DENVER BOTANIC GARDENS

Final Report for Water Plan Grant: Denver Botanic Gardens South Platte Restoration

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Date: August 2, 2021

Project Update: All analyses for the plant monitoring along Deer Creek have been completed. All the monitoring methods and data have been published and are publicly available. We are working to finalize a manuscript to submit for publication. Faculty at MSUD wrapped up work on the GIS component of the work and provided their recommendations for future work. A report of this work and recommendations for future restoration work was shared with Jefferson County Open Space. While work associated with this funding has been completed, Denver Botanic Gardens continues to do monitoring along Deer Creek to assess the long-term impacts of this restoration work.

Final status of SOW tasks

Task 1: Identify potential locations for in-stream structure installation on Jefferson County Open Space parcels.

Summary of work completed: Sarah Schliemann worked with interns at MSUD to identify potential locations. The students used GIS to conduct this task. Analyses were conducted and preliminary locations were identified in 2019. We created a short program using python code to identify potential areas using elevation data (DEM layer). The first intern working on the project presented his work at the MSUD research day. The top 10 locations were identified and scouted in 2019. Some of the locations were great but we also identified additional locations that could work. We revised the algorithms used and made suggestions for how this could be used beyond the scope of just this project. They concluded that higher resolution data is needed to reduce error in the model. We were able to partner with a consultant who offered their services for free and attempted several dates to gather additional data. While we were hoping to conduct drone flights in 2020 to get higher resolution data, both COVID and weather prohibited the various days that were scheduled. Due to financial and staffing constraints (drone flights were not in the original budget and the original staff working on this project at Jefferson County Open Space no longer work there), we were not able to collect additional data. We recommended to Jefferson County what additional data is needed to take this work further. We conducted three volunteer planting dates with students, partnering with Wildlands Restoration Volunteers. Two events were held in 2019 and the 2020 planting was cancelled due to the Covid-19 pandemic in spring 2020. We were able to successfully reschedule this in fall 2020.

After successfully installing three Beaver Dam Analogs (BDAs) along Deer Creek at Denver Botanic Gardens Chatfield Farms, we aimed to identify potential locations for BDAs on Deer Creek on Hildebrand Ranch Park, part of Jefferson County Open Space. The Gardens has been conducting annual monitoring along Deer Creek since 2015, with nine of the 18 long-term monitoring sites located on

Hildebrand Ranch. We assessed the topography of the creek and identified several locations that could potentially be good sites to install additional BDAs on the creek to improve hydrology and floodplain connectivity (Table 1, Figure 1). Additionally, we saw evidence of active beaver activity along the creek (Table 1, Figure 1), which indicates likely no work would be needed in areas in and around the active beaver work. Installing three additional structures along the creek would improve 2.5 miles of Deer Creek, rewet an acre of historical oxbows, and improve about 50 acres of riparian habitat (see figures below).

Table 1: Potential locations for BDA installation and site of current beaver activity at Hildebrand Ranch

Type	Latitude	Longitude
Proposed Location	39.54936	-105.132
Proposed Location	39.54932	-105.131
Proposed Location	39.55074	-105.129
Proposed Location	39.5509	-105.129
Proposed Location	39.55096	-105.128
Proposed Location	39.55102	-105.128
Beaver Activity	39.55176	-105.127
Proposed Location	39.55193	-105.126
Proposed Location	39.55184	-105.126
Proposed Location	39.55279	-105.122
Proposed Location	39.55347	-105.117
Proposed Location	39.55339	-105.116
Proposed Location	39.55343	-105.116
Proposed Location	39.55338	-105.114
Proposed Location	39.55322	-105.114
Proposed Location	39.5532	-105.114
Proposed Location	39.55269	-105.112
Proposed Location	39.55084	-105.102

Figure 1: Location of potential BDA installations and current beaver activity at Hildebrand Ranch

Using spatial data to identify historic wetlands

While our initial goal of the project was to identify locations just on Hildebrand Ranch for potential BDA installations, we decided to collaborate with Metropolitan State University of Denver to try to build a model that would allow for more automated identification of BDAs to be applied to larger areas. Our goal in this part of the project was to use publicly available data to build a spatial model that would identify historic wetlands for future restoration. We focused on relative elevation, slope angle, bank height, and flow rate. Ultimately, we used the data in the table below as being the most appropriate and useful data to identify potential restoration locations.

