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| Lab Assignment 3  **Assessment Modeling for Natural Capital Improvement Programming** |

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Office hours: MW 11:30 - 12:30, TTH 12:30 - 1:30 and by appointment

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| **Section** | **Assigned** | **Due** |
| **AB** | **4/24** | **5/3** |
| **AA** | **4/25** | **5/4** |

Lab policy: <http://courses.washington.edu/geog464/guidelines_win2017.html>

Lab schedule: <http://courses.washington.edu/geog464/labschedule_17.html>

Canvas: <https://canvas.uw.edu/courses/1152834>

**1.0 Background about Planning, Improvement Programming, and Project Implementation**

Water Resource Inventory Areas (WRIA) planning, programming, and project implementation are representative of participatory approaches directed principally at salmon recovery, responding to the endangered species act mandates. Efforts in King County completed watershed plans for [WRIAs 7-10](http://www.kingcounty.gov/environment/watersheds.aspx). Plan and project activity occurs among a coalition of local governments, business, and not-for-profit groups, principally funded by local governments due to mandates to protect endangered salmon species and their habitats. However, capital improvement programs exist for many functional elements, are pervasive around the world in most organizations, and have existed for quite a long time. Plans linked to programs have not always occurred as the two information products are developed by different units and groups within organizations, but in this day and age of digital tools, they are often being linked. At times, water quality is improved on a project by project basis, within connecting projects into a program. WA Dept of Ecology [tracks water quality improvement projects](http://www.ecy.wa.gov/programs/wq/tmdl/TMDLsbyWria/TMDLbyWria.html).

In the early 2000’s within [WRIA 9, 16 local governments](http://www.govlink.org/watersheds/9/reports/default.aspx) convened citizens, scientists, businesses, environmentalists, and government representatives to develop a science-based Salmon Habitat Recovery Plan. Carrying out the plan recommendations will protect and restore a healthy watershed ecosystem for both people and fish. King County Dept of Natural Resources provided staff under contract to assist with coordination, with funds coming from the 16 local governments. Chinook salmon are listed as *threatened* under the Endangered Species Act. See the salmon recovery fund [project map](http://www.govlink.org/watersheds/9/funding/SRFBprojects.aspx) from 2009. However, remember that our activity is about improvement of water flow and/or water quality with influence on habitat recovery for salmon, thus a slightly broader, but linked causal activity in relation to habitat restoration and recovery. More recent activity has turned to that broader effort to plant trees within the riparian corridor as an attempt to [Re-green the Green River](http://www.govlink.org/watersheds/9/plan-implementation/Re-Green.aspx#ReGreen), that is, a focus on water flow and water quality. The planting plan extends to 2025.

An innovative example outlining how to fund an improvement program for a watershed came in 2009 with discussion in the WA State Legislature about a [watershed investment district (WID) for WRIA 9](http://www.govlink.org/watersheds/9/pdf/WID-DraftLegislationSummary-Final7-27-11.pdf).

Starting in 2009, the WRIA9 Watershed Ecosystem Forum was exploring [funding mechanisms for development of a WID](http://www.govlink.org/watersheds/9/plan-implementation/FundingMechanisms.aspx). A rationale for watershed taxing is critical part of justifying the importance of investment in ecosystems infrastructure. In [proposed Washington State legislation for WID’s](http://www.govlink.org/watersheds/9/pdf/WID-DraftLegislation-Section-by-Section-Summary7-20-11.pdf), Sec. 306 Revenue Sources “…authorizes a district board to fix or impose a fee, tax, surcharge or assessment as approved by a majority of voters within the district and lists a menu of options, including general property tax; utility fee; sales and use tax; real estate excise tax; per parcel assessment; and pollution discharge tax.” Consequently, in this lab assignment it is crucial to understand that both revenue and cost are important to forming a budget for an improvement program.

The WID was cast with broader concerns other than salmon recovery, but nonetheless had salmon recovery at its core intent. The basis of the effort argued that ecosystem services are provided by natural capital as infrastructure, and thus ecosystem services offer significant value, e.g. habitat homes for fish and places where people can swim without being harmed. In 2008, Earth Economics estimated the value of [ecosystem services in Puget Sound basin](https://www.floods.org/ace-files/documentlibrary/committees/A_New_View_of_the_Puget_Sound_Economy.pdf) to be worth between $7 billion to $61

billion per year. In 2014, a similar but more detailed study was performed for [WRIA9 Green-Duwamish River Watershed ecosystem services](https://drive.google.com/file/d/0ByzlUWI76gWVUkEtcC1DVk1yaGc/view). Identifying value of natural capital service, e.g. attenuation of flooding, is important to understanding investment in the service infrastructure, as it is for any infrastructure such as electric, gas, cable etc.

