COVER PAGE DATA ELEMENTS

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c. Federal Grant or Other Identifying Number Assigned by Agency (prepopulated):
US Department of Energy
d. Project Title (prepopulated):
Advancing a Watershed Hydro-Biogeochemical Theory: Linking Water Travel Time and Reaction Rates Under Changing Climate
e. PD/PI Name, Title and Contact Information (e-mail address and phone number) (prepopulated):
Li Li, Barry and Shirley Isett Professor in Civil and Environmental Engineering, Penn State University, lili@engr.psu.edu, 814-867-0151
f. Name of Submitting Official, Title, and Contact Information (e-mail address and phone number), if other than PD/PI (prepopulated)
Li Li, Barry and Shirley Isett Professor in Civil and Environmental Engineering, Penn State University, lili@engr.psu.edu, 814-867-0151
g. Submission Date (prepopulated): 3/5/2024
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i. Recipient Organization (Name and Address) (prepopulated)
The Pennsylvania State University
j. Project/Grant Period (Start Date, End Date) (prepopulated)
09/01/2019 – 08/31/2023
k. Reporting Period End Date (prepopulated)
08/31/2023
l. Report Term or Frequency (annual, semi-annual, quarterly, final, other) (prepopulated)
Final

Abstract:

The major goal of the project is to answer the question how and to what degree does a warming climate alter hydrological functioning and (biogeochemical and chemical weathering) reaction rates at the watershed scale? In particular, how does hydrological functioning (water storage, flow paths, and travel time) change responding to a warming climate? What are the corresponding alterations in biogeochemical and chemical weathering rates at the watershed scale? What is the general watershed-scale reaction rate law that causally links reaction rates to metrics of hydrological functioning that are determined by external hydroclimatic conditions and internal watershed structure characteristics? To answer these questions, we have used field measurements and reactive transport modeling. We have found that: 1) stream chemistry has altered tremendously in warmer years; 2) In this water-limited environment, hydrology is the dominant driver for soil respiration and carbon lateral export at the watershed scale; 3) deeper carbon respiration plays an essential role in regulating the patterns of stream carbon in low and high flow conditions, and deeper groundwater will become increasingly important as warming intensifies. This indicates in mountain streams, a warming climate will modify not only the timing and magnitude of streamflow as expected, but also the chemistry and quality of stream water.

II. ACCOMPLISHMENTS: Mandatory
What was done? What was learned?
The information provided in this section allows the agency to assess whether satisfactory progress has been made during the reporting period. The PI is reminded that the grantee is required to obtain prior written approval from the Contracting Officer whenever there are significant changes in the project or its direction. Requests for prior written approval must be submitted to the Contracting Officer (submission via Fedconnect is acceptable).

1. What are the major goals of the project?
List the major goals of the project as stated in the approved application or as approved by the agency. If the application lists milestones/target dates for important activities or phases of the project, identify these dates and show actual completion dates or the percentage of completion. Generally, the goals will not change from one reporting period to the next. However, if the awarding agency approved changes to the goals during the reporting period, list the revised goals and objectives. Also explain any significant changes in approach or methods from the agency approved application or plan.

The major goal of the project is to answer the question **how and to what degree does a warming climate alter hydrological functioning and (biogeochemical and chemical weathering) reaction rates at the watershed scale?** In particular, *how does hydrological functioning (water storage, flow paths, and travel time) change responding to a warming climate? What are the corresponding alterations in biogeochemical and chemical weathering rates at the watershed scale? What is the general watershed-scale reaction rate law that causally links reaction rates to metrics of hydrological functioning that are determined by external hydroclimatic conditions and internal watershed structure characteristics?*

Along these lines we aim to test the following hypothesis:
H1 (Hydrology). Precipitation shifts from snow to rainfall subdue snowmelt peaks and prolong summer low flow periods, skewing the transit time distribution (TTD) toward longer tails and higher fractions of old water.
H2 (Biogeochemistry). Temperature is the dominant driver of SOM decomposition but hydrology is the first-order control of DOC export at the watershed scale.
H3 (Weathering). Chemical weathering of the deeper subsurface is less influenced by temperature but more influenced by hydrologic changes.
H4 (Theory). To determine watershed-scale reaction rates, it is critical to include a reactive water fraction (F_r), defined as the fraction of water that interacts with reacting materials, in addition to temperature and water content that are typically included in rate laws derived from laboratory or small-scale field systems.

