River Restoration Toolbox
Practice Guide 10

Dam Mitigation

Iowa Department of Natural Resources

April, 2018

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Executive Summary

Dam infrastructure may need to be removed or mitigated for various reasons. Many dams constructed in Iowa are aging and/or at risk of failing, which can be a public safety hazard and economic liability. Others may be no longer functional or causing unintended issues such as impeded sediment transport, reduced aquatic habitat, barriers to fish movement, and diminished recreational activities. This practice guide presents the following dam mitigation techniques to remove or improve dam infrastructure:

1. Single Stage Dam Removal
2. Phased Dam Removal
3. Height Reduction with Fish-Passable Grade Control Structure
4. Replacement of Dam Function with Free-Standing Fish Passable Grade Control Structure

The *River Restoration Toolbox Practice Guide 10: Dam Mitigation* (Practice Guide) has been developed to assist with the presentation of design and construction information for stream restoration in Iowa. It is intended to provide guidance to:

- Those responsible for reviewing and implementing stream restoration,
- Professionals responsible for the design of stream restoration projects,
- Others involved in stream restoration at various levels who may find the information useful as a technical reference to define and illustrate dam mitigation techniques.

The Practice Guide includes a written assessment and description of dam mitigation techniques. Each technique includes design guidelines, a specifications list, photographs, and, when applicable, drawings.

The information in the Practice Guide is intended to inform practitioners and others, and define typical information required by the State of Iowa to be included with the use of dam mitigation techniques. The information and drawings are not meant to represent a standard design method for any type of technique and shall not be used as such. The Practice Guide neither replaces the need for site-specific engineering and/or landscape designs, nor precludes the use of information not included herein.

The Practice Guide may be updated and revised to reflect up-to-date engineering, science, and other information applicable to Iowa streams and rivers.

1.0 INTRODUCTION

Dam mitigation practices improve and restore stream functions lost to hydrologic and hydraulic modifications, and often improve public safety as well. Dams may need to be removed as infrastructure deteriorates or becomes obsolete, or dam mitigation may be needed to improve infrastructure function in areas where dams still serve a purpose. The lifespan of dams is limited by both the structural integrity of the dam and sedimentation of the dam reservoir (Aadland, 2010). While risk of dam failure is a major concern, even dams in functioning condition cause public safety risks due to the creation of hydraulic undertows below the dam (Leutheusser and Birk, 1991). Dams can also prevent fish passage, impact mussel habitat, and disturb other functions of a natural stream ecosystem.

Dam removal, replacement, and/or mitigation projects are often complex and can require large investments from communities. There are usually multiple stakeholders and various project goals and priorities. In addition, because dams alter the course and function of rivers, restoration and bed stabilization is often conducted in conjunction with dam removal (Katopodis and Aadland, 2006). Iowa Department of Natural Resources (in cooperation with Iowa State University and other agencies) has conducted research and planning regarding dam mitigation, including the *2010 Plan for Dam Mitigation*, referenced throughout this document. This Practice Guide summarizes some of the dam mitigation options currently used and recommended by Iowa DNR.

2.0 KEY CONSIDERATIONS FOR DAM REMOVAL PROJECTS

Project Goals

When considering a dam removal or mitigation project, the intended goals are important considerations in the decision-making process. There are frequently many stakeholders involved, and the projects are complex often requiring large investments from communities. The type of dam mitigation required and the feasibility of the project depend not only on the existing circumstances of the dam but also the future use and requirements of the waterbody. As stated previously, dam mitigation projects are often necessary for public safety, due to aging dam infrastructure, flood potential, or hazardous flow conditions. Dam mitigation projects may also be necessary to improve and restore stream functions, or this may be a secondary goal. Finally, dam mitigation projects may also require that certain dam functions be maintained or improved. Project goals should be considered in the project design and may be important factors in the type of dam removal technique used. Whatever the purpose of the dam removal, the project should result in a more stable, functional river system. Benefits of dam removal projects are well documented in case studies throughout the region and vary widely depending on the project goals. Numerous project goals have been cited in case studies of completed

dam removal projects. The following are examples of the goals and potential benefits of successful dam removal projects:

- Eliminate dangerous hydraulic jumps (Leutheusser and Birk, 1991)
- Eliminate maintenance costs and liability due to failure risk or drowning (Aadland, 2010)
- Restore migratory pathways, nutrient and sediment regimes, and ecological and channel forming processes (Aadland, 2010)
- Stabilize channel degradation and restore normal sediment supply downstream of the dam and restore connection to floodplain (Aadland, 2010)
- Re-create or imitate critical high-gradient or rapids habitat (Aadland, 2010)
- Improve water quality, dissolved oxygen concentrations, and clarity (Aadland, 2010 and Wisconsin DNR, 2017)
- Normalize temperature regimes and restore biological diversity (Wisconsin DNR, 2017)

Removal Options

As stated, a range of options are available for dam mitigation projects, including complete removal, replacement, height reduction, or other modifications. Important considerations for removal or the type of mitigation used include current use or function of the dam, potential sediment release issues, potential for sediment contamination, access during construction, historic value of the dam and infrastructure.

