A BROAD LEVEL CLASSIFICATION SYSTEM FOR DAM REMOVALS

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Abstract Conceptual models of dam removal processes, backed by extensive expertise, provide a solid foundation for the deconstruction of dams. In this paper we propose a broad level classification system for dam removal projects to initiate the creation of better conceptual models for future dam removal projects. Although removing dams is not a new endeavor – people have been removing dams for almost as long as they have been building them – there is little literature on the responses of different riverine systems to dam removal. The authors of this paper have been involved in over 100 dam removal projects and have found some obvious patterns and similarities in responses between specific "categories" of dam removals.

Owners, practitioners and regulators need an accurate conceptual model to help predict project outcomes at the initial stages of a project. Several current papers point to the fact that a solid conceptual model is a critical element to a successful advanced numerical model. Academics and researchers need a compiled experience base such that their research results can be more appropriately applied to a variety of projects and regions.

This paper focuses on our initial endeavor to categorize dam removal efforts based on past experience in order to better predict the outcomes and potential impacts of dam removal projects, as well as start to develop conceptual models for dam removal. Key issues include, when is the removal of a dam a simple effort that could be completed quickly at minimum cost, and with little to no potential for long term impact on the river system? Which projects should include more detailed analysis and take more precautions before the dam is removed? The hundreds of dams already removed have started to unveil the answers for us. Wide impoundments with fine grained sediments respond very different than steep narrow impoundments with coarse grained sediments. Some dams have no impounded sediment stored behind them at all, while others have a century or more of accumulated sediment within the impoundment. The system response to a removal can vary greatly if the downstream channel is significantly degraded or if the sill of a dam is left in place during the removal. The results and complexity of a dam removal project can vary widely depending on these factors and others. Our classification system will help expand the discussion of whether dam removal projects fall into predictable categories, that once sorted, may help to answer many of these questions up front.

INTRODUCTION

A growing number of small dam removal projects (<30 feet high) have been completed in recent years providing extensive formal and informal information on post dam conditions. These observations have been used, in conjunction with the output of traditional empirical and analytical techniques, to categorize dam removal projects with respect to their probable channel and impoundment responses.

This empirical procedure is being used during the early planning phase to help forecast if post dam sediments will erode, if post dam channels will likely be straight or sinuous, the likely mechanism of erosion, and potential recovery rates.

Several channel and impoundment characteristics are used within the classification system as indicators of future behavior and recovery rates, including the type and general quantity of sediment deposits, the ratio of the impoundment's width to the channel width, the presence of a well defined legacy channel beneath the impoundment, and the grain size distribution of the impounded sediment. In addition several complicating factors are incorporated into the classification such as the presence of, or the potential for, channel bed degradation below the original riverbed elevation, the vertical and horizontal extent of dam removal, and the use of additional in-channel structures to stabilize sediment post dam removal.

