ANNUAL REPORT

Monitoring and Evaluating a Level Spreader Stormwater Best Management Practice in a Subwatershed of Hinkson Creek

Reporting Period:

December 5 2018 – December 10 2019

Submitted to:

Hinkson Creek Collaborative Adaptive Management (CAM)

Funding Partners:
The Curators of the University of Missouri
The City of Columbia, Missouri
Boone County, Missouri

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Report Date:

December 5, 2019

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PROJECT DESCRIPTION

Hinkson Creek is listed as an impaired water for pollutants including e.coli and placed on the EPA's 303(d) list. One pollutant that may contribute to the impairment is sediment. Stormwater best management practices that reduce erosion and runoff volume may help to increase the water quality in the creek.

A level spreader, paired with riparian buffer strip, is a stormwater best management practice (BMP) that functions to decrease impacts of urban stormwater on a receiving stream. The level spreader receives water diverted from a stream, construction site or other development and the water is distributed evenly along the length of the structure. The water then flows as sheet flow through the riparian buffer zone, which facilitates infiltration and removal of pollutants. (Knight, Hunt and Winston 2013) The practice has been adopted mainly in east coast states.

The Forum Nature Area level spreader was designed to divert and attenuate peak flows in an unnamed tributary of Hinkson Creek (illustrated in Figure 1). The watershed for the level spreader is about 120 acres and is composed of residential and business use areas, with two large man-made ponds upstream of the level spreader. Before installation of the level spreader system, the tributary was experiencing erosion and bank cutting, and soil loss into the Hinkson, despite influence of the small lakes.

After construction was completed, a monitoring program was put in place at the site, including measurements of volumetric soil water content, water level within the level spreader, and climate data at the site. Monitoring has continued since 2016, with weekly volumetric soil water content readings taken each Monday. Water depth in the level spreader is continuously logged, and this data is available from April through October. Together with climate data, these are being used to characterize the level spreader response to storm events.

