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State Street Dam History and Strategy

The State Street Dam, located in Alma, Michigan, is a small dam that has been receiving attention in recent years for its impact on the Pine River and the Alma community. It's a city-owned gravity dam on the Pine River whose construction was completed in 1938.[1] Originally, the dam was created to supplement the city's logging industry. After the decline of large-scale logging, the reservoir was used to contribute to the City of Alma's water supply. However, due to years of pollution from the area's brownfield sites and nearby large-scale agricultural centers, the dam is no longer serving its intended purpose, as the water quality doesn't meet drinking water standards. After discussing the construction and general effects and risks of dams, this paper will examine the history and impacts of the State Street Dam on the community and environment, as well as investigate potential options for addressing these issues, including dam removal.

A dam is any structure that restricts flowing water. While dams can form naturally, in the context of this research, a "dam" refers to a human-made structure built to control the movement of water.[2] While all dams control water movement, they're built for a variety of purposes,[3] including irrigation,[4] hydroelectric power generation,[5] water storage and supply, navigation,[6] recreation, and wildlife habitat.[7] The State Street Dam was constructed in 1867 to assist with logging and act as a privately-owned mill. In 1876, a logging jam destroyed the original dam, which was rebuilt in 1938 following a citywide vote.[8] Reconstruction was completed in 1947 and it was updated in 2000. Today, there are at least 2,500 dams in Michigan alone.[9] Many of Michigan's dams, including the State Street Dam, are regulated by the Michigan Department of the Environment, Great Lakes, and Energy (EGLE).[10]

To address the problems with the State Street Dam, it's important to understand the general impacts dams have on rivers. Firstly, all dams create obstacles to the movement of aquatic organisms, nutrients, and sediment. This can prevent fish from migrating and reaching spawning areas. Additionally, there can be imbalances in nutrient levels between the waters upstream and downstream of the dam, as organic material becomes trapped in the impoundment

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[1] "State Street Dam." 2021. National Inventory of Dams. https://nid.sec.usace.army.mil/#/dams/system/MI00005/summary.
[2] Royall, Dan. 2022. "Land-Use Impacts on the Hydrogeomorphology of Small Watersheds." *Treatise on Geomorphology* 9 (March): 36-64. https://doi.org/10.1016/B978-0-12-818234-5.00010-9.
[3] Zarivny, Andrew. 2023. "Dams." National Geographic Society. https://education.nationalgeographic.org/resource/dams/.
[4] "Role of Dams for Irrigation, Drainage and Flood Control." 2000. International Commission on Irrigation and Drainage. https://www.icid.org/dam_pdf.pdf.
[5] "Types of Hydropower Plants." n.d. Department of Energy. Accessed January 3, 2024. https://www.energy.gov/eere/water/types-hydropower-plants.
[6] "Navigational Dams." n.d. Orsanco. Accessed January 3, 2024. https://www.orsanco.org/river-facts/navigational-dams/.
[7] "Recreation Near Dams." n.d. Virginia Department of Conservation & Recreation. Accessed January 3, 2024. https://www.dcr.virginia.gov/dam-safety-and-floodplains/document/ds-recreation-flier.pdf.
[8] Dam Removal PowerPoint
[9] "Program overview." n.d. State of Michigan. Accessed January 3, 2024. https://www.michigan.gov/egle/about/organization/water-resources/dam-safety/program-overview.
[10] "Department of Environment, Great Lakes, and Energy." n.d. State of Michigan. Accessed January 3, 2024. https://www.michigan.gov/egle.

and decomposes. Pollutants like metals and organic materials are often concentrated in trapped sediments.

Dams cause streams to slow down by creating obstacles that water must flow through, reducing how much sediment it can carry. In slower streams, more sediment is deposited on the stream floor, resulting in a shallower stream. As water slows down behind the dam and gets shallower, it widens. With slower, shallower water, the stream becomes more lake-like, conditions which are unsuitable for cold-water fish species like brown trout, which used to thrive in the Pine River.[11] Additionally, as the stream widens and shallows, it can "drown" plant life along the bank, reducing tree cover and harming native species. The increased surface area absorbs more sunlight, warming the water, which changes the levels of dissolved oxygen within the stream. The warmer and stiller the water, the less dissolved oxygen it can store. As water temperatures increase and the stream slows, less dissolved oxygen is available for aquatic organisms. Lower concentrations of dissolved oxygen change the kinds of species that can live in the stream. As more sediment and organic matter is deposited, oxygen levels lower more while the demand for it further increases. In some cases, this causes fish and other aquatic organisms to suffocate.