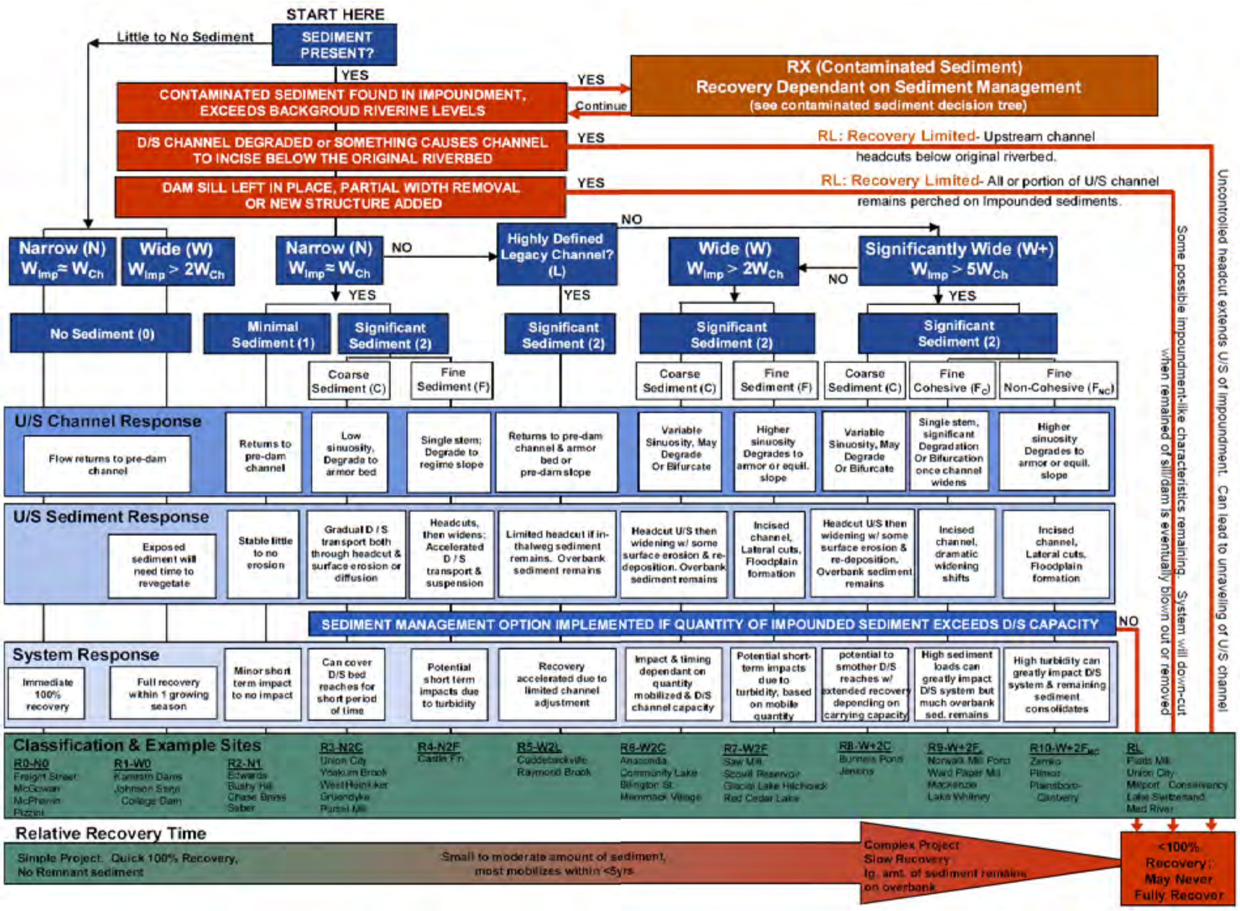

Figure 1 Dam Removal Classification System.

Feasibility studies of proposed dam removal projects frequently lead to discussions and concerns about the potential channel and impoundment conditions after the dam is removed. Common questions include the appearance and stability of the former impoundment, potential sediment deposition in the downstream channel, and progressive erosion in the upstream channel. In addition, on a larger scale, we are concerned about the potential ecological impacts and the likely recovery period of the entire fluvial system. Special management measures may be appropriate to avoid and minimize potential adverse impacts, to mitigate unavoidable impacts, or to accelerate recovery. Full recovery to pre dam conditions may not always be possible. There is a need for simple and economical tools to help screen potential projects and identify key issues and necessary mitigation measures

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The dam removal classification system was created after we noticed obvious patterns and similarities in the channel, sediment and system responses to a number of dam removals. This classification system helped us both document these similarities in response as well as to determine how many "categories" of dam removal projects might exist, when attempting to group similar projects. The classification allows us to then compare similar sites, create better conceptual models at the initiation of a project and better predict trends and the complexity of a project (i.e. define if a project maybe easy or difficult).

The classification can also help dam owners, stakeholders and professionals to better understand the risks and rewards of specific projects at the onset of a project. By categorizing projects on a sliding scale from relatively "easy" to "complex" we can help frame regulatory concerns, such that regulators better understand when to be comfortable with a dam removal, and when additional questions, relevant to that specific dam category, still need to be addressed; avoiding overgeneralization relating to the potential impacts of dam removal. We can also use the classification to strategically monitor different dam removal categories that are likely to have similar responses and response periods, or as a simple framework to help determine what type of numerical modeling analysis may be needed.

We envision the classification system being further refined in the future, adding threshold metrics based on field measurements of channel, sediment, system, and even ecological response. Perhaps the classification system could also aid in the ongoing discussion of legacy sediment and dam removal, helping to define which categories of dam removal projects this issue might relate to.