Name	Type	Resolution
LiDAR1.img - LiDAR12.img	Mosaic Raster Dataset	1meter
lidarDEM.tif	Raster Image	1meter
5contour.shp	5 Meter Contour Shapefile	5meters
Hydro_From_SDE.gdb	Hydrography Geodatabase	N/A
ProjectData.gdb	Wetlands Geodatabase	1ft-5meters

We believed that areas with relatively low elevation near the current creek channel could be historic oxbows. In addition, areas in the current creek with very steep and/or high banks would not be suitable for restoration because it would be difficult to build the channel up high enough for water to flow back into a historic wetland. Finally, we identified areas with lower flow rates to minimize damage to future in-stream structures; during especially high flow events, such as spring runoff.

Using ArcGIS (ArcMap 10.5.1), we first inspected the data visually and quickly realized that the resolution was much too coarse to provide useful visual information at the scale we need. As shown in the figure 1 below, when displayed at the appropriate scale, the data is not of proper resolution, and therefore is very grainy, and has large gaps with no information. Yellow and red pixels show contour lines. Colors indicate steepness. We first searched for additional data online that would provide the resolution we needed but were not successful.

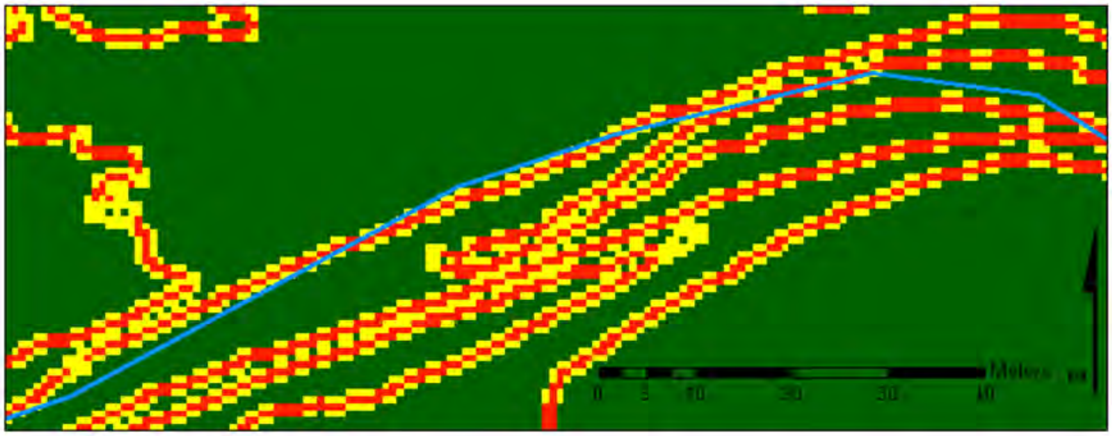


Figure 1: Visual representation of the data.

We then tried to compensate for the low resolution of the data using the tools in the *Spatial Analyst* extension for ArcGIS (see model in figure 2). In this model, *Fill* is used to extrapolate low points from the elevation data and then a calculation is used to denote those low points from the original DEM. From DEM data, slope is extrapolated, and used to derive areas of flow and accumulation. Unfortunately, even with these calculations, the low-resolution data only allows us to make predictions at a very low level of confidence. However, a model and code were generated in Python so that once sufficient Lidar data are collected for this site, the model can be run and better sites identified. The Lidar data can provide the necessary small-scale elevation data required. This is input into the model (DEM, first blue circle) and the Python code can be run to assess low elevation points and flow. This could then also be used at other sites as well. Below is a visualization of the code that was written. With sufficient high-resolution Lidar data providing elevation and slope data, the model will identify low points and flow. Once areas of low points are created, you can then assess the direction of historical flow and identify areas where restoration can reconnect the current flow to historical flow. An additional product from this work was the research experience for the undergraduate students involved with the project. His poster presentation is attached.