Agriculture is causing significant pollution in the Pine River. Alma College has been studying the river since 2004 and has found that CAFOs strongly contribute to its degradation.[12] As a result of the impairment, the watershed above the State Street Dam is polluted by algal blooms, *E. coli*, pesticides, and plankton. Algae thrives in the warm, low-velocity, nutrient-rich environments created by dams. The physical and biological impacts on rivers also affect human communities. Algae blooms and organic pollution lower property values and impact the stream's recreational capacities. Due to the pollution, it's unsafe to use the Pine River for recreation like swimming and fishing. For popular fishing spots and communities relying on rivers for tourism income, a fish consumption advisory from impoundment pollution can harm city income and image, as well as the health of low-income residents who supplement their diet with fish from the river. Due to the high costs of water treatment, treating the river isn't currently a feasible option for the community.

Impoundment pollution also causes aesthetic concerns. In Alma, agricultural runoff including manure is reported floating down the river on multiple occasions each year.[13] This comes from misapplication of manure as fertilizer in nearby agricultural areas.[14] Due to the slow-moving waters, this remains in the stream for long periods of time, worsening algal blooms. **These events can reduce waterfront property value and damage the city's reputation**.

In addition to these concerns, dams present a risk to residents living within the flood inundation area.[15] Michigan has seen all too recently the effects of dam failure. In May of 2020,

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[11] Burroughs, Bryan, et al. "Dam Removal and the Pine River." Feb. 2024.
[12] Borrello, M, et al. Alma, MI, 2023, *General Overview of the Status of the Upper Saginaw River Drainage Basin*.
[13] Gittleman, Linda. 2014. "Pine River in Alma is sick with too much ammonia, manure and E.coli." *The Morning Sun*, October 10, 2014. https://www.themorningsun.com/2014/10/10/pine-river-in-alma-is-sick-with-too-much-ammonia-manure-and-ecoli/.
[14] Gittleman, Linda. 2020. "Solution for Pine River: Stop farm over fertilization?" *The Morning Sun*, January 11, 2020. https://www.themorningsun.com/2020/01/11/solution-for-pine-river-stop-farm-over-fertilization/.
[15] Association of State Dam Safety Officials. Living With Dams: Know Your Risks, Federal Emergency Management Agency, 2012.

mid-Michigan experienced heavy rainfall, which resulted in flooding[16] that overwhelmed and caused the failure of the Edenville Dam, a privately-owned and undermaintained dam upstream of Sanford and Midland.[17] After breaching the dam, the floodwater moved downstream to Sanford Lake and the Sanford Dam, which couldn't handle the quantity of water and was badly damaged.[18] After overrunning the Sanford Dam, the water continued down the Tittabawassee River and into Midland, which was hit hard by this record flood.[19] That August, EGLE wrote on how the event "illuminated… the consequences of inadequately investing in our State's infrastructure".[20] **The State Street Dam has a significant hazard potential, meaning its failure would likely result in economic, environmental, and facility damage, but no loss of human life.**[21]

Eight brownfield sites exist along the Pine River as it runs through Gratiot County, one of which has historically generated pollution concerns. 115 North State Street is the former site of Alma Iron and Metals (AIM). In 2007, NTH Consultants recorded levels of several contaminants in exceedance of water quality regulations, including benzene, arsenic, lead, and mercury. Similar findings were reported from soil tests, with levels of DDT, arsenic, lead, mercury, and other metals found to exceed safe levels. In 2008, the site was partially cleaned up, though its groundwater was not. In 2014 and 2015, the city switched its drinking water supply from the Pine River to a joint project with St. Louis.

Due to the risks of dams and the State Street dam's lack of functionality, several approaches have been outlined, some of which have been successfully applied to similar dams.