**1.1 Introduction to Lab Assignment Instructions**

In this lab assignment we explore how improvement programs implement plans. The purpose of an improvement program is to invest in functional performance of a system to enhance its service in line with the plans that set out broad-based functional goals. Watershed improvement programs exist in many forms. Most of them follow goals of functional performance. Improvement programs are used to compose a collection of projects that together are budgeted for implementation. The development of budget is commonly dependent on the expenses (as total costs) of the collection of projects and the collection of revenues used to pay for them. However, we still need to know about the value of improvement, so for this we will use ecosystem services value. The best investment is a balanced budget (revenue = expenses), while also seeking the highest ecosystem services value.

**1.2 Learning Objectives:**

1. Understand how to narrow the focus, while deepening understanding about functional need for improvement of functional services.
2. Develop further insight about need by sharpening focus on criteria, objective, goal associated with functional performance. Develop the criteria suitable to the program under consideration.
3. Refine an understanding of functional performance levels, comparing current and desired performance levels for improvements when trading off impacts to set priorities based on ecosystem services value.
   1. **Tools for this lab**

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| [ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336)  [CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342) | [SUMMARIZE TABLE](https://canvas.uw.edu/courses/1152834/discussion_topics/3773869)  [JOIN FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757280) | [CALCULATE GEOMETRY](https://canvas.uw.edu/courses/1152834/discussion_topics/3792440)  [INTERSECT](https://canvas.uw.edu/courses/1152834/discussion_topics/3783772) |

**2.0 Forming an assessment model for natural capital improvement program**

Water is one of the most basic natural resources; and as such can be considered natural capital. The basic difference between a plan and an improvement program for water is that an improvement program focuses on some of the elements of a plan, but adds to those elements an understanding of revenue, expenses, and valuation in terms of monetary unit. In other words, programs deal with budgets wherein expenses should be equal to revenue for a ‘balanced budget’. How might we develop an assessment model that includes a budget for an improvement program? We can make investments in WF, or WQ, or a combination of these to compose a program based upon an assessment of the current conditions and expected outcomes. Programs are commonly restricted to the generalized projects that are listed in plans, but this depends on the functional performance of plans and projects of concern. We will use three sub-models to do this: representation, space-time process, and evaluation.

**2.1 Representation Model**

The first step is to select what portion of the study area plan, that is, WF or WQ or the combination is to be addressed. This selection of sub-watersheds establishes the study area. If we select all sub-watersheds then we must be willing to draw upon revenue and costs from all jurisdictions within the WRIA, which is what we will do. We are considering three approaches to functional improvement:

1. Water flow improvement in sub-watersheds based on analysis units
2. Water quality improvement in sub-watersheds based on analysis units
3. Combination of above for overall water function improvement based on analysis units

As we learned in Lab 1, a representation model is at least a WRIA study area boundary with the content and structure of features within. The jurisdictions and sub-watersheds are the features that provide context for the study. Water flows through the jurisdictions, and this water has a certain water quality as the landscape features. In addition to water flow and water quality on the landscape as part of the representation model, we need revenue and cost to form a balanced budget for making improvements in line with those features.

A robust representation model contains the WRIA study area, jurisdiction unit, sub-watershed units, analysis units (AU) plus revenue, expenses, and valuation information for these units. It is best to have computed data for all domain scales, i.e. WRIA (often thought of as watershed), sub-watershed, jurisdiction (the cities and unincorporated King County) and analysis unit (AU, which is also called a sub-sub-watershed when speaking of drainage unit).

We ask you to use the provided WRIA geodatabases linked below so everyone will have the same data as you begin work on Lab 3. Remember to choose the geodatabase that matches the same WRIA you used in Lab assignments 1 and 2.

The files on Canvas in this folder: <https://canvas.uw.edu/courses/1152834/files/folder/lab/data/Lab3_restart>

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| [Lab3\_WRIA7.zip](https://canvas.uw.edu/files/42091542/download?download_frd=1) | [Lab3\_WRIA8.zip](https://canvas.uw.edu/files/42091552/download?download_frd=1) | [Lab3\_WRIA9.zip](https://canvas.uw.edu/files/42091559/download?download_frd=1) |

Download and extract the files to your Lab 3 working folder. Remember: ArcMap cannot read files from inside a zip archive.

