THEODROS M. WOLDEYOHANNES

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https://yanlingeo.wordpress.com/health-environmental-research-gis-lab/

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Professional Statement

I have strong skills in geospatial modeling, geography, community engagement, and project management based on in-depth academic research and professional experience over the past decade. I am a very versatile and accomplished researcher and professional in a range of fields, including environmental science, geography, and environmental health and safety (EHS). This multi-faceted background gives me the ability to manage several projects at once and bring unique perspectives to research problems. I aim to continue pursuing research/professional experiences that involve environmental justice issues, helping to better understand public health hazards and improve the livelihoods of people in impacted communities.

My current position as a trainee at National Institutes of Health (NIH) allows me to further apply my skills as aligned with my environmental justice values. I am involved with several research projects at two Centers at University of New Mexico (UNM): Center for Native American Environmental Health Equity Research and Metal Exposure Toxicity Assessment on Tribal Lands in the Southwest. This work is focused on studying environmental exposures in Indigenous and rural communities from pollutant sources such as mining, municipal solid waste burning, and fossil fuel extraction. Research is inclusive and involves co-facilitation with community partners, allowing me to foster my community engagement skills. For example, I am directly involved in the creation of materials and design of plans for community engagement activities. This includes the development of collaboration plans specifically tailored for different community partners and organizations. From a technical standpoint, this experience as a trainee exemplifies skills including coding/programming, GIS, field-work, and other scientific methods. I have taken advantage of opportunities to lead study design. Working on a large volume of studies has been an exercise in project management and organizational hierarchies.

Resume

Theodros Mentesinot Woldeyohannes

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PURPOSE

I have a strong passion for health geography, bolstering the voices of marginalized communities facing environmental injustices and helping to create a more equitable and sustainable future through science.

EDUCATION

Fall 2021-Present, University of New Mexico

- Doctor of Philosophy in Geography

Fall 2018-Spring 2020, Rochester Institute of Technology

- Master of Science in Environmental Science

WORK EXPERIENCE

- **August 2021-Present, Research Assistant, UNM Department of Geography**
  - Research Assistant at the Health and Environmental Research GIS Lab, specialist in geospatial modeling.
- **August 2021-Present, Research Trainee, National Institutes of Health**
  - UNM METALS Superfund Research Program Center
  - Center for Native Environmental Health Equity Research
- **September 2020-June 2021, EHS Technician, HSE Consulting Services**
  - Environmental Health & Safety
  - Industrial Hygiene, Air Quality, Asbestos, Lead, Mold
  - OSHA Compliance, Training, Environmental Services
- **March 2019 – November 2019, CAMP Technician/Environmental Scientist, AECOM**
  - Air quality and noise monitoring, structural and settlement monitoring.
  - Monitored environmental and structural factors with various instruments and monitoring systems
- **August 2017 – May 2018, Teaching Assistant, Rochester Institute of Technology**
  - Applications of GIS TA. Helped foster student GIS skills

LEADERSHIP

- **2022 – Present, President, Student Association of Geography and Environmental Studies (SAGES)**
  - **Geography Awareness Week**
    - Coordinated and planned weeklong roster of events, including a conference, workshops, film screenings, and guest speakers.
  - **Facilitation of student professional development**
    - Secured funding for student professional development, including travel to conferences, workshops, and materials for projects.
- **Lead instructor for Diné College GIS Workshop** (2022)
- **Inducted Member into the National Society of Leadership and Success** (2015 – Present)

SKILLS

- GIScience, GIS, Spatial Analysis, Python, R, Modeling, Machine Learning.
- Proficient in ArcGIS Pro, ENVI, Idrisi, GeoPandas, and other proprietary and open-source GIS software.
- Photoshop, Illustrator, Acrobat
- Regulatory understanding
- Teamwork and interdisciplinary skills
- Remote sensing (imagery analysis, LIDAR, delineation and training of classification algorithms)
- Air and water quality monitoring
- Strong writing and public speaking skills
- Community Based Participatory Research
- Political ecology and environmental justice
- Proficient in Excel, Word, PowerPoint, Publisher
- Analytical chemistry protocols such as HPLC, GC, and Mass Spectrometry
- GPS, field skills, forestry skills
- Map design
- Statistics
- Meteorological monitoring

CONFERENCES

Southwest American Association of Geographers (SWAAG) – Presenter (2022)

- Geographic mixed methods approaches to assess environmental justice issues relating to unregulated waste disposal sites
- Fayetteville, AR

American Association of Geographers (AAG) – Presenter (2022)

- Geospatial modeling of potential contamination exposure to abandoned or inactive mine sites and trash dumps on the Crow Nation
- New York, NY (virtual)

PROJECTS

NIH Funded Research Project (August 2021 – Present)

NIH P50 Center for Native American Environmental Health Equity Research

Research Project 2

Evaluating Cumulative Environmental Exposure to Metals and Non-metals and Community-level Health Using Geospatial Modeling and Personal Exposure Assessment

National Institutes on Minority Health and Health Disparities

Study effects of potential exposure from mines and trash burning on Tribal lands. Geospatial modeling and creation of exposure maps.

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Doctoral Dissertation, University of New Mexico (August 2021 – Present)

Doctoral Dissertation Research

Community Engaged Multi-Scale Geospatial Modeling of Exposure to Environmental Contaminants on Tribal Lands of the American Intermountain West

Model potential for exposure to contaminants from mining and unregulated waste disposal on multiple geographic scales

Considers several environmental pathways, focusing on Tribal lands.

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Publication in review (co-author), University of New Mexico (August 2021 – Present)

Comparing performance of meteorological data sources – a case study in geospatial modeling of potential environmental exposure to abandoned mine sites on Navajo Nation

Determined the effect of meteorological data sources on predictions

Biography

Narrative Biosketch

Current PhD student in Geography at the University of New Mexico (UNM). Graduated with a BS and MS degree in Environmental Science from The Rochester Institute of Technology (RIT). Advanced knowledge in GIS & remote sensing, conservation biology, environmental systems and ecology, water quality measurements, as well as environmental public policy and waste processing/regulations. Research Assistant at the UNM Health and Environmental Research GIS Lab and trainee for the NIH P50 Project. Previous industry work experience in environmental remediation of MGP sites. Knowledge in environmental monitoring and structural/settlement monitoring. Experience in maintenance and construction of environmental/structural monitoring systems and equipment. Trained in construction and mechanical maintenance. Ready to apply these interdisciplinary skills to a position with a demand for excellent teamwork skills, communication, technical writing, and multitasking abilities, including demand for work involving heavy lifting, machinery operation, and activities in industrial settings.

Curriculum Vitale

Education

University of New Mexico, Albuquerque, NM — August 2021 – Present

Doctor of Philosophy in Geography

- Relevant Coursework: Intro to Geographic Theory, Integrative Research Design, Introductory Programming for GIS, Spatial Analysis and Modeling, Seminar in Geographies of Power, Advanced Programming for GIS, Professional Geographic Development, Environmental Justice, Advanced GIS Seminar

Rochester Institute of Technology, Rochester, NY — August 2013 – December 2020

Master of Science in Environmental Science — May 2018 - December 2020

Bachelor of Science in Environmental Science, **Cum Laude**

School for Field Studies, Cairns, Queensland Australia — February 2016 - May 2016

- Graduated with BS in May 2018. All graduate classes completed. Thesis defended in November.
- Immersion in Public Policy and concentration in Chemistry.
- Relevant Coursework: Environmental Applications of Remote Sensing, Applications of GIS, Graduate Hydrology GIS, Introduction to Statistics I & II, Graduate Statistics, Graduate Regression Analysis, Graduate Decision Analysis, Environmental Science Field Skills, Concepts of Environmental Science, General Ecology, Intro to Biology I & II, Soil Science, Environmental Policy, Technology Public Policy & Patent Law, Project Based Calculus I & II, Organic Chemistry I & II, Chemical Separations, Computer Science I.

Skills & Expertise

- Spatial Analysis
- Python, R
- Modeling
- Machine Learning
- Quantitative skills
- Scientific Writing
- Verbal communication
- Teamwork
- Political Ecology and Environmental Justice
- Community Based Participatory Research
- Basic understanding of NEPA, MEPA and Clean Water Act.
- Analytical chemistry protocols, including HPLC, GC, and Mass Spectrometry

- Interdisciplinary skill set
- GIS
- GPS
- Proficient knowledge of ArcGIS, ENVI, and Idrisi Selva software
- Remote Sensing (imagery analysis, LIDAR, delineation & training of raster classification algorithms/neural-networks, NDVI, etc.)
- Linear & non-linear, geographically weighted spatial regression models (Generalized Linear Regression, Ordinary Least Squares, Local Bivariate Analysis, Geographically Weighted Regression, Forest Based Classification & Regression, etc.)
- Map design
- R, Minitab, Excel statistical analysis
- Microsoft Access
- Some python experience
- Environmental Health & Safety
- Community Outreach
- Data Presentation Skills
- Strong Public Speaking Skills
- Experimental Design
- Air quality monitoring (VOCs & dust)
- Water quality monitoring (Turbidity, pH, DO, conductivity, temperature, etc.)
- Meteorological monitoring
- Noise monitoring
- Artesian deep aquifer well gauging
- Inclinometer well gauging
- Visual inspection for MGP impacted material
- Soil sampling of MGP impacted material (confirmation & documentation samples, MS & MSD)
- Structural & settlement monitoring (AMTS, vibration monitoring, liquid level, ground water gauging, inclinometer wells, manual laser level checks).
- Set up and maintenance of water quality data buoys
- Knowledge in the use and maintenance of PIDs, aerosol monitors, noise dosimeters, water quality sondes, AMTS, vibration monitors, and liquid level systems
- Experience in setting up of telemetry systems, integration of equipment with data loggers and modems, etc.
- Extensive experience with YSI sondes and CB-450 data buoys, including Netronix modems and telemetry system
- Extensive experience with Mini Rae PIDs, TSI Dust Traks, and Digitilt Inclinometers
- Extensive experience with Sokkia AMTS and other laser level systems (automated and manual)
- Field data collection experience (water quality, identifying northeast US plants and fauna, forestry measurements, soil quality)
- Power tools, vehicles/machinery (ATV, commercial vehicles, etc.)
- Extensive driving time in a Ford Transit 250 Utility Van
- Infrastructure maintenance
- Ability to life heavy loads and perform strenuous work for prolonged periods.
- Experience with inventory stocking and management
- Risk management processes and analysis

Relevant Research Projects and Experience

NIH Funded Research Project August 2021 – Present

NIH P50 Center for Native American Environmental Health Equity Research, Research Project 2: "Evaluating Cumulative Environmental Exposure to Metals and Non-metals and Community-level Health Using Geospatial Modeling and Personal Exposure Assessment," National Institutes on Minority Health and Health Disparities.

- Study effects of potential exposure from mines and trash burning on tribal lands
- Geospatial modeling and creation of environmental risk maps

- Analysis of meteorological and mining data, trash burning sites, and existing pollutant datasets (NURE)
- Outreach and engagement with tribal communities

Doctoral Dissertation, University of New Mexico August 2021 – Present

Doctoral Dissertation Research: "Community -Engaged Multi-Scale Geospatial Modeling of Exposure to Environmental Contaminants on Tribal Lands of the American Intermountain West"

- Model potential for exposure to contaminants from mining and unregulated waste disposal on multiple geographic scales
- Considers several environmental pathways, focusing on Tribal lands of the North American Southwest and Intermountain West
- Leverages cutting-edge GIS methods and geospatial technologies
- Central question: *How is exposure potential distributed across Tribal lands, from the scale of entire Tribal nations to the community level, and finally on the individual level*
- Novel approach of integrating bigdata based spatiotemporal modeling with community engaged scholarship in a phenomenological framework
- Represents a mixed-methods, holistic analysis combining both geospatial technology/GIScience with critical/theoretical approaches, that has the potential to lead to a more nuanced and broader understanding of environmental health disparities in indigenous communities

Publication in progress (lead author), University of New Mexico August 2022 – Present

Publication: "Utilizing remote sensing to detect fires and unregulated waste disposal sites"

- Novel method to integrate advancements in remote sensing platforms and spatiotemporal analysis methods to examine fires resulting from unregulated waste disposal in new ways

Publication in progress (lead author), University of New Mexico August 2021 – Present

Publication: "Applying community engaged practices for geospatial modeling of potential exposure to environmental contaminants from unregulated solid waste disposal"

- Adapted an existing geospatial model to predict exposure potential to contaminants from unregulated waste disposal sites including: GIS-based multi-criterial decision analysis (GIS-MCDA), fuzzy logic, and the analytic hierarchy process (AHP)

Publication in progress (lead author), University of New Mexico August 2021 – Present

Publication: "Applying community engaged practices for geospatial modeling of potential exposure to environmental contaminants from abandoned and inactive mines"

- Adapted an existing geospatial model to predict exposure potential to contaminants from abandoned and inactive mine sites including: GIS-based multi-criterial decision analysis (GIS-MCDA), fuzzy logic, and the analytic hierarchy process (AHP)

Publication in review (co-author), University of New Mexico August 2021 – Present

Publication: "Comparing performance of meteorological data sources – a case study in geospatial modeling of potential environmental exposure to abandoned mine sites on Navajo Nation"

- Determined the effect of various meteorological data sources on potential exposure model predictions

Publication in progress (lead author), University of New Mexico January 2022 – Present

Publication: "Bombs and Energy: The Politics of Uranium Mining on the Navajo Nation"

- Argues that an intersection of colonialism, American Cold War identity, and capitalism are necessary to understand the production of mining on Navajo lands

- Sheds light on these forces, revealing the nuance between the multitude of socio-economic forces and agents in both the U.S. government, mining interests, and parties within the Navajo community that led to uranium mining

Master's Thesis, Rochester Institute of Technology May 2018 – December 2020

Master's Thesis: "Exposure to pesticides and hepatocellular carcinoma (HCC) risk in and around Monroe County, NY"

- Study effects of pesticide application in agriculture and land-care industries on the health of local populations, specifically the link between long-term pesticide exposure in the environment to occurrences of HCC
- GIS geo-spatial statistical analysis on the relationship between volumes of applied pesticide and occurrences of HCC in a localized area of Western New York (the nine-county region around Rochester, NY, including full state models and various spatial extents).
- Analysis of federal and state data, including data on pesticide application and health data.
- Construction of complex, non-linear multi-variate regression model utilizing random forest algorithm.
- Found statistically significant impact from pesticide exposure on distribution of HCC cases.

Directed Research, The School for Field Studies, Yungaburra, QLD, AUS March - May 2016

Directed Research: "Secondary Rainforest Regrowth of the Wet Tropics: The Effect of Streams on Vegetation Structure and Species Distribution"

- Study effects of selective logging on tree diversity and vegetation structure in Wet Tropics bioregion of Australia.
- GIS geo-spatial statistical analysis of the relationship between stem location, forest structure, flora diversity, logging practice, and distance from stream riparian zones.
- Collection of various tropical forest parameters (densitometer measurements, DBH, canopy height, bird counts, vegetation species identification) and acquisition of GIS data (logging maps, hydrological maps, digital elevation models, and forest spatial data, including the precise location of over 23,000 stems in the study area).

Imagine RIT – Environmental Science Exhibit May 2014 – May 2015

- Climate change exhibit of institute survey and sociological discussions
- Interactive modules from local stream ecosystems
- Community outreach and interactive education geared towards children

Conferences

Southwest Association of American Geographers (SWAAG) – *Presenter* 2021

- Graduate student Paper Award Competition
- *Assessment of hepatocellular carcinoma (HCC) risk from exposure to pesticides in upstate NY, using a GIS-based statistical model*
- Oklahoma City, OK

Association of American Geographers (AAG) – *Presenter* 2022

- Geospatial modeling of potential contamination exposure to abandoned or inactive mine sites and trash dumps on the Crow Nation
- New York, NY (virtual)

Work Experience

University of New Mexico – *Research Assistant* August 16, 2021 – Present

- RA at Health and Environmental Research GIS Lab
- Specialized in geospatial modeling

National Institutes of Health – *Research Trainee* August 16, 2021 – Present

- UNM METALS Superfund Research Program Center
- Center for Native Environmental Health Equity Research

University of New Mexico – *Lead Instructor* June 13^{th} – 24^{th}, 2022

- Was lead instructor and helped to facilitate 2-week GIS workshop for students from Diné College

University of New Mexico – *President of SAGES* August 16, 2022 – Present

- President of the Student Association of Geography and Environmental Studies (SAGES)

HSE Consulting Services – *EHS Technician* September 28, 2020 – June 18, 2021

- Environmental Health & Safety
- Industrial Hygiene, Air Quality, Asbestos, Lead, Mold
- OSHA Compliance, Training, Environmental Services

AECOM – *CAMP Technician/Environmental Scientist* March 22, 2019 – November 1, 2019

- Air quality and noise monitoring, structural and settlement monitoring.
- Monitored environmental and structural factors with various instruments and monitoring systems. Taking of soil samples. Pulled, organized, and analyzed environmental/structural data. Sent data to team members for additional analysis when needed.
- Maintained and set up equipment/monitoring systems when needed. Oversaw work of subcontractors
- Former MGP site, focus of project was coal tar extraction and environmental restoration, including preservation/restoration of on-site historical buildings.

Rochester Institute of Technology — *Teaching Assistant* August 2017 – Graduation

- Applications of GIS TA
- Helped students develop GIS skills

Housing Operations, RIT — *Mechanical Assistant* August 2014 - May 2018

- RIT housing infrastructure maintenance
- Appliance maintenance, carpentry, flooring, roofing, electrical, painting, grounds upkeep

Certifications

OSHA 40hr HAZWOPER
OSHA 30hr Construction Safety and Health
Asbestos Inspector Initial
Member of ASSP & AIHA

Awards

National Society of Leadership and Success – *Inducted Member* January 2015 – Present
Dean's List Spring 2014 – December 2020
Pittsford Mendon High School - Advanced Regents with Distinction Diploma June 2013

References

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  - (315) 427 – 1412
- Karl Korfmacher
  - kfkscl@rit.edu
  - (909) 499 – 1111

Professional Development Plan

Planning Period**:** From 2022 To 2027

Performance Expectations	Knowledge, Skills, and Behaviors Needed to Achieve Each Expectation	Professional Development Activities	Resources and Support Needed from Others (e.g., dept, univ., AAG, grant providers)	Target Dates for Expectations
Teaching				
Teaching is not my main focus at this time, though I would like to continue to participate in teaching experiences and foster related skills. This could include an expectations of teaching a course after I go ABD, and leading workshops. For example, I would like to lead the Diné College internship GIS workshop again or something similar. There are also community engagement workshops planned as part of several different research projects I am working on.	Deep understanding off topics I would teach. Much of my teaching experience has been focusing on GIS and geospatial modeling. If I continue to teach, I would like it to be focused on technical topics such as GIS. Alternatively, I could also see myself teaching more theoretical/seminar-based topics such as political ecology and environmental justice.	Teach course in final year of PhD after going ABD. Lead workshops (i.e. Diné College summer internship) Community engagement workshops	Support from University and Research Centers, mostly related to funding to facilitate professional development activities. Training on how to develop and teach a full semester course. Support from community agencies (i.e. Crow Environmental Health Steering Committee).	Teach course in final year of PhD after going ABD: 2024 - 2025 Lead workshops (i.e. Diné College summer internship): 2022 onward (one workshop or related activity per year at least) Community engagement workshops: From summer 2023 onward

Research Research is my main long term focus of performance. As described in my previous assignments, I would like to attain a research position in business or a governmental institution. I do not wish to stay in academia and pursue a tenure-track position at this time, but I could see myself doing a post-doc given the right opportunities. In the short-term, my expectations are to complete and publish manuscripts relating to several different research projects I am currently leading/working on, and to develop and finish my dissertation.	Gain continued knowledge and expertise in the fields I want to continue research in. This includes a diverse interest in both geospatial modeling and critical/theoretical concepts, with a focus on critical applied geospatial modeling. Specific skills needed to achieve this are largely technical, including coding, GIS, software, and instrumentation. Furthermore, continued reading of theory and science is of high priority.	Various research projects/ Publications Defend Proposal Pass Comprehensive Exam Complete dissertation Post-doc Corporate/government research position	Continued funding/research positions from university Support from advisors and research centers Support from community partners Support from AAG, NIH, etc. for dissemination of research at conferences, job opportunities, etc.	Various research projects/ publications: 2023 onward (at least one publication per year) Complete dissertation: 2025 Post-doc: 2028 Corporate/government research position: 2025 onward

Performance Expectations	Knowledge, Skills, and Behaviors Needed to Achieve Each Expectation	Professional Development Activities	Resources and Support Needed from Others (e.g., dept, univ., AAG, grant providers)	Target Dates for Expectations
Service				

My service expectations are broad and involve both service to my academic department and service needs as related to various research projects. The most significant is my position as president of SAGES, which has been the most involved "service" role I have undertaken in my career so far. Other major service aspects include the development of a Collaboration Plan with one of our partner communities, and a leadership role in facilitating a partnership between my research center and the Montana Mesonet. I do not have concrete long-term service plans, but I foresee leadership roles and related activity/skills being beneficial to any career path I choose.	Interpersonal skills, organizational skills, multi-tasking skills Skills in event planning, design of promotional materials such as fliers Leadership skills	President of SAGES Community collaboration plan Facilitate developmental partnerships with relevant organizations (i.e. Montana Mesonet)	Support from department, relevant institutions at university Support from SAGES officers, student body Support from my network of personal/professional relationships Support from advisors, research centers, community partners	President of SAGES: Spring 2023, with continuing support for future SAGES leaders and departmental activities Community collaboration plan: By end of 2022, onward as partnerships with communities develop Facilitate developmental partnerships with relevant organizations (i.e. Montana Mesonet): 2023 and onward (target for initial meteorological stations to be set-up and fully integrated with Montana Mesonet summer 2023)

Beyond the workplace				

My expectations beyond the workplace are the least defined, as are interrelated to the other expectations. I want to do things to better my workplace, local community, and society. For example. I feel that a lot of what SAGES does falls along these lines, such as facilitating team-building exercises, field trips, and working to boost the morale and well being of the student population. I would like to get more involved with charity work once I have some more "free-time" (i.e when I don't have to take anymore classes). I also continually strive to improve my own physical/mental health and continue trying new things.	Mixture of all the described skills, with a focus on continuing to develop interpersonal skills and give back to my local community/society.	Activities related to SAGES to foster the student community, such as field trips, team building exercises, etc. Charity work Self-improvement	Support from my personal/professional network	Activities related to SAGES to foster the student community, such as field trips, team building exercises, etc: 2022 onward (target major field trip such as White Sands for Spring 2023) Charity work: Get involved with some org. after I'm done with classes (2023-2024) Self-improvement: 2022 onward

Faculty/Graduate/Student Employment

ASSISTANTSHIP OFFER

Date: 08/30/2022

Contract Number: 2809106

The University of New Mexico hereby offers Theodros Woldeyohannes, ID # 101945074, the position of Research Assistant subject to the following terms and conditions and contingent upon final approval by the Dean of Graduate Studies.

PERFORMANCE PERIOD: from 9/13/2022 to 12/31/2022

DUTIES: The student will complete research task as assigned in support of the project, including data collection, analysis, and report, presentation, and publication preparation. SPerform research related to research project 2 within The P50 center for Native Environmental Health Equity.

APPOINTMENT PERCENT: 50.00%

STIPEND: $2,750.00 monthly (to be paid on the last working day of each month during the performance period).

ESTIMATED TUITION & FEES PAYMENT: 9 credit hours for the Fall 2022 term

- Actual tuition & fees payment is based on offered contract hours and Bursar's calculation

ESTIMATED OTHER MANDATORY FEES AND COURSE FEE(S) PAYMENT : Up to department awarded maximum of $.00 for the Fall 2022 term

- The tuition and course fee payments are non-transferable. Payments may only be used for courses approved by the graduate program in which the student is currently enrolled.
- Non-Resident students are eligible for the resident tuition rate provided the appointment percent is 25% or higher and the assistantship is held for at least one-half the semester.

HEALTH INSURANCE: The University provides full payment of your medical insurance coverage premium, on a semester-by-semester basis, provided the appointment percent is 25% or higher and all other assistantship conditions are met. You will automatically be enrolled in coverage unless you choose to opt out. (Further information on opt-out will be provided upon final approval.)

TOTAL ESTIMATED VALUE OF ASSISTANTSHIP:** $14,537.30 (not including insurance)

**Value of actual contract is based on actual tuition and fees allowed and incurred by student's registration

Degree Progress

Passed Qualifying Exam

Extended Abstract for Qualifying Exam

Overview. Exposure to environmental contaminants is a significant public health issue around the world, with rural geographies in particular facing some of the most serious threats. Rural areas often lack robust healthcare infrastructure and are frequently populated by indigenous and other marginalized groups, causing these local communities to be disproportionately impacted by environmental exposures. Some of the most prolific contaminant sources is rural areas result from industrial practices, including wastes related to mining activities, and a lack of infrastructure for municipal services, such as waste processing, which causes frequent occurrences of unregulated solid waste disposal. Historically, mining has been the source of widespread environmental contamination, in which contaminants are dispersed through numerous factors such as air and water pathways. Unregulated solid waste disposal consists of refuse that is often disposed of in open-pit dumps and/or burned (both intentionally and unintentionally) through spontaneous combustion. Exposures to contaminants from these sources has been associated with numerous adverse human health effects.

Despite this body of evidence regarding health impacts related to exposure to contaminants from mining and unregulated waste disposal, most studies assessing these health impacts in rural areas have been limited (especially in indigenous areas) in geographic scope and modeling applications, taking the form of targeted medical studies or questionnaire-based cohorts. Complex modeling of contaminant dispersion, such as AERMOD, require detailed environmental/meteorological data, which is often lacking in rural areas. My doctoral research aims to address this literature gap, focusing on Tribal lands of the American Southwest and Intermountain West. These communities are an example of under-served populations that have witnessed historically intensive mining. Unregulated waste disposal is widespread on Tribal lands as well, and is often the norm due to severely lacking infrastructure and municipal waste services. This project will focus on three sovereign and indigenous Tribal states in the Intermountain West that have seen extensive histories of mining and face issues related to solid-waste disposal infrastructure: the Crow Nation, the Navajo Nation, and the Cheyenne River Indian Reservation. This study will employ a novel mixed-methods theoretical/modeling approach that aims to answer is how potential exposure to these contaminants are distributed across Tribal lands at multiple geographic levels. Data collection and the design of modeling frameworks will be based around the following research objectives:

1) Modeling large geographic-scale potential exposure using GIS-based, big-data geospatial methods

2) Integrating community engaged scholarship (CES) to model community-scale exposure

3) Investigating individual-level exposure by relating lived experience with exposure potential using GIS-based phenomenological mixed methods

For the purposes of this project, I define potential exposure as the probability of being exposure to contaminants from mining and unregulated waste disposal. This research aims only to model this potentiality to exposure, not to determine with certainty where an exposure will take place, or the probability that certain health outcomes will occur. This research will be constructed on a framework of CES, utilizing convergent research design to incorporate Tribal members' expertise and knowledge into the models I develop. Furthermore, a mixed-methods framework of holistic triangulation will be employed, combining machine learning driven GIS-based methodologies with phenomenology to gain a more complete and contextual portrayal of this potential exposure at multiple geographic levels. This study will build upon and contribute to existing research as part of various National Institute of Health (NIH) and United States Environmental Protection Agency (USEPA) projects, including the NIH P50 Center for Native American Environmental Health Equity Research and the P42 UNM Metal Exposure Toxicity Assessment on Tribal Lands in the Southwest (METALS) Superfund Research Program, under the supervision of my PI, Dr. Yan Lin. This includes collaborations with Tribal partners, including the Navajo Nation EPA, the Crow Environmental Health Steering Committee (CEHSC), and the Cheyenne River Sioux Tribe Department of Environment and Natural Resources.

This work will include developing big-data machine learning driven geospatial methods to predict exposure potential to contaminants at large geographic scales. Models with be developed using pre-existing datasets and data collected through community partnerships. These datasets are derived from multiple sources including pollution point sources, meteorological and hydrological data, chemical measurements for groundwater and soil samples, and topographic data. This doctoral research will build off existing GIS-MCDA models developed as part of my NIH work. Machine learning (ML) algorithms will be used to both inform the GIS-MCDA models and be utilized in stand alone prediction models as well. The primary algorithms used will be random forest, maximum entropy, and neural-network regressions.

Numerous different types of datasets will be collected through community engaged approaches with Tribal partners, as well as involving Tribal partners in the research design process through a convergent framework. For example, through on-going partnerships with Tribal members, community dump sites have been identified and monitored in prominent towns. The Analytic Hierarchy Process (AHP) is a pairwise comparison method that will be utilized to incorporate community member expertise and insight into the model design. Field monitoring will be conducted as well, including passive environmental sampling and working with Tribal partners to install meteorological and particulate matter (PM) monitoring stations. AERMOD will be another primary modeling method utilized primarily for community scale modeling in areas where sufficient data is available, and as data collection is improved though CES efforts.

Finally, a phenomenological approach in conjunction with big-data GIS will be performed in a framework of holistic triangulation. By conducting personal exposure assessments and interviews, the above-described methods with by synthesized in the production of geo-narratives and deep maps as I investigate ways to relate lived experienced to interaction with the landscape and subsequent potential exposure.

Intellectual Merit. The intellectual merits of this research include empirical, theoretical, and methodological contributions to the fields of geography and environmental/health-disparities research of marginalized communities, including multi-level understanding of exposure.

Broader Impacts. The spatial products generated as part of this research will be useful for identifying areas with greater potential for exposure, including areas on Tribal lands where contamination is a consequence of multiple environmental factors. Results generated for this research will have the potential to further inform epidemiological research and ongoing remediation efforts.

Dissertation Proposal

Doctoral Dissertation Research: Community-Engaged Multi-Scale Geospatial Modeling of Exposure to Environmental Contaminants on Tribal Lands of the American Intermountain West

I. Overview

My doctoral research aims to model potential for exposure to contaminants from mining and unregulated waste disposal on multiple geographic scales while considering several environmental pathways, focusing on Tribal lands of the American Southwest and Intermountain West. **The central question of this research is how such exposure potential is distributed across Tribal lands, from the scale of entire Tribal Nations, to the community level, and finally on the individual level. This will be facilitated by a novel approach of integrating big-data based spatiotemporal modeling with community engaged scholarship in a phenomenological framework.**

II. Introduction

Exposure to environmental contaminants is a significant public health issue around the world, with rural geographies in particular facing some of the most serious threats. Rural areas often lack robust healthcare infrastructure and are frequently populated by indigenous and other marginalized groups, causing these local communities to be disproportionately impacted by environmental exposures (Fox and Porca 2001; Bh and Dutta 2005). Some of the most prolific contaminant sources in rural areas result from industrial practices, including wastes related to mining activities (Jain 2015), and lack of infrastructure for municipal services, such as waste processing, which causes frequent occurrences of unregulated solid waste disposal (Nanda and Berruti 2021).

Historically, mining has been the source of widespread environmental contamination, in which contaminants are dispersed through numerous factors such as air and water pathways (Branan 2008; Sutton and Weiersbye 2008; Khalil et al. 2013; Gałuszka et al. 2015; Olías and Nieto 2015; Punia 2021; Sengupta 2021). These contaminants, often in the form of heavy metals, have been linked to numerous human health effects, including cancers, cardiovascular disease, neurological disorders, and developmental defects (Kusiak et al. 1991; Yáñez et al. 2003; García Gómez et al. 2007; Bose-O'Reilly et al. 2010; Brugge and Buchner 2011; Plumlee and Morman 2011; Gamiño-Gutiérrez et al. 2013; Moon et al. 2013; Martin et al. 2014). Unregulated solid waste disposal consists of refuse that is often disposed of in open-pit dumps and/or burned (both intentionally, and unintentionally) through spontaneous combustion (Reingold 2019; Nanda and Berruti 2021). Contaminants from this waste are dispersed through air pathways in the form of particulate matter (Kim et al. 2015; Mukherjee and Agrawal 2017) and water pathways through surface runoff and groundwater leachate (Freeze and Cherry 1979; Vasanthi et al. 2008). These contaminants most commonly consist of microplastics, heavy metals, and other dangerous compounds from disposed objects such as electronics. As with mining, numerous health effects have been linked to exposures to contaminants from unregulated trash disposal, including lung diseases, cancers, and hypertension (Lewtas 2007; Mukherjee and Agrawal 2017; Prata et al. 2020).

Despite this body of evidence of the health impacts related to exposure to contaminants from mining and unregulated waste disposal, most studies assessing these health impacts in rural areas have been limited in geographic scope and modeling applications, taking the form of targeted medical studies or questionnaire-based cohorts (Gilbreath, Zender, and Kass 2000; Holmes and Morawska 2006; Krajčovičová and Eschenroeder 2007; Lewtas 2007; Calder 2008; Hadlocon et al. 2015; Gonzales et al. 2018; Zhai et al. 2018; Hoover et al. 2019). Complex modeling of contaminant dispersion, such AERMOD (US EPA 2016), require detailed environmental/meteorological data (Hadlocon et al. 2015; Zhai et al. 2018), which is often lacking in rural areas (Holmes and Morawska 2006). Because of this, complex and large-scale geographic modeling often takes place in more urbanized areas, where this data is more readily available.

My doctoral research aims to address this literature gap, focusing on Tribal lands of the American Southwest and Intermountain West. These Tribal communities are an example of underserved populations that have witnessed historically intensive mining (Lewis 1995; Kirkemo et al. 1998; Brugge and Goble 2002; Ong et al.

2014; Lewis et al. 2017). Much of this exploitation consisted of hard rock mining, which covers excavation techniques used in extraction of "hard" minerals, most often those containing metals or other ore-based resources such as coal (De la Vergne 2008; Trahant 2016). Common metals include copper, gold, lead, manganese, cadmium, vanadium, and uranium (Mason and Arndt 1996; Kirkemo et al. 1998). During historical mining operations, little care was taken to mitigate pollution and environmental impacts (Eichstaedt 1994). Additionally, many of these mines were later abandoned, with little efforts taken at sealing or remediation (Brugge and Goble 2002; Erdei et al. 2019). Many mines are still currently active, especially coal mines, which form the basis of many Tribal economies (Trahant 2016). An example of the environmental impact these mining activities have had on Tribal lands can be seen in the contamination of the Bighorn River, which is classified as a 303d impaired water body downstream of the Crow Nation in south-central Montana (MCWAC n.d.).

Unregulated waste disposal is widespread on Tribal lands as well, and often is the norm due to severely lacking infrastructure and municipal waste services (Lewis 1995; Gilbreath et al. 2000; Reingold 2019). This has led to widespread environmental contamination on Tribal lands along the pathways discussed above and has been subsequently linked to disproportionally higher occurrences in Tribal communities of the mentioned health impacts (Gilbreath et al. 2000; U.S. EPA 2007; Plumlee and Morman 2011; Lewis et al. 2017; Gonzales et al. 2018; Hoover et al. 2019; Lin et al. 2020). Because of these threats to the public health of tribal communities, there is a pressing need to understand the distribution of this exposure potential, which can further be applied to rural areas in general.

Building upon and extending my existing research as part of National Institute of Health (NIH) efforts to assess these public health issues in tribal communities, this study will employ a novel approach of integrating big-data based spatiotemporal modeling with community engaged scholarship in a phenomenological framework. **The central question this research aims to answer is how potential exposure to these contaminants are distributed across Tribal lands at multiple geographic levels.** This approach is poised to make critical empirical contributions in the form of potentially more accurate, large-scale models that detail the distribution of potential exposure to contaminants from mining and unregulated waste disposal while also incorporating the lived experience of community members.

III. Intellectual Merit

The intellectual merits of this research include empirical, theoretical, and methodological contributions to the fields of geography and spatial science, in particular that of environmental exposure modeling and understanding environmental/health-disparities research of marginalized communities. The way this study implements research design contributes to its originality, such as the non-typical utilization of CES in conjunction with machine learning applications and theoretical investigations into lived experience. This research will help to confirm the viability of big-data geospatial methods as a framework for modeling environmental contaminants when applied in a community-based approach. It will also showcase methods that can be used when comprehensive environmental and meteorological monitoring data is lacking in an area of interest, such as rural areas in general. Furthermore, it will investigate ways to help bridge the gap between the spatial and humanistic sides of geography through mixed-methods approaches, helping to build frameworks that future research can build off of.

IV. Broader Impacts

The spatial products generated as part of this research will be useful for identifying areas with greater potential for exposure, including areas on Tribal lands where contamination is a consequence of multiple environmental factors. Community engagement will be central to this research and forms a foundational basis of study plans and pre-existing work with the NIH, and will highlight public health risks faced by Tribal communities. The results of this research will be directly disseminated back to Tribal community members, in addition to the larger scientific community at large. This includes ongoing regular discussions with Tribal governmental bodies such as the CEHSC and Navajo Nation EPA. A related impact of this CES work will be the inclusion of marginalized groups in research, something that is too often a rare occurrence. This work has already been presented at conferences, such as Southwest AAG and the national AAG. Work will be published in journals that balance relevance and impact. In particular, Tribal communities can use this research to aid them during deliberations with government organizations such as the EPA. This could potentially aid in the acquisition of funding for initiatives such as remediation efforts. Results generated from this research will have the potential to help further inform epidemiological research and ongoing remediation efforts to reduce human exposures to mine wastes and particulate matter/contaminants from trash combustion/disposal.

V. Objectives

Data collection and the design of modeling frameworks will be based around the following research objectives:

1. Modeling large geographic-scale potential exposure using GIS-based, big-data geospatial methods

Historically, most approaches to assessment of potential exposure to contaminants from mining and unregulated trash disposal on tribal lands (and rural areas in general) has been through geographically constrained, small-scale human-health studies with limited modeling approaches (Hoover et al. 2019; Lin et al. 2020). By employing GIS-based geospatial modeling, advanced computational techniques such as machine learning, and utilizing multi-scale modeling at high spatial-temporal resolutions, dynamic environmental processes across multiple pathways can be modeled simultaneously. For example, there have been recent applications of such techniques on Tribal lands (deLemos et al. 2009; Hund et al. 2015; Hoover et al. 2018), such as an environmental exposure assessment for contaminants from abandoned uranium mines across the entirety of the Navajo Nation (Lin et al. 2020). With my training in model design and support from the mentioned NIH efforts, this study will utilize these techniques to create robust, multi-path environmental models of potential exposure to contaminants from mining and unregulated waste disposal on Tribal lands at large geographic scales.

2. Integrating community engaged scholarship (CES) to model community-scale exposure

Community engaged scholarship (CES) is a research framework that has seen increased utilization in recent years, spurred on by paradigm shifts within the scientific community and funding agencies in aim of greater public accountability and relevance, with a predominant goal of fostering mutually beneficial partnerships between researchers and local communities (Barreno et al. 2013; da Cruz 2018; Sadler et al. 2019). This is exemplified by the fact that CES is now frequently stated as a core mission of numerous academic institutions (Gelmon et al. 2013). CES has seen widespread applications, often focused on studies related to health disparities (Sadler et al. 2019), and equity issues, such as racism in housing practices and urban development (Sadler and Lafreniere 2017).

Some of the geospatial methods I propose, such as GIS-MCDA, are well suited for integration with CES. The MCDA framework is structured as such that it allows for direct input from community members, such as during the weight determination process as a form of convergent research design. For example, Sadler et al. (2019) engaged community partners to determine relative criteria, and further inform weights of these criteria, for an MCDA modeling health-disparities in Flint, Michigan.

Regarding tribal communities, CES has also been employed, frequently in developmental and ethnohistorical frameworks (Carlson et al. 2018). In more recent years, CES on tribal lands has begun to be used in more quantitative and traditional modeling frameworks, including community engagement in method development, such as through convergent research design (Turner et al. 2017). Such efforts include studies related to health disparities and environmental justice (Gilbreath et a;. 2000; Baker 2016; Diver 2018; Willett et al. 2020), employing a variety of methodologies including questionnaire-based self-reporting, in which community members are interviewed on experiences and symptoms related to exposure (Gilbreath et al. 2000), medical studies in which participants are monitored for exposure symptoms and give bodily samples (Lewis et al. 2017; Gonzales et al. 2018; Hoover et al. 2019), personal exposure assessments (Gonzales et al. 2018), and gathering community members' input to inform model design (Turner et al. 2017), in which members serve as solicited domain experts.

This research will advance CES scholarship by using CES methods to create community informed models, as well as personal exposure assessments and qualitative GIS methods such as the construction of geo-narratives and story mapping, in order to model community-scale exposure.

3. **Investigating individual-level exposure by relating lived experience with exposure potential using novel GIS-based phenomenological mixed methods**

The everyday lived experience of human beings is a critical component missing in traditional quantitative geospatial modeling methods. It is often the case that research conducted on cultural landscapes (such as that of a Tribal nation) are divided along either quantitative or qualitative frameworks (Rouse 2018). This represents a significant literature gap, as lived experience can potentially impact factors of a model, such as an individual Tribal community member's potential level of exposure to contaminants from mine-waste and unregulated waste disposal. For example, many Tribal members retain traditional practices that foster ties and define relationships to the land (Harris and Harper 1997; Van Horne et al. 2021). Therefore, the lived experience of Tribal members' (their personal/spiritual sense and meaning of place), could have an impact on levels of contact with potentially contaminated environmental media.

With advancements in GIScience and phenomenology approaches, frameworks have begun to be developed which have the potential to bridge the gap in this sector of geographic research on cultural landscapes. I will utilize these phenomenological approaches in conjunction with GIS in an attempt to synthesize the above-described objectives of GIS-based, big data geospatial methods and CES in a novel mixed methods approach. This approach will focus on investigating individual-level exposure by relating the place-based lived experience (i.e. one's personal sense/meaning of place) to personal exposure.

Synthesis

These three ROs will be synthesized through a framework of holistic triangulation in order to gain a more complete and contextual portrayal of potential exposure to environmental contaminants from mining and unregulated waste disposal across different geographic levels (Figure 1).

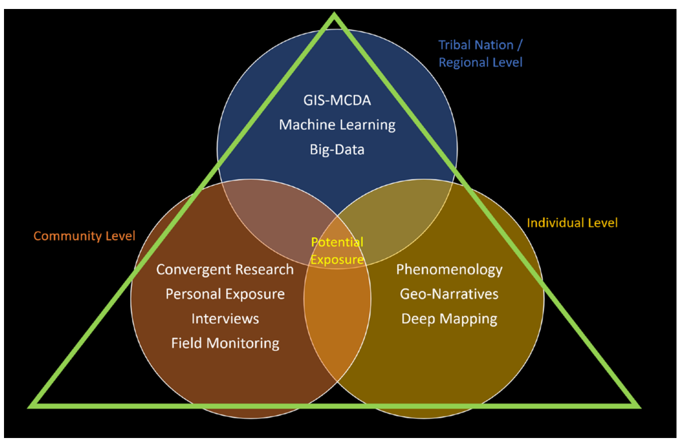

Figure 1 – Holistic triangulation of different methodologies across multiple geographic levels.

VI. Theoretical and Methodological Framework

6.1 Community Engaged Scholarship (CES) and Phenomenological Mixed Methods Frameworks

When conducting studies that involve and potentially impact localized communities, such as those in the Tribal lands of the Intermountain West, it is critical to engage with community members during the research process. It is often the case that researchers do not relay findings back to the community under study or consider the effects of how particular language is used. Furthermore, community members often possess a deeper understanding of the human-environment systems that they live in, compared to that of outside researchers that lack the same sense of place and lived experience. Because of these factors, my dissertation work is foundationally constructed on pre-existing strong relationships with Tribal partners in a framework of community engaged scholarship (CES).

Convergent research design is a methodological framework that works in conjunction with CES. Convergent research design, or convergence research, is an approach that involves diverse teams working together in novel ways that transcend traditional disciplinary and organizational boundaries, often focused on social, economic, environmental, and technical challenges (Peek et al. 2020). In a community context of convergent research design, community members and researchers directly work together in the design and implementation of research (Turner et al. 2017; Peek et al. 2020). I have already begun utilizing convergent research design in my NIH work with the Crow Nation, in which community partners were directly involved in study design and contributed expertise and local knowledge in the construction of models.

Besides convergent research design, community engaged, qualitative techniques can be combined in a mixed-methods approach through a framework of triangulation, in which multiple, different approaches are used in the same study in order to generate a better understanding of a phenomenon that might otherwise be limited by a singular approach (Burton and Obel 2011; Singleton and Straits 2017; Turner et al. 2017). This research will follow an encompassing theoretical framework of holistic triangulation, in which a fuller understanding of a situation is garnered through unique insights and perspectives gained from the different research strategies utilized, allowing for a more complete picture and contextual portrayal of an analyzed situation (Jick 1979; Turner et al. 2017). This holistic triangulation will be a synthesis of big data geospatial methods and CES based phenomenological approaches to better understand potential exposure to contaminants from mine waste and solid waste disposal by incorporating the unique insights and perspectives of Tribal members.

Phenomenology is a theoretical framework that represents both a philosophy and qualitative methodological framework of inquiry. Beginning as a philosophical movement, phenomenology has a central focus on the nature of experience from the point of view of the person experiencing a phenomenon (Connelly 2010). In other words, phenomenology can be utilized to understand the lived experience of an individual, and how that lived experience relates to the broader context of a study. With advancements in GIScience and phenomenology approaches, frameworks have begun to be developed that integrate phenomenology with more traditional geography. Such frameworks represent a holistic synthesis of geospatial and phenomenological perspectives, through methods such as geospatial-narratives, story mapping, and deep mapping, which has the potential to incorporate geographic features, feelings, events, and senses (i.e. lived experience/sense of place) into a potential exposure model (Yuan 2020). Geospatial narratives, or geo-narratives, are a mixed method that extends the traditional GIS framework with narrative materials such as oral histories, life histories, and biographies (Kwan and Ding 2008). For example, Bell et al. (2017) used geo-narratives to better understand how peoples' perception of "green" and "blue" spaces ("therapeutic landscapes") in conjunction with their spatial-temporal activity related to their overall lived experience and sense of wellbeing. Deep mapping evolved as an avant-garde technique in 1950s France, that attempted to understand the nuance of place through juxtapositions and interpenetrations, the political, discussive, and sensual to create a multilayered view of place. Such concepts in recent years have been integrated into GIS, to create visual, time-based, and structurally open style of mapping, that can incorporate abstract layers such as heritage, culture, memory, and sense of place (Bodenhamer et al. 2013). Initially developed to incorporate spatial modeling techniques into the humanities, deep mapping has begun to see growing use in numerous fields, seeing applications in anthropology (Roberts 2016), the development of "spatial histories" in archaeology (Earley-Spadoni 2017), understanding urban-media landscapes (Mattern 2015), and the mapping of environmental injustices in relation to assessing environmental health and equity (Maantay 2002).

This mixed-methods approach is well suited for work with Tribal communities, who possess an intrinsic understanding and sense of the place they live in (Harris and Harper 1997; Van Horne et al. 2021). For example, Wu (2019) used GIS, interviews, and historical ethnography to investigate how lived experience of Paiwan Tribal members in Taiwan facilitate the creation and maintenance of social memory. Furthermore, lived experience can be related environmental exposure/health-equity issues, such as assessments of time-activity relationships to VOC personal exposure factors (Edwards et al. 2006).

