A geodesign inspired multiple criteria decision tool for prioritizing levee setback project sites

Synopsis

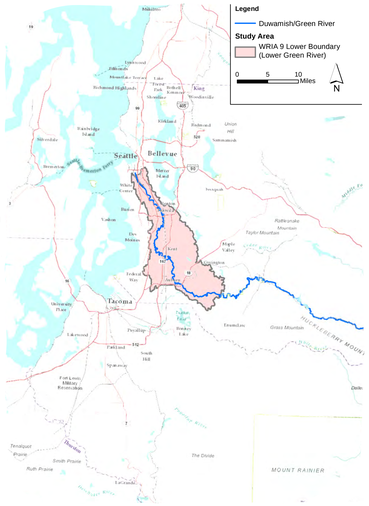
A GIS-based multiple criteria decision tool for prioritizing levee setback project locations on the Lower Green River, WA has been created. This initial planning level tool addresses the complexity of land use decisions within floodplains by enabling the consideration of multiple views of a wide range of stakeholders. The tool is a four step model process created using ESRI ArcInfo and ArcGIS Model Builder to summarize the existing conditions in the lands adjacent to levees, standardize the values of eleven chosen criteria, and create an interface where stakeholders can weigh the criteria according to importance. The eleven criteria cover the subjects of cost, hazard mitigation, ecological considerations, and built capital. The individual models are referred to as the **1**) Representation Model and Process Model, **2**) Spatial Screening Model, **3**) Alternatives Criteria Model, and **4**) Decision Support Model. The models are run at a parcel level in order to create results that transfer to real world decisions in regards to land purchase and land use change. The resulting output is a prioritization list and associated mapping products ranking parcels from favorable to non-favorable.

The Decision Support Model was run to show results when weighting all criteria evenly, each criterion by itself in a sensitivity analysis, and with values derived from a hypothetical stakeholder outreach exercise where subject professionals were asked to role-play six hypothetical characters. The results from the different model runs were fairly similar, with the exception of a few criteria outputs in the sensitivity analysis. The parcels downstream of river mile seven (7) were almost exclusively considered least suitable, the parcels in the middle section between river miles seven (7) and fourteen (14) were varied, and the parcels above river mile fourteen (14) were considered most suitable.

Emphasis is made on the tool process and methods more than the individual criteria and results. The goal of this thesis is not to tell a municipality where projects should occur, but to implement a process where stakeholder views can be transferred to weighting multiple criteria, with resulting location prioritization. This is the advantage of using GIS as a decision support tool, versus just a medium for a suitability analysis.

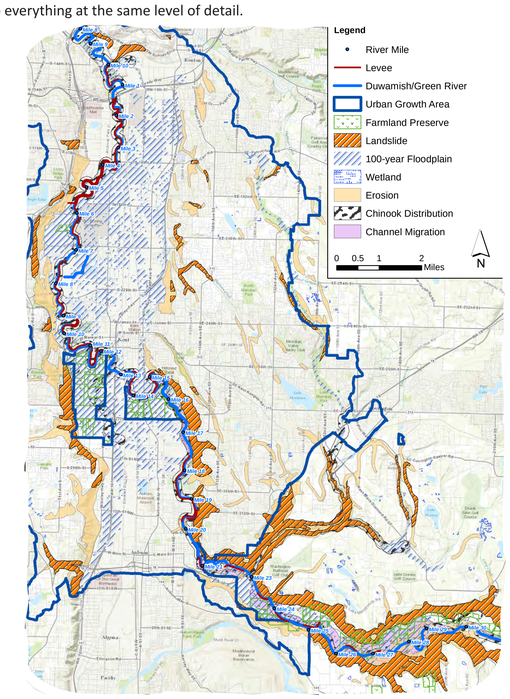
The Study Area

The lower section of the Green River, WA subwatershed is shown in pink. This area was chosen because of a wide range of land uses within a small area. The transition from intensive industrial to open space is seen as a great test area for the tool.



1 - Representation Model and Process Model

This model consists of data acquisition, preprocessing, organizing and aggregating into a single geodatabase. The majority of the data comes from the King County GIS website, with a couple of layers from the Washington State Department of Ecology. Already created data was used for the purpose of simplicity due to resource constraints. Also, it was desired to keep everything at the same level of detail.



Example of a levee setback project - Lower Canyon Creek, Whatcom County, WA - picture taken by Jesse Reynolds, September 2013

Overview of Concepts

What is Geodesign?