Create a new empty ArcMap project and save it to your Lab 3 working folder then load the data from your Lab 3 WRIA geodatabase. The geodatabase contents are the following:

* city\_kc\_dslv – Jurisdiction feature class with attributes
  + population - human population
  + PCI - per capita income
  + jacres – jurisdiction area in acres
* AU\_WFWQ – baseline scenario data with attributes.
  + WF\_order – water flow order from Figure D-14
  + WQ\_order – water quality order from Figure D-19
  + WFstnd – standardized WF\_order
  + WQstnd – standardized WQ\_order
  + WFI – water function index
* WRIA?\_outline – This feature class is from the WA Department of Ecology’s geodatabases. The ‘?’ is a wildcard character for the number of your WRIA.
* wet\_dry\_cost – a look-up table of cost / acre for GSI improvement for the two water functions (WF, WQ) and land types (dry, wet).
  + WFWQorder – Order score for WF and WQ. WQ\_wet\_caa and WQ\_dry\_caa with WQ\_order.
  + WF\_wet\_caa – $Cost Amount / Acre for water flow wetland GIS improvement
  + WF\_dry\_caa – $Cost Amount / Acre for water flow dryland GIS improvement
  + WQ\_wet\_caa – $Cost Amount / Acre for water quality wetland GIS improvement
  + WQ\_wet\_caa – $Cost Amount / Acre for water quality dryland GIS improvement
* wtrcrs - King County water courses. [metadata](http://www5.kingcounty.gov/sdc/Metadata.aspx?Layer=wetlands)
* wetlands – King County wetlands. [metadata](http://www5.kingcounty.gov/sdc/Metadata.aspx?Layer=wtrcrs)

**2.1.1 Identifying Revenue for Improvements Across All WRIA Jurisdictions**

**Tools needed**: [ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336), [CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342), [IDENTITY](https://canvas.uw.edu/courses/1152834/discussion_topics/3783332), [ALTER FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3783333), [SUMMARIZE TABLE](https://canvas.uw.edu/courses/1152834/discussion_topics/3773869), [JOIN FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757280), [CLIP](https://canvas.uw.edu/courses/1152834/discussion_topics/3792495)

We will assess the conditions for revenues, costs, and value for ecosystem service function within WRIAS.

A consistently available revenue source that can provide a revenue stream over time is needed to generate realistic, fair, and substantial funds. Each jurisdiction within King County, including unincorporated King County as a jurisdiction, has an estimated 2010 population and an income per capita developed from the Census Fact Finder website. Multiplying the population count times the income per capita for each jurisdiction provided the total potential income (TPI) for the jurisdictions, including [unincorporated King County](http://www.kingcounty.gov/~/media/depts/executive/performance-strategy-budget/regional-planning/Demographics/UKC-profile2016.ashx?la=en).

Calculate the total potential income (TPI) of each jurisdiction in city\_kc\_dslv.

[ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336). Feature class: city\_kc\_dslv. Type: float. Name “JTPI”

[CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342) Parser set to Python. “JTPI” = !Population! \* !PCI!

However, the income is a base for what revenue might be available. Only a portion of that income could be dedicated to water flow, water quality, or overall water function improvement; a fair amount by a legislative body need be chosen; but we will not worry about the legislative body. We assume a 1/10 of 1% (.001) tax could be levied, which is not unusual for large program beneficial to a population of a jurisdiction. We will not worry about how the local jurisdictions would collect this tax, but it is essentially a local income tax (which of course does not exist in WA State). The equity issue is based on the notion that problems are worse where more people live. That is, we assume that populations create impervious surface and therefore, more population causes more impervious surface. However, more people also means more ability to pay when totaled by jurisdiction; but of course this is dependent on income level, so we will make some assumptions.

Compute the total amount funds that could be generated within each jurisdiction using the above rate of 0.001 per dollar \* total potential income with each jurisdiction, which will equal Jurisdiction Total Potential Revenue (JTPR)

[ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336) float named “JTPR” to city\_kc\_dslv.

[CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342). Parcer set to Python. “JTPR” = !JTPI! \* 0.001

Create a map of JTPR for all jurisdictions across the WRIA, symbolizing amount by jurisdiction. The basemap will be jurisdiction boundaries, but show the WRIA boundary as well.

**2.1.2 Identifying Revenue Potential Inside of the WRIA**

Total revenue generated within a WRIA across all jurisdictions must equal total expenses (cost of management action of protection, restoration, recovery) within WRIA. However, if only a portion of a jurisdiction is contained within a WRIA or then only a portion of the revenue from that jurisdiction will be used for the WRIA. The portion of the jurisdiction that is NOT contained in your WRIA will not be available for spending. To accomplish this, we will assume income potential (revenue to be generated) is proportional to area; that is, the area of jurisdiction within the sub-watershed will be proportional to its contribution to the total income to be generated within the sub-watershed. This assumption of uniform distribution of population and income simplifies our effort. To quantify this you have to determine the area of each jurisdiction in each subwatershed and sum the area proportional potential revenue of the intersection jurisdiction parts.