Taking an approach similar to the GIS-phenomenological framework discussed above, this research will focus on the under-examined lived experience of Tribal members in relation to predicting environmental exposure potential. My study will be the first to utilize such community driven methods in conjunction with big-data spatiotemporal modeling on the Tribal communities of the Intermountain West, including at such diverse geographic scales.

6.2 Defining Potential Exposure

For the purposes of the project, I define potential exposure as the probability of being exposed to contaminants from mining and unregulated waste disposal. This research aims only to model this potentiality to exposure, not to determine with certainty where exposure will take place. Furthermore, this research will not be a risk assessment or perform environmental risk mapping. While terms like “risk assessment” and “potential exposure” are similar at face value, they have inherently different connotations and implications. A risk assessment follows an epidemiological framework in which the likelihood of a health effect is predicted based on exposure to a contaminant, in which assessing potential exposure is a preceding step (Paustenbach 2000). In the case of environmental risk mapping, this would be to model areas that are vulnerable to contamination (Lahr and Kooistra 2010). Such an epidemiological framework is beyond the scope of this study. Furthermore, the term “risk” can contain a negative connotation, especially when working with Tribal community partners or in cultural landscapes. For example, stating that a part of a landscape poses a “risk” can be seen as degrading that landscape, in a way reducing it to something that has been damaged or tarnished (and in turn the communities which inhabit the land), which can be disrespectful to Tribal communities that have culturally intrinsic ties to the landscape (Harris and Harper 1997; Van Horne et al. 2021). Because of this, and the scope of this research, modeling is limited to assessing potential exposure, and does not attempt to classify risk levels or establish correlations or causalities between observed health effects and exposures.

6.3 Geospatial Modeling Frameworks

A component of this research will be based in big-data spatiotemporal modeling of large geographic areas. To accomplish this, the project brings together geospatial modeling theories with machine learning methods and big data approaches.

This study will employ a multi-criteria decision analysis (MCDA) geospatial modeling framework (Malczewski 2006; Lin et al. 2020). MCDA has been used in conjunction with GIS (GIS-MCDA) research since the early 1990s (Jiang and Eastman 2000; Malczewski 2006; Lin et al. 2020). MCDA provides a framework for structuring decision problems. MCDA involves the use of weighted critical “decision” layers which can be applied in a linear weighted sum to estimate a parameter of interest. Fuzzy set theory can be further applied to address potential uncertainties in the MCDA approach (Kuo et al. 2002). This allows for modeling generalized environmental factors in which highly detailed data is lacking. Because of this, MCDA is well suited to modeling potential exposure to contaminants from mining and solid waste disposal at the full geographic scales of the Tribal nations of the Intermountain West, in which high quality environmental/meteorological data (that would be required for complex volumetric dispersion modeling such as AERMOD) is lacking (US EPA 2016; Lewis et al. 2017). Through MCDA, several environmental factors that may explain distribution of contaminants can be modeled simultaneously to predict potential exposure (Figure 2).

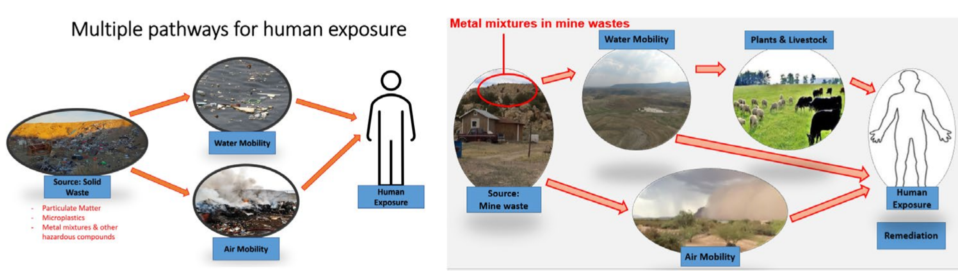

Figure 2 – This research will model multiple environmental pathways for human exposure to contaminants simultaneously.

Machine learning (ML) methods will be employed to create more robust models of potential exposure that take advantage of advancements in GIScience. ML is a subset of computer science in which algorithms are designed that emulate human intelligence. These algorithms form the basis of modern “big-data computing” and have been successfully applied in a wide range of fields (El Naqa and Murphy 2015), including numerous environmental issues.

Big-data computing, or big-data approaches, are a recent research paradigm that combines large-scale computational and data intensive techniques with mathematical models to conduct robust analysis. Big data computing has seen widespread adoption in recent years as data streams and the number of sensors around the world continue to exponentially increase (Kune et al. 2016). These approaches have seen widespread adoption in geospatial modeling. With the large amount of observation platforms such as satellites and sensors spread over the world, there are new data-streams, both greater in volume and more detailed than ever before. These data-streams, through big-data approaches, can be integrated with machine learning methodologies applied in a geospatial framework. Such geospatial applications are wide ranging, falling into general approaches of Big Data Search, Knowledge Representation, Big Data Mining, and Big Data Computation Methods (Li et al. 2020). My modeling work will pull mostly from Knowledge Representation and Computational Methods, as I work to not only create more robust models, but to also incorporate Tribal knowledges.

VII. Case Studies, Methods, and Analysis

7.1 Case Studies

This project studies three sovereign and indigenous tribal communities in the Intermountain West that have seen extensive histories of mining and face issues related to solid-waste disposal infrastructure. These communities include the Crow Nation, the Navajo Nation, and the Cheyenne River Indian Reservation.

Crow Nation: The Crow Nation (CN) is a sovereign indigenous nation located in the Mountain West United States. The legal boundary of the CN is approximately 9,345 km^2 located in south-central Montana, extending to the border with northern Wyoming, with the principal reservation towns being Crow Agency, Lodge Grass, Wyola, and Pyror. The Tribal lands of the CN are sparsely populated, with large portions of the populace living in rural and geographically remote areas with limited infrastructure (Doyle et al. 2018; US Census Bureau n.d.). (Figure 3).

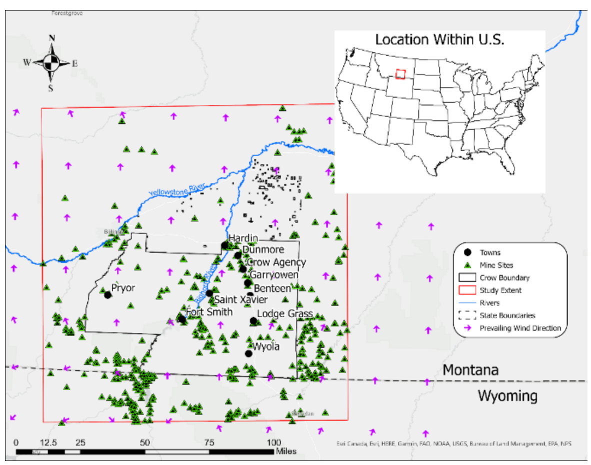

Figure 3 – Crow Nation detailing abandoned mine sites.

Navajo Nation: The Navajo Nation (NN) is a sovereign and indigenous nation located in the southwest United States. The conterminous boundary of the NN covers an area of 70,000 km^2 and is located in Arizona, New Mexico, and Utah. The NN is divided into administrative units called agencies, and include: Eastern, Central, Northern, Western, and Ft. Defiance (Figure 4). The tribal lands of the NN are sparsely populated, and a large proportion of the population lives in rural and geographically remoted locations with limited infrastructure. (Lin et al. 2020; US Census Bureau n.d.).

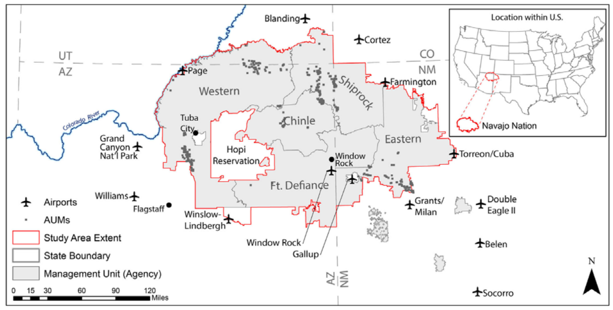

Figure 4 – Navajo Nation detailing abandoned uranium mines, from Lin et al. (2020).

<u>Cheyenne River Indian Reservation</u>: The Cheyenne River Indian Reservation (CRIR) is a sovereign indigenous nation located in the Mountain West United States home to the Cheyenne River Sioux Tribe (CRST). The total land area of the reservation is 5,667 km^2 with the main municipality being Eagle Butte (South Dakota Department of Tourism 2022). The Tribal lands of the CRIR are sparsely populated, and a large proportion of the population lives in rural and geographically remote areas. Infrastructure is deficient, with many lacking water systems, making living in sanitary conditions difficult. (Sprague 2003; U.S. Census Bureau n.d.).

7.2 Access to Tribal Spaces and NIH Work

This doctoral research builds off current work with the NIH as part of the NIH P50 Center for Native American Environmental Health Equity Research and P42 UNM Metal Exposure Toxicity Assessment on Tribal Lands in the Southwest (METALS) Superfund Research Program, under the supervision of my PI Dr. Yan Lin. This includes pre-dissertation and preliminary research on the NN and CR and collaborative work on other NIH and EPA projects through relationships with researchers at the centers. Furthermore, this work is foundationally built on collaborations with Tribal partners, including relationships with the NN EPA, CEHSC, and Cheyenne River Sioux Tribe Department of Environment and Natural Resources. Dr. Lin and others at these research centers that I directly work with (such as co-director Dr. Joseph Hoover, co-director Johnnye Lewis, and co-director Debra Mackenzie) have fostered long term relationships with these Tribal partners and have built an academic resource pool (of both physical and intellectual resources) which will enable the tasks presented here to be completed.

Success for this project will be assessed as the creation of robust spatial models. There are direct measures of success as well, including the successful installation of field monitoring stations. The degree of success will also be evaluated based on community feedback.

7.3 Methods

<u>Research Objective (RO) 1: Modeling large geographic-scale potential exposure using GIS-based, big data geospatial methods</u>

Utilizing both pre-existing/pre-collected datasets, and collected data through community partnerships, this study will build off geospatial models currently under development as part of my NIH work. These models will be primarily focused on big-data machine learning driven geospatial methods to predict exposure potential to contaminants at large geographic scales. For example, preliminary potential exposure models for the NN and CN have already been implemented at various geographic scales, up to the full scale of Tribal nations.

<u>*Data:*</u> Pre-existing datasets used to fulfill RO1 are derived from multiple sources including: Pollution point sources, meteorological and hydrological data, chemical measurements for groundwater and soil samples, and topographic data. Point sources of pollution relevant for my study included abandoned or inactive mines on CN (N = 477 point features) and abandoned uranium mines on the NN (N = 523), obtained from the Montana Bureau of Mines and Geology (MBMG) (MBMG n.d.) and U.S. Environmental Protection Agency (U.S. EPA) (U.S. EPA 2007), respectively. Meteorological data consists of several sources, including: modeled wind data (daily wind direction and speed, averaged over the past 30 years) from the North American Regional Reanalysis (NARR) obtained from the National Oceanic and Atmospheric Administration (NOAA) (NOAA 2020); meteorological data from local airport meteorological stations sourced from historical aerodrome reports

(METARs) managed from Iowa State University (Iowa State Univerity 2022); in-field meteorological stations maintained by the Montana Mesonet on CN (University of Montana n.d.), and the Uranium Mill Tailings Remedial Action (UMTRA) project (Office of Environmental Management n.d.) and UNM Metals superfund program (METALS n.d.) on the NN; and radiosonde upper air meteorological data sourced from NOAA (NOAA n.d.). Topographic data, including landform classification, slope, and aspect, were generated using digital elevation models (DEMs) at 30 to 90 m resolutions obtained from the U.S. Geological Survey (USGS) (U.S. Geological Survey n.d.). Soil data and land use/land cover (LULC) information were obtained from the U.S. Department of Agriculture (USDA) (USDA n.d.) and USGS (U.S. Geological Survey 2016), respectively. Groundwater quality data were obtained from MBMG using the Groundwater Information Center data portal (MBMG n.d.) and NURE data from the US Geological Survey (USGS 1980).

GIS-MCDA: This doctoral research will build off existing GIS-MCDA models as part of my NIH work (Lin et al. 2020) for environmental factors relevant to detailed modeling of meteorological and hydrological factors, incorporating machine learning techniques and community engagement practices during the model development process. The GIS-MCDA framework will allow for simultaneous modeling of several environmental factors. The cumulative potential exposure to contaminants from pollution sources will be determined using a weighted linear combination of standardized factors serving as a proxy of interaction with contaminant dispersal pathways.

Machine Learning: ML algorithms will be used to both inform GIS-MCDA models and be utilized in standalone prediction models as well. The primary algorithms used will be random forest (Breiman 2001; Breiman et al. 2017), maximum entropy (Wu 2012), and neural-network regressions (Dreiseitl and Ohno-Machado 2002).

Research Objective (RO) 2: Integrating community engaged scholarship (CES) to model community-scale exposure

Numerous different types of datasets will be collected through community engaged approaches with Tribal partners, as well as involving Tribal partners in the research design process through a convergent framework. **These factors will both inform RO1 model design and the RO3 synthesis through phenomenological approaches.**

Trash Burning Sites: Through an on-going partnership with Tribal members, community dump sites have been identified and monitored in prominent towns. Community partners met to identify sites where much trash is dumped and to reflect on the frequency of use and the history of burning activities at each location. Sites were visited and geo-coded using GPS coordinates collected with a handheld Garmin eTrek GPS. These locations were confirmed using satellite imagery and digitized. The identification of trash sites continues to be an on-going process.

Analytic Hierarchy Process: The Analytic Hierarchy Process (AHP) is a pairwise comparison method that will be utilized to incorporate community member expertise and insight into the model design. By using the AHP, environmental factors can be ranked for relative importance through conversations with local residents.

Environmental Sampling Media: Passive environmental sampling media, such as silicone wrist bands, have been placed in communities to measure contaminants from Trash burning events. The design of these field studies is done in conjunction with community partners. This monitoring using wrist bands continues to be an on-going process.

Instillation of Field Monitoring Stations: Working with Tribal partners, a network of new meteorological and particulate matter monitors will be installed across the NN and CN. Instillation sites will be focused on schools. Additionally, portable and hand-held field monitoring equipment will be utilized to monitor for PM and other contaminants.

AERMOD: AERMOD will be another primary dispersion modeling method utilized besides the GIS-MCDA. This will be focused on modeling particulate matter (PM) dispersal from trash burning events where detailed meteorological data is available, and will increase in utilization in conjunction with the construction of the monitoring network as part of RO2.

Research Objective (RO) 3: Investigating individual-level exposure by relating lived experience with potential exposure using novel GIS-based phenomenological mixed-methods

A phenomenological approach in conjunction with big-data GIS will be performed through a framework of holistic triangulation. The above-described methods will be synthesized in the production of geo-narratives and deep maps as I investigate ways to relate lived experience to interaction with the landscape and subsequent potential exposure.

Personal Exposure Assessments: Personal exposure assessments will be conducted on community members. This will be a comprehensive approach, including the use of GPS-tracking and activity mapping to inform geo-narratives, environmental sampling media worn by community members, and biological samples provided by community members to test for contaminants.

In-depth Interviews: Interviews will be conducted with community members over the course of this research. Interviews will cover and be used to inform all three research questions, through they will be primarily directed at constructing senses of lived experience to be used in the phenomenological mixed methods approach. Interviews will follow a semi-structured format, in which participants are prompted with questions, but are allowed for unstructured long-form responses that allow conversations to evolve naturally. Interviews will be conducted in-person as available but also remotely over videoconferencing or phone calls. Interviews will be focused on subjects' experiences and histories related to life-experience, relationship with the land, and experiences related to environmental contamination and health disparities.

VIII. Timeline

August 2021 – May 2022: Conduct preliminary large-scale and community-scale geospatial modeling work. Begin to engage with community members to inform model design.

May – August 2022: Continue modeling work. Travel to sites across Tribal lands for community meetings and to conduct environmental sampling fieldwork. Identify more trash sites, perform sampling events. Begin installing meteorological and PM stations. Funds and resources for traveling and equipment during this phase will be critical.

August 2022 – May 2023: Continue to refine models. Plan for personal exposure assessments and interviews. Develop mixed methodologies.

May – August 2023: Conduct personal exposure assessments, interviews. Develop geo-narratives and deep maps.

August 2023 – May 2024: Data organization and analysis. Continue to refine models. Organize preliminary results.

May – August 2024: Continue to work with community partners, disseminate results to community members.

August 2024 – May 2025: Preparation of manuscripts and dissertation.

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Course Work

Number	Course Name	Campus	Semester	Competency	Grade
ENVS 670	Advanced Concepts of Environmental Chemistry	RIT	From MS	2 Physical	A
ESHS 613	Solid and Hazardous Waste Management	RIT	From MS	3 Socio-Ecological Systems	A
ENVS 601	Environmental Science Graduate Studies	RIT	From MS	4 Geog Thry/Methods	A
ENVS 630	Energy Policy	RIT	From MS	3 Socio-Ecological Systems	A
PUBL 702	Graduate Decision Analysis	RIT	From MS	4 Geog Thry/Methods	B+

GEOG 601	Intro to Geographic Theory	UNM	2021 Fall	4 Geog Thry/Methods	A+
GEOG 602	Integrative Research Design	UNM	2022 Spring	4 Geog Thry/Methods	A+
GEOG 527	Introductory Programming for GIS	UNM	2021 Fall	5 Map Use	A
GEOG 587L	Spatial Analysis and Modeling	UNM	2021 Fall	5 Map Use	A+
GEOG 515	Seminar in Geographies of Power	UNM	2022 Spring	1 Human	A
GEOG 528	Advanced Programming for GIS	UNM	2022 Spring	7 Spatial thinking	A
GEOG 603	Professional Geographic Development	UNM	2022 Fall	4 Geog Thry/Methods	TBD
GEOG 499*	Environmental Justice	UNM	2022 Fall	3 Socio-Ecological Systems	TBD
GEOG 525	Advanced GIS Seminar	UNM	2022 Fall	4 Geog Thry/Methods	TBD

New Mexico
Doctoral Program in Geography Handbook

Academic Year 2022/2023

1.Introduction

Welcome to the New Mexico Doctoral Program in Geography (NMDPG). The NMDPG offers a rigorous, research-based degree focusing on integrative human-environment interactions, including environmental change, dryland resource management, and complex cultural landscapes – and the methods needed to understand them. This program is unique because it is a consortium between two universities. This means that policies of UNM'S Office of Graduate Studies and NMSU's Graduate School together establish the general requirements for the NMDPG, which also has program-specific requirements for all students. The joint doctoral program is designed to build both theoretical and applied knowledge in geography, which enables students to pursue a wide range of career pathways

The program builds on the strengths of the Department of Geography at New Mexico State University and the Department of Geography and Environmental Studies at the University of New Mexico. The two departments began their partnership in the late 2000s under the leadership of respective department chairs Dr. Paul Matthews (at UNM) and Dr. Christopher Brown (at NMSU). Successive Department Chairs Dr. Carol Campbell (NMSU), and Drs. Scott Freundschuh and Maria Lane (both at UNM) further developed the NMDPG. The program was approved by the Boards of Regents at both universities in 2018 and was then authorized by Governor Michelle Lujan Grisham in May 2019. The first cohort of the New Mexico Doctoral Program in Geography enrolled in Fall 2020.

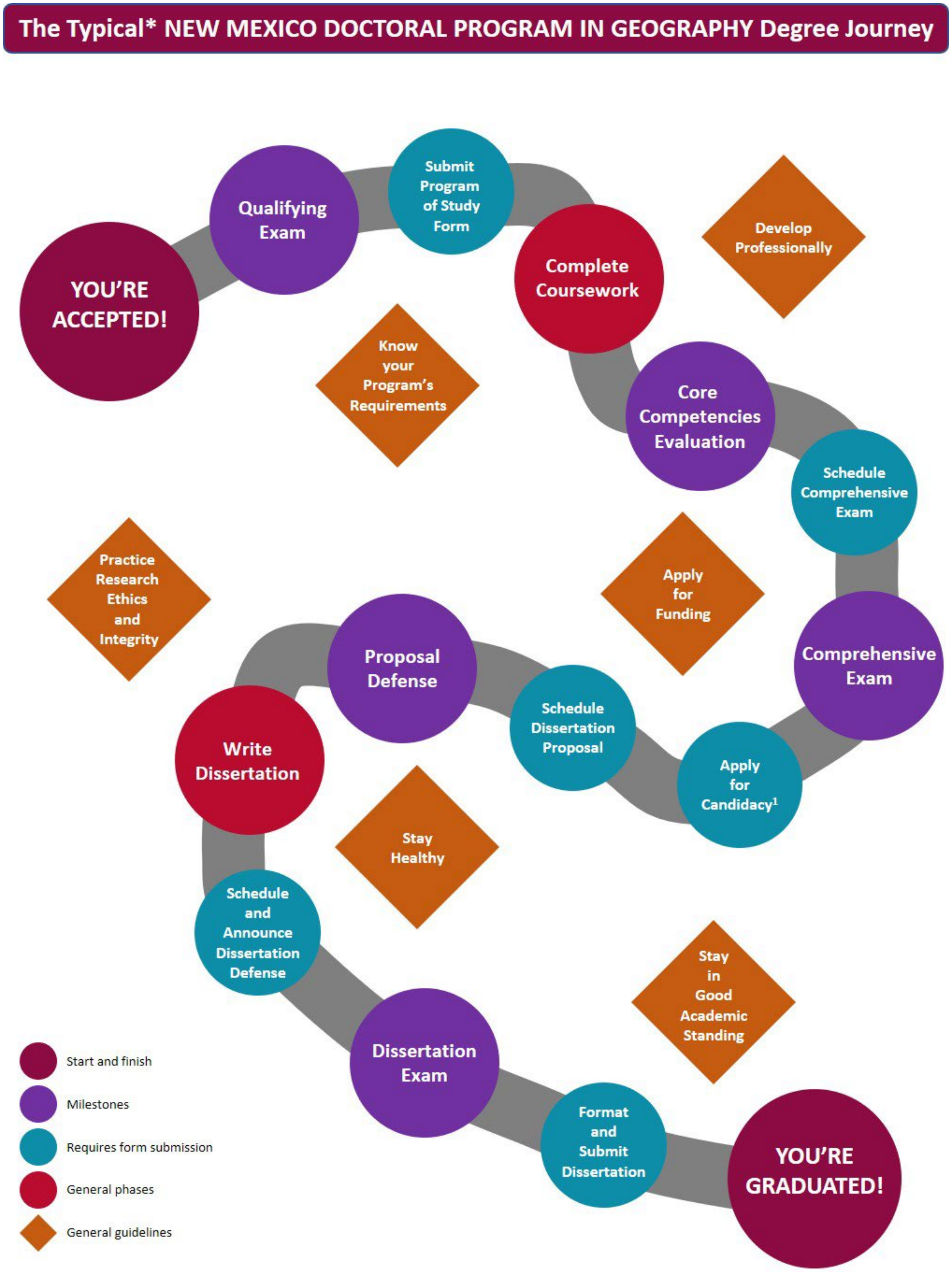
Both campuses offer state-of-the-art technical facilities, faculty expertise across human and physical geographies and quantitative and qualitative methods, and easy access to distinctive geographic features ranging from wilderness areas to urban centers, and the Rocky Mountains to the Chihuahuan Desert. We hope you take advantage of the rich opportunities the NMDPG offers.

For some important links and Graduate Program Director contact information, see Table 1 below.

Table 1: Resources at UNM and NMSU.

UNM	NMSU
City of Albuquerque	City of Las Cruces
University of New Mexico	New Mexico State University
UNM Graduate Studies	NMSU Graduate School
Department of Geography and Environmental Studies	Department of Geography
DGES Faculty	DG Faculty
Graduate Program Director: Dr. Maria Lane Email | Web Bandelier East 108 Phone: 505-277-5041	Graduate Program Director: Dr. Michaela Buenemann Email | Web Breland Hall 139 Phone: 575-646-6493

2.Roadmap



[1] UNM students only; NMSU students are automatically advanced to candidacy after passing the comprehensive exam.

3. Timeline Planner

Specific timelines for degree completion will vary from student to student. However, for your reference and planning, two timelines are provided below.

Table 2: Milestone timeline to finish in 4 years.

Year 1	
Fall	▪ Core course: GEOG 601 ▪ Elective coursework: 1-2 additional courses ▪ Plan your course of study: 18 credits from master's + 30 additional credits that meet all grad school requirements and satisfy all 7 program competencies
Spring	▪ Core course: GEOG 602 ▪ Elective coursework: 1-2 additional courses ▪ Submit Competency Plan* ▪ Submit Qualifying Exam Form, take Qualifying Exam*
Year 2	
Fall	▪ Core course: GEOG 603 ▪ Elective coursework: 1-2 additional courses ▪ Finalize your doctoral committee and submit CV of unapproved committee members to grad program office, if needed* ▪ Schedule your first committee meeting ▪ Apply for research funding
Spring	▪ Elective coursework: 2-3 total courses ▪ Begin preparation for comprehensive exams
Year 3	
Fall	▪ Take GEOG 595 (NMSU) or GEOG 696 (UNM) to prepare for comps ▪ Submit competency evaluation* ▪ Schedule comprehensive exam* ▪ Take comprehensive exam ▪ Advance to candidacy* ▪ Submit research proposal to committee ▪ Defend dissertation proposal
Spring	▪ Begin 18 dissertation hours for graduation ▪ Complete a teaching assignment or schedule one for fall
Year 4	
Fall	▪ Register for dissertation hours ▪ Committee meeting to gauge progress ▪ Attend dissertation formatting workshop ▪ Declare intent to graduate*
Spring	▪ Register for at least 3 dissertation hours ▪ Announce final oral exam* ▪ Defend dissertation ▪ Submit completed and approved dissertation within 90 days of defense ▪ Upload your dissertation* ▪ Deliver final document copy to grad program office and committee members ▪ Submit certification of final form of dissertation* ▪ Complete exit survey*

* Asterisks indicate that a form is required at either UNM or NMSU (see the section on "Forms" below)

Table 3: Milestone timeline to finish in 5 years.

Year 1	
Fall	▪ Core course: GEOG 601 ▪ Elective coursework: 1 additional course ▪ Plan your course of study: 18 credits from master's + 30 additional credits that meet all grad school requirements and satisfy all 7 program competencies
Spring	▪ Core course: GEOG 602 ▪ Elective coursework: 1 additional course ▪ Submit competency plan* ▪ Take qualifying exam*
Year 2	
Fall	▪ Core course: GEOG 603 ▪ Elective coursework: 1 additional courses ▪ Finalize your doctoral committee and submit CV of unapproved committee members to grad program office, if needed* ▪ Schedule your first committee meeting ▪ Apply for research funding
Spring	▪ Elective coursework: 2 total courses ▪ Apply for research funding
Year 3	
Fall	▪ Elective coursework: 2 total courses ▪ Begin preparation for comps
Spring	▪ Take GEOG 595 (NMSU) or GEOG 696 (UNM) to prepare for comps ▪ Submit competency evaluation* ▪ Schedule comprehensive exam* ▪ Take comprehensive exam ▪ Advance to candidacy*
Year 4	
Fall	▪ Begin 18 dissertation hours for graduation ▪ Submit research proposal to committee ▪ Defend dissertation proposal ▪ Complete a teaching assignment or schedule one for the coming year
Spring	▪ Register for dissertation hours ▪ Committee meeting to gauge progress
Year 5	
Fall	▪ Register for dissertation hours ▪ Attend dissertation formatting workshop ▪ Declare intent to graduate
Spring	▪ Register for at least 3 dissertation hours ▪ Announce final oral exam* ▪ Defend dissertation ▪ Submit completed and approved dissertation within 90 days of defense ▪ Upload your dissertation* ▪ Deliver final document copy to grad program office and committee members ▪ Submit certification of final form of dissertation* ▪ Complete exit survey*

* Asterisks indicate that a form is required at either UNM or NMSU (see the section on "Forms" below)

4. Policies

4.1 Credit Requirements

Overall Requirements

All students in the NMDPG must successfully complete required credits and milestones, as shown below. Each of the milestone requirements is addressed in separate sections of the NMDPG handbook.

- Credits: Core Courses (9), Elective Courses (39), Dissertation (18)
- Milestones: Qualifying Examination, Competency Requirement, Comprehensive Examination, Dissertation Proposal Defense, Final Oral Examination

Coursework Credit Requirements

All students must complete a minimum of 48 credits of coursework at the master's and/or doctoral levels, excluding dissertation credits.

General Requirements

- No more than 50% of course credits can be taken with a single faculty member.
- At least three hours of graduate credit must be taken in the semester in which the comprehensive examination is taken.
- Students must maintain a GPA >3.0 while enrolled in the program.
- No more than 6 credit hours of coursework can count toward the degree with the grade of C, C+, or CR. Courses offered only on a CR/NC basis and required by the graduate program are excluded from this limitation. [CR grades from Spring 2020 also do not count toward this limit.] No coursework with a grade lower than C can count toward the degree.

Core Courses

- 9 credits of core courses are required.
- Core courses may not be taken in non-degree status.

Elective Courses

39 credits of electives are required that meet all of the following criteria:

- At least 21 credit hours of graduate electives must be completed after the master's degree (i.e. no more than 18 credits can be transferred from a master's program).
- No more than 12 credits taken while in non-degree status may be counted.
- A minimum of 6 credits and a maximum of 15 credits of non-GEOG courses shall be counted toward the degree, including courses transferred from a master's program.
- At least 9 credit hours must be taken in courses numbered 500 or above.

Home-Campus vs Non-Home-Campus Credits

- At least 24 credit hours of coursework must be taken at the home university, excluding cross-enrollment credits. There is no limit to the number of courses that can be taken at the non-home campus, as long as all other requirements are met.

Dissertation Credit Requirements

All students must complete at least 18 hours of dissertation credits (GEOG/GESP 699 at UNM, or GEOG/GESP 700 at NMSU) in addition to other coursework requirements. At least 1 hour of graduate credit must be taken in the semester in which the student completes degree requirements.

Specific Coursework Requirements

Table 4: Coursework requirements that apply to all students in the NMDPG.

Type	Specific Courses	Credits	Notes
Core courses (9 credits)[a]	GEOG/GESP 601	3	Required during Semester 1
	GEOG/GESP 602	3	Required during Semester 2
	GEOG/GESP 603	3	Required during Semester 3
Electives [b] (39 credits)	GEOG/GESP courses	24-33	Specific courses must be approved by the student's advisor on the Program of Study.
	Non-GEOG/GESP courses	6-15	Specific courses must be approved by the student's advisor on the Program of Study.
Dissertation (18 credits)	GEOG 699 or GESP 700[c]	18	Up to 6 credit hours may be taken on the non-home campus.
Total Credits		**66[d]**	

[a] Core courses must be completed with a grade of B or higher. Core courses may not be taken in non-degree status.

[b] Up to 18 credits transferred from the master's degree can be used to fill elective requirements.

[c] Dissertation credits may be taken only after successful advancement to candidacy. Dissertation credits at UNM are in the catalog as GEOG 699; at NMSU, these credits are GEOG 700. Dissertation hours are normally taken at the home university with the student's faculty advisor.

[d] A minimum of 24 credits (non-dissertation) must be taken at the home university. Courses taken through cross-enrollment are not home-campus credits. There is no limit on courses taken at the non-home university, as long as all other requirements are met.

Waivers

Some requirements may be waived based on prior coursework or expertise. Students should consult their academic advisor to determine whether to petition for a waiver. All waiver requests must be made within the first year of the Ph.D. program and must comply with general coursework requirements. The NMDPG Steering Committee, which is composed of three geography faculty members from NMSU and three from UNM, evaluates and decides upon waiver requests.

4.2 Competency Areas

Students who complete the program are expected to demonstrate the following seven specific academic core competencies through the completion of coursework, teaching, research, and other activities.

Core Program Competencies

1. Analyze and interpret spatiotemporal patterns and processes of human activity and

organization with respect to their political, economic, cultural, social, and/or historical dimensions (Human Geography).

2. Analyze and interpret spatiotemporal patterns and processes of climate, biota, water, soil, and/or landforms (Physical Geography).
3. Analyze and interpret the social and biophysical processes that produce human-environment interactions, and make reasonable predictions about the impacts of changes in socio-ecological system components across space and through time (Socio-Ecological Systems).
4. Identify and describe geographic epistemologies, ontologies, and methodologies, and evaluate their suitability for answering different research questions (Geographic Theory and Methods).
5. Read, analyze, and interpret topographic and thematic maps (Map Use).
6. Create functional and aesthetically pleasing maps (Cartography).
7. Integrate spatial concepts, tools of representation, and reasoning processes to solve spatial problems (Spatial Thinking).

Requirements

Students are expected to achieve basic knowledge of all seven competencies. Students normally exhibit achievement of these competencies through completion and passing of graduate-level coursework or through assignment as a Teaching Assistant. Undergraduate-level courses cannot be used to satisfy a competency unless special approval is granted by the graduate program director at the home institution. The Doctoral Committee, in consultation with the NMDPG Steering Committee, may also determine that a student has exhibited achievement through an internship experience, employment, or, rarely, some other manner. To assist students in course selection, the NMDPG will actively maintain a list of courses at each institution that can be used to satisfy each competency.

Students will document their progress toward achieving competency at two points before advancing to candidacy.

Competency Plan

At the time of the Qualifying Examination, the student will identify competencies already acquired (e.g. in a master's program) and specify future coursework planned to achieve the remainder. The NMDPG Steering Committee will approve or disapprove the plan, providing direct feedback to the student about which courses or alternative courses of action should be taken.

Competency Evaluation

Before the student is approved to schedule the Comprehensive Examination, they must submit a final list of courses or other activities that fulfills the seven competencies. Students must obtain approval of the Competency Evaluation from the grad director at the home institution before they will be approved to schedule their comprehensive examination.

Courses For Meeting Competencies

Course offerings at UNM and NMSU change over time both within our geography programs and within our affiliated programs. However, for your reference and planning, we provide below a list of courses at UNM and NMSU you could complete to satisfy each of the program competency areas.

Table 5: Courses and competency areas at UNM.

Course prefix, number, and name	Competency Area[1]						
	1	2	3	4	5	6	7
GEOG *450. Hazards and Disasters[2]		X					
GEOG *421L. Map Design and Geovisualization[3]					X	X	X
GEOG 514. Human Dimensions of Climate Change[4]			X				
GEOG 515. Seminar in Geographies of Power	X			X			
GEOG 516. Seminar: Globalization and Development	X			X			
GEOG 518. Political Ecology			X	X			
GEOG 522. Intro to Spatial Data Management					X		
GEOG 523. Environmental Systems Modeling[5]			X				X
GEOG 524. Advanced Remote Sensing Seminar[6]				X	X		X
GEOG 525. Advanced GIScience Seminar				X			X
GEOG 526. Critical Cartography[7]							
GEOG 527. Introductory Programming for GIS					X		X
GEOG 528. Open Source GIS Programming[8]					X		X
GEOG 540. Race and Geography[9]	X						
GEOG 541. Environmental Management[10]			X				
GEOG 542. Water Governance[10]			X				
GEOG 543. Public Lands[11]			X				
GEOG 547. Governing the Global Environment[12]			X				
GEOG 551. Drylands		X					
GEOG 557. Environmental Security: Energy[13]			X				
GEOG 558. Environmental Security: Food & Water[14]	X		X				
GEOG 559. Peoples & Environments of Latin America	X						
GEOG 564. Food, Environment, and Society	X		X				
GEOG 566. The City	X						X
GEOG 575. Geography of New Mexico and the Southwest[15]	X						
GEOG 580L. Spatial Statistics				X			X
GEOG 581L. Intro GIS for Grad Students				X	X		X
GEOG 583L. Intro to Remote Sensing				X	X		X
GEOG 584L. Advanced Remote Sensing					X		X
GEOG 585L. Internet Mapping					X	X	X
GEOG 586L. Applications of GIS					X		X
GEOG 587L. Spatial Analysis and Modeling					X		X
GEOG 588L. GIS Concepts					X		X
GEOG 589. Qualitative Methods[16]				X			
GEOG 601. Intro to Geographic Theory				X			
GEOG 602. Integrative Research Design				X			

Course prefix, number, and name	Competency Area[1]						
	1	2	3	4	5	6	7
CRP 516. Watersheds		X					
CE 541. Hydrogeology		X					
CE 542. Intermed Hydrology		X					
CE 545. Open Channel Hydrology		X					
CE 547. GIS Water Resources		X					
CE 549. Vadose Zone Hydrology		X					
CE 565. Soil Behavior		X					
EPS 510. Fundamentals of Geochemistry		X					
EPS 555L. Computational and GIS Applications in Geomorphology		X					
EPS 562. Hydrogeology		X					
EPS 581L. Geomorphology and Surficial Geology		X					
EPS 536. Climate Dynamics		X					
BIOL 505. Ecosystem Dynamics		X					
BIOL 516. Basic Graduate Ecology		X					
BIOL 575. Community Ecology		X					
ECON 540. Natural Resource Modeling I			X				
ECON 542. Ecol Economics	X		X				
ECON 543. Natural Resource Modeling II			X				
WR 571. Water Resource I Issues			X				
WR 572. Water Resource II Modeling			X				

[1] Human geography = 1, physical geography = 2, social-ecological systems = 3, Geographic Theory and Methods = 4, map use =5, cartography = 6, spatial thinking = 7. For additional details, see Core Program Competencies above.

[2] previously GEOG *450 Environmental Hazards, [3] previously GEOG *481L Map Design and Geovisualization, 4 previously GEOG 514 Natural Resource Management Seminar, 5 previously GEOG 523 Environmental Systems Modeling, 6 previously GEOG 524 Advanced Topics in Remote Sensing, 7 previously GEOG 513 Critical Cartography, 8 previously GEOG 528 Advanced Programming for GIS, 9 previously GEOG 540 Geography of Bodies, 10 previously GEOG 561 Environmental Management, 11 previously GEOG 563 Public Land Management, 12 previously GEOG 567 Governing the Global Environment, 13 previously GEOG 570 Environmental Security: Energy, 14 previously GEOG572 Environmental Security: Food & Water, 15 previously GEOG 445 Geog of NM & SW, 16 previously GEOG590 Qualitative Methods

Table 6: Courses and competency areas at NMSU.

Course prefix, number, and name	Competency Area[1]						
	1	2	3	4	5	6	7
GEOG 467. Transportation Geography	X						
GEOG 472. Soil Morphology and Classification		X					
GEOG 491. Special Topics							
GEOG 491 Special Topics: Critical Approaches to Place	X						
GEOG 491 Special Topics: Geohumanities	X						
GEOG 493. Special Problem Research							
GEOG 535. Environmental Planning			X				
GEOG 552. Landscape Ecology		X					
GEOG 553. Geomorphology		X					
GEOG 555. Southwest Environments			X				
GEOG 557. Fundamentals of Biogeography		X					
GEOG 571. Cartography and Geographic Information Systems					X	X	X
GEOG 572. Geodatabase Design					X		X

Course prefix, number, and name	Competency Area[1]						
	1	2	3	4	5	6	7
GEOG 573. Introduction to Remote Sensing				X	X		X
GEOG 578. Fundamentals of Geographic Information Science				X	X		X
GEOG 581. System Design for Geographic Information Science					X		X
GEOG 582. Advanced Remote Sensing					X		X
GEOG 583. Field Explorations in Geography			X		X		X
GEOG 585. Advanced Spatial Analysis				X	X		X
GEOG 588. GIS and Water Resources					X		X
GEOG 595. Directed Readings							
GEOG 601. Introduction to Geographic Theory & Application				X			
GEOG 602. Integrative Research Design				X			
ANTH 516. Advanced Archaeology of the American Southwest	X						
ANTH 551. Advanced Indigenous Peoples History of the United States	X						
BIOL 536. Advanced Disease Vector Biology		X					
BIOL 568. Communities and Ecosystems		X					
ENVS 470. Envir. Impacts of Land Use and Contaminant Remediation			X				
ENVS 605. Arid Land Water Resources			X				
FWCE 537. Wildlife Damage Management			X		X		X
FWCE 540. Wildlife Habitat Relationships		X					
HIST 511. Making the American West	X						
HIST 575. History of the Global Political Economy	X						
PHIL 505. Advanced Studies in Philosophy and Literature	X						
PHIL 532. Advance Studies in Ethics and Global Poverty	X						
POLS 536. Public Policy and Indigenous Communities	X						
POLS 569. Advanced Issues in Globalization	X						
RGSC 513. Advanced Rangeland Ecology		X					
RGSC 575. Climate Studies, Water and Society			X				

[1] Human geography = 1, physical geography = 2, social-ecological systems = 3, Geographic Theory and Methods = 4, map use =5, cartography = 6, spatial thinking = 7. For additional details, see Core Program Competencies above.

4.3 Doctoral Committee

Each student will assemble a four-person Doctoral Committee to oversee the student's Comprehensive Examination and dissertation research (including the Dissertation Proposal Defense and Final Oral Examination), under the direction of the student's faculty advisor.

Composition

The Doctoral Committee must include their faculty advisor, at least one other geography faculty member from the home campus, and at least one geography faculty member from the non-home campus. The home-campus Graduate Program Director must approve the Doctoral Committee, in compliance with any general campus requirements at the home university. Membership on the Committee of Study can be changed following the general guidelines of the two universities.

Role and Responsibility

A student's Doctoral Committee shall fulfill the roles defined in the NMSU catalog for the "Doctoral Graduate Committee", and in the UNM catalog for the "Doctoral Committee on Studies", "Comprehensive Examination Committee", "Dissertation Committee", and "Final Examination Committee." At minimum, committee members will:

- Contribute questions for the Comprehensive Exam and provide feedback on the answers.
- Attend the oral portion of the Comprehensive Examination.
- Provide feedback on the dissertation proposal and attend the Dissertation Proposal Defense.
- Read the final draft of the dissertation and attend the Final Oral Examination.

4.4 Qualifying Exam

Students must complete the Qualifying Examination, which assesses professional readiness for advancement in the Ph.D. program.

Format

Before this exam, a student must provide the NMDPG Steering Committee with:

1. Proposed/tentative committee members from each university.
2. A completed competency plan that lists at least one completed/intended graduate-level course, or alternative activity (e.g. TA experience, internship, employment) for each of the program's seven areas of competency. Refer to the Policy on Competency for further detail.
3. Declaration of a minimum of two areas of mastery on which the student's comprehensive exam will focus.
4. An extended abstract (500-1000 words) of an intended area of research for the dissertation project.

The student must collaborate with their faculty advisor to complete items 1, 2, and 3, while the extended abstract (item 4) should be the student's independent work.

The NMDPG Steering Committee will assess the student's readiness to pursue the intended area of research by evaluating the extended abstract and will determine whether the competency plan is sufficient to satisfy the core competency requirement. The Steering Committee will provide feedback and guidance to the student on coursework or other preparations that may improve the student's capabilities in the intended research focus.

Outcomes

Based on the result of the Qualifying Examination, the NMDPG will take one or more of the following actions:

- Approve the student for further work toward the doctorate.
- Recommend a re-evaluation of the student's progress after the lapse of one semester.
- Recommend a discontinuation of graduate work.

For NMSU-based students, results of the Qualifying Examination will be reported to the Graduate School at NMSU in accordance with institutional policy. In all cases where the student is recommended to continue in the program, the Qualifying Examination paperwork will also be filed internally with the NMDPG Steering Committee. The list of courses intended to satisfy the competency requirement will be reviewed before Comprehensive Exams may be scheduled.

Scheduling

Students will complete the Qualifying Exam by the end of Semester 2.

4.5 Comprehensive Exam

By the end of Semester 6, each student should complete the Comprehensive Examination, which assesses mastery of knowledge in a minimum of two broad areas of geographical competency. Each student takes an individualized exam that focuses on specific subdisciplinary content relevant to the student's research, training, and professional goals. The Comprehensive Examination is conducted by the student's Doctoral Committee, under the direction of the student's faculty advisor. Each student should work with their Doctoral Committee to define the topical areas to be examined, develop a list of readings, and identify other activities that should be completed to prepare for the Comprehensive Examination. Students are advised, though not required, to enroll in "GEOG 595 Directed Readings" (at NMSU) or "GEOG 696 Supervised Research" (at UNM) during the semester they intend to take the Comprehensive Examination. Each student should refer to the requirements of the home institution to verify eligibility to take the Comprehensive Exam.

Format

The Comprehensive Exam contains both written and oral components. It begins with a written examination taken over four days. Each member of the Doctoral Committee is responsible for the format and content of one day's question(s). In the event the student has chosen a Doctoral Committee with more than four members, the student's faculty advisor will determine how to apportion the committee members' questions across the four days. The faculty advisor will make each day's question(s) available to the student at 8:00 am, and the completed answer(s) will be due back to the advisor no later than 5:00 pm. Once the examination is complete, each Committee member will assess and provide detailed feedback on the answer(s) to the question(s) they assigned. Each Committee member will also review the remainder of the written answers.

After the completion of the written portion of the Comprehensive Exam, the Doctoral Committee will convene to conduct an oral examination. In general, the oral examination should take place no more than two weeks after the written examination is completed, and it is customary for only Committee members to attend. The oral examination should be based on follow-up questions stemming from the student's answers to the written exam. It does not require a presentation by the student and should not introduce new topics.

Outcomes

Based on the results of the written and oral examination components, the Doctoral Committee will determine whether the student has passed, conditionally passed, or failed the examination.

Students who pass the Comprehensive Examination may advance to candidacy. Students who pass conditionally will receive a detailed set of conditions from the Committee and must satisfy those conditions by the end of the subsequent term. If a student fails the Comprehensive Examination, the Committee of Study may recommend a second examination, which must be administered after at least one semester has passed, but no longer than one calendar year from the date of the first examination. The doctoral Comprehensive Examination may be taken only twice. A second failure results in the student's termination from the program.

Scheduling

Usually, students will complete the Comprehensive Examination before the Dissertation Proposal, but this is not required.

4.6 Advancement to Candidacy

A student may advance to doctoral candidacy after:

1. completing all coursework required to satisfy NMDPG competency area requirements;
2. passing the Comprehensive Examination;
3. completing all required program coursework, as confirmed by the Graduate School at the home institution; and
4. receiving approval from the Doctoral Committee.

Before scheduling the Comprehensive Examination, students must complete all competency requirements and gain approval from the Graduate Program Director at the home institution. After passing the Comprehensive Examination, students will advance to candidacy following the specific requirements and procedures specified by the Graduate School at their home institution. (For NMSU students, advancement to candidacy is automatic. UNM students will follow a filing process.) After advancement to candidacy, the student must meet the residency and minimum enrollment requirements specified by the Graduate School at their home institution.

4.7 Proposal Defense

By the end of Semester 6, the student should complete the Dissertation Proposal Defense, which assesses the soundness of the proposed research design, the student's readiness to undertake the project, and the student's expertise in research areas required to complete the dissertation. The student should circulate the written dissertation proposal to all members of the Doctoral Committee at least 10 days before the scheduled defense.