CATEGORY NAMES

- **R0:N0**: Narrow, No Sediment
- **R1:W0**: Wide, No Sediment
- **R2:N1**: Narrow, Min Sediment
- **R3:N2C** and **R4:N2F:** Narrow, Significant Sediment (coarse or fine sediment)
- **R5:W2L**: Wide, Significant Sediment, Legacy Channel
- **R6:W2C** and **R7:WCF**: Wide, Significant Sediment (coarse or fine sediment)
- **R8:W+2C**: Significantly Wide, Significant Sediment (coarse)
- **R9:W+F_C** and **R10:W+2F_{NC}**: Significantly Wide, Significant Sediment (fine sediment, cohesive or non-cohesive)
- **RL**: Dam Sill or Portion of Dam Left In Place; Structure(s) Added (recovery limited); or Channel Degraded or Degrades Below Original Pre-dam Riverbed
- **RX**: Sediment contaminated; system recovery dependant on sediment management option selected

DEFINITION OF TERMS

Each dam removal project is identified by a Relative Recovery Rate followed by a 2 or 3 digit Descriptive Code. The Relative Recovery Rate is described below and varies from R0 to R10. The first digit of the Descriptive Code describes the impoundment width; with N representing a narrow impoundment, W representing a wide impoundment (>2 times the channel width) and W+ representing a significantly wide impoundment (>5 times the channel width). The second digit of the Descriptive Code describes the relative quantity of sediment; 0 represents a dam where no impounded sediment is present, 1 represents a dam where little impounded sediment is present, and 2 represents a dam where a significant amount of impounded sediment is present, such that further analysis is needed even if the sediment is clean. The third digit of the Descriptive Code describes the characteristics of the sediment, F represents fine grained sediment (which is further divided in to F_C and F_{NC} to differentiate between fine grained cohesive sediment and fine grained non-cohesive sediment, respectively), C represents coarse grained sediment, and L represents the existence of a legacy channel.

	2 or 3 Digit Descriptive Code		
Relative Recovery Rate –	**1st digit**	**2nd digit**	**3rd digit**
R0 through R10, RL, or RX –	N, W or W+	0, 1, or 2	F, F_C, F_{NC}, C, or L

Examples: Relative Recovery Rate: Descriptive Code
R0: N0
R6: W2C

Relative Recovery Rate R: Relative recovery rate. This is a sliding scale for the relative rate of recovery from 0 to 10; where 0 represents a relatively simple project with a fast recovery rate, and 10 represents a complex project with a slow recovery rate, where the potential for longer term sediment input from bank and overbank erosion exists. In addition, there are two special case recovery categories, RL and RX. RL refers to a project where the recovery is limited due to a variety of reasons, including a portion of the dam being left in place, new structures being added, or the degradation of the channel bed below the pre-dam riverbed elevation. RX refers to a project where contaminated sediment is present within the impoundment. The recovery of this system is therefore highly dependent on the sediment management option selected and how it is implemented.

1st Digit of Descriptive Code Impoundment Width N: Narrow refers to an impoundment that's impoundment width is equal to or similar to the width of the stream channel upstream and downstream. This could refer to an impoundment that is equal to or double the width of the channel; basically long and narrow. This type of impoundment should look similar to an un-impounded river from an aerial view.

W: Wide refers to an impoundments that's width is greater than double the bankfull channel width but less than the belt width (if the channel is meandering), or less than 5 times the bankfull channel width (if the channel is straight). This type of impoundment should look like a narrow pond or a wider reach of the river from an aerial view.

W+: Significantly Wide refers to an impoundment that is significantly greater in width than the upstream and downstream channel, i.e. greater in width than the meander belt width (if the channel is meandering), or greater than 5 times the bankfull channel width (if the channel is straight). This type of impoundment should noticeably resemble a pond or lake from an aerial view.

2nd Digit of Descriptive Code: Sediment Quantity 0: If the second digit in the descriptive code is 0, then no impounded sediment is present.

1: If the second digit in the descriptive code is a 1, then a minimal amount of clean impounded sediment exists. Minimal sediment means that there is sediment present but the quantity is so small and clean that there is no concern for sediment management or accumulation/impacts downstream and the sediment can be released without assessment.

2: If the second digit in the descriptive code is 2 then there is a significant amount of impounded sediment behind the dam. A significant amount of impounded sediment just means that there is enough sediment impounded to be an issue and to require further assessment and the possible implementation of a sediment management plan. It is not just used for sites with very large quantities of sediment

3rd Digit of Descriptive Code: Sediment Characteristics F: The impounded sediment is primarily fine grained sediment.