When a project's limitations require the dam structure to be left in the stream, the general preference is to not remove any part of the dam. This "no removal" approach may be selected to limit downstream effects or impacts to wildlife and can be used alongside other measures to prevent river degradation. These measures include planting vegetation between streams and agricultural areas to prevent agricultural runoff from further polluting the water[22] or creating fish passages and bypass channels to allow improved migration. This approach benefits warm-water fish migration but doesn't allow the stream to fully return to the same climate it had before the dam was constructed. This approach can be seen in the Barton Dam, which is on the Huron River

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[16] Beggin, Riley. 2020. "Midland failed dams, floods caused $200M in damages to 2,500 buildings." Bridge Michigan. https://www.bridgemi.com/michigan-government/midland-failed-dams-floods-caused-200m-damages-2500-buildings.

[17] "INVESTIGATION OF FAILURES OF EDENVILLE AND SANFORD DAMS." 2021. AWS. https://damsafety-prod.s3.amazonaws.com/s3fs-public/files/Edenville-Sanford_Interim%20Report_Sept2021_Final.pdf.

[18] Clark, Anna, and Ben Tierney. 2020. "When the Dams Broke in Midland, Michigan." Belt Magazine. https://beltmag.com/dam-broke-midland-michigan-flood/.

[19] "Michigan Floods and Dam Failures May 2020." 2020. NASA Applied Sciences. https://appliedsciences.nasa.gov/what-we-do/disasters/disasters-activations/michigan-floods-and-dam-failures-may-2020.

[20] Clark, Liesl E. 2020. "Preliminary Report on the Edenville Dam Failure and Response Efforts." State of Michigan. https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Multi-Division/Edenville-Dam/Report-Preliminary.pdf?rev=1da6d729c0ab45c59e25ed070ac38a87&hash=E7BE916E513D5104D1181391C0D63DDA.

[21] "Dam Awareness." 2018. FEMA. https://www.fema.gov/sites/default/files/2020-08/fact-sheet_dam-awareness.pdf.

[22] Mekuria, Deshu M., Alemnew B. Kassegne, and Seyoum L. Asfaw. 2021. "Assessing pollution profiles along Little Akaki River receiving municipal and industrial wastewaters, Central Ethiopia: implications for environmental and public health safety." *Heliyon* 7, no. 7 (July). https://doi.org/10.1016/j.heliyon.2021.e07526.

in Washtenaw, Michigan, and owned by the City of Ann Arbor.[23] While it's mainly a hydropower dam, it also supports the city's water supply. The dam is in the process of overhaul, as it has extensive damage but its benefit to the city outweighs its high hazard potential and the cost of repairs.[24] This is not recommended for the State Street Dam, as the problems associated with it are unlikely to be solved by a passive approach.

Partial removal may be used if historical structures stand in a downstream area that would be inundated or undermined by a full removal, factors which should be considered in the removal of any dam. This approach is also useful if there is concern about invasive species movement following full removal. Partial removal can involve vertical or horizontal structure modification. Horizontal modification means removing sections parallel to the water's surface, like lowering the dam across the stream. Vertical modifications are when the structure is cut perpendicular to the water's surface, removing a section of the dam all the way to the stream bottom but not all the way across the stream. This approach is planned for the Carp River Intake Dam, where the dam's upper portion will be removed to lower the reservoir by ten feet.[25] This will reduce the risk presented by a potential dam failure and lower the dam's hazard potential classification.

If the difference in elevation of the stream bottom upstream and downstream is big enough, there may be concerns about erosion. Grade control can be used with full dam removal to limit erosion while lowering the impoundment to restore channel function. This approach is scheduled for use in removing Genesee County's Hamilton Dam, a dam with a high hazard potential that plans to use rock riffles to promote fish passage.[26] The project's goal is to preserve lake sturgeon habitat[27] in the river while reducing the threat to humans.[28]

Full removal without grade control is a viable option if constraints allow for sediment movement but won't threaten property, infrastructure, or downstream habitats. In this type of removal, no structures are needed to control the grade of the stream bottom. It is possible, though uncommon, for a stream post-removal to return fully to its condition before dam construction.[29] The more likely outcome, due to other changes in the area since the dam's construction, is that the stream will partially return to its pre-dam condition.