If the dam has current function that must be maintained, complete removal is likely not an option. In this case, to improve river function and/or safety, replacement of dam function or height reduction may be considered. Options may also include keeping the dam in place and utilizing fish passage structures.

The potential for sediment release must be carefully considered in the planning stages of dam mitigation projects, as discussed further below. A single stage dam removal may not be feasible depending on the sediment contained in the impoundment. A phased removal or other options may need to be considered. There are generally at least four options for addressing sediment associated with dam removal (Aadland, 2010):

1. Remove the dam and allow the river to transport the sediment unimpeded,
2. Phased removal over a period of years, controlling the amount released at any one stage,
3. Dredging sediments before completing the removal

4. Removal as part of river restoration efforts to stabilize channel.

National Historical Registration Review

Many dam removal projects require a Section 404 of the Clean Water Act permit from the US Army Corps of Engineers (USACE). The Section 404 permit process includes a review of the historic or cultural value of the dam and associated infrastructure. The historic/cultural resource review process for dam mitigation projects should include the following steps:

- Have a qualified Historic Preservation consultant evaluate the project area to determine potential for the dam and associated infrastructure to be eligible for listing on the National Register of Historic Places (NRHP). The report should be submitted to the USACE as part of a complete Section 404 Permit Application package.

- The USACE will evaluate the report and coordinate the project with the Iowa State Historic Preservation Office (Iowa SHPO). The Iowa SHPO must provide concurrence with the USACE's recommendations for the Section 404 process to be completed.

- Alternatives analysis: If the report recommends the dam and / or associated infrastructure as "eligible for NRHP listing" an alternatives analysis shall also be included the Section 404 Permit Application package. The alternatives analysis shall include a description of attempts to avoid and/or minimize impacts to historic properties by adapting the design of the project.

- If avoidance of NRHP eligible structures is not feasible, the USACE and the Iowa SHPO will develop a Memorandum of Agreement (MOA) to mitigate the effect of the proposed project. Examples of mitigation efforts outlined in the MOA can include (but are not limited to): any design changes incorporated into the new project, photographic documentation of the existing structure, and historic context reports.

Sediment Characterization

Surveys of existing conditions are required prior to dam mitigation project design. At a minimum, project cross sections, longitudinal profile, and sediment characterization are required. Sediment characterization should include depth of refusal surveys to determine sediment depths in the impoundment and determination of sediment D50 and D84 for the impoundment and the nearest upstream riffle.

- Potential for contamination – If there is a history of industrial use in the area near the impoundment, there may be potential for sediment contamination. Typically, the Department of Natural Resources should be involved in project planning to determine if contaminant sampling is required. Amount of colloidal and very fine sediments in the impoundment should also be considered, as some contaminants bind to these particles. Release of sediments must not introduce a harmful level of contaminants into the waterbody. Mechanical removal of contaminated sediments

within the impoundment is likely costly, but is an option if project goals require removal of the dam.

- Volume of sediment available for release – Analysis should determine the amount of sediment expected to be mobilized by removal, versus background sediment. NRCS RUSLE2 method is one acceptable method for background sediment calculations. A bathymetric survey of the impoundment can be useful in determining volume of sediment. Some projects may also have pre-construction or as-built bathymetry from the time the dam was constructed to provide another source of information for volume estimation. The annual sediment load compared to amount mobilized by removal must be considered to determine how sediment release should be controlled. Typically, mobilization of over one year of sediment load will require phased removal to control sediment release. Larger amounts may require grade control replacement or height reduction with fish passable grade control. Considerations must also be made based on environmental or biological review, as sediment release may impact mussel populations or other ecological functions.

Upstream Utilities/Infrastructure

Since dam removal will often result in the lowering of the bed elevation upstream of the dam, there is a potential that upstream utilities and other infrastructure may be exposed or impacted following dam removal. The presence of utilities upstream of a dam should be thoroughly investigated and the potential impact on removing the dam on the utility should be evaluated and coordinated with utility companies. Consideration should also be given to impacts on infrastructure such as upstream bridges.

Dams as Fish Barriers

While dams are typically considered detrimental to native aquatic species, in certain cases, existing dams provide physical barriers that prevent undesirable invasive species (often Asian carp) from spreading into new waterways. This should be a consideration if the dam is separating invaded and un-invaded segments of a stream or river. In most cases, the benefits of dam mitigation outweigh the potential negative result of removing a barrier to undesirable species, but experts must make this determination on a case-by-case basis. A diverse and experienced team of resource professionals should be consulted during planning for any dam mitigation project to prevent unintended consequences.

