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DEVELOPMENT OF INITIAL CRITERIA TO IDENTIFY DAMS WITH HIGH POTENTIAL FOR REMOVAL AND APPLICATION OF THE CRITERIA IN WESTERN NEW YORK

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ABSTRACT: Dam removal has received widespread national attention and it is an important watershed management issue. The increase in aging dams necessitates research and planning methods to identify potential measures to manage these structures and determine whether or not they should be removed or repaired. The National Inventory of Dams was used to create an inventory of dams in seven western New York counties and to develop criteria to identify those dams with high potential for removal. Dam age, primary purpose, and hazard potential provide initial, screening-level criteria to identify dams with a high potential for removal. These criteria capture the two most common rationales for dam removal: environment and safety.

INTRODUCTION

Dam removal has received widespread national attention and it is an important watershed management issue. This is especially true in the northeastern United States, where there is a long history of damming streams to provide power for mills (MacBroom, 2007). Many stakeholders, including citizens, government agencies, and environmental organizations, now advocate for removing dams. Pohl (2002) found that rationales for dam removal have changed over time and that, in recent decades, the most commonly cited reason for removal was the environment, followed by safety. The environmental rationale stems from the impacts dams have on stream ecology, including impacts on fish populations and riparian vegetation. The environmental rationale also encompasses the whole of river restoration, which seeks to restore more natural flow conditions, sediment transport regimes, channel morphology, and water quality. Dam removal has been increasingly recognized as a potential method to achieve river restoration by researchers, watershed managers, and other stakeholders (Hart et al., 2002). The safety rationale for dam removal stems from concerns about an increased risk of dam failure with age. Dams have been built for a variety of reasons including flood control, hydroelectric power generation, recreation (e.g., fishing, camping, swimming), drinking water supply, and farmland irrigation. The typical lifespan of a dam is 50 years (International Rivers Network [IRN], 2002). Given that most U.S. dams were built in the mid-twentieth century (Graf, 1999), it is estimated that approximately 85% of dams will be at least 50 years old by the year 2020 (IRN, 2002). The increasing age of U.S. dams necessitates the development of planning methods to identify effective management measures and to facilitate decisions about removal or repair. Although interest in dam remo-val is increasing, removal of dams may not be appropriate in all situations; for example, when they are used for hydropower generation or when contaminated sediment is stored behind the dam.

The removal of dams is not a new idea (Graf, 2001); however, dam removal research is still relatively new and most research has focused on the short-term impacts of small dam removal (Stanley and Doyle, 2003). In fact, Hart et al. (2002) noted that less than 5% of all known dam removal projects have been accompanied by published studies. The results that are available tend to have focused on single environmental aspects of dam removal (e.g., ecological, geomorphological) and they have been mixed. Sethi et al. (2004), for example, showed that small dam removal in Koshkonong Creek, WI led to an increase in mortality to mussels, including the complete loss of one rare species due to exposure to the air as the reservoir was depleted of water and increased siltation occurred downstream. Stanley et al. (2002) found little change and rapid recovery in macroinvertebrate communities and downstream channel form following a small dam removal in the Baraboo River, WI. Hansen and Hayes (2011) found that macroinvertebrate communities recovered in terms of taxonomic similarity and richness in three to seven years following dam removal, but concluded that densities could take decades to recover. Burroughs et al. (2009) investigated the impacts of dam removal on stream geomorphology and found that changes in the velocity, substrate size, and channel width were still occurring three years after the removal and expected to continue for years. Several streams in the mid-Atlantic region with gravel-bedrock channels were studied to assess potential long-term geomorphic effects of dam removal (Skalak and Pizzuto, 2005; Skalak et al., 2009). Their work concluded that channel changes in their particular geologic setting would be limited to increases in fine sediment on the bed downstream of the dam

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removal (Skalak and Pizzuto, 2005; Pizzuto et al., 2009) and that the final channel configuration would not be significantly different from the initial configuration after the stream reaches equilibrium (Skalak and Pizzuto, 2005). As noted by Stanley and Doyle (2003), dam removal is a trade-off because not all parameters are likely to improve and timescales of improvement are likely to differ for each parameter. Recovery of a river system will be site-specific and influenced by local conditions, such as the height of the dam and the volume of sediment stored behind the dam.