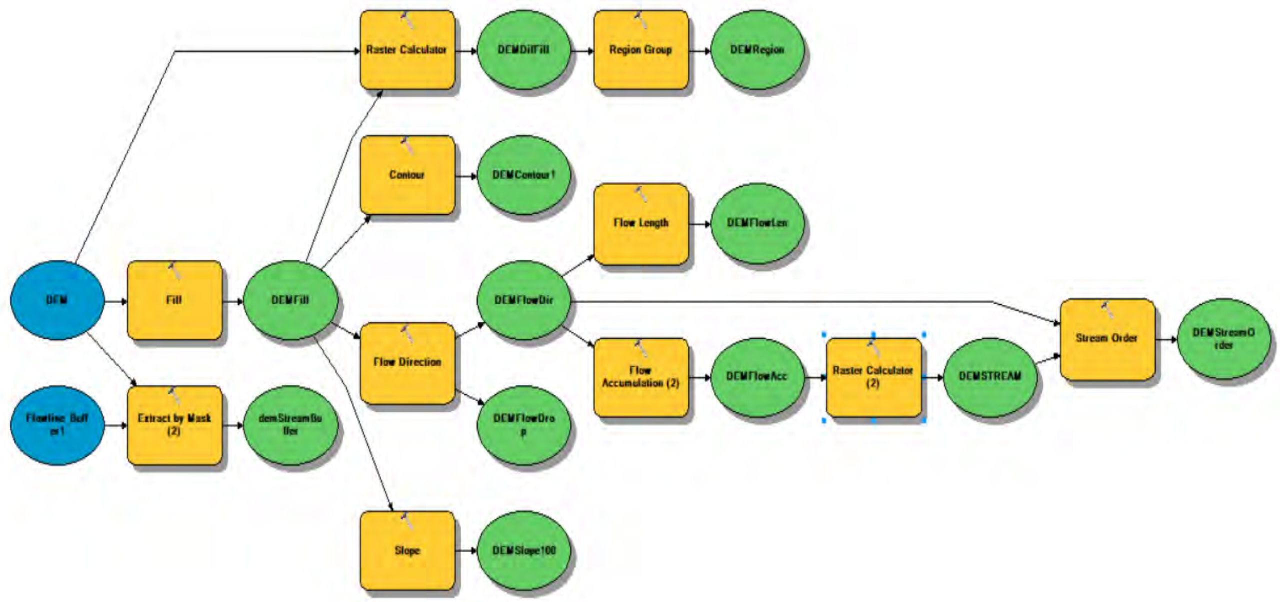


Figure 2: Spatial model.

Without data at the appropriate scale, we really were not able to develop a robust model. Working with spatial data is just like any statistical data analysis: you make educated guesses about possible relationships and run a model to test if they are true. Given the data we had, we really were not able to test our model in a meaningful way. If higher resolution data was obtained, the model could be simplified significantly. Because the data we had was not adequate, we tried to compensate by using interpolation tools (these are all the yellow boxes and green circles in the model in Figure 2) that would not be necessary if the resolution was higher. Interpolation works pretty well if you have a linear slope between the two points (like the actual slope, in the real world, not a mathematical value). But because the two points represent 1 m of elevation change, it is very unlikely that the slope between those points is linear. Nature is very rarely linear.

The model in Figure 2 uses two input data sources: DEM (digital elevation model) and Flowline Buffer (stream location). The flowline buffer layer identifies the location of the stream and is fine and does not need to be improved. The DEM is the layer that was useless at the resolution that was available. With LiDAR data at a 10 cm or better resolution, subtle differences in elevation could be identified using selection tools in GIS. Direct measurements of flow/ discharge are likely not necessary if a high resolution DEM is obtained because the DEM could identify areas with steep banks and a narrow stream channel where flow would be high (see more below). The data table on page 3 refers to the different data we tried to use in the model, but in the end, we really only used the lidarDEM layer and the Hydro_From_SDE.gdb layer. But, as mentioned above, the DEM data was not at a usable scale. The stream location (Hydro_From_SDE.gdb) was fine. With high resolution elevation LiDAR data, a new simplified model could be developed using only the DEM layer, the stream location layer, a few simple selection tools, and the "flow" tool in the spatial analysist extension in GIS.