* Compute WRIA total potential revenue (WRIA\_TPR). This will require the city\_kc\_dslv and WRIA?\_outline feature classes. City\_kc\_dslv already has the fields ‘JTPR’ and jacres’ that is the area of the each jurisdiction in acres. Because you want to discard the portion of the jurisdictions outside the WRIA boundary and have no need for the attributes of the WRIA outline feature class you can use the CLIP operation to perform this task.
  + [CLIP](https://canvas.uw.edu/courses/1152834/discussion_topics/3792495). Input features: city\_kc\_dslv. Clip features: WRIA?\_outline. Name the output feature class: city\_kc\_clip.
* Recalculate and overwrite the field JTPR with the new value of the clipped portion of the jurisdictions.
  + [CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342). Field name: JTPR. Set Parser to Python.   
    Equation: JTPR= !JTPR! \* (!shape.area@acres! / !jacres!)
    - ‘jacres’ is the area of the unclipped jurisdiction polygon in acres. The fraction in this equation used is the proportion of the clipped jurisdiction area divided by the area of the unclipped jurisdiction polygon. When multiplied by the full jurisdiction JTPR the result is the commensurate JTPR of the clipped jurisdiction area. Some of the jurisdictions are inside the WRIA outline and the fraction will be 1 and the unclipped and clipped jurisdiction polygons are the same except for a tiny bit of error because ArcMap has a limit to how many decimal places it can accommodate.
  + NOTE: city\_kc\_dslv has the complete (unclipped) total potential revenue in the field JTPR while city\_kc\_clip has the adjusted total potential revenue for the portions of the jurisdictions inside the WRIA.
* To Find the total (sum) potential revenue for the WRIA from the clipped jurisdictions use ‘statistics’ for the field JTPR. Make a note of this value, you will need it in section 2.3.1. Hereafter it will be called ‘$WRIA\_TPR’

Make two maps of city\_kc\_clip, one showing the JTPI values of the unclipped jurisdictions (clip\_kc\_dslv) with an overlay of the outline of WRIA?\_outline and another of JTPR of the clipped jurisdictions (city\_kc\_clip).

**2.1.3 Identifying Potential Total Expense of Improvements Based on Green Infrastructure Cost**

**Tools needed**: [ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336), [CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342)

We must compute total acres of WF and WQ in the WRIA to be able to compute total costs for green stormwater infrastructure (GSI) within a WRIA. This will require an understanding of the WF and WQ functions in relation to GSI improvement strategies. Each of WF and WQ functions provide different services. To address WF and WQ functional improvement we use two approaches, a dryland approach and a wetland approach. The combination of function and improvement type gives us four functional improvement types (FITs): WF-dryland, WQ-dryland, WF-wetland, and WQ-wetland. The water functions (WF and WQ) and GSI approaches (dryland and wetland) each has an effort and thus cost associated with it.

To simplify, we will assume that WF and WQ functions are similar in cost. However, for dryland and wetland GSI approaches, we differentiate those dry and wet approaches in terms of costs.

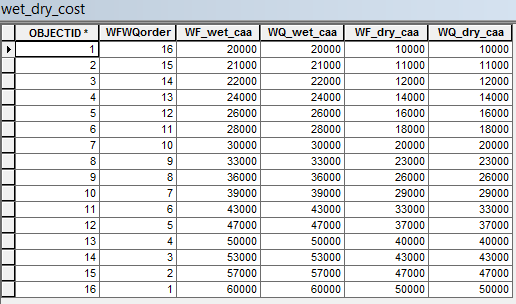
DRYLAND GSI improvement

Information from reports about green stormwater infrastructure show that costs of improvement range between $10,000 and $50,000 per acre depending on the condition of land. When land is in a more natural condition then the cost of improvement is lower. When land is in a more developed (degraded with regard to water function) condition, then costs of improvement are higher. These conditions and amount of effort translate into the following cost schedule in light of the difference in cost of improvement. (Note the inverse relationship)

WETLAND GSI improvement

Information from reports about green stormwater infrastructure show that costs of improvement range between $20,000 and $60,000 per acre depending on the condition of wetlands. When wetlands are more pristine then the cost of improvement is lower. When wetlands are in a more degraded condition, then costs are higher. These conditions and amount of effort translate into the following cost schedule in light of the difference in cost of improvement. (Note the inverse relationship between $ and function units)

The lookup table (wet\_dry\_cost) of the dryland and wetland improvement approaches for WF & WQ function order scores 16 (low cost) to 1 (high cost).



The fields are:

* WFWQorder – Order score for WF and WQ. Note: WFWQorder is used twice as the join field, once to join WF\_wet\_caa and WF\_dry\_caa with WF\_order and the other to join WQ\_wet\_caa and WQ\_dry\_caa with WQ\_order.
* WF\_wet\_caa – $Cost Amount / Acre for water flow wetland GIS improvement
* WF\_dry\_caa – $Cost Amount / Acre for water flow dryland GIS improvement
* WQ\_wet\_caa – $Cost Amount / Acre for water quality wetland GIS improvement
* WQ\_wet\_caa – $Cost Amount / Acre for water quality dryland GIS improvement

We now compute the cost of WF and WQ improvement using each of the dryland and wetland strategy for each subwatershed in by multiplying the number of acres to be improved by the cost per acre in light of the functional level (order) of WF and WQ.