2. What was accomplished under these goals?
For this reporting period describe: 1) major activities; 2) specific objectives; 3) significant results, including major findings, developments, or conclusions (both positive and negative); and 4) key outcomes or other achievements. Include a discussion of stated goals not met. As the project progresses, the emphasis in reporting in this section should shift from reporting activities to reporting accomplishments.

1) Major activities:
   - Li's graduate student Kerins has been using the model BioRT-Flux-PIHM and BioRT-HBV to understand how warming influence hydrological flow paths and biogeochemical reaction rates; Devon has also been doing large scale analysis for DOC and DIC data in the whole rocky mountain area.

- The graduate student of Sullivan (Oregon State University subcontractor) has worked on the hydrology aspect of the summer streamflow
- Procurement of sensors;
- Installation of soil gas sensors and lysimeters in a few locations at Coal Creek
- Monthly discussion within the group (Li, Sullivan, Williams, Carroll, and Li's graduate student Devon Kerins) to understand existing data and to plan for installation of sensors for soils and drilling plans for groundwater

2) significant results,

- a couple of new papers (Zhi et al., 2019, 2020) were published on the significant response of stream chemistry to warming. Currently we have one manuscript published on WRR on contrasting concentration-discharge patterns in Coal Creek. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018WR024257
- Johnson et al. (2023) describes how summer low flow is related to different characteristics of watersheds. https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2023WR035126
- We are working on multiple manuscripts on DOC and DIC concentrations in rocky mountains and a third manuscript on modeling water and carbon processes in Coal Creek

3. What opportunities for training and professional development has the project provided?

Describe opportunities for training and professional development provided to anyone who worked on the project or anyone who was involved in the activities supported by the project. ."Training" activities are those in which individuals with advanced professional skills and experience assist others in attaining greater proficiency. Training activities may include, for example, courses or one-on-one work with a mentor. "Professional development" activities result in increased knowledge or skill in one's area of expertise and may include workshops, conferences, seminars, study groups, and individual study. Include participation in conferences, workshops, and seminars not listed under major activities.

Li's graduate student Devon Kerins started fall 2019. She has been taking courses but also work on the data and models to develop her insights about the processes. Devon is scheduled to defend her PhD thesis in early May, 2024. She will be publishing three papers out of this award.

Devon has attended fall AGU in 2020, 2021, 2022, and 2024 and presented her work on Coal creek. She won the first place for her presentation award in the Environmental chemistry and microbiology conference at Penn State.

4. How have the results been disseminated to communities of interest?

Describe how the results have been disseminated to communities of interest. Include any outreach activities that have been undertaken to reach members of communities who are not usually aware of these research activities, for the purpose of enhancing public understanding and increasing interest in learning and careers in science, technology, and the humanities.

We continuously to have publications out each year, which is our major venue for scientific dissemination.

We have also been working with Ashley Bembenek, a Soil and Water Scientist in Alpine Environmental Consultants LLC, with main focus on water quality related issue. We are

coordinating with her about sampling collection and distribute our research outcome on metals and water quality to concerned citizens in Crest Butte, where Coal Creek is located.

We have gotten funding from NSF, as part of a larger Critical Zone Coordination Network, to work more on Coal Creek. in this NSF funded project, we have funds to recruit two REU student for 3 years to work on Coal Creek. There are also funding to support new graduate students.

Li gave a talk about Coal Creek in the Watershed science bimonthly seminar series organized by Ken Williams, an invited talk at ORNL, and a Water Insight talk at Penn State water community, as well as invited talks at AU 2023.

5. What do you plan to do during the next reporting period to accomplish the goals?
Describe briefly what you plan to do during the next reporting period to accomplish the goals and objectives.

We have started collecting data from the soil gas sensors since august 2020. This data set, together with groundwater data and stream water data, will provide information about soil processes and will be used to calibrate the watershed scale model.

We have used the calibrated model to test hypothesis on key controls of water and biogeochemistry response to warming at Coal Creek. These papers are in review.

III. PRODUCTS: Optional (Mandatory if Products Exist)
What has the project produced?
Publications are the characteristic product of research. Agencies evaluate what the publications demonstrate about the excellence and significance of the research and the efficacy with which the results are being communicated to colleagues, potential users, and the public, not the number of publications. Many projects (though not all) develop significant products other than publications. Agencies assess and report both publications and other products to Congress, communities of interest, and the public.
List any products resulting from the project during the reporting period. Examples of products include: publications, conference papers, and presentations; website(s) or other Internet site(s); technologies or techniques; inventions, patent applications, and/or licenses; and other products, such as data or databases, physical collections, audio or video products, software or NetWare, models, educational aids or curricula, instruments, or equipment, or any other public release of information related to the project.