3.0 DAM MITIGATION TECHNIQUES

3.1 SINGLE STAGE DAM REMOVAL

3.1.1 Narrative Description

Under certain circumstances, problems caused by a dam can be solved by completely removing the dam, without additional restoration of the channel upstream or downstream of the structure. The dam is typically removed down to or near the pre-structure elevation of the river bed. While this may be the most straightforward solution, it can often only be applied after studies conclude that dam removal would not result in harmful sediment release or other unintended adverse effects. This technique may work well on dams that have already been breached.

3.1.2 Technique Information

- **Use:** Single stage dam removal is used to return the stream bed elevation to the natural level, connecting the bed upstream and downstream of the former dam and restoring regular stream flow and sediment transport.

- **Best applications:** Used for low dams with narrow impoundments, often on dams that have been breached for several years (Iowa DNR, 2010). Used when dam function is no longer needed and river sediments in the impoundment have been determined to not pose a risk if released to the system.

- **Variations:** If necessary, dam removal can be phased; as described in following sections. Dam removal can be accompanied by stream restoration of the impoundment. Other ancillary infrastructure associated with the dam may also be removed. The dam footing may be retained as grade control, or may be removed if it is deemed unnecessary.

- **Computations:**

    - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of single stage dam removal. Hydraulic analysis is required to determine that post-removal water levels and sediment transport capacity will be stable without additional restoration.

    - Sediment calculations are required to determine if single stage dam removal will result in harmful sediment release. If volume of anticipated sediment release is significant (mobilization of more than one year of typical sediment load), a phased approach may be necessary. Note that sediment contamination analysis may be required to assess potential contaminants.

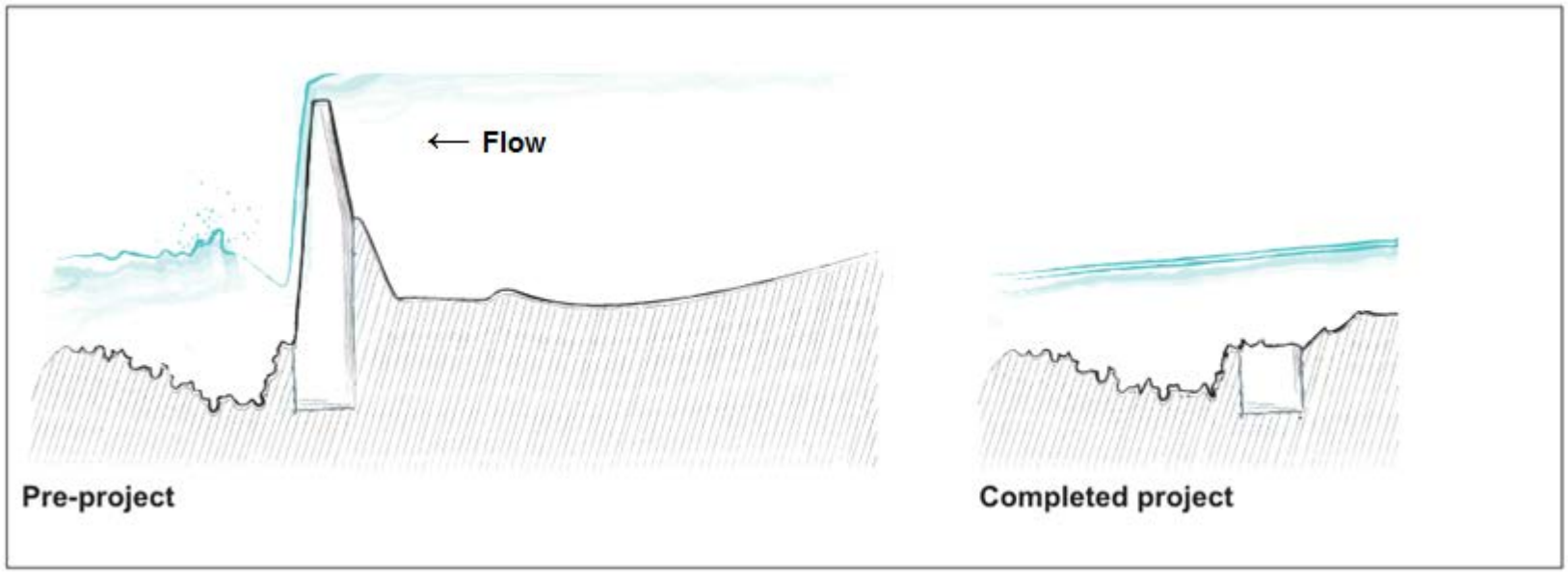
  - Information regarding the structural integrity and composition of the dam are necessary to determine appropriate demolition methods and construction phasing. There may also be some considerations regarding hazardous materials if the dam is constructed of concrete, as it could contain asbestos. Testing may be necessary.

- **Key Feature:** Performed in streams where dam function is no longer needed and dam may already be breached.