There are also different methods for removing dams. The process can begin after receiving the proper permits.[30] Often, the most expensive and technical step of dam removal is sediment management. If the sediment is clean, which is not the case in the Pine River, it isn't

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[23] "Barton Dam." 2023. National Inventory of Dams. https://nid.sec.usace.army.mil/#/dams/system/MI00560/description.

[24] Stanton, Ryan. 2018. "Ann Arbor approves $543K for Barton Dam overhaul." MLive.com. https://www.mlive.com/news/ann-arbor/2018/02/ann_arbor_approves_543k_for_ba.html.

[25] Johnston, Jeff. 2023. "Sixteen Michigan dams get safety upgrade funding through $15.3M risk reduction program." State of Michigan. https://www.michigan.gov/egle/newsroom/press-releases/2023/05/18/sixteen-michigan.

[26] "$1.5M grant will help remove 'high-hazard' dam from downtown Flint." 2023. State of Michigan. https://www.michigan.gov/egle/newsroom/mi-environment/2023/05/30/one-point-five-million-grant-will-help-remove-high-hazard-dam-from-downtown-flint.

[27] "Hamilton Dam & Fabri Dam." n.d. Genesee County Parks. Accessed January 3, 2024. https://geneseecountyparks.org/riverfront-project/hamilton-dam-faq/.

[28] "Hamilton Dam Removal: Removing a High Hazard Dam in Flint, MI." n.d. U.S. Fish and Wildlife Service. Accessed January 3, 2024. https://www.fws.gov/project/hamilton-dam-removal-removing-high-hazard-dam-flint-mi.

[29] Doyle, Martin W., et al. "Stream ecosystem response to small dam removal: Lessons from the Heartland." Geomorphology, vol. 71, no. 1–2, Oct. 2005, pp. 227–244, https://doi.org/10.1016/j.geomorph.2004.04.011.

[30] "National Management Measures to Control Nonpoint Source Pollution from Hydromodification." 2007. Environmental Protection Agency (EPA). https://www.epa.gov/sites/default/files/2015-09/documents/chapter_9_dam_removal_info_web.pdf.

always necessary to remove the sediment, and the water can be safely drained as the first step of the dam's removal. **This is done slowly to reduce the risk of overwhelming downstream waters with mobilized sediment**. In Alma, this is a more serious concern. The flocculant zone, a layer of fine organic material above the sediment, is so thick in the impoundment that there's a high risk to aquatic organisms if it's washed downstream.

Dredging, or scooping out sediments and debris from the bottom of an impoundment, helps increase channel depth and reduce the amount of sediment washed downstream when velocity increases.[31] Selective dredging involves dewatering the dam to allow the sediments to consolidate before dredging the areas where the post-removal channel will run. This is an expensive process but may be more cost-effective than dredging the entire channel. The extent to which the sediment should be dredged or managed can be determined by observing the streambed's characteristics further upstream. Certain streambed features, like natural riffles and pools, are found outside of impoundments, only appearing past its edge.

However, regardless of precautions, some sediment will always be transported downstream.[32] **To limit the effects of these sediments on aquatic life, sediment release should be planned to occur during a time of year when fish are not spawning.** Sediment traps or basins can help to manage smaller amounts of sediment, but it's necessary to decide on what's an acceptable loss of downstream aquatic life and habitat immediately following dam removal.

When determining the most applicable approach for the State Street Dam, there are a few things that must be considered: the river's velocity, its morphology (width and depth), its flow type (laminar or turbulent), and sediments that will be mobilized by a change in these factors. Additionally, the flood inundation area near the river and changes in habitat should be part of the decision-making process. In 2016, transects (measurements of the river's width and depth) of the Pine River were recorded by BARR Engineering in a sediment analysis study. In 2022, students from Alma College measured the dam's retaining wall and river velocity along the stream, and the sediment thickness at different points in the channel. Using this data, students calculated the quantity of water flowing through the Pine River at various transects (4517.89).