Geodesign is a blending of the design and geospatial information sciences. This is done through spatial analysis and iteratively creating designs custom to local landscape and land use, with a desired future in mind. It is completed within a set framework. Geodesign often involves the blending of GIS analysis and landscape architecture, with support from applied sciences and engineering. The ideal scale for geodesign is a multiple site area the size of a district, municipality, or watershed.

What is GIS-based Multi-Criteria Decision Analysis?

Multi-Criteria Decision Analysis (MCDA) is a collection of formal methods that seek to create an impartial decision environment for problems involving multiple considerations, goals, and objectives. GIS allows this process to be spatially enabled, meaning the question of 'where' can be added to the question of 'how'.

Why levee setbacks?

Levee setbacks are where an existing levee impeding a river from its historical floodplain is removed and replaced by a levee farther away from a river channel, restoring connection between the river and the surrounding lands. These newly connected lands in most cases were historically part of the floodplain. Levee setbacks are seen as a way to improve habitat, while potentially increasing floodwater retention by allowing the river channel and floodway more room to migrate.

2 - Spatial Screening Model

The purpose of this model is to isolate the parcels of interest in order to focus the analysis where stakeholders should influence levee setback decisions. The first step in a tool of this sort should always be a pre-selection based on limiting constraints. This can be done manually by hand picking parcels of interest. In the case of this model we automated the process by querying parcels adjacent to levees.

Step 2a
Define the study area by assigning a desired distance from parcels to the levees in question.

Step 2b
Query out parcels that fall within the river.

Now there is a study area. This study consists of 330 parcels found within a 100ft distance of levees.

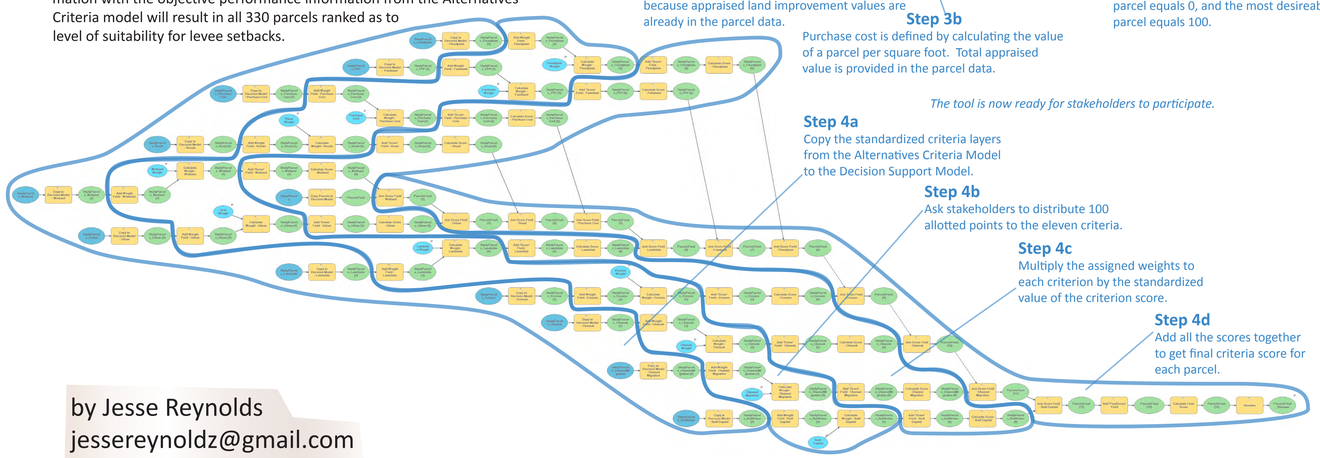
The criteria applied in Models 3 and 4

The eleven criteria shown in their four groups of general consideration below

General Consideration	Criteria	Brief Explanation	Influence
Cost	Land Purchase Cost	The total cost of land and improvements on a parcel. Criteria is standardized by calculating cost per square foot	negative
Ecological	Chinook Habitat	Proximity of parcels to Chinook salmon habitat	positive
Ecological	Erosion	Proximity of parcels to erosion areas	positive
Ecological	Wetlands	Proximity of parcels to wetlands	positive
Existing Land Use/Cultural	Built Capital	The total cost of improvements on a parcel	negative
Existing Land Use/Cultural	Farmland Preservation	Proximity to King County Farmland Preservation Program lands	negative
Existing Land Use/Cultural	Roads	Proximity to roads	negative
Existing Land Use/Cultural	Urban Growth Area	Proximity to Urban designated areas under the Washington State Growth Management Act	negative
Hazards	100yr Floodplain	Proximity of parcels to the 100 year flood plain	positive
Hazards	Channel Migration	Proximity of parcels to river channel migration zones	positive
Hazards	Landslide	Proximity of parcels to landslide prone areas	positive

