MANAGING UNCERTAINTIES DURING HYDROPOWER DAM REMOVALS

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ABSTRACT

Dam removals have inherent uncertainties in both costs and schedules for dam removal design, deconstruction, and post-removal monitoring. Case studies of three dam removals plus the author's experience with six other dam removals are used to illustrate ways engineers can reduce owner and regulatory risk for dam removal costs, schedules, and expectations. These risk reduction measures include upfront questions about watershed contamination, sediment volume, lakefront property owners, local fish management strategies, and status of project licensure and ownership.

INTRODUCTION

The author's employer (Ayres Associates) entered the dam removal industry in the 1980s and 1990s. With few exceptions, early removals included a short plan set showing existing and proposed contours with few staging, dewatering, or restoration details. Permits were issued without much public opposition, except perhaps where a dam was forcibly removed against the owner's wishes. In general, the removal process was designed as a simple earthwork project, included little stream restoration effort, and cost about one third of today's costs. The design effort and construction costs for these early removals were predictable, certain, and structured.

As with many other firms, removal project managers experienced remarkable differences between 20th and 21st century removals. As environmental advocacy groups increased public awareness of dam removal permits and promoted public involvement, project costs and durations became more uncertain. While these advocacy groups are now partnering with engineering companies (like Ayres Associates) to improve design efficiency and also helping to fund dam removal construction, their original focus on creating public awareness of dam removals also opened the public eyes to issues such as post-removal sediment load, contaminated soil transport, and competing stream restoration goals. Based on the author's experience with nine dam removals, more public involvement has led to more uncertainty with regard to permit lawsuits, schedule delays, and costs of dam de-construction.

While public involvement and project accountability improve both designers and regulators, this article focuses on how project uncertainties arise and attempts to make engineers better at communicating dam removal uncertainties to owners and regulators. Three case studies are presented, including the 2008 Woodley Dam Removal, the 2012 Grimh Dam Removal, and the upcoming 2015 Gordon Dam Removal.

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Case 1: Woodley Dam

In 2001 Woodley Dam nearly overtopped during a large flood event, and the Department of Natural Resources (DNR) soon ordered a mandatory drawdown until repairs could be completed. Citing excessive repair expenses, the grist mill building (last producing hydroelectric power in 1994) was removed in 2003 with little opposition (Figure 1), but the County's subsequent application for dam removal was met with multiple unexpected oppositions.

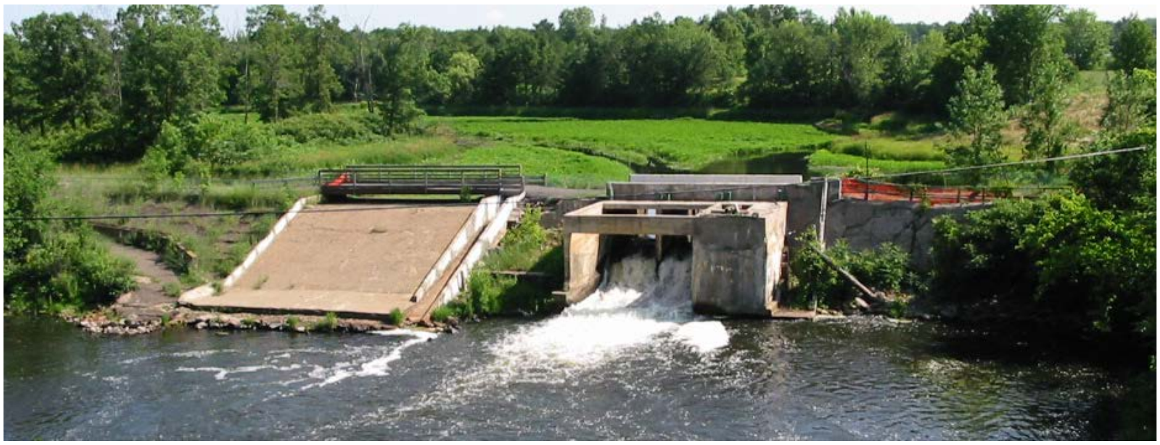

Figure 1. Woodley Dam Pre-Removal (Powerhouse Already Removed).

