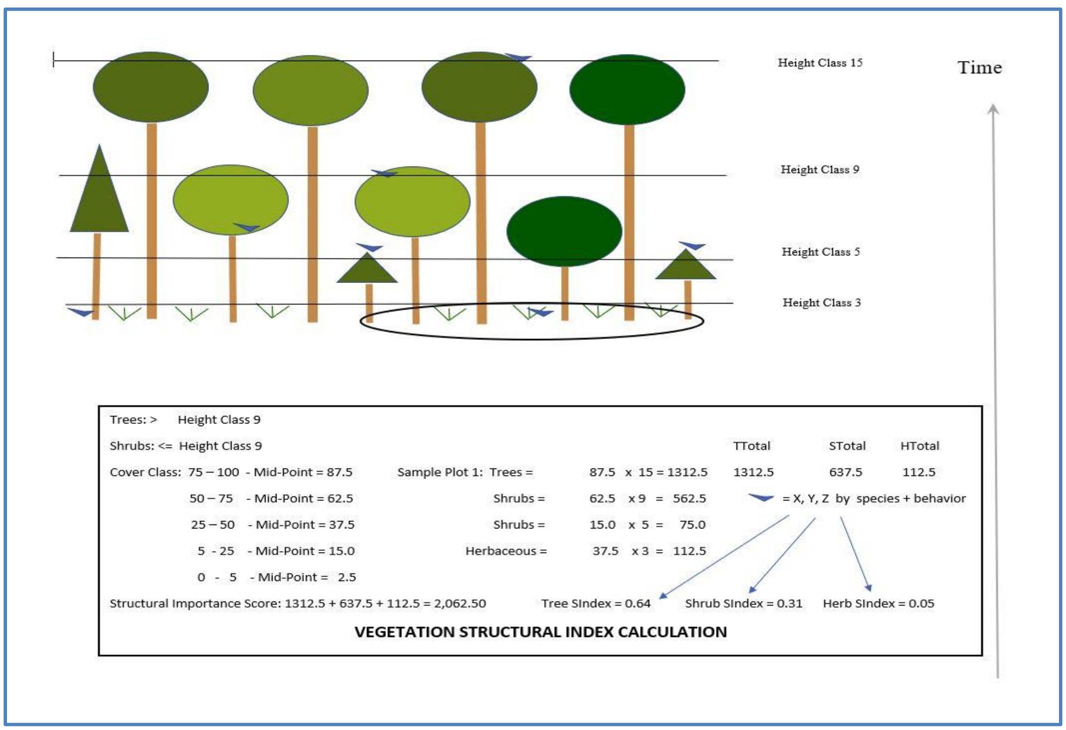


Figure 24. Vertical Use of Plant Community Structure Use by Birds as a Structural Plant Community Index.[9]

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[9] 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.

7. Conclusions and Recommendations

7.1 Conclusions

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.[10] 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.

[10]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.

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.

7.2 Recommendations

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.

8. References

Braun-Blanquet, J. G. Fuller, H. Conard. (1932). Plant Sociology: The Study of Plant Communities, McGraw-Hill Book Company, Inc., York, PA.

Codd, E.F. (1990). "Relational Philosopher." DBMS. 34-40, 60.

Corps of Engineers. (1987). Corps of Engineers Manual for Identifying and Delineating Jurisdictional Wetlands. Vicksburg, Mississippi.

Daubenmire, R. (1968). Plant Communities: A Textbook of Plant Synecology, Washington State University, Harper & Row Publishers, Inc., New York, N.Y.

Frenkel, R. and R. Streatfield. (1997). Ecological Survey and Interpretation of the Willamette Floodplain Research Natural Area, W.L. Finley National Wildlife Refuge, Oregon, U.S.A., Department of Geosciences, Oregon State University, Corvallis, Oregon: In Natural Areas Journal, Volume 17(4).