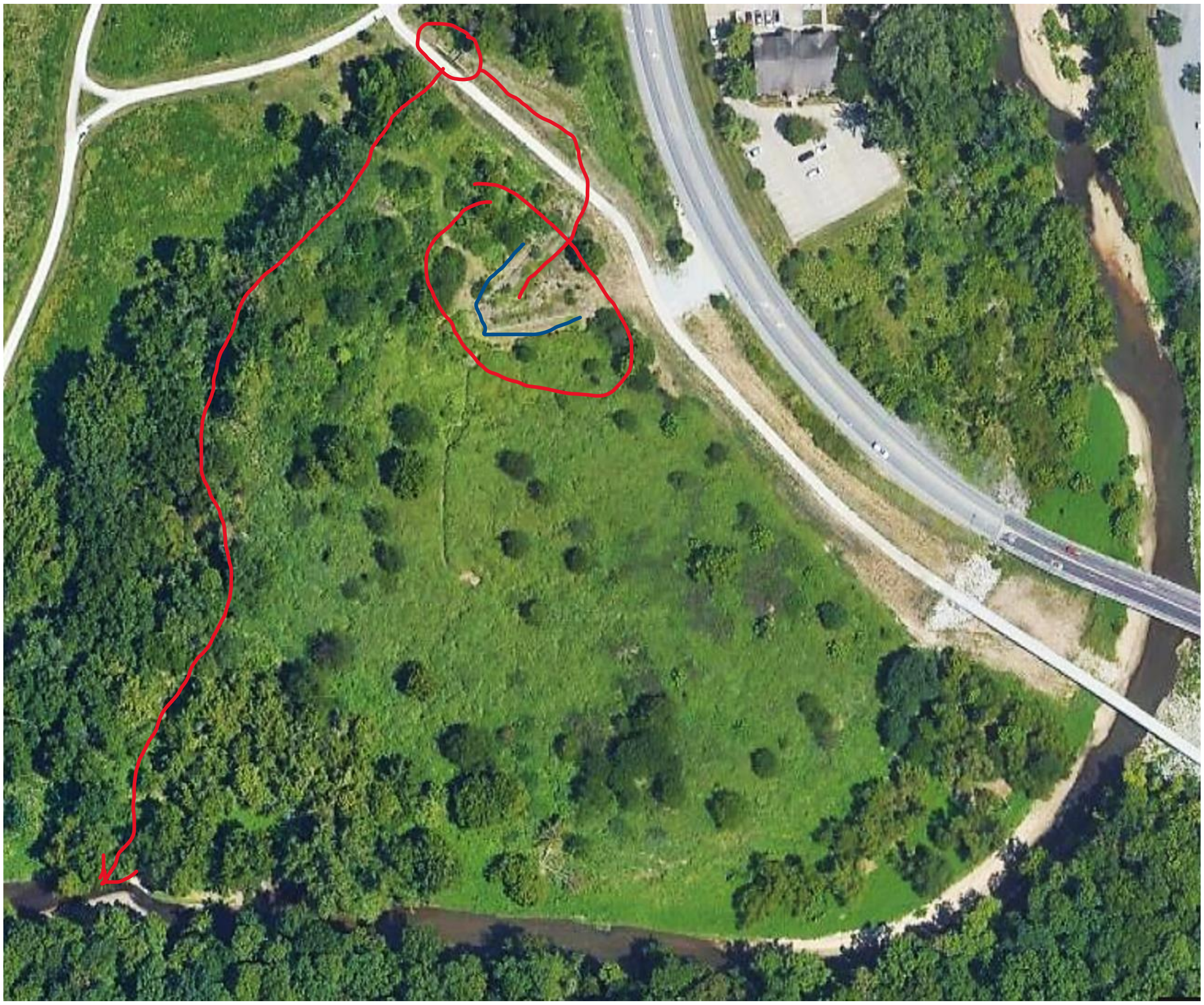


Figure 1: Aerial Image of the Forum Level Spreader and Hinkson Creek

(splitter box at top of image, most of flow diverted to level spreader (circled) and away from unnamed tributary to the left of the image)

PROJECT GOALS AND OBJECTIVES

The ultimate objectives of this project are to evaluate the effectiveness of the level spreader for attenuating peak flows in the tributary and increasing stormwater flow through other pathways into the surrounding environment, and to develop site selection criteria for placement of future level spreaders. One important step to evaluating the structure is through the creation of a water balance. Through use of a water balance, the pathways for water as it enters and leaves the level spreader such as overflow, infiltration and evaporation can be quantified. Knowing how much water leaves the level spreader through each pathway is important to determine whether the level spreader is effective as a stormwater management structure for accomplishing various goals. For example, if a large volume of water for each storm leaves the level spreader through infiltration, then the level spreader may be good for promoting baseflow in a nearby stream. If evapotranspiration is more significant, then the level spreader may act more as a retention basin with the added ability to spread flow over a larger area.

The second phase of the study includes using the water balance found through modelling as one tool to predict and suggest new locations for level spreaders in the local area and establishing some criteria for site selection. When selecting a site for a level spreader, the site must have physical attributes that are favorable to level spreader function, such as a relatively small watershed and a large open area where water can be safely diverted. In addition, there must be a strong need for a level spreader. Sites with small streams that are eroding or are at risk of streambed erosion, developments with newly paved areas adjoining a stream, and construction areas may be good candidates for a new level spreader. Another important consideration are the implications of allowing a floodplain or open area to experience flooding on a regular basis. How the open area of the site is used will ultimately determine whether it may be used for a level spreader or not. An ideal site is one such as Forum Nature Area, where the area that is allowed to flood is not used as anything other than a place for native plantings and a floodway, and the water does not pose a threat or an inconvenience to the public who use the walking trails onsite. All of these factors will be used to develop criteria for future level spreader site selection and to identify several example sites within the City of Columbia.

ACCOMPLISHMENTS AND PROGRESS

To examine the hydrology of the level spreader and determine how water moves through the area, the basic water balance equation will be used with the level spreader and swale as the control volume:

Precipitation + Inflow = Evapotranspiration + Level Lip Overflow + Diverter Overflow + Orifice Plate Outflow + Infiltration

For each storm being analyzed, different models and datasets will be used to quantify each part of the water balance equation:

Precipitation: The climate station onsite provides precipitation depth measurements in five-minute intervals. The volume of water that falls as precipitation onto the level spreader and swale area over one time interval will be the rain depth for that interval multiplied by the level spreader and swale area.