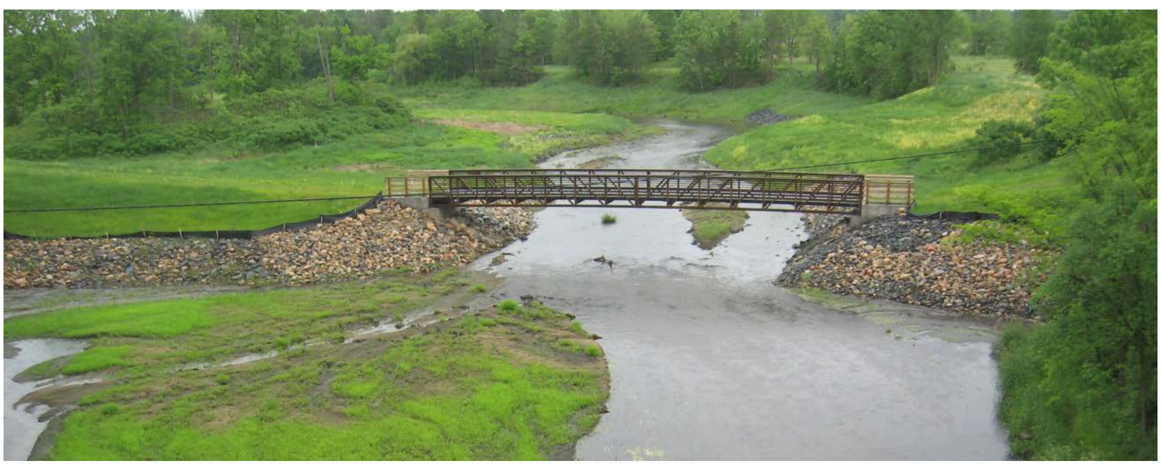

Figure 2. Woodley Dam Post-Removal (Same View as Figure 1).

The permit for the Woodley Dam removal was contested because the local river canoe industry teamed with Trout Unlimited to oppose artificial riprap on geotextile, even though this sediment stabilization measure was designed to preserve the the trout stream's clarity and restore trout migration across the four feet of stream grade between upstream and downstream bed elevations. Arguing that the riprap fish weirs and boulders (designed to restore fish passage) prevented a "free-flowing, natural stream," the constituents requested the DNR order a wider dam removal and removal of more reservoir sediments. The local snowmobile advocacy group contested the dam removal because their snowmobiles could no longer cross the river, as they had done for many prior years across the dam.

While the dam owner argued in court the right to remove the dam, the plaintiffs disagreed on whether the restoration plans were in the public interest. The competing restoration goals halted the project as the case proceeded to an administrative law judge. Ultimately the dam owner conceded to dredge an extra 1300 cubic yards, limit riprap use to protection of the bridge structure, and replace the in-stream armor with a new snowmobile bridge ($114,000 extra), all requiring an extra25% in engineering fees for design changes. The contested case was discontinued, and the dam was removed as shown in Figure 2. The engineering design and permits had taken five years to complete, and yet the construction process required only five months.

<u>Case 2: Grimh Dam</u>

When North Central Power Company decided to remove the 30 foot high, 1100 foot long Grimh Dam in a sparsely populated region of northern Wisconsin, few anticipated the legal, environmental, and public safety challenges ahead. Grimh Dam originally supplied power to a local shingle factory which grew the Village of Radisson around the Grimh Dam impoundment. As the shingle business faded, the dam was raised nine more feet to produce hydroelectricity for the region's wood-products industries and surrounding communities. By 1997, the dam required significant repairs to meet Federal Energy Regulatory Commission (FERC) standards, so the owner filed a legal notice to abandon the dam. In what might have been a short dam removal process in the late 1990s, the removal process was delayed during attempts to sell the dam to the community and other hydropower producers.