3.1.3 Illustrative Drawings

The following illustrative drawings depict information that should be included in construction plans for single stage dam removals. Detail drawings developed by a design professional are required.

Drawing 1. Single Stage Dam Removal



Source: Iowa's 2010 Plan for Dam Mitigation

3.1.4 Photographs

Photo 1. Low-head dam on Deer Creek in Williamsport, Ohio. Source: Stantec.

Photo 2. Deer Creek after single stage dam removal. Source: Stantec.

Photo 3. Cornbelt single stage dam removal. Source: Iowa DNR.

Photo 4. Post-removal view of previous low-head dam location. Source: Iowa DNR.

Photo 5. Pre-construction view of 5th Avenue Dam on the Olentangy River in Columbus, OH. Source: Stantec.

Photo 6. Olentangy River following removal of dam. Source: Stantec.

3.2 PHASED DAM REMOVAL

3.2.1 Narrative Description

Phased dam removal is similar to single stage dam removal in that the end goal is to restore the original bed elevation and stream flow. However, phased dam removal differs from single stage dam removal in that the elevation of the dam is lowered in stages or steps of a certain height over a prescribed length of time. A phased removal is required when the design must control the volume of sediment released in a single event. Phased removal may take years to complete as stored sediment is gradually released. Additionally, phased removal can be used to conserve mussel populations by allowing recovery of any significant populations within the impoundment and by protecting downstream populations from excessive sediment release.

3.2.2 Technique Information

- **Use:** Phased dam removal is used to return the bed elevation to the natural level, in situations when a single stage dam removal would not sufficiently control sediment release.

- **Best applications:** Used in streams where complete dam removal is desirable, but single stage dam removal would release a harmful amount of sediment or unacceptable level of contaminants downstream.

- **Variations:** The first step of a phased dam removal may be to remove the top of the dam, or it may include stages of breaching the dam or opening existing gates to gradually release sediment. Removal can be completed in conjunction with stream restoration of the channel in the former impoundment. Other ancillary infrastructure associated with the dam may also be removed.

- **Computations:**

    - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of phased dam removal. Hydraulic analysis is required to determine that post-removal water levels and sediment transport capacity will be stable without additional restoration.

    - Sediment calculations are required to determine if phased dam removal will result in harmful sediment release. The potential release of sediments will be compared to the annual sediment transport rate of the river, and stages of removal must be designed to control each release event to an acceptable level. Note that sediment contamination analysis may be required to assess potential contaminants.

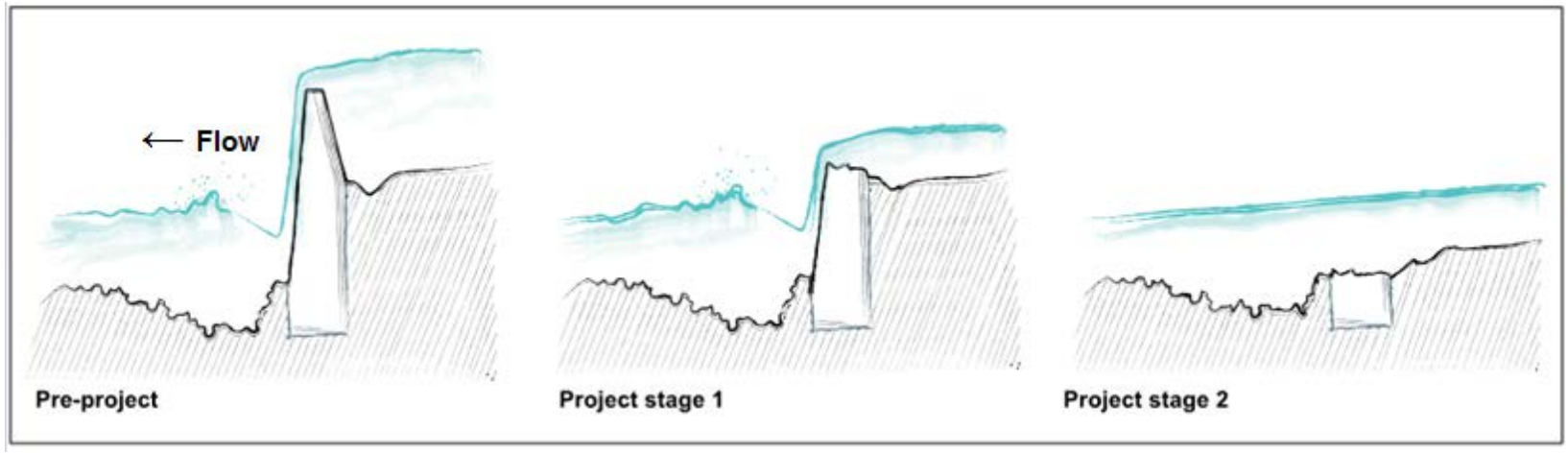
  - Information regarding the structural integrity and composition of the dam are necessary to determine appropriate demolition methods and construction phasing. There may also be some considerations regarding hazardous materials if the dam is constructed of concrete, as it could contain asbestos. Testing may be necessary.