Inflow: Level and precipitation data will be used in conjunction with an altered version of an existing HEC-HMS model (Figure 3) used by the City of Columbia to predict inflow into the level spreader. The model can also be checked against level measurements for accuracy.

Evapotranspiration: The climate station collects various parameters that can be used for evapotranspiration calculations. Solar radiation, temperature, relative humidity, windspeed and other parameters will be input into a model such as Penman-Monteith with general information on plant types present in the level spreader area (native grasses, trees and bushes).

Level Lip Overflow: The concrete level lip works similar to a broad-crested weir, allowing for use of the broad crested weir equation to calculate flow over top of the lip for any depth.

Diverter Overflow: The diverter box is thin wood with a metal cap and acts as a sharp crested weir. Given the height of water behind the diverter and length and height of the box, flow over this structure during very large storm events can be calculated if needed. Note: the level spreader lip height minimizes the occurrences of this type of overflow.

Orifice Plate Outflow: The orifice plate is thin PVC and flows full during events where the level lip is overflowing or close to overflowing. The orifice equation can be used for this outflow.

Infiltration: Infiltration will be estimated by measuring the time the level spreader takes to empty with consideration of other pathways such as the diverter box underdrain and evapotranspiration. The volume of water infiltrated, as well as the approximate infiltration rate of the soil in and around the level spreader can be estimated in this way.

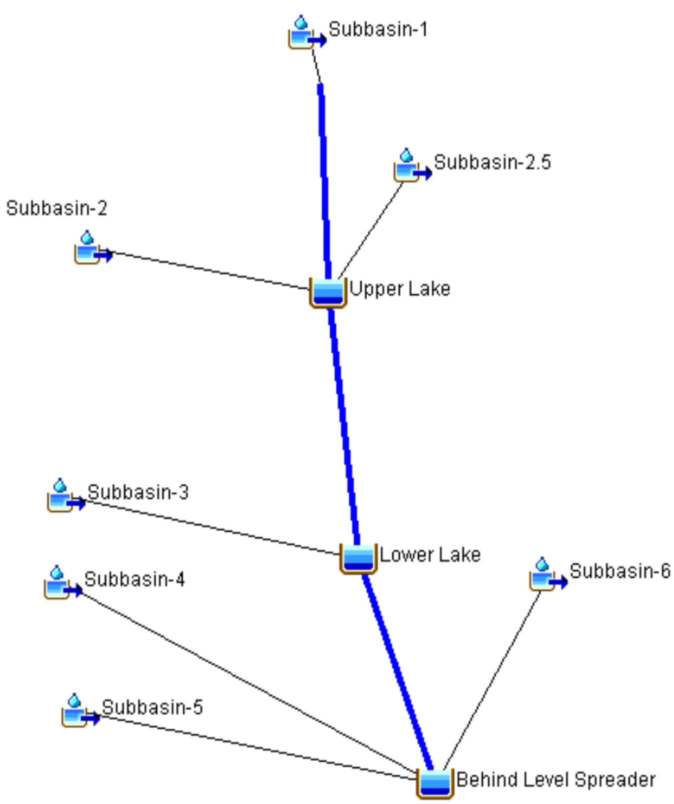
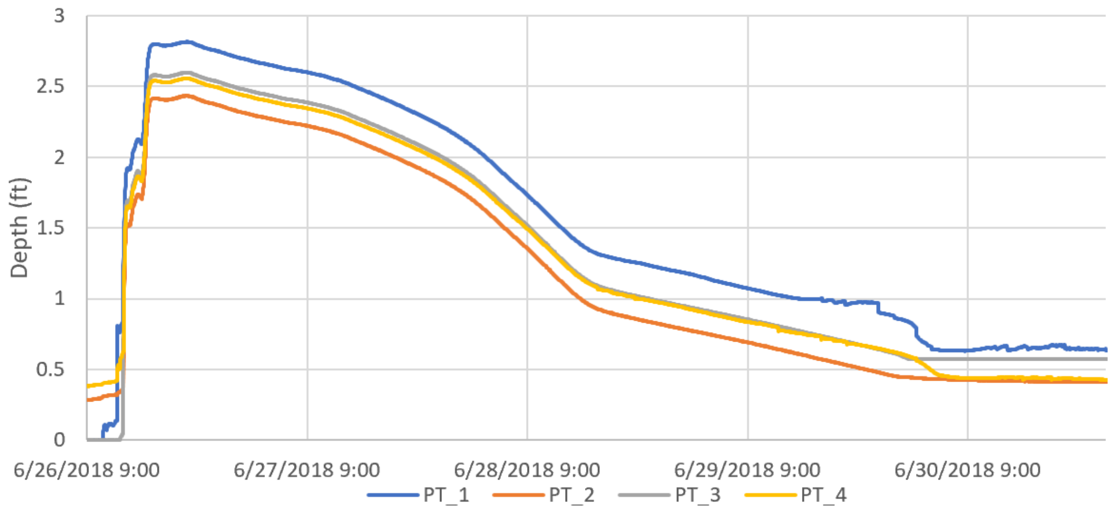