F_C or F_{NC}: F_C represents the presence of fine grained cohesive impounded sediment. F_{NC} represents the presence of fine grained non-cohesive impounded sediment. This distinction is only made for significantly wide channels (W+) where both cohesive and non-cohesive sediments can be found depending on the site. For these sites the cohesive nature of the sediment plays a significant role in the channel, sediment and system responses.

C: the impounded sediment is primarily coarse grained sediment.

CATEGORY DESCRIPTIONS

An **R0:N0** dam removal is a very typical type of dam removal project. The upstream impoundment width is very similar to the river channel width both upstream and downstream of the impoundment, commonly referred to as a run-of-the-river dam, and where no sediment has accumulated behind the dam. This is typical for small stoplog irrigation diversion dams where the stoplogs are regularly removed such that sediment never accumulates behind the dam. This is also common for small, low head dams on rivers with low bed and suspended loads, or where the rivers higher flows regularly scour out any sediment that accumulated when river flows were low. It is a common misconception that there are sediment accumulations behind all dams. In fact, there are multiple dam removal examples of this dam removal category.

An **R1:W0** dam removal is not a common category, as far as completed dam removal projects, and typically occurs at the uppermost range of the headwaters, where an impoundment has been created but there is no sediment source to fill it. However, this category can also occur if the sediment supply upstream of a wider impoundment has been blocked since the creation of the impoundment (i.e. through multiple large capacity impoundments upstream, or is a highly supply limited system) or if the dam is off-line of the river (i.e. farm pond filled by pumping). R1 dam removals are likely not as common since they are typically not a concern relating to fish passage or system fragmentation, therefore their removal is more commonly sought only due to concerns relating to dam safety, the lack of an economically viable use, or the degraded condition of the dam.

An **R2:N1** dam removal is also a typical type of dam removal, for many of the same reasons why an R0 is typical. Many low head dams simply do not capture and retain a large amount of sediment. Sometimes this is due to the low bed and suspended sediment loads in the river system, but more commonly it is due to the self scouring nature of many low head dam impoundments, which creates a repeating cycle of deposition during low flows followed by re-suspension and transport during high flows. The velocities within the impoundments of these run-of-the-river, low head dams, are simply too high to retain large quantities of impounded sediment.

Categories **R0**, **R1**, and **R2** are typically straight forward dam removal projects with relatively short detention times and quick system response periods.

R3:N2C and **R4:N2F** are the first dam removal categories where sediment becomes an issue and must be assessed to determine if a sediment management option will be needed, such as sediment removal, sediment stabilization, or a staged release of impounded sediments. However, due to the narrow configuration of the impoundments for both the R3 and R4 categories, dam removal will typically lead to a full mobilization of all impounded sediment through single stem headcuts, surface erosion and diffusion. Therefore the potentially mobile volume of sediment is usually easily quantifiable, and the sediment management options do not typically include a stabilize in place option, unless the dam is only lowered or new dams/weir are proposed, which would turn the project into a Recovery Limited (RL) project and a full riverine system recovery maybe not be possible.

The assessment of an **R5:W2L** dam removal is greatly simplified by the presence of a highly defined legacy channel within the impoundment. A legacy channel is a remnant of the original riverbed and once the dam is removed the upstream channel within the dewatered impoundment will typically reutilize this legacy channel. A legacy channel is not a defined thalweg through the impounded sediment created solely by the regular opening of dam gates and/or low level outlets that are not in-line with the original riverbed channel. While these man-made thalwegs can be helpful during the removal of a dam, they do not supply the same benefits of a highly defined legacy channel that will again become the river channel once the dam has been removed. A legacy channel will often still have its original pre-dam channel bed substrate, allowing the site to easily readjust to the higher channel velocities post dam removal.

The **R6:W2C** and **R7:WCF** dam removal categories represent projects where the impoundment width is greater than 2 times the average upstream and downstream bankfull channel widths, and where a significant amount of impounded sediment exists. The metric of 2 times the bankfull channel width dividing the W categories from the less complex N categories, and the metric of 5 times the bankfull channel width dividing the W categories from the W+ categories, have been somewhat randomly assigned based on project examples and observations. In the future a representative sample of dam removal projects would have to be analyzed in more detail, comparing their channel, sediment, and system responses, to see if there are statistically valid metrics that divide these three impoundment width categories (N, W, and W+). The authors of this dam removal categorization feel there is a difference between the complexity of analysis needed and the responses of projects with significantly different impoundment width to channel width ratios, and have created these placeholder threshold metrics, until more justifiable metrics can be established.