1. Publications
Report only the major publication(s) resulting from the work under this award. There is no restriction on the number. However, agencies are interested in only those publications that most reflect the work under this award in the following categories:

i. **Journal publications.** List peer-reviewed articles or papers appearing in scientific, technical, or professional journals. Include any peer-reviewed publication in the periodically published proceedings of a scientific society, a conference, or the like. A publication in the proceedings of a one-time conference, not part of a series, should be reported under “Books or other non-periodical, one-time publications.” Identify for each publication: Author(s); title; journal; volume: year; page numbers; status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).

1. Sadayappan, K., Stewart, B., Kerins, D., Vierbicher, A., Zhi, W., Vis, M., Seibert, J., & Li, L. 2024. BioRT-HBV 1.0: a Biogeochemical Reactive Transport Model at the Watershed Scale. Journal of Advances in Modeling Earth Systems (in review)
2. Kerins, D., Sadayappan, K.Z., Wei , Sullivan, P.L.W., Kenneth H. , Carroll, R.W.H., Barnard, H.R.S., Matthias Dong, Wenming , Perdrial, J., Li, L. (2024) Hydrology as the predominant driver of dissolved carbon production and export in a water-limited mountain catchment. Water Resources Research, (in review).

3. Johnson, K., Harpold, A., Carroll, R.W.H., Barnard, H., Raleigh, M.S., Segura, C., Li, L., Williams, K.H., Dong, W., Sullivan, P.L. (2023) Leveraging groundwater dynamics to improve predictions of summer low flow discharges. Water Resources Research.

4. Zhi, W., Li, L., Dong, W., Brown, W., Kaye, J., Steefel, C., Williams, K.H. (2019) Distinct Source Water Chemistry Shapes Contrasting Concentration-Discharge Patterns. Water Resources Research 55, 4233-4251.

5. Zhi, W., Williams, K.H., Carroll, R.W.H., Brown, W., Dong, W., Kerins, D., Li, L. (2020) Significant stream chemistry response to temperature variations in a high-elevation mountain watershed. Communications Earth & Environment 1, 43

In Preparation

6. Kerins, D., Sullivan, P.L., Williams, K.H., Barnard, H., & Li, L. Unraveling Dissolved Organic Carbon Dynamics in High-Elevation Streams: Identifying the role of catchment characteristics by comparing Colorado mountain watersheds

7. Kerins, D., Knapp, A., Andrews, E., Vierbicher, A., Sadayappan, K., Liu, F., Berzonsky, M., Stewart, B., & Li, L. Variation in flow partitioning between shallow and deep groundwater flow paths across 15 catchments within the contiguous United States

ii. **Books or other non-periodical, one-time publications.** Report any book, monograph, dissertation, abstract, or the like published as or in a separate publication, rather than a periodical or series. Include any significant publication in the proceedings of a one-time conference or in the report of a one-time study, commission, or the like. Identify for each one-time publication: author(s); title; editor; title of collection, if applicable; bibliographic information; year; type of publication (book, thesis or dissertation, other); status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).

NONE

iii. **Other publications, conference papers and presentations**. Identify any other publications, conference papers and/or presentations not reported above. Specify the status of the publication as noted above.

Devon Kerins' presentations coming out from this work (Kerins as the first authors, others on the project as co-author):

Oral presentations:

1. “Defining mechanisms of dissolved carbon production and export in Rocky Mountain catchments,” Colorado School of Mines, Dynamic Water Critical Zone Cluster Graduate Student Meeting, 1-3 March 2024
2. “Unraveling Dissolved Carbon Dynamics in High-Elevation Streams: Identifying the Role of Catchment Characteristics by Comparing Colorado Mountain Watersheds,” AGU Fall Meeting, 11-15 December 2023
3. “Hydrology is the Dominant Driver of Dissolved Carbon Production and Export in a Water-Limited Mountain Catchment,” AGU Fall Meeting, 11-15 December 2023
4. “Production and Export of Dissolved Carbon Simultaneously Driven by Hydrology in a Water-Limited Mountain Catchment,” The 2nd Annual Global Evapotranspiration Symposium: Advances, Challenges, and Future Needs in Measurements, Modeling, and Applications, 23-27 October 2023
5. “High dissolved carbon concentrations in arid Rocky Mountain streams,” Penn State College of Engineering Student Symposium, 12 April 2023
6. “Connecting water ages and biogeochemical processes in the critical zone: Carbon,” Frontiers in Hydrology Meeting, 19-24 June 2022
7. “Higher dissolved carbon in drier and warmer Rocky Mountain streams,” Frontiers in Hydrology Meeting, 19-24 June 2022
8. “Drivers of dynamic dissolved organic carbon response to warming in a high elevation mountain watershed in Colorado,” AGU Fall Meeting, 13-17 December 2021
9. “Design responsibility during construction,” Pacific Northwest American Society of Civil Engineers Student Conference, 17-18 April 2015