Figure 2: HEC-HMS Basin framework used to model the level spreader watershed



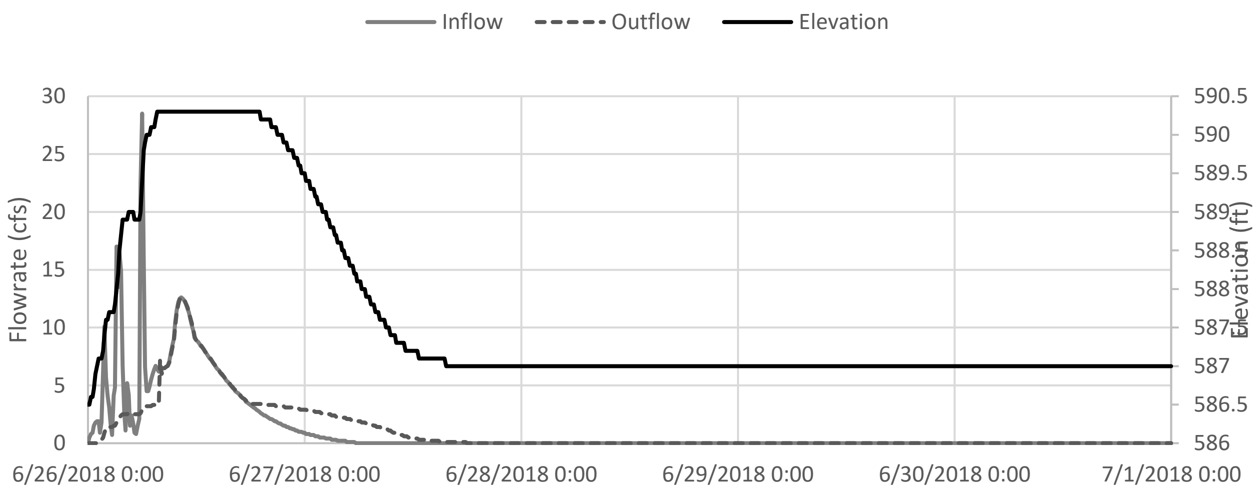


Figure 3: HEC-HMS and Pressure transducer results for water elevation and depth over a 5-day period during and after rain event

The above figures show water elevation results from a simulation run of the current HEC-HMS model of the level spreader site compared with measured results from the pressure transducers. The elevation curves during inflow are similar and reach a peak of about 590.4 ft (corresponding to a depth reading of 2.5 ft), slightly overtopping the level lip whose elevation is 590.3 ft. The pressure transducers show that the level spreader releases water more slowly and retains water for a longer period after the precipitation has ended, but the HEC-HMS model shows the water level holding steady at the level lip elevation for longer and decreasing relatively quickly and becoming completely empty after about 1.5 days. There are differences between the HEC-HMS model and the pressure transducer measurements, however the purpose of this model is only to find inflow into the level spreader, so some error is acceptable after the elevation-discharge and elevation-storage functions were updated.

One important result to note from the model is how the inflow and outflow curves from the level spreader are different. The inflow from the upper watershed shows several spikes at the beginning of the time interval (during precipitation), but these spikes are dampened and attenuated by the level spreader. The outflow curve still has a peak, but is much smoother and releases water for a few hours longer than the inflow curve. This result implies that the level spreader is effective at reducing the impact of the storm on the Hinkson Creek at this location.