Generally, dams have similar impacts (e.g., disrupting sediment transport, modifying hydrology) on stream systems across physiographic regions; however, there are factors that will warrant more localized planning efforts and decision-making guidelines for potential dam removal projects. These factors include the presence of threatened/endangered species in a given watershed, historic stream use and potential sediment contamination, and local land use downstream from impoundments. The spread of invasive species is also a factor that must be considered for each individual dam removal project, as some studies have indicated that dam removal may result in the potential spread of invasive species such as the round goby (*Neogobius melanostomus*) (Kornis and Vander Zanden, 2010). In some cases, low head dams have been used to help prevent the spread of invasive sea lamprey (e.g., Pratt et al., 2009), but this has to be balanced with the fact that dams have been recognized as impediments to non-invasive fish passage (Stephens, 2006; Wells and Haynes, 2007; Wooster and Matthies, 2008). Another factor that must be considered in cold regions is the potential for impacts of dam removal on river ice regimes (White and Moore, 2002). Aside from environmental concerns and river restoration goals, the presence of aging dams creates an urgent need to assess the current status of existing dams and develop a framework to evaluate their potential for removal.

The goals of this current research are: (1) to create an inventory of western New York (WNY) dams, and (2) to develop criteria to identify dams with high potential for removal and apply those criteria to dams in WNY. The dams with high removal potential should be targeted for further site-specific analysis as well as involvement of relevant stakeholders to determine the appropriateness of dam removal.

METHODS

Study Area

The geographic focus of this study was western New York State, which includes seven counties: Cattaraugus, Chautauqua, Erie, Genesee, Niagara, Orleans, and Wyoming (Figure 1). The land use in WNY varies, including urban (e.g., City of Buffalo, City of Niagara Falls), suburban, and rural areas. With the exception of portions of Chautauqua and Cattaraugus counties, which are part of the Ohio River watershed, the majority of land in this area is part of the Great Lakes watershed, specifically the Eastern Lake Erie (HUC 041201) and Southwestern Lake Ontario (HUC 041300) watersheds. The area contains three designated Great Lakes Areas of Concern (AOC): Buffalo River (Erie County), Niagara River (Niagara County), and Eighteenmile Creek (Niagara County). Area of Concern designations result when one or more beneficial uses are impaired (e.g., degradation of fish and wildlife populations, loss of. fish and wildlife habitat). There are numerous efforts across the WNY region related to the management, remediation, and restoration of freshwater resources, including investigating dam removal fish and wildlife habitat). There are numerous efforts across the WNY region related to the management, remediation, and restoration of freshwater resources, including investigating dam removal

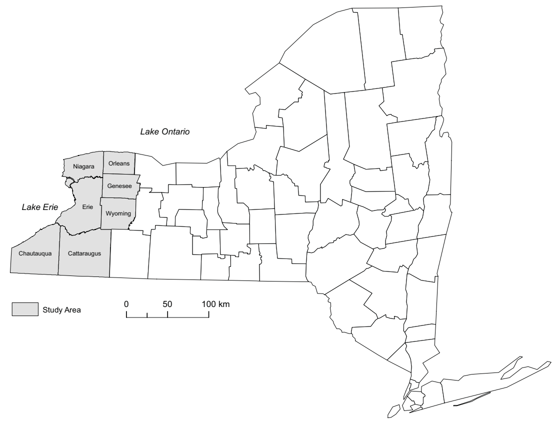

Figure 1. Map showing the seven counties investigated in western New York.

Dam Inventory and Characterization

An inventory of WNY dams was created using the U.S. Army Corps of Engineers' (USACE) National Inventory of Dams (NID) database (USACE, 2010). The NID was created in 1999 and is periodically updated by the USACE with the latest update in 2010. Inclusion of dams in the NID is based on the size and the dam hazard potential, which ranges from low to significant to high (USACE, 2010). Low hazard potential means that failure or misoperation of the dam is not likely to cause loss of human life and property damage would be limited to the owner's property (USACE, 2010). Low hazard dams are included in the NID based on the following size characteristics: (1) dams that exceed 2 m in height and 18,500 m^3 in storage; and (2) dams that exceed 25 m in height and 61,700 m^3 in storage (USACE, 2010). Significant hazard potential means that failure or misoperation of the dam poses a threat to economic activity, property, and lifeline facilities, but no probable loss of life (USACE, 2010). High hazard potential means that failure or misoperation of the dam poses a threat to economic activity, property, lifeline facilities, and loss of human life is probable (USACE, 2010). Significant and high hazard dams of any size are included in the NID.