Format

The Dissertation Proposal Defense is an oral examination with both public and non-public components. It begins with a public presentation and public questioning from the Doctoral Committee and audience. It concludes with a non-public discussion between the student and Doctoral Committee.

Outcomes

Based on the result of the Dissertation Proposal Defense, the Doctoral Committee will take one of the following actions:

- Approve the student to undertake the dissertation as proposed.
- Recommend a revision of the written proposal before undertaking dissertation research.
- Recommend a revision of the written proposal, with subsequent oral re-evaluation, before undertaking dissertation research.
- Recommend a discontinuation of graduate work.

Once the proposal is approved, the student's faculty advisor will notify the home institution's Graduate Program Director.

Scheduling

Usually, students will undertake the Dissertation Proposal Defense after having completed the Comprehensive Examination, but this is not required. The Dissertation Proposal Defense is not a pre-requisite for advancement to candidacy, so the student and advisor have flexibility in its scheduling. It should be done at the earliest opportunity, however, to ensure that the student receives clear feedback from the Doctoral Committee about the direction and significance of the proposed dissertation research design. At minimum, the Dissertation Proposal Defense must be held no more than one year after the completion of the Comprehensive Exam and at least two semesters before the intended Final Oral Examination (dissertation defense).

4.8 Dissertation

Every student must complete a dissertation that presents the results of original investigations of a significant problem. The dissertation should display a mastery of the literature of the subject field, be methodologically sound, present an organized and coherent development of ideas with a clear exposition of results, and provide a critique of the limits and validity of the student's conclusions. At a minimum, the dissertation should provide the basis for publishable contributions to the research literature in the student's field.

Format

The NMDPG accepts both traditional and non-traditional (hybrid) dissertations. A traditional dissertation is a single written document, authored solely by the student, and formatted as a monograph with multiple chapters. A non-traditional (hybrid) dissertation consists of an introduction, a minimum of three related first-author articles prepared and/or submitted for publication (or already published), and a conclusion. The student, in consultation with their Doctoral Committee, must decide which format is appropriate. In either case, the dissertation must be substantially and primarily the student's original work. A contributions statement must be included in each paper to clarify research and authorship roles.

Completion

After the written dissertation is submitted to the student's Doctoral Committee, it must be orally defended in a public presentation that constitutes the final examination for completion of the degree. Refer to the section on “Final Oral Exam” for requirements.

4.9 Final Oral Exam (Dissertation Defense)

No later than 5 years after completion of the Comprehensive Examination, each student must complete and pass the Final Oral Examination (Dissertation Defense), through which the Doctoral Committee assesses both 1) the soundness and intellectual merit of the completed research project, and 2) the student’s understanding of the project’s results and significance within relevant academic fields. The student should circulate the final draft of the dissertation to all members of the Committee on Studies at least two weeks before the scheduled defense.

Format

The Final Oral Examination has both public and closed portions. The student’s presentation and the questions of both the audience and Doctoral Committee are public. The Committee’s deliberation is closed to the public.

Outcomes

At the conclusion of the examination, the Doctoral Committee members confer and make one of the following recommendations:

- That the dissertation be approved without change;
- That the dissertation be approved subject only to minor editorial corrections: or
- That the dissertation be rewritten or revised before approval.

The committee may also assign the grade of “Conditional Pass” and require that the student meet additional conditions before a grade of "pass" is awarded.

The results of the examination will be reported to the Graduate School at the home institution, and the student will format and submit the final version of the dissertation in accordance with the specific requirements of the home institution.

5.Required Forms and Documents

Table 7: Guide to required forms and documents.

Student-Initiated Forms and Required Documents	Submit To: UNM GS	NMSU GS	NMDGP	Signatures Required
Qualifying Exam				
Tentative Committee			✓	Student, NMDPG Steering Committee
Competency Plan			✓	Student, NMDPG Steering Committee
Mastery Areas			✓	Student, NMDPG Steering Committee
Extended Abstract			✓	Student, NMDPG Steering Committee
Competency Areas				
Competency Evaluation			✓	Student, NMDPG Steering Committee
Program of Study and Committee				
Program of Study and Committee		✓		Student, Major Advisor, Minor Faculty, Department Head, Academic College Dean, Graduate School
Declaration of Committee, CV for any new members	✓			Student, All Doctoral Committee Members
Comprehensive Exam				
Announcement of Exam	✓			N/A; Submit to Graduate Program
Doctorate of Philosophy Examination Form		✓		Student, Major Advisor, Minor Faculty, Department Head, Graduate School
Advancement to Candidacy				
Candidacy Application	✓			Student, Major Advisor
Dissertation				
Announce Proposal Defense			✓	Student, Major Advisor
Proposal Form			✓	Student, All Doctoral Committee Members
Doctorate of Philosophy Examination Form		✓		Student, Major Advisor, Minor Faculty, Department Head, Graduate School
Announce Final Oral Exam (Dissertation Defense)	✓			N/A
Dissertation Manuscript	✓			N/A
Dissertation Title Submission Form		✓		N/A
Certification of Final Form	✓			Student, Major Advisor
Graduation				
Intent to Graduate			✓	Student, major advisor

]Exit Survey	✓	No signatures needed

Transcript

Theodros Mentesinot Woldeyoha
UNM ID: 101-94-5074
DATE OF BIRTH: 17-DEC-1994

THE UNIVERSITY OF NEW MEXICO
OFFICE OF THE REGISTRAR
ALBUQUERQUE, NEW MEXICO 87131-0001

PAGE: 1
DATE ISSUED: 04-AUG-2022

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 Course Level: Graduate/GASM

Current Program
Doctor of Philosophy
           Program : PHD Geography
           College : Graduate Programs
            Campus : Albuquerque/Main
             Major : Geography

SUBJ  NO.               COURSE TITLE          CRED GRD     PTS R
-----------------------------------------------------------------

INSTITUTION CREDIT:

Fall 2021
  Graduate Programs
GEOG 527       Intro Programming for GIS       3.00 A      12.00
GEOG 587L      Spatial Analysis and Modeling   3.00 A+     12.99
GEOG 601       Intro Geog Theory & Applic      3.00 A+     12.99
        Ehrs:  9.00 GPA-Hrs: 9.00   QPts:    37.98 GPA:    4.22

Spring 2022
  Graduate Programs
GEOG 515       Sem: Geographies of Power       3.00 A      12.00
GEOG 528       Advanced Programming for GIS    3.00 A+     12.99
GEOG 602       Integrative Research Design     3.00 A+     12.99
        Ehrs:  9.00 GPA-Hrs: 9.00   QPts:    37.98 GPA:    4.22

Fall 2022
IN PROGRESS WORK
GEOG 499       T: Environmental Justice        3.00 IN PROGRESS
GEOG 525       Advanced GIScience Seminar      3.00 IN PROGRESS
GEOG 603       Prof Geographic Practice        3.00 IN PROGRESS
             In Progress Credits      9.00
********************** TRANSCRIPT TOTALS ***********************
                  Earned Hrs  GPA Hrs    Points     GPA
TOTAL INSTITUTION      18.00    18.00     75.96    4.22

TOTAL TRANSFER          0.00     0.00      0.00    0.00

OVERALL                18.00    18.00     75.96    4.22
********************** END OF TRANSCRIPT ***********************
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ISSUED TO:

Theodros M. Woldeyohannes
twoldey94@unm.edu

UNOFFICIAL ACADEMIC TRANSCRIPT

NOT TO BE RELEASED
TO THIRD PARTY WITHOUT
STUDENT CONSENT

Teaching

UNM - Diné College Summer Internship 2022

Geospatial Data Science, Environment, Community, and Health

Instructor: Dr. Yan Lin
Email: yanlin@unm.edu
Term / Semester: Summer 2022
Meeting Day(s): June 13th - 24th, 2022
Meeting Time: 9:00 am - 4:30 pm
Meeting Location / Room: PAIS 1010 (Address: 210 Yale Blvd NE, Albuquerque, NM 87106)
TA: Theodros Woldeyohannes (master TA), Daniel Beene, Chris Girlamo, Zhuoming Liu, Eric Brannen

DESCRIPTION

The complex spatio-temporal relationships between the environment and health/health disparities remain an interdisciplinary research challenge. This summer internship with the University of New Mexico Department of Geography & Environmental Studies, in collaboration with Diné College, National Science Foundation (NSF) funded TickBase Team, UNM METALS Superfund Research Program Center and Native Environmental Health Equity Research Center, will provide training on GIS and Geospatial Data Science addressing environmental health issues, which includes: (1) introduction to GIS for managing, integrating, analyzing, and visualizing geospatial data and information; (2) geospatial analysis and modeling concepts, methods, and applications in environmental health; (3) performing GIS and geospatial analysis using GIS software; (4) topics on the intersection of GIS & geospatial spatial analysis and environmental health; and (5) developing projects for real-world problem solving. Students are welcome to participate in existing ongoing environmental health projects at UNM.

Sunday June 12th 2022

Interns arrive in Albuquerque, NM. Dormitory check in
On Campus Housing: Casa del Rio (Address: 420 Redondo E Dr NE, Albuquerque, NM 87106)

Day 1: Monday, June 13th 2022

PAIS ASPIRE 1010	9:00 – 10:30 AM	**Orientation & Introduction** Yan Lin, PhD. Assistant Professor, UNM Geography	Breakfast Refreshments
PAIS ASPIRE 1010	10:30 – 11:00 AM	**Greetings from Associate Dean** Christopher Lippitt, Ph.D. Associate Dean for Research, College of Arts & Sciences Associate Professor, GES, UNM	

PAIS ASPIRE 1010	11:00 AM – 12:00 PM	**GIS Basics I** - **What is GIS?** Theodros Woldeyohannes, MS Research Assistant, UNM Zhuoming Liu, MS Research Staff/Assistant, UNM	
PAIS ASPIRE 1010	12:00 – 1:00 PM	Lunch Break	Food -Panera Bread
PAIS ASPIRE 1010	1:00 – 4:00 PM	**Lab 1** - **Introduction to Software and Data Fundamentals** Theodros Woldeyohannes, MS Research Assistant, UNM Zhuoming Liu, MS Research Staff/Assistant, UNM	
	4:00 – 4:30 PM	**UNM main campus tour**	
Day 2: Tuesday, June 14th 2022			
PAIS ASPIRE 1010	9:00 – 9:20 AM	**Introductions – meeting guest speakers**	Refreshments
PAIS ASPIRE 1010	9:30 – 10:20 AM	**Lecture in GeoSpatial Analysis in Health Studies I** Xun Shi, Ph.D. Professor of Geography Dartmouth College	
PAIS ASPIRE 1010	10:30 – 11:20 AM	**Lecture in GeoSpatial Analysis in Health Studies II** Meifang Li, Ph.D. Research Scientist, Geography Dartmouth College	
PAIS ASPIRE 1010	11:30 – 12:00 AM	**Discussions**	
PAIS ASPIRE 1010	12:00 – 1:00 PM	Lunch Break Greetings from GES Chair Chris Duvall, Ph.D. Professor of Geography	Food - EL PINTO

		UNM Department of Geography & Environmental Studies (GES)	
PAIS ASPIRE 1010	1:00 – 4:30 PM	**Lab 1** Zhuoming Liu, MS Research Staff/Assistant, UNM	

Day 3: Wednesday, June 15th 2022			
PAIS ASPIRE 1010	9:00 – 12:00 AM	**GIS Basics II - Geospatial Data Types and Interpretation** Daniel Beene, MS Data Manager, UNM Zhuoming Liu, MS Research Staff/Assistant, UNM	Refreshments
PAIS ASPIRE 1010	12:00 – 1:00 PM	Lunch Break	Food – East Ocean
PAIS ASPIRE 1010	1:00 – 2:30 PM	**Lab 2 – part 1** Daniel Beene, MS Data Manager, UNM Zhuoming Liu, MS Research Staff/Assistant, UNM	
GES	2:30 – 3:00 PM	**GES tour**	
BE105	3:00 – 4:00 PM	**Research Colloquium** Xun Shi, Ph.D. Professor of Geography Dartmouth College	
UNIVERSITY CLUB Address: 1923 Las Lomas Albuquerque, NM 87131	4:30 – 7:30 PM	**Welcome Reception Dinner**	Open to UNM faculty and students

Day 4: Thursday, June 16th 2022			
PAIS ASPIRE 1010	9:00 – 10:30 AM	**GIS basics III – Table, Attributes & Query** Zhuoming Liu, MS Research Staff/Assistant, UNM	Refreshments
PAIS ASPIRE 1010	10:30 – 11:30 AM	**Join P50 Hoover-Lin project group meeting**	
PAIS ASPIRE 1010	11:30 – 1:00 PM	Lunch Break	Food- Jimmy John's
Zoom	1:00 – 1:30 PM	**UNM METALS SRP meeting**	

PAIS ASPIRE 1010	2:00 – 4:30 PM	**Lab 2 – part 2** Zhuoming Liu, MS Research Staff/Assistant, UNM	

Day 5: Friday, June 17th 2022

PAIS ASPIRE 1010	9:00 – 10:30 AM	**GIS basics IV – Raster Basics** Chris Girlamo, BS Research Assistant, UNM Zhuoming Liu, MS Research Staff/Assistant, UNM	Refreshments
PAIS ASPIRE 1010	10:30 – 11:00 AM	Environmental fate and toxicity of heavy metals Eliane EL Hayek, Ph.D. Research Assistant Professor, College of Pharmacy, UNM	
CENT Lab	11:00 AM – 12:00 PM	CENT Lab Tour Eliane EL Hayek, Ph.D. Research Assistant Professor, College of Pharmacy, UNM	
PAIS ASPIRE 1010	12:00 – 1:00 PM	Lunch Break	Food – Slice Parlor
PAIS ASPIRE 1010	1:00 – 2:00 PM	**Lab 3 - Raster Basics** Chris Girlamo, BS Research Assistant, UNM Zhuoming Liu, MS Research Staff/Assistant, UNM	
College of Pharmacy	2:30-4:30 PM	COP lab tour & HSC Campus Tour Matthew J Campen, Ph.D. Professor, College of Pharmacy, UNM	

Day 6: Saturday, June 18th, 2022

Free Day

Day 7: June 19th 2022

Free Day

Day 8: Monday, June 20th 2022

PAIS ASPIRE 1010	9:00 – 11:00 AM	**Introduction to geospatial analysis and modeling I**	Refreshments

		- **GIS Analysis: Patterns and Relationships** Theodros Woldeyohannes, MS Research Assistant, UNM Zhuoming Liu, MS Research Staff/Assistant, UNM	
PAIS ASPIRE 1010	11:00 – 12:00 PM	**Natural hazards and risk modeling** Yolanda C. Lin, Ph.D. Assistant Professor GES, UNM	
PAIS ASPIRE 1010	12:00 – 1:00 PM	Lunch Break	Food – Golden Pride
PAIS ASPIRE 1010	1:00 – 4:30 PM	**Lab 4: Part I** - **Analyzing Patterns and Relationships in Census Data** Theodros Woldeyohannes, MS Research Assistant, UNM Zhuoming Liu, MS Research Staff/Assistant, UNM	

Day 9: Tuesday, June 21st 2022

PAIS ASPIRE 1010	9:00 – 12:00 AM	**Geospatial Data Science & Climate Change** Chao Fan, Ph.D. Assistant Professor University of Idaho Zhe Wang, MS University of Idaho	Refreshments
PAIS ASPIRE 1010	12:00 – 1:00 PM	Lunch Break	Food - TBD
PAIS ASPIRE 1010	1:00 – 4:00 PM	**Lab 4: Part II** - **Modeling Meteorological Data** Theodros Woldeyohannes, MS Research Assistant, UNM Chris Girlamo, BS Research Assistant, UNM	

		Zhuoming Liu, MS Research Staff/Assistant, UNM	

Day 10: Wednesday, June 22nd 2022

PAIS ASPIRE 1010	9:00 – 12:00 PM	**Introduction to geospatial analysis and modeling II** - **Environmental Contaminants and Exposures** Theodros Woldeyohannes, MS Research Assistant, UNM Zhuoming Liu, MS Research Staff/Assistant, UNM	Refreshments
PAIS ASPIRE 1010	12:00 – 1:00 PM	Lunch Break	Food - TBD
PAIS ASPIRE 1010	1:30 – 2:15 PM	**Environmental Justice** Miriam Gay-Antaki, Ph.D. Assistant Professor GES, UNM	
PAIS ASPIRE 1010	2:30 – 4:30 PM	**Lab 5** - **Environmental Exposure Modeling** (including fundamentals of the multi-criteria decision analysis (MCDA) framework) Theodros Woldeyohannes, MS Research Assistant, UNM Zhuoming Liu, MS Research Staff/Assistant, UNM	

Day 11: Thursday, June 23rd 2022

PAIS ASPIRE 1010	9:00 – 12:00 AM	**ABQ City tour & Field Trip** Maria Lane, Ph.D. Professor, UNM GES	
PAIS ASPIRE 1010	12:00 – 1:00 PM	Lunch Break	Food - TBD
PAIS ASPIRE 1010	1:00 – 4:00 PM	**Health Equity** Eric Brannen Research Assistant, UNM	

		Yan Lin, PhD. Assistant Professor, UNM Geography	

Day 12: Friday, June 24th 2022

PAIS ASPIRE 1010	9:00 – 12:00 AM	**Community Geography** Maria Lane, Ph.D. Professor, UNM Geography	Refreshments
PAIS ASPIRE 1010	12:00 – 1:00 PM	Lunch Break	Food - TBD
	1:00 – 4:00 PM	**Project discussions & Closing Remarks** Yan Lin, PhD. Assistant Professor, UNM Geography	
Restaurant: Hausammann Brewhaus (Address: 2004 Central Ave SE, Albuquerque, NM 87106)	4:30 – 7:00 PM	**Social Gathering**	Open to UNM faculty and students

Day 13: Saturday, June 25th, 2022

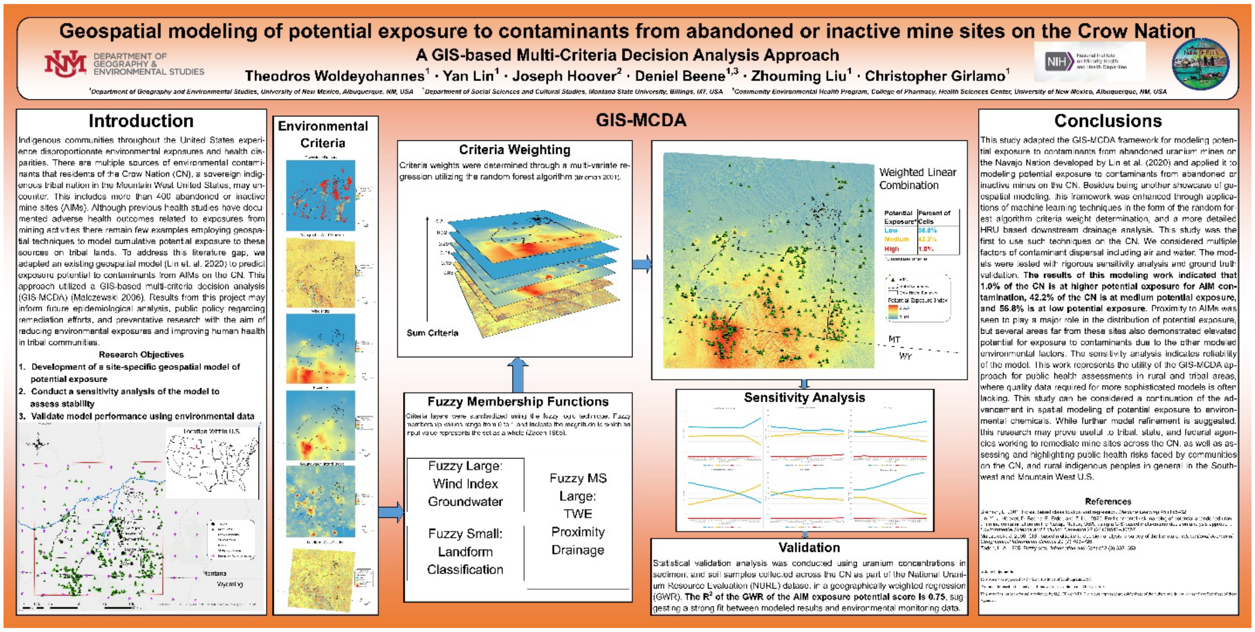
Free Day

Day 14: Sunday, June 26th 2022

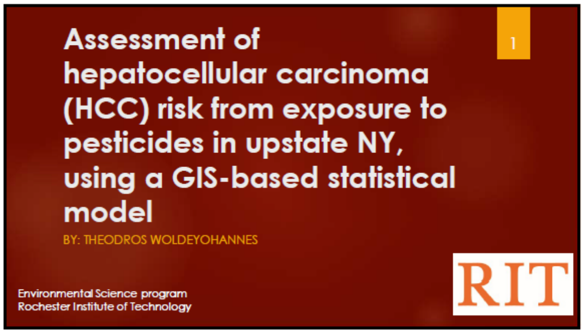
Departure for National Environmental Health Association (NEHA) conference in Spokane, WA.

Scholarship and Research

Poster: AAG 2022



Talk: SWAAG 2021



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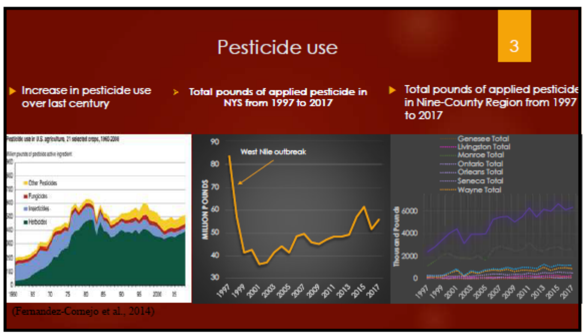

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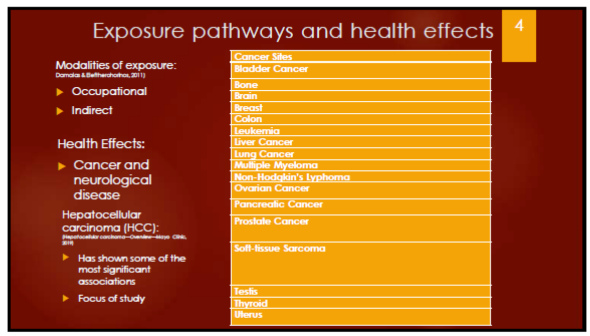

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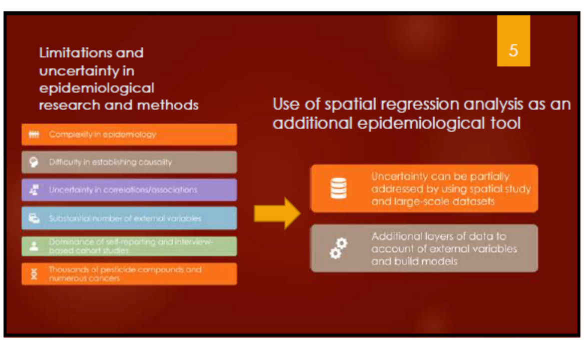

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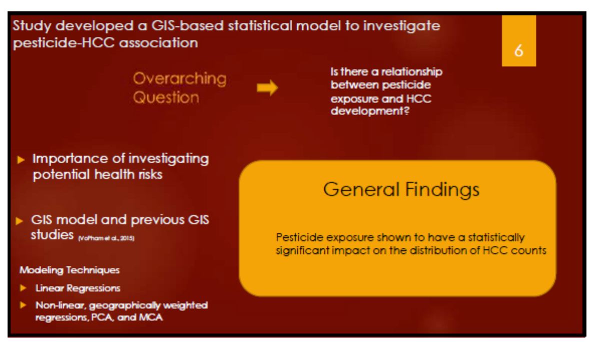

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Methods

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Study population and areas of interest

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- Population study area covers all of NYS
- AOIs
- Analysis was performed at multiple stratified levels, including all of NYS, AOIs, a subset analysis on agriculturally intensive areas, and geographic AOIs generated from Multivariate Cluster Analysis (MCA).
- Data aggregated to zip-codes

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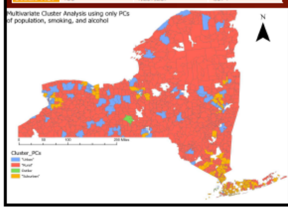
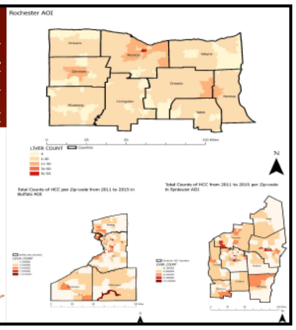
Main AOIs and clusters

Extent	Number of Zip-codes	Population	Area (SQMI)
NYS	1408	10,849,192	46,623
Rochester AOI	166	1,310,800	6,223
Syracuse AOI	207	1,141,201	10,095
Buffalo AOI	135	1,259,259	4,394





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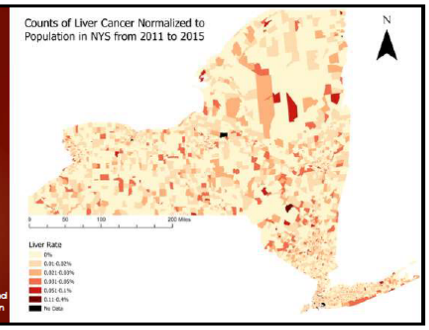
Cancer data

NYSDOH Cancer Mapping Datasets (2005-2015) covering 23 anatomical cancer types (*Cancer Mapping Data: 2005-2009 | Health Data NY, 2015; Cancer Mapping Data: 2011-2015 | Health Data NY, 2018*)

Observed counts of liver cancer (HCC) per zip-code from 2005-2015 across NYS and within the Nine County Region



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Pesticide exposure

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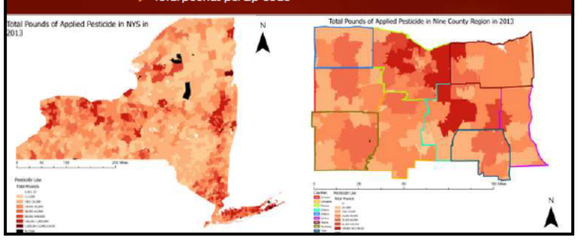
- NYSDEC Pesticide Sales and Use reports (1997-2017) (NYSDEC, 2017)
- Total pounds per zip-code



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General Model Design and Range of Data Analyzed

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- Covariates
  - Additional sources include census data, and rural-urban commuting area (RUCA) codes
  - Demographic information
  - External health variables
  - Environmental variables
- Final models utilized forest-based classification and regression (FBCR) on pesticide exposure from 1997-2001 and HCC indices from 2011-2015.

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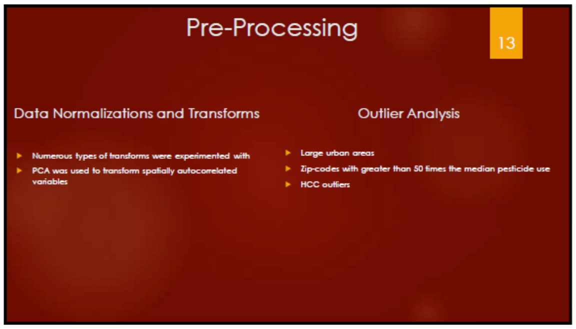

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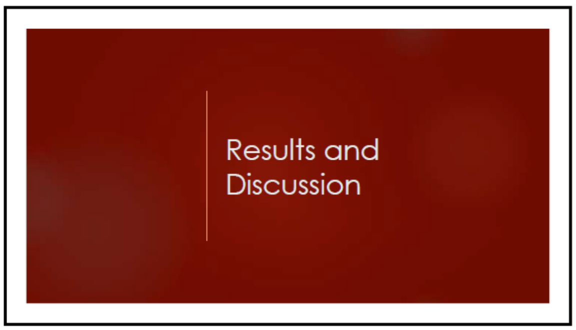

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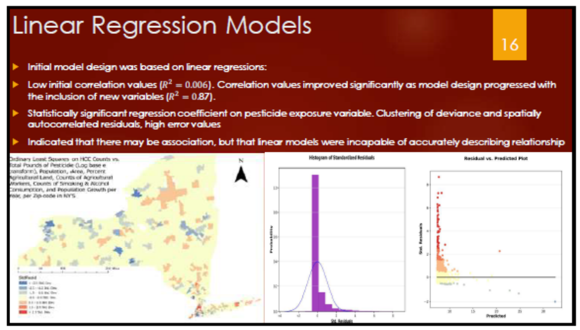

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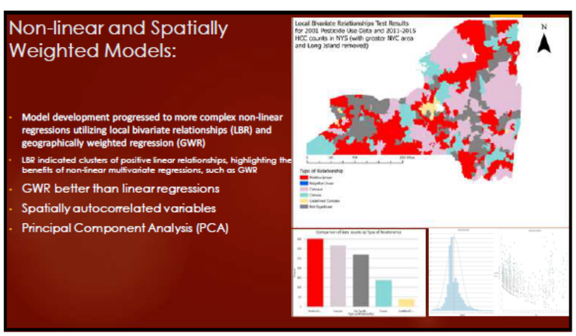

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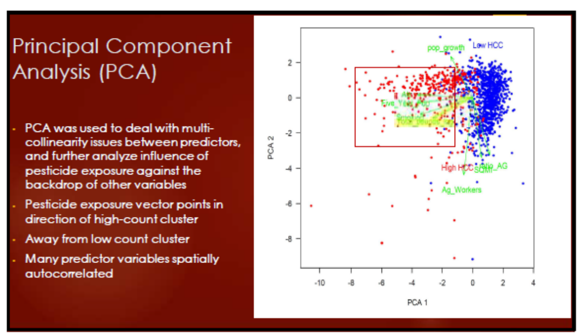

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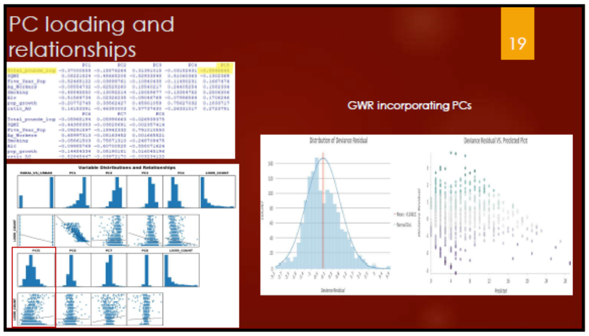

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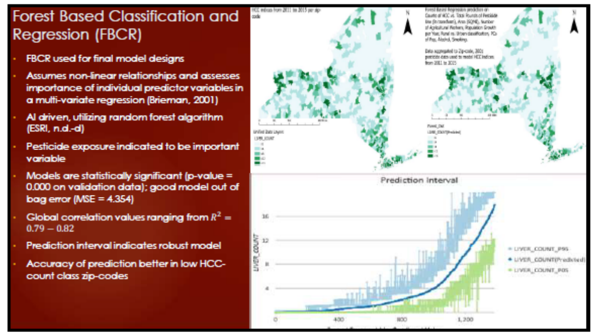

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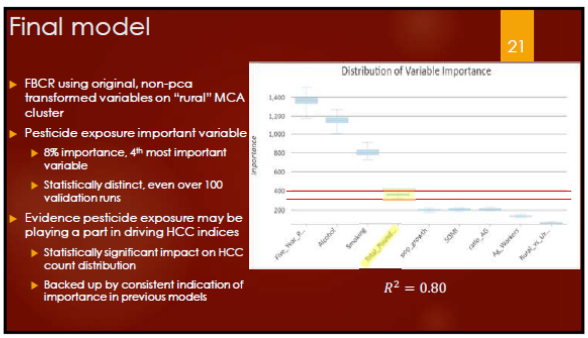

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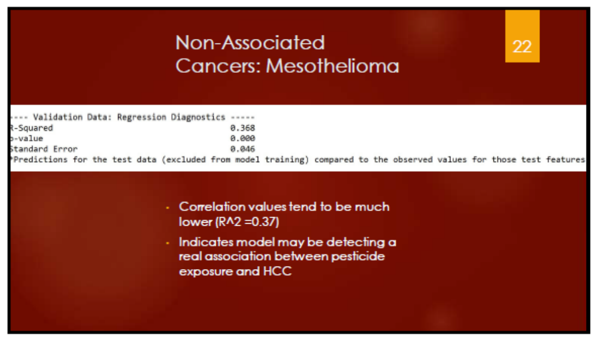

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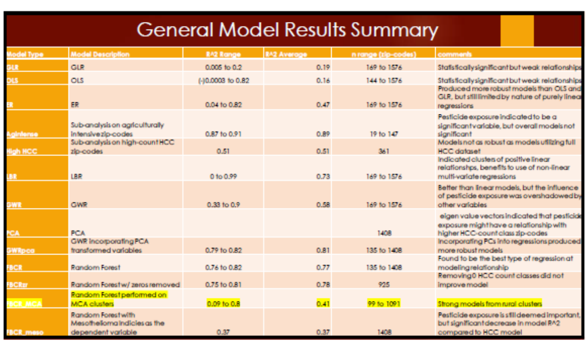
General Model Results Summary

Model Type	Model Description	R^2 Range	R^2 Average	n range (zip-codes)	comments
GLR	GLR	0.005 to 0.2	0.19	169 to 1576	Statistically significant but weak relationships
OLS	OLS	(-)0.0003 to 0.82	0.16	144 to 1576	Statistically significant but weak relationships
ER	ER	0.04 to 0.82	0.47	169 to 1576	Produced more robust models than OLS and GLR, but still limited by nature of purely linear regressions
Agintense	Sub-analysis on agriculturally intensive zip-codes	0.87 to 0.91	0.89	19 to 147	Pesticide exposure indicated to be a significant variable, but overall models not significant
High HCC	Sub-analysis on high-count HCC zip-codes	0.51	0.51	361	Models not as robust as models utilizing full HCC dataset
LBR	LBR	0 to 0.99	0.73	169 to 1576	Indicated clusters of positive linear relationshps, benefits to use of non-linear multi-variate regressions
GWR	GWR	0.33 to 0.9	0.58	169 to 1576	Better than linear models, but the influence of pesticide exposure was overshadowed by other variables
PCA	PCA			1408	eigen value vectors indicated that pesticide exposure might have a relationship with higher HCC-count class zip-codes
GWRpca	GWR incorporating PCA transformed variables	0.79 to 0.82	0.81	135 to 1408	Incorporating PCs into regressions produced more robust models
FBCR	Random Forest	0.76 to 0.82	0.77	135 to 1408	Found to be the best type of regression at modeling relationship
FBCRzr	Random Forest w/ zeros removed	0.75 to 0.81	0.78	925	Removing 0 HCC count classes did not improve model
FBCR_MCA	Random Forest performed on MCA clusters	0.09 to 0.8	0.41	99 to 1091	Strong models from rural clusters
FBCR_meso	Random Forest with Mesothelioma indicies as the dependent variable	0.37	0.37	1408	Pesticide exposure is still deemed important, but significant decrease in model R^2 compared to HCC model

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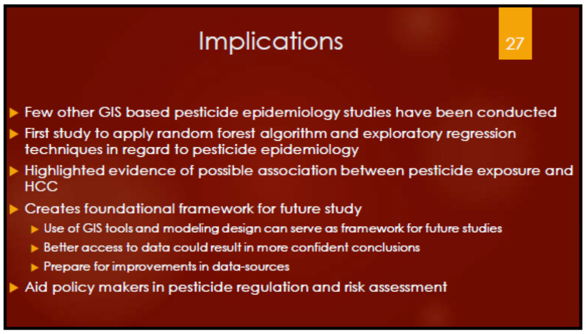

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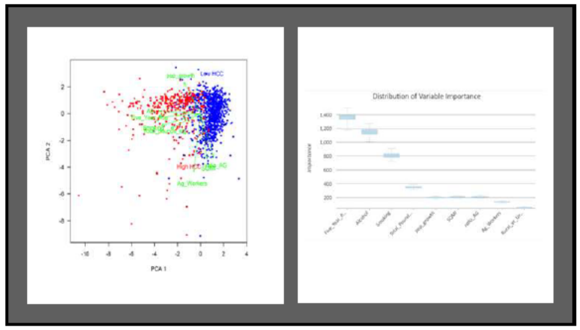
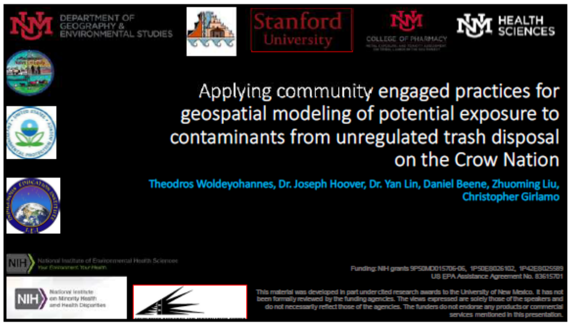


34

Talk: Superfund Research Program Student Research Showcase 2022



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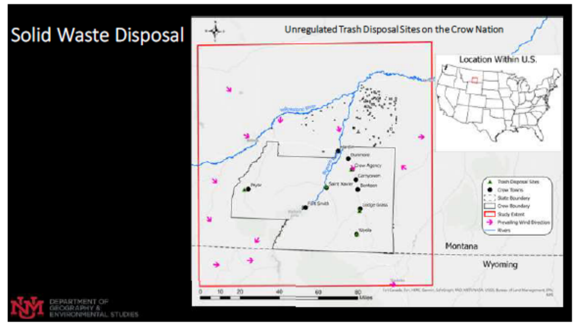

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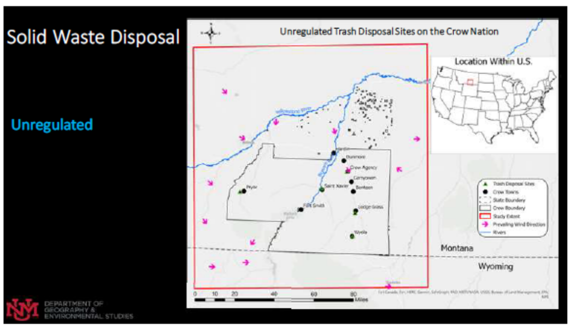

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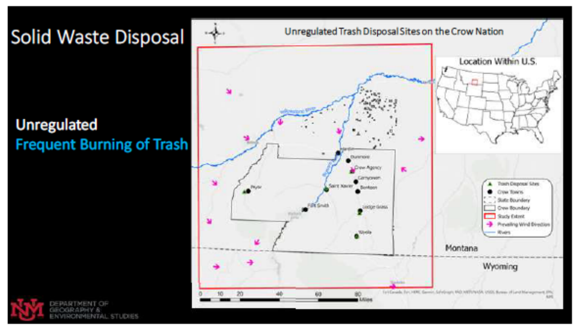

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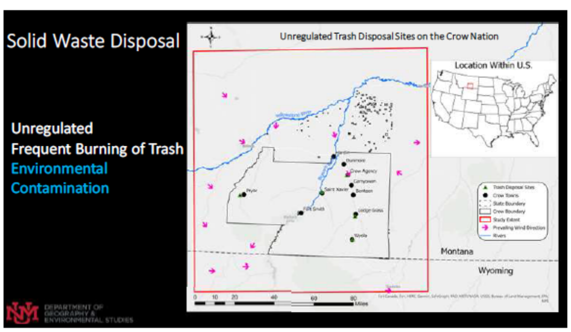

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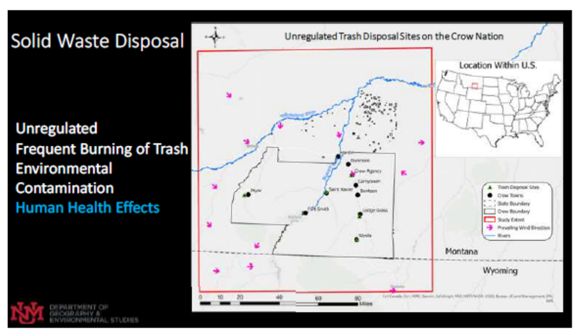


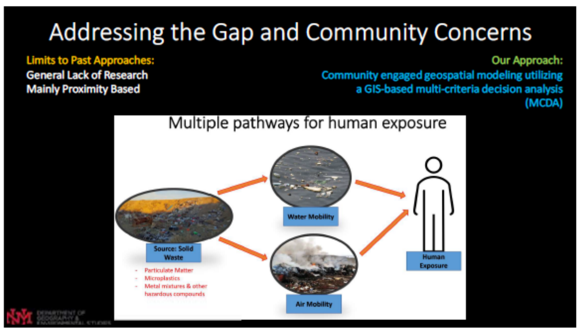
6


Literature Gap
DEPARTMENT OF GEOGRAPHY & ENVIRONMENTAL STUDIES

7


Literature Gap
Community Concerns
DEPARTMENT OF GEOGRAPHY & ENVIRONMENTAL STUDIES

8


Addressing the Gap and Community Concerns
Limits to Past Approaches:
General Lack of Research
Mainly Proximity Based
Our Approach:
Community engaged geospatial modeling utilizing a GIS-based multi-criteria decision analysis (MCDA)
Multiple pathways for human exposure
Source: Solid Waste
- Particulate Matter
- Microplastics
- Metal mixtures & other hazardous compounds
Water Mobility
Air Mobility
Human Exposure

9


Community Engaged Scholarship (CES)

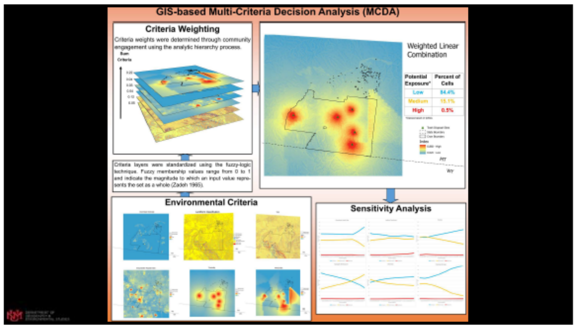
10


Identification of Trash sites through partnership with Tribal members
Identify Sites
Visit sites, Geo-coded using GPS
Trash Fire in Crow Agency, Crow Nation
Credit: Joseph Hoover
DEPARTMENT OF GEOGRAPHY & ENVIRONMENTAL STUDIES

11


Analytic Hierarchy Process (AHP)
Pairwise Comparison Method
Incorporate Community Member Expertise and Insight
Rank Environmental Factors
DEPARTMENT OF GEOGRAPHY & ENVIRONMENTAL STUDIES

12



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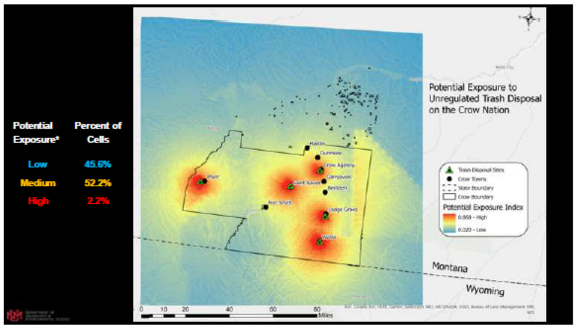

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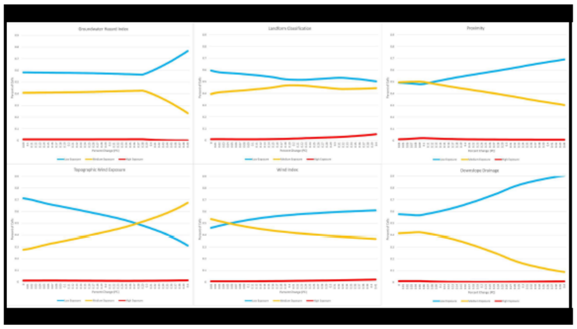

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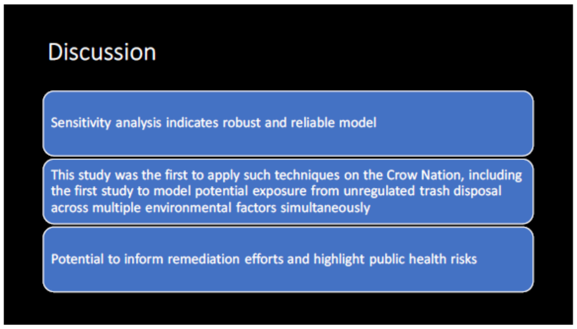

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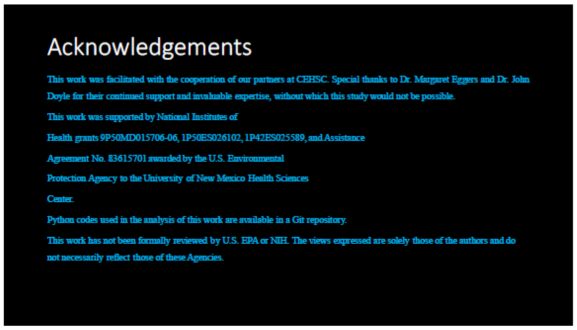

17

18

Teaching (Diné College GIS Workshop)

Lecture – GIS Basics I

What is GIS?

1

What is GIS?

Geographic Information System

2

3

4

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6

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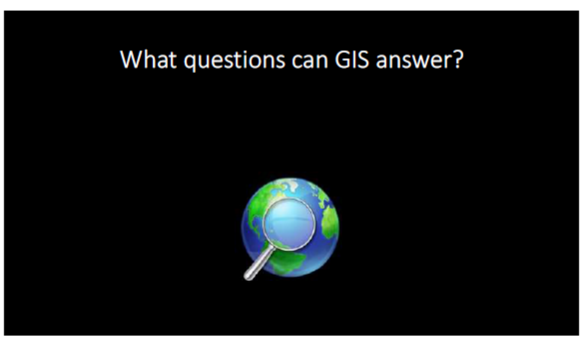
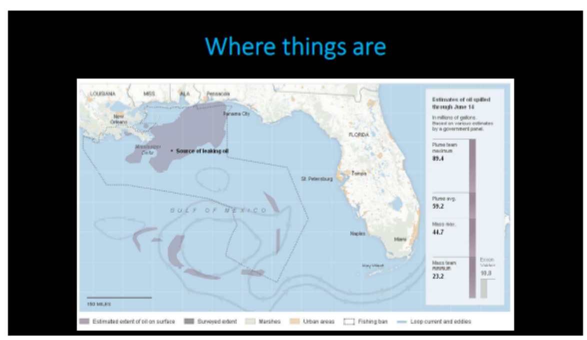
9


What do you think GIS is?
• Form 2 groups
• Describe what you think GIS is and list 3 ways it can be applied

10


What questions can GIS answer?