We calculated flow (velocity) using the "flow" tool in the spatial analysist extension. This tool uses elevation (DEM layer) to determine bank steepness and stream channel width and calculate velocity.

However, given our inadequate data, the flow rates generated by our model were <u>not</u> reliable. If an adequate DEM was obtained from LiDAR, this tool could be used with much higher confidence to determine areas with high or low flow. The most promising model was presented in the GasserPoster.pdf included with the final report. Here is a summary of that model:

1. Use a DEM (10 cm or better resolution) and a stream shapefile. The one in the model already in the report is good (Hydro_From_SDE.gdb layer).
2. Create a buffer of 100 feet around the stream to limit the amount of data to be processed.
3. Use the *slope* tool to identify areas with low slope angles next to the stream (0-2 m). This will identify low banks.
4. Then, use the *slope* tool to identify areas 2 - 100 m of the stream with low slope angles. This should identify areas that are relatively flat and likely historic oxbows.
    a. Alternatively, you could use the elevation data within the DEM to identify areas near the stream with lower (or the same) elevation than the stream; also likely oxbows.

This general method is laid out in the attached poster. We ground-truthed the locations output from this model and they were ok, but not great. The data we were working with was just too coarse to be useful for reliable predictions. I think the method is promising, though (with better data). We didn't collect any field data. The goal was to use publicly available spatial data to generate the model. The DEM layer was from USGS (National Map). We also looked for other DEMs, but none had a resolution better than 1m. The stream layer was from The National Hydrography Dataset Plus (NHDplus), from the USGS. In the end, we learned that the elevation data (DEM layers) publicly available are not sufficient for our needs. With a high resolution DEM (from LiDAR), a new model could be developed to accurately identify potential BDA locations.

We focused in on a few locations that looked most promising (see images below). We walked the points put out by the model described above. A site looked promising if you could see the historical oxbow/flow. For all of the restoration locations at Denver Botanic Gardens Chatfield Farms, you could walk the site and find the low areas where the creek used to flow (if the bank height and separation from the creek were mitigated). We used this experience to walk around the locations identified in the model to determine if the model was correct in not only the location where the structure would go but where the water would be likely to flow if you installed a structure. We also excluded locations if they were close to the road/structures, where it might be difficult to alter water flows. These sites were discussed with Jefferson County Open Space and were sited for permission and access to allow a drone to collect additional high-resolution elevation data. The model developed in this project could be used to predict possible locations for restoration when higher resolution data is obtained. We recommend using a UAS (drone) and LiDAR equipment to obtain data sufficient to produce a raster data set with a resolution of 10 centimeters or smaller. Working with staff from Jefferson County Open Space, we had plans to use a UAS to gather this data at Hildebrand Ranch in 2020. Unfortunately, due to constraints from poor weather and the Covid-19 pandemic, we were unable to complete this work to add this additional data to test out this model. The MSUD staff and students working on this component are no longer available to continue working on this project and have completed the initial aim of task 1. We do still think this is a good future direction for this work to take. Once sites are selected with the model, a field inspection is needed to confirm selected sites are appropriate. During the field visits, information such as distance from roads and structures relative to the modeled new flow should be discussed to determine if the structure will undermine any existing infrastructure. On site, you can also determine the extent of the disconnect of the existing stream bed and what type of structure and channel manipulation might be required to reconnect the creek to the original flow.