4 - Decision Support Model

Now it is the stakeholder's job to assign weights to each of the criteria according to their preferences and what they feel is most important. Combining this information with the objective performance information from the Alternatives Criteria model will result in all 330 parcels ranked as to level of suitability for levee setbacks.



Step 3a
Create a separate parcels layer for each of the eleven criteria. Calculate the distance from each parcel to nine of the eleven criteria. This step is not needed for the built capital criterion because appraised land improvement values are already in the parcel data.

Step 3b
Purchase cost is defined by calculating the value of a parcel per square foot. Total appraised value is provided in the parcel data.

Step 3c
The range of values for each criterion parcel is calculated.

Step 3d
The values for each criterion are standardized so that the least desireable parcel equals 0, and the most desireable parcel equals 100.

The tool is now ready for stakeholders to participate.

Step 4a
Copy the standardized criteria layers from the Alternatives Criteria Model to the Decision Support Model.

Step 4b
Ask stakeholders to distribute 100 allotted points to the eleven criteria.

Step 4c
Multiply the assigned weights to each criterion by the standardized value of the criterion score.

Step 4d
Add all the scores together to get final criteria score for each parcel.

Now the results are ready to be viewed cartographically

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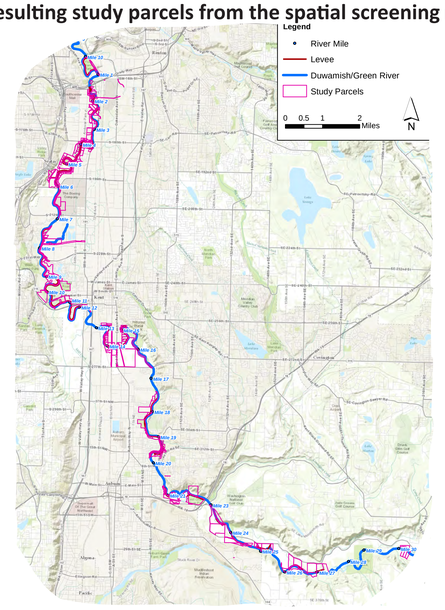
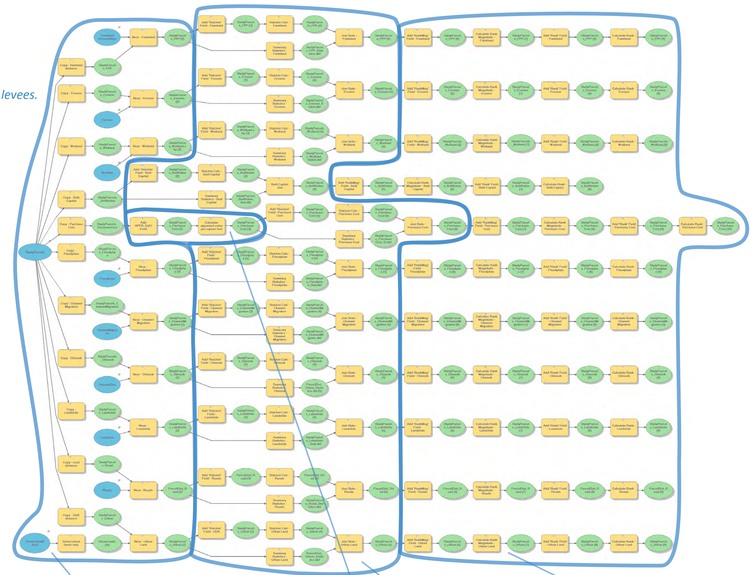
The resulting study parcels from the spatial screening model



