### Thesis Prospectus 2022-23

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**Student Final Submission (date): December 13, 2022**

**Faculty Reader Approval (date): December 15, 2022**

**MES Director Approval (date):**

1. **Working title of your thesis[[1]](#endnote-1).**

**Effects of increased Discharge from Winter Storm Events on the Carbon Exports of a Suburban Low Order Stream**

1. **In 250 words or less, summarize the key background information needed to understand your research problem and question.**

Rivers and streams hold and transport a substantial amount of the global carbon (C) budget, are similar to the annual terrestrial carbon sink of 2.7 + 0.7 Pg C year-1 (Ward et al., 2017; Regenier et al., 2013). Approximately 5.7 Pg C passes through inland waters each year, with three quarters evading as CO2. The majority of the remaining portion is exported to oceans (Ward et al., 2017; Argerich, et al., 2016). The carbon in rivers is present in multiple forms of organic and inorganic forms, and it is derived from different sources. The concentrations of these pools of C are constantly fluctuating due to water discharge and watershed characteristics such as vegetation, climate, topography, soil type, primary productivity, and river size.

The carbon in a river system stems from allochthonous and autochthonous inputs, with the latter resulting from primary production of benthic algae, suspended phytoplankton and aquatic macrophytes within the system (Ward et al., 2017). Allochthonous inputs are defined as those that originate outside the river, such as carbon that comes from upland terrestrial material (like forest vegetation, etc.) Carbon inputs can be differentiated based on size (particulate organic carbon (POC), dissolved organic carbon (DOC)), as well as whether they are organic or inorganic constituents (IC) (Ward et al., 2017). The OC is derived from a mix of material including vascular plant detritus, soil organic carbon (SOC), older fossil OC from sedimentary rock erosion (petrogenic carbon), and through deposition of atmospheric particles (Ward et al., 2017; Bianchi, 2011). DIC includes the inorganic carbon found dissolved in stream water, with the fraction of the individual species dominating dictated by pH (species include carbonic acid (H2CO3), bicarbonate ion (HCO3-), and carbonate ion (CO32-)). DIC is controlled by changing precipitation patterns, groundwater influxes and respiration in the benthic and hyporheic zones of a river, as well as through water-column respiration in large rivers (Dosch, 2014; Fellows, et al., 2001). DIC leaves rivers as CO2 through evasion at the surface as well as through export along with DOC and POC.

Discharge fluctuation caused by seasonal changes and storm events has the largest control on instream C fluxes (Wallin et al., 2010; Medeiros et al., 2012; Voss et al., 2015). Measuring the concentrations and fluxes of C in a stream in response to discharge provides insight into which pools of C are affected and how the C budget of the surrounding ecosystem is impacted by storm events (Voss et al., 2015). This data is particularly relevant in the face of future projected climatic changes in the PNW including more severe drought in the summer and more intense precipitation in the rest of the year (Kunkel et al., 2013).

1. **State your research question(s).**

How does increased river discharge as a result of winter storm events effect carbon (C) exports and CO2 efflux in the small, forested stream of Snyder Creek located in the southern Puget Sound area?

1. **Situate your research problem within the relevant literature. What is the theoretical and/or practical framework of your research problem?**

The exploration of this research problem relies heavily on current models of the global carbon cycle. This model is a result of field measurements on individual processes within the cycle, whole ecosystem carbon budgets, and fundamental concepts of biogeochemistry such as respiration, mineralization, and sorption. Specifically, this research builds off research on rapid water influxes in low order streams.

A model for the mobilization of DOM from heavy rainfall or snowmelt in headwaters is known as the Pulse Shunt Concept (PSC) (Raymond et al., 2016). PSC proposes that headwater streams during storms input a major, underreported portion of the DOC that is metabolized in larger streams and then transported to the oceans. DOC is the most mobile pool and often sees a major spike in exports that peaks and falls quickly after initial storm surges. This results from labile pools of surface DOC being exhausted and unable to regenerate during periods of high precipitation (Neu et al., 2016; Voss et al., 2015). In addition to the hydrologic event, the material available in a watershed determines the type and extent of C exported in streams (Ward et al., 2017). The size and length of the DOC peak is therefore highly dependent on the individual watershed. The variability of materials, landscape, and climate can have a drastic effect on C cycling between ecosystems. Consequently, improving upon the knowledge of small stream C fluxes during storm events through small scale field research is necessary.