Potential Restoration Locations

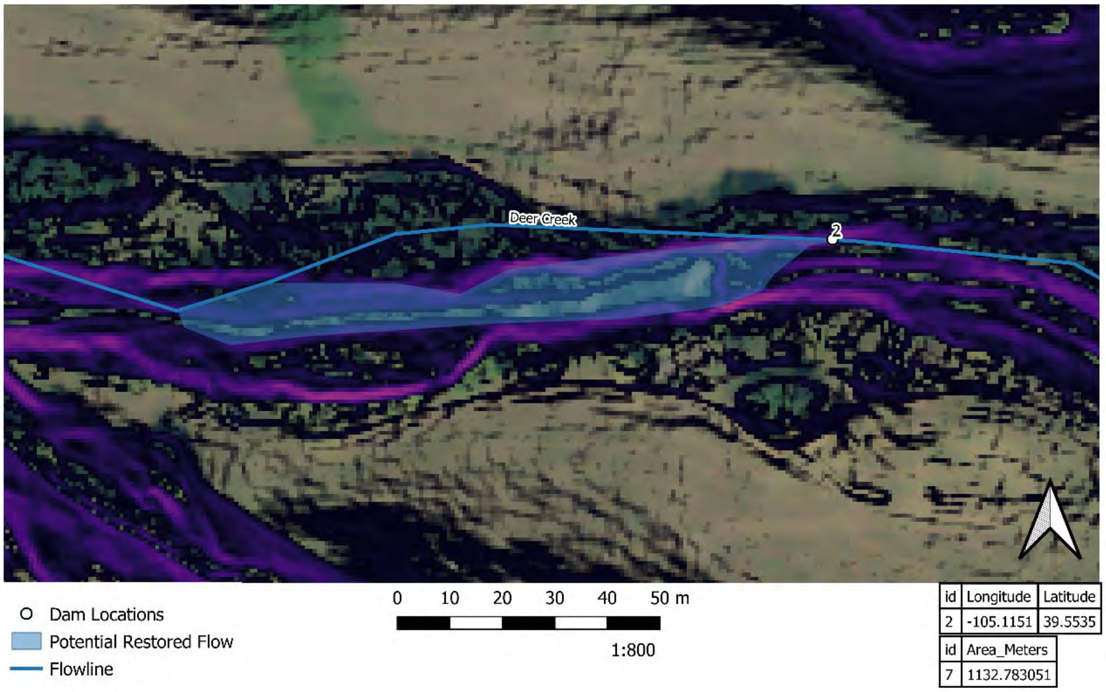
Full Extent View

Dam Locations
Potential Restored Flow
Flowline

id	Longitude	Latitude
2	-105.1151	39.5535
3	-105.1226	39.5527
4	-105.1254	39.5518
5	-105.1274	39.5511

maps created by: Ian Boddie, 29 Aug 2019
for: Denver Botanic Gardens and Metropolitan State University of Denver, Department of Earth and Atmospheric Sciences
data provided by:
USGS
Jefferson County Colorado GIS Open Data
manually collected GPS points from Sarah Schlieman