11

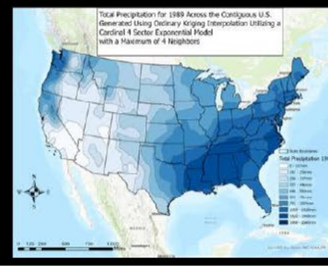

Where things are

12

Map how much

13

Predict how much

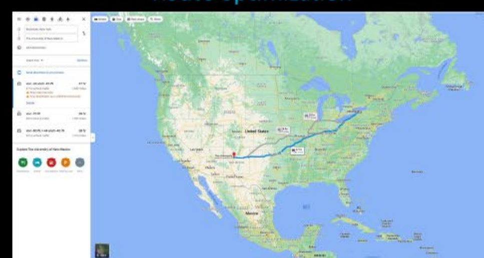


14

Map how things have changed

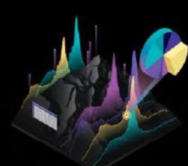
15

Route optimization



16

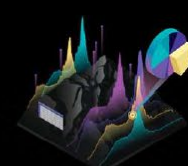
Geographic Information System (GIS)



17

Geographic Information System (GIS)

System of data management



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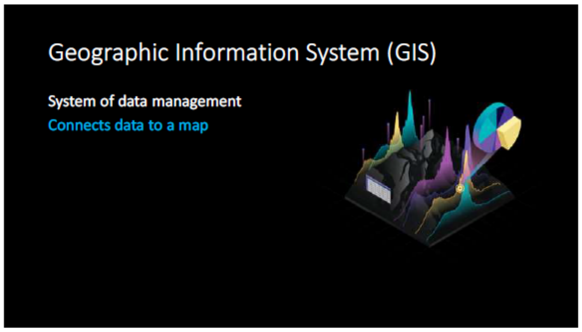

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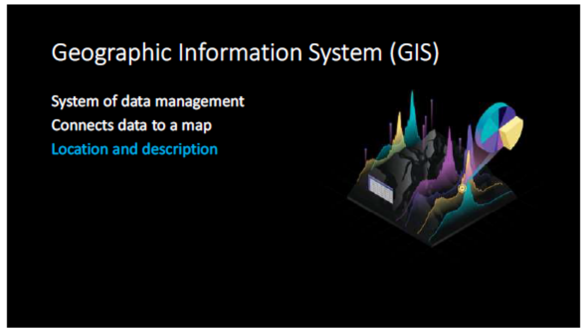

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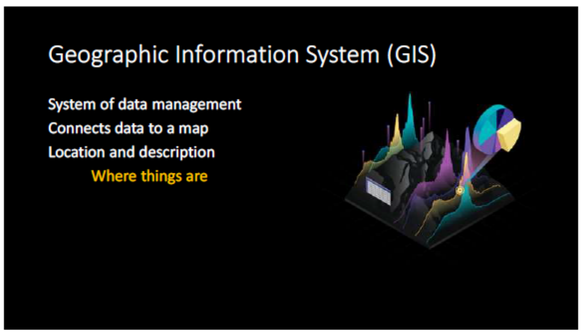

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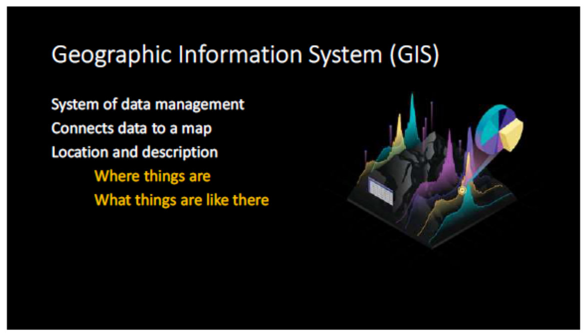

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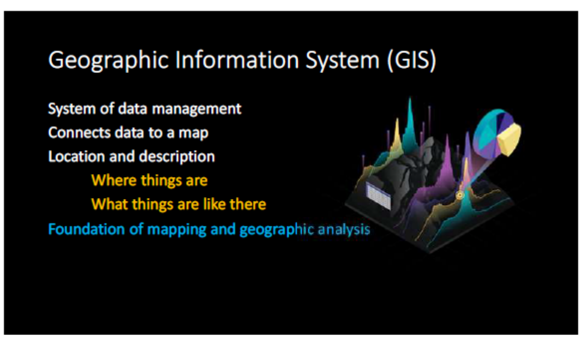

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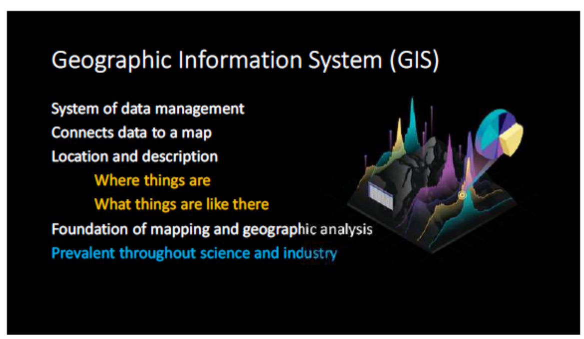

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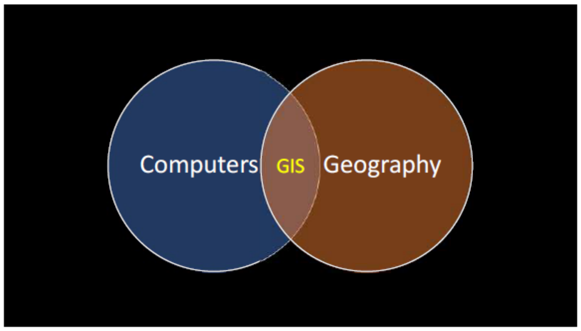

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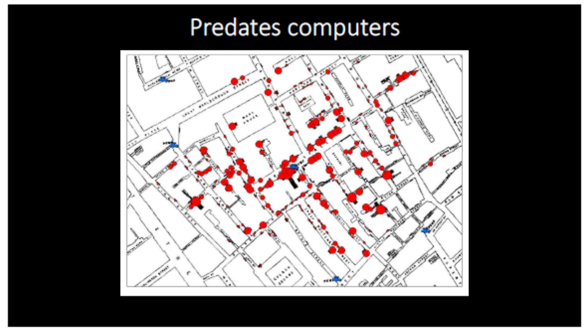

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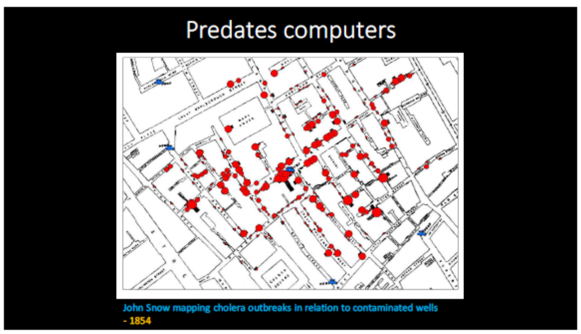

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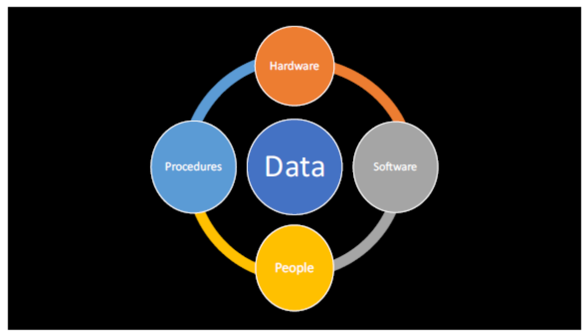

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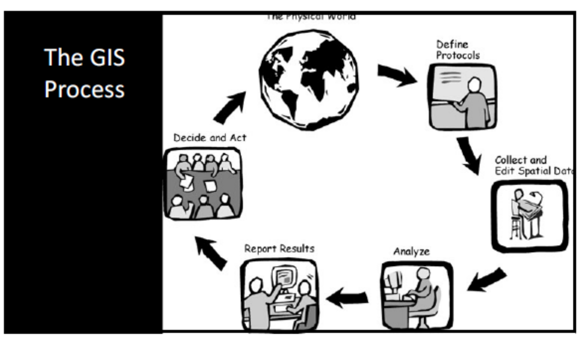

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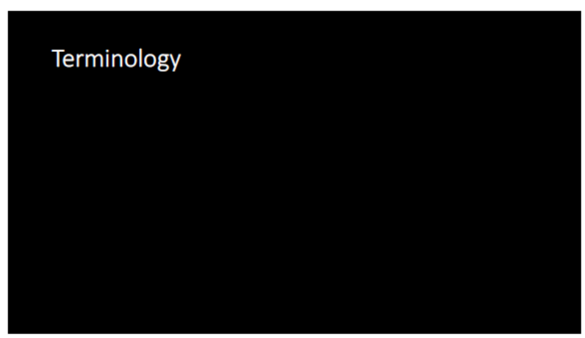


30

Terminology

Geographic Information System: GIS

31

Terminology

Geographic Information System: GIS
Geographic Information Systems: GISystems

32

Terminology

Geographic Information System: GIS
Geographic Information Systems: GISystems

Geographic Information Science: GIScience

33

Terminology

Geographic Information System: GIS
Geographic Information Systems: GISystems

Geographic Information Science: GIScience

34

Applications

35

Applications

Data integration

36

Applications

Data integration
Spatial analysis

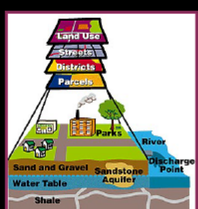
37

Applications

Data integration
Spatial analysis
Visualization

38

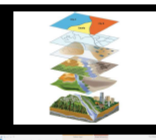
Data Integration

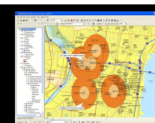


39

Spatial Analysis

Where is it?
What is it?
How is it distributed?
What has changed?
Time and Travel
What is near me?





40

Visualization

Data can be viewed in new and different ways
Reveals hidden relationships
Provides better communication

41

Who uses GIS?

Banking, Insurance, Logistics, Media, Marketing, Real Estate, Retail, Politics, Government, Homeland Security, Military, Emergency Management, Law Enforcement, Health Care, Transportation, Research, Libraries, Museums, Archeology, Economics, Education, Agriculture, Conservation, Restoration, Mining, Engineering, Energy Exploration, Electricity, Gas, Biology, Telecommunication, Water, Wastewater, Surveying

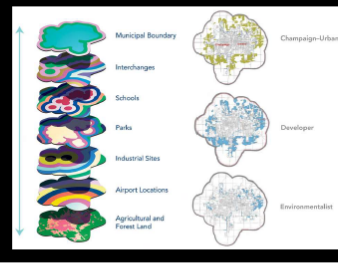
42

Where can GIS be applied?

- Urban and Regional Planning
- Environmental Management
- Disaster Management
- Search and Rescue
- Monitoring of Habitats
- Social Science
- …

43

Urban and Regional Planning



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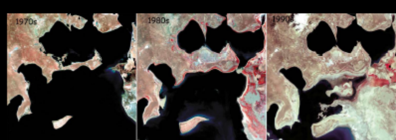
Environmental Management



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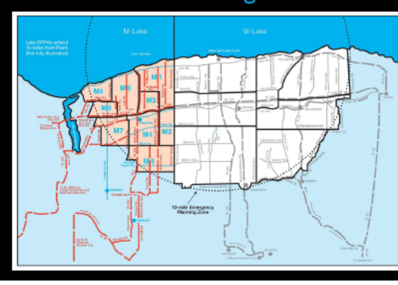
Disaster Management



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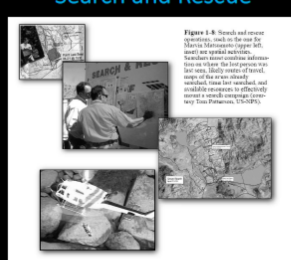
Search and Rescue



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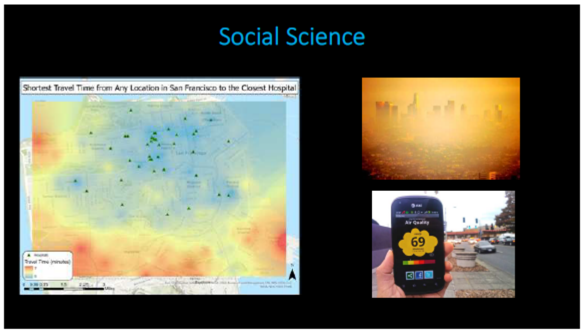
Monitoring of Habitats

48



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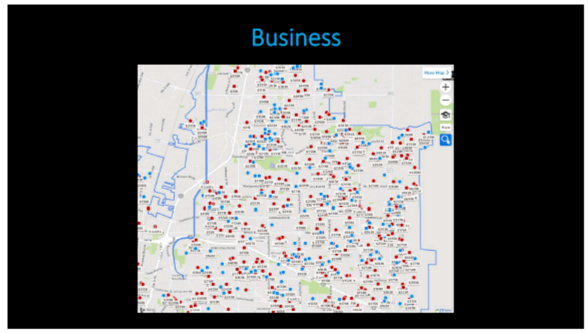

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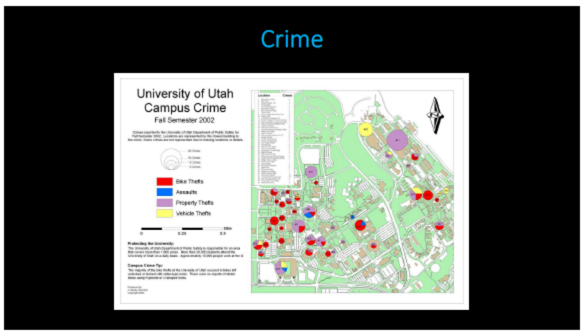

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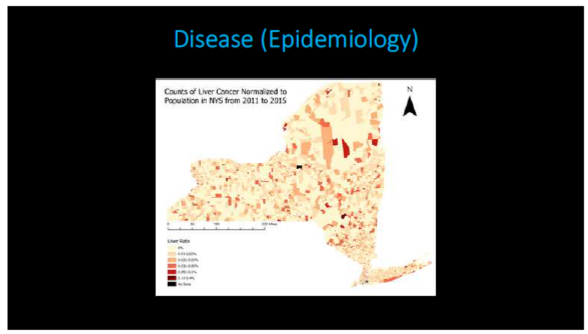

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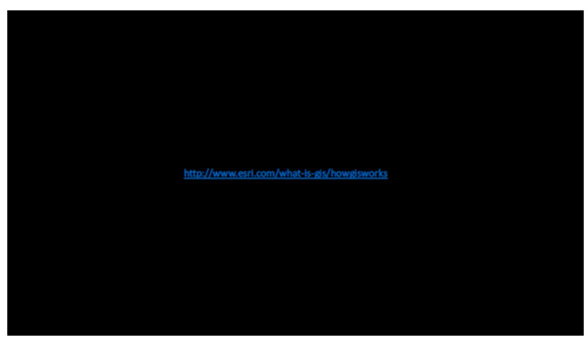

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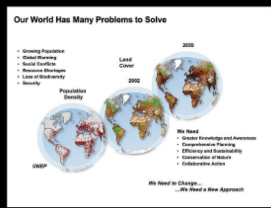

. . . . *the application of GIS is* ***limited only by the imagination*** *of those who use it. – Jack Dangermond*

55

GIS is built on knowledge from geography, cartography, computer science, and mathematics.

56

GIS is built on knowledge from geography, cartography, computer science, and mathematics.

GIScience is a new interdisciplinary field build out of the use and theory of GIS.

57

GIS is built on knowledge from geography, cartography, computer science, and mathematics.

GIScience is a new interdisciplinary field build out of the use and theory of GIS.

All GIS definitions recognize that spatial data are unique because they are linked to maps.

58

GIS uses map features to manage data; it can do query, analysis, modeling, and prediction.

59

GIS uses map features to manage data; it can do query, analysis, modeling, and prediction.

Almost all human activity and natural phenomena are spatially distributed, so they can therefore be studied using a GIS.

60

GIS is about everyday life.

61

GIS is about everyday life.

GIS is NOT only for Geographers!

62

GIS is a multibillion-dollar business

"The growth of GIS has been a marketing phenomenon of amazing breadth and depth and will remain so for many years to come. Clearly, GIS will integrate its way into our everyday life to such an extent that it will soon be impossible to imagine how we functioned before".

$

63

Median wages (2021)	$45.80 hourly, $95,270 annual
Employment (2020)	442,000 employees
Projected growth (2020-2030)	5% to 10%
Projected job openings (2020-2030)	37,500
Top industries (2021)	Government Professional, Scientific, and Technical Services

https://www.onetonline.org/link/summary/15-1299.02?redir=15-1199.05

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Discussion

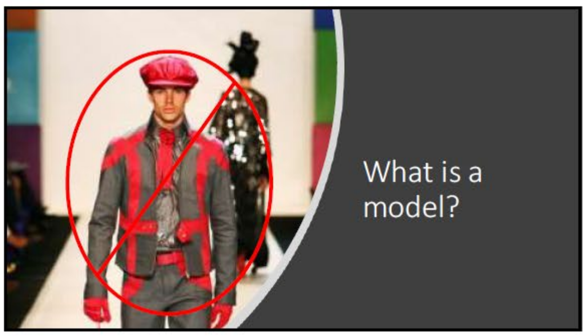
What ways to you see yourself using GIS in your field?

65

Lecture – Introduction to Geospatial Analysis and Modeling I

1

2



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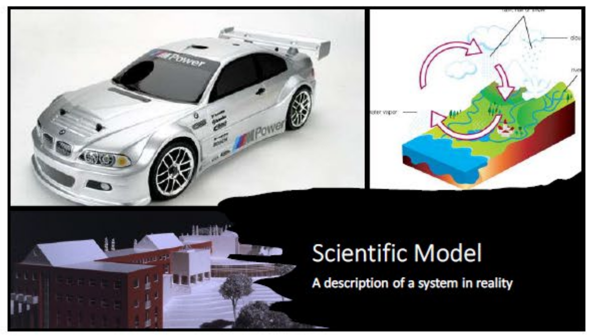

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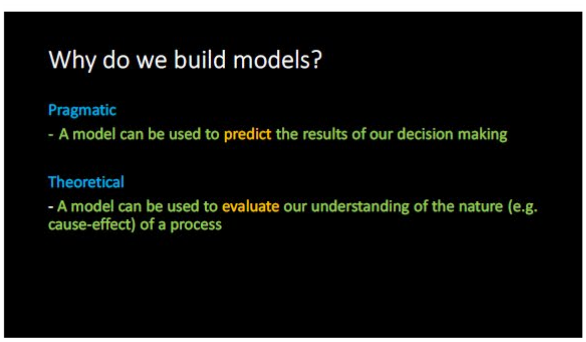

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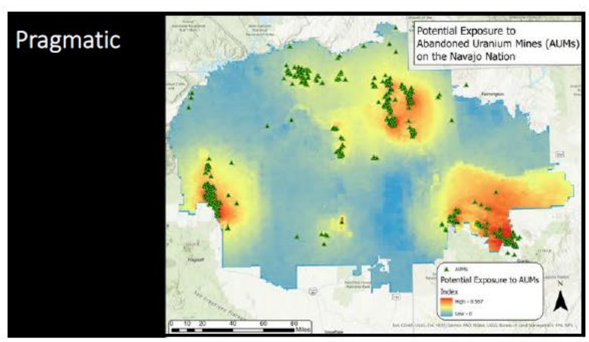

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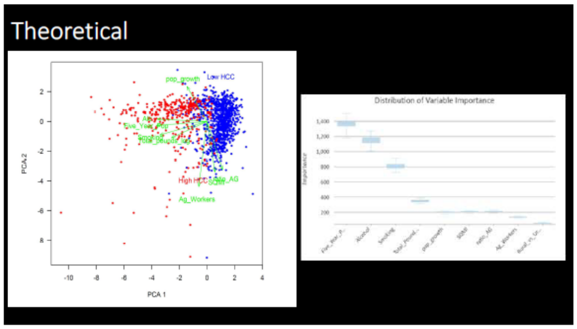
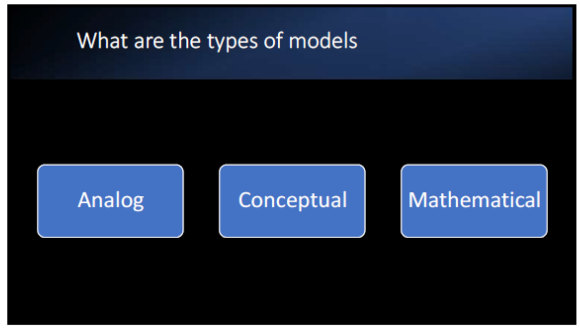
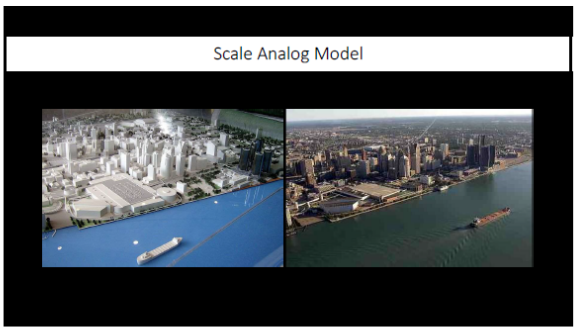

Theoretical
Distribution of Variable Importance

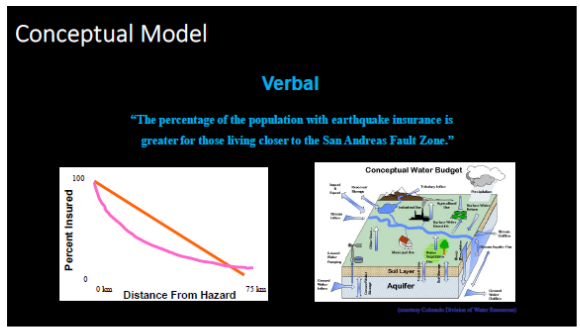
7


What are the types of models
Analog
Conceptual
Mathematical

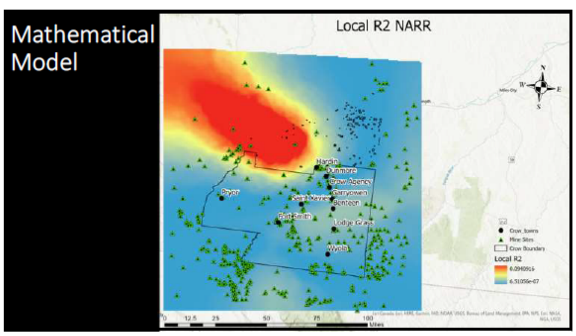
8


Scale Analog Model

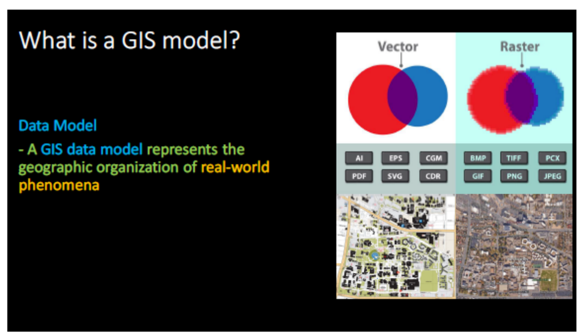
9


Conceptual Model
Verbal
"The percentage of the population with earthquake insurance is greater for those living closer to the San Andreas Fault Zone."
Percent Insured
Distance From Hazard
Conceptual Water Budget
Soil Layer
Aquifer

10


Mathematical Model
Local R2 NARR

11


What is a GIS model?
Data Model
- A GIS data model represents the geographic organization of real-world phenomena
Vector
Raster
AI
EPS
CGM
PDF
SVG
CDR
BMP
TIFF
PCX
GIF
PNG
JPEG

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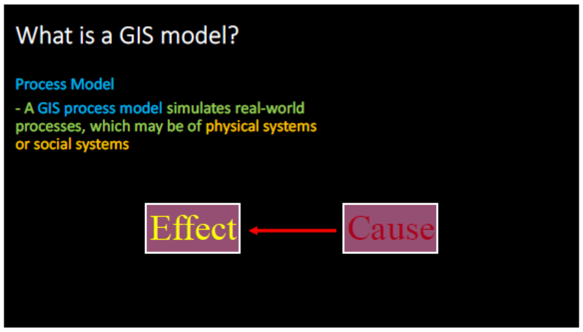

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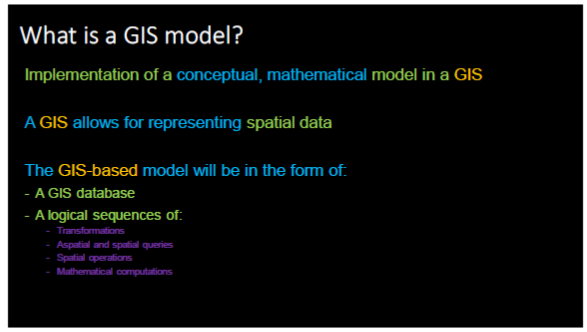

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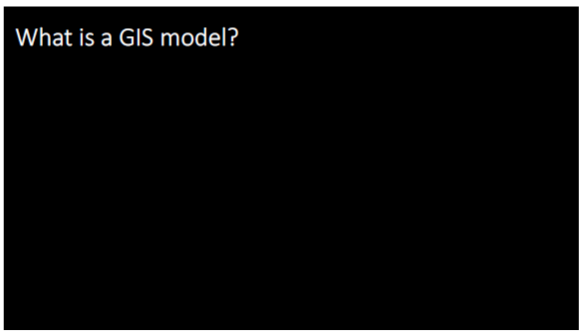

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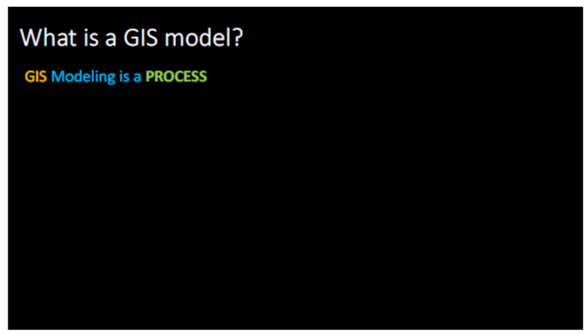

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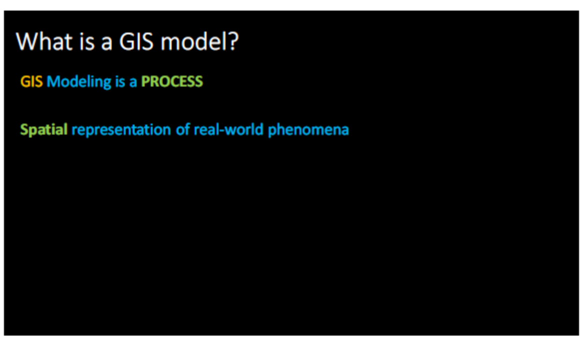

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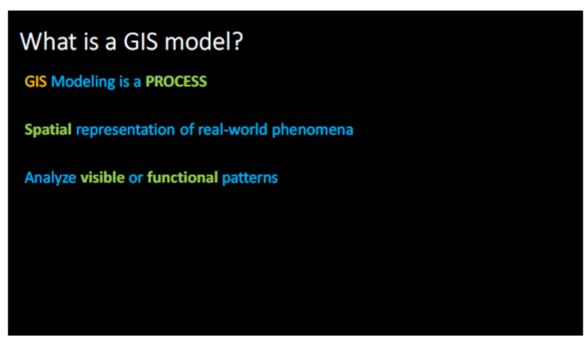

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What is a GIS model?

GIS Modeling is a PROCESS

Spatial representation of real-world phenomena

Analyze visible or functional patterns

Understand the spatial relationships between data

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What is a GIS model?

GIS Modeling is a PROCESS

Spatial representation of real-world phenomena

Analyze visible or functional patterns

Understand the spatial relationships between data

Follows a set of basic methodological modeling frameworks

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GIS modeling frameworks

Cartographic modeling
Simple spatial model
Spatio-temporal models
Network models
Cell-based models
Agent-based modeling

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Cartographic modeling

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Cartographic modeling

Combine general data sets, functions, and operations in a sequence to answer questions, typically producing an output map from various input maps

23

Cartographic modeling

Combine general data sets, functions, and operations in a sequence to answer questions, typically producing an output map from various input maps

Examples:

-distribution of suitable habitats, viable populations
-migration route/corridor studies
-water distribution systems, natural and constructed
-species invasions
-mill site selection
-harvest scheduling
-pollution response planning

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Cartographic modeling

Often temporally static *(features represented at a fixed period of time)*

Values don't change during the model. It may include a temporal component when it compares change through time *(comparing vegetation in 1990 to vegetation in 2000)*

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Examples

Suitable Home Sites

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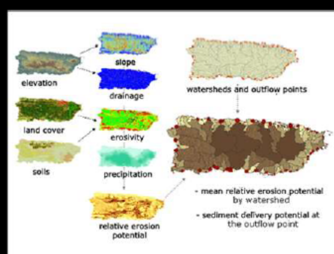

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Simple Spatial Models

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Simple Spatial Models

Apply a set of equations to spatially-resolved variables

e.g., $GPP = \epsilon \times NDVI \times PAR$

Develop equations from data at a set of observations at points or sub-areas, and then apply across broader geographic areas

Through sampling and a statistical fitting process

-West Nile virus infection distributions

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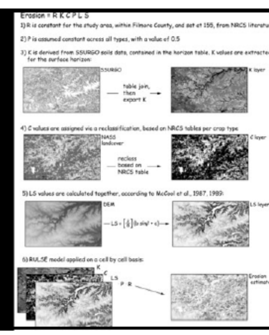
Example



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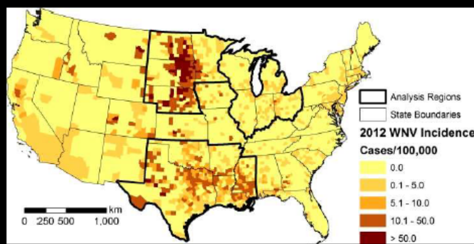
Example



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Spatio-temporal models

- Dynamic in both space and time (3D variation in space and through time)
- Time passes explicitly within the running of the model
- Changes in time-driven process cause changes in spatial variables
- Change in geometry & attribute
- More limited than other models in analyzing spatial themes
- Examples: dispersion of oil after a spill, air temperature, precipitation, soil moisture, and atmospheric pollutants, land use change

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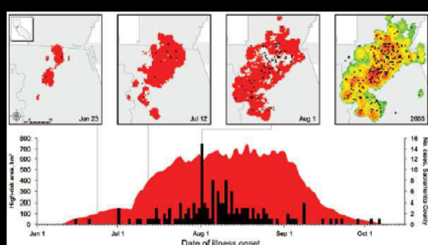
Example: Early Warning System for West Nile Virus Risk Areas



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Network models

May be temporally dynamic or static

Objectives:

- Find connected paths through a network(s)
- Estimate flows, costs of moving through, or accumulating resources in a network
- Manage/analyze parts of the network or assets associated with the network

Description of entities and their relations in the real world

- Transportation systems
- Utility networks
- Stream networks
- Geological networks

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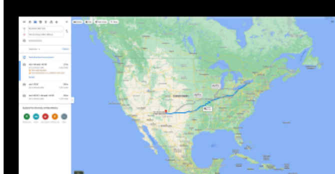

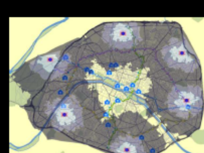

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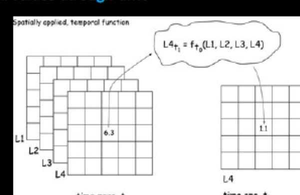
Cell-based models

Invoke a set of functions and logic, driven by cell values, to update these or other cell values through time



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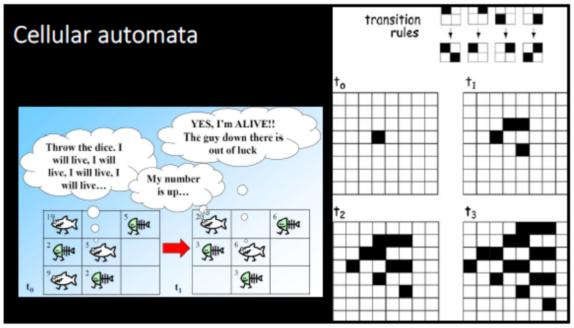

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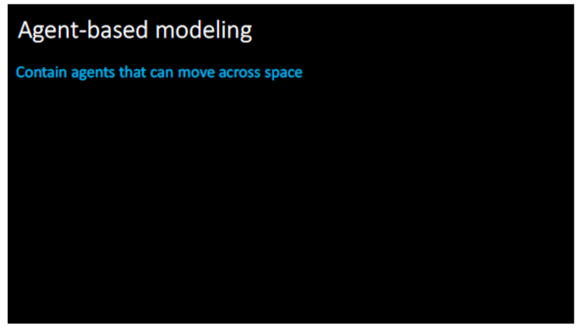

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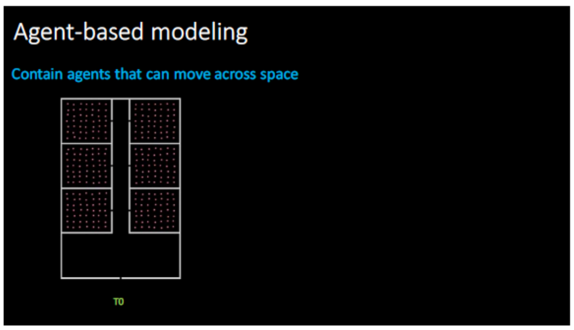

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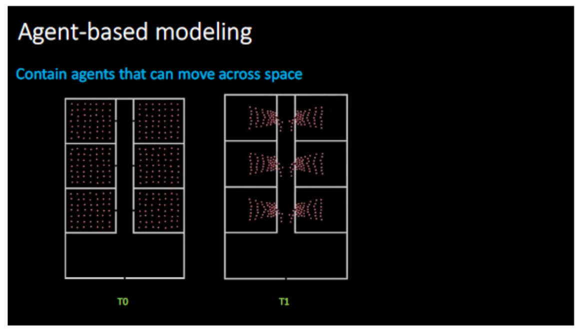

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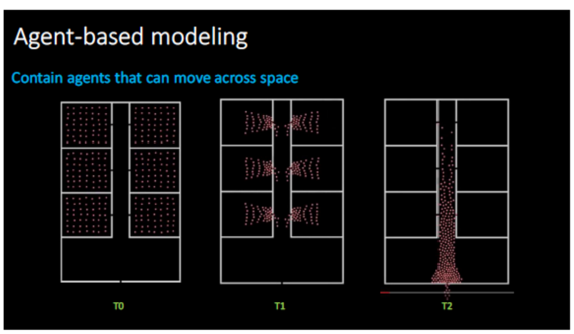

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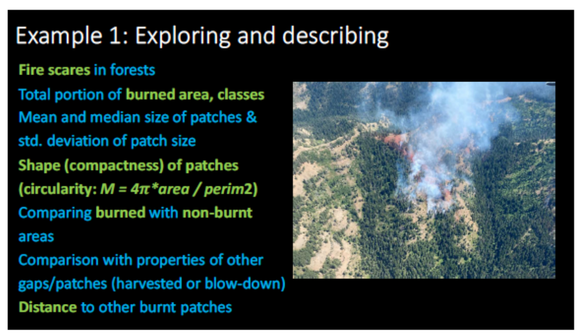

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Example 2: Explaining the occurrence

- Trying to **explain** the occurrence of forest fires by **analyzing** and **exploring** the available **data**
- **Formulating Hypotheses** (fuel, climatic conditions, land use, traffic) and **data** needed…
- **Sampling** (autocorrelation)
- **Significant** variables for **regression** analysis?
- **Evaluation** of 'predictions'

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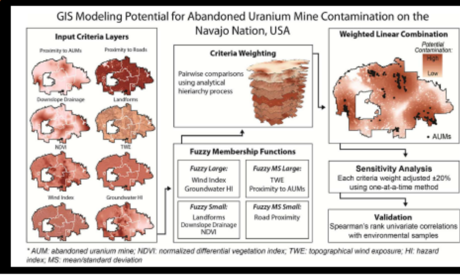
Example 3: Predicting potential exposure to uranium on the Navajo Nation



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Prior to carrying out the modeling

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What is the model trying to tell us (explaining, predicting relationships or consequences / evaluating situations for resource uses,…)?

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Plan out methods of model design.

48

Prior to carrying out the modeling

What is the model trying to tell us (explaining, predicting relationships or consequences / evaluating situations for resource uses,...)?

What type of data do we need?

Plan out methods of model design.

Decide on the right tools, use these tools to carefully and appropriately derive a **meaningful** model.

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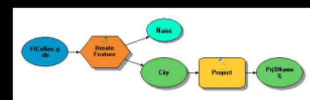
Model Builder – A Visual programming language

To see a visual representation of analysis and geoprocessing operations
To automate and manage geoprocessing workflows
To run a complex succession of processes as one tool
To plug in additional tools and parameters as needed
To be able to share geoprocessing workflows with other users by sending them the model you've created in ModelBuilder



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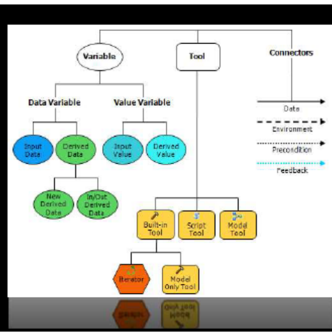
Model Elements

Three types of elements
- Variables
- Tools
- Connectors



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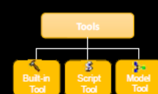
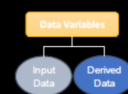
Adding tools and data to a model





Tools
- Drag and drop from Catalog
- Drag and drop from Search
- Drag and drop from Toolbox
- Use Add button in ModelBuilder
- Use Insert menu in ModelBuilder

Data
- Drag and drop from TOC
- Drag and drop from Catalog
- Drag and drop from Search
- Fill in dialog
- Use Add button in ModelBuilder
- Use Insert menu in ModelBuilder

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Derived data is created by processes

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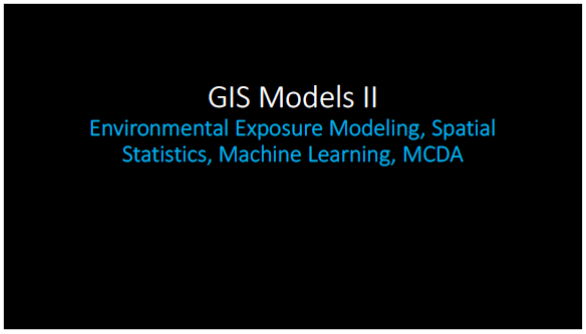
Lecture – Introduction to Geospatial Analysis and Modeling II



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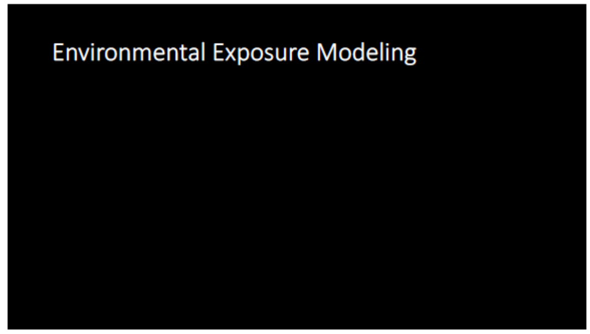

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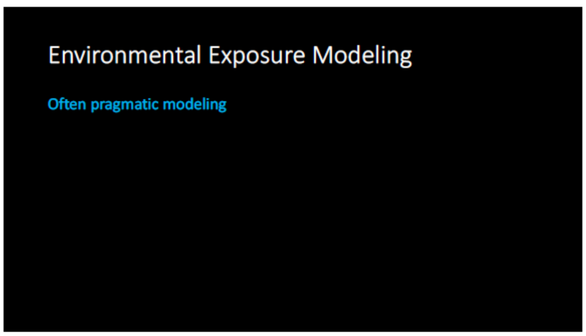

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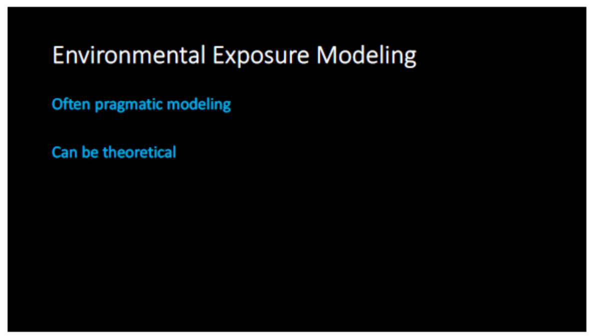

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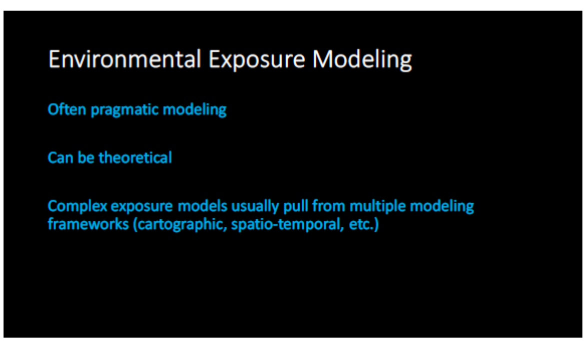

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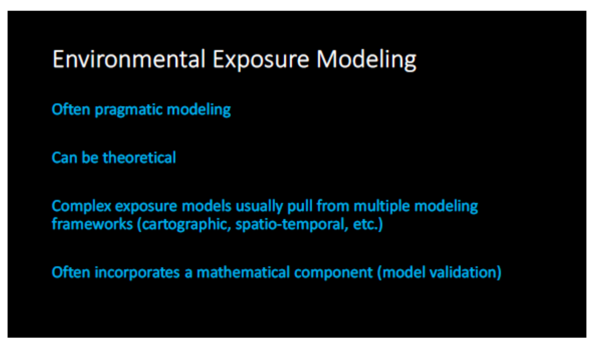

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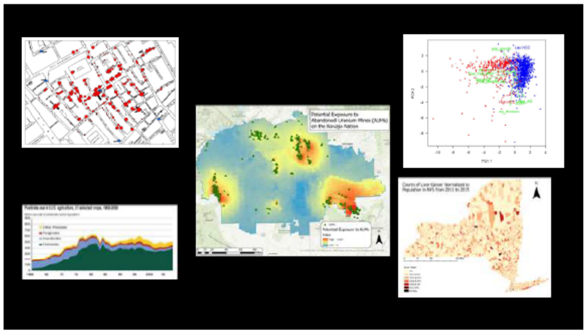

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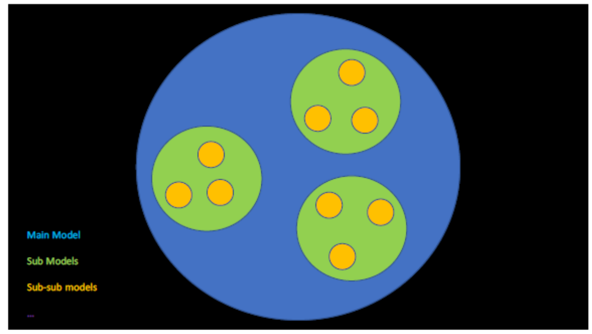
Main Model
Sub Models
Sub-sub models
...

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Potential Exposure

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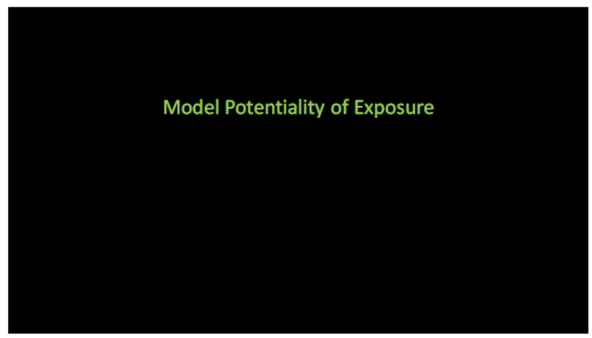
Model Potentiality of Exposure

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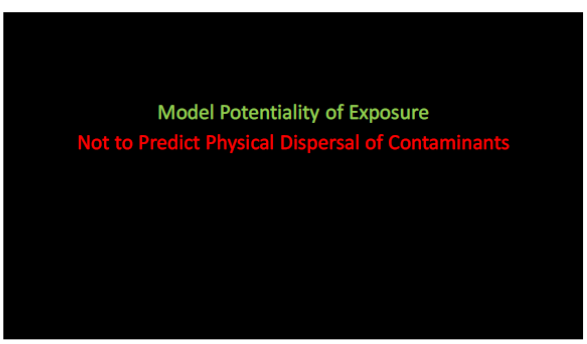
Model Potentiality of Exposure
Not to Predict Physical Dispersal of Contaminants

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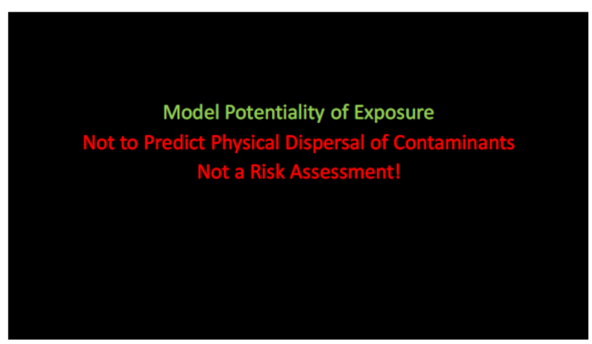
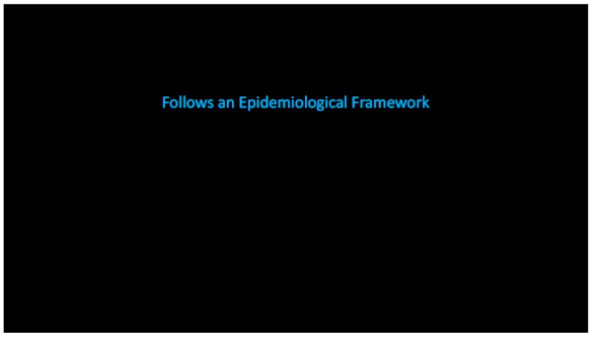

Model Potentiality of Exposure
Not to Predict Physical Dispersal of Contaminants
Not a Risk Assessment!