Like DOC, POC in streams generally increases with precipitation, however the fluxes are not nearly as rapid (Tank et al., 2017; Galy et al., 2015; Smith et al., 2013). The majority of POC enters streams during high discharge events, including both terrestrially sourced petrogenic and biogenic particulates (Tank et al., 2017). Therefore, predictions of increased extreme precipitation events will likely increase POC fluxes in streams (Hilton et al., 2012; Galy et al., 2015). However, unlike DOC, POC pools cannot be quickly depleted suggesting that a changing climate could result in a large, sustained increase in POC exports.

POC is derived from both minerals and organic matter. Petrogenic POC (typically insoluble kerogen) is not quickly mobilized, and its availability is dependent on underlying geology (Cui, et al., 2015). The exception to the incredibly slow and small inputs comes from landslides caused by extreme storms and anthropogenic land changes. Although some petrogenic POC may be transported into Snyder creek through erosion caused by heavy storm events, this pool of C is more prevalent in alpine headwaters with steep tectonically active weathering slopes (Leithold, et al., 2006). Plant derived POC on the other hand will be present and is formed in soils as result of aggregation of DOC, ablation of SOC, and microbial production (Tank et al., 2017). Typically, the majority of POC enters streams through erosion, which is aided by steep slopes, however lateral movement of fine POC through ground water can be substantial in some soils. Although it is not as recalcitrant as petrogenic POC, plant derived POC is less likely to be respired than DOC (Tank et al., 2017).

Similarly to other pools of allochthonous C exported by streams, the available organic material, underlying geology, and topography have a major influence on the type and amount of DIC that leach into streams with adequate saturation (Mayorga et al., 2005; Ward et al., 2017). Dissolved inorganic carbon (DIC) is transported to streams from soils as CO2 and HCO3-. Dissolved CO2 saturation in water increases in soils through organic matter decomposition and root respiration. As this CO2 saturated water filters through soil layers some of it is lost to the production HCO3- through the weathering of minerals.

Alpine streams with mineral rich watersheds tend to have larger proportions of HCO3- compared to streams such as Snyder creek with an OM rich lowland watershed (Ward et al., 2017). Additional dissolved CO2 accumulates in a stream through the microbial respiration of allochthonous and autochthonous OM. DIC if unaccounted for can drastically misrepresent the export of C as into oceans or through CO2 outgassing. A carbon budget of a small order stream in western Oregon revealed that 40% of the annual C exports were laterally transported in the form of DIC and 27% was evaded as CO2 (Argerich et al., 2016).

Lastly, this project will use the current understanding of riverine CO2 fluxes in streams to guide the research. Additionally, it will attempt to make a small contribution to filling the gap of knowledge about these fluxes. Carbon dioxide flux rates and gas transfer velocity vary more drastically in small streams than large rivers and are significantly greater than rivers during high discharge events (Alin et al., 2011; Wallin et al., 2010). As a result, dissolved CO2 concentrations and CO2 outgassing are particularly underestimated in small streams (Ward et al., 2017). These inaccuracies stem from the difficulty associated with constraining gas transfer velocities, underestimating global stream surface area, and a lack of field measurements (Regnier et al., 2013, Raymond et al., 2013). Quantifying CO2 efflux will be secondary to lateral export in this project however, the goal is to provide some insight into the export of this important fraction of C in Snyder Creek.