Add the fields for **dryland** costs per acre to the subwatershed feature class AU\_WFWQ.

[JOIN FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757280). Input table: AU\_WFWQ. Input join field: WF\_order. Join table ‘wet\_dry\_cost’. Output join field: WFWQ\_order. Join fields: WF\_dry\_cost, WF\_wet\_cost.

Add the fields for **wetland** costs per acre to the subwatershed feature class AU\_WFWQ

[JOIN FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757280). Input table: AU\_WFWQ. Input join field: WQ\_order. Join table ‘wet\_dry\_cost’. Output join field: WFWQ\_order. Join fields: WQ\_dry\_cost, WQ\_wet\_cost.

Improvement will be limited to a percentage of the AU area calculated by multiplying the AU area by a constant between 0 and 1. To begin exploration of cost schedules GSI improvement of dryland and wetland will be limited to five one-hundredths of a percent (0.0005).

Create fields and calculate the cost schedules for each subwatershed.

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| New field name. ([ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336). Type: float) | Equation ([CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342). Parser is Python) |
| WF\_dry\_cs | (!shape.area@acres! \* 0.0005) \* !WF\_dry\_caa! |
| WF\_wet\_cs | (!shape.area@acres! \* 0.0005) \* !WF\_wet\_caa! |
| WQ\_dry\_cs | (!shape.area@acres! \* 0.0005) \* !WQ\_dry\_caa! |
| WQ\_wet\_cs | (!shape.area@acres! \* 0.0005) \* !WQ\_wet\_caa! |

Four surfaces result, as we have two cost schedules (dryland and wetland) and two sets of function scores (WF and WQ).

Make four maps, one each for the AUs according to the four combinations of costs in your WRIA, Use a quantile, e.g., septile (7) or decile (10) strategy.

1. WF-dryland cost schedule (WF\_dry\_cs)
2. WQ-dryland cost schedule (WQ\_dry\_cs)
3. WF-wetland cost schedule (WF\_wet\_cs)
4. WQ-wetland cost schedule (WQ\_wet\_cs)

These maps tell us where more and less work needs to be done. We would expect more work where there is more degradation. Where would you expect more degradation and is your logic reflected in the cost schedule calculations?

**2.2 Space-time Process Model**

This section provides a description of process models as additional insight; but we will not be developing a process model as it is considerable work. Therefore, we will use the datasets as before, without going into the details of the models. Remember, the representation model information is nested within the process model information and the process model information nests within the evaluation model, as we create the evaluation model in Section 2.3

As before, we use the water flow model and water quality model developed by WA Ecology for the particular WRIA of your choice. (If you want to know the details about the process modeling effort, consult the [Snohomish WRIA 7 report](https://fortress.wa.gov/ecy/publications/SummaryPages/1506009.html).) Process is the core of the water flow model, wherein process is characterized using four structural components: water delivery, surface storage (rivers, streams, lakes, ponds), water recharge into groundwater, and water discharge from groundwater back to surface storage. The four components represent a staged-sequence of water flow, developed across three scales at any given time. The macro scale is the study boundary, i.e. the WRIA. The meso scale is the sub-watershed scale at which the four components are aggregated. The micro scale is ‘reach’ (sub-sub-watershed) scale at which data are compiled, and then aggregated across the four components for each sub-watershed, and thus reported as flow. As such, every water flow model is composed of a triplet of scales. Although we are not diving into the details of the structure of the models, we know that water flow process affects the functional performance of the water flow over time. We know that sub-watersheds influence other sub-watersheds by their location in a WRIA. Generally, uphill-downhill (upstream-downstream) from east to west will matter within WRIA flow. Thus, the performance of water flow and water quality on which sub-watersheds are chosen from east to west as flow occurs over time in cycles. That is, the more east the project, the more benefit downstream.

The Water Quality model was developed using the Open Nonpoint-Source Pollutant Evaluation and Comparison ([OpenNSPECT](https://coast.noaa.gov/digitalcoast/tools/opennspect)) tool that was developed and made available through NOAA’s Digital Coast website. (If you want to know the details about how the water quality modeling was applied, consult the [Snohomish WRIA 7 report](https://fortress.wa.gov/ecy/publications/SummaryPages/1506009.html).) The tool operates on a grid-based stochastic probability process to model stormwater runoff. Stochastic probability is a technique that relies on neighborhood relationships to establish the influence of one grid cell neighbor on another for stormwater accumulation to carry pollutants.

**2.3 Evaluation Model**

Our evaluation model works with revenue and expenses to form a balanced budget, and then we compute ecosystem value to determine how much improvement is made. NOTE: the value of ecosystems services in $/area as provided by water flow (volume or quantity) and water quality (cleanliness) is a different number than $revenue per jurisdiction and the $cost per acre. So, all three numbers are relevant in our evaluation.