12



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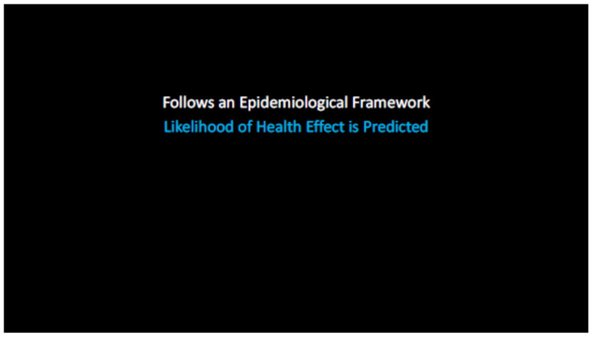

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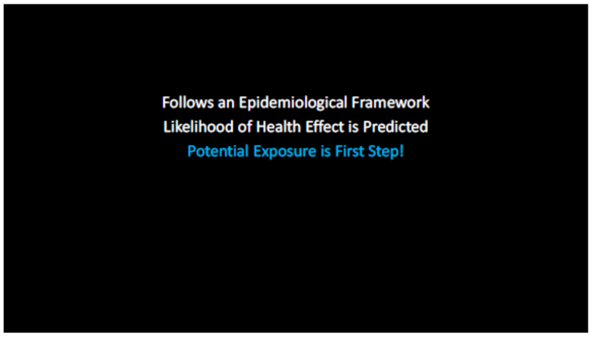

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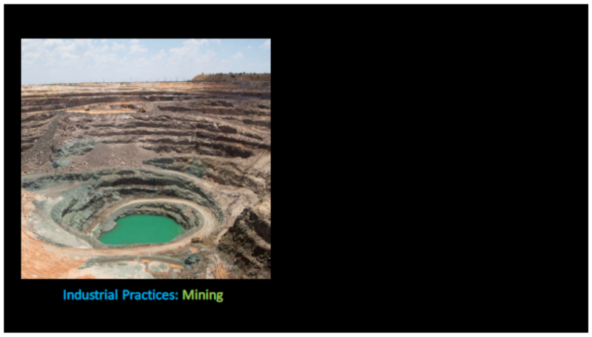

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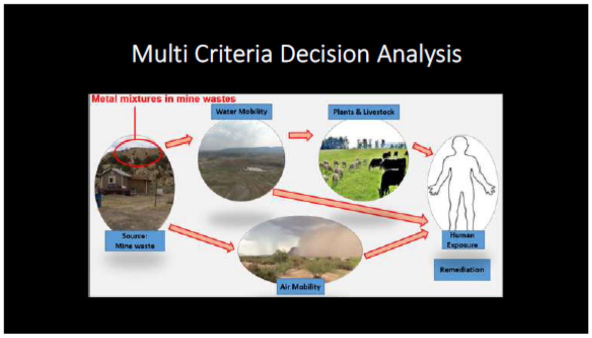

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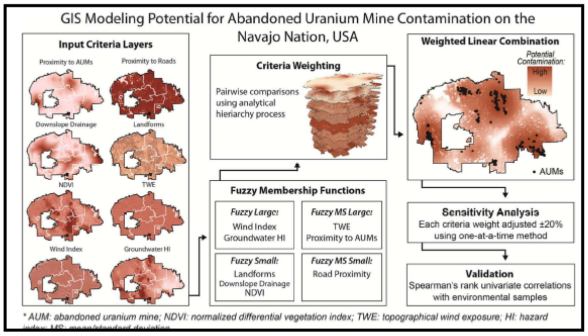

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Multi Criteria Decision Analysis (MCDA)

Provides a framework for structuring decision problems

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Commonly utilized for risk mapping or vulnerability assessments

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Transforms and combines geospatial data
Provides avenue for community engagement

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Multi Criteria Decision Analysis (MCDA)

Provides a framework for structuring decision problems
Commonly utilized for risk mapping or vulnerability assessments
Transforms and combines geospatial data
Provides avenue for community engagement
Modeling of Dynamic Environmental Processes Simultaneously

Steps	Description
1	Define the context
2	Select Criteria (Factors)
3	Discern relative importance of criteria
4	Calculate exposure value

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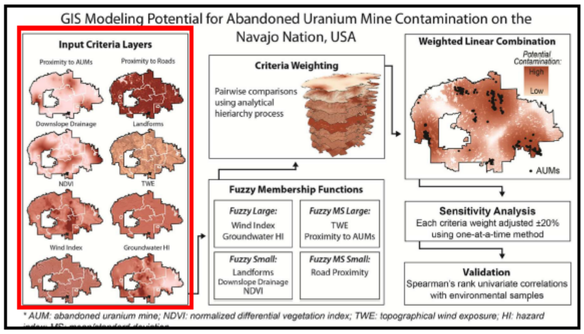

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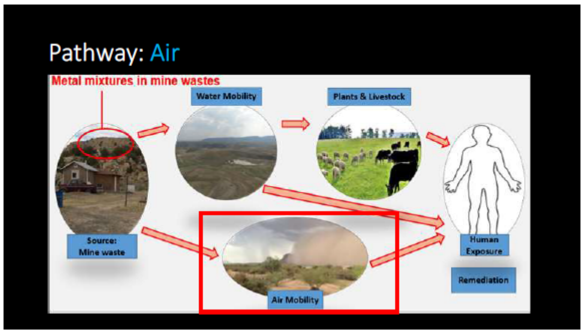

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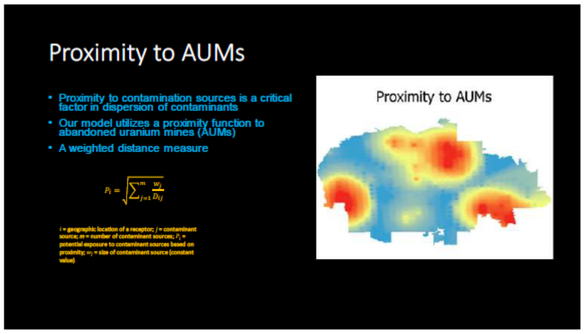

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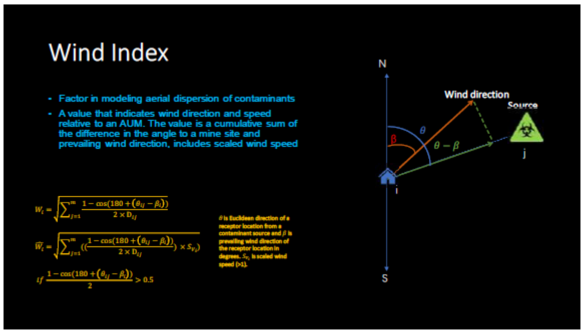

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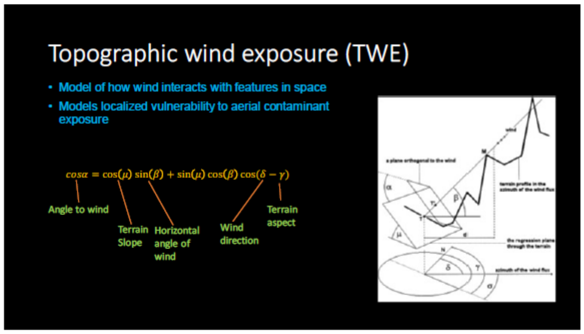

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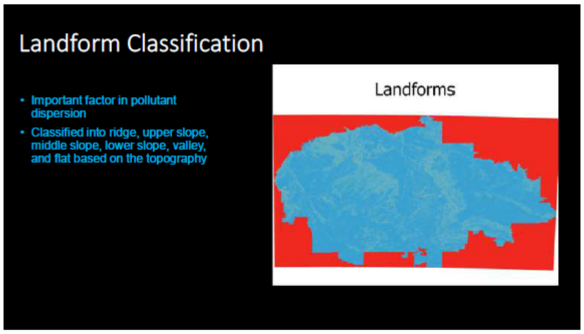

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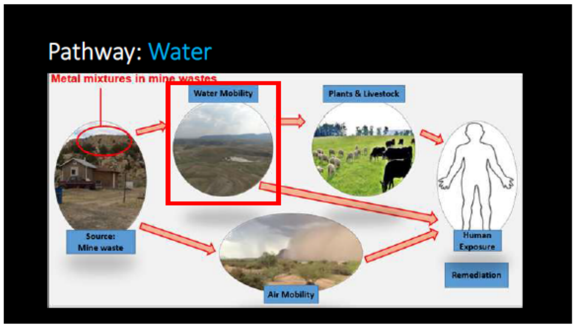

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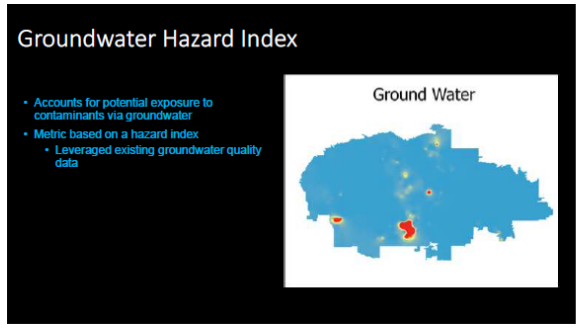

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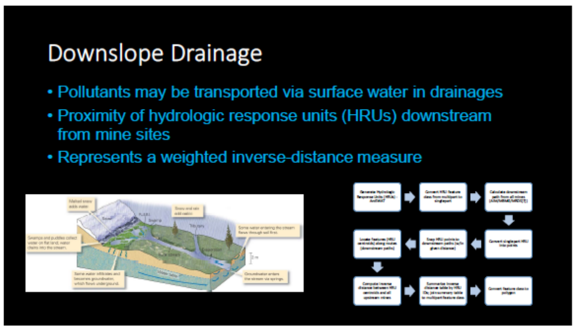

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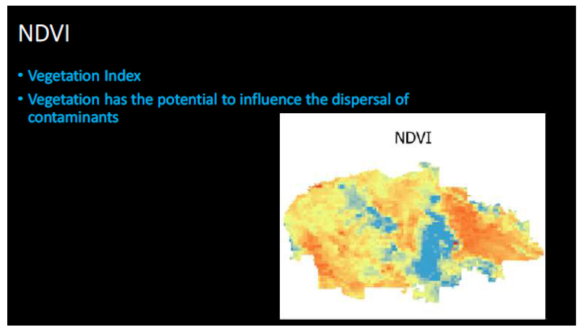

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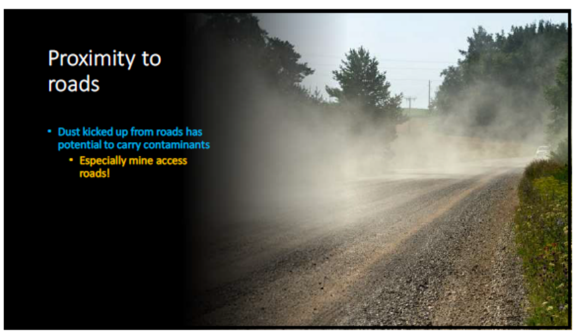

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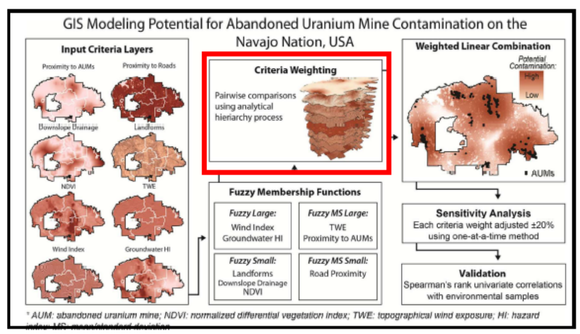

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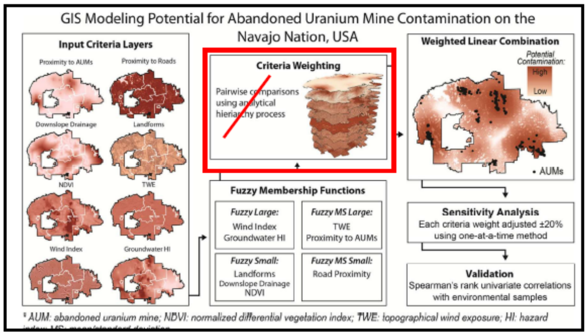

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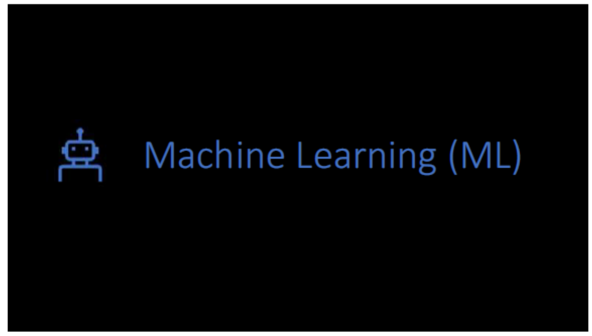

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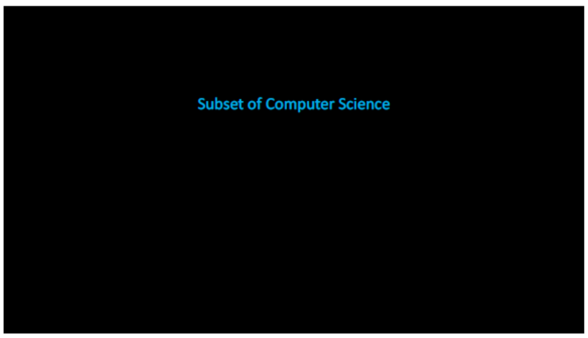

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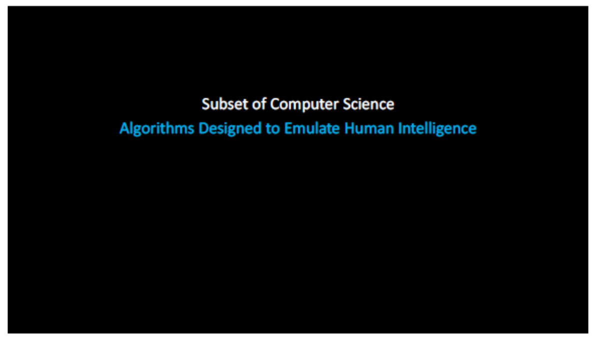

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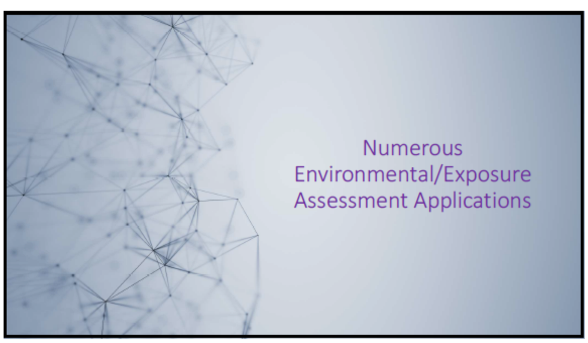

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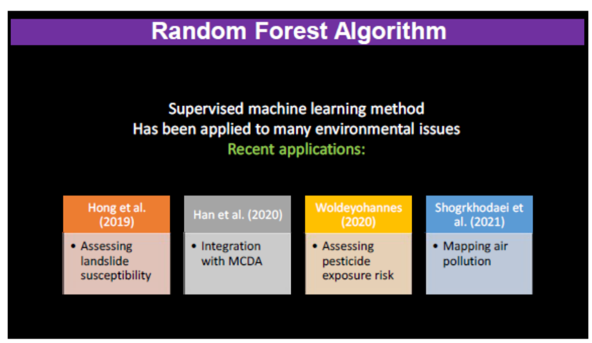

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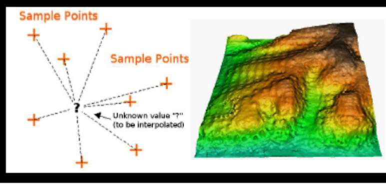
Interpolation

- **Spatial Interpolation** is the process of estimating the value of unknown locations across space from a set of observations
- An **observation** is a location on the surface at which measurements of an attribute have been made



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Algorithms

- **Nearest Neighbor Interpolation (i.e. Thiessen Polygons)**
- **Average Neighbor Interpolation**
- **Inverse Distance Weighted Interpolation**
- **Polynomial**
  - **Global**
  - **Local**
- **Radial Basis Function**
- **…**
  - Method
  - Advantages
  - Disadvantages

44

Algorithms

- **Nearest Neighbor Interpolation (i.e. Thiessen Polygons)**
- **Average Neighbor Interpolation**
- **Inverse Distance Weighted Interpolation**
- **Polynomial**
  - **Global**
  - **Local**
- **Radial Basis Function**
- **…**
  - Method
  - Advantages
  - Disadvantages

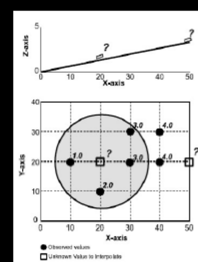
45

Inverse Distance Weighted Interpolation (IDW)

- **Method:** value at each grid cell location is a distance weighted average of the values at the nearby observations

$$z' = \frac{\sum_i^k z_i \times \frac{1}{d_i^p}}{\sum_i^k \frac{1}{d_i^p}}$$

- where
  - z' = interpolated value
  - z_i = observed value
  - d = Euclidean distance between the observations and location of unknown value
  - p = exponent modeling friction of distance
  - k = number of observations in neighborhood



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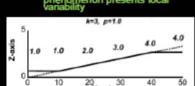
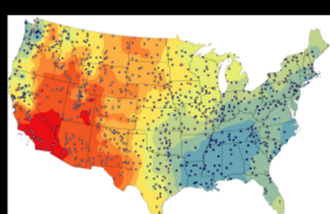
Inverse Distance Weighted Interpolation (IDW)

- **Advantages**
  - Results in a continuous and smooth surface
  - Is an exact interpolator (i.e. derived surface passed through observed values)
- **Disadvantages**
  - Requires subjective selection of parameters (*k* and *p*)
  - Does not extrapolate beyond the minimum and maximum of observed values
  - Does not consider direction of observations
- **Application**
  - most appropriate when the phenomenon presents local variability





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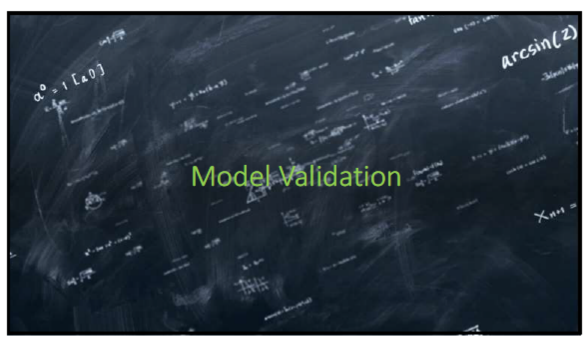

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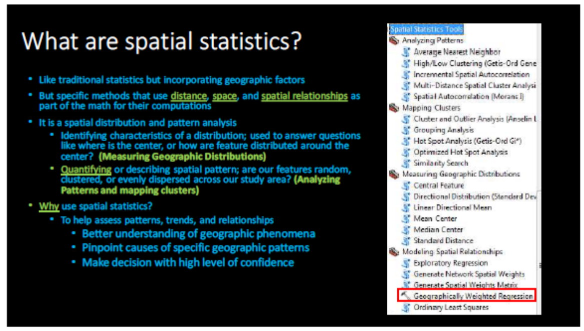

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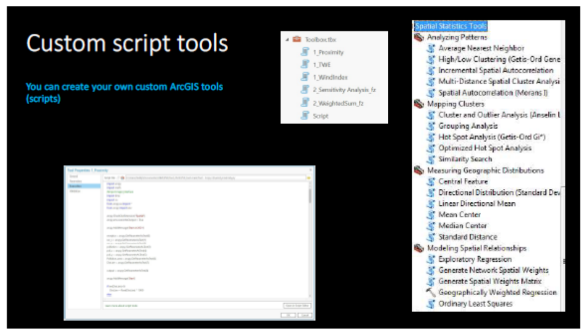

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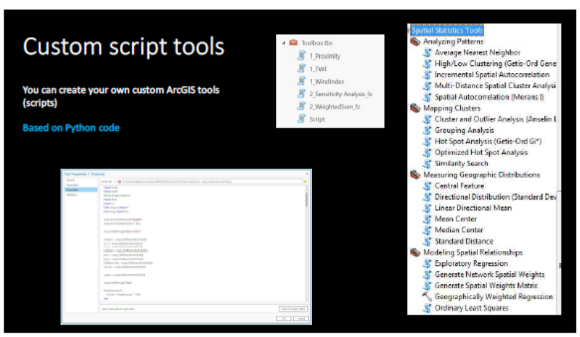

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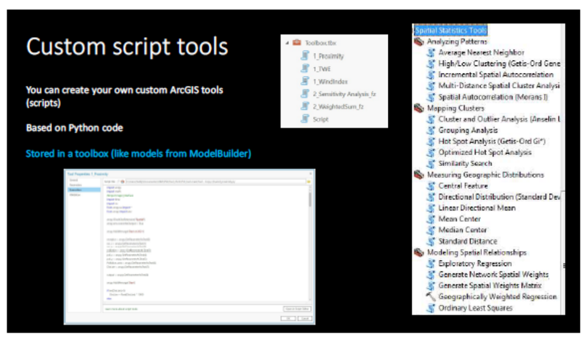

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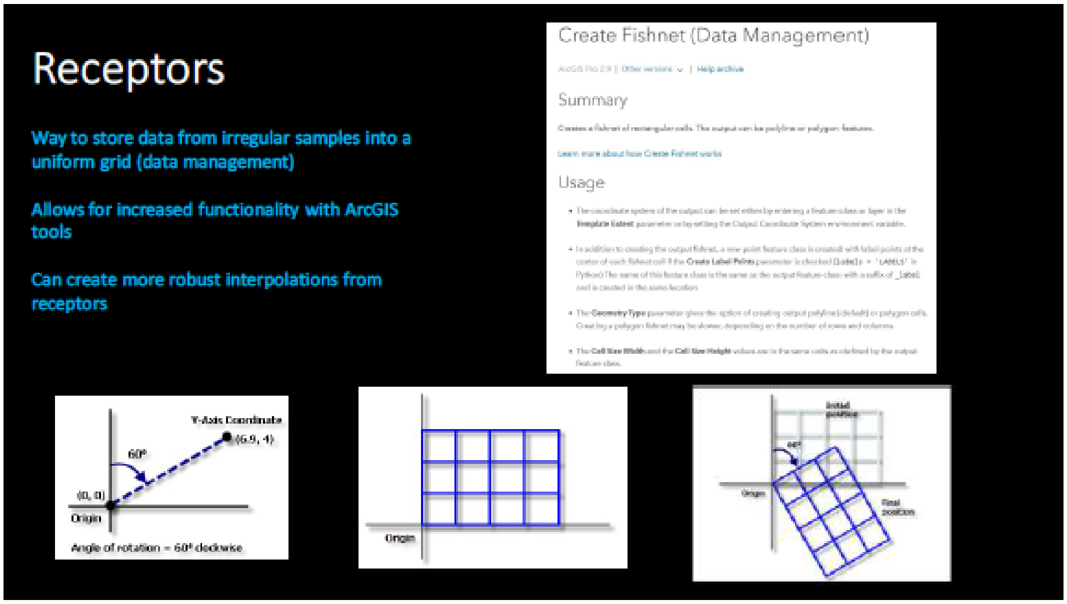


Receptors
Way to store data from irregular samples into a uniform grid (data management)
Allows for increased functionality with ArcGIS tools
Can create more robust interpolations from receptors
Create Fishnet (Data Management)
Help archive
Summary
Usage
Y-Axis Coordinate
(6.9, 4)
60°
(0, 0)
Origin
Angle of rotation = 60° clockwise
Origin
Origin

55

Lab – Introduction to Software and Data Fundamentals

Instructions: In this lab we will become familiar with ArcGIS Pro, the industry leading GIS software.

CONVENTIONS USED IN THESE LABORATORY ASSIGNMENTS

When the instructions refer to two or more keys on the keyboard, linked by a "+", it means to press them simultaneously. When ">" or "→" is used, it means to press the keys (or perform some other actions) sequentially. Thus,

- Ctrl + V means to press the Control and the V buttons at the same time (to paste the last item on your clipboard into a document), whereas
- Insert > New Layout means to click on the Insert tab and then New Layout

You will frequently use keyboard shortcuts such as:

- Ctrl + C to copy
- Ctrl + V to paste
- Ctrl + Z to undo the last action

DO SAVE AND BACK UP YOUR FILES. You cannot believe how frustrating it is to lose all your work and have to start again if ArcGIS crashes. This can happen when you are performing complex calculations. Thus develop the habit from the onset of frequently saving your work after major steps or processes.

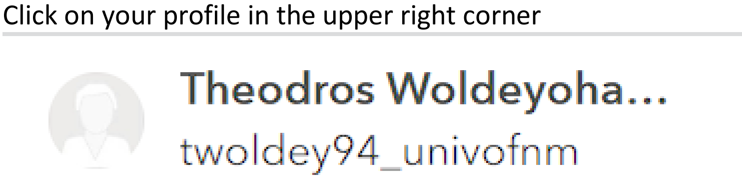
BE SURE TO SAVE YOUR WORK OFTEN! ARCGIS IS KNOWN TO BE "BUGGY" AND CAN CRASH.

Task #1

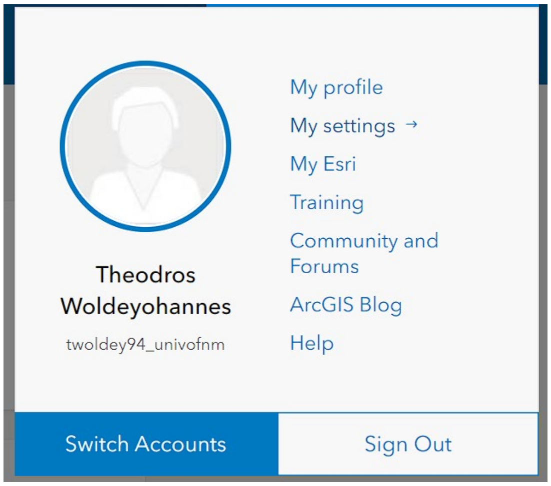
(Download and install ArcGIS Pro on your computer)

Instructions for these steps can also be found at: https://pro.arcgis.com/en/pro-app/2.8/get-started/download-arcgis-pro.htm (Download ArcGIS Pro from ArcGIS Online)

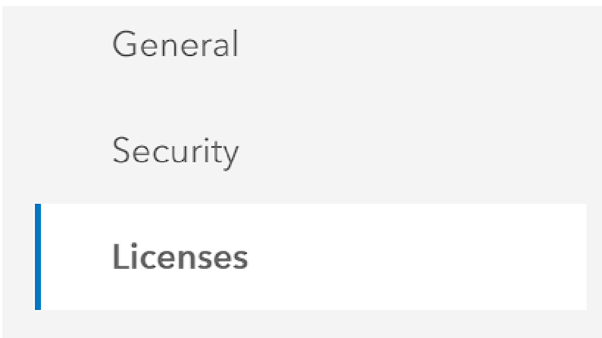
1. Go to the ArcGIS Online website: https://www.arcgis.com/index.html
2. Click on **Sign In**
3. Where it asks for Organization URL, enter **Univofnm**
4. Enter your ArcGIS Login info
5. Click on your profile in the upper right corner



6. Click on **my settings**



7. Click on **Licenses** on the licenses tab



8. Look for ArcGIS Pro from the list of available software and click on **Download ArcGIS Pro**

9. Make sure the language is set to English
10. Click download. A .exe file will be downloaded to your computer. Run this file to begin the installation process.
11. Follow the onscreen prompts, accept all defaults.

Task #2

(Set up folders, Run ArcGIS Pro, Explore software, Bring in data, Manipulate data, Make a simple map)

Set up folders:

Good file management is critical to GIS, in which you will have to deal with several different files, such as projects, data, etc. We will create a folder where we can store everything. Keeping things organized will make your life much easier as your projects get more complicated!

In **Documents**, create a new folder called **GIS**. Within GIS, create a new folder called **Lab1**. We will store our GIS project and all data for the lab in this folder.

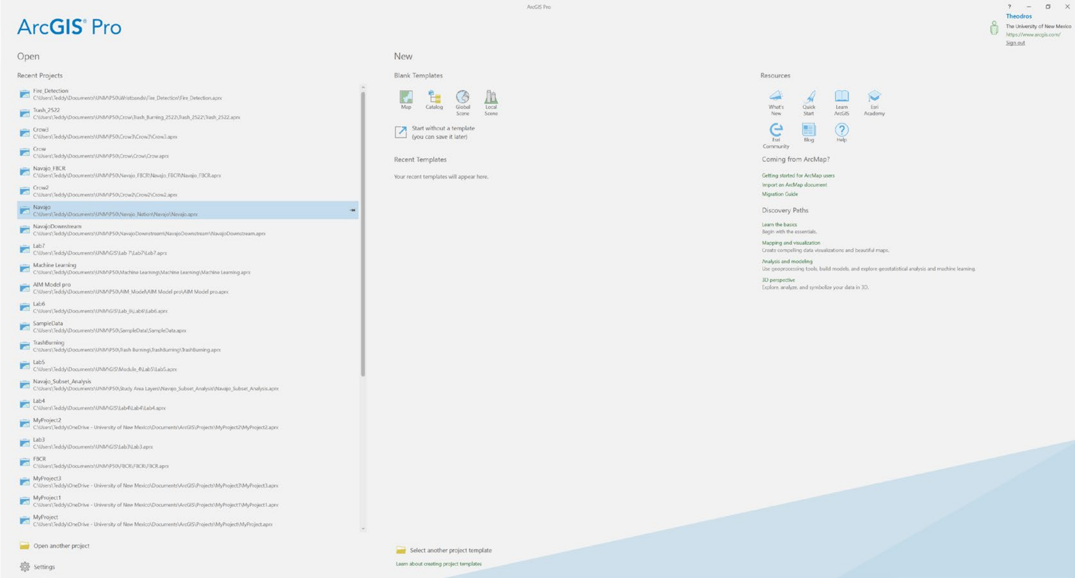
Copy the **NN_bound.zip** file into your **Lab1** folder. Extract the file. Contained inside the folder is a shapefile representing the boundary of the Navajo Nation.

Run ArcGIS Pro:

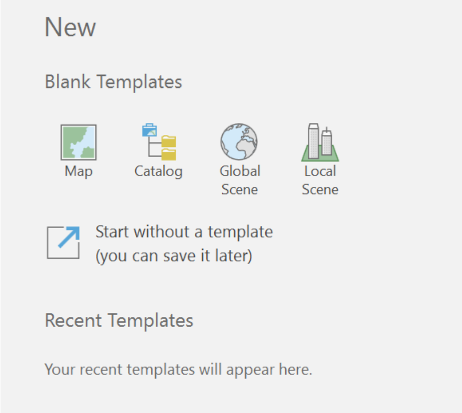
1. In the Windows search bar, search for **ArcGIS Pro**
2. Click on the ArcGIS Pro app to start the software.
3. Choose the option to sign in with Organization URL. Enter **Univofnm**.
4. When prompted, sign in with your ArcGIS Login info

Explore software:

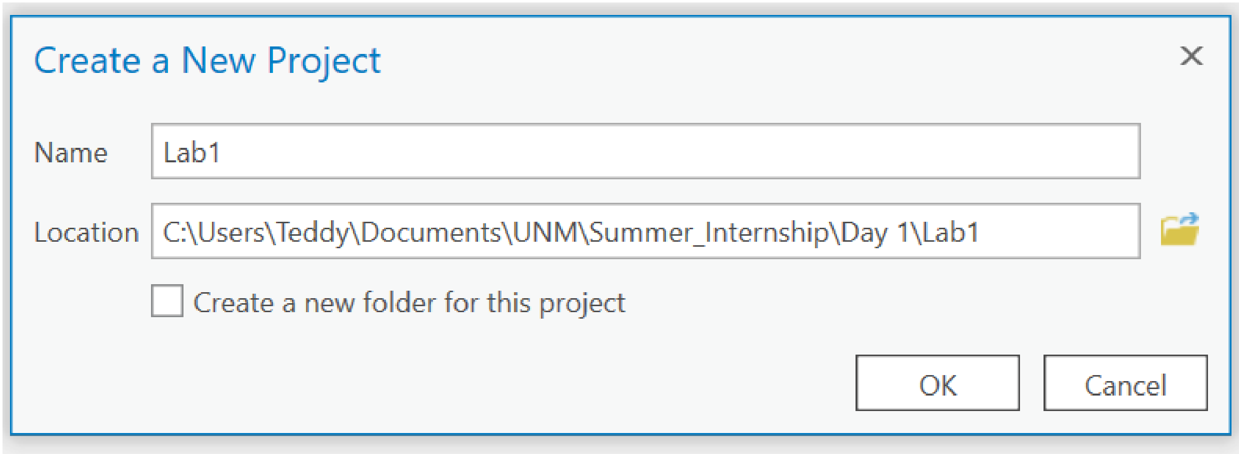
5. The startup page of the software gives options to open recent projects, create a new project, and offers links to helpful resources.



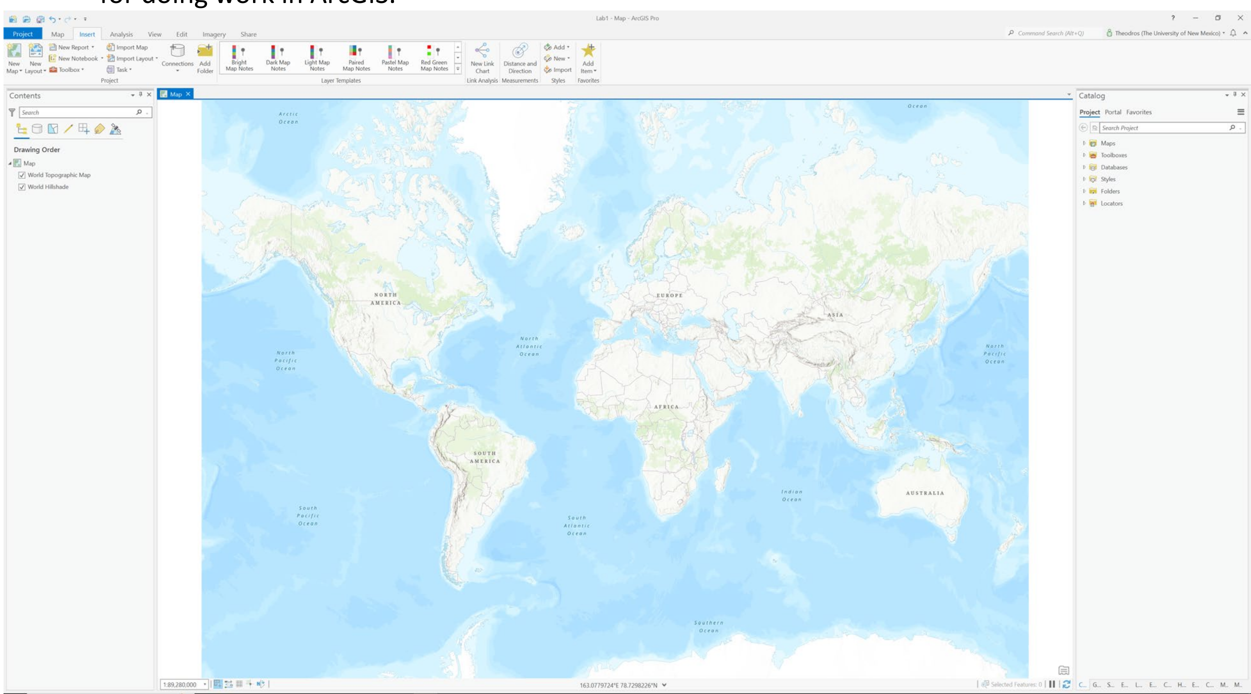
6. Once you make a project, it will show up under **Recent Projects**. We can create a new map/project based off different templates. **Resources** offers links to guides and tutorials. Explore these resources on your own time to learn more about the software and its functionality.
7. Click on **Map** under **Blank Templates.**



8. The **Create a New Project** window will appear. For **Name** enter **Lab1**. For **Location**, change the file path to your Lab1 folder. **Uncheck Create a new folder for this project**.

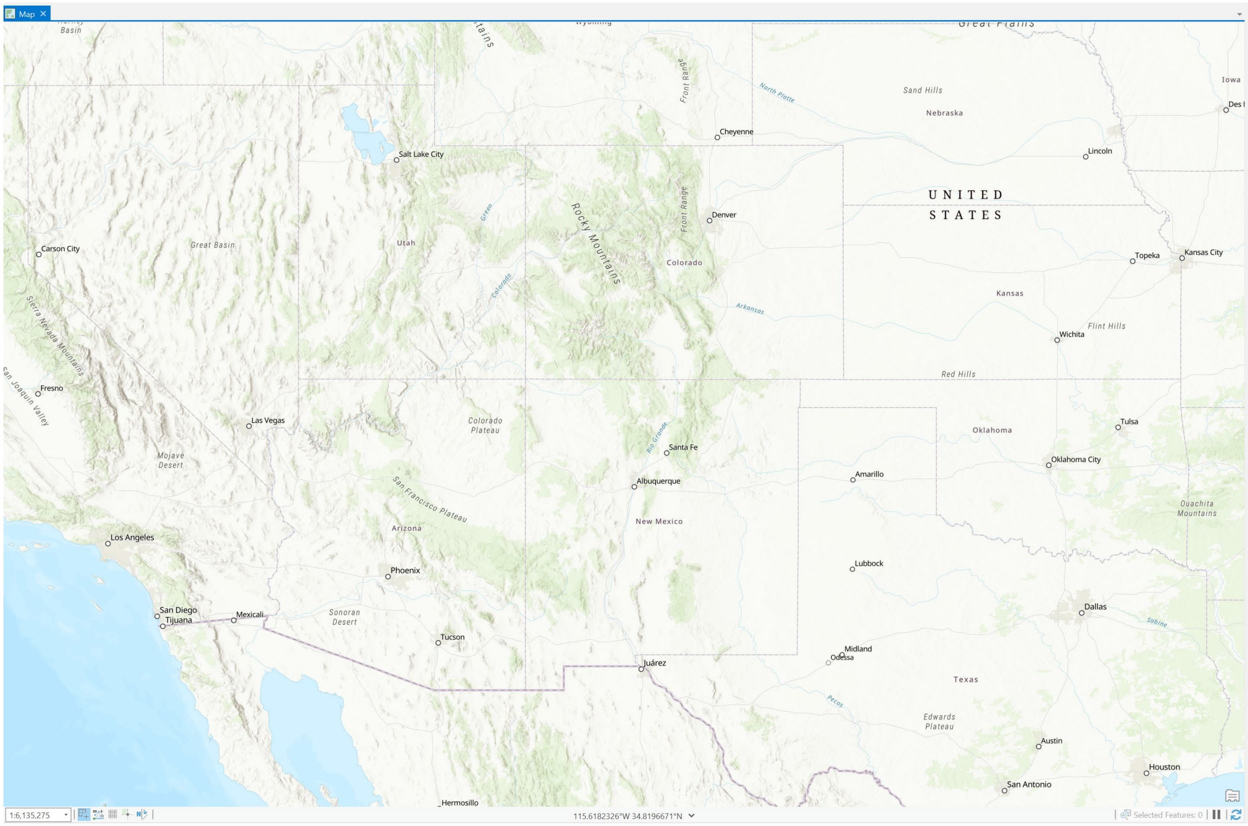


9. Click **OK**. The main Project window of the software will now open, this is the default interface for doing work in ArcGIS.



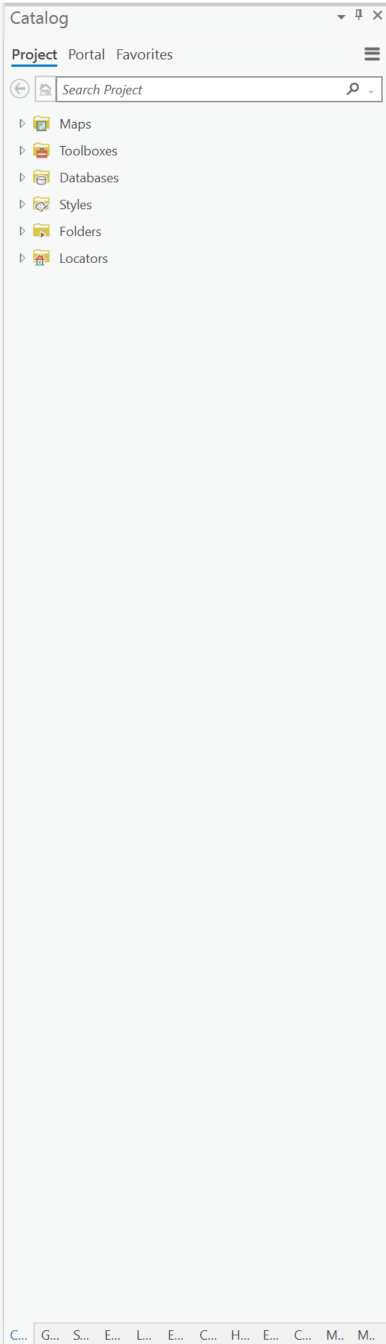
10. In the center of the window is the **Map Frame**. This is where your data will be visualized. By default, a view of the world is loaded in, fully zoomed out. This view is called a **Basemap** and is the first **Layer** of your project. GIS works by stacking up data in **Layers** on-top of each other (like Photoshop). All your data will be loaded on-top of this **Basemap**. There are many different **Basemap** templates suitable for different purposes (it can also be turned off entirely). By default, the **Topographic Basemap** is loaded.
11. In the **Map Frame**, click and drag to navigate, and scroll to zoom in/out.

12. Task: Zoom in to the Four Corners area (New Mexico, Arizona, Utah, Colorado).

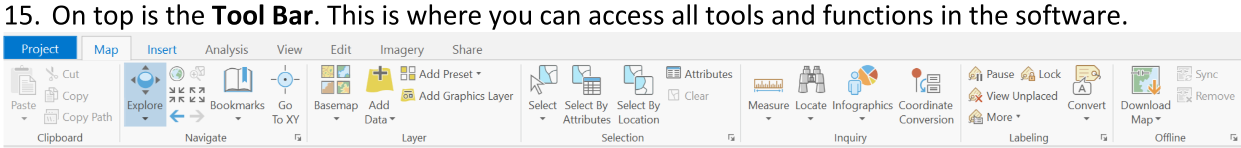


13. On the left of the window is the **Contents** pane. This is where your different Layers and their drawing order will be listed.

14. On the right side of the window is the **Catalog** pane. This is a built-in file explorer that will let you quickly access data stored on your computer and import it into the project.

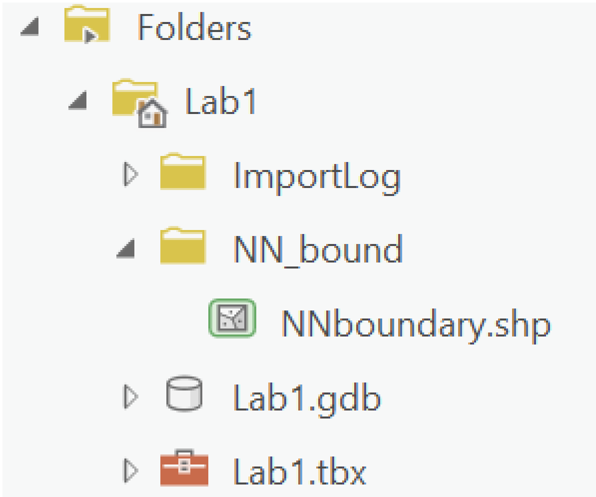


15. On top is the **Tool Bar**. This is where you can access all tools and functions in the software.

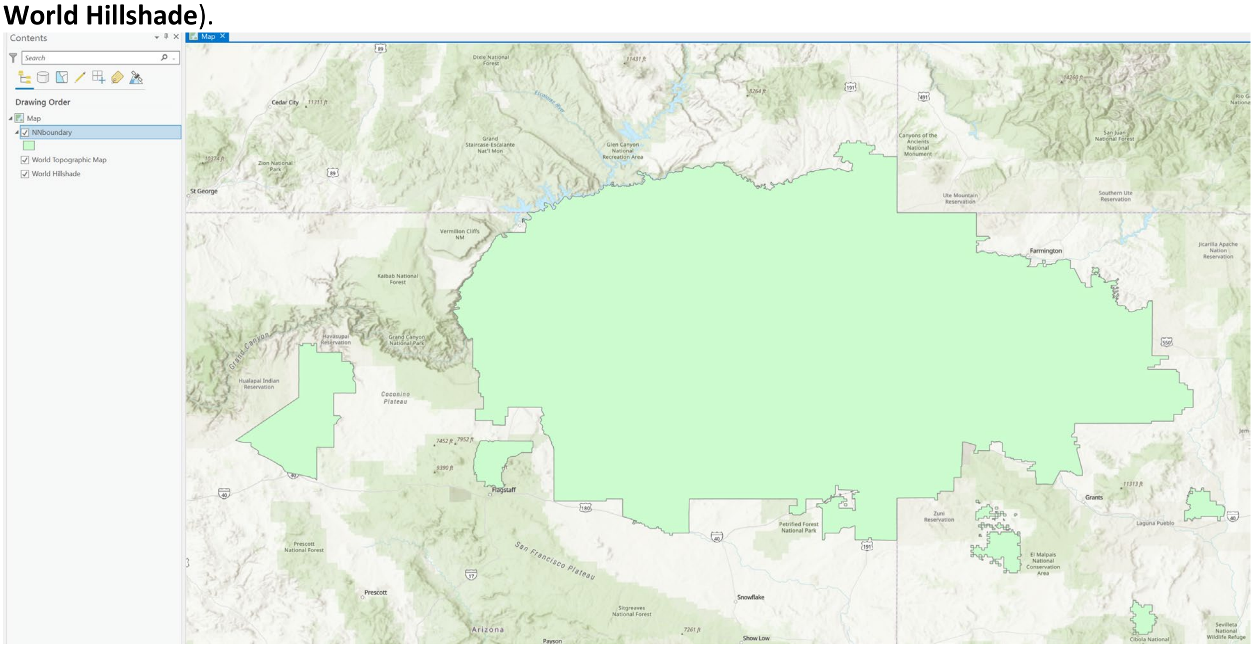


Bring in data:

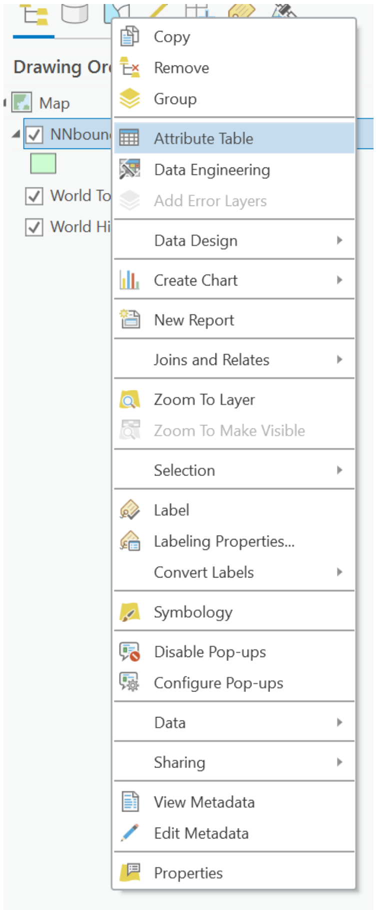
16. In the **Catalog** pane, expand **Folders** by clicking on the arrow. Repeat for the **Lab1** and **NN_bound** folders. Once expanded, the Navajo Nation boundary shapefile will appear (**NNboundary.shp**).



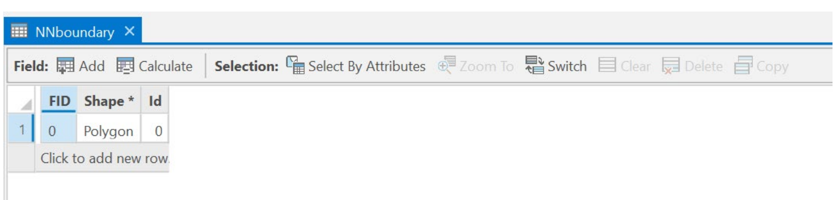
17. Click and drag **NNboundary.shp** into the **Map Frame**. The shapefile will be loaded into the project. The **Map Frame** will zoom into the boundary of the Navajo Nation, represented here as a polygon. The color of your polygon may vary. The boundary is now a Layer in our project and will show up in the **Contents** pane drawn over the **Basemap** (**World Topographic Map and World Hillshade**).