1. **Explain the significance of this research problem. Why is this research important? What are the potential contributions of your work? How might your work advance scholarship?**

Quantifying the organic and inorganic carbon concentrations in relation to discharge will reveal how precipitation impacts carbon fluxes in Snyder Creek. This will provide some insight into C fluxes for the stream based on climate projections. It will also set a baseline for future studies on Snyder Creek and similar streams. In the Pacific Northwest, climate change is projected to cause an increase in extreme weather events during the rainy season as well as increased drought in summers and higher annual temperatures (Kunkel et al., 2013, Christensen et al, 2007). There is expected to be 13% (+ 7%) more days that experience greater than one inch of rain in 2050 in comparison with the beginning of the century (Kunkel et al., 2013, Christensen et al., 2007). Meanwhile summer rainfall is projected to decrease by 6%-8% although some models predict a far greater degree of drought (Mote et al., 2013, Christensen et al., 2007). Hydrological models show initial decreases in annual stream flow with a small increase by 2040; however, stream flow is projected to increase by 30.3% by the 2080s (Wu et al., 2013). Annual temperatures are projected to steadily increase by1.68° C (?) during the same time frame and summer temperatures by 2.10° C (Wu et al., 2012). This will result in drastic changes to stream chemistry and consequently the production and export of carbon (Singh et al., 2021). The type and amount of C in a stream and how changes in flow and temperature effect it is dependent on stream and watershed characteristics (vegetation, surface/ soil type and texture, landscape, etc.) (Neu, 2016; Luce et al., 2014). Measuring the organic and inorganic carbon concentrations in relation to discharge will reveal how weather events impact carbon fluxes in Snyder Creek. It will also give some insight into a future C budget based on climate projections and set a baseline for future studies on similar streams.

The majority of studies are on large rivers, but as more data is emerging it has become clear that headwaters play an important role in inputting the C that is present in larger rivers and is released to the ocean (Ward et al., 2017; Leithold et al., 2006; Schlessinger & Bernhardt, 2013). As rivers transition to higher order rivers the concentration of OC transitions from allochthonous to autochthonous as a result of changes in riverbank to stream proportion and light availability (Creed et al., 2015). Small rivers are likely responsible for the input of the majority of aged POM to oceans (Leithold, et al., 2006). Consequently, the watersheds of low order streams are at the highest risk of losing relatively stable pools of C (Ward et al., 2017). Yet, this same recalcitrant C has the greatest potential to be transported to the deep oceans for long term storage. With future storm events projected to increase in the PNW, small streams are at risk of exporting larger than usual amounts of this pool of C (Tank et al., 2017; Voss et al., 2017). A 2012 study tracked upland sediment and particulate organic carbon biomarkers during a storm event and found that OC from headwaters traveled significantly further down river than during base river flow; in fact, during the storm event, they traveled all the way to the point of saltwater intrusion (Medeiros et al., 2012).

The results from studies that have investigated C budgets in small streams suggest that the role of forests as carbon sinks may be far less than are reported if the export of C via streams is not properly accounted for (Argerich et al., 2016; Wallin et al., 2010). This proposed study will provide an important glimpse into the export of C in this stream in response to winter storm events. Measuring all pools of C in the creek individually, will reveal which pools are available in the watershed and how discharge interacts with them. Similar studies are limited and mostly reference studies on alpine streams which have steep topography, less vegetation, and abundant minerals in the soil. Little to none exist on streams in this region, in low elevation suburban watersheds, that flow directly into the ocean.

1. **Summarize your study design[[2]](#endnote-2). If applicable, identify the key variables in your study. What is their relationship to each other? For example, which variables are you considering as independent (explanatory) and dependent (response)?**

This study will measure the different pools of carbon in a stream in the winter during storm events and between storms at base flow. During storm events, samples and measurements will be collected between four and five times starting at the beginning of the storm and ending as the hydrograph recedes. The independent variable of the is discharge and the dependent variables are the C concentrations in the stream. This includes DIC, POC, DOC, and evasion of CO2 to the atmosphere. I will measure/ calculate these variables during storm events, ideally sampling several rising hydrograph points, a point at peak discharge, and one point representing the falling limb of the hydrograph. All the measurements will be taken during the winter/ spring and therefore will be during relatively high discharge compared to summer. The goal is to gain a picture of how rapid increases in discharge affect concentrations and export different forms of C. Some additional variables that will be important in the data analyses are pH, dissolved oxygen, and temperature. These variables should be impacted to some degree by discharge and have influence over the flux of both inorganic and organic C within the stream. Weather depending, different intensities of storms (ideally three to four) will be targeted to gain data on how different amounts of discharge increase impact in stream C fluxes.