The **R8:W+2C, R9:W+F$_C$** and **R10:W+2F$_{NC}$** dam removal categories represent the most complex dam removal projects to analyze and predict. Their excessively wide impoundments and significant quantities of impounded sediment often lead to dynamic changes within the former impoundment, pulses of sediment released over long periods of time, quick and often unpredictable evulsions, and longer recovery periods post dam removal. When a significant amount of fine grained impounded sediment (both cohesive and non-cohesive) is present, as is the case with the **R9:W+F$_C$** and **R10:W+2F$_{NC}$** categories, these dam removal projects and their analyses are further complicated.

The Recovery Limited (**RL**) dam removal category includes project examples where the recovery of the riverine system was impacted or limited by a portion of the dam structure being left in place, a new structure or structures being constructed in the channel as part of the dam removal effort, or where the existing downstream channel is degraded, or the newly exposed upstream channel incises below the original (pre-dam) riverbed grade. It has been our observation that some of these projects, may never fully recover. The level of system recovery will differ dramatically based on the extent of degradation below the original pre-dam riverbed or the extent of the dam structure left in place. In some cases the final site still has many characteristics of an impounded river reach.

The **RX** category includes all dam removal projects where the impounded sediment is contaminated above background levels within the river system. If contaminated sediments are found behind the dam, regardless of category, the project takes on a much more complex nature and sediment management becomes a critical component to protect human and aquatic health from re-suspension of contaminates into the system.

EXAMPLES

The following examples of dam removal projects were taken from an earlier paper entitled "10 Dam Removals, 10 Years Later" by Wildman et al., and are representative of the variety of dam removal categories in the dam removal classification system. For each site we have included an aerial photograph taken of the site approximately ten years post dam removal. Overlain on the aerial photograph we have shown the former location of the dams along with the extent of their former impoundments. Before and after photographs of the sites taken from similar vantage points are included in the original paper (Wildman et al 2008).

Our classification of dam removal sites is currently based on experience from small dam removal projects, less than 30 feet high, since many of the larger proposed dam removal projects have not yet been removed and system responses have not been assessed, even visually.

Freight Street Dam Classified as an **R0-N0** dam removal. The Freight Street Dam was constructed in the 1950's on the Naugatuck River in Connecticut, but was never utilized. The dam was approximately 4 feet high and 100 foot long, constructed of concrete reinforced with steel sheetpile within the core of the dam. The dam was fully removed in October 1999.

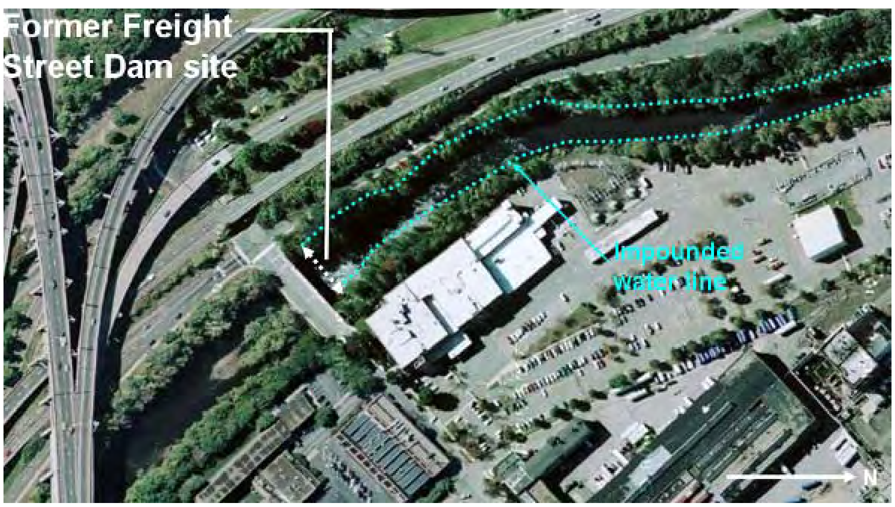

Figure 2 Freight Street Dam site 10 years post removal.

There was little to no sediment impounded behind the Freight Street Dam, and during the dam removal, the site was excavated an additional 3 feet so that the crushed concrete from the dam could be disposed of on site. The crushed concrete fill was then topped with large rounded cobbles, typical of the river bed both upstream and downstream of the dam. The impoundment was minimal due to the low head of the dam and the fact that the channel width above and below the dam were consistent throughout this reach of the river. Ten years later the site appeared much as it did the day the dam was fully removed. No sediment appeared readily mobile either above or below the dam, and, if it were not for the west abutment that was left in place, most observers would never guess that there had been a dam at this site (Wildman et al. 2008).