In 2000, the DNR required a drawdown to address unrepaired safety concerns, and the resulting drawdown initiated a civil lawsuit from local property owners. Local residents claimed their shallow wells were losing water, the once pristine fishing area was destroyed, and property values were lowered because of the unsightly mud flats where the reservoir once flowed. Since objecting to the DNR drawdown was not successful, residents quickly turned to contesting the dam abandonment permit, and an administrative law judge was appointed to oversee eight months of legal arguments about dam removal. Eventually the judge ruled that the owner and DNR had sufficient rights to proceed with removal, but afterwards the DNR requested additional justification for the sediment management plan to handle 100,000 cubic yards of silt behind the dam plus revised plans to accommodate native species and stream restoration concerns. Lesson learned from this and other dam removals: Owners should budget about $2000 per adjacent private landowner bordering the impoundment to cover uncertainty in securing a permit through the contested case process. Even if the dam is apparently an eyesore to the community, citizens may not agree on the restoration goals (Woodley Dam) or the removal itself (Grimh Dam).

Environmental hazards encountered during deconstruction of Grimh Dam included a large flood event, contaminated soil discoveries, asbestos mitigation, and constant concerns about the 100,000 cubic yards of very soft sediment. Cofferdams have inherent risks of overtopping, and designing a cofferdam for a ten-year flood (a non-codified but generally-accepted regional design standard) creates a 10% risk of overtopping in the first year of construction, 19% risk of overtopping within a two year construction period, and 27% chance of overtopping during a three year construction period. As luck (or unluckiness) would have it, two rainfall events (4.0 and 5.5 inches of rain in two days) both produced ten-year floods. The first flood overtopped the first stage cofferdam in early September and the second flood nearly overtopped the second stage cofferdam in early October (a normally low-flow period). One lesson learned: make sure annually-compounded risk and overtopping uncertainty are fully understood by the contractor, DNR, and owner.

While the project's asbestos items were fairly inexpensive (about $11,000) to mitigate in the first weeks of construction, fuel-contaminated soil was discovered during the second year of construction in soil lenses below the concrete slab of the powerhouse's old diesel generator building. The unexpected contamination required extensive remediation of the west bank, including about $100,000 extra to remove contaminated soils and complete the required DNR testing and site deed restriction paperwork.

Over 75 years of project operation, the reservoir has amassed 100,000 cubic yards of extremely soft sediments. The DNR required the owner to post "danger" signage all around the flowage, and the author can confirm by personal experience that one small step off of the upstream cofferdam and onto grassed-over reservoir sediments required an hour to extract one's lower body from the soft sediments. While sand drains easily, it became apparent though the project that the reservoir silts and clays were going to take many years to stabilize. Through constant, frequent, purposeful communication with the DNR and owner, Ayres Associates was able to inform them about risks of sediment mobilization during each removal phase. Through the project, the DNR became more comfortable with slowly releasing sediments downstream given the following risk reduction measures: 1) the larger Chippewa River was only 1.5 miles downstream of the dam, 2) the reservoir had been half way drawn down for 10 years prior to removal, and 3) the reservoir's remaining volume was drawn down over two growing seasons and monitored during the third season.

While the DNR did not require upfront dredging at Grimh Dam, the design team and owner were always prepared that the DNR would require additional sediment stabilization measures even up to the last month of deconstruction. In fact and at the end of the project, all reservoir sediments had been exposed to at least two growing seasons, had vegetation growing on them, and yet were still easily liquefied by passing construction traffic. The lack of reservoir sediment consolidation and drainage required an additional 132 cubic yard berm of riprap to lessen cutting into the final western channel bank. The DNR would also accepted three additional years of slow head-cutting upstream before the head-cuts halted in a reach of large boulders. In short, sediment removal could have added $500,000 to $800,000 in construction costs, but the above risk reduction measures allowed the DNR to stand by their plan to 1) slowly release sediments as the natural environment could accept and 2) undertake only reactive repairs to discrete areas of bank instabilities.

For Grimh Dam, the total dam decommissioning to removal process elapsed 15 years. Figures 3 and 4 show the before and after removal photographs (note the same house under the red arrow, though 15 years later, and with a new roof on the house!).

Figure 3. Grimh Dam Pre-Removal.