- **Key Features:** Used in streams where complete removal of the dam is desirable but the impoundment holds a volume of sediment that may be harmful to aquatic life or river stability if released in a single event, or the dam is too tall to remove in a single phase.

3.2.3 Illustrative Drawings

The following illustrative drawings depict information that should be included in construction plans for phased dam removals. Detail drawings developed by a design professional are required.

Drawing 2. Phased Dam Removal



Source: Iowa's 2010 Plan for Dam Mitigation

3.2.4 Photographs

Photo 7. First notch placed in West Milton Dam during phased removal. Source: Stantec.

Photo 8. Stillwater River in West Milton, OH following dam removal. Source: Stantec.

Photo 9. Coggon dam prior to removal. Source: Iowa DNR.

Photo 10. Coggon dam after 1st stage of dam removal. Source: Iowa DNR.

Photo 11. Englewood Dam in Englewood, OH prior to phased removal. Source: Stantec.

Photo 12. First stage of dam removal at Englewood Dam. Source: Stantec.

Photo 13. Further stage of dam removal in Englewood, OH. Source: Stantec.

Photo 14. Stillwater River post-restoration in Englewood, OH following dam removal. Source: Stantec.

3.3 HEIGHT REDUCTION WITH FISH-PASSABLE GRADE CONTROL STRUCTURE

3.3.1 Narrative Description

Height reduction with fish-passable grade control is a good option to manage cost, prevent sediment release to the system, and still provide habitat continuity for fish species. This technique is used when total removal of the dam is infeasible due to cost, potential sediment release, land ownership/access, or other issues. In addition, this method can be used if a smaller impoundment is desired. Using this technique, the height of the dam is reduced and a fish passage structure is constructed immediately downstream of the dam such that fish passage through the dam is achievable. This approach does not restore natural function of the river or water quality of the impoundment.

3.3.2 Technique Information

- **Use:** This technique is used to restore aquatic habitat continuity when total removal of the dam is infeasible.

- **Best applications:** This technique is typically used when total removal of the dam is infeasible due to cost, potential for harmful sediment release, or land ownership/access issues.

- **Variations:** Notched Dam with Fish-Passable Grade Control Structure is a similar application. Height reduction can be conducted in conjunction with stream restoration.

- **Computations:**

    - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of this technique. Hydraulic analysis is required to determine that post-removal water levels and sediment transport capacity will be stable without additional restoration.

    - Sediment calculations are required to determine appropriate dam reduction elevation to prevent harmful sediment release. Note that sediment contamination analysis may be required to assess potential contaminants.

    - Geometric calculations are required to properly size and situate the fish-passable grade control structure within the context of the stream flow. Computations are necessary to properly size rock material and should accompany any design using rock. Consideration of the fish species composition of the river is also important in the design of the structure. This structure requires design by a professional.

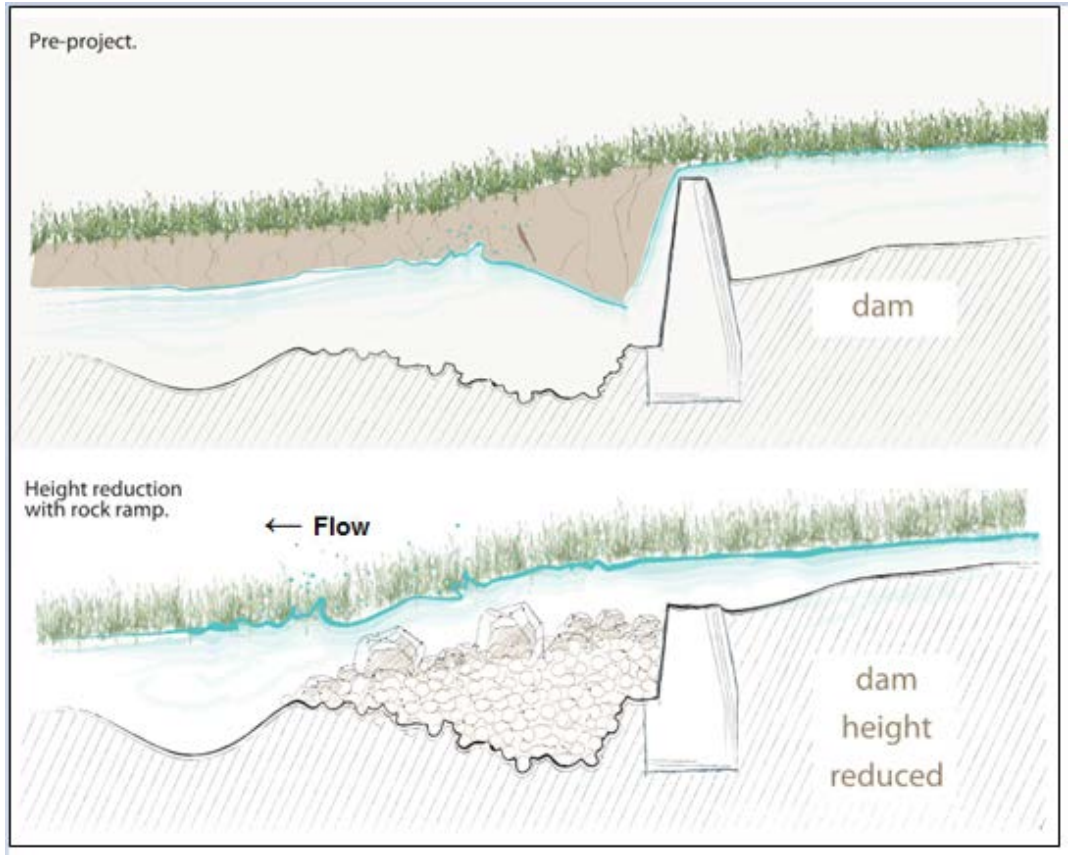
  - Information regarding the structural integrity and composition of the dam are necessary to determine appropriate demolition methods and construction phasing. There may also be some considerations regarding hazardous materials if the dam is constructed of concrete, as it could contain asbestos. Testing may be necessary.