Kamrath Dams Classified as an **R1-W0** dam removal. The Kamrath Dam removal project in Plymouth, Wisconsin, on Kamrath Creek consisted of the removal of two earthen dams and one concrete dam built around the 1950's. The impoundments created by the dams were used to rehabilitate horses and as a former fish hatchery operation. Each earthen dam was approximately 12 feet high. The concrete dam was approximately 5 feet in height and 15 feet in length. The demolition of the three dams was initiated in May 1999 and fully completed by July 2002.

Ten years after the initiation of dam removal there are no obvious signs of bank erosion within the former impoundments and the banks appeared to be very stable. The water clarity was excellent. There were also no signs of persistent deposition below the former dam sites. The site appeared to have fully stabilized (Wildman et al. 2008).

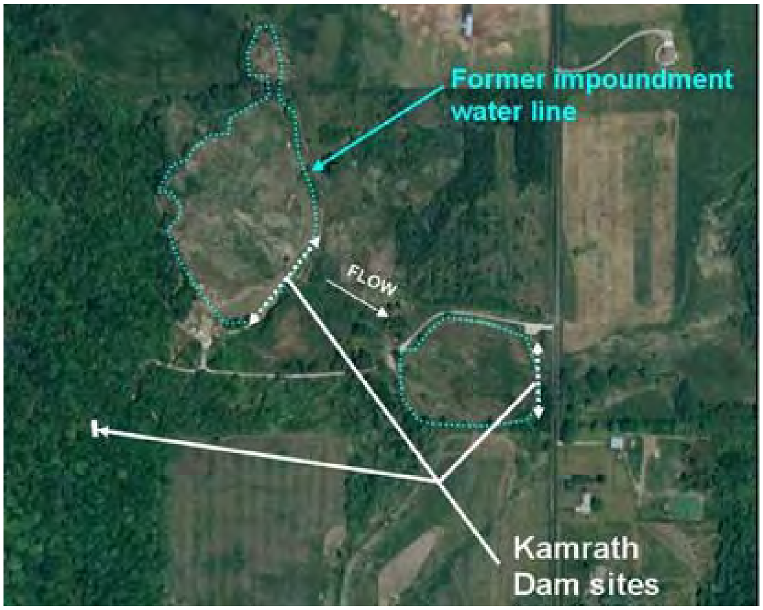

Figure 3 Kamrath Dams site 10 years post removal.

Edwards Dam Classified as an **R2-N1** dam removal. The Edwards Dam was a 24 foot high and 917 foot long dam extending across the width of the Kennebec River in Augusta Maine. The dam was built in 1837 to facilitate upstream navigation and provide mechanical power to a saw mill. The dam was a rock-filled timber crib structure with some concrete sections along its spillway. The dam was removed in two stages, using mechanical methods in July 1999 and August 1999.

Figure 4 Edwards Dam site 10 years post removal.

There was very little impounded sediment above the Edwards Dam, likely due to the low profile of the dam in comparison to the width of the Kennebec River at the site. This low dam-height-to-channel-width ratio allowed for the scour and transport of the river's sediment load over the crest of the dam. In addition, there are several other dams upstream, also on the Kennebec River, that likely trap a portion of the sediment that would have reached the former Edwards Dam site.

The dam's impoundment was linear and extended upstream 17 miles. The width of the impoundment varied little from the width of the undammed reaches of the river. Therefore, when the dam was removed in 1999, the upstream channel width only reduced slightly, exposing a limited amount of the formerly submerged upstream channel banks.

Ten years later, there were few visible signs of bank erosion within the former 17 mile impoundment. However, directly upstream of the former dam site, there were sections where undercut river banks and sand sediment bars were still evident along the eastern side of the riverbed during periods of lower flow. Signs of dam removal within the former upper impounded reach were minimal. There were no signs of large sediment deposits or islands created below the dam site, and it is likely that the majority of course grained sediment transported downstream through the system and out to the ocean (Wildman et al. 2008).

Union City Dam Classified as an **R3-N2C** dam removal. The Union City Dam on the Naugatuck River in Naugatuck, Connecticut, was a 7 foot high, 190 foot long timber crib and rock fill dam, capped with grouted riprap. The dam was initially an abandoned industrial dam in poor condition, abutting Linden Park. The full width of the Union City Dam was removed in October 1999 by mechanical methods.