The State Street Dam's retaining wall is on the site east of North State Street. The wall is around 17 inches wide and 7.9 feet tall and is made of mortar and cobbles with some steel traps along its outside length. The retaining wall's face is covered by a concrete veneer.[33]

Deciding on a recommended removal approach will require more steps and research in the sphere of engineering, which the Healthy Pine River Group is taking. Sediment samples were collected in early April to be analyzed for particle size and composition. Using the results, which should be received in the upcoming months, the Healthy Pine River Group can determine the best course of action based on potential downstream impacts of mobilized sediment. In the meantime, interested parties should **focus on community education and engagement events to gather support and funding**, as well as a number of volunteers for lowering the expenses of future efforts. Downstream sites should be surveyed to identify any structures at risk in the event of a change in the river's flow, and a timeline and budget for removal should be developed.

The voices of stakeholders and community members are important in the planning and discussion stages of small dam removal. Surveys and meetings can and should be used to gather

[31] NOAA. 2023. "What is dredging?" National Ocean Service. https://oceanservice.noaa.gov/facts/dredging.html.
[32] Leading Small Dam Removal, Huron Pines, Gaylord, Michigan, 2012.
[33] Dam Removal PowerPoint

opinions, address concerns, and foster community education and discussion. In some steps of the process, **volunteer efforts can lower project costs**.

Immediately after the removal of a small dam, and up to several years following, the Pine River will show higher levels of sediment transport downstream as the water picks up and moves particles. The river may return to its natural (undammed) temperatures and flow patterns, and the water levels upstream of the dam site will lower. Community members and landowners along the river may be concerned about the formation of "mud flats", but with proper management, **the revealed sediment can be revegetated, sometimes with native species**. Studies of ecosystems following small dam removal have found that the recolonization of plant species takes place very quickly, and by a year after the removal, it's rare for bare sediment to be observed.[34] Over several years, the land may return to natural conditions, although this depends on the specific features of the river.

[34] Tonitto, Christina, and Susan J. Riha. "Planning and implementing small dam removals: Lessons learned from dam removals across the Eastern United States." Sustainable Water Resources Management, vol. 2, no. 4, 6 Oct. 2016, pp. 489–507, https://doi.org/10.1007/s40899-016-0062-7.

HEALTHY PINE RIVER/STATE STREET DAM WHITEPAPER

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2023-2024

List of Questions:

1. What are the general impacts dams can have on rivers?
2. What is the historical significance of the State Street Dam?
3. Specifically, what are the impacts that State Street Dam has on the community and the environment surrounding it?
4. Which dam removal techniques could be used to remove the State Street Dam?
5. How quickly could the Pine River recover after the State Street Dam removal?
6. What are the potential downsides to the removal of the State Street Dam?
7. How can we limit the risks of these downsides?
8. How can you help with the process of the State Street Dam removal?

Consensus Statements:

1. Dams are barriers that interrupt natural river dynamics and become obstacles to the movement of organisms, nutrients, and sediment. They prevent fish from migrating and reaching spawning areas and create imbalances in nutrient levels as organic material gets trapped in the impoundment and decomposes. Pollutants are often concentrated in trapped sediments.
2. The Alma River and the impoundment behind the State Street Dam are impacted mainly by agricultural pollution from the misapplication of fertilizer, which runs off into the river during rain events, encouraging algae blooms and creating high levels of *E. coli*.
3. Brownfield sites, specifically the former Alma Iron and Metals site, present potential concerns due to contaminants residing in groundwater and soil.
4. There are different removal techniques that could be used to remove the State Street Dam. These include partial removal and full removal without grade control. With these techniques, there are also important technical steps to be taken for sediment management.
5. When determining the most applicable approach for the State Street Dam, there are a few things that must be considered: the river's velocity, its morphology (width and depth), its flow type (laminar or turbulent), and sediments that will be mobilized by a change in these factors. Note that habitat changes should also be considered when making these decisions.

Action/Solution Statements:

1. Surveys and meetings can and should be used to gather opinions, address concerns, and foster community education and discussion.
2. To determine the best course of action, additional work is currently being conducted by the Healthy Pine River Group, an engineering firm, and engineering student Maxwell Mengyan.
3. Until sediment analysis and downstream surveying is complete, focus on community engagement, education, and fundraising. Recruit potential volunteers to lower the future costs of dam removal.