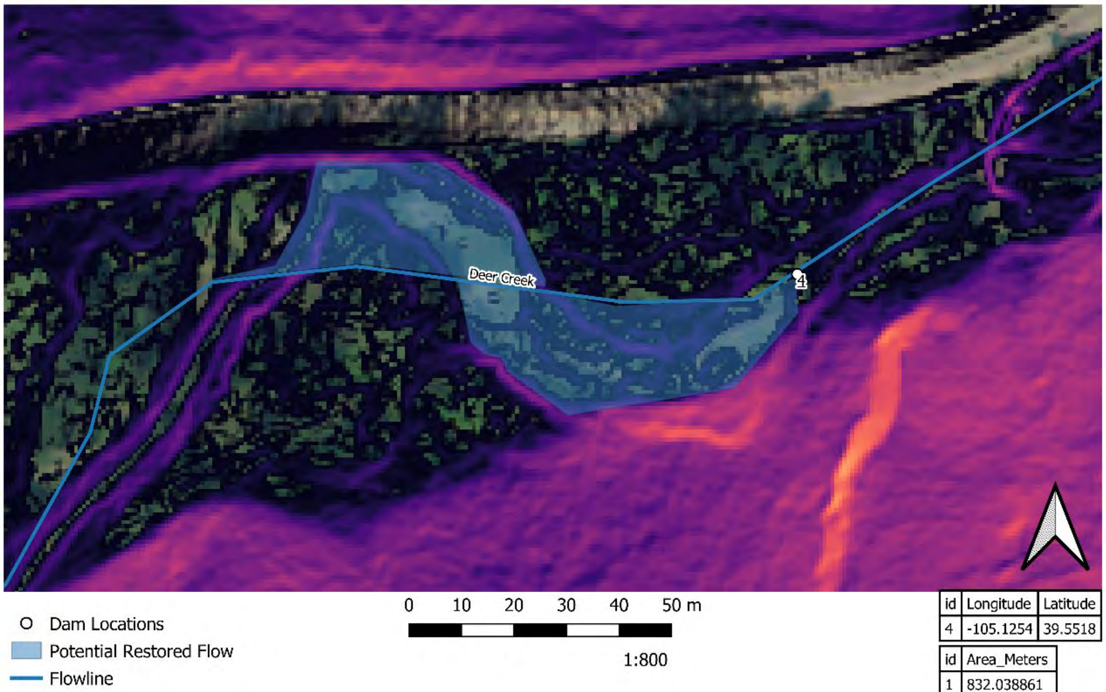
Dam Location ID: 2



id	Longitude	Latitude
2	-105.1151	39.5535

id	Area_Meters
7	1132.783051

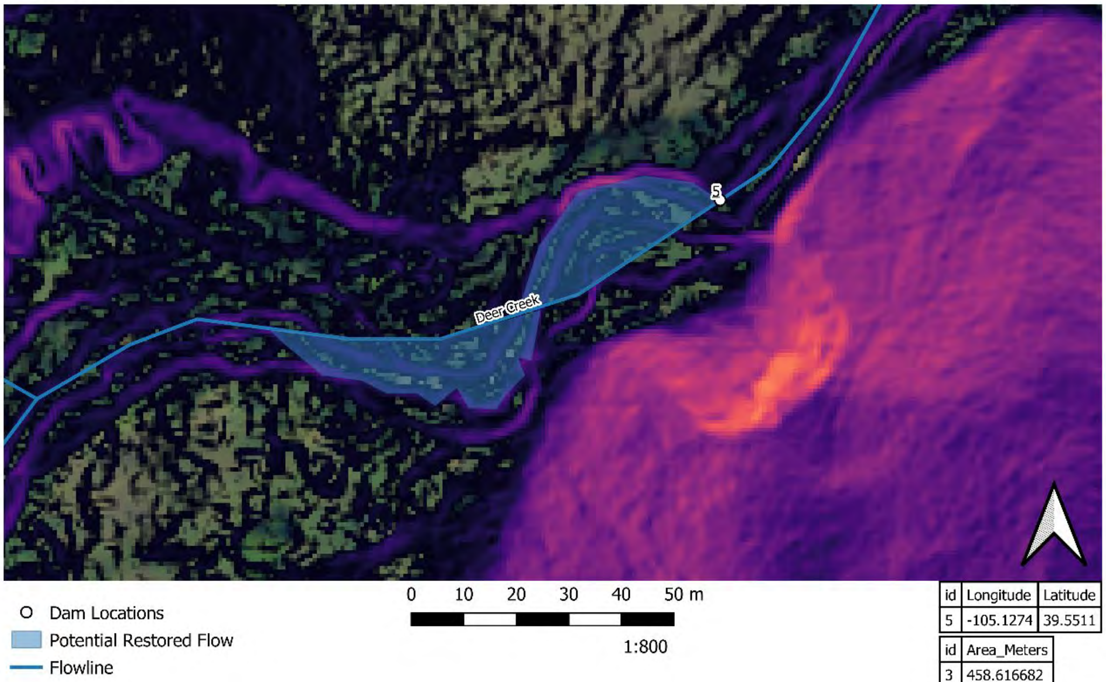
Dam Location ID: 4



id	Longitude	Latitude
4	-105.1254	39.5518

id	Area_Meters
1	832.038861
2	1068.564952

Dam Location ID: 5



id	Longitude	Latitude
5	-105.1274	39.5511

id	Area_Meters
3	458.616682
4	485.352639

Metropolitan State University of Denver planting willow stakes at Deer Creek restoration sites.