Hernandez, M.J. (2013). Database Design for Mere Mortals. Addison-Wesly, Saddle River, New Jersey.

Holland, M. (1996). Wetlands and Environmental Gradients, In: Wetland Environmental Gradients Boundaries and Buffers, Edited by: G.Mulamoottil, B. Warner, and E. McBean, Lewis Publishers, Washington, D.C.

Huxhold, W. (1991). Chapter 7, The Model Urban GIS Project. In *Urban GIS* (pp. 230-269). Oxford Press.

Jones & Stokes. (2002). Discovery Park. Final Vegetation Management Plan. (No. J&S01383.01.). Bellevue, WA. Prepared for Seattle Department of Parks and Recreation, Seattle, WA.

Marshall, J. (2010). An Analysis of Plant Moisture Indexes and Potential Dependent Weed Indexes for Wetland Prairie Vegetation at the Muddy Creek Wetland Mitigation Bank, Term Paper, Submitted for Partial Completion of Digital Compilation and Database Design, GIS Certificate Program, Portland State University, Portland, Oregon.

Mueller-Dombois, M. and H. Ellenberg. (1974). Aims and Methods of Vegetation Ecology, John Wiley & Sons, Inc., New York, N.Y.

Odum, E. (1959). Fundamentals of Ecology, University of Georgia, Professor of Zoology, W.B. Saunders Company, Philadelphia, PA.

Smith, Katherine Manaras, William S. Keeton, Therese M. Donovan, and Brian Mitchell. 2008. Stand-Level Forest Structure and Avian Habitat: Scale Dependencies in Predicting Occurrence in a Heterogeneous Forest, FOR. SCI. 54(1):36–46.

US Army Corps of Engineers - Wetland Indicator Plant List. http://wetland-plants.usace.army.mil/nwpl_static/v33/home/home.html

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.

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

Appendix C. Mitigation and Conservation Banking: A Means of Trading in Ecosystem Services Markets.

There are a considerable number of terms common to the field of ecosystem services used to identify and define a large suite of related entities and operations. An exhaustive list is beyond the scope of this document but a few key definitions are provided to help support the following discussion.

Definitions

- **Bank Sponsor** - any public or private entity responsible for establishing and, in most circumstances, operating a conservation bank.

- **Conservation Actions** - the restoration, enhancement, or preservation of habitat for the purpose of benefiting at-risk species and their respective distinct population segments.

- **Conservation Bank** - a site where habitat is managed in perpetuity to benefit federally listed and other at-risk species expressly for the purpose of offsetting adverse effects to those species in areas outside the conservation bank boundaries but inside the Service Area of the conservation bank.

- **Mitigation Bank –** a site or suite of sites where regulated aquatic resources and their ecologically associated uplands have been restored, created, enhanced, and / or protected for the purpose of offsetting adverse effects to these resources outside the mitigation bank boundaries but inside the Service area of the mitigation bank.

- **Conservation Bank Review Team (CBRT)** - an interagency group of Federal, State, tribal and/or local regulatory and resource agency representatives that are signatory to a conservation bank agreement and/or MOA and oversee the establishment, use, and operation of a conservation bank.

- **Interagency Review Team (IRT)** - an interagency group of Federal, State, tribal and/or local regulatory and resource agency representatives that are signatory to a mitigation bank agreement and/or MOA and oversee the establishment, use, and operation of a mitigation bank

- **Conservation Easement** - a recorded legal document (usually held by an approved third party dedicated land steward) established to protect and conserve regulated aquatic resources and biological resources in perpetuity, and which requires explicit restrictions on activities that would conflict with the long-term protection of conservation and / or mitigation bank lands. The restrictive elements of the easement follow the deed of the property and to whomever has current ownership.

- **Credit** -a unit of measure representing the quantification of at risk species and/or habitat conservation values within a conservation bank or aquatic and associated upland resource values in a mitigation bank. Credits must be measured by the same methods used to measure the debits that they are charged to offset.