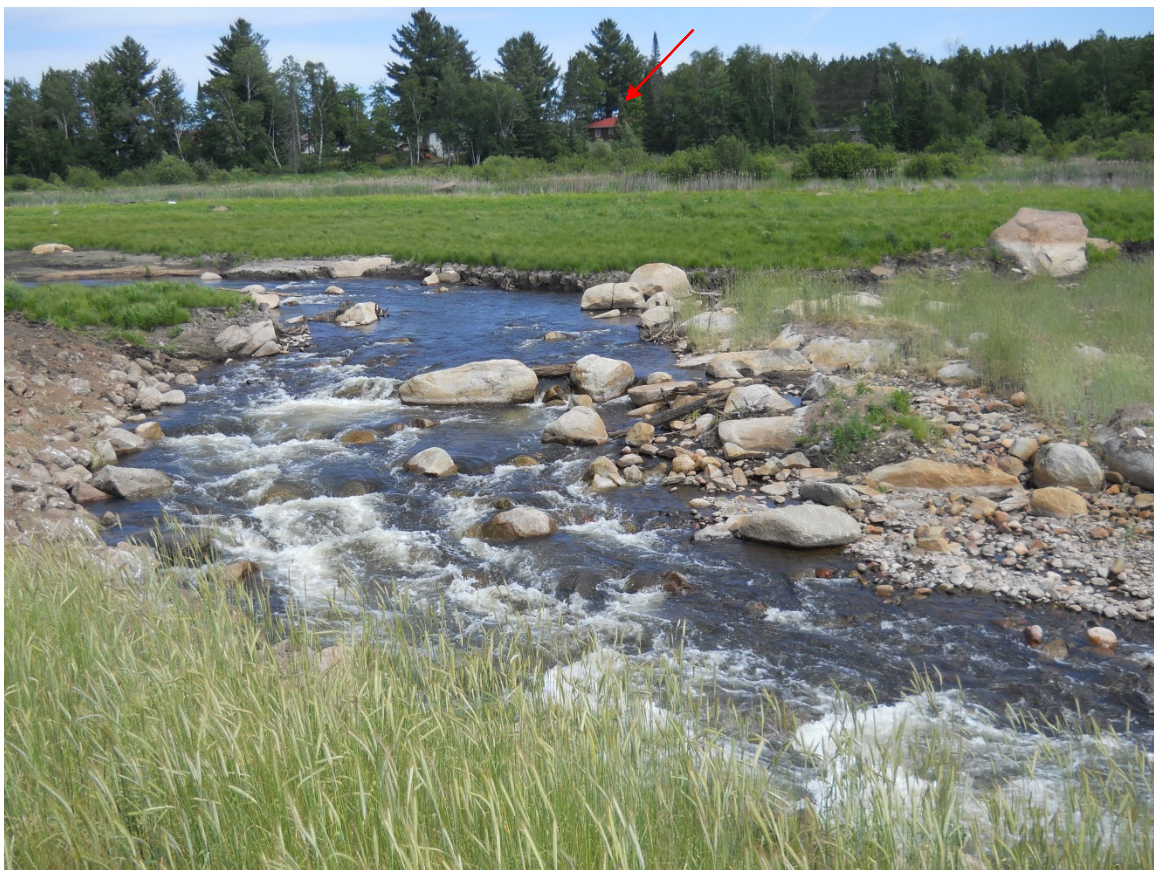

Figure 4. Grimh Dam Post-Removal.

Case 3: Gordon Dam

After a protracted search for a buyer, Dahlberg Light & Power decided to remove the 33 foot high, 1550 foot long Gordon Dam in 2010. An earlier FERC Petition for Declaratory Order and attempts to relicense the dam were stalled by requirements to increase hydraulic capacity and fix embankment seepage issues. In terms of dam removal uncertainty, Gordon Dam offered a unique situation where the dam owner, State of Wisconsin, and a large timber company own 95% of the flowage perimeter. Therefore the risks and uncertainties for this dam were much different than for Grimh or Woodley Dam. First, with only one private landowner on the upstream impoundment, the project had a low risk of proceeding to a contested case permit hearing. Second, the impoundment had no sediment near the dam, mainly because sediments dropped out about a mile upstream of the dam and remained stationary since the dam was half drawn down in 2010. While there was some mercury in the local soils and a few leaking underground storage tanks within the watershed, the sediments in the upstream delta were not likely to contain heavy metals or other contamination sufficient to require dredging. Therefore, no dredging was budgeted for this project. Third, the DNR Fisheries Biologist considered lake sturgeon as the species of interest, so the stream restoration channel easily sustained swimming velocities low enough to accommodate sturgeon.