**2.3.1 Evaluating Expenses and Revenues to Achieve a Balanced Budget**

**Tools needed**: [ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336), [CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342)

When considering a WRIA, a balanced budget exists when total potential revenue across all jurisdictions is equal to total costs for the WRIA.

First, let us consider the potential range of the number of acres that can be improved with total potential revenue and cost units.

WRIA\_TPR should equal WRIA\_Cost for improvement

We have two cost schedules presented in Section 2.1.3. The highest cost for improvement per acre is associated with the wetland schedule at a WF or WQ score of 1, which is $60,000 per acre. The lowest cost for improvement per acre is associated with dryland schedule at a WF or WQ score of 16, which is $10,000 per acre. As such we can use the combination of WRIA total potential income (WRIA\_TPR) and these two extremes to provide a range of possible acres to be improved.

Compute the range of acres between fewest\_#\_acres to greatest\_#\_acres.

$WRIA\_TPR/$60,000 = fewest #

$WRIA\_TPR/$35,000 = middle #

$WRIA\_TPR/$10,000 = greatest #

NOTE: To calculate the proportion of the WRIA that could be improved at these costs divide the acres identified above by the **area of the clipped jurisdictions** (jurisdiction areas only within WRIA) contributing to the $WRIA\_TPR.

This gives us a maximum range of acres to be improved. It tells us that if all WF and WQ scores indicated pristine conditions (score of 16), then we could improve using a protection only strategy. It also tells us if that all WF and WQ scores indicated worst conditions (score of 1), then we would have to improve using redevelop strategy.

Next, let us consider how to assess potential costs in light of the TPR. Remember that this is assessment modeling and not intervention modeling. So, our strategy is experimental as we are interested in ranges of what might be done as insight for need.

As mentioned above, DRYLAND and WETLAND have different cost schedules per acres.

We know that you cannot reach the minimum and maximum acres computed in Section 2.1.3 because the WF and WQ scores range across 1 – 16, there are differences in cost schedules, and we have a maximum for expenditure as given by the total potential revenue for the WRIA.

What if all improvements were for either WF or for WQ using each of the cost schedules? We still have a TPR ($WRIA\_TPR) as the ceiling of our budget for incurring cost.

There are four possible combinations between WF and WQ plus DRYLAND and WETLAND as mentioned previously.

Create new fields for the acres of dryland and wetland GSI improvement and populate them with the same areas used to calculate the cost schedules in section 2.1.3. In the equations below ‘!shape.area@acres!’ calculates the subwatershed area in acres so you do not have to use CALCULATE GEOMETRY as a separate calculation. As above, calculation of area for dryland and wetland improvement will be five one-hundredths of a percent (0.0005).

[ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336). Type: float. Name: x\_acres.

[CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342). Set Parser to Python. x\_acres = !shape.area@acres! \* 0.0005

[ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336). Type: float. Name: y\_acres.

[CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342). Set Parser to Python. y\_acres = !shape.area@acres! / 0.0005

Did you notice that x\_acres and y\_acres are the same? It will be valuable to keep separate track of these two fields in Lab 4 where we may want to consider more or less investment in dryland improvement than wetland. For the purpose of evaluation they will remain set as they are to the same value.

Create a field for the GSI cost of each AU:

[ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336). Type: float. Name: GSI\_cost.

The following [CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342) equations will produce the cost for these combinations of water function and land type. Do the calculations and each time open ‘statistics’ for GSI\_cost and note the sums for each.

|  |  |  |  |
| --- | --- | --- | --- |
| Description | Function / landtype combination | [CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342) equation. Parser is Python | GSI\_cost  Statistics sum |
| All | Water flow wetland  Water flow dryland  Water quality wetland  Water quality dryland | GSI\_cost = (!x\_acres! \* !WF\_dry\_caa!) + (!x\_acres! \* !WF\_wet\_caa!) + (!y\_acres! \* !WQ\_dry\_caa!) + (!y\_acres! \* !WQ\_wet\_caa!) | $ |
| Flow | Water flow wetland  Water flow dryland | GSI\_cost = (!x\_acres! \* !WF\_dry\_caa!) + (!x\_acres! \* !WF\_wet\_caa!) | $ |
| Quality | Water quality wetland  Water quality dryland | GSI\_cost = (!x\_acres! \* !WQ\_dry\_caa!) + (!x\_acres! \* !WQ\_wet\_caa!) | $ |
| Dry | Water quality dryland  Water flow dryland | GSI\_cost = (!x\_acres! \* !WF\_dry\_caa!) + (!y\_acres! \* !WQ\_dry\_caa!) | $ |
| Wet | Water quality wetland  Water flow wetland | GSI\_cost = (!x\_acres! \* !WF\_wet\_caa!) + (!y\_acres! \* !WQ\_wet\_caa!) | $ |

Compare the differences in $WRIA\_TPR and the five cost sums All, Flow, Quality, Dry and Wet. How well does the budget balance in these cases? That is, how much are you spending, is it more or less than $WRIA\_TPR. How much more or less?