- **Development Acres** - This is the amount of acreage of a given natural resource type (e.g., frequent emergent wetland, wet grass prairie, vernal pool, snowy plover breeding habitat, etc.) that will be converted to alternative uses (e.g., housing subdivisions, shopping malls, highway interchanges, etc.).

- **Development Multiplier -** This is an assigned number often representing the relative importance of a particular resource type. Resources assigned high importance values are assumed to require a proportionally greater number of acres to compensate for their loss. Factors that can affect the assignment of resource value include but are not limited to: 1) scarcity in the landscape relative to historical extent, 2) time periods required to reach a fully functioning condition, 3) importance to focal concerns (e.g., imperiled species, watershed TMDLs, aesthetic and recreational opportunity, 4) the relative capability of a habitat unit to provide life-cycle requirements for a species, etc.). The acreage of a given development site multiplied by its assigned development multiplier equals the amount of debit accrued by the development action and the amount of credit needed from the mitigation site to offset the debit.
  If the development site is equal to 10-acres and the Development Multiplier is 2, then the number of debits is 20 (10 x 2). It should be noted here that mitigation "ratios" are often derived directly from ranking comparisons between development sites and compensatory mitigation sites. For example, if the relative value of the development site is 3 and the relative value of the mitigation site is 2, then the ratio applied to the mitigation action is 3/2 or 1.5:1. Under this principle it is also possible (and hopefully probable) that the development site may be lower value than the mitigation site after the mitigation action is complete and meeting its performance objectives. For example, if the relative value of the development site is 2 and the relative value of the mitigation site is 3, then the ratio that is applied to the mitigation action is 2/3 or 0.67:1. Since ratios of < 1 result in a net loss of natural resource acres, many regulatory agencies have taken the option of imposing a minimum compensatory mitigation ratio of 1 (also represented as 1:1).

- **Endowment Fund** - an investment fund maintained by a designated party approved by the regulatory authorities as a non-wasting endowment to be used exclusively for the management of the conservation or mitigation bank lands in accordance with the management plan and the conservation easement.

- **Debit** - a unit of measure representing the quantification of species and/or regulated aquatic resource values that will be lost through a development action and subsequently charged against a conservation or mitigation bank. Debits must be measured by the same methods used to measure the conservation or mitigation bank credits that they are charged to.

- **Enhancement** - activities conducted in existing species habitat and / or aquatic resources that increase one or more ecosystem functions.

- **Fee title** - a fee title estate is the least limited interest and the most complete and absolute ownership in land; it is of indefinite duration, freely transferable and inheritable.

- **Management Plan** - means the plan prepared to manage a conservation or mitigation bank to, at a minimum, maintain the listed species value on the bank. This includes on- the-ground management activities, funding, and monitoring and reporting requirements.

- **Mitigation Acres -** This is the amount of acreage of a given parcel of land (often degraded farmland) that will be converted to alternative conservation uses (e.g., frequent emergent wetland, wet grass prairie, vernal pool, snowy plover breeding habitat, etc.) to offset the loss of the same or similar resources somewhere else.

- **Mitigation Divider -** This is an assigned number often representing the relative likelihood of mitigation success depending on the compensatory mitigation method(s) employed. Methods that have a low track record of failure are generally assigned low mitigation dividers and those with a demonstrated high risk of failure are typically given higher mitigation dividers. Also, compensatory mitigation methods that result in 100% loss of resource acreage are often assigned higher mitigation dividers. The acreage of a given mitigation site divided by its assigned mitigation divider equals the amount of credit available at that mitigation site. If the mitigation site is equal to 10-acres and the mitigation divider is 2, then the number of credits available is 5 (10 / 2).

- **Non-wasting management endowment -** an investment account that generates enough interest each year to keep pace with inflation and cover the yearly management costs of a mitigation or conservation bank.

- **Off-site conservation -** conservation actions occurring outside the boundaries of a project development site that they are serving to offset.