After identifying all the WNY dams listed in the NID, the following NID information was filtered and evaluated for each dam: year built, hazard potential, and primary purpose. This information was selected to define the environmental and safety characteristics of each dam. These criteria were used to identify dams with high potential for removal defined as follows: 1) the dam was at least, or within five years of approaching, 50 years of age (i.e., the typical design lifespan of a dam); 2) the hazard potential was listed as either significant or high; and 3) the dam's primary listed purpose was recreation. Dam removal based on safety concerns (age and hazard potential) may be warranted because of the high costs of repair and continued maintenance as well as the dangers to human life and property if these dams fail (Pyle, 1995; Graf, 2005). Moreover, if a dam's primary purpose was recreation, then the dam is not providing a vital service (e.g., flood control, water supply) and restoring a more naturally functioning physical and ecological system may be more feasible in these locations.

RESULTS

There were a total of 156 dams in the seven WNY counties investigated (Table 1) out of 1,982 dams listed in the NID for all of New York State. Cattaraugus County had the most dams (26% of all WNY dams - Table 1), most of which are located on Cattaraugus Creek or its tributaries. Niagara County had the fewest dams identified (Table 1); however, it contained the tallest dam (47 m) and four of the dams had hydropower listed as their primary purpose (Table 2). Three of these dams are owned by the New York State Power Authority (NYPA) and are associated with the Niagara Power Project. Hydropower dams are also located in Orleans County with two Orion Power NY-owned dams on Oak Orchard Creek. Almost half (47%) of the dams were built during the 1950s and 1960s (Table 3).

Numerous dam purposes were listed in the NID including fire protection, fish and wildlife, stock/small fish pond, flood control, hydroelectric, irrigation, navigation, recreation, water supply, and a category for "other" (Table 2). There were 70 dams (45% of all WNY dams) that listed recreation as their primary purpose, the highest use category in WNY. The next highest use category was flood control (15%), followed by water supply (12%) (Table 2).

Table 1. Number of dams per WNY county

County	Number of dams	Percentage of total WNY dams located in each county
Cattaraugus	40	26
Chautauqua	25	16
Erie	27	17
Genesee	16	10
Niagara	8	5
Orleans	14	9
Wyoming	26	17

Table 2. Primary purpose of dam

Primary purpose	Number of dams	Percentage of total WNY dams in each primary purpose category
Fire protection	2	1
Fish and wildlife*	8	5
Flood control	24	15
Hydroelectric	7	4
Irrigation	1	1
Navigation	1	1
Recreation	70	45
Water supply	18	12
Other	11	7
Not listed	14	9

Table 3. Decade dam construction was completed

Decade dam built	Number of dams	Percentage of total WNY dams built in each decade
No date listed	11	7
1820-1899	6	4
1900-1909	4	3
1910-1919	5	3
1920-1929	13	8
1930-1939	10	6
1940-1949	3	2
1950-1959	25	16
1960-1969	49	31
1970-1979	15	10
1980-1989	7	4
1990-1999	3	2
2000-2015	5	3

Table 4. Hazard potential of dams

Hazard potential	Number of dams	Percentage of total WNY dams in each hazard potential category
High	24	15
Significant	58	37
Low	67	43
Unavailable	7	5

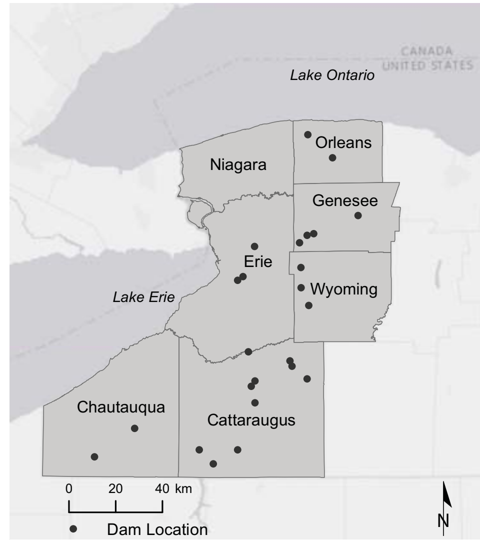

Figure 2. Locations of the 24 dams in western New York with high potential for removal.