18. There can be a multitude of data associated with shapefiles. **Right click on the Layer** in the Contents pane. This will bring up several different options that allow us to access different aspects of the Layer or perform functions. Click on **Attribute Table**.

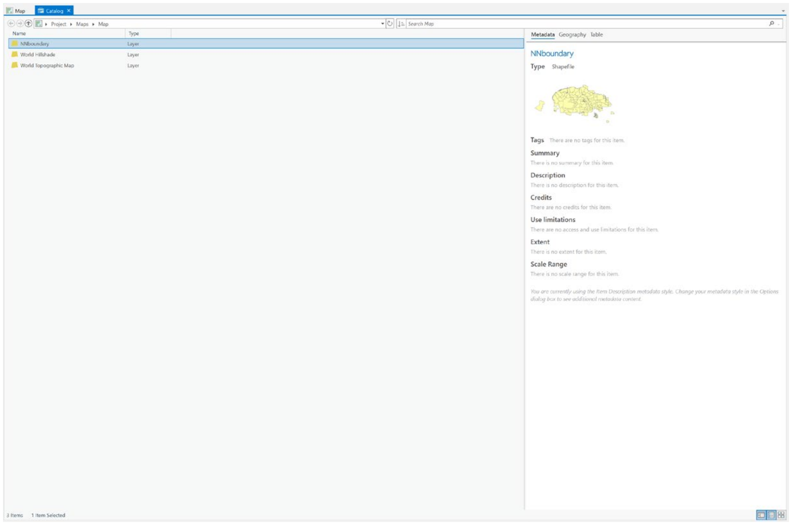


19. A new pane will open up at the bottom of the window displaying the attribute table. This shapefile has no data associated with it as it is just a polygon representing a boundary, so the table will be small. There is only one row, with columns **FID (Feature ID), Shape (identified as Polygon), and Id**. All vector data follows this format, with each feature represented by a row. FID stands for Feature ID, and begins at 0. For example, if we had a shapefile with multiple features (such as hundreds of points or polygons) we would have a row for each feature. The ID is included by convention as a counter that you can use for additional more advanced calculations. The FID is a special datatype that allows the software to recognize and catalog each feature, and therefore cannot be used in expressions.

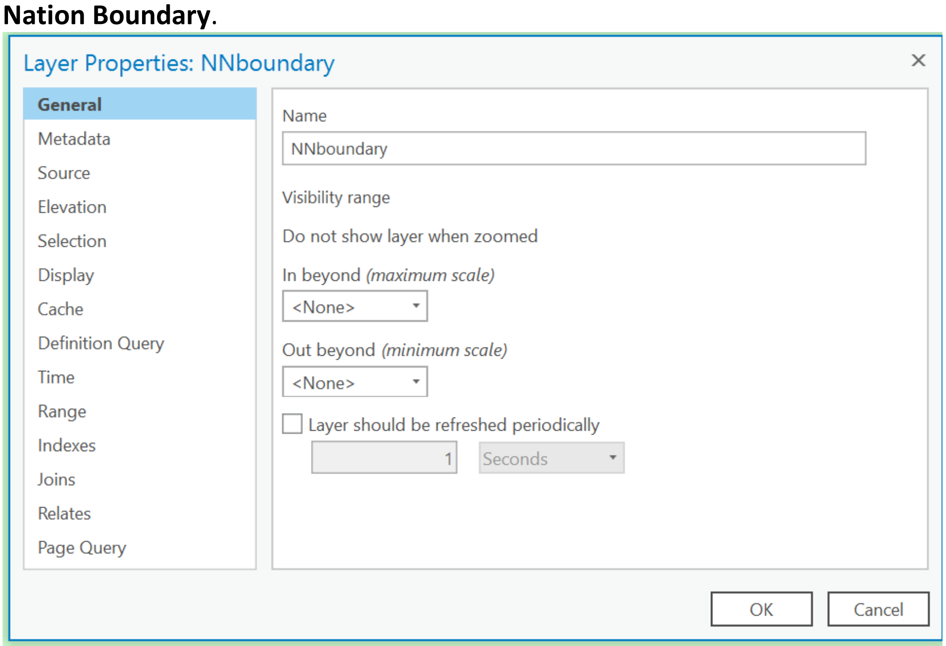


20. Right click on the Layer again and select **Metadata**. This will open the detailed Catalog, providing for more options such as viewing a files metadata. Metadata is descriptive data associated with a file that provides information such as file type, where the data came from, when the file was created, etc. You will see that the metadata for this file is empty, though data from sources such as government agencies often have detailed metadata. When publishing your own files, it is

always a good idea to provide metadata so other researchers can better understand what your data is.

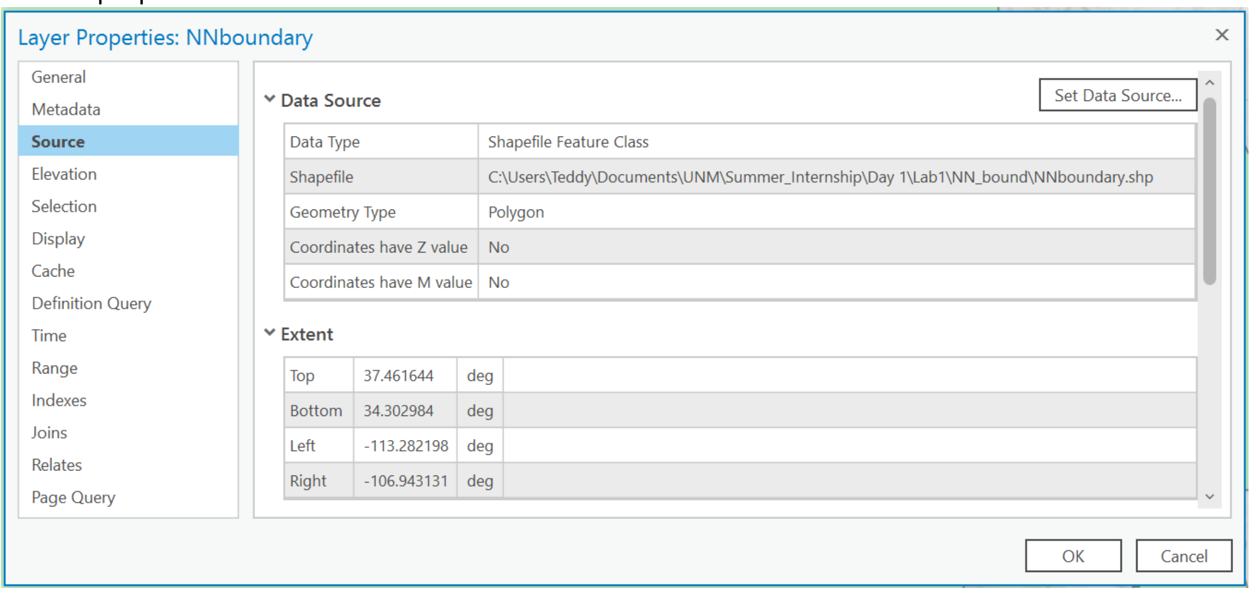


21. Close the Catalog.
22. Right click on the Layer again and select **Properties**. This will bring up a new window displaying information on the Layer (metadata can be viewed here as well). The first tab is general information. Here you can edit the name of the Layer (this will only change the Layer name as displayed in ArcGIS, not the actual filename of the shapefile). **Change the name to Navajo Nation Boundary**.



23. Click on the **Source** tab. This will display **Source, Extent, Spatial Reference**, and other information. Under **Data Source** is information such as the Datatype (**Shapefile**), the file path, and the geometry type (**Polygon**). Click the arrows next to **Extent and Spatial Reference** to expand them. **Extent** details the latitude and longitude of the side of the Navajo Nation boundary in each direction. **Spatial Reference** details the coordinate system that is used to

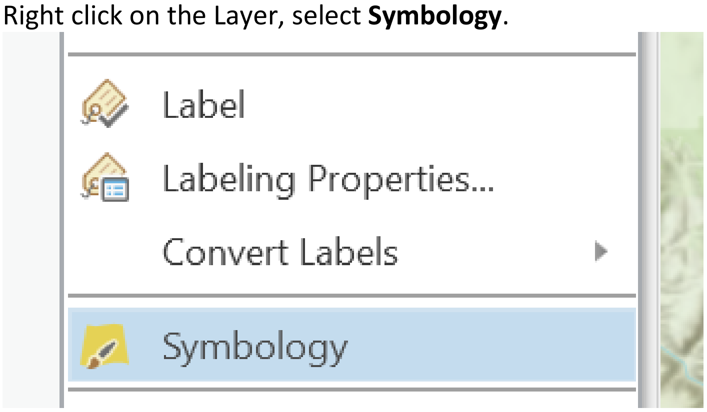
project the data. You will learn more about coordinate systems over the next 2 weeks. Close the properties window.



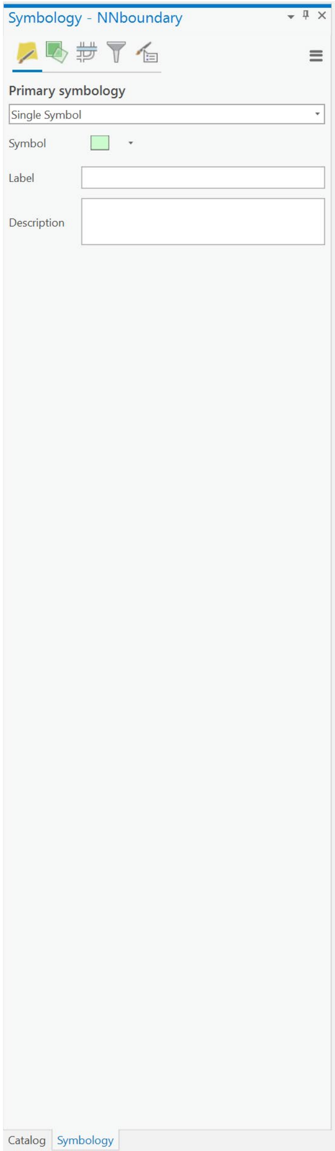
Manipulate data:

ArcGIS gives us powerful tools to edit how a Layer is visualized. The way a Layer is displayed is referred to as its **Symbology**.

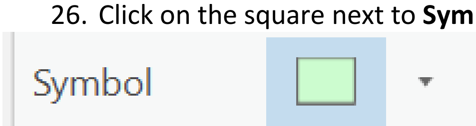
24. Right click on the Layer, select **Symbology**.



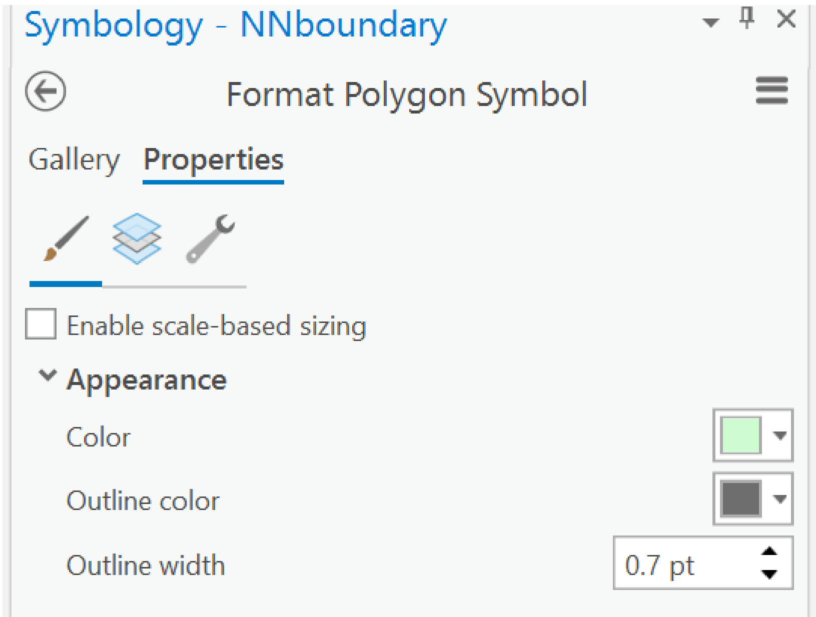
25. On the right of the window the **Symbology** pane will appear (where the Catalog pane was).



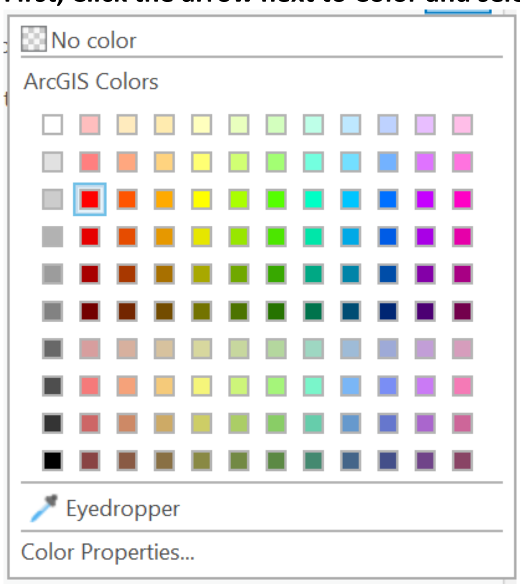
26. Click on the square next to **Symbol**.



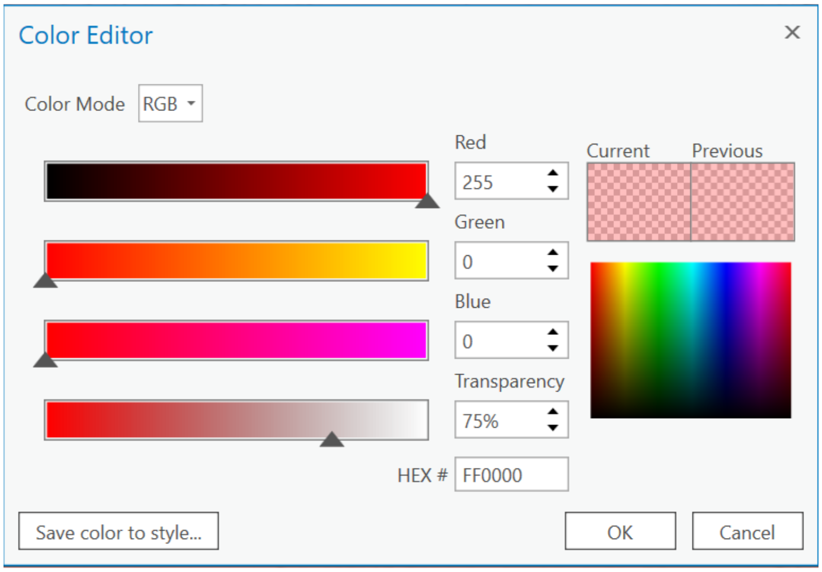
27. This will bring up the **Format Polygon Symbol** window. Click on **Properties**. This will bring up formatting options.



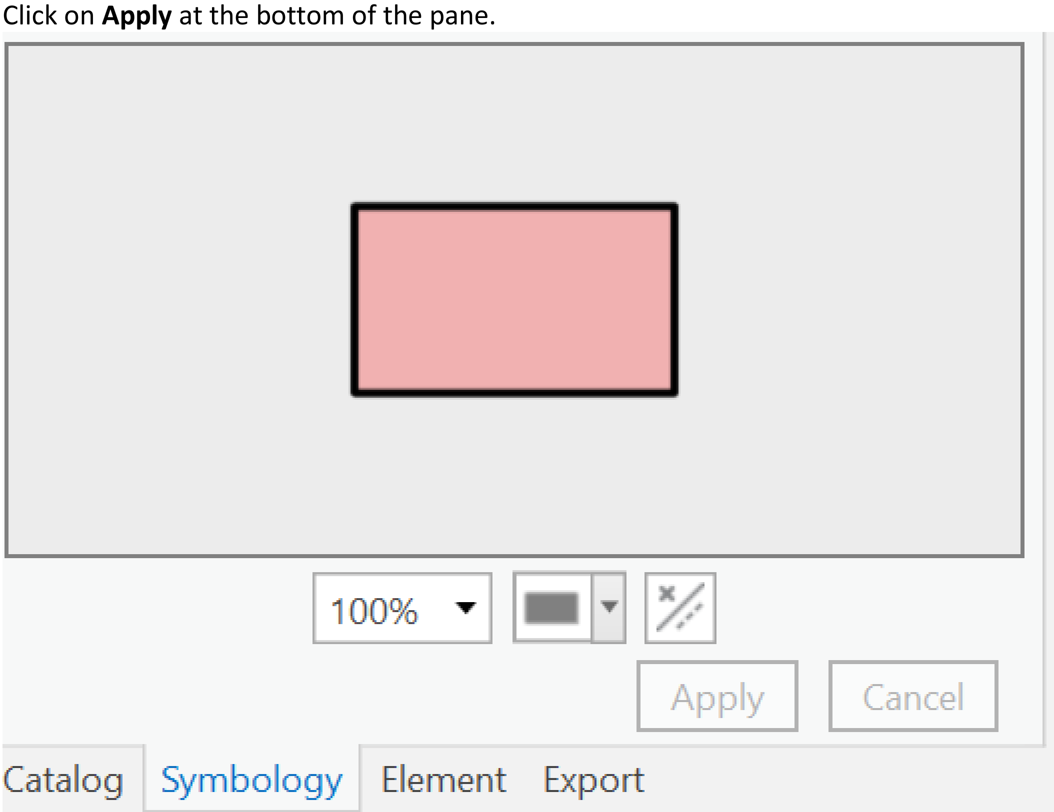
28. At the bottom of the pane is a preview window to show us what the Symbology will look like before we apply it.
29. We are going to make the Layer look like a transparent boundary line for the Navajo Nation. **First, Click the arrow next to Color and select Mars Red.**



30. Then click on **Color Properties**. This will bring up a window with options to modify the color. **Enter 75% for the Transparency**. This will make the Layer transparent so we can see the basemap below.



31. **Change the Outline Color to black**.
32. **Change the Outline Width to 2 pt using the up arrow (you can also manually type it in). This will make the boundary sharp and easy to see**.
33. Click on **Apply** at the bottom of the pane.

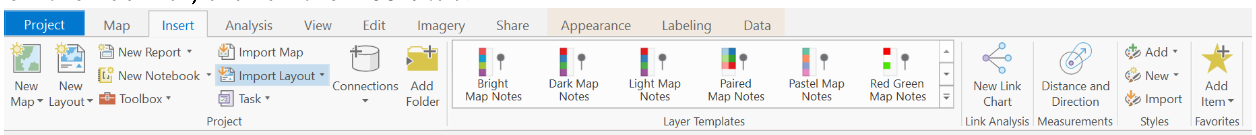


We now have an outline of the Navajo Nation!

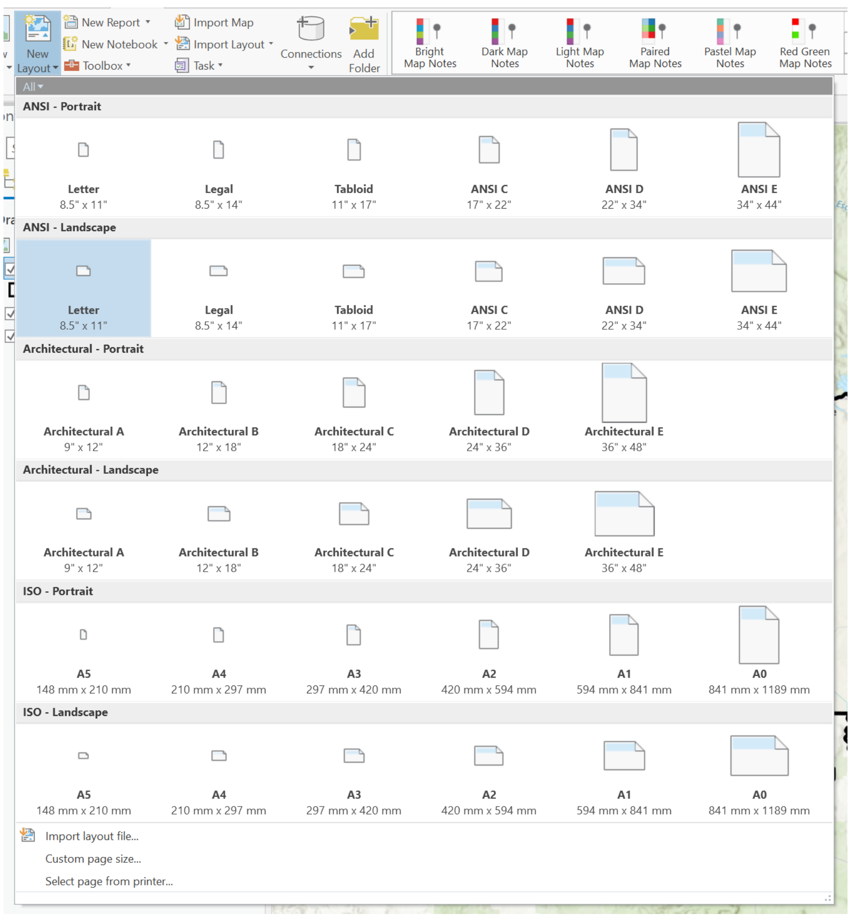
Make a Simple Map:

The Layer looks nice in the software, but to share it with others we will make a map. Results in GIS are almost always displayed as maps. The map editor in ArcGIS is called the **Layout**.

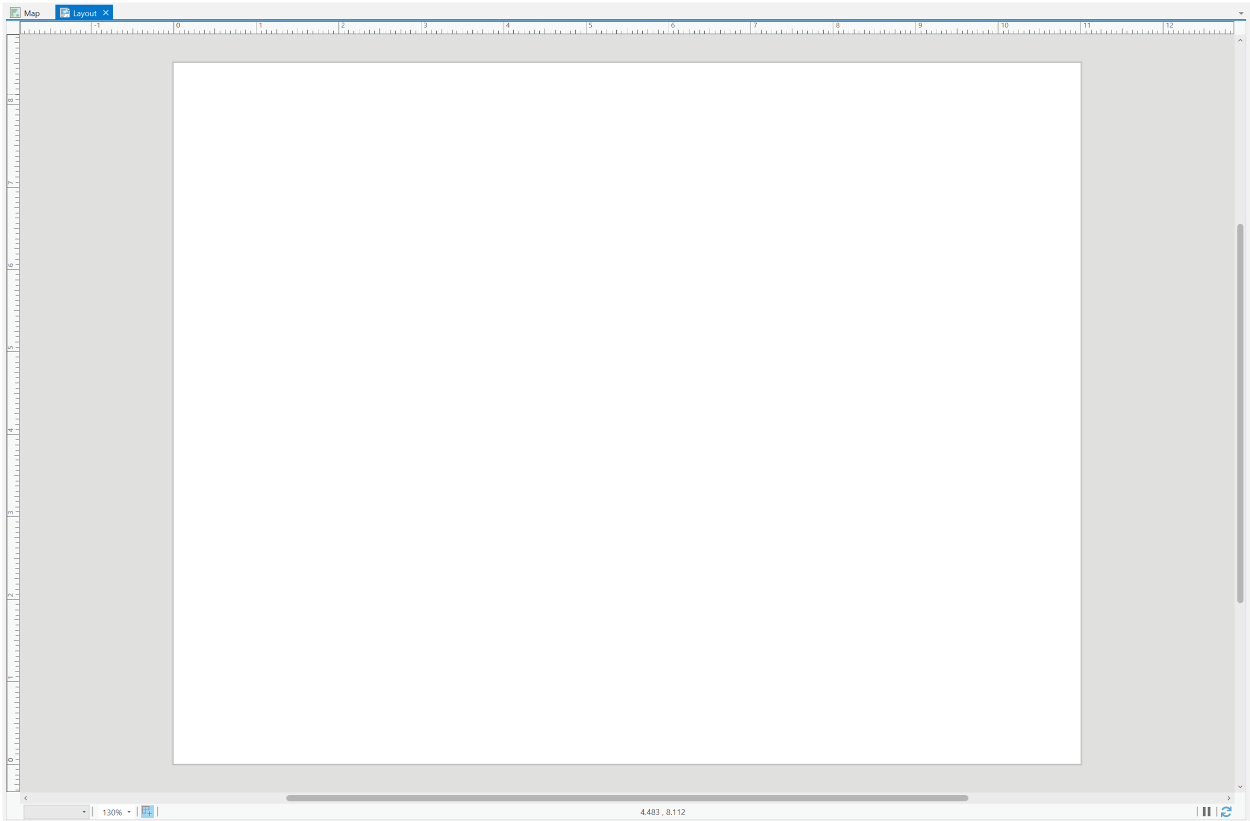
34. On the Tool Bar, click on the **Insert** tab.



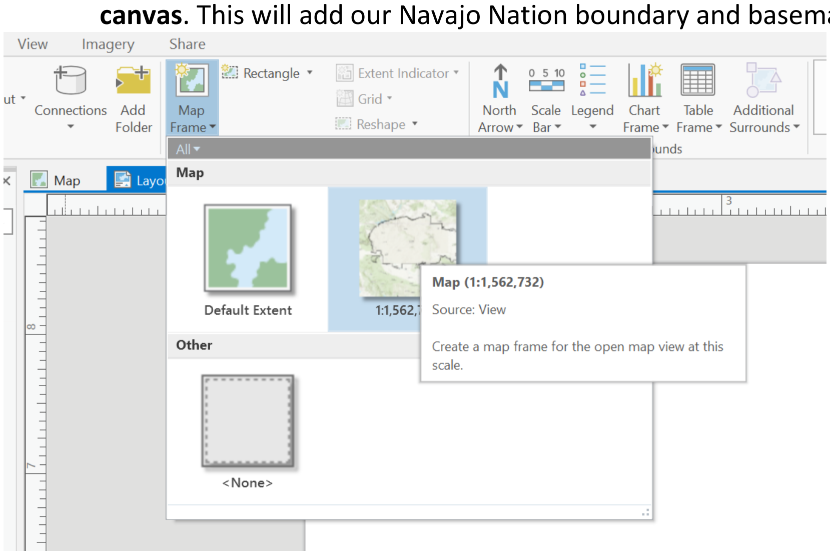
35. Click on **New Layout**. Choose **ANSI – Landscape, Letter size**.

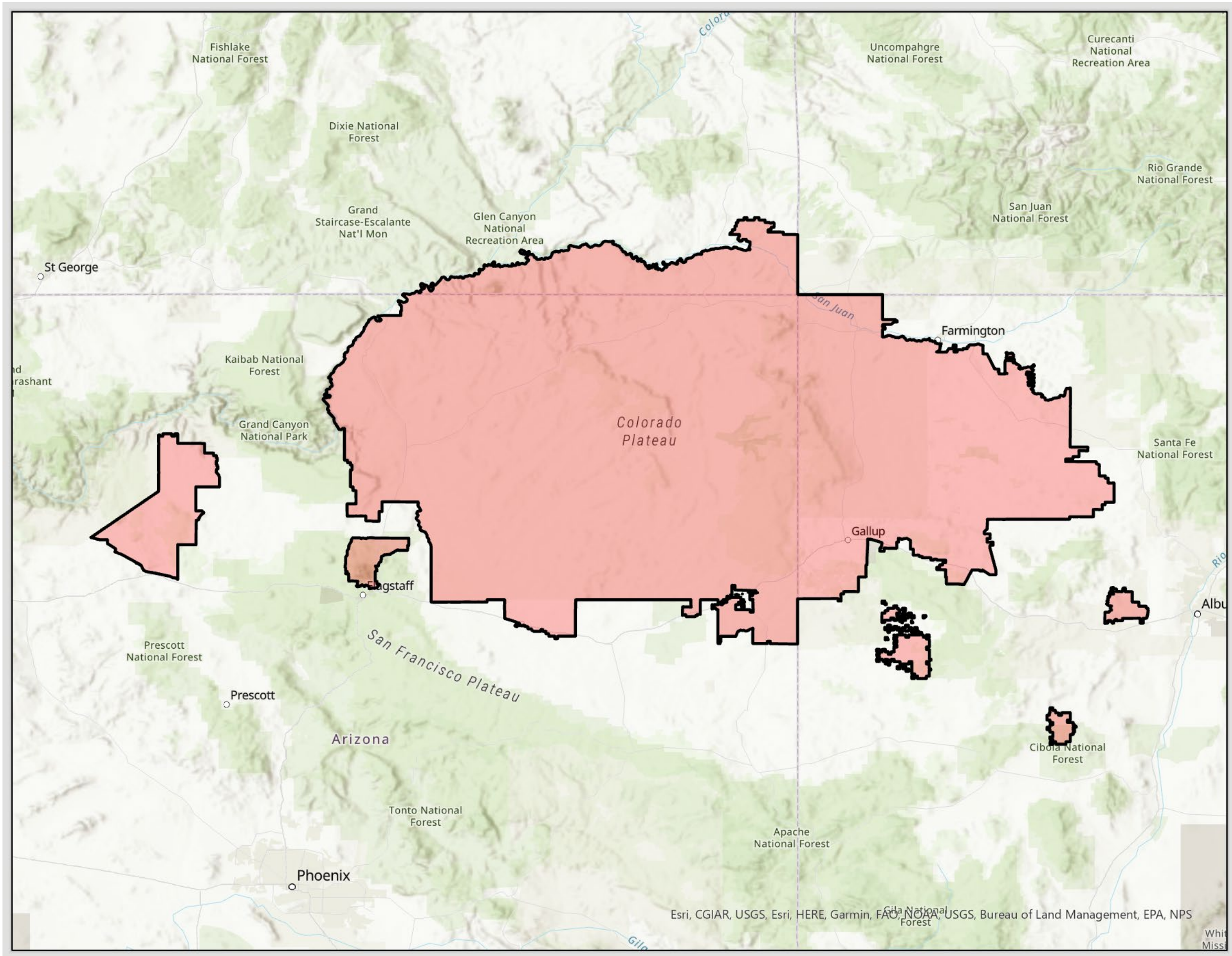


The Layout will appear as a blank canvas (where the Map Frame was)



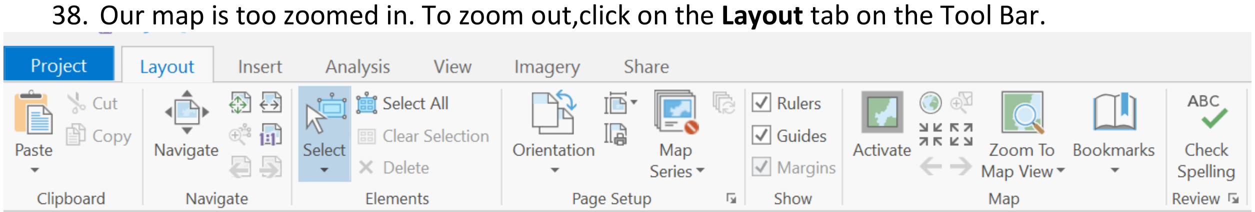
36. On the Tool Bar, click on **Map Frame** and select the map extent from the available options. Place your cursor in the top left corner of the Layout canvas. **Click and drag to match the size of the canvas**. This will add our Navajo Nation boundary and basemap into the Layout.



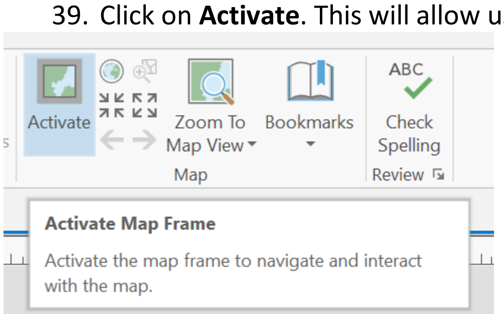


37. Click the gray space outside the layout to change back to the normal selection cursor.

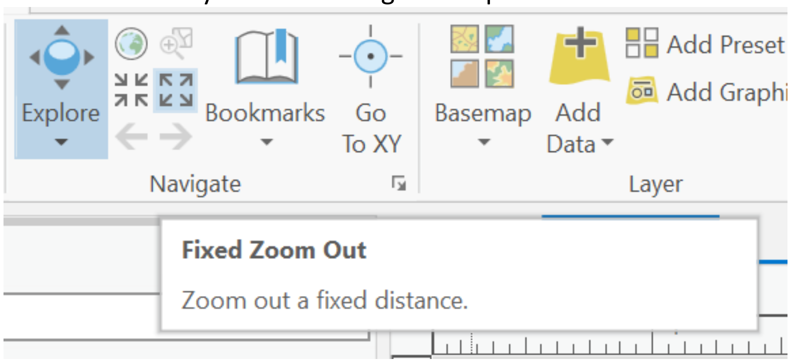
38. Our map is too zoomed in. To zoom out,click on the **Layout** tab on the Tool Bar.

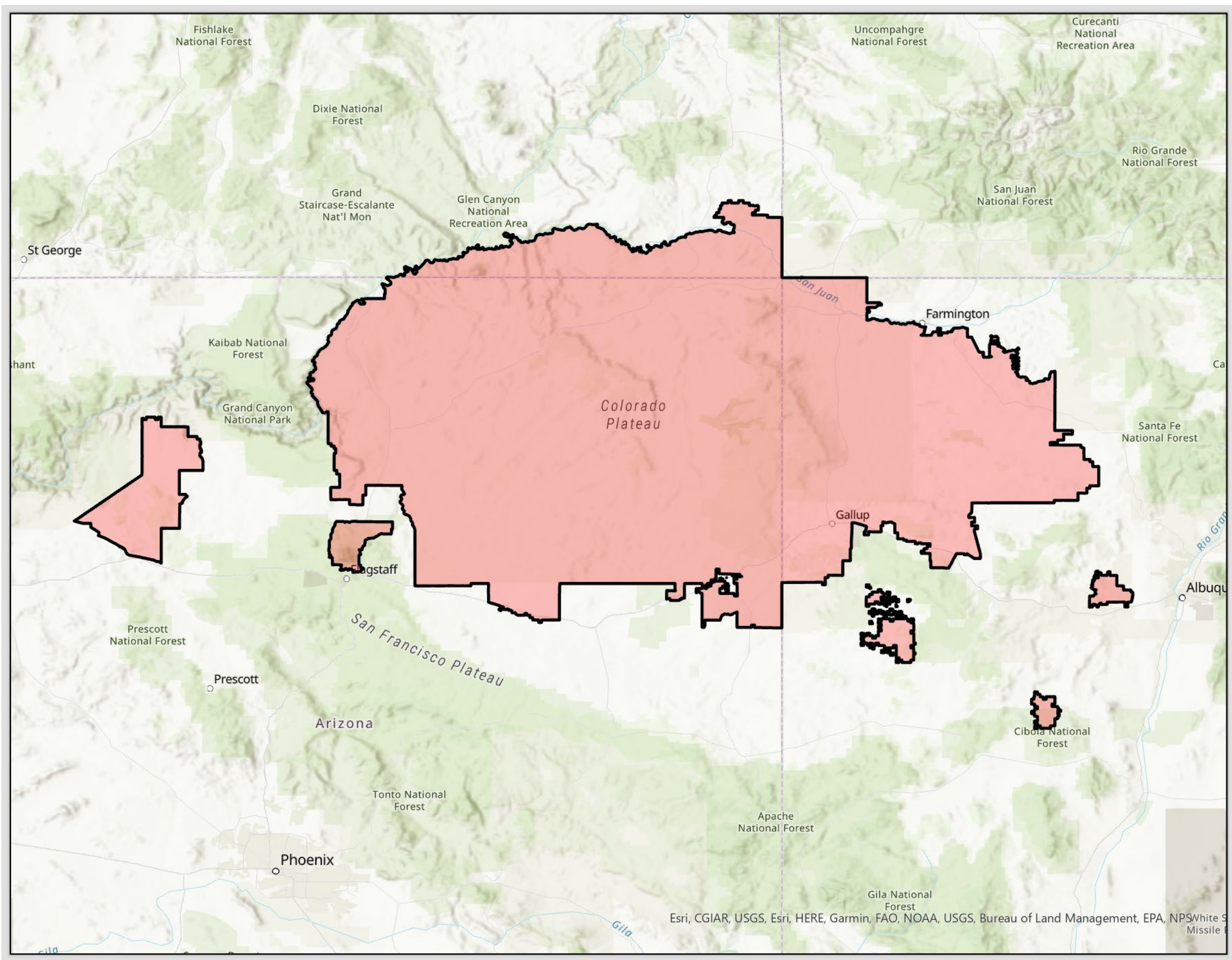


39. Click on **Activate**. This will allow us to move the map around and zoom in and out in the Layout.

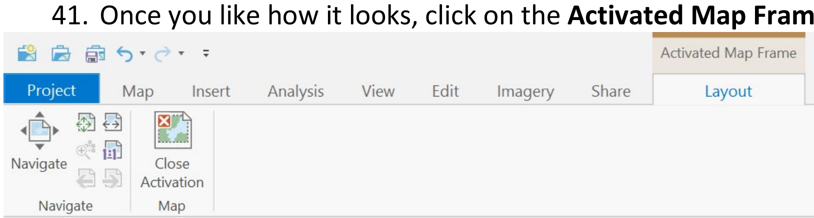


40. Under the **Navigate** group, click on **Fixed Zoom** out until you can see the entire Navajo Nation boundary. Click and drag the map frame to center the Navajo Nation.

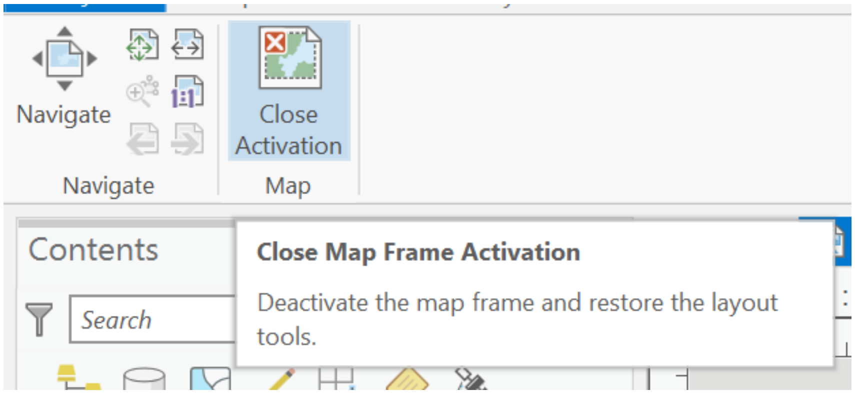




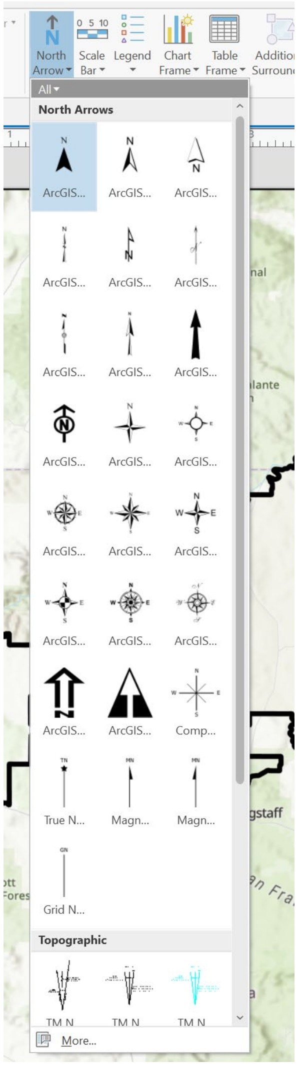
41. Once you like how it looks, click on the **Activated Map Frame** tab.



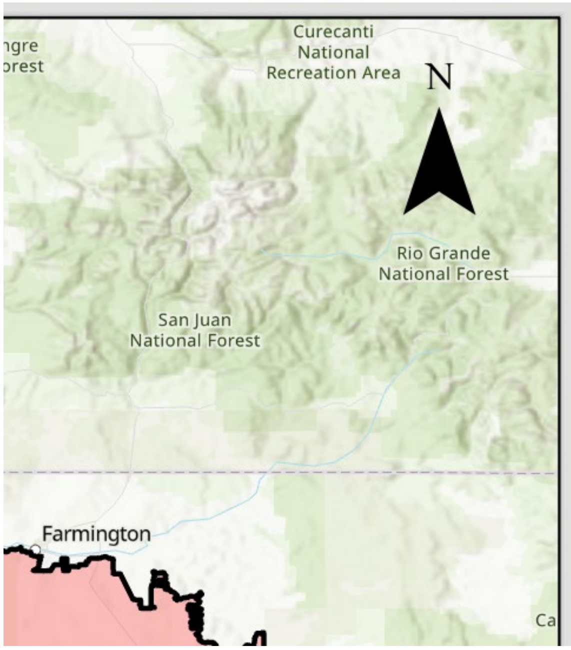
42. Click **Close Activation**.



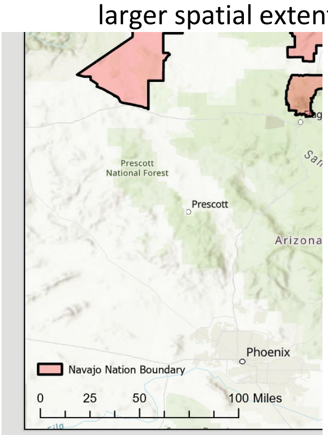
43. We will now add the necessary components to the map: **north arrow, scale bar, legend, and title**. Click on the **Insert > North Arrow**, click on the arrow to expand a drop-down menu with different north arrow templates. Choose a north arrow you like from the drop-down menu.



44. Like when you inserted the Map Frame, click and drag a box the size and place you want your north arrow (north arrows are usually placed in a corner). **Remember to click the gray space outside the layout to change back to the normal selection cursor!**

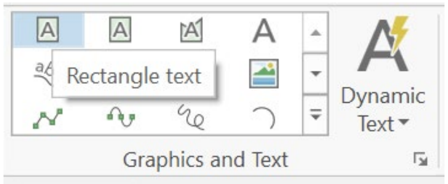


45. Click on **Scale Bar**. Expand the drop-down menu and choose a scale bar you like from the dropdown menu. Repeat the same process as the north arrow to size and place the scale bar (scale bars are usually placed at the left bottom corner of the map). Drag the scale bar to the desired length (scale bars are usually drawn to an even or easily divisible number. For example, a scale bar of 100 miles is easier to understand than a scale bar of 117 miles. Don't worry about getting your scale bar exact at this point. This can be a finicky and glitchy process, especially at larger spatial extents!).

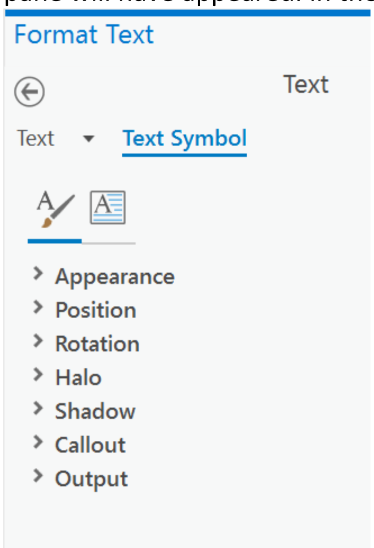


46. Click on **Legend**. Insert the same way as the north arrow and scale bar. Place the legend in a relatively empty part of the map outside of the Navajo Nation boundary where it will be easy to read (legends are usually place on the side or bottom of maps, or above the scale bar).

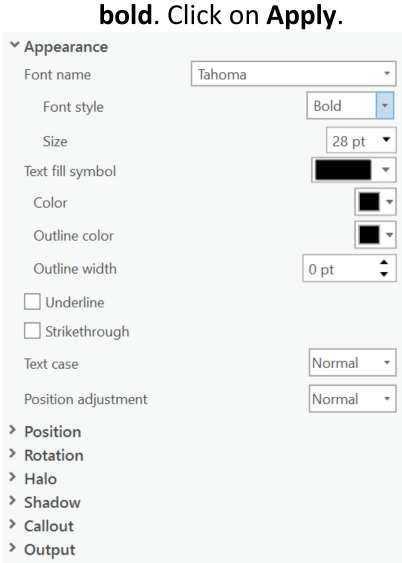
47. In the **Graphics and Text** group, click on the **Rectangle Text** option. Insert the same way as the other map objects.



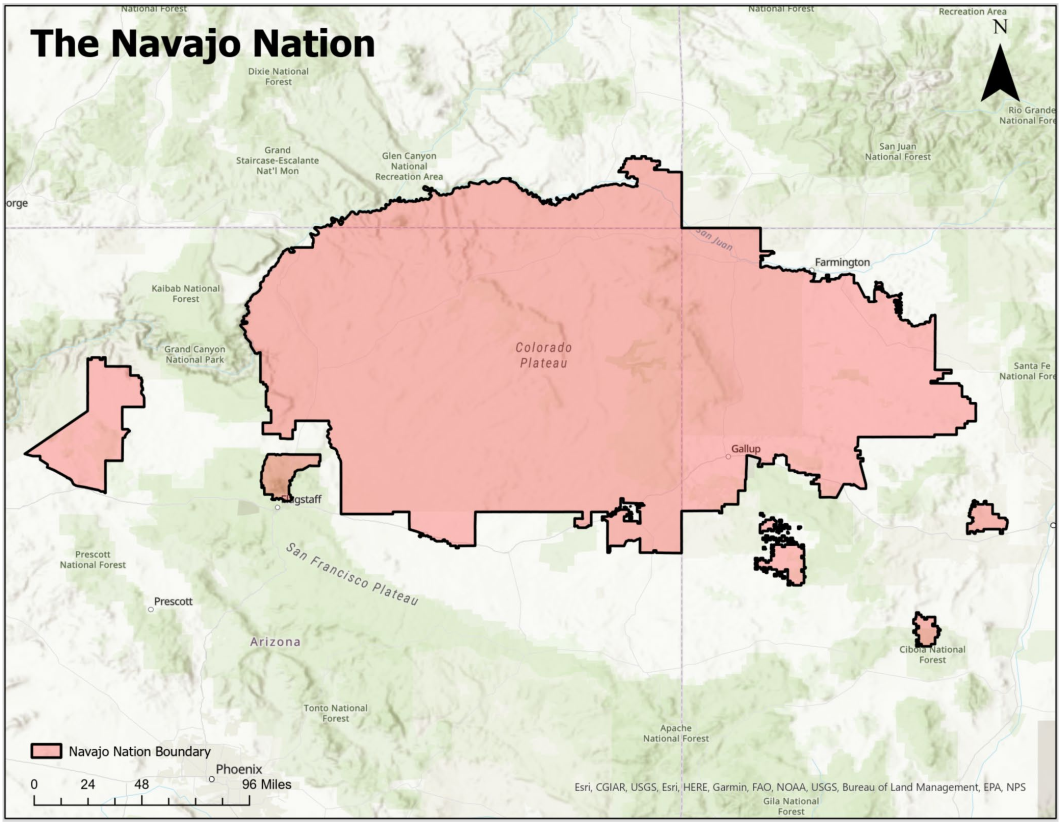
48. Type in what you want the title to be. The text will be small. On the right a **Text formatting** pane will have appeared. In the pane, click on **Text Symbol**.