- **On-site conservation -** conservation actions occurring within or abutting the boundaries of a project development site they are serving to offset.

- **Perpetuity** – The long-term foreseeable future.

- **Preservation -** the protection of existing ecologically important habitat and or other ecosystem resources in perpetuity through the implementation of appropriate legal mechanisms (e.g., conservation easements, protective zoning, etc.

- **Price Per Credit -** is generally a free-market determined decision often based on the sale prices of credits in the general area being "serviced" by a mitigation site. Factors such as the monetary cost of producing a credit (e.g., costs of land acquisition, site-preparation, maintenance, long-term endowments, etc.) combined with the prices of credits from competing mitigation providers have a relatively large influence on the price a credit is sold for. These prices tend to vary temporally and spatially depending on such factors as supply and demand, the strength of the economy, and proximity to major metropolitan areas.

- **Restoration** – reestablishment of ecologically important habitat and/or other ecosystem resource characteristics and function(s) at a site where they have ceased to exist, or exist in a substantially degraded state.

- **Service Area -** the geographic area (e.g., species recovery unit or watershed) surrounding a conservation or mitigation bank where species and/or regulated aquatic resource debits (i.e., development actions) may be accrued against the credits generated by the conservation or mitigation bank.

Advantages of Conservation Banking.

- ## Regulatory and Resource Agencies

  a. Consolidation of otherwise disparate compensatory mitigation actions within a smaller set of mitigation and conservation banks increasing the efficiency of limited agency resources in project review and compliance monitoring.

  b. Allows economies of scale on collective mitigation and conservation actions that can be targeted toward the recovery and protection of regionally and nationally important species and ecosystems.

- ## Regulated Public

  a. Conservation and mitigation banks provide greater flexibility to applicants needing to comply with mitigation requirements;

  b. The availability of conservation and mitigation banks may reduce permit processing times for applicants that qualify; and

  c. Establishment of a conservation or mitigation bank can provide less expensive compensatory mitigation opportunities for projects that qualify.

- ## Federally Listed Species

a. It may be more ecologically desirable to consolidate conservation actions into larger or contiguous parcels strategically located in the landscape;

  b. Establishment of a conservation or mitigation bank can bring together financial resources, planning and scientific expertise not practicable to many project- specific compensatory mitigation proposals. This consolidation of resources can increase the potential for the establishment and long- term management of successful mitigation that maximizes opportunities for contributing to biodiversity and/or watershed function;

  c. Conservation and mitigation banks are typically functioning in advance of a given development project's adverse effects, and can thereby reduce the temporal losses to regulated aquatic resources and to habitat suitable for federally listed species, effectively reducing the uncertainty over whether the mitigation will be successful; and

  d. Conservation and mitigation banks can contribute towards the conservation of federally listed species by providing opportunities to offset unavoidable adverse effects when mitigation might not otherwise be appropriate or practicable.

Disadvantages of Conservation Banking

- ## Regulatory and Resource Agencies

  a. A considerable amount of up-front investment is required in terms of time and staff resources (at multiple levels) to establish mitigation and conservation bank programs;

  b. A considerable investment in staff time is required (at multiple levels) to continually participate in each of the mitigation and conservation banks, from initial planning through implementation, and monitoring/follow-up; and

  c. A considerable investment in staff time is required (at multiple levels) to continually participate in the development and implementation of conservation and mitigation bank program policy.

- ## Bank Sponsors

  a. Each conservation and mitigation bank sponsor cumulatively assumes the full burden of the mitigation obligation for each developer they sell credits to and are, therefore, accountable for the aggregate success of their conservation bank's performance in order to offset the total respective debits that have been charged against their bank; and

  b. Each conservation bank sponsors commits to a considerable financial investment without a guarantee of a profitable economic return. Bankers assume a great deal of risk with the uncertainty associated with ecosystem recovery and management technologies as well as their market base.