The DNR and Corps of Engineers staff were involved early in the Gordon Dam removal process. DNR dam safety staff considered a cofferdam sized for the 10-year event to be sufficient but desired the remaining reservoir head to be drawn down over two construction phases. During a preliminary consultation, regulatory staff revealed a design preference to remove all of the dam's concrete and shape the remaining embankments to 1) not cause any backwater during the 100-year flood and 2) include at least some flat area as an overbank to mimic the downstream channel. These preferences were accepted early in the removal design phase so that both the owner and engineer could proceed with less uncertainty about project costs and review schedule.

The design uncertainty was reduced by following the regulatory suggestions as far as the owner's budget allowed, but other methods also helped to reduce design risk. First, Wisconsin requires an asbestos survey prior to beginning construction, but since there is no record of diesel generators onsite, a separate onsite soil survey was not a necessity. Second, native species seeding is generally recommended for all dam removals, especially for areas below the Ordinary High Water Mark since those area's seeds have a good chance of being transported to environmentally sensitive areas downstream. Therefore, a three step seeding plan (dry, mesic, and wet) was specified for this project. Third, construction costs were more certain without the unknowns of impoundment stabilization (no sediment is adjacent to the dam), contaminated soils (not expected by any reasonable measure), or protracted delays due to contested case litigation (there is only one private landowner). The project so far has been ahead of schedule (design phase ends in December), and the construction costs are expected to be much lower than for the Grimh Dam project.