As mentioned, this is an exploratory task. If we knew all of the stakeholder values and all of the criteria it might be easier, but there is no guarantee about this.

**2.3.2 Evaluating Ecosystem Values in the Context of a Balanced Budget**

**Tools needed:** [ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336), [CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342), [IDENTITY](https://canvas.uw.edu/courses/1152834/discussion_topics/3783332), [ALTER FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3783333), [SUMMARIZE TABLE](https://canvas.uw.edu/courses/1152834/discussion_topics/3773869), [JOIN FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757280)

In the above approach we are investigating balanced budget ideas, although we are not guided by much information in regards to actual value of improvement. True, the WF and WQ function scores tell us what management action is important, that is, high function scores are important (e.g. 13-16 quartile are more valuable so to speak than 9-12 quartile scores).

Each land cover is associated with several ecosystem services. Some land covers address stormwater runoff attenuation and water quality filtering better than others. Resources in pristine condition provide the most $value (as a high value), whereas resources in good condition provide a medium value, and resources in degraded condition provide least value. Earth Economics in 2014 estimated ecosystems services $values in the WRIA 9 watershed ([Zachary Christin, Tracy Stanton, Lola Flores 2014](https://drive.google.com/file/d/0ByzlUWI76gWVUkEtcC1DVk1yaGc/view)). If we protect and restore rivers/lakes and wetlands then we accrue benefit from WF and WQ improvements, together called water function. In the table below we can see that wetlands per acre have a greater range of benefit than rivers/lakes per acre.

Ecosystem services value by two land cover types

|  |  |  |  |
| --- | --- | --- | --- |
| Land cover type | Low $/acre | High $/acre | Mean value $/acre |
| Rivers/Lakes | 7000 | 28000 | 17,500 |
| Wetlands | 600 | 83000 | 42,000 |

Zachary Christin, Tracy Stanton, Lola Flores 2014. Nature’s Value from Cities to Forests: A Framework to Measure Ecosystem Services Along the Urban-Rural Gradient, from Table 12. Total Value of 14 Ecosystem Services Produced over 16 Land Cover Types in WRIA 9, p. 33. <https://drive.google.com/file/d/0ByzlUWI76gWVUkEtcC1DVk1yaGc/view>

From the above information, we estimate ecosystem service value for rivers/lakes and wetlands in the following way.

**River/Lakes Functional Value Per Acre**

To begin the rivers in each AU subwatershed must be known and the ones outside AU\_WFWQ discarded. Intersect wtrcrs and AU\_WFWQ to split the rivers into each AU subwatershed polygon.

[INTERSECT](https://canvas.uw.edu/courses/1152834/discussion_topics/3783772). Features: wtrcrs, AU\_WFWQ. Output feature class: au\_rivers

Use au\_rivers to compute the number of lineal river feet within each of the analysis units. Assume that 500 lineal feet of river equals one acre of water. Convert to acres of river/lakes.

Add a new field to hold the acres calculation.

[ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336). Feature class: au\_rivers. Type: float Name: “river\_ac”

[CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342). Set Parser to Python. river\_ac = !shape.length@feet! / 500.0.

Summarize au\_rivers to create a table with the acres of rivers/lakes in each AU subwatershed.

[SUMMARIZE TABLE](https://canvas.uw.edu/courses/1152834/discussion_topics/3773869). Table: au\_rivers, Field to summarize: AU\_ID, Summary statistic: ‘river\_ac’ SUM. Output table name: river\_ac\_sum

Join the results to the AU\_WFWQ subwatersheds.

[JOIN FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757280). Input table: AU\_WFWQ. Input join field: AU\_ID. Join table: river\_ac\_sum. Output join field: AU\_ID. Join field: Sum\_river\_ac.

The environmental service values vary with the WF and WQ order increments. For this evaluation the environmental service value for flow and quality are the same but will be calculated in separate fields for clarity and the possibility that the costs might be adjusted differently at a later date. The following value endpoints are used to create a linear equation to assign river/lake value amount per acre:

$28,000 per acre for increments at highest data value (16) of condition of WF or WQ

$7,000 per acre for increments at lowest data value (1) of condition of WF or WQ

We can establish a computed cost from the range of costs from $28,000/acre at data value 16 to $7,000/acre at data value 1.

[ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336). Table: AU\_WFWQ. Type: float. Name “F\_riv\_esv”

[CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342) Set Parser to Python.

[ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336). Table: AU\_WFWQ. Type: float. Name “Q\_riv\_esv”

\* Where is higher density of average value (pristine acres) of river/Lake acres?