- ## Regulated Public

  a. Potential exports of significant natural resource values out of urban and urbanizing watersheds;

  b. May incur considerable natural resource value losses if one or more mitigation or conservation banks fail.

Aquatic Resources and Federally Listed Species

a. In practice, biologists working on biological opinions or Fish and Wildlife Coordination Act reports may be tempted to inappropriately discount the role of avoidance and minimization strategies and favor conservation or mitigation bank options;

b. The use of conservation and mitigation banks may result in placing ecological “eggs” in fewer “baskets” and thereby could increase the risk of larger overall ecosystem loss if the conservation performance measures at one or more large conservation bank sites could not be sustained;

c. Conservation and mitigation banks are not likely to benefit many of the populations segments and specific systems of aquatic resources that, due to proximity, will be immediately adversely affected by the development actions in their broad Service Areas; and

d. If not given proper oversight, conservation and mitigation banks may favor certain priority habitats to the degree that the recovery opportunities of other important habitat types are discounted.

Site Selection

Banks may be sited on public or private lands. Cooperative arrangements between public and private entities to use public lands for mitigation banks may be acceptable. In some circumstances, it may be appropriate to site banks on Federal, state, tribal or locally-owned resource management areas (e.g., wildlife management areas, national or state forests, public parks, recreation areas). The siting of banks on such lands may be acceptable if the internal policies of the public agency allow use of its land for such purposes, and the public agency grants approval. *Mitigation credits generated by banks of this nature should be based solely on those values in the bank that are supplemental to the public program(s) already planned or in place, that is, baseline values represented by existing or already planned public programs, including preservation value, should not be counted toward bank credits.*

Conservation and Mitigation Bank Funding

Funding for mitigation and conservation bank activities will include short and long-term financial commitments for planning, implementing, monitoring, and otherwise operating the bank. Short and long-term financial needs will be estimated based preferably on a method such as the Center for Natural Land Management’s Property Analysis Record (PAR). Short-term funding needs will be provided by the bank sponsor, and guaranteed by a performance bond or its equivalent. Long-term funding needs will be provided by the bank sponsor via an endowment or its equivalent. Endowment funds may be held in a non-wasting, inflation based interest- bearing account and managed by a third party conservation easement holder as approved by the regulatory authorities in coordination with the CBRT or IRT. The following are considerations related to conservation bank funding:

a. A mechanism will be established to provide funding from the endowment to enable the conservation easement holder or the land donee to address conservation bank activities;

b. The regulatory authorities will not approve sales of credits if a conservation or mitigation bank does not achieve performance standards;

c. If at any time during the credit life of a bank, performance standard are found to not be met, credit sales may be suspended by the regulatory authorities pending an investigation by the CBRT and/or IRT with the final decision to be made by the regulatory authorities; and

d. Credit sales will not be allowed to resume until such the time the regulatory authorities, in consultation with the CBRT and/or IRT, determine that the problems contributing to poor performance standard reports have been resolved and subsequent monitoring indicates the performance standards are consistently being met.

Long-term Management Plan

All conservation and mitigation banks must have a long term management plan focused on maintaining the habitat and or regulated aquatic resources for the targeted recovery species or regulated aquatic resource. The Management Plan should contain the following:

- Property description, including geographical setting, adjacent land uses, location in relation to regional open space, geomorphology, and cultural or historic features;
- Description of biological resources on site, including a vegetation map;
- Identification of the activities allowed and prohibited on conservation bank land;
- Identification of biological goals, objectives, and performance standards of the bank;
- Management needs of the property, including control of public access, restoration or enhancement of habitats, monitoring of resources, maintenance of facilities, public use, start-up funding, budget needs and endowment funds necessary to sustain budgetary requirements and yearly reporting of monitoring reports, special management actions necessary to implement the bank's biological objectives and goals;
- Indication that the mitigation or conservation bank performance goals, objectives, and performance standards will be considered a central focus in the development of the long- term management strategy for the bank;
- Any monitoring schedules and special management activities, including contingency plans and/or adaptive management actions; and
- Any decision trees or other networks necessary to carry future management decisions (e.g., bank sponsor appeal for a change in a provision in the conservation easement via a procedure shared with the easement holder, regulatory authority, and CBRT/IRT members).