Irrigation and navigation were the lowest primary use cited with one dam each (Table 2). Twelve dams had either two or three purposes listed. The secondary and tertiary purposes were mainly "other," fire protection, and/or stock/small fish pond. Fifty-four percent of the dams (84 dams) were identified as privately owned. The re-maining dam ownership was identified as local (29%), state (12%), and federal (4%) government, and none listed (1%). Most dams (43%) had a low hazard potential, followed by significant and high; hazard potential information was unavailable for seven dams (Table 4). The majority of WNY dams were classified as medium size, which corresponds to approximately 10^5-10^7 m^3 in reservoir storage (Graf, 2005).

Twenty-four of the 156 dams in WNY met the criteria for having high potential for removal based on age, primary purpose, and hazard potential (Table 5 and Figure 2). Niagara County did not have any dams that met the criteria, although there were dams in the other six WNY counties investigated (Table 5 and Figure 2). Most (9) of the dams that meet the criteria are located in Cattaraugus County, whereas Chautauqua and Orleans Counties each only had two dams that met the criteria (Table 5 and Figure 2). Over half (58%) of these dams were built in the 1950s and 1960s and sixty-seven percent are privately owned. All but two of the dams that met the criteria for having high potential for removal (Panama Dam in Cattaraugus County and Springville Dam in Erie County) have significant hazard potentials (Table 5).

DISCUSSION

Almost half (47%) of all of WNY dams were built in the 1950s and 1960s, which means that these dams are approaching or have already exceeded their design lifespan. This local trend in dam building mimics the national trend that saw a large number of dams being built during the mid-twentieth century (Graf, 1999). The increase in dam building during the mid-twentieth century occurred in large part because of economic developments in hydropower and the need for urban water supplies (Graf, 2005). Recreation is listed as the primary purpose of 45% of the dams in WNY and over half (52%) have significant or high hazard potentials.

Table 5. Dams identified as having high potential for removal based on age, primary purpose, and hazard potential.

Dam name	County	River	Year built	Primary purpose	Hazard potential	Owner
Red House Lake Dam	Cattaraugus	Red House Brook	1929	R	S	S
Camp Chautauqua Pond Dam	Cattaraugus	Tributary Little Conewango Creek	1965	R	S	P
Harwood Lake Dam	Cattaraugus	Tributary of Ischua Creek	1963	R	S	S
Willam O. Nannen Pond Dam	Cattaraugus	Tributary of Great Valley Creek	1964	R	S	P
Richard Weishan Pond Dam	Cattaraugus	East Otto Creek	1961	R	S	P
Efner Davis Pond Dam	Cattaraugus	Lime Lake Outlet	1961	R	S	P
Lime Lake Outlet Dam	Cattaraugus	Lime Lake Outlet	1850	R	S	P
James Hughey Dam	Cattaraugus	Tributary of Connoisarauley Cr.	1964	R	S	P
Quaker Run Dam	Cattaraugus	Quaker Run	1930	R	S	S
Panama Dam	Chautauqua	Little Brokenstraw Creek	1910	R	H	P
Den Adelsmans Klub Dam	Chautauqua	Tributary Cassadaga Creek	1962	R	S	P
Springville Dam	Erie	Cattaraugus Creek	1922	R	H	L
Green Lake Dam	Erie	South Branch Smoke Creek	1909	R	S	L
Erie Park Commission Dam	Erie	Cayuga Creek	1926	R	S	L
Freemans Dam	Erie	Smoke Creek	1912	R	S	P
Darien Lake State Park Dam	Genesee	Tributary Eleven Mile Creek	1958	R	S	S
Horseshoe Lake Dam	Genesee	Bigelow Creek	1953	R	S	P
Darien Lake Fun Country Dam	Genesee	Tributary of Crooked Creek	1954	R	S	P
Jericoh Lake Dam	Genesee	Tributary of Crooked Creek	1952	R	S	P
Otter Creek Dam	Orleans	Otter Creek	1916	R	S	P
Village of Lyndonville Dam	Orleans	Johnson Creek	1948	R	S	L
Camp Schoellkopf Dam	Wyoming	Tributary of Cayuga Creek	1955	R	S	P
Camp Schoellkopf #2 Dam	Wyoming	Tributary of Cayuga Creek	1957	R	S	P
Everett Riesdorf Dam	Wyoming	Tributary of Beaver Meadow Creek	1964	R	S	P

Primary Purpose: R = Recreation
Hazard Potential: S = Significant; H = High
Ownership: L = Local Government; P = Private; S = State