Poster Presentations

10. “Response of subsurface carbon transformation and transport to changing mountain hydrology,” Gordon Research Conference and Symposium, Catchment Science: Interactions of Hydrology, 17-23 June 2023
11. “Response of subsurface carbon transformation and transport to changing mountain hydrology,” Penn State Climate Solutions Symposium, Penn State Climate Solutions Symposium, 22-23 May 2023
12. “Response of subsurface carbon transformation and transport to changing mountain hydrology,” U.S. Department of Energy Environmental System Science Program Principal Investigator Meeting, 16-17 May 2023
13. “Digging through the subsurface with Reactive Transport Modelling: How carbon transformation and transport changes in a warmer and drier mountain watershed,” Penn State Environmental Chemistry and Microbiology Student Symposium, 14-15 April 2023
14. “Digging through the subsurface with Reactive Transport Modelling: How carbon transformation and transport changes in a warmer and drier mountain watershed,” Penn State Water Conference and Community Event, 23-24 March 2023
15. “Carbon transformation and transport in a high elevation catchment,” Frontiers in Hydrology Meeting, 19-24 June 2022
16. “Carbon transformation and transport in a high elevation catchment,” U.S. Department of Energy Environmental System Science Program Principal Investigator Meeting, 24-26 May 2022

iv. **Website(s) or other Internet site(s)** List the URL for any Internet site(s) that disseminates the results of the research activities. A short description of each site

should be provided. It is not necessary to include the publications already specified above in this section.

NONE

2. Intellectual Property
Identify inventions, patent applications with date, and/or licenses that have resulted from the research. Submission of this information as part of an interim research performance progress report is not a substitute for any other invention reporting required under the terms and conditions of an award.

NONE

3. Technologies or Techniques
Identify technologies or techniques that have resulted from the research activities. Describe the technologies or techniques and how they are being shared.

NONE

4. Other Products
Identify any other significant products that were developed under this project. Describe the product and how it is being shared. Examples of other products are: Databases; Physical collections; Audio or video products; Software or NetWare; Models; Educational aids or curricula; Instruments or equipment; Data & Research Material (e.g., cell lines, DNA probes, animal models); and Other.

NONE

IV. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS: Mandatory
Who has been involved?
Agencies need to know who has worked on the project to gauge and report performance in promoting partnerships and collaborations. The following information on participants must be provided:

1. Participants
What individuals have worked on the project?
Provide the following information for: (1) principal investigator(s)/project director(s) (PIs/PDs); and (2) each person who has worked at least one person month per year on the project during the reporting period, regardless of the source of compensation (a person month equals approximately 160 hours of effort).

PIs: 2 weeks per year
Student: > 160 hours per month

Provide the name and identify the role the person played in the project. Do NOT include any other identifying information on individuals. Indicate the nearest whole person month (Calendar, Academic, Summer) that the individual worked on the project. Show the most senior role in which the person has worked on the project for any significant length of time. For example, if an undergraduate student graduates, enters graduate school, and continues to work on the project, show that person as a graduate student, preferably explaining the change in involvement. Describe how this person contributed to the project and with what funding support. If information is unchanged from a previous submission, provide the name only and indicate “no change”. Identify whether this person is collaborating internationally. Specifically is the person

collaborating with an individual located in a foreign country and whether the person had traveled to the foreign country as part of that collaboration and duration of stay. The foreign country(ies) should be identified.