A tool is currently being developed that will use ArcGIS to find locations within Boone County hat have characteristics suitable for use of a level spreader. The map will use the design criteria being developed from the water balance as requirements for consideration of a site. The ArcGIS project and outputs will be presented as part of the final report and given to CAM after the corresponding article is published. A preliminary output from the map is shown in Figure 6. Areas that are light have been selected as having some favorable characteristics for a level spreader, including low to medium paved area, close proximity to a road or other stormwater source, and low to medium tree cover. Much more fine tuning is required before the final map is to be generated.

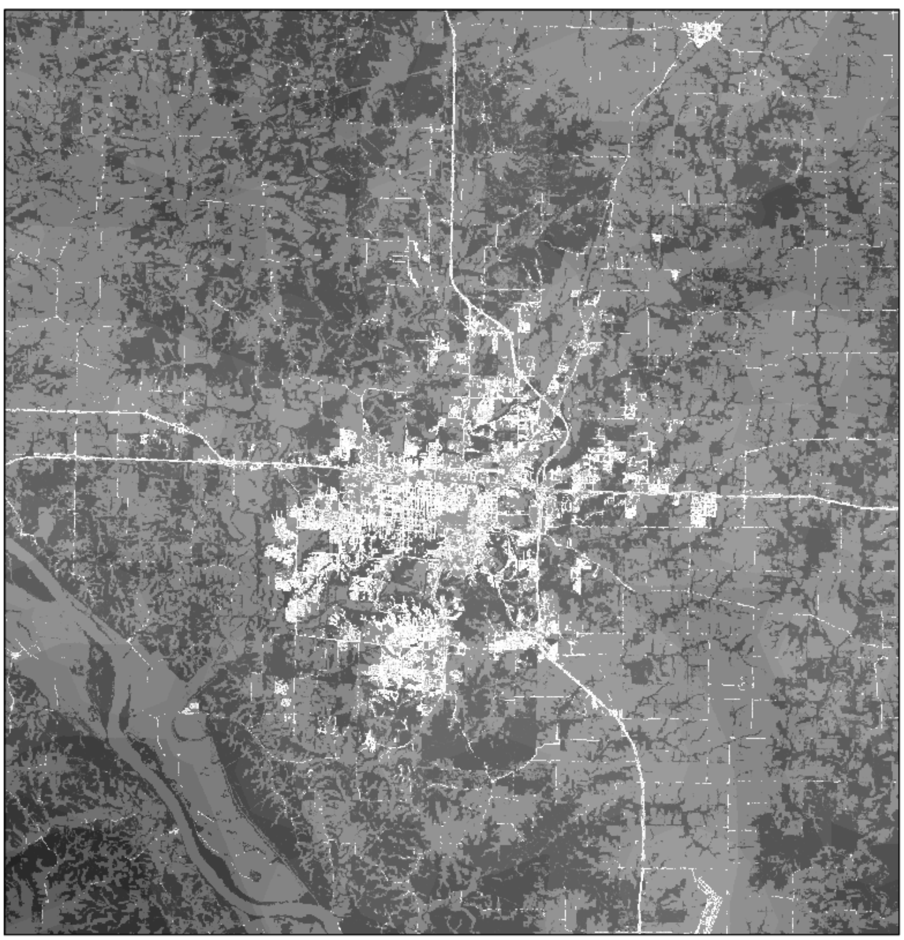


Figure 4: Preliminary Output of ArcGIS showing favorable locations for level spreaders (white and light gray areas)

A podium presentation was given by Laura Wiseman at the 2019 ERN (Emerging Researchers National) Conference in Washington DC in February 2019 and then a poster presentation on the same topic was shared during the Mid-America Environmental Engineering Conference (MAEEC) in October 2019. The title and abstract for those presentations are provided below.