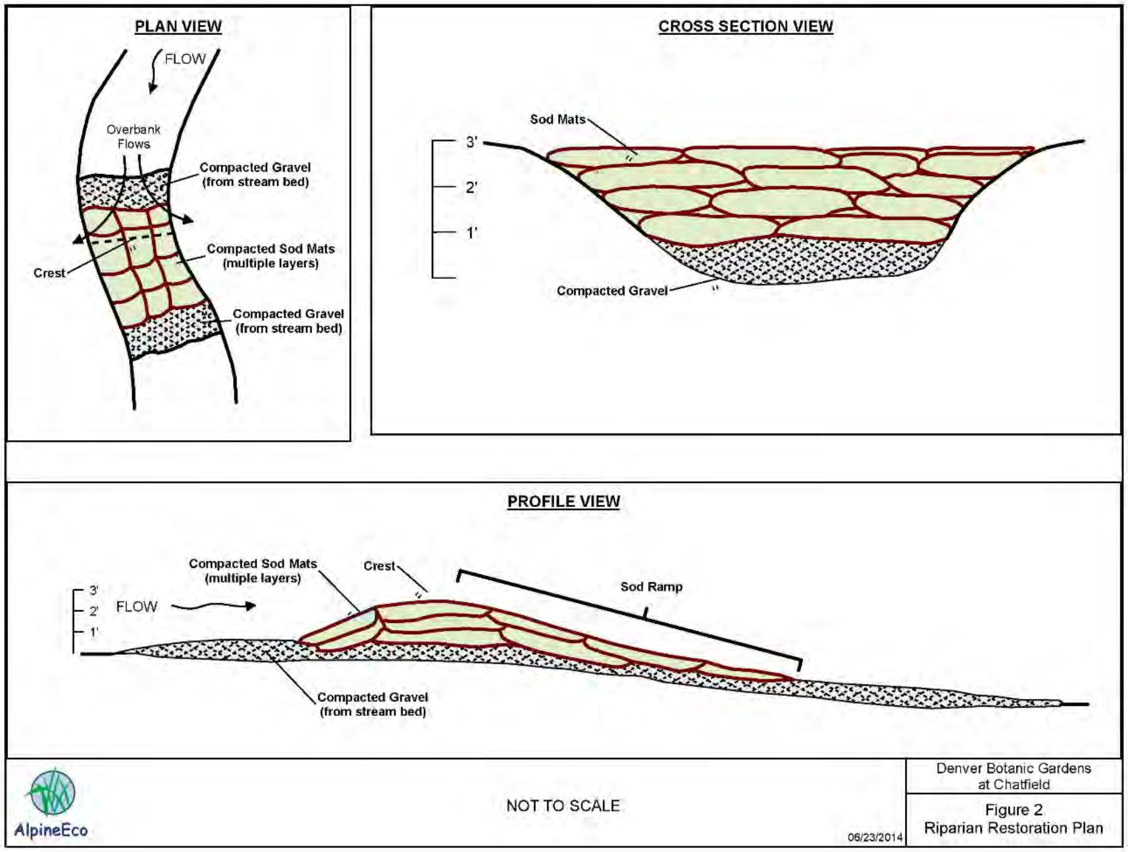
Task 2: Work with Jefferson County Open Space staff to conduct a feasibility study.

We worked with Jefferson County Open Space staff as we narrowed down our potential locations for the installation of in-stream structures and restoration opportunities. We worked with them to obtain a permit to fly the drone to obtain higher resolution data and did one walk-through of the site with their staff prior to flying the drone to discuss the status of the project. While we were ultimately not able to do the drone work due to poor weather and then COVID, we have provided them information to continue this work in the future. The Jefferson County Open Space staff originally working on this project are no longer with the organization. We were advised prior to their departure to provide JCOS with all the information we have gathered, and they would move forward on their own to determine the feasibility of installation and take the next steps. The requested location information and they would work internally to discuss permitting and plans for installation.

Once permitted, we would recommend installation of structures like those shown below. These have held up well over the past five years with little to no maintenance required. All of the photos shown in this report are of these structures. The original sod structures worked initially but washed out after one season. These were rolled sod (smooth brome) that was torn out with excavators in the process of removing the tall bank to create connection to the historical oxbow. They were rolled and then placed in the creek with additional boulders from the site. They did work for the first season, but upon inspection after waters retreated for the season, it was clear much had been washed away and they were compromised and would not function well in future years. AlpineEco designed both of our structures. The images and designs included in the proposal were the good design that are still functional after 5 years. We installed them with a frontloader because we had easy access into our spots from our parking lot and we installed them when it was cold and dry and there was minimal ground and bank disturbance other than where we were doing the installation and needed to remove part of the bank. However, one could install them by hand, it would just take longer. We think BDAs are very promising to help restore creek function and habitat, as well as improve water retention times along the front range.