PIs: Li Li, Pam Sullivan
Student: Devon Kerins

Example:
1) Name: Mary Smith
2) Project Role: Graduate Student
3) Nearest person month worked: 5
4) Contribution to Project: Ms. Smith has performed work in the area of combined error-control and constrained coding.
5) Funding Support: The Ford Foundation (Complete only if the funding provided from other than this award.)
6) Collaborated with individual in foreign country: Yes
7) Country(ies) of foreign collaborator: China
8) Travelled to foreign country: Yes
9) If traveled to foreign country(ies), duration of stay: 5 months
2. Partners
What other organizations have been involved as partners?
Describe partner organizations – academic institutions, other nonprofits, industrial or commercial firms, state or local governments, schools or school systems, or other organizations (foreign or domestic) – that have been involved with the project. Partner organizations may provide financial or in-kind support, supply facilities or equipment, collaborate in the research, exchange personnel, or otherwise contribute.
Provide the following information for each partnership:
1) Organization Name:
2) Location of Organization: (if foreign location list country)
3) Partner's contribution to the project (identify one or more)
4) Financial support;
5) In-kind support (e.g., partner makes software, computers, equipment, etc., available to project staff);
6) Facilities (e.g., project staff use the partner's facilities for project activities);
7) Collaborative research (e.g., partner's staff work with project staff on the project);
8) Personnel exchanges (e.g., project staff and/or partner's staff use each other's facilities, work at each other's site).
9) More detail on partner and contribution (foreign or domestic).
3. Other Collaborators

Have other collaborators or contacts been involved?

Some significant collaborators or contacts within the recipient's organization may not be covered by "What people have worked on the project?" Likewise, some significant collaborators or contacts outside the recipient's organization may not be covered under "What other organizations have been involved as partners?" For example, describe any significant: collaborations with others within the recipient's organization; especially interdepartmental or interdisciplinary collaborations; collaborations or contact with others outside the organization; and collaborations or contacts with others outside the United States or with an international organization, country(ies) of collaborations or contacts.
It is likely that many recipients will have no other collaborators or contacts to report.

V. IMPACT: Optional (but strongly encouraged)
What is the impact of the project? How has it contributed?
Over the years, this base of knowledge, techniques, people, and infrastructure is drawn upon again and again for application to commercial technology and the economy, to health and safety, to cost-efficient environmental protection, to the solution of social problems, to numerous other aspects of the public welfare, and to other fields of endeavor.
The taxpaying public and its representatives deserve a periodic assessment to show them how the investments they make benefit the nation. Through this reporting format, and especially this section, recipients provide that assessment and make the case for Federal funding of research and education. Agencies use this information to assess how their research programs: increase the body of knowledge and techniques; enlarge the pool of people trained to develop that knowledge and techniques or put it to use; and improve the physical, institutional, and information resources that enable those people to get their training and perform their functions. This component will be used to describe ways in which the work, findings, and specific products of the project have had an impact during this reporting period. Describe distinctive contributions, major accomplishments, innovations, successes, or any change in practice or behavior that has come about as a result of the project relative to: the development of the principal discipline(s) of the project; other disciplines; the development of human resources; physical, institutional, and information resources that form infrastructure; technology transfer (include transfer of results to entities in government or industry, adoption of new practices, or instances where research has led to the initiation of a startup company); or society beyond science and technology.

Publications are out. We will be working with water quality and environmental groups on water issues at Coal Creek

1. What is the impact on the development of the principal discipline(s) of the project?
Describe how findings, results, and techniques that were developed or extended, or other products from the project made an impact or are likely to make an impact on the base of knowledge, theory, and research and/or pedagogical methods in the principal disciplinary field(s) of the project. Summarize using language that an intelligent lay audience can understand (*Scientific American* style). How the field or discipline is defined is not as important as covering the impact the work has had on knowledge and technique. Make the best distinction possible, for example, by using a “field” or “discipline”, if appropriate, that corresponds with a single academic department (i.e., physics rather than nuclear physics).

Hydrology and biogeochemistry
This project will lead to integrated understanding of how flow paths influence soil and aquifer biogeochemical reactions. This will be a major advance in hydrology and biogeochemistry as these processes are typically studied in separate fields.

2. What is the impact on other disciplines?
Describe how the findings, results, or techniques that were developed or improved, or other products from the project made an impact or are likely to make an impact on other disciplines.

Geology, environmental engineering,
other fields such as geochemistry and environmental engineering can also benefit these findings as the project outcome will push forward forecasting for water quality

3. What is the impact on the development of human resources?
Describe how the project made an impact or is likely to make an impact on human resource development in science, engineering, and technology. For example, how has the project: provided opportunities for research and teaching in the relevant fields; improved the performance, skills, or attitudes of members of underrepresented groups that will improve their access to or retention in research, teaching, or other related professions; developed and disseminated new educational materials or provided scholarships; or provided exposure to science and technology for practitioners, teachers, young people, or other members of the public?