- Contingency management, funding, and ownership plans should be established in the event the bank sponsor fails to fulfill the obligations of the conservation bank agreement or any of its accompanying documents, including but not limited to establishing a conservation easement and long-term management plan.

Emergency and Dispute Resolution Processes

A mutually agreed upon dispute resolution process should be established during the development of the conservation and/or mitigation bank agreement to be utilized if there are irreconcilable issues between the parties signatory to the conservation bank agreement. Special provisions may need to be inserted in the conservation easement anticipating a contingency plan in the event the conservation easement holder becomes financially or otherwise unable to uphold their responsibilities specified in the easement. In these circumstances the regulatory authorities may need to undertake the responsibility of temporary easement holder until a permanent replacement for the conservation easement can be found.

Conservation and Mitigation Banking Agreements

The conservation and mitigation bank agreement is the primary contract between the regulatory authorities and the conservation bank sponsor and as such discloses all the procedures and documents necessary to establish, own and operate a bank. At a minimum, the Bank Agreement should contain the following:

a. A section listing the members of the CBRT or IRT charged with oversight of the conservation bank agreement and a description of their respective roles in that process;

b. A general location map and legal description of the property, including spatial coordinates;

c. Accurate maps and recent aerial orthophotographs of the bank property at a scale of 1:2400 or larger;

- Name of bank;
    - Name of person(s) or organization(s) to hold fee title to the bank;
    - Name of person(s)/organization(s) with management responsibility for the bank and the period of time they are obligated to those responsibilities. Bank managers must have demonstrated sufficient experience in natural lands management to carry out the conservation goals, objectives, and performance standards established for the conservation bank in order to be acceptable by the CBRT and/or IRT;

- Name of person(s) or entity that will hold the conservation easement of the bank property;

- Proof a performance bond, accessible by the regulatory authority, or its equivalent for ongoing management during the regulatory life of the bank;

- Preliminary title report indicating any easements or encumbrances on the property. If the CBRT determines that any one or more easements (e.g., roads, pipelines or power lines) will significantly impair the ability of the site to meet its conservation objectives, they may find that the site is ineligible to serve as a bank;

- An enumeration of the types of activities that may include public access and are compatible with the property's primary function as a conservation bank for one or more federally listed species and/or as a protected managed regulated aquatic resource;

- A description and assessment of the biological value of the bank in relation to the life-cycle requirements of the species and or ecosystem services it is intended to preserve and recover;

- The method for accounting bank credits and debits and the strategy proposed for reporting of credit/debit transactions;

- The methods for monitoring and reporting performance standards and the strategy that will be used to incorporate the results of monitoring into the management strategy of the bank (e.g., contingency plan or adaptive management);

- Description of the Service Area for the conservation bank based on the conservation needs of the target species and ecosystem services as well as the market needs of the bank sponsor;

- If a phased approach is selected for developing the bank, a description of the process required to obtain approval from the CBRT/IRT for each initiation of a new bank phase and, if needed (e.g., bank sponsor bankruptcy) , an agreed upon process for terminating future anticipated expansions of the bank while protecting all previous phases in perpetuity;

- Documentation that the bank is in compliance with existing State, Federal, and local government laws, policies, and land use requirements;

- Demonstration that there are no hazardous materials (requires at a minimum a Level 1 hazardous materials survey for the property) on the bank site or proximate to vulnerable species and/or habitat at the bank site;

- Demonstration there are no existing mineral rights, water rights, timber rights, or other resource extraction rights that are potentially useable by the landowner or other parties and, if exercised, would significantly undermine the conservation goals, objectives, and performance standards of the bank;

