Debris Clogging Assessment at Dams

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Information was collected on debris clogging and debris management of spillway and outlet works structures at various Bureau of Reclamation (Reclamation) dams to identify data trends and key research needs. A short survey was sent to each Reclamation Area Office for information on debris occurrence, debris type and size, location of debris accumulation, interaction of sediment with debris, cost of debris management, and mitigation and monitoring techniques. Survey responses were also received for various facilities from Tennessee Valley Authority and Federal Energy Regulatory Commission. Reclamation results show that excessive debris occurs during flood events at 70% of reported facilities and during normal operations at 22% of reported facilities. Debris typically arrives during the beginning of high flows events such as spring runoff or heavy rain events and often during spring months. Burn events and extreme hydrological events often contribute to excessive debris. Debris loads consist most frequently of deadfall trees (88%) and vegetative debris (65%) with 78% of facilities reporting debris in the medium to small size range. Submerged debris typically starts as surface debris and then sinks rather than moving through the reservoir along the bed. Once debris is no longer floating, its eventual fate is largely unknown. Twenty-two percent of Reclamation respondents indicated that a facility currently has notable issues with sediment impacting outlet structures. Large debris removal is typically conducted physically by crane for debris near the dam or saw-cutting and hand removal for debris deposited on rip rap or banks. Debris management costs are generally 5-10% of operating and maintenance budgets, but direct and indirect costs can become very high when an urgent issue is detected.

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Acronyms and Abbreviations

FERC	Federal Energy Regulatory Commission
O&M	Operations and Maintenance
Reclamation	Bureau of Reclamation
TVA	Tennessee Valley Authority

Contents

Executive Summary

Information was collected on debris clogging and debris management of spillway and outlet works structures at various Bureau of Reclamation (Reclamation) and other agency dams. A short survey was sent to each Reclamation Area Office to determine if operators had concerns with debris management including debris occurrence, debris type and size, location of debris accumulation, interaction of sediment with debris, cost of debris management, and mitigation and monitoring techniques. Survey responses were also received for various facilities from the Tennessee Valley Authority (TVA) and Federal Energy Regulatory Commission (FERC). Results were used to identify data trends and key research needs for future investigation.

Reclamation results show that excessive debris occurs during flood events at 70% of reported facilities and during normal operations at 22% of reported facilities. Debris typically arrives during the beginning of high flows events such as spring runoff or heavy rain events and often during spring months. Burn events and extreme hydrological events often contribute to excessive debris. Debris loads consist most frequently of deadfall trees (88%) and vegetative debris (65%). In 78% of the responses, the size of most debris was reported as medium (could potentially pass through feature) or small (passes through on its own but plugs when arriving in mats or recruits other material). Submerged debris typically starts as surface debris and then sinks at the dam rather than moving through the reservoir along the bed. Once debris is submerged, its eventual fate is largely unknown. Twenty-two percent of Reclamation respondents indicated that a facility currently has notable issues with sediment impacting outlet structures. Most Reclamation facilities with larger debris reported that debris management occurs through physical removal with a crane for debris near the dam features or saw-cutting and removing debris by hand if debris was located on rip rap or banks. Occasionally, divers are required to remove submerged debris. Direct costs of debris management are generally low (5-10% of operating and maintenance budget), but costs can become very high when an urgent issue is detected.

1. Introduction

The purpose of this scoping level project was to collect information on debris clogging of either spillway structures or outlet works at various Bureau of Reclamation (Reclamation) and other agency dams. A short survey was sent to each Reclamation Area Office and other federal entities to determine if operators had concerns with debris management including when debris issues occurred, what types of debris were problematic, the location of debris accumulation, the interaction of sediment with debris, the cost of debris management, and mitigation techniques. Compiled information about debris issues and subsequent debris management can help researchers identify data trends and key research needs for future investigation with the goal of improving efficient debris management at Reclamation facilities.

1.1 Background

Debris such as large individual trees, mats of connected wood pieces, vegetation, and other natural and anthropogenic items can dislodge and travel through the reservoir to the dam. These pieces of debris can be floating, partially submerged, or fully submerged and transported as bed load. Debris can become racked against or lodged inside dam outflow structures such as radial gates, spillways, and submerged outlet works. Submerged woody debris that racks against grated submerged outlet works and/or intakes can exacerbate problems with sediment accumulation. When these outflow structures become partially or fully obstructed, the water surface elevation in the reservoir raises and there is greater risk of dam overtopping. Clogging of the reservoir outlet works can also lead to delay or inability to return the pool to normal operating elevation. Debris can also cause reductions in power production or water delivery when intakes are completed clogged or if the reservoir must be drained for debris mitigation.

Concerns about debris clogging of spillways and outlet works were identified by several federal and non-federal agencies as a research priority. When outflow structures are obstructed, debris management becomes urgent. An inventory of Reclamation spillway structures and research on potential reservoir impacts with debris loading on spillways exist; however, there is no comprehensive view of the types of debris concerns and mitigation techniques at Reclamation dams.

1.2 Previous Work

For the past 3 years, Reclamation’s Hydraulics Laboratory has been researching impacts of large debris to reservoir water surface elevation and discharge capacity for Reclamation’s Dam Safety Office. Results of the physical model study better quantify the potential impacts of debris clogging at gated ogee crest spillways and morning glory spillways on facility operation in order to better understand risk associated with debris clogging (Walker 2018, in draft and Shinbein 2020, in draft).

The impacts observed in the physical model illustrate the importance of researching debris accumulation and clogging at various types of Reclamation facilities. Physical modeling results can be used to identify trends and research gaps. An existing Reclamation spillway inventory (Brom,

2014) lists spillway types and geometry, but does not specify if debris accumulation is a concern for project operators or provide any information on outlet works.