 Snyder creek is located almost entirely on the Evergreen State College campus in Olympia, WA and flows into the Puget sound. The drainage basin for the creek is around 0.25 square miles and the creek is roughly 1600m long (Fisheries Consultants, Inc 2007). The stream starts at a part of the campus with paved land, buildings, and roads. It quickly enters a protected piece of forest and does not pass near roads and buildings again until it reaches private property near the shoreline. The watershed is a mixed conifer forest with a moderate to flat slope except for near the shoreline where a small amount of erosion is occurring (Blue Coast Engineering, 2021).

1. **Describe the data that will be the foundation of your thesis. Will you use existing data, or gather new data (or both)? Describe the process of acquiring or collecting data[[3]](#endnote-3).**

**Field Measurements**

New data will be acquired for this thesis. The data that will be obtained from in field measurements include, temperature, depth, water velocity, pH, and pCO2 levels (if possible), and dissolved oxygen concentrations. A pH meter will be used to collect pH levels and a YSI probe will be used to collect dissolved oxygen and temperature. These measurements will be made five times over the course of each storm. Velocity measurements will be made in a straight section of the river.

**Samples**

Several measurements will be collected and processed in the field, and then sent out for further analysis, which includes the organic and inorganic carbon concentrations. The organic fractions include dissolved organic carbon (DOC), and fine particulate organic carbon (FPOC) and coarse particulate organic carbon (CPOC). Furthermore, DIC will also be collected. These samples will be sent to different labs as they require unique analyses. The POC samples will be filtered in field to obtain the bulk size fractions for CPOC and FPOC. CPOC fraction includes particulate > 63um and FPOC includes 0.7-63 um. Coarse and fine particulates will be analyzed for C:N ratios, and possible isotopic composition (13C). In addition, measurements will be taken for coarse and fine suspended sediment concentrations, with these analyses done at Evergreen. DOC concentrations will be determined using a CHN analyzer. The fluxes of these three variables will be calculated using the discharge data.

**Calculations**

 CO2 evasion rates will be calculated using instream CO2 levels, gas transfer coefficients(kgas), and stream discharge. Discharge will be calculated from depth and velocity measurements. The equation that will be used ECO2=(KCO2\*Q\*t(pCO2 atm -pCO2water)). KCO2 is the CO2 transfer rate, Q is discharge, t is nominal travel time and (pCO2 atm -pCO2water) is the difference between CO2 concentration in stream and in the atmosphere (Argerich et al., 2016).

1. **Summarize your methods of data analysis. If applicable, discuss any specific techniques, tests, or approaches that you will use to answer your research question.**

1. Propagation of error will be used to combine the uncertainties of multiple measurements to gain an accurate uncertainty within the different pools of C exports in the study.

2. A Shapiro-Wilk’s test for normality will be used to determine if the variables are normally distributed.

3. Standard linear regression will then be used to assess the relationship between the different carbon pools and discharge over the course of the seasonal hydrograph

4. An Anova will be used to assess if the different C pools vary depending on the stage of the storm event and between events at base flow.

5. Another Anova will be used to assess if peak C concentrations are different between storm events.

1. **Address the ethical issues[[4]](#endnote-4) raised by your thesis work. Include issues such as risks to anyone involved in the research, as well as specific people or groups that might benefit from or be harmed by your thesis work, perhaps depending on your results. List any specific reviews you must complete first (e.g., Human Subjects Review or Animal Use Protocol Form).**

The land that I will be carrying my research out on is the ancestral land of the Coast Salish indigenous people, who were forcibly removed by federal accession.