A portion of the impounded sediment was removed from behind the Union City dam prior to dam removal. However, the remainder of the impounded sediment was allowed to be transported downstream. Little evidence remains of the course grained deposits that were evident downstream of the dam directly after its removal.

Figure 5 Union City Dam site 10 years post removal.

The Union City Dam removal project was unique in the fact that, when the dam was removed and the headcut propagated upstream, it encountered a previously unknown and unused pipe encased in riprap that traversed the width of the river. This obstruction created a hydraulic jump that spread the width of the impoundment and created excessive bed degradation below the elevation of the original channel bed. It also temporarily stalled the headcut in this location and created a secondary headcut that then migrated upstream below the elevation of the pre-dam channel bed. This condition was still evident after ten years. The stalled headcut location had become a riffle approximately mid way up the former impoundment length. A deep pool persisted just below the riffle. Large sections of the pipe were fully exposed and dislodged from their channel bed location. The secondary headcut migrated the length of the impoundment and was in the same location it was three years after the removal. However, the grade change in this location was no longer dramatic and the headcut appeared stable, as a steep gradient cobble riffle. The channel bed upstream of the former impoundment was comprised of imbedded cobbles and therefore further progression of the uppermost headcut would likely only occur under significantly high follow events.

Although we have classified the Union City Dam removal an R3, it also has characteristics of a category RL dam removal, due to the down cutting of the channel below the original pre-dam riverbed grade and the slowly progressing headcut, created by the exposure of the riprap encased pipe that traversed the entire channel width (Wildman et al. 2008).

Anaconda Dam Classified as an **R6-W2C** dam removal. The Anaconda Dam was a 330 foot long dam located in Waterbury, Connecticut along the Naugatuck River, consisting of a 137 foot long, 10 foot high timber crib spillway and a 190 foot long, 11 foot high earthen and rock fill embankment reinforced with steel sheetpile. The dam was initially built prior to the 1900's as a farm pond. It was later converted for industrial water diversion use by the Waterbury Brass Company. The timber crib portion of the dam partially breached during a storm prior to the dam's scheduled removal, allowing the majority of the mobile impounded sediment to move down through the river system, and undermining an active sewage pipeline. The timber crib spillway was then fully removed shortly after the initial breach in February 1999. The remaining 190 foot long earthen and rock filled portion of the dam still remains in place.

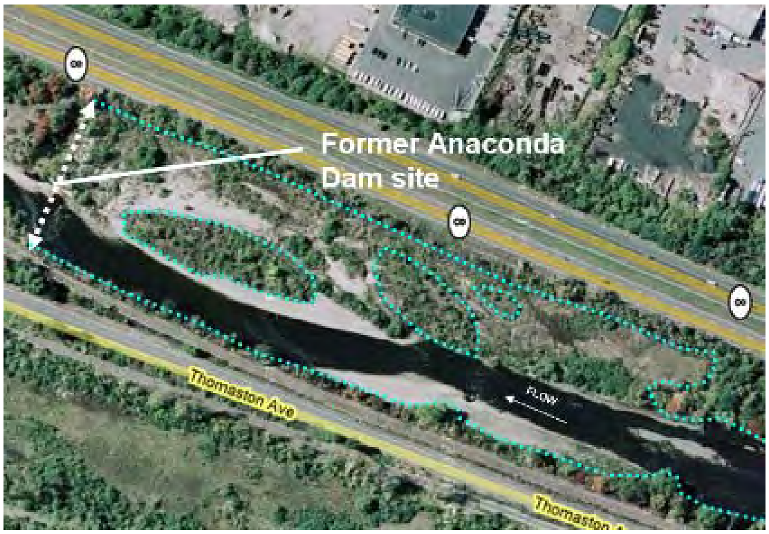

Figure 6 Anaconda Dam site 10 years post removal.

Ten years post removal there were still obvious signs of bank erosion along the western bank of the channel upstream of the former dam site. However, this undercut bank appeared much as it did during a 2003 site visit, and the bank seems to have reached a semi-equilibrium state, even though it was not vegetated down to the water level. The eastern bank of the upstream channel had continued to aggrade since the 2003 observations, with new sand and gravel deposits from upstream, on top of what was initially an undercut bank directly after removal.