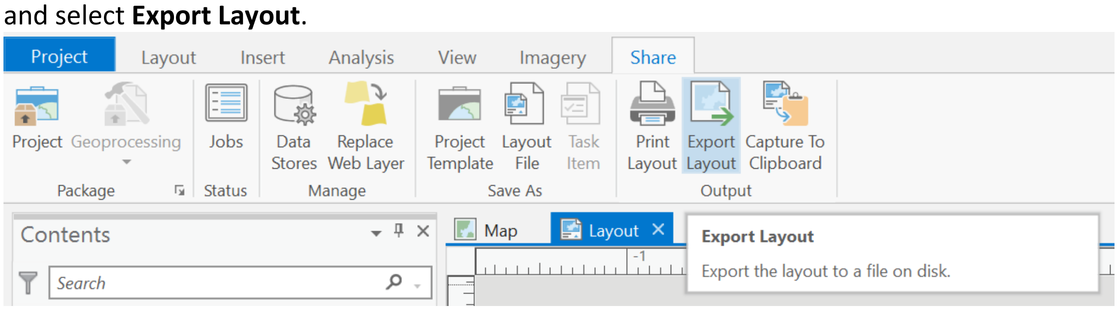
49. The Text Symbol works the same way as Symbology, with different appearance options, and a preview window. Expand **Appearance**. Change the size of the font to **28** and change font style to **bold**. Click on **Apply**.



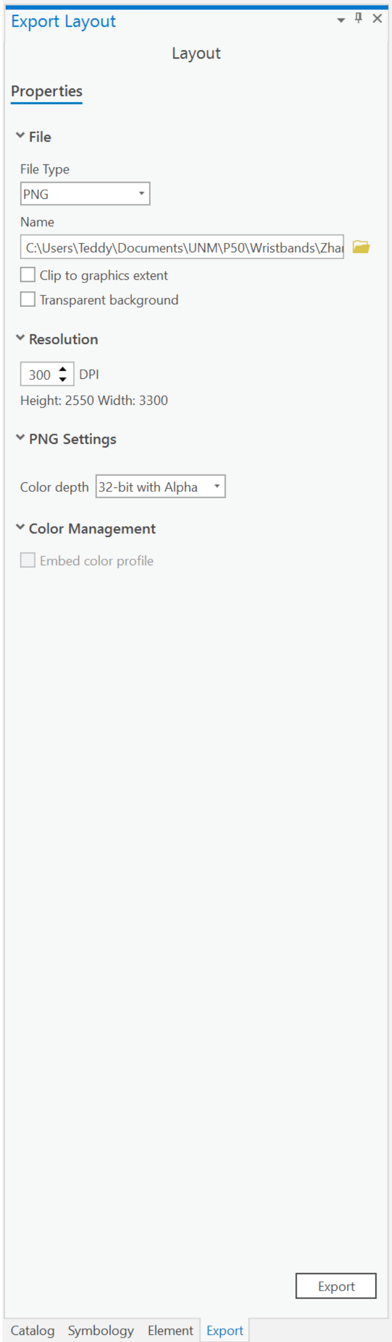
50. Click on the title and drag the text box until all the text is visible (works like PowerPoint). Our map is now complete!



51. We will now export our map so it can be saved and shared with others. Click on the **Share** tab and select **Export Layout**.



52. The Export Layout options will appear in the right pane.



53. Set the File Type as **PNG**. Under Name, name your layout **Navajo_Map** and save it to your **Lab1** folder. Set the resolution to **300 DPI** and Color depth to **32-bit with Alpha**. Click on **Export**. The map will be saved to your computer as an image that you can easily share with others.
54. Check you Lab1 folder and open the map image to make sure it was exported correctly.

You have now created your first map in GIS!

Free work

For the rest of the lab period, experiment on your own with the different Layout and Symbology settings. Check out the other basemaps or explore other parts of the software.

Instructions: In this lab we will become familiar with ArcMap, the industry leading GIS software (older version). We will introduce some more complex GIS fundamentals such as selections.

CONVENTIONS USED IN THESE LABORATORY ASSIGNMENTS

When the instructions refer to two or more keys on the keyboard, linked by a "+", it means to press them simultaneously. When ">" or "→" is used, it means to press the keys (or perform some other actions) sequentially. Thus,

- Ctrl + V means to press the Control and the V buttons at the same time (to paste the last item on your clipboard into a document), whereas
- Insert > New Layout means to click on the Insert tab and then New Layout

You will frequently use keyboard shortcuts such as:

- Ctrl + C to copy
- Ctrl + V to paste
- Ctrl + Z to undo the last action

DO SAVE AND BACK UP YOUR FILES. You cannot believe how frustrating it is to lose all your work and have to start again if ArcGIS crashes. This can happen when you are performing complex calculations. Thus develop the habit from the onset of frequently saving your work after major steps or processes.

BE SURE TO SAVE YOUR WORK OFTEN! ARCGIS IS KNOWN TO BE "BUGGY" AND CAN CRASH.

Task

(Measuring and Identification, Selection, Advanced Symbology and Calculations, Find Tool)

1. Start up ArcMap. Select New Maps > Templates. Choose Blank Map.
2. Go to Open. Navigate to the mgisdata folder. Open Lab_1_Map.mxd.

Part A: Measuring and Identification

The ruler is a helpful tool that allows us to easily measure the distance between objects.

3. Click on measure on the tool bar (looks like a ruler). To measure a simple linear distance, click where you want your starting point to be. The tool will measure the distance to wherever your cursor is. Use the tool to measure the rough east-west distance of Oregon. Double click to end the measurement.
4. The measure tool can also be used to figure out a perimeter. Measure the rough perimeter around Oregon by drawing a box with the tool. To start a new line segment, single click. Return the cursor to your starting point to see the total perimeter. Double click to end the measurement.
5. The measure tool can also be used to figure out an area. In the measure tool window, click on measure an area. Build line segments like when finding a perimeter until you have all vertices of a bounding box to get the rough area of Oregon.

Identify is a helpful tool that allows us to easily identify a data layer and the respective attributes at a specific location.

6. Click the Identify tool (looks like an "i") and click anywhere on the map. The identify tool can be used to quickly check the attributes from any of the layers on the map at a given location (the top layer is displayed first by default).
7. In the Identify tool menu, change identify from to a specific layer and click somewhere again. You will get results for that specific layer. Change identify from to counties to get the county and associated demographic information for that given area. Close the measurement and identify tool windows.

Flash and Zoom To can help us pinpoint specific features.

8. Turn off all layers except counties.
9. Open the attribute table. Click on a row, right click and select Flash. Note how the feature is highlighted. This will also select the feature (we will learn more about selections in the next section).
10. Right click and select Zoom To to zoom to the feature.
11. Click the clear selection button, close the attribute table, right click the layer and select Zoom to Extent to return to the full extent.

Find is a more robust way to find specific features based on specified conditions, such as searching for a specific County in Oregon by name.

12. Click on the Find Tool (looks like binoculars). Click on the Features tab. Type Wheeler under Find. Set in to counties. Click Find. Click on the row that shows up to flash Wheeler county. Right click to bring up Zoom, Selection, and other options.
13. Close the Find Tool and the Attribute Table.

Part B: Selection

Selection is a powerful method of identification. We can select specific features in a layer, view these selections in the attribute table, and perform operations on that selection such as creating a new shapefile from that selection.

14. Click on select features (white cursor with blue and white box). Turn off all layers except for parks. Click on one of the parks. This will select the specific park (represented as a polygon feature, will be highlighted once selected).
15. Open the layer's attribute table. Note how the attribute table indicates the number of selected features. Click on show selected records (solid blue table icon) to show the selected row.
16. Return to the full table. You can also select features from the attribute table by click on rows. To select multiple rows (works for features as well) hold down shift while selecting features. Select some rows and note howe your selections are also highlighted on the map.
17. Click on clear selection (next to select button). Close the attribute table.
18. Turn off parks and turn on counties. Select any counties you like.
19. Right click on the layer and choose Data > Export Data.
20. Export will be set to Selected Features by default. Coordinate will be set to Layer's Source Data by default.
21. Change the file path to be set to the mgisdata folder. Use Connect to Folder and navigate to mgisdata. Change the filetype to Shapefile. Name it My_Counties.
22. When prompted if you want to add the data as a new layer, select yes.

23. Clear selection, turn off countties. Note how you have created a new layer of only the selected counties.

Part C: Advanced Symbology and Calculations

Symbology can get more advanced than just aesthetics. We can base symbology off variables (attributes) in our data.

24. Turn on counties.
25. Open Symbology. Change to Quantities. Under fields change the value to POP2000. Choose a color ramp you like and click apply. We now have a map showing the distribution of population by county in Oregon.
26. We need to normalize our data in order to deal with the MAUP (modifiable aerial unit problem, there are distortions in the data distribution given the irregular size of the counties). To solve this problem, we will create a new population density field by diving the population by the area od each county.
27. Open the attribute table. Expand Table Options, select Add Field. Name it POP_Per_SQMI. Change the data type to double (decimal). The new field will be appended to the end of our attribute table.
28. Sort the Attribute Table based on population by right clicking the POP2000 field and selecting Sort Ascending.
29. Right click the column (Field), chose Field Calculator. When warned you are entering an edit session, click OK. In the field calculator window we can write scripts to perform table calculations (similar to Excel expressions). Write the following expression (double click on field names and single click operators to build the expression, or copy past from this document): [POP2000] / [SQMI]
30. Click OK to run the calculation and populate our population density field (number of people per square mile in each county).
31. Change the Symbology value to our new population density field. Note how the distribution changes.

Tutorial

(Follow below instructions and answer questions using what you learned in the tutorial)

32. Turn on the counties layer.
33. What is the name of the county in the northeast corner of Oregon?
34. How many counties are there in Oregon?
35. Which county has the smallest 2000 population?
36. How long is the southern border of Oregon?
37. Turn on the Volcanoes layer.
38. Which county is Blue Lake Crater in?
39. Turn on the highways layer.
40. What is the name of the highway close to Blue Lake Crater?
41. Which volcano is closest to Blue Lake Crate?

Challenge:

- Turn off the display for all of the layers except Highways, Counties and Volcanoes.
- Make the outline of the counties Gray 60% with outline width of 1.

- Change the symbol for the Interstate from the “Expressway” to the “Highway” symbol. Do not change the color. For the remaining roads, change all symbols to the “Major Road” symbol in “Ultra Blue”.

Lab 4 – Analyzing Patterns and Relationships in Census Data

Instructions: In this lab we will introduce some more complex GIS fundamentals such as selections and perform basic analysis.

CONVENTIONS USED IN THESE LABORATORY ASSIGNMENTS

When the instructions refer to two or more keys on the keyboard, linked by a “+”, it means to press them simultaneously. When “>” or “→” is used, it means to press the keys (or perform some other actions) sequentially. Thus,

- Ctrl + V means to press the Control and the V buttons at the same time (to paste the last item on your clipboard into a document), whereas
- Insert > New Layout means to click on the Insert tab and then New Layout

You will frequently use keyboard shortcuts such as:

- Ctrl + C to copy
- Ctrl + V to paste
- Ctrl + Z to undo the last action

DO SAVE AND BACK UP YOUR FILES. You cannot believe how frustrating it is to lose all your work and have to start again if ArcGIS crashes. This can happen when you are performing complex calculations. Thus develop the habit from the onset of frequently saving your work after major steps or processes.

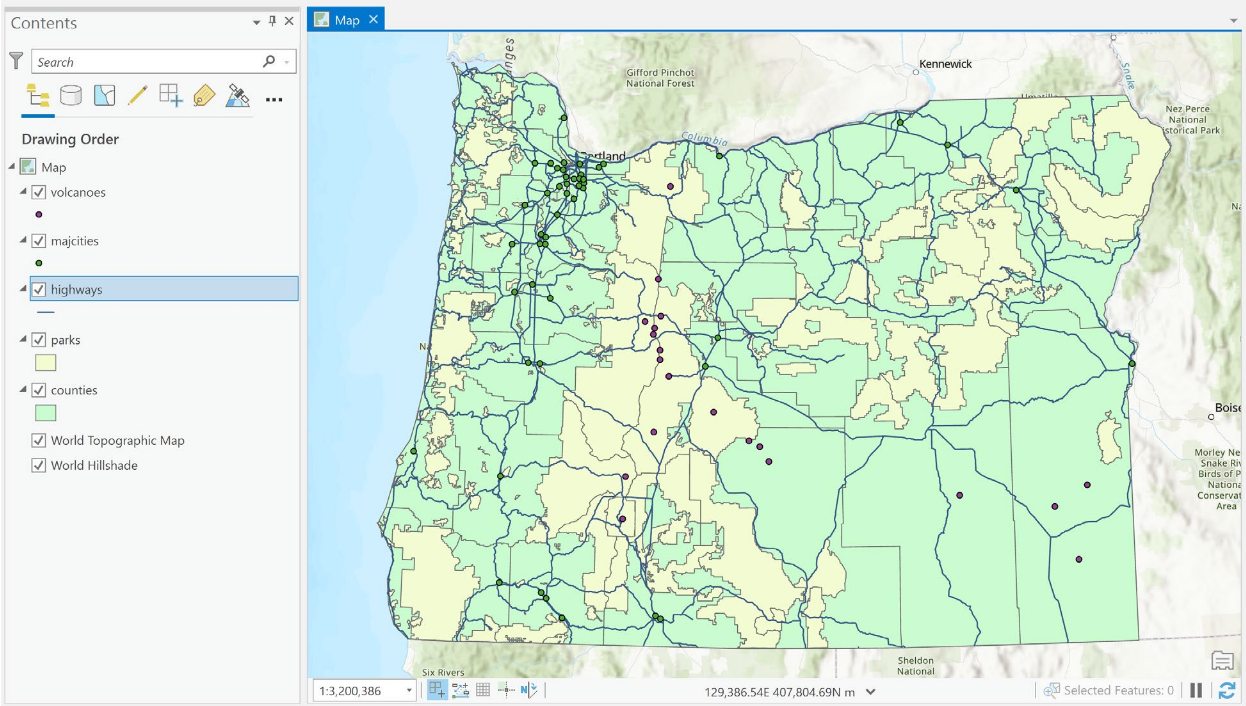
BE SURE TO SAVE YOUR WORK OFTEN! ARCGIS IS KNOWN TO BE “BUGGY” AND CAN CRASH.

Tutorial

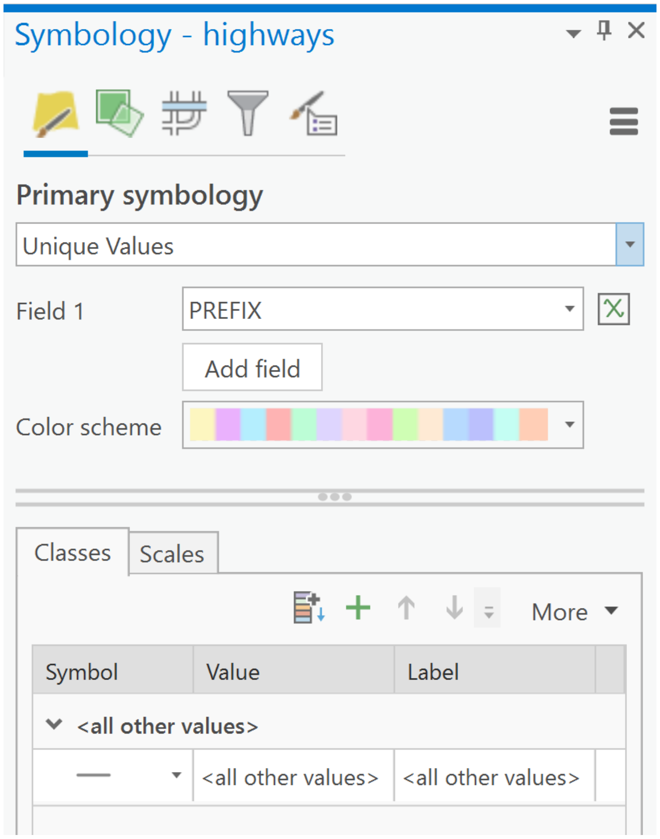
(Measuring and Identification, Selection, Advanced Symbology and Calculations, Find Tool)

42. Start up ArcGIS. Create a new map.
43. Save to a new folder (Lab4) in your GIS older. Name it Lab4.
44. Copy the lab data into this folder.
45. Pull in the majcities (major cities), volcanoes, highways, parks, and counties shapefiles into your map frame. This data will be under a geodatabase in the Oregon folder.

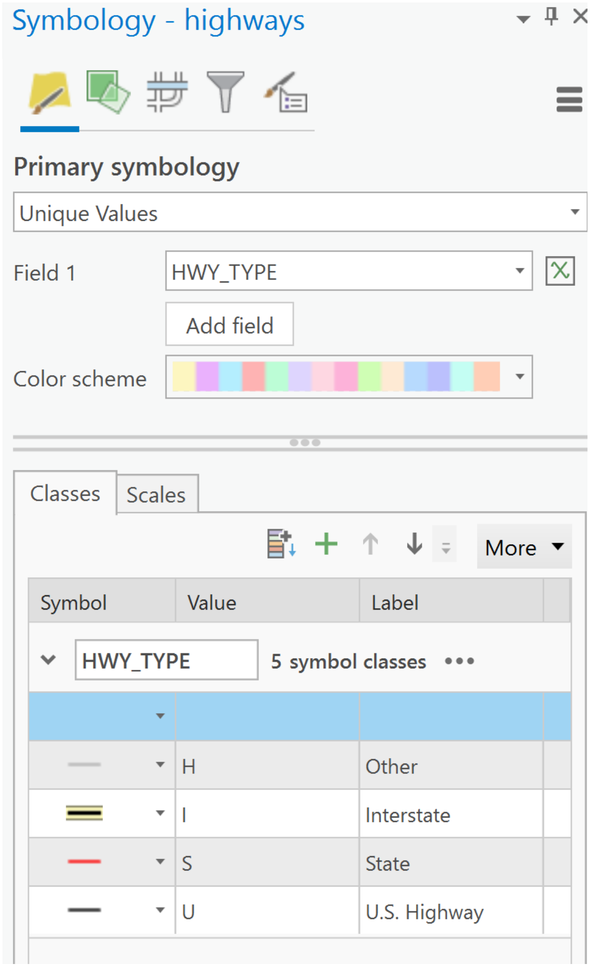
In this lab we will explore different geographic features in Oregon. We will pull in the following data: counties, parks, volcanoes, and highways, and apply symbology. Expand the transportation group, and pull in the highways data.



46. This looks nice, but we can use symbology to make it better! For example, we can make the volcanoes standout, or apply categories to the highways so we can clearly differentiate between road types.
47. Change the color of the counties to Topaz Sand.
48. Change the color of the parks to Medium Apple.
49. For the highways we will apply categorical symbology, with a different symbol based on the highway type.
50. Change the highway symbology type to Unique Values.

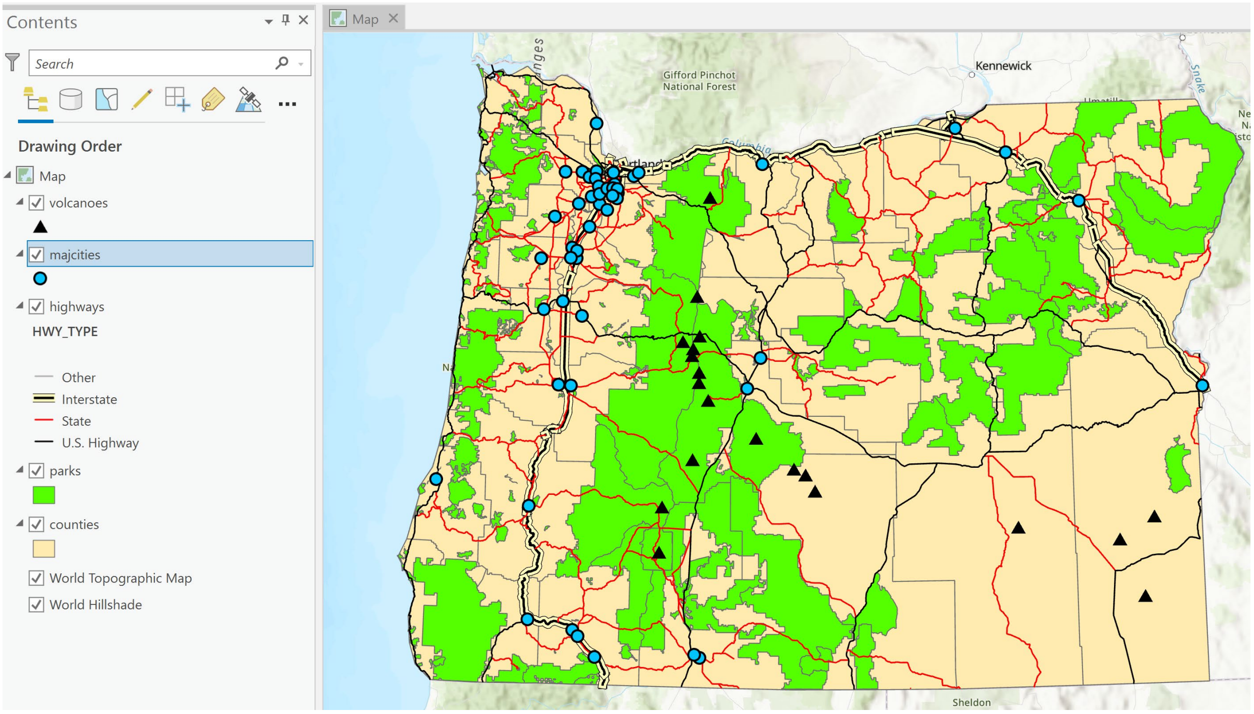


51. Change Field 1 to HWY_TYPE.
52. The labels are hard to understand. Change to full words for each type as follows:
    a. I = Interstate
    b. S = State Highway
    c. U = U.S. Highway
    d. H = Other
53. We can now edit the individual symbols to make each highway type stand out. Change the symbols are follows:
    a. Interstate = Tripple Yellow Black, size = 6 pt
    b. State = Mars Red, size = 1 pt
    c. U.S. Highway = Black, size = 1pt
    d. Other = Gray, size = 1pt
54. There is a blank type that represents some special highway service road. We don't need to see these. Change the symbol to No Color.
55. Expand More > Uncheck Show Other Values.



56. Change the volcanoes symbol to Triangle #1
57. Change the major cities color to Big Sky Blue, size = 8pt

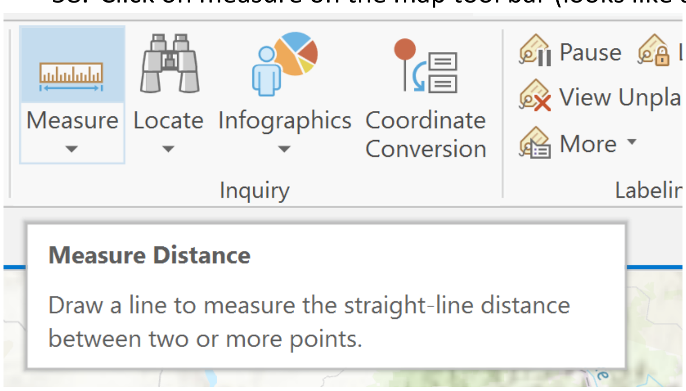
We now have a map with easily identifiable elements. This looks much better!



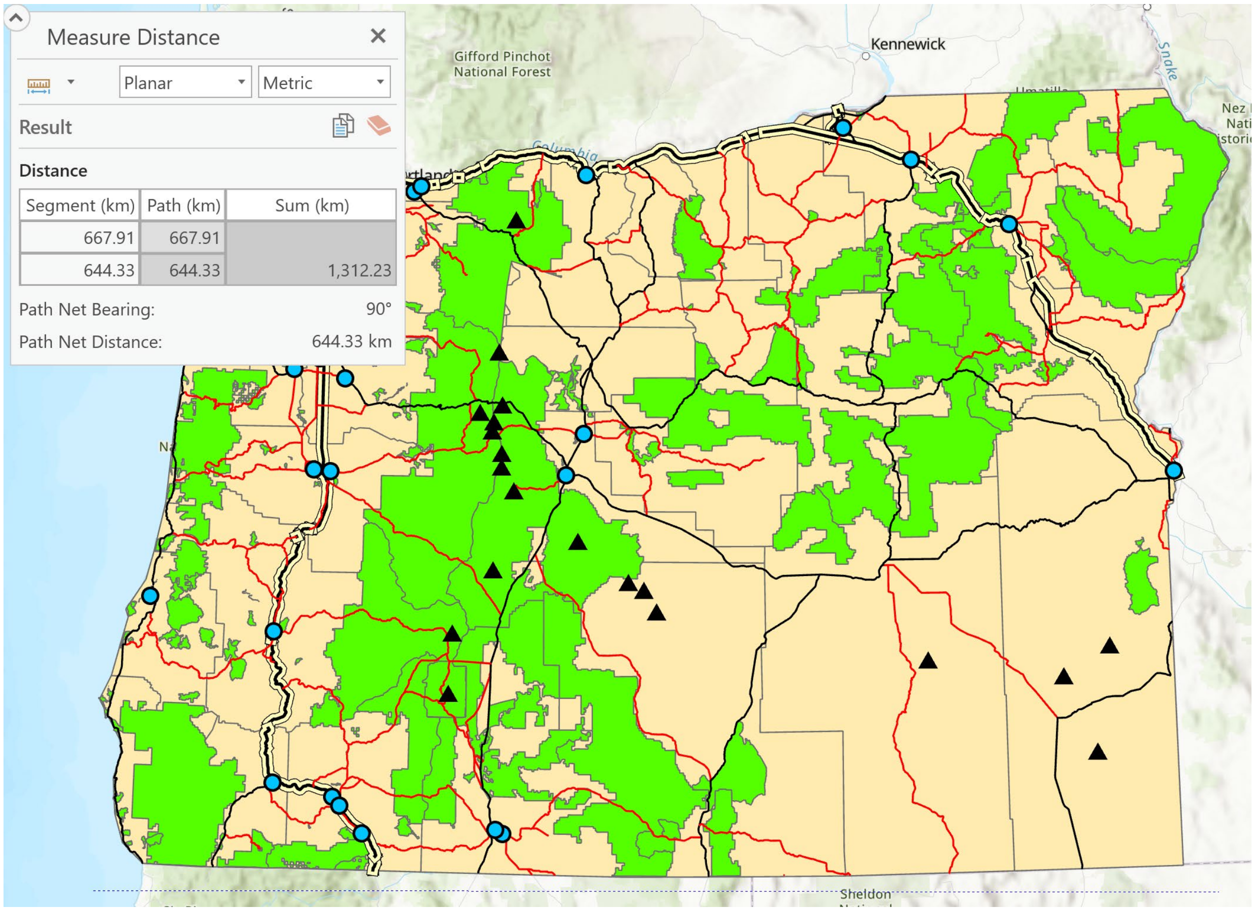
Part A: Measuring and Identification

The ruler is a helpful tool that allows us to easily measure the distance between objects.

58. Click on measure on the map tool bar (looks like a ruler).



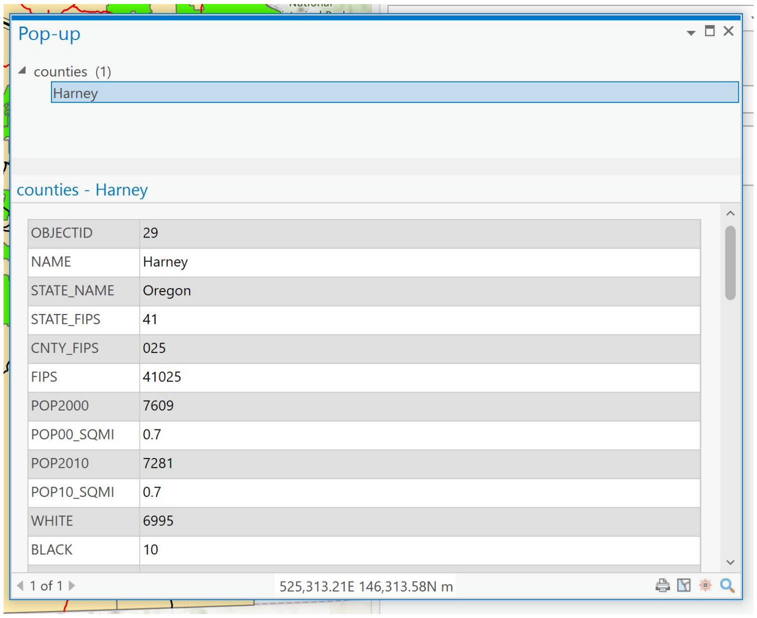
59. To measure a simple linear distance, click where you want your starting point to be. The tool will measure the distance to wherever your cursor is. Use the tool to measure the rough east-west distance of Oregon. Double click to end the measurement.



60. The measure tool can also be used to figure out a perimeter. Measure the rough perimeter around Oregon by drawing a box with the tool. First, click the eraser symbol to clear measurements. To start a new line segment, single click. Return the cursor to your starting point to see the total perimeter. Double click to end the measurement. Clear the results.
61. The measure tool can also be used to figure out an area. In the measure tool window, click on measure an area. Build line segments like when finding a perimeter until you have all vertices of a bounding box to get the rough area of Oregon.
62. When done, clear results and close the measure tool. Change back to the Explorer cursor.

Identify is a helpful tool that allows us to easily identify a data layer and the respective attributes at a specific location.

63. To identify objects, simply click on them while using the Explorer cursor. The identify tool can be used to quickly check the attributes from any of the layers on the map at a given location (the top layer is displayed first by default).
64. Click on features in different layers to identify them. Identify a county to get the county and associated demographic information for that given area. Close the pop-up window.

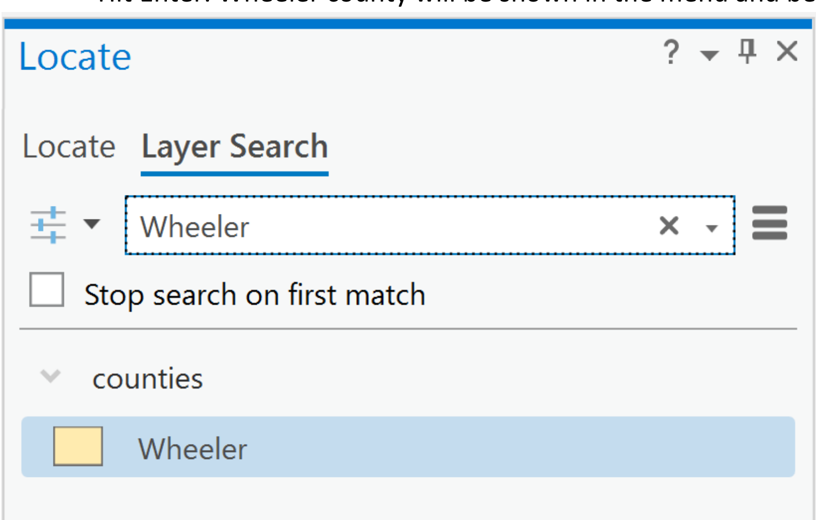


Flash and Zoom To can help us pinpoint specific features.

65. Turn off all layers except counties.
66. Open the attribute table. Click on a row, right click and select Flash. Note how the feature is highlighted.
67. Right click and select Zoom To to zoom to the feature.
68. Select Zoom to Layer to return to the full extent.

Locate is a more robust way to find specific features based on specified conditions, such as searching for a specific County in Oregon by name.

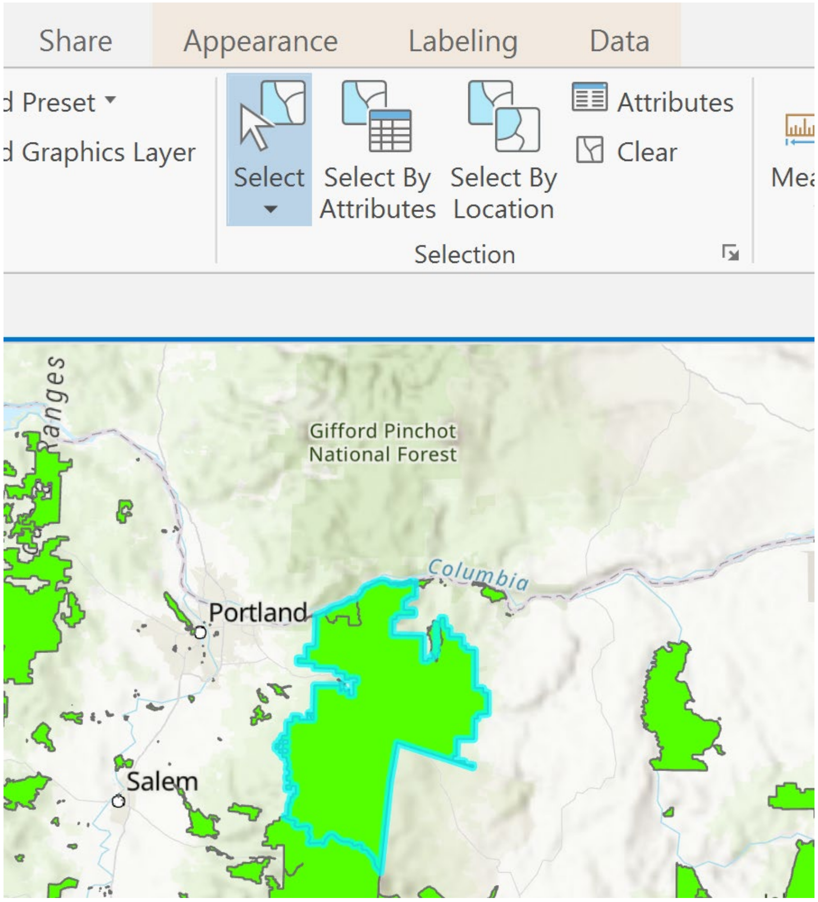
69. Click on the Locate Tool (looks like binoculars). Type Wheeler under search. Set to Layer Search. Hit Enter. Wheeler county will be shown in the menu and be highlighted on the map.



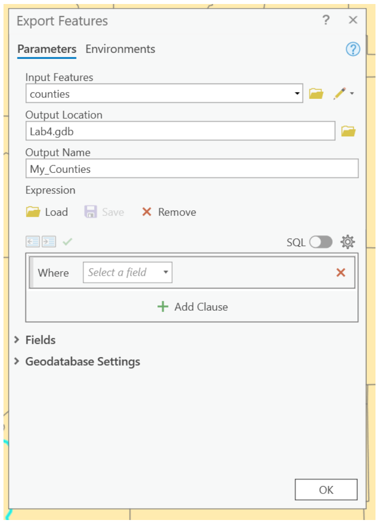
Part B: Selection

Selection is a powerful method of identification. We can select specific features in a layer, view these selections in the attribute table, and perform operations on that selection such as creating a new shapefile from that selection.

70. Click on select features (white cursor with blue and white box). Turn off all layers except for parks. Click on one of the parks. This will select the specific park (represented as a polygon feature, will be highlighted once selected).



71. Open the layer's attribute table. Note how the attribute table indicates the number of selected features. Click on show selected records (solid blue table icon) to show the selected row.
72. Return to the full table. You can also select features from the attribute table by clicking on rows. To select multiple rows (works for features as well) hold down control while selecting features. Select some rows and note howe your selections are also highlighted on the map.
73. Click on clear selection (next to select button). Close the attribute table.
74. Turn off parks and turn on counties. Select any counties you like. To select multiple features from the map frame (as opposed to the attribute table) hold down shift while selecting.
75. Right click on the layer and choose Data > Export Features.
76. The default location (geodatabase) is fine. Name the output My_Counties. Click OK.

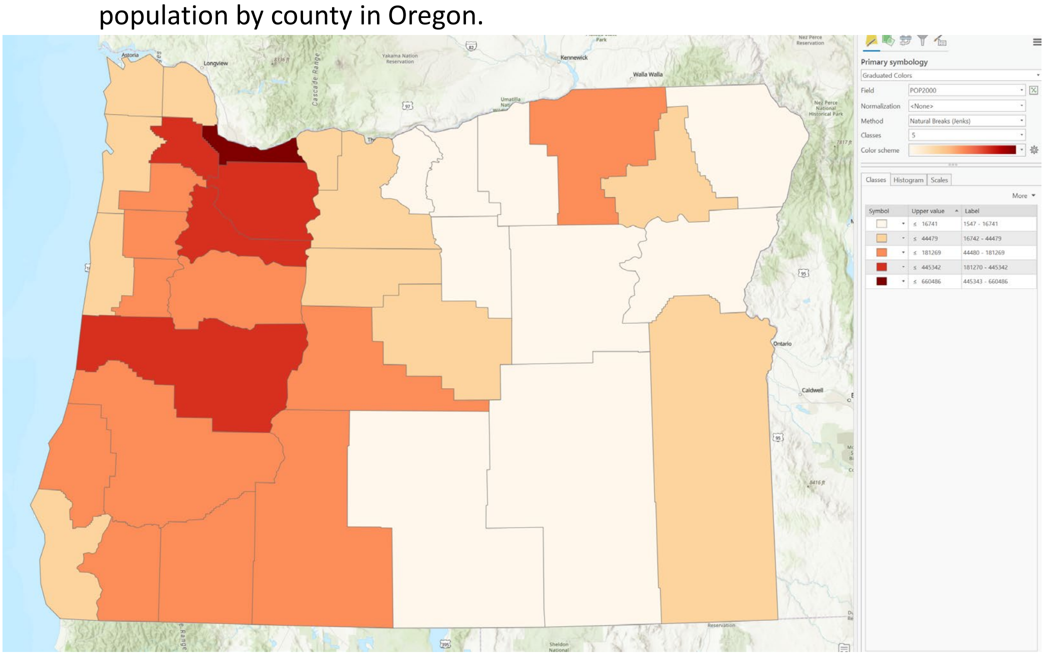


77. If prompted to add the data as a new layer, select yes (might be automatic depending on settings).
78. Clear selection, turn off countries. Note how you have created a new layer of only the selected counties.

Part C: Advanced Symbology and Calculations

Symbology can get more advanced than just aesthetics. We can base symbology off variables (attributes) in our data.

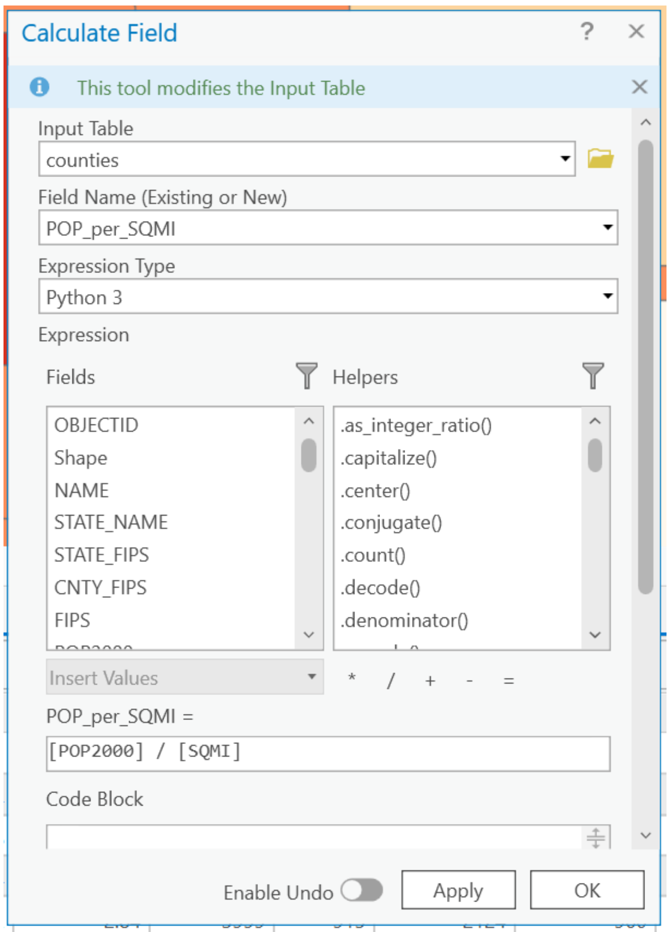
79. Turn on counties.
80. Open Symbology. Change to Graduated Colors. Under fields change the value to POP2000. Choose a color ramp you like and click apply. We now have a map showing the distribution of population by county in Oregon.



81. We need to normalize our data in order to deal with the MAUP (modifiable aerial unit problem, there are distortions in the data distribution given the irregular size of the counties, population

is not evenly distributed across counties). To solve this problem, we will create a new population density field by diving the population by the area of each county.

82. Open the attribute table. Select Add Field. Name it POP_Per_SQMI. Change the data type to double (decimal, remember datatypes!). Click save. The new field will be appended to the end of our attribute table.
83. Sort the Attribute Table based on population by right clicking the POP2000 field and selecting Sort Ascending.
84. Right click the column (Field), chose Calculate Field. If warned you are entering an edit session, click OK. In the field calculator window we can write scripts to perform table calculations (similar to Excel expressions). Write the following expression (double click on field names and single click operators to build the expression, or copy past from this document): !POP2000! / !SQMI!



85. Click OK to run the calculation and populate our population density field (number of people per square mile in each county).
86. Change the Symbology value to our new population density field. Note how the distribution changes.

Task

(Follow below instructions and answer questions using what you learned in the tutorial)

87. Turn on the counties layer.

88. What is the name of the county in the northeast corner of Oregon?
89. How many counties are there in Oregon?
90. Which county has the smallest 2000 population?
91. How long is the southern border of Oregon?
92. Turn on the Volcanoes layer.
93. Which county is Blue Lake Crater in?
94. Turn on the highways layer.
95. What is the name of the highway close to Blue Lake Crater?
96. Which volcano is closest to Blue Lake Crate?

Challenge:

- Turn off the display for all of the layers except Highways, Counties and Volcanoes.
- Make the outline of the counties Gray 60% with outline width of 1.
- Change the symbol for the Interstate to the ArcGIS 2D Highway symbol. Do not change the color. For the remaining roads, change all symbols to the “Major Road” symbol in “Ultra Blue”.

Task #2

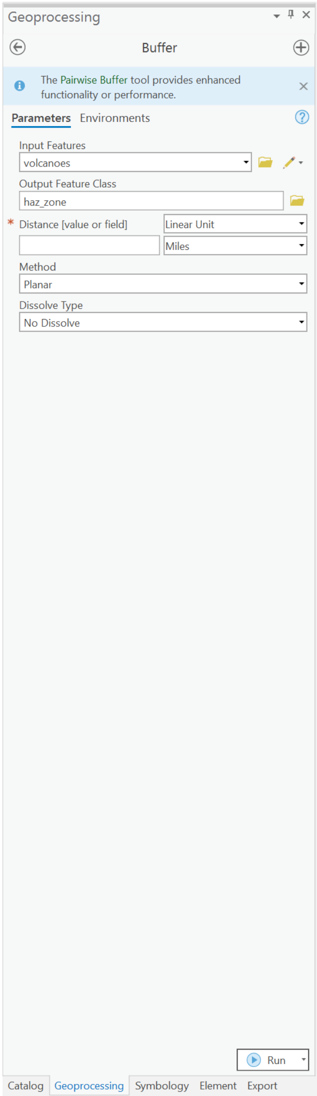
(Build a simple model)

In this tutorial we will perform simple modeling operations using this layers in Oregon.

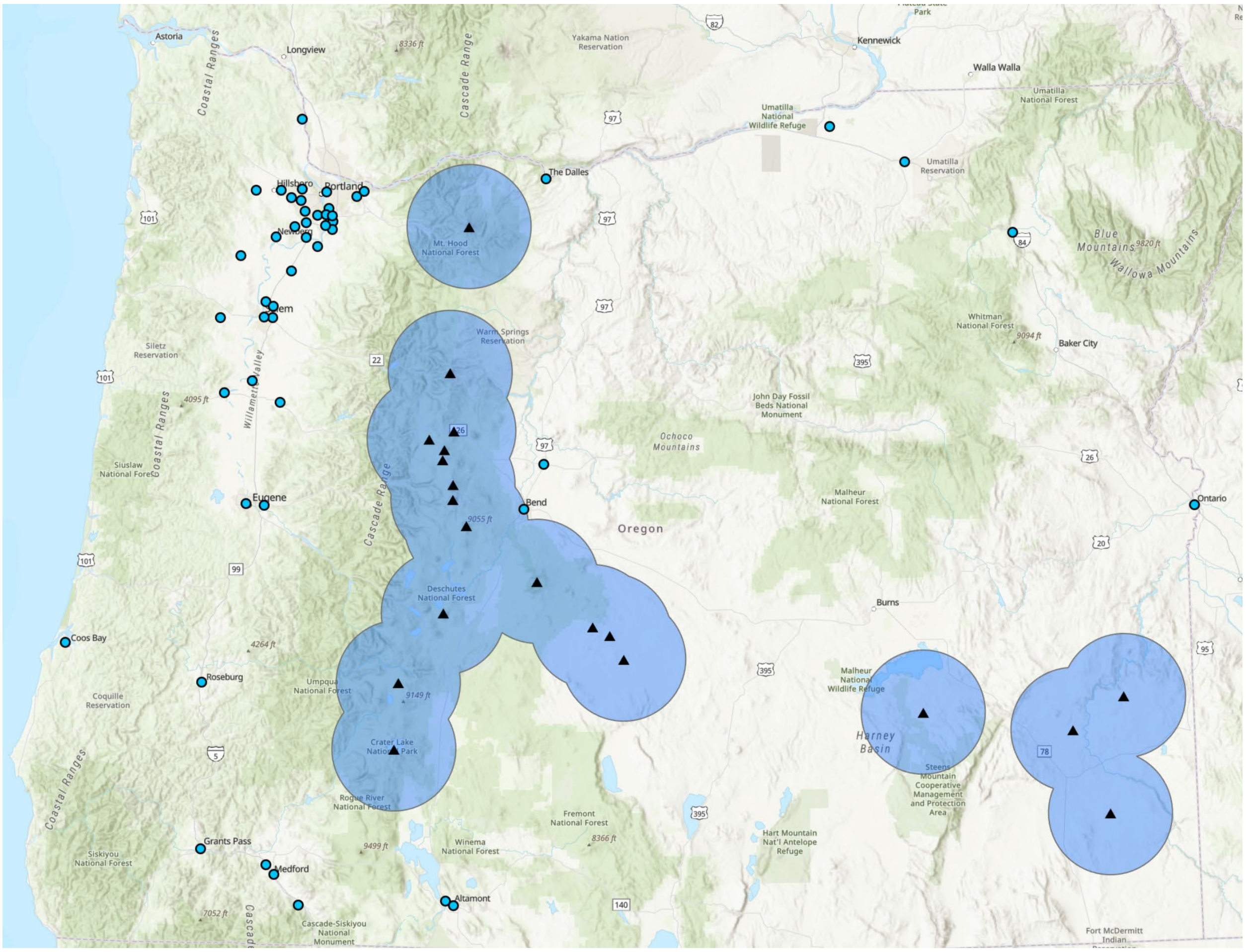
Part A: Build Model by Hand

We will manually construct a model that tells us how many major cities are within a hazard zone of a volcano.

97. Turn on the major cities and volcanoes layers.
98. The approximate danger radius of a volcano is 20 miles. We will use the Buffer tool to create buffers around the volcanoes representing this radius, this will be our hazard zone.
99. Click on View > Geoprocessing to open the geoprocessing pane. Search Buffer under Find Tools. Click on Buffer (Analysis Tools) to open the buffer tool. For input features select volcanoes. Name the output feature class Haz_Zone. Set the distance as a linear unit to 20 Miles. Set Dissolve to Dissolve all Output Features into a Single Feature. Leave all other options default. Click Run.