The graduate students on this project will grow and will become scientists and professionals in this area. In particular, in a male-dominated modeling field, growing female student like Devon Kerins will add diversity and new ideas to the field.

4. What is the impact on physical, institutional, and information resources that form infrastructure?
Describe ways, if any, in which the project made an impact, or is likely to make an impact, on physical, institutional, and information resources that form infrastructure, including: physical resources such as facilities, laboratories, or instruments; institutional resources (such as establishment or sustenance of societies or organizations); or information resources, electronic means for accessing such resources or for scientific communication, or the like.

5. What is the impact on technology transfer?
Describe ways in which the project made an impact, or is likely to make an impact, on commercial technology or public use, including: transfer of results to entities in government or industry; instances where the research has led to the initiation of a start-up company; or adoption of new practices.

6. What is the impact on society beyond science and technology?
Describe how results from the project made an impact, or are likely to make an impact, beyond the bounds of science, engineering, and the academic world on areas such as: improving public knowledge, attitudes, skills, and abilities; changing behavior, practices, decision making, policies (including regulatory policies), or social actions; or improving social, economic, civic, or environmental conditions.

The scientific insights gleaned in this project will help citizens in areas of high elevation mountains understand how they should manage and adapt to rapidly changing climate.

7. Foreign Spending: What dollar amount of the award's budget is being spent in foreign country(ies)?
Describe what percentage of the award's budget is being spent in foreign country(ies). If more than one foreign country is involved, identify the distribution between the foreign countries.

VI. CHANGES/PROBLEMS: Optional (but strongly encouraged); Carryover Amount Mandatory
The PI is reminded that the grantee is required to obtain prior written approval from the Contracting Officer whenever there are significant changes in the project or its direction. Requests for prior written approval must be submitted to the Contracting Officer (submission via Fedconnect is acceptable). If not previously reported in writing, provide the following additional information, if applicable: Changes in approach and reasons for change; Actual or anticipated problems or delays and actions or plans to resolve them; Changes that have a significant impact on expenditures; Significant changes in use or care of animals, human subjects, and/or

biohazards.

1. Changes in approach and reasons for change

Describe any changes in approach during the reporting period and reasons for these changes. Remember that significant changes in objectives and scope require prior approval of the agency.

NONe

2. Actual or anticipated problems or delays and actions or plans to resolve them

Describe problems or delays encountered during the reporting period and actions or plans to resolve them.

NONE

3. Changes that have a significant impact on expenditures

Describe changes during the reporting period that may have a significant impact on

expenditures, for example, delays in hiring staff or favorable developments that enable meeting objectives at less cost than anticipated.

NONe

4. Significant changes in use or care of human subjects, vertebrate animals, and/or Biohazards

Describe significant deviations, unexpected outcomes, or changes in approved protocols for the use or care of human subjects, vertebrate animals, and/or biohazards during the reporting period. If required, were these changes approved by the applicable institution committee and reported to the agency? Also specify the applicable Institutional Review Board/Institutional Animal Care and Use Committee approval dates.

NONe

5. Change of primary performance site location from that originally proposed

Identify any change to the primary performance site location identified in the proposal, as originally submitted.

NONe

6. Carryover amount

Provide an estimate of the carryover amount expected at the reporting period end date.

NONe

VII. DEMOGRAPHIC INFORMATION: Mandatory (providing email addresses)

Provide email addresses for each participant listed in the participant section of this report. Once you submit this report, PAMS will send the participants not registered in PAMS an email inviting them to register and complete their PAMS person profiles so that any demographic information provided can be collected. Entering demographic information is optional for participants. Demographics are collected for reporting purposes.

Li Li: lili@engr.psu.edu

Pamela Sullivan: sullipam@oregonstate.edu

Devon Kerins: dmk6015@psu.edu

Keira Johnson: johnkeir@oregonstate.edu

Kenneth Hurst Williams: khwilliams@lbl.gov

VIII. SPECIAL REPORTING REQUIREMENTS: Mandatory only if specified in the Reporting Requirements Checklist

Respond to any special reporting requirements specified in the award terms and conditions, as well as any award specific reporting requirements.

IX. ACKNOWLEDGEMENT and DISCLAIMER

We acknowledge the support of US Department of Energy Environmental System Science (DE-SC0020146). This publication reflects the authors' professional views and opinions and should not be construed to represent any determination or policy of the US Department of Energy.