Due to the wide nature of the former impoundment much of the impounded sediment remained on site and was stabilized by vegetation on the far western side of what was once a string of vegetated islands in the center of the former impoundment. These islands were created by the coarse grained sediment delta that formed behind the Anaconda Dam. The delta had progressed from the upstream end of the impoundment to the dam itself. The impounded sediment islands also remained intact upstream of the dam, although the former impoundment was only inundated, as a floodplain, under high flow conditions. Post-removal, a headcut migrated upstream and stalled approximately mid impoundment. A riffle formed in that location and the headcut then proceeded to the upper end of the former impoundment where it appeared relatively stable, ten years post removal. Large coarse grained sand and gravel bars, made up of former impounded sediment, still resided mid-channel and along the riverbanks downstream of the former dam site, and have dissipated little in the last 9 ½ years since the dam was removed (Wildman et al. 2008).

Mill Port Conservancy Dam Classified as an **RL** dam removal. The Millport Conservancy Dam, located near Millport, Lancaster County, Pennsylvania, was 10 feet in height and 50 feet in length. The spillway of the dam was removed in 1998 by mechanical methods with no sediment dredging or channel shaping proposed as part of the dam removal design. The earthen embankment of the dam remains as a separation between the new stream channel and three small ponds on an adjacent tributary.

Figure 7 Mill Port Conservancy Dam site 10 years post removal.

The dam was breached in a different location from its likely original channel, causing, in effect, an approximately 3 foot high dam to remain in place, Therefore, much of the impounded sediment is still retained within the former impoundment site, and underlies the current channel bed. The site shows no significant signs of continued down-cutting and head-cutting and is now heavily vegetated. However, if the remaining portion of the dam were to ever breach naturally, the site would likely go through another period of transition and down cutting before it reached its original channel bed elevation. Ten years post removal, the site retained many characteristics of an impounded channel. Some coarser grained material appeared to be depositing on top of the finer grained underlying impounded sediment that still remained within the channel bed. There were some undercut banks, but, otherwise, banks were generally incised with dense herbaceous vegetation along them (Wildman et al. 2008).

FUTURE WORK

This dam removal classification system has been created using the combined experience of its authors, who have worked on over 100 dam removal efforts nationwide. However the classification system is based primarily on visual observation and pre dam removal analysis. Metrics relating to impoundment width ratios, sediment characterization/quantity, sediment caring capacity, and system responses need to be further refined and added to this classification system to better define critical threshold numbers needed by those using this system. We are envisioning an effort that takes field measurements and collects data for a representative number of sites, where dams have been removed at least ten years prior. Additionally, this classification system will benefit from input from more professionals with a variety of dam removal experiences from different regions. We would also like to define and integrate a consistent and simple capacity protocol into this classification system, and potentially add ecological response to the classification.

Due to the abbreviated nature of this paper a detailed discussion of our observation regarding channel, sediment and system responses has not been included at this time. For more information on these issues as well as the example projects discussed in this paper please refer to "Evolution of Channels Upstream of Dam Removal Sites" (MacBroom, upcoming 2010 ASCE publication) and "10 Dam Removals, 10 Years Later" (Wildman et al., 2008) Future papers on this classification system are currently underway and a more detailed discussion of these observations will be included in those papers.

ACKNOWLEDGEMENTS

This classification system originates from earlier work by James MacBroom for a paper entitled "Evolution of Channels Upstream of Dam Removal Sites". In that paper MacBroom discusses impounded sediment formations, sediment stability, channel evolution, channel incision and evolution models, channel evolution examples, and channel evolution trends for newly exposed upstream channels post dam removal. Much of the basis for the channel and sediment responses within the classification system are described in this earlier paper, which is soon to be published in an ASCE Monograph on Sediment Dynamics Post Dam Removal. The multiple project examples used in this paper to represent different categories of dam removals were taken from an earlier paper by Laura Wildman et al., entitled "10 Dam Removals, 10 Years Later" that was published in the Proceedings from the 2008 Association of Dam Safety Officials (ASDSO) National Conference. Additional thanks go to Brian Graber of American Rivers who has provided input regarding the classification system utilizing his extensive dam removal expertise; Joe Rathbun of MI DNR who has provided his incite on contaminated sediments behind dams; and Tim Randle of the Bureau of Reclamation for inviting us to be part of the Federal Interagency Advisory Subcommittee on Sedimentation for Sediment Management relating to Dam Removal, which has been an invaluable asset to our further understanding the complexities of dam removal and sediment dynamics.

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