100. Buffers representing the hazard zone will be generated around the volcanoes.

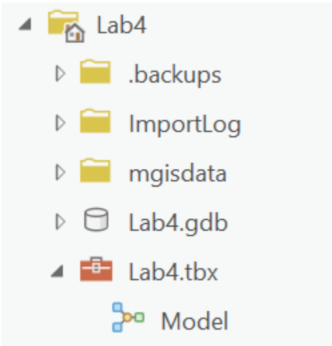


101. As we can see, only 1 major city falls into this hazard zone.
102. Identify the city.

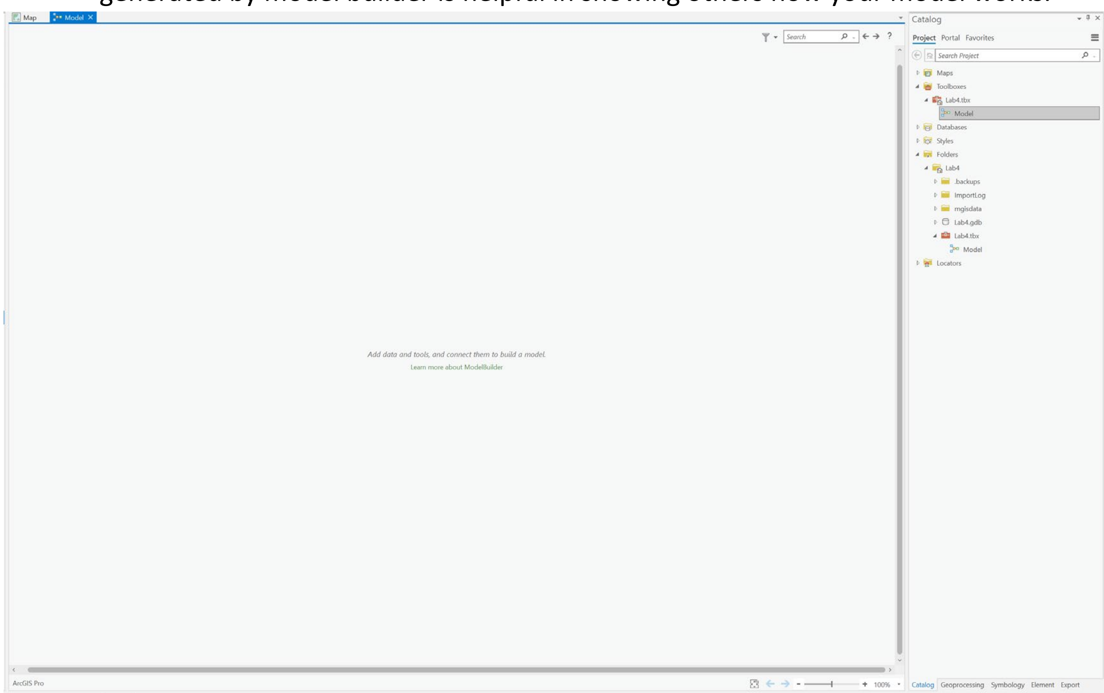
Part B: Build Model using Model Builder

We will now use model builder to automate the process. Model builder will create a custom tool that we can use to easily run through the model. While our model is simple, more complex models can have many steps and take significant amounts of time to run through by hand, so automating them using model builder is common (or if you know how to code, Python can be used for even more functionality and user control).

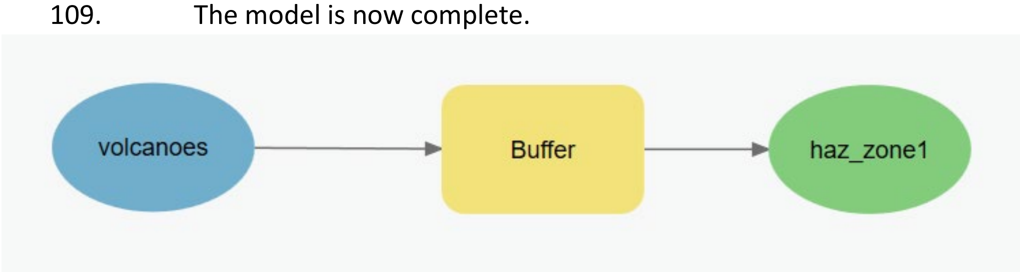
103. Expand the Lab4 folder. Models are stored in a toolbox. Rightclick the Lab4 toolbox. Select New > Model.



104. Double click on the model to open the Model Frame. This is where we will build our model. Model Builder works like an interactive flow chart, in which data and tools can be dragged in, programmed, and connected. Besides automating geoprocessing, the flowchart generated by model builder is helpful in showing others how your model works.



105. Drag in the volcanoes layer (our data).
106. Go back to geoprocessing and drag in the Buffer tool.
107. Click and drag from volcanoes to Buffer and select Input Features.
108. Double click on Buffer, set up the tool as in Part A, except make the output name haz_zone1 (so we don't overwrite our original).
109. The model is now complete.



110. Right click in the white space and select Run.
111. Close the model window when it is finished running.
112. Under the ModelBuilder tab, click on Save.
113. Go back to the Map Frame and open the Catalog. Expand the Lab4 geodatabase. Note how the new hazard zone generated from the model is in the geodatabase. Add it to the Map Frame.

Lab – Environmental Exposure Modeling

Instructions: In this lab we will partially recreate a geospatial model that predicts potential exposure to contaminants from abandoned uranium mines (AUMs) on the Navajo Nation. This lab will utilize all of the GIS skills and knowledge you have learned so far.

CONVENTIONS USED IN THESE LABORATORY ASSIGNMENTS

When the instructions refer to two or more keys on the keyboard, linked by a "+", it means to press them simultaneously. When ">" or "→" is used, it means to press the keys (or perform some other actions) sequentially. Thus,

- Ctrl + V means to press the Control and the V buttons at the same time (to paste the last item on your clipboard into a document), whereas
- Insert > New Layout means to click on the Insert tab and then New Layout

You will frequently use keyboard shortcuts such as:

- Ctrl + C to copy
- Ctrl + V to paste
- Ctrl + Z to undo the last action

DO SAVE AND BACK UP YOUR FILES. You cannot believe how frustrating it is to lose all your work and have to start again if ArcGIS crashes. This can happen when you are performing complex calculations. Thus develop the habit from the onset of frequently saving your work after major steps or processes.

BE SURE TO SAVE YOUR WORK OFTEN! ARCGIS IS KNOWN TO BE "BUGGY" AND CAN CRASH.

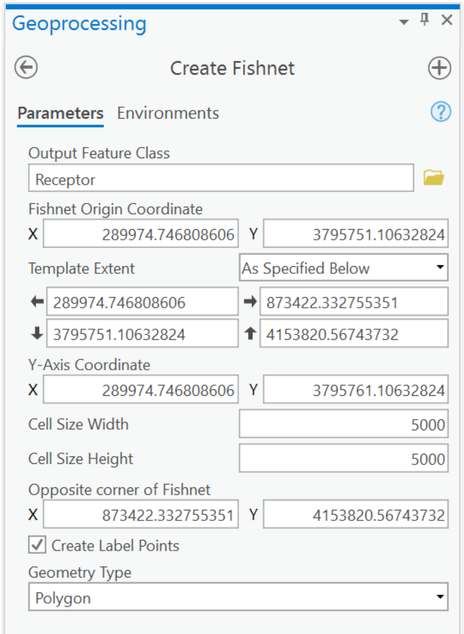
Task

(Develop an environmental machine learning driven multi-criteria decision analysis model)

1. Create a new folder (Lab5) in your GIS folder. Copy the lab data to this folder.
2. Open ArcGIS Pro. Create a new project and save it in the Lab5 folder.
3. Add in all of the lab data (environmental criteria rasters, Navajo Nation boundary, and soil sample validation data points, and AUM points, and tools)

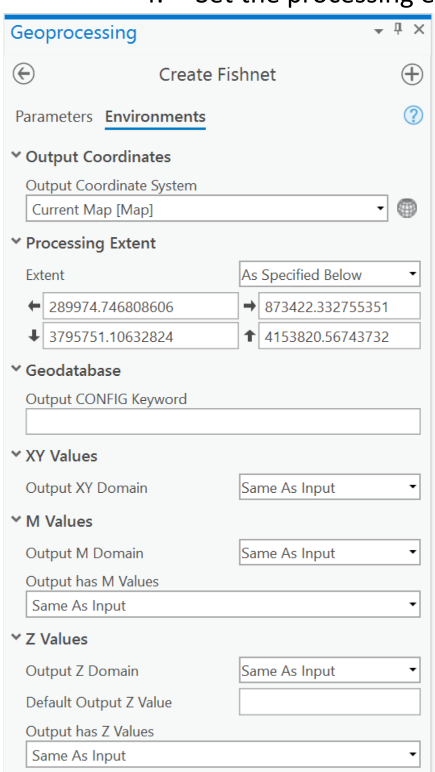
We will now generate the Proximity layer using one of our custom script tools. This script tools works off of receptors. We need to spatially join our data to a receptor which will then be input into the tool.

4. Open the create fishnet tool. Set the parameters as follows:
    a. Output Feature Class = Receptor
    b. Set the template extent to the Navajo Nation boundary layer. This will generate a receptor grid the size of the Navajo Nation. Note how the coordinate fields are automatically populated.
    c. We now how to set the cell width/height. This will determine the number of cells in our grid (resolution of receptor). Set the cell width/height = 5000.
    d. Change the geometry type to polygon.



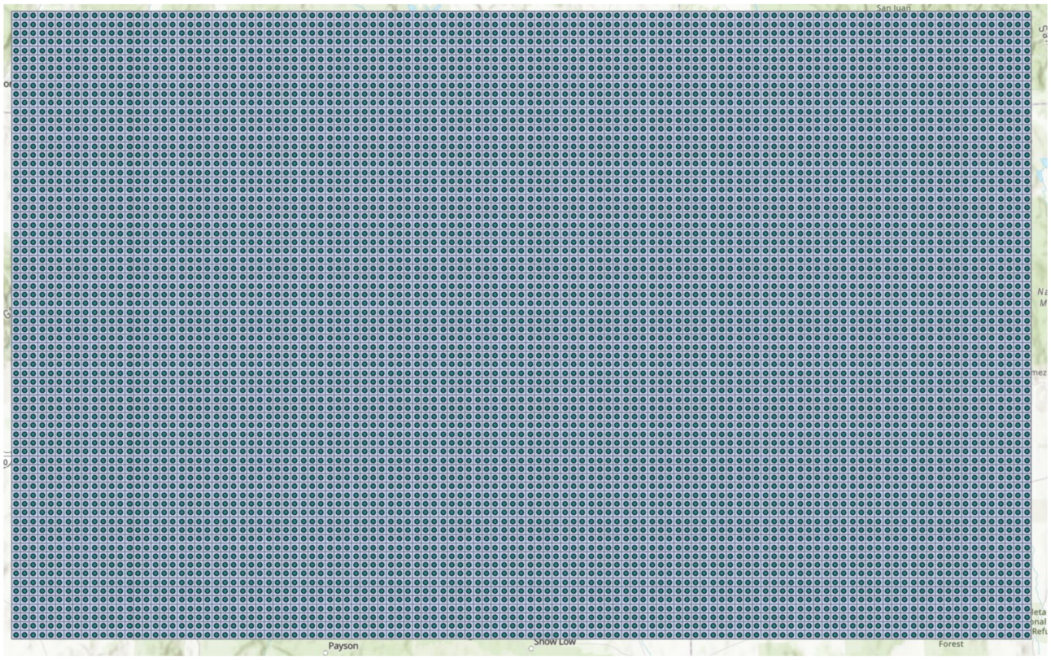
e. Under Environments, change the Output Coordinate system to the Current Map. Check the map properties and see how the coordinate system is NAD1983 UTM Zone12N. Remember from last week that we want to use a coordinate system that provides the most accurate projection for our localized area, which this one does.

f. Set the processing extent to the Navajo Nation boundary.



g. Click on Run.

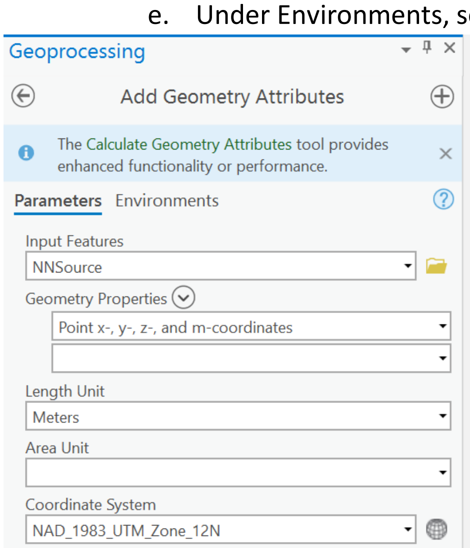
A recptor grid, and points representing the centroids of the cells, is generated.



5. Turn off the grid and leave on the points. We will use points because they work better for interpolation.

We will generate new coordinates for our mine points (NNSource). We do this because the reported coordinates in Lat./Long. Will not work for our current coordinate system.

6. Open the Add Geometry Attributes tool. Set the parameters as follows:
    a. Input Features = NNSource
    b. Geometry Properties = Point coordinates
    c. Length Unit = Meters
    d. Coordinate System = Current Map
    e. Under Environments, set Output Coordinate System = Current Map

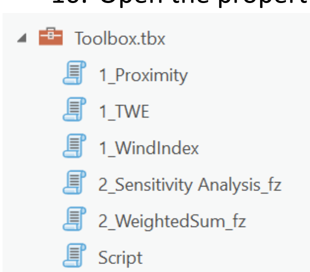


    f. Click Run.

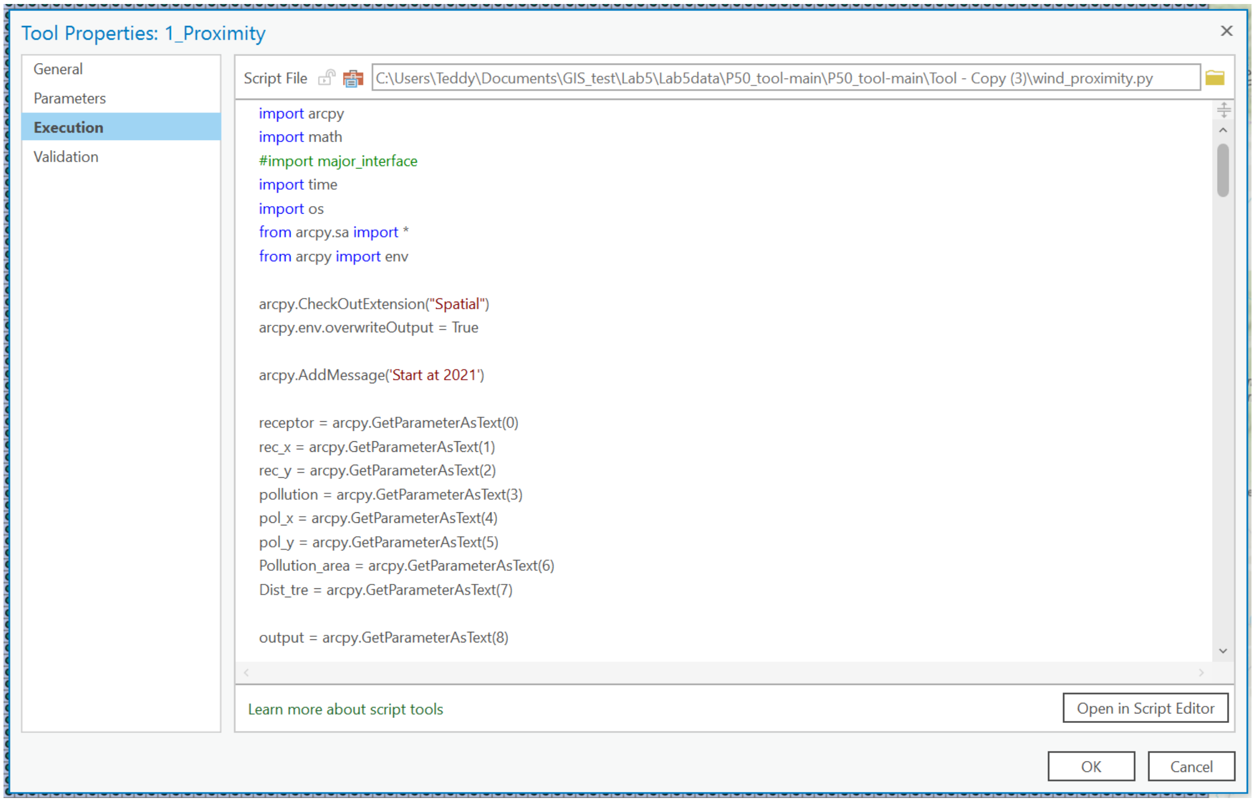
7. Open the attribute table for NNSource. Note how the new correct coordinates have been appended to the end of the attribute table.

POINT_X	POINT_Y
675186.73235	4062979.70066
677767.523394	4064255.38923
675207.104731	4066282.07434
464174.220323	3995718.24525
461981.378485	3972533.20361
464069.76434	3973915.35121
463818.859302	3977642.40003
469922.510382	3964445.75441
467400.936294	3967869.77822
464642.401427	3970419.98161
464767.289915	3970693.67069
465273.571154	3970853.19852
464819.667351	3970159.56732
676633.022003	4066117.86829
466302.037351	3970690.05959
465965.262843	3970559.60546
465924.103485	3970197.76116
466528.857748	3970170.00586
466308.145158	3970102.52593

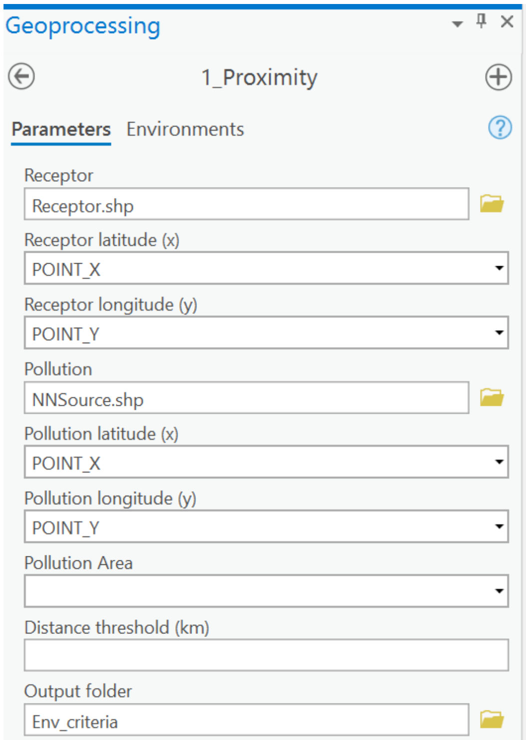
8. Repeat this process for the Receptor layer, which current has no coordinate attributes.
9. The recptor is current stored in a geo-database. This might caught issues in our script tool. Export the recptor layer as a new feature named Receptor. Save it to your Lab5 folder. Remove the old receptor layer.
10. Open the properties for the proximity script tool.



11. Click on the execution tab. Change the file path to where the script is stored. Select the python file containing the script: wind_proximity.py.

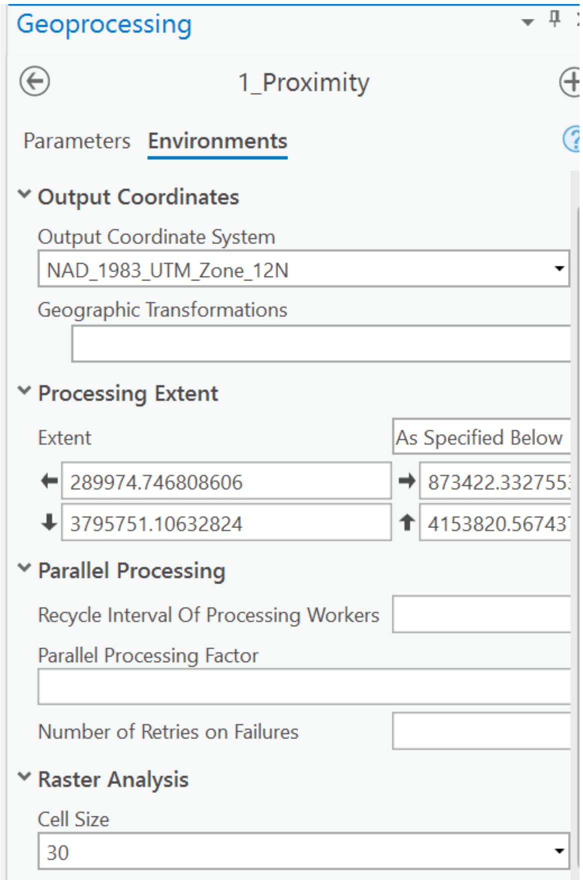


12. Click ok.
13. Open the proximity tool. Set the parameters as follows:
    a. Receptor = Receptor.shp (you will have to navigate to the file, and may need to refresh the file browser for the newly created receptor shapefile to apprear).
    b. Receptor latitude (x) = POINT_X
    c. Receptor longitude (y) = POINT_Y
    d. Pollution = NNSource.shp
    e. Set X,Y the same as steps b,c.
    f. Output Folder = Env_criteria



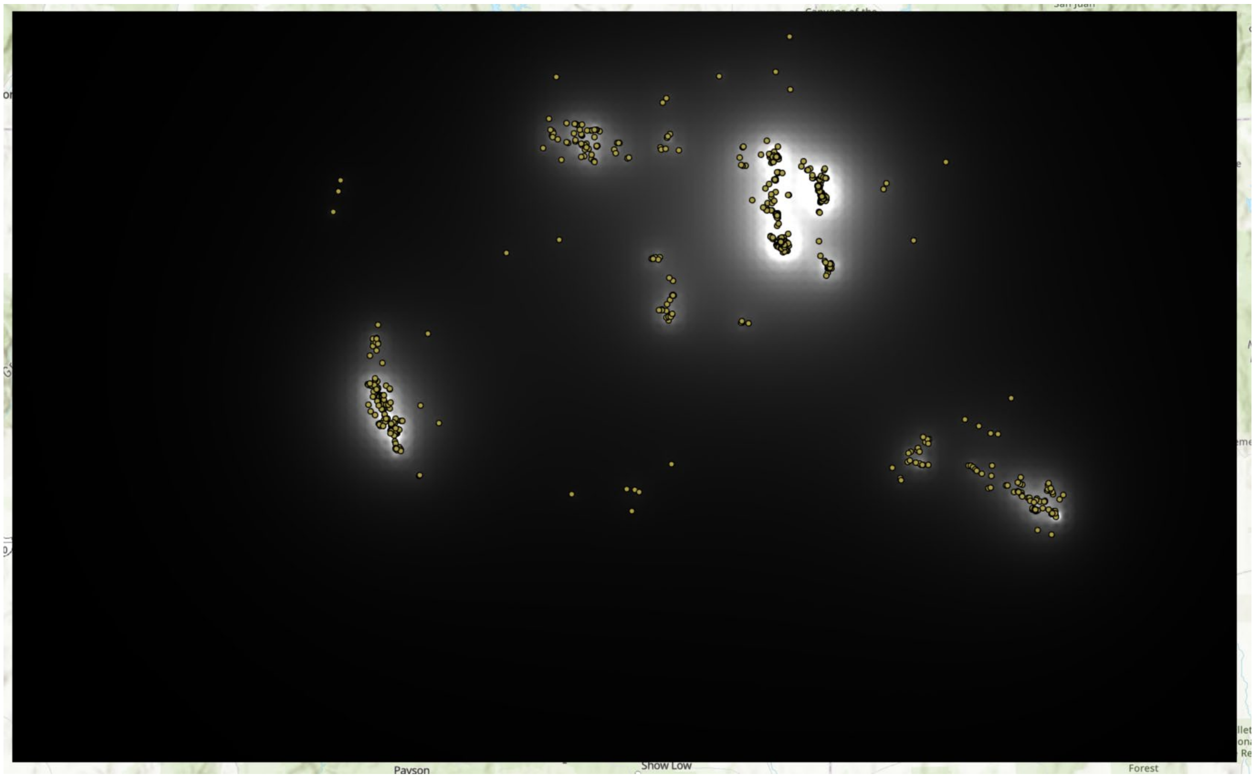
Under environments

g. Output Coordinate System = Current Map
h. Processing Extent = NNBoundary
i. Cell Size = 30



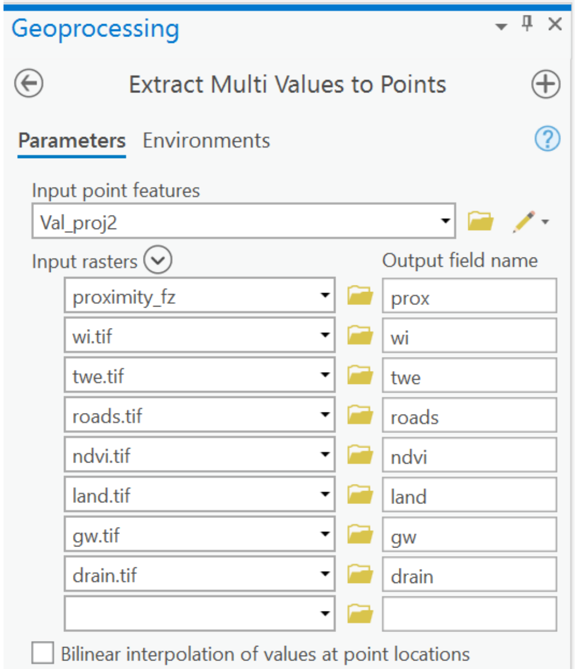
j. Run the tool (should take around 3-5 minutes to run depending on your computer).

14. Once finished, navigate to your Env_criteria folder in the Catalog. Referesh the folder and the generated layers will appear (proximity_fz). Besides generating the proximity layer, this tool has applied the apprriate fuzzy-logic transformation to it as well. Add this layer to the map frame.
15. If it asks if you want to build pyramids, say yes.
16. Turn off the receptors and turn on the AUMs (NNSource). Note how high values in the proximity layer (white) follow the mine clusters.



We now need to extract the values from our environmental layers to our soil sample point data (Val_proj2).

17. Turn off all layers and turn on Val_proj2. This are soil samples collected across the Navajo Nation with contaminant data. Open the attribute table and note the information and contaminant type (med_U_PPM). This represents the amount of uranium in each soil sample. We will extract our enviuronmental criteria values to these points, after which we can use this layer to train our machine learning algorithm.
18. Open the Extract Multi Values to Points tool. Set the parameters as follows:
    a. Input point features = Val_proj2.
    b. Set the input rasters as our 8 environmental criteria layers. Set the output field names as follows:
        i. Proximity_fz = Prox
        ii. Wi.tif = wi
        iii. Twe.tif = twe
        iv. Roads.tif = roads
        v. Ndvi.tif = ndvi
        vi. Land.tif = land
        vii. Gw.tif = gw
        viii. Drain.tif = drain



19. Run the tool.
20. Open the attribute table. Note how the values from our criteria rasters have been appeneded to each point (value of cell that lines up with the point).

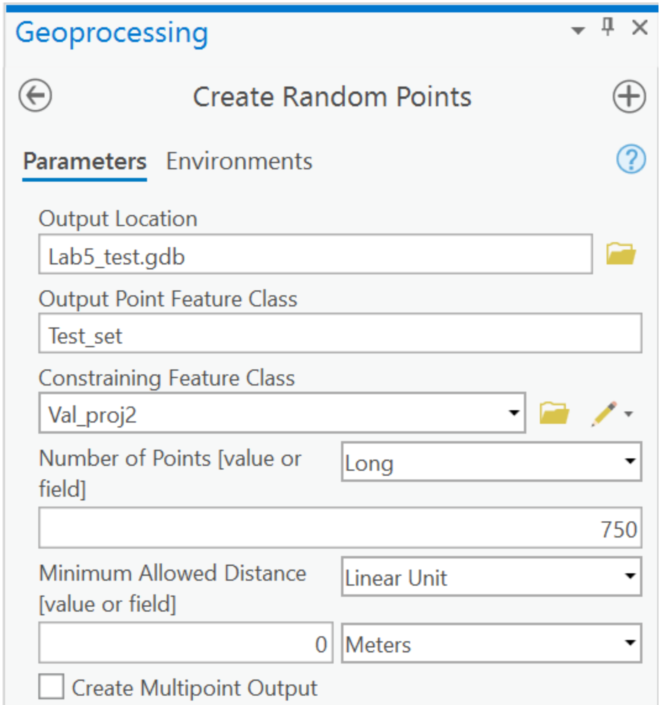
We will now train our machine learning algorithm on this data to generate importance scores for each environmental criteria.

21. First we need to split our data into training and validation subsets.
22. Open the Create Random Points tool and set the parameters as follows:
    a. Output Point Feature Class = test_set
    b. Constraining Feature Class = Val_proj2
    c. Number of Points = 750

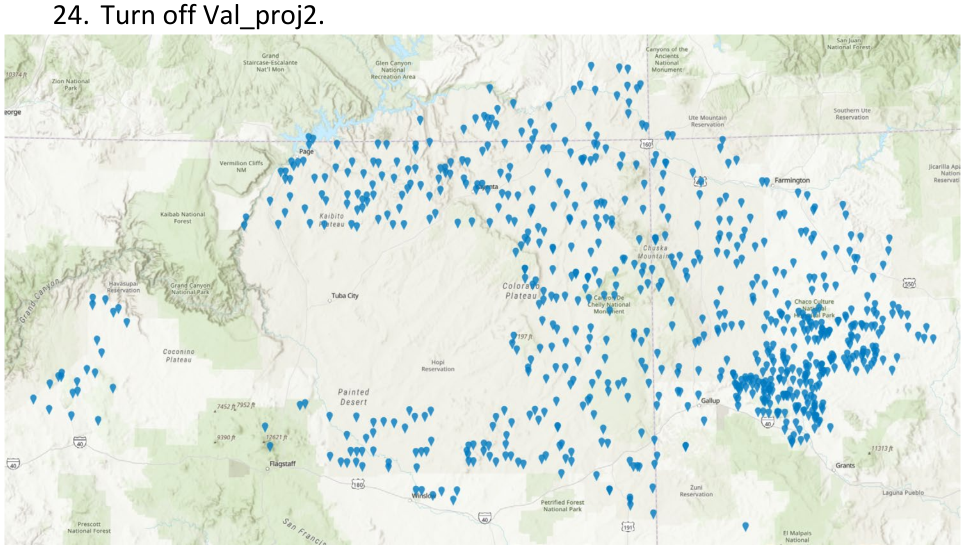
Under environments

    d. Output Coordinate System = Current Map

23. Run the tool. (This will generate a subset of 750 random points based on our input points).

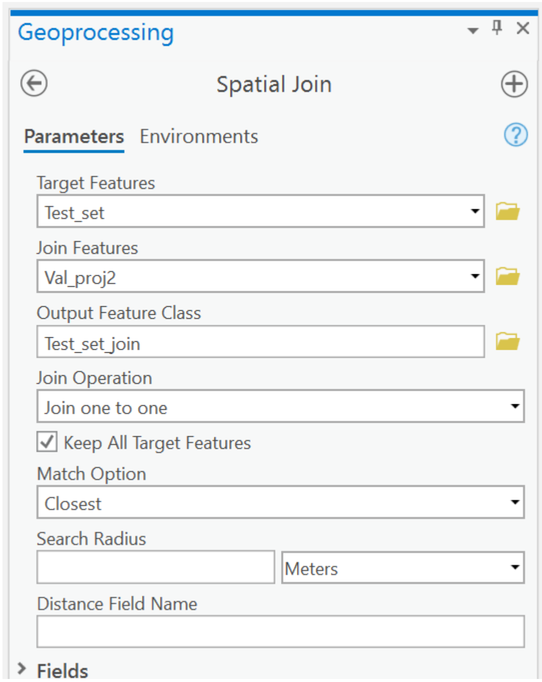


24. Turn off Val_proj2.



We now need to join back our data from the original points to these points.

25. Open the Spatial Join tool and set the parameters as follows:
    a. Target Features = test_set
    b. Join Features = Val_proj2
    c. Output Feature Class = Test_set_join
    d. Match Option = Closest
    e. Search Radius = 0



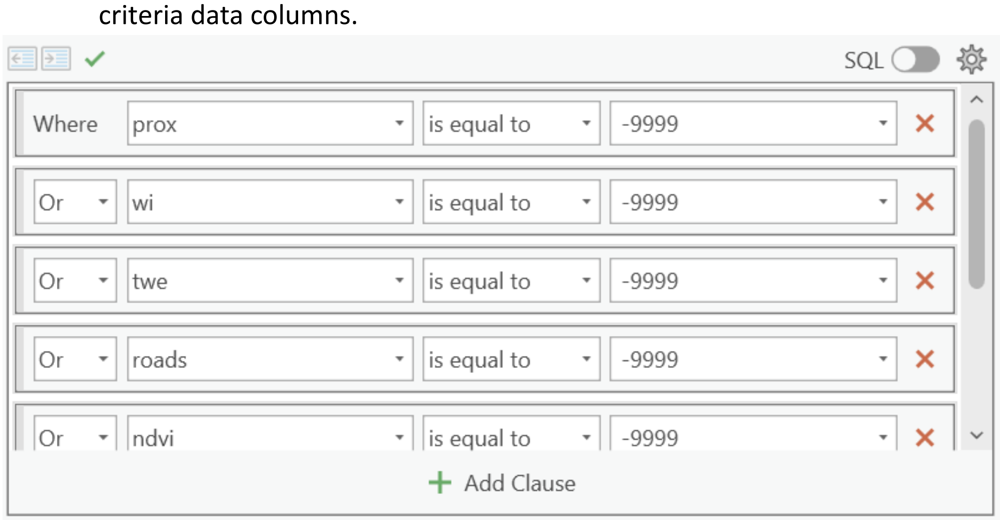
Under environments

f. Output Coordinate System = Current Map

26. Run the tool.
27. Turn off the old test_set layer. Open the attribute table of the joined layer. Note how our data has been added in.

Before we can feed this data to the random forest algorithm, we need remove missing values (-9999 is the missing value identifier for raster data in ArcGIS). This number will skew the algorithm outputs. We can select and remove rows that contain missing values.

28. Open the attribute table. Click on Select by Attribute.
29. Build an expression that looks for missing values in each row for each of our environmental criteria data columns.



Note: You can turn on SQL and past this expression in alternatively: prox = -9999 Or wi = -9999 Or twe = -9999 Or roads = -9999 Or ndvi = -9999 Or land = -9999 Or gw = -9999 Or drain = -9999

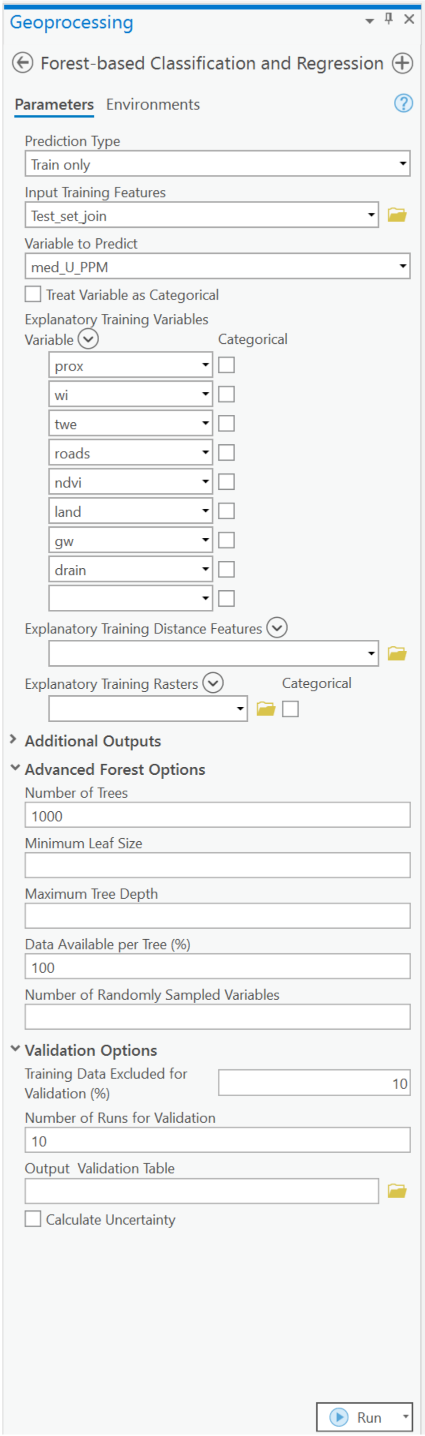
This will parse our datatable and select rows that have missing values.

30. Click OK. The bad rows will be selected (note the exact number of rows may vary for you.)
31. Click on delete to get rid of these rows.
32. Under pending edits click on save edits to finalize the deletion.

Our data is now ready to be input into random forest.

33. Open the Forest Based Classification and Regression tool (spatial stats). Set the parameters as follows:
    a. Input Training Features = test_set_join
    b. Variable to Predict = med_U_PPM (random forest will decide how important each criteria is in predicting uranium)
    c. Add in our criterial variables under Explanatory Training Variables
    d. Expand Advanced Forest Options and set parameters as follows:
        i. Number of Trees = 1000

    e. Under Validation Options set the parameters as follows:
        i. Number of Runs for Validation = 10



34. Run the tool. Random forest will determine the importance of our criteria.
35. Once finished, click on View Details.

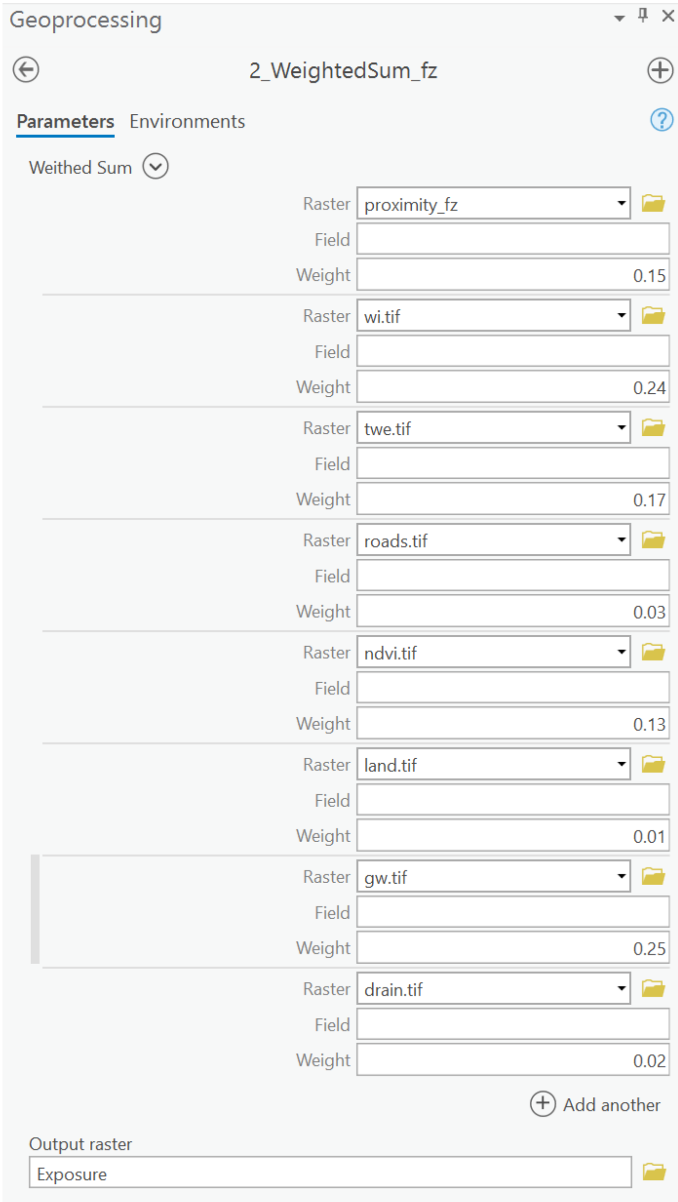
Take note of the variable importance scores (note your scores will likely vary slightly due to inherent randomness in the machine learning process).

Top Variable Importance

Variable	Importance	%
gw	287.15	24
wi	285.79	24
twe	210.11	17
prox	184.01	15
ndvi	161.21	13
roads	36.52	3
drain	21.32	2
land	15.74	1

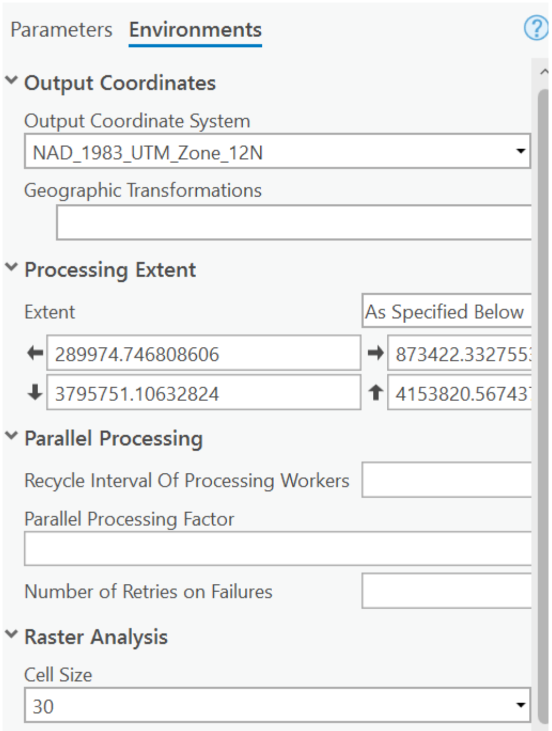
We will use these scores as weights.

36. Turn off all layers.
37. Set up the Weighted Sum script tool the same way as the Proximity tool. Set the parameters as follows:
    a. Add in the 8 environmental criteria rasters. Under weight type in the relative importance scrore (divided by 100, i.e. 24% importance = 0.24). Note: The scores need to add up to 1. Due to rounding, the reported % importances might add up to 99% (0.9) instead (stupid ESRI!). Add 0.01 to a criteria if necessary. The best bet is the most important factor (gw). Gw is listed first so it was likely rounded down. Change gw to 25% (0.25).
    b. Output raster = Exposure

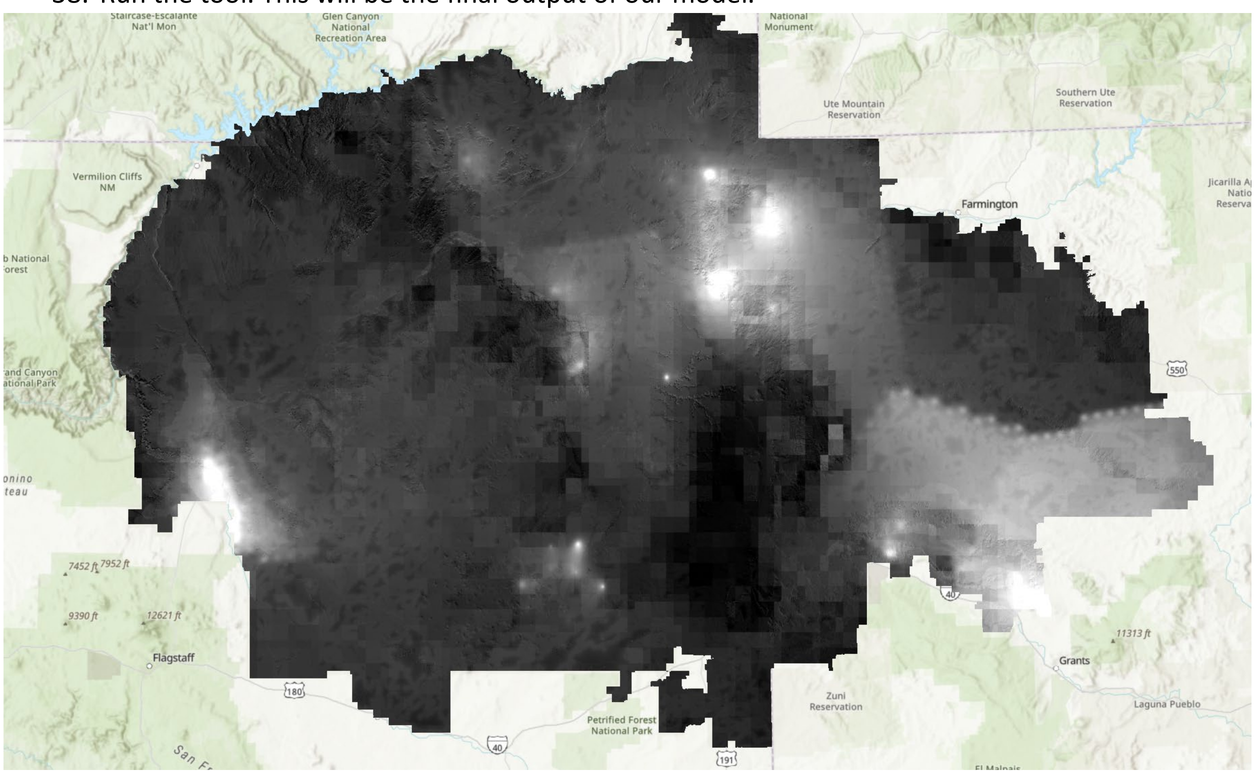


Under environments

c. Output Coordinate System = Current Map
d. Processing Extent = NNBoundary
e. Cell Size = 30



38. Run the tool. This will be the final output of our model.



39. Make a map of this predicted exposure.

Compliance

IACUC
Certifications

Certificate of Completion

OSHA EDUCATION CENTER®

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THEODROS WOLDEYOHANNES

has successfully completed the following course:

OSHA 40-Hour HAZWOPER Training

GRADUATION DATE

3/23/2019

Big Apple Occupational Safety Inc

505 Eighth Avenue, #2305, New York, NY 10018
(212) 564-7656

This Is To Certify That

Theodros Woldeyohannes
SS#: XXX-XX-XXXX
301 Allen Street, Syracuse, NY, 13210

HAS SUCCESSFULLY COMPLETED THE ENVIRONMENTAL PROTECTION AGENCY APPROVED COURSE

EPA-Lead Based Paint Inspector Initial - ONLINE WEBINAR

THIS COURSE IS APPROVED FOR PURPOSES OF CERTIFICATION UNDER THE ENVIRONMENTAL PROTECTION AGENCY - 40 CFR PART 745.225

Course Date: 02/08/2021 - 02/10/2021

Course Completion Date: 02/10/2021

Expiration Date of Interim Certification: 08/10/2021

Certificate Number: LII-21-4107

Examination Grade: 90%.

Radha Reddy
Training Director

HSE Consulting Services, LLC

Certificate of Completion

is hereby granted on this 11th day of February 2021 to:

Theodros Woldeyohannes

to certify satisfactory completion of

Radiation Safety Training

Olympus ANI Radiation Safety & Operator Training For Field Portable X-Ray Fluorescence Spectrum Analyzers

02/11/2021

Christopher R. Torell, CSP, P.G.

Date