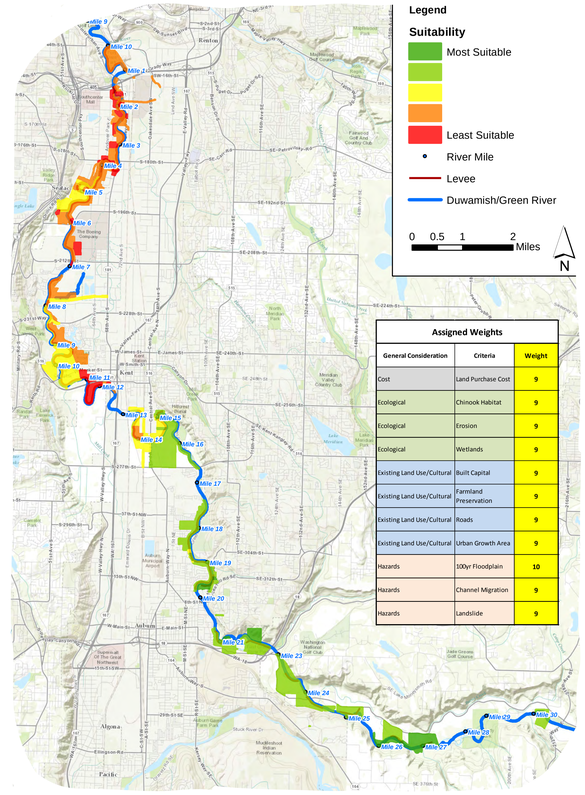
3 - Alternatives Criteria Model

Now that the study area has been defined each individual criterion, found in separate features or within the parcels data, becomes its own feature class and is standardized so that it can be comparable to all the others. This is done by creating copies of the parcel layer to represent each criterion. Then a series of calculations occurs in an effort to standardize the data.



Results from evenly weighting the criteria

Each criterion was given nine points with the exception of the 100yr floodplain criterion, which was given ten (the only way to add to 100). Below is the resulting output. One can see the obvious pattern of increasing suitability the farther one moves upstream.

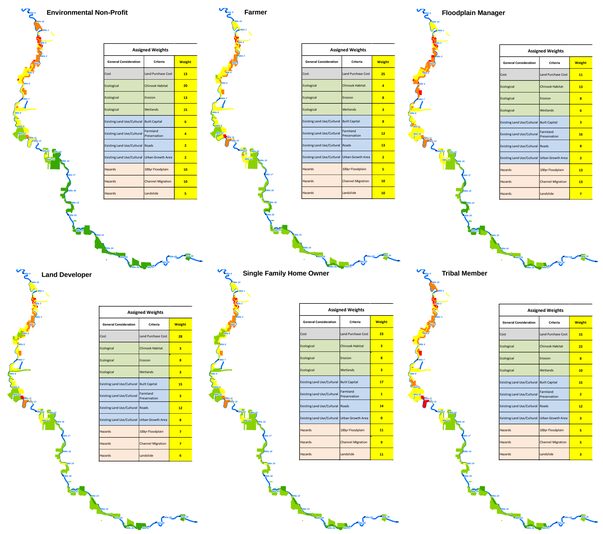


Assigned Weights

General Consideration	Criteria	Weight
Cost	Land Purchase Cost	9
Ecological	Chinook Habitat	9
Ecological	Erosion	9
Ecological	Wetlands	9
Existing Land Use/Cultural	Built Capital	9
Existing Land Use/Cultural	Farmland Preservation	9
Existing Land Use/Cultural	Roads	9
Existing Land Use/Cultural	Urban Growth Area	9
Hazards	100yr Floodplain	10
Hazards	Channel Migration	9
Hazards	Landslide	9

Results from the Hypothetical Stakeholder Exercise

Professionals within floodplain management and closely related professions were asked to participate in a role-play exercise where they pretended to be the six hypothetical stakeholders shown below. The criteria scores they gave the stakeholders were averaged and applied to the Decision Support Model. Below are the results.



Other Planning Applications

The process and methods of this model can be applied to many planning and environmental management disciplines beyond floodplain management, including transportation corridor planning, low income housing development, brownfield redevelopment prioritization, and transmission line right-of-way planning. Any planning problem with the questions of what and where could benefit from this tool, as long as there is spatial data available.

A Future Direction

A successful stakeholder outreach tool must have public access. Currently this tool sits on a desktop application, meaning one has to be a GIS user with a GIS software license to use it. This makes for major constraints in regards to access. A next step beyond this thesis that would alleviate these constraints would be to publish the tool and associated maps online. Because ArcGIS is used, the recommended web-GIS application is ArcGIS Online. Once online, anyone with internet access could add their criteria weights and view the results. This would be a key move to take participation beyond meetings that a limited number of people can attend.