- The provisions that are to be used to ensure the development of a conservation easement that adequately addresses all future management goals, objectives, and performance standards (i.e., restrictions on hunting, amelioration of unauthorized activities, weed management, etc.) that may significantly impair the conservation value of the bank;

- Provisions to allow the regulatory authorities and other CBRT/IRT members to inspect the bank to maintain adequate quality control;

- A long-term management plan for the bank;

- A statement indicating the bank sponsor understands the regulatory authorities can suspend credits at any time performance standards are found to be below their target thresholds; and

- The Banking Agreement is the principle controlling document and will contain a number of supporting documents, including but not necessarily limited to the following:

  - Copy of property deed with signature of owner;
  - Proof of water rights;
  - Proof of conformance to local government comprehensive plan;
  - As-built reports (including maps and photos);
  - Monitoring plan;

- Contingency plan and adaptive management strategy;
- Performance bond;
- Conservation easement; and
- Adequate endowment.

Eligible Lands

Conservation and mitigation banks may be established on Tribal, local, private, public or State lands where managing agencies maintain or will maintain habitat in the future.

Land used to establish conservation and mitigation banks must not be previously designated for conservation purposes (e.g., parks, green spaces, municipal watershed lands), *unless the proposed designation as a bank would add additional conservation benefit.* For instance, it may be advantageous to place in a conservation bank the biological and habitat benefits that a species has gained under a Safe Harbor Agreement, where the landowner would agree to maintain those resource values in perpetuity.

Where conservation values have already been permanently protected or restored under other Federal, State, Tribal, or local programs benefiting federally listed species, the regulatory authorities will not recommend, support, or advocate the use of such lands as conservation or mitigation banks. This includes programs that compensate landowners who permanently protect or restore habitat for federally listed species on private agricultural lands, as well as easement areas associated with inventory and debt restructure properties, lands protected or restored for conservation purposes under fee title transfers, lands protected by a habitat management agreement (unless the agreement is extended in perpetuity by a bank agreement), or habitats protected by similar programs. For example, lands conserved under the section 6 habitat conservation plan land acquisition grant program would not be available for conservation bank establishment. Where public funds have been used in the establishment of a bank, the allocation of credits to the bank will be proportionate to the non-public contribution. A bank capable of sustaining 10 credits, but with a 50 percent public contribution, will be allocated 5 credits.

Similarly, Federally-funded wetland conservation projects undertaken via separate authority and for other purposes, such as the Wetlands Reserve Program, Farmers Home Administration fee title transfers or conservation easements, and Partners for Wildlife Program, cannot be used for the purpose of generating credits within a mitigation bank. However, mitigation credit may be given for activities undertaken in conjunction with, but supplemental to, such programs in order to maximize the overall ecological benefit of the conservation project.

Additional Mitigation and Conservation Banking Resources

Department of Defense Department of the Army, Corps of Engineers 33 CFR Parts 325 and 332 Environmental Protection Agency 40 CFR Part 230 Compensatory Mitigation for Losses of Aquatic Resources; Final Rule:

https://www.epa.gov/sites/production/files/2015-03/documents/2008_04_10_wetlands_wetlands_mitigation_final_rule_4_10_08.pdf

Guidance for the Establishment, Use, and Operation of Conservation Banks;

http://moderncms.ecosystemmarketplace.com/repository/moderncms_documents/Federal%20Guidance%20on%20Conservation%20Banking%202003.pdf

RIBITS (Regulatory In-Lieu Fee and Bank Information Tracking System):

https://ribits.usace.army.mil/ribits_apex/f?p=107:2

Washington Department of Ecology Mitigation Banking Website

https://ecology.wa.gov/Water-Shorelines/Wetlands/Mitigation/Wetland-mitigation-banking

https://ecology.wa.gov/Water-Shorelines/Wetlands/Mitigation/Wetland-mitigation-banking/Contacts