- **Key Features**: Used when the reservoir is not needed or can be reduced, but the dam impounds contaminated, or large amounts of sediments.

3.3.3 Illustrative Drawings

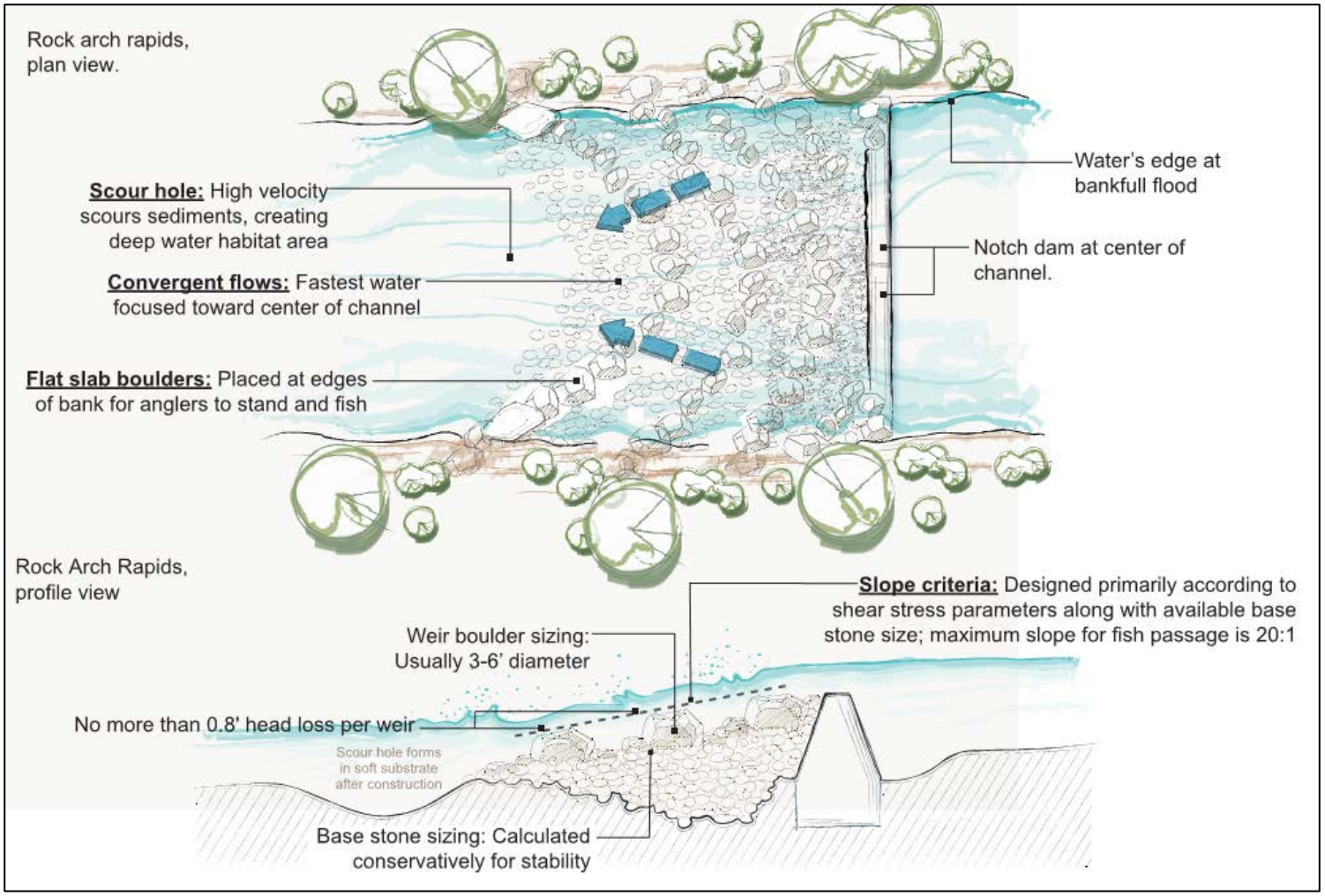
The following illustrative drawings depict information that should be included in construction plans for height reduction with fish-passable grade control structure. Detail drawings developed by a design professional are required.