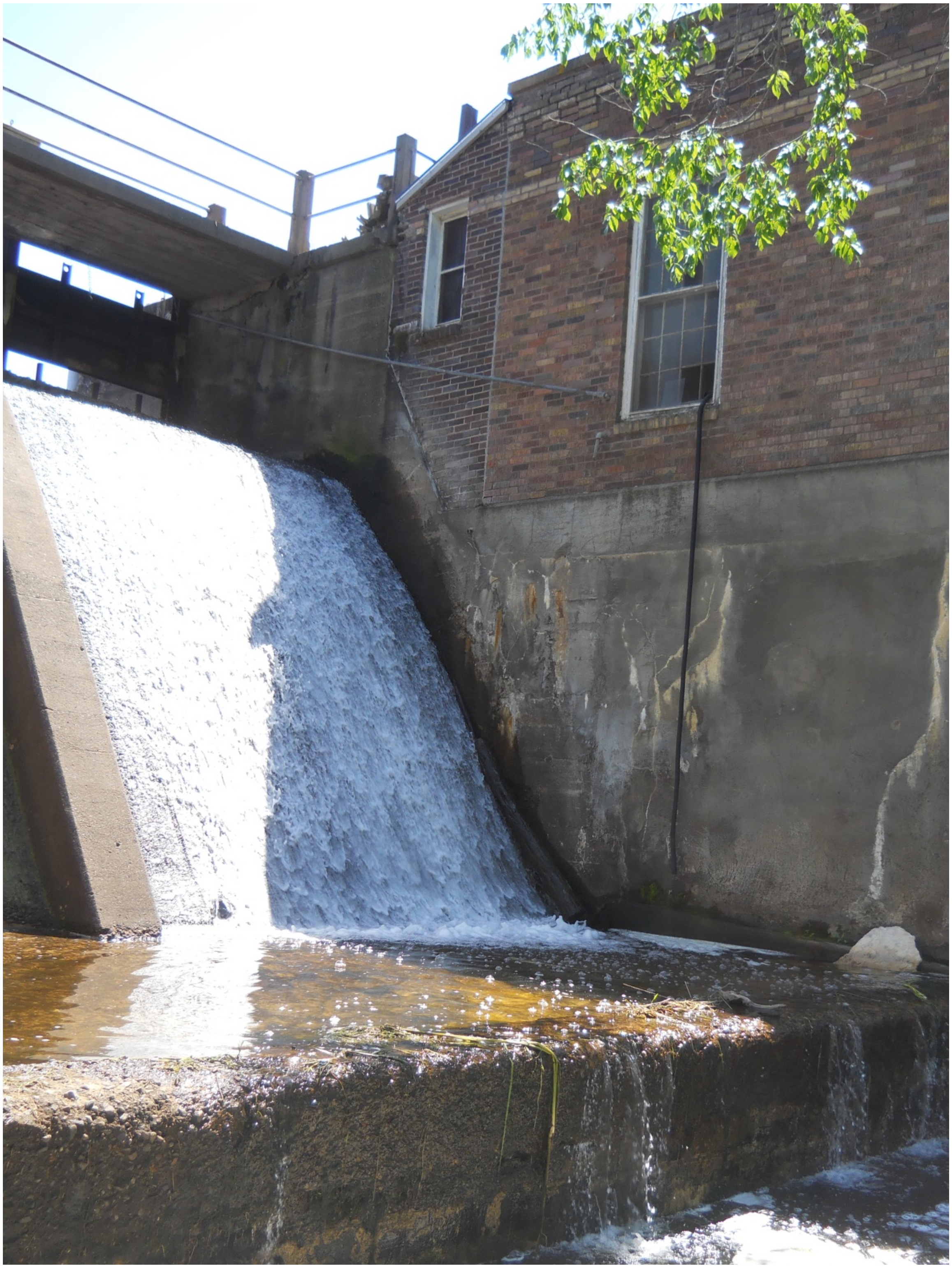

Figure 5. Gordon Dam Pre-Removal.

The Gordon Dam Removal case study illustrates the extremes of dam removals. Whereas Woodley and Grimh Dams took multiple years for both projects' design phases, Gordon Dam will require half the time to permit even though it is a larger dam to remove. Lesson learned: while dam removal construction cost is correlated with the dam's physical size, removal design and permitting can be less costly and require shorter timeframes for larger than smaller dams.

CONCLUSIONS

This article presented two challenges. First, how does a designer reduce the uncertainties in estimating dredge extents, bank stabilization costs, contaminated soil mitigation costs, cofferdam overtopping events, and other construction issues? Second, how can engineers better inform owners of these uncertainties at earlier project stages so that budgets are not escalating as time progresses.

Certainly upfront communication and risk education are key in most engineering projects, but especially critical in dam removals. Engineers owe dam owners an upfront list of project uncertainties. A line items in an early removal cost opinions might read "$100,000 for contaminated soil removals" when design-phase soil tests were not positive for diesel range organics, but such a line is justified if diesel generators have been used within the removal extents. A line item of "$140,000 for contested case litigation" when no one has objected to the project would also be justified if docks stretch into the reservoir and vacation homes surround the lake.

To facilitate owners' awareness of dam removal design and construction cost uncertainties, Ayres Associates has developed cost estimating regressions based on dam height, reservoir area, embankment length, and other physical parameters but the cost opinion also addresses questions like:

___ Has the FERC license been surrendered already?
___ Have diesel generators been used onsite frequently?
___ Do local DNR fish biologists favor fish passage modifications post-removal?
___ Does the watershed have a history of soil contamination (mills, mines, etc.)?
___ How many privately-owned parcels can view the reservoir impoundment?
___ How much has the impoundment filled with sediment?
___ Does the dam form an artificial barrier to invasive species migration upstream?
___ Does the dam create wild rice or other protected habitat upstream?

In answering the above questions upfront, designers can relay to owners how their removal project compares with other dams in terms of project complexity.

Ayres Associates has reduced some environmental hazard uncertainties and resulting permit review times by pushing owners to accept upfront (prior to regulatory agency involvement) sediment retention strategies like staged drawdown, multiple season removal efforts, and native species restoration. Wisconsin dam removals almost never allow a drawdown more than 15 feet in one year, and most drawdown volumes are also used as a storage reduction in the inflow hydrograph for cofferdam height design. Multiple growing seasons allow the engineer to correct deficiencies in the initial native species mix, ascertain how fast reservoir sediments can consolidate, and reduce the risk of a single mid-construction flow event eroding all the reservoir sediments.

As a concluding statement, dam removal projects are generally unique with individual challenges that make prediction of design effort and construction costs difficult. However, by recognizing the common sources of design uncertainty (contested case litigation potential, sediment handling issues, and contaminated soil presence), offering regulatory reviewers low cost consolations (native species seeding, removal sequences spread over multiple growing seasons, and making the grading plan mimic downstream channel shapes), and educating owners and contractors about risks (cofferdam overtopping, sediment transport risk, and experiences on other similar projects), the overall uncertainty with regard to design times, permit schedules, and construction costs can be reduced.