To answer that question, use the average value per acre since we do not have locations of low to high values; and will not infer them from WF and WQ function.

\* How many acres of river/lakes are in each AU?

Map of the absolute amount of river/lake acres per AU across the WRIA.

Map of the density of river/lake acres per AU across the WRIA.

**Wetlands Functional Value Per Acre**

As with the rivers and lakes the wetlands need to be intersected with AU\_WFWQ to evaluate the wetland acres in each AU subwatershed.

[INTERSECT](https://canvas.uw.edu/courses/1152834/discussion_topics/3783772). Features: wetlands, AU\_WFWQ. Output feature class: au\_wetland

Add a new field to hold the wetland acres calculation.

[ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336). Feature class: au\_wetland. Type: float. Name: “wet\_ac”

[CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342). Set Parser to Python. wet\_ac = !shape.area@acres!

Summarize au\_wetland to create a table with the acres of wetlands in each AU subwatershed.

[SUMMARIZE TABLE](https://canvas.uw.edu/courses/1152834/discussion_topics/3773869). Table: au\_wetland, Field to summarize: AU\_ID, Summary statistic: ‘wet\_ac’ SUM. Output table name: wetland\_ac\_sum

Join the results to the AU\_WFWQ subwatersheds.

[JOIN FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757280). Input table: AU\_WFWQ. Input join field: AU\_ID. Join table: wetland\_ac\_sum. Output join field: AU\_ID. Join field: Sum\_wet\_ac.

The environmental services value of wetlands is also linear bounded by the minimum and maximum order values for WF and WQ.

$83,000 per acre for increments at highest data value (16) of condition of WF or WQ

$600 per acre for increments at lowest data value (1) of condition of WF or WQ

We can establish a computed cost from the range of costs from $83,000/acre at data value 16 to $600/acre at data value 1.

[ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336). Table: AU\_WFWQ. Type: float. Name “F\_wet\_esv”

[CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342) Set Parser to Python. F\_wet\_esv = !Sum\_wet\_ac! \* (600.0 + (82400.0 \* ((!WF\_order! - 1.0) / 15.0)))

[ADD FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757336). Table: AU\_WFWQ. Type: float. Name “Q\_wet\_esv”

[CALCULATE FIELD](https://canvas.uw.edu/courses/1152834/discussion_topics/3757342) Set Parser to Python Q\_wet\_esv = !Sum\_wet\_ac! \* (600.0 + (82400.0 \* ((!WQ\_order! - 1.0) / 15.0)))

\* Where is higher density of average value (pristine acres) of wetlands acres?

To answer that question, use the average value per acre since we do not have locations of low to high values; and will not infer them from WF and WQ function.

\* How many acres of wetlands are there in each AU?

Map of the absolute amount of wetland acres per AU across the WRIA.

Map of the density of wetlands acres per AU across the WRIA.

**2.3.3 Overview of Evaluation Modeling**

For the subwatersheds, jurisdictions, and analysis units within your WRIA, the results of an assessment model composed of representation, process, and evaluation sub-models should provide insight about 1) how to attain a balanced budget and 2) the ecosystem service values in connection with a balanced budget. Note that an evaluation model does not have you choose which areas to improve, but provides insight about conditions for improvement.

Making choices for improvement in particular is the objective of an intervention model (that is, Lab 4). The above computations considering total potential total potential revenue, total costs as expenses, and ecosystem service valuation – in combination provide an evaluative overview of the opportunity for improvement design changes that we will use in Lab assignment 4 as part of the intervention model.

Write an essay that compares the acres of WF and/or WQ improvement on the improvement map and the ecosystem services values map. Are we improving in AUs of high ecosystem values or not? Where exactly on the maps is there a disconnect between the improvements assessed and the acres valued?

**3.0 Deliverables**

Map of TPI by jurisdiction across the WRIA, symbolizing amount by jurisdiction. The basemap will be jurisdiction boundaries, but show the WRIA boundary as well. Choropleth of JTPI attributes.

Map of total jurisdiction total potential revenue (JTPR) across the WRIA, symbolizing amount by jurisdiction. The basemap will be jurisdiction boundaries, but show the WRIA boundary as well. Choropleth of JTPR attributes.

Four maps, one each for the AUs according to the four combinations of costs in your WRIA, Use a quantile, e.g., septile (7) or decile (10) strategy.

- WF-dryland cost schedule

- WQ-dryland cost schedule

- WF-wetland cost schedule

- WQ-wetland cost schedule

Map of the absolute amount of river/lake acres per AU across the WRIA.

Map of the density of river/lake acres per AU across the WRIA.

Map of the absolute amount of wetland acres per AU across the WRIA.

Map of the density of wetland acres per AU across the WRIA.

Essay describing interpretation of evaluation model which involves your perspective on balanced budgeting and areas that are potentially ripe for improvement in light of the ecosystem services valuation.