This study will require the use of disposable materials including filters and nitrile gloves. These materials will likely end up in a landfill. The justification for producing this waste is that this research aims to provide data on the loss of C through stream export in the Evergreen Forest. The hope is that this data can inform if there is a need for future land use changes to limit erosion and runoff in this watershed. It will also provide a baseline for future studies as precipitation is projected to increase in the region.

This research will require gathering data and samples from a stream during storms. To ensure my safety I will make sure to let others know when and where I will be, take appropriate precaution, and have a communication device that is able to reach help if needed. If winds are too high, I will refrain from entering the field until they reach a safe level.

1. **List specific research permits[[5]](#endnote-5) or permissions you need to obtain before you begin collecting data (e.g. landowner permissions, agency permits).**

There are not any permits needed for my data collection.

1. **Reflect on how your positionality as a researcher could affect your results and how you will account for this in the research process[[6]](#endnote-6).**

I am relatively new to the study of hydrology, and aquatic C as such I come to this research with relatively little expectations. I am fortunate that I do not have any incentive to produce a clean story or specific outcome. However, I do have ideas about what the results may be based on previous research for this study. Therefore, during the data analysis for this project, I need to make sure to not aim towards any specific results. If I see results that go against previous research, I will accept these results as opposed to finding a pathway toa different outcome.

1. **Provide at least a rough estimate of the costs associated with conducting your research, if any.  Provide details about each budget item so that the breakdown of the final cost is clear.**

The bulk of the costs associated with this research will be allocated to getting samples analyzed by multiple labs. I plan on having around 30 samples for each type of C analyses however it depends on the number of storms samples. This means that I will send out a total of roughly 120 samples for analyses. I am waiting to hear back from labs that I have reached out to for costs however I am currently estimating this cost to be around $2,000 however it could be more or slightly less.

Additional costs should be around $300 and will be used for to purchase filters, glass bottles, capsules, gloves, and other sampling and lab materials.

1. **Provide a detailed working outline of your thesis.**
2. **Abstract**
	1. Introduction of Stream C Fluxes and influence from storms
	2. Justification for Study (projected increased precipitation, lack of data, and importance of quantifying C exports in response to discharge)
	3. Brief Description of Study Design
	4. Summary of Findings
3. **Title Page**
4. **Table of Contents**
5. **Introduction**
6. **Literature Review**
7. **Overview/ roadmap**

**Different Carbon Pools**

1. **Terrestrial Sources**
	1. Allochthonous (terrestrial) vs. Autochthonous C in rivers
	2. Allochthonous (DOC)
	3. Allochthonous (POC)
2. **Soil Organic Carbon (SOC)**
3. **Petrogenic Organic Carbon**
	1. Differences between large rivers and small streams/ headwaters
	2. Differences between streams (topography and location)
4. **Autochthonous Carbon**
	1. Microbial activity
	2. Nutrient availability
	3. River characteristics and C production
5. **Nitrogen and Phosphorous in Streams in relation to C in rivers**
	1. Nitrogen
	2. Phosphorous
	3. Other chemicals
6. **Inorganic Carbon**
	1. DIC pools
	2. Hyper saturation
	3. CO2 efflux
	4. Hydrology impacts on efflux
	5. pH controls on DIC
	6. Terrestrial controls on DIC