While the original proposal sought to develop permitting documentation and plans along with the location information, given the change in direction the landowner wished to take, we agreed to continue working with them as they requested. Since submitting our final information to them, we have followed up with them and have scheduled and conducted a walk-through (April 15, 2021) of our existing restoration projects to show the current Jefferson County Open Space staff what the in-stream structures look like and how they are still functioning five years after installation. We continue to work with them on ways that we can help them pursue installing additional restoration structures on their property upstream of Chatfield Farms. Specifically, there is concern about sufficient breeding habitat for the rare northern leopard frog and some habitat losses that have occurred on Jefferson County Open Space. We helped coordinate a frog survey on Chatfield Farms by Jefferson County Open Space staff on April 29, 2021 to determine the presence of the frogs at Chatfield Farms. In addition to continuing to work with them to share our knowledge on in-stream structures for restoration, we are working to continue frog monitoring to better evaluate the landscape-scale conservation for this species and how such restoration might improve their habitat. Based on the initial frog surveys, due to the size and depth of some of the property's wetland resources, we are planning a follow-up investigation of leopard frog breeding habitat that will include dip-netting and/or funnel trapping. Colorado Parks and Wildlife has also expressed interest in assisting with any follow-up on this project and Michelle Christman, PARC federal coordinator, has also expressed her interest in helping with any subsequent field work on this metapopulation.

Once restoration locations are selected, design drawings will be required to construct the restoration structures. Below is an example of one type of structure that can be used.



Once locations are selected and structure design is determined, several pieces of site information are required to obtain the required permits. A key piece of the restoration we have done is that we have rewetted historical oxbows, we did not create new wetlands. This is very important from a permitting perspective. We used the topographic maps showing elevation gradients and GIS analyses to show where the creek originally flowed and areas where the creek was now disconnected from the floodplain. This is the same work that is used to select the restoration sites above. You also need to identify areas that will be rewetted if the structure is installed (as in the modelling figures above). This will not only include the amount of land that will be rewetted but is also important for determining flood risks. You need to model how high the water could flow in large flooding events to ensure that existing roads and buildings or historic sites will not be impacted by the restoration project.

Once the above designs are created and information gathered, there are a couple of permissions that are needed to proceed. First, the landowner and manager where the restoration will occur (in this case, Jefferson County Open Space) must approve the designs. Next, permission from the US Army Corps of Engineers (USACE) is required for such restoration in a waterway. The lead organization doing the restoration needs to submit a Preconstruction Notification (PCN) to USACE to request concurrence that the project is authorized under Nationwide Permit (NWP) 27, pursuant to Section 404 of the Clean Water Act (Section 404). The PCN should include the source of funding for the project, the organizations involved, and the ownership and management of the property. It should also include the following information: project background, existing conditions, work to be completed (including acreage of impacted area), impact to species protected under the Endangered Species Act, impact to areas protected under the National Historic Preservation Act, and any required mitigation measures.

Once the project is approved, the restoration project can begin. The overall budget and timeline for project completion will vary based on the type of installation chosen for a specific site. For the installations that were installed at Denver Botanic Gardens Chatfield Farms, we used a consultant to help us assess our site and develop the original installation designs ($5280) and install the three structures ($9300). While the structures worked very well in the first year (2016), they were very washed out and compromised by the end of that season. We decided we should modify the designs in the second year so had the consultant install a modified version at the three restoration locations in 2017 ($10,300). Since 2017, we have done annual checks of the structures and our staff have conducted minor repairs to maintain them, but we have not spent any additional money on the structures or bringing in outside help with them. As of this season (the 5th year for these structures), they still are functioning great and I've included photos from this year below. There are many different versions of these structures that practitioners are deploying successfully throughout the west. Alternatives to the ones we used include installing the structures by hand with staff and/or volunteers and can be done less expensively than the version we used.