The 24 dams that met the initial, screening-level criteria (Table 5 and Figure 2) may be appropriate for removal based on the environmental and safety characteristics of each dam. However, additional factors, such as economic activity and ecological conditions, must be examined in order to prioritize a list of potential dam removal projects (Pejchar and Warner, 2001; Johnson and Graber, 2002; Doyle et al., 2003; Mullens and Wanstreet, 2010). Many of the dams identified using the screening-level criteria developed for this research are located at popular recreational facilities and, therefore, removal may not be favored from social and economic standpoints (e.g., Johnson and Graber, 2002). While these dams may not be providing a vital community service, such as flood protection, the reservoirs that dams create for recreation provide the opportunity for fishing, boating, swimming, and other activities that generate economic revenue. Red House Lake Dam (Cattaraugus County), for example, is located in Allegany State Park and is surrounded by camping areas, and Darien Lake State Park Dam (Genesee County) creates a swimming beach area in Darien Lake State Park. Local residents often have a stake in the preservation of these reservoirs, especially if they own property along the reservoir, as they may feel that their property values will decrease if the reservoir is removed (Pyle, 1995). Provencher et al. (2008) concluded that shoreline frontage along small impoundments had no noticeable increase in residential property price compared to frontage along free-flowing rivers and that residential non-frontage property located near a free-flowing river is more valuable than the identical property located near an impoundment. Public support for dam removal may be weak in areas where dams create popular recreational reservoirs; however, support for dam removal might increase if the cost of repairing and maintaining the dam are higher than the revenue generated by the recreational use of the reservoir.

Recreational dams that are on private property and privately owned may be the best options for removal projects. These dams are not located in publicly used recreational areas and the costs to maintain them may not always be feasible for individual property owners if they are not creating a revenue stream. Several dams identified using the screening-level criteria, such as the William O. Nannen Pond Dam (Cattaraugus County) and the James Hughey Dam (Cattaraugus County), fall into this category. The New York State Department of Environmental Conservation (NYSDEC) revised their regulations in 2009 to require all dam owners in New York to operate and maintain their dams in a safe condition at all times subject to fines and penalties (NYSDEC, 2012). This may provide more removal incentive to individual dam owners because some dams may need costly repairs or upgrades to meet current dam safety regulations. Additionally, if a dam is already beginning to fail, it may be appropriate to invest in removal rather than repair, especially if downstream damage is occurring.

Ecological conditions that should be considered for prioritizing dam removal projects include the presence of threatened and endangered species, as well as the presence of invasive species. Some streams in WNY have mussels that are state and/or federally listed threatened or endangered species, such as the clubshell (*Pleurobema clava*) and rayed bean (*Villosa fabalis*). As shown by Sethi et al. (2004), mussels can be adversely affected by siltation and exposure after dam removal. In WNY, the presence of invasive species and the potential for their spread would need to be evaluated. In some instances, the use of fishways and ladders may be successful in mitigating fish passage issues while still limiting the spread of invasive species (Pratt et al., 2009).

After economic factors and ecological conditions are considered, all of the dams that have been identified as having high potential for removal will need further site-specific analysis of environmental conditions, including stream channel morphology, hydraulics, quality and quantity of sediment stored behind the dam, and land use surrounding the dam. River ice regimes also need to be considered in WNY to evaluate the potential for downstream flooding and/or erosion issues caused by the removal of a dam currently providing ice jam control (White and Moore, 2002). Landowners and other stakeholders would need to be involved throughout the planning and removal process as well as state and federal regulatory/permitting agencies. Lastly, a before, during, and post-removal monitoring plan would need to be developed and implemented to determine and document project success.

CONCLUSIONS

The criteria based on dam age, primary purpose, and hazard potential developed for this research provides an initial, screening-level method to identify dams with a high potential for removal. Applying these screening-level criteria to specific geographic areas allows those engaged in watershed planning to determine priority dams for further investigation. Further analysis would consider economic impacts, ecological conditions, environmental conditions, and stakeholder input associated with removal. As the science and practice of stream restoration, including dam removal projects, continue to evolve, there is greater focus on incorporating the human and societal valuation of rivers into the process (Bennett et al., 2011).

As a national database available for use throughout the U.S., the NID is an appropriate database to use to identify and gather information on the criteria for potential dam removal opportunities. The structure of the NID creates better planning opportunities by allowing for the identification of dams in a specific geographic region or watershed. This planning can reduce the need for responding to dam safety and environmental concerns on a case by case basis.

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