Drawing 3. Height Reduction with Fish-Passable Grade Control Structure



Source: Iowa's 2010 Plan for Dam Mitigation

Drawing 4. Notched Dam with Free-Standing Fish-Passable Grade Control Structure



Source: Iowa's 2010 Plan for Dam Mitigation

3.3.4 Photographs

Photo 15. Example of rock ramp structure for fish passage and grade control. Source: Unknown.

Photo 16. Rock arch rapid following Quasqueton Dam removal. Source: Iowa DNR.

3.4 REPLACEMENT OF DAM FUNCTION WITH FREE-STANDING FISH-PASSABLE GRADE CONTROL STRUCTURE

3.4.1 Narrative Description

If maintenance of the pool upstream of the dam is desired, replacing the dam with a free-standing fish-passable grade control structure may be a viable removal option. This technique is used when the pool needs to be maintained, fish passage is desired, and the dam infrastructure needs to be removed. This technique does not restore river function.

3.4.2 Technique Information

- **Use:** Alternative for removing aging dam infrastructure while maintaining impounded pool and allowing for aquatic habitat continuity.

- **Best applications:** Used to replace aging dam infrastructure when impoundment needs to be maintained. This technique allows for fish passage, which is not typically achievable with a conventional dam.

- **Variations:** Can be conducted in conjunction with stream restoration. Other ancillary infrastructure associated with the dam may also be removed.

- **Computations:**

    - Hydrologic and hydraulic computations aid in verifying that the appropriate conditions exist for use of this technique. Hydraulic analysis is required to determine that post-removal water levels and sediment transport capacity will be stable without additional restoration. Additionally, hydraulic modeling should be used to evaluate the suitability of the remaining impoundment following the installation of this technique.

    - Sediment calculations are required to determine if dam removal will result in harmful sediment release. Mechanical removal of sediment may be necessary to construct fish-passable grade control structure.

    - Geometric calculations are required to properly size and situate the fish-passable grade control structure within the context of the stream flow. Computations are necessary to properly size rock material and should accompany any design using rock. Consideration of the fish species composition of the river is also important in the design of the structure. This structure requires design by a professional.

    - Information regarding the structural integrity and composition of the dam are necessary to determine appropriate demolition methods and construction phasing. There may also be some considerations regarding hazardous materials if

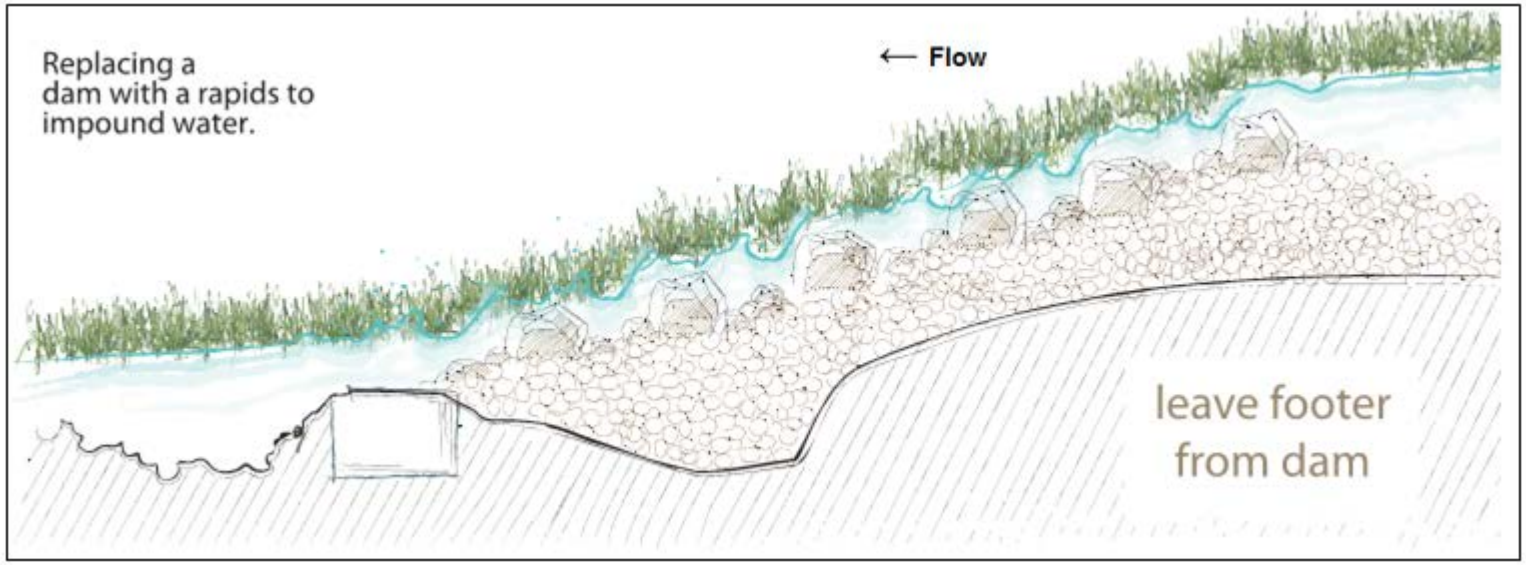
the dam is constructed of concrete, as it could contain asbestos. Testing may be necessary.