**Climate Influences**

1. **Overland Flow/ Storm Events impact on C stream exports**
	1. Seasonal changes vs rapid changes from storms and stream C response
	2. Increases in usual discharge and stream C response
	3. Review of different pools reaction
	4. Prediction of what C response will be in Snyder Creek based on previous research and Snyder Creek Characteristics
2. **Climate Change Impacts in the PNW**
	1. Changes in annual precipitation patterns
	2. Changes in annual temperatures
	3. Changes in stream flow
	4. **Effects on C export**
3. **Land Degradation/ deforestation impacts on river C**
	1. Change in c pools
	2. Change in age of carbon
	3. Change in response to increased discharge
4. **Small Streams**
	1. Alpine vs low elevation streams
	2. Watershed characteristics
5. **Snyder Creek Characteristics**
	1. Underlying geology
	2. Topography
	3. Previous research (CO2)
6. **Conclusion**
7. **Methods**
8. **Results**
	1. Total C exports by pool over the course of the seasonal hydrograph
	2. C exports by degree of precipitation event and in comparison to base flow measurements
	3. C concentrations over the course of each storm from start to finish
	4. Temperature, pH, and dissolved oxygen concentrations over the course of the hydrograph
9. **Discussion**
	1. Discuss temporal patterns from first sampling to last sampling
	2. Discuss base flow vs storm event and degree of discharge increase
	3. Discuss temperature and pH in regards to discharge and C pools
	4. Discuss possible implications for C exports in the face of increased discharge events (quantity and intensity)
10. **Conclusion**
11. **Provide a specific work plan and a timeline for each of the major tasks in the work plan. Be as realistic and specific as you can at this point, including the deadlines for Spring quarter.**

**Dec 16th** Detailed Rough draft of sampling procedures and sample storage, perspective Sampling Schedule, and list of materials, lab needs and how to go about getting needed materials and lab time-

**January 1st** Finalized Weather Dependent Sampling schedule, Second Draft of Lit review, completed grant Funding proposals, and work schedule for January

**Month of January-** Prepare materials and equipment for sampling as well as become comfortable with procedures.

**January 14th-** Second Draft of Procedures with details on lab analysis, calculations, and sending out samples with tentative schedule.

**End of January through March -** Field Sampling and Lab Work

**February 1st-** Semi-Final Draft of Literature Review and Intro

**March 1st-** Semi-Final Draft of Methods

**March- Beginning of April-** Work on Data Analysis

**March 15th-**Working Draft of Results and Discussion

**April 1st-** Second Draft of Results and Discussion Section

**April 14th-** Send Final Draft of Thesis to Advisor

**May-29th-** Send in Final Draft of Thesis to Advisor

1. **Who (if anyone), beyond your MES thesis reader, will support your thesis (in or outside of Evergreen)? Be specific about who they are and in what capacity they will support your thesis. If you are working with an outside agency or expert, be specific about their expectations for your data analysis or publication of results.**

In addition to my thesis reader, I will be supported by Jenna Nelson who is a SIT at Evergreen. She will assist me in my lab analyses along with my thesis reader.

1. **Provide the 5 most important references you have used to identify the specific questions and context of your topic, help with issues of research design and analysis, and/or provide a basis for interpretation. Annotate these references with notes on how they relate to/will be helpful for your thesis. For any other sources cited in your prospectus in other answers, provide a complete bibliographic citation here as well.**

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1. You are not locked into this title; we want you to identify the main point or topic of your thesis. [↑](#endnote-ref-1)
2. You might discuss selection of case studies, sampling methods, experimental design, and/or specific hypotheses you will test. You should also address any specialized knowledge or skills that are necessary to complete the research. [↑](#endnote-ref-2)
3. If you are planning to use existing data, explain the specific source, contact information, arrangement with collaborating agencies, and expectations about use of data and final products of your research. If you are planning to gather new data, describe specific methods, time, place, and equipment that will be required. [↑](#endnote-ref-3)
4. If you’re not sure where to start, consult a ‘Code of Ethics’ or other similar document from an academic society in an applicable field of study. [↑](#endnote-ref-4)
5. If you are collecting ANY samples or data, even observational data, on public lands (city, county, state and/or federal) it is your responsibility to find out the permit requirements BEFORE you collect data. Conducting research with tribal members/on tribal lands will have different and additional requirements. [↑](#endnote-ref-5)
6. Your *positionality as a researcher* refers to the fact that one’s “…beliefs, values systems, and moral stances are as fundamentally present and inseparable from the research process as [one]’s physical, virtual, or metaphorical presence when facilitating, participating and/or leading the research project…” (The Weingarten Blog 2017). [↑](#endnote-ref-6)