Monitoring of an Urban Level Spreader as Part of the Collaborative Adaptive Management Process

Laura M. Wiseman, University of Missouri

Co-Authors: Lynne Hooper, Boone County, MO; Dr. Enos C. Inniss, University of Missouri, MO; Tom Wellman, City of Columbia, MO

Irregular flows, such as the high flows caused by stormwater runoff after a rain event are a major cause of stream impairment in urbanized watersheds. The Hinkson Creek CAM (Collaborative Adaptive Management) approach is doing long-term monitoring of a level spreader system in the Hinkson Creek watershed. The CAM process was implemented after Hinkson Creek was listed as an Impaired Water (EPA 303d) to encourage collaboration between the City of Columbia, University of Missouri, and Boone County, Missouri. The three entities develop strategies to address the impairment, including monitoring and evaluation of stormwater best management practices (BMPs) such as the level spreader. The purpose of this study is to determine the effectiveness of this stormwater BMP as a method to regulate flow in a small tributary to Hinkson Creek by forcing more infiltration and evaporation of urban stormwater runoff, contributing to the health of the larger watershed. Monitoring equipment placed at the site measures 1) the level of water upstream of the level spreader, 2) volumetric soil water content at multiple depths and in locations near the level spreader as well as farther from and closer to Hinkson Creek, and 3) climate data including precipitation, temperature and solar radiation. Measurements taken by the equipment are used together to characterize the fluxes of water through the level spreader system during and after a rain event, to begin to define the water balance into and out of the level spreader. Based on measurements collected from 2016 through the present, the level spreader functions well to increase evaporation, transpiration and infiltration of stormwater. By diverting water from the stream and into the level spreader, higher flows in the stream during rain events are reduced. Continuing efforts of the study will focus on evaluation of the monitored level spreader, optimal placement for similar level spreaders, and possible design improvements. The presentation will include the study design, the premise of the project in comparison to what the data is suggesting, and how the results of this study may inform where "urban" level spreaders may be used to improve hydraulics of a watershed.

Conferences:

1. February 2019: Emerging Researchers National (ERN) Conference, Washington DC
2. October 2019: MAEEC Conference (Poster)

PROJECT CHANGES

The project has moved from the data collection phase (ended in November 2019) to the analysis and report generating phase, and so field measurements are not being conducted at the site between November 2019 and end of the project in Summer 2020. The pressure transducers and datalogger have been removed permanently and the soil moisture sensors will be removed during spring of 2020.

Collaboration at the site began during the summer of 2019 with Dr. Alba Argerich. Several small wells were dug and some preliminary data on nutrients and groundwater levels was collected. During Spring 2020 data sharing will continue to determine what, if any, insights can be developed from the shared data.

CHANGES IN PERSONNEL

The graduate student, Laura Wiseman, will be completing writeup of the project during Spring 2020, with the PI Dr. Inniss advising remotely from Texas.

EQUIPMENT AND DATA FATE

As the data collection portion of the study has ended, all equipment is being pulled from the site and put into storage. This includes:

1. Four Pressure transducer sensors
2. CR300 datalogger with tripod and solar panel
3. Hydrosense 2 soil moisture reader and 22 soil moisture probes

The pressure transducers and associated datalogger are in need of maintenance, but are generally in working order. The Hydrosense reader is also in need of maintenance but still works, however the 21 buried soil moisture probes have reached the end of their usable life and are experiencing frequent malfunctions.

Data collected from the Forum site will be available on request with access limited to CAM members only. It will be fully released to CAM for posting publicly along with any models, tools and articles after they have had an opportunity to be published in May 2020, along with the full thesis text.

BUDGET STATUS

The are currently in Fiscal Year 5 of a 5-year, $62,250 project. Currently 72% of the project budget has been invoiced with 12% encumbered as labor (e.g., the stipend for supporting the graduate student Laura Wiseman). The remaining 16% unencumbered budget was intended for maintenance of the monitoring equipment and was not utilized as the equipment performed longer than anticipated.

UPCOMING ACTIVITIES

The next several months will be used for analyzing and finding results from the data collected since 2016. The anticipated next steps and results are the following:

1. Final water balance for the level spreader
2. List of site selection criteria and justifications
3. ArcMap of potential new level spreader locations based on the site selection criteria
4. Completed thesis with two articles:
    a. Water Balance Quantification for an Urban Level Spreader
    b. Site Selection of Level Spreaders for Stormwater Management

Final CAM Report and Thesis Defense:

The final report to the CAM Stakeholders, Action and Science Teams will be Laura Wiseman's Master's thesis, or an abridged version summarizing results. A presentation of final results of the study is scheduled for mid-April 2020.

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