- **Key Feature:** Fish-passable grade control structure design is critical, particularly if the pool serves as a water supply. Fish-passable grade control structure must be constructed prior to dam demolition or a pool maintenance plan needs to be implemented.

3.4.3 Illustrative Drawings

The following illustrative drawings depict information that should be included in construction plans for replacement of dam function with free-standing fish-passable grade control. Detail drawings developed by a design professional are required.

Drawing 5. Replacement of Dam Function with Free-Standing Fish-Passable Grade Control Structure



Source: Iowa's 2010 Plan for Dam Mitigation

3.4.4 Photographs

Photo 17. Pond Lily Dam on West River, New Haven, CT before construction. Source: Stantec.

Photo 18. Pond Lily Dam location following replacement of dam function with free-standing fish-passable grade control. Source: Stantec.

Photo 19. View of free-standing fish-passable grade control at Pond Lily Dam site. Source: Stantec.

4.0 REQUIREMENTS FOR DRAWINGS AND SPECIFICATIONS

Projects involving dam mitigation techniques should be designed by qualified professionals. Detailed construction drawings, including project phasing, are required for the dam mitigation techniques described in this Practice Guide. A typical design for a dam removal project may include at least the following sheets, and others may be added based on the specific project needs:

- Cover Sheet (sheet index, project location)
- General Notes and General Construction Sequence
- Existing Conditions (and regulated resources areas)
- Work Plan / Dam Demolition Plan (may be multiple phases as needed)
- Grading Plan (final grading, post construction/permanent ESC measures)
- Revegetation / Planting Plan
- Erosion and Sedimentation Control (ESC) Plan (details)
- Profile and Cross Sections

The following general information should be developed into specifications to accompany the implementation of all dam removal techniques. In projects involving grade control structures, calculations will be required for rock sizing. Specifications will vary based upon the techniques used and should also be developed by a qualified professional.

- Materials: None for removal, additional materials may be required for variations involving restoration or grade control structures. These may include:
    - Rock material, including cobble, riprap, and/or boulders.
    - Vegetative material, including woody material, live brush, plantings, live cuttings, etc.
    - Soil or backfill material.
- Equipment/Tools:
    - Excavator with thumb and hoe ram attachments.
    - Haul Truck

- Sequence:
    - Accessing the dam such that the excavator will not be overwhelmed by the flow of water through the dam, begin demolition with hoe ram attachment. Prevent chunks of the dam from being transported downstream. Continue demolition until the stream bed elevation is reached; in the case of a phased removal, continue demolition until the desired stage elevation is reached, and remobilize and repeat for subsequent demolition stages. Note that during removal, it is important that the structure does not breach in an uncontrolled manner, resulting in flooding downstream. It may be necessary to build a temporary structure to support the impoundment during removal.
    - Load rubble into a haul truck and dispose of in an approved landfill or as an acceptable beneficial reuse.
    - Additional work sequencing will vary based on design, and may include installation of grade control structures or other restoration practices. Removal of water diversion structures and temporary ESC measures will follow final stabilization and revegetation.
- Workmanship: Make sure that rubble is removed from the river. Final elevations should be consistent with the project plans.
- Maintenance: The river may make some profile adjustments once the dam is removed. Intervention may be required if adjustments cause significant instabilities. Also, rapid drawdown of the impoundment may cause some stability concerns along the banks within the former reservoir. Depending on severity, bank stabilization measures may be warranted. Fish-passable grade control structures should be monitored after construction for stability. Adjustments may be necessary if instabilities are noted. Projects involving river restoration may require other maintenance and monitoring based on the design.

5.0 REFERENCES

Aadland, Luther, 2010. *Reconnecting Rivers: Natural Channel Design in Dam Removal and Fish* Passage. Minnesota Department of Natural Resources, Fergus Falls, MN.

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