Ubing et al. (2016) reported that current debris management options in reservoirs focus on floating debris. Current options for floating debris control include trash racks, upstream debris catchment structures (log booms), debris conveyance structures (piles to orient debris downstream), and debris sluicing/flushing. Less information was available in literature for assessing and mitigating against the effects of waterlogged debris at hydraulic control structures (Ubing et al. 2016). Authors report that submerged debris management options include prevention (upstream debris collection using log booms, pile posts, or artificial eddies), passing debris through or around dam features, large-scale debris grinding, and dredging.

2. Methods

Researchers developed a short survey in Microsoft Forms with an array of questions regarding debris presence, accumulation, and management with input from the Technical Service Center, Dam Safety Office, and Reclamation's Underwater Inspection Team. Survey questions are listed in Appendix A.

A link to the survey was sent out to contacts in all of Reclamation's Area Offices along with some program offices and construction offices via email. Contacts were asked to distribute the survey to specific facility operators as needed. Survey data on dams with known debris issues were specifically requested. The survey was also distributed to contacts at the Tennessee Valley Authority (TVA), Federal Energy Regulatory Commission (FERC), and United States Army Corps of Engineers who expressed concerns about debris issues for either surface spillways or submerged intake structures within their organization. Partners were asked to distribute the survey information throughout their agency. The broader data set helped provide knowledge transfer of current practices from various parts of the country that potentially could result in improved practices at Reclamation projects.

Responses were compiled and sorted in an Excel spreadsheet. Information about project location and purpose, debris history, source and timing of debris, debris type and size, fate of debris, debris management and removal, and associated costs were included. Trends were identified from the data and recommendations were made about research gaps and future needs.

3. Results and Discussion

Responses were received for some facilities in all of Reclamation's regions – California-Great Basin, Columbia-Pacific Northwest, Upper Colorado Basin, Lower Colorado Basin, and Missouri Basin and Arkansas-Rio Grande-Texas Gulf. Twenty-three responses provided details for a specific facility while four respondents provided generalized debris information for several facilities managed by a specific office. In addition, TVA provided responses for 16 facilities and FERC provided responses for 20 facilities. Responses were not received from the U.S. Army Corps of Engineers. Full responses are displayed in Appendix B for Reclamation facilities and Appendix C for non-Reclamation facilities.

3.1 Source and Timing of Debris

Of the 27 survey responses from Reclamation facilities, 16 indicated that previous burn events in the drainage basin contributed to excessive debris entering the facility. Fifteen responses indicated that a previous extreme hydrological event contributed to excessive debris. A large forest fire can bring a significant increase to the amount of sediment and woody debris entering a facility, especially when combined with a period of excessive flooding or drought. One response did mention a severe avalanche season and citied it later in the survey as the primary reason for a spike in large woody debris that was entering the facility.

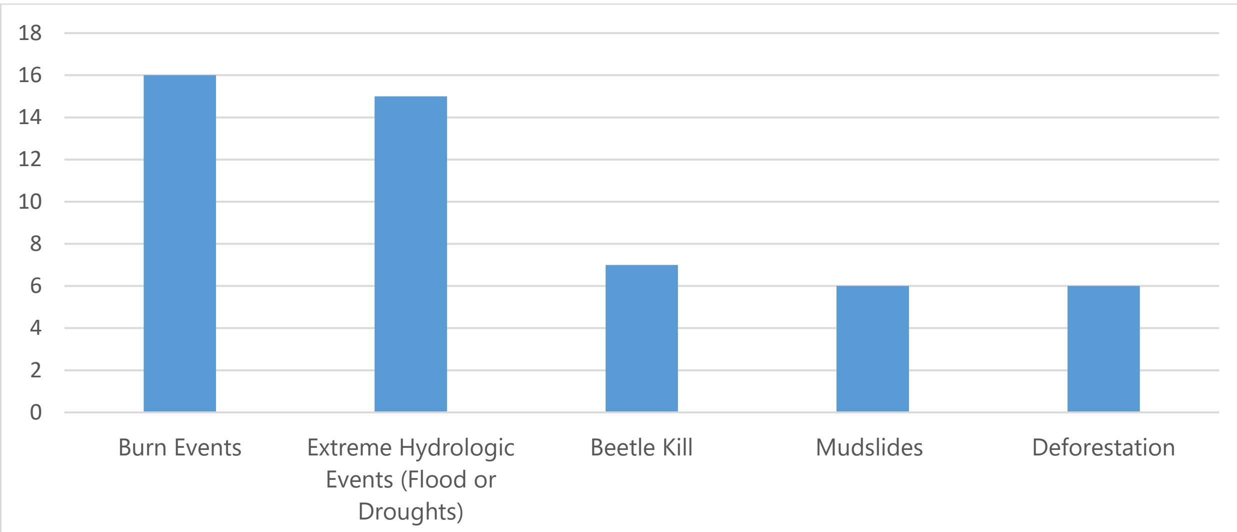

Figure 1. Response to the survey question "What events (if any) have occurred in the drainage basin in recent history that might cause excessive debris to come downstream?". Multiple choices could be selected by the respondent.

Survey participants were asked when excess debris enters the facility and 70% responded that debris enters the facility during flood events while 22% specified that excessive debris enters during normal operations. Other responses included spring run-off, windy conditions, low reservoir elevations, and vegetation die-off.

Respondents indicated that debris enters facilities most often at the beginning of high flow events such as spring runoff or heavy rain events at 52% of facilities. Debris events were also indicated to occur when the reservoir entered a period of high overall storage with 37% of responses. This aligned with several comments mentioning that high reservoir water surface elevations allowed stranded debris to re-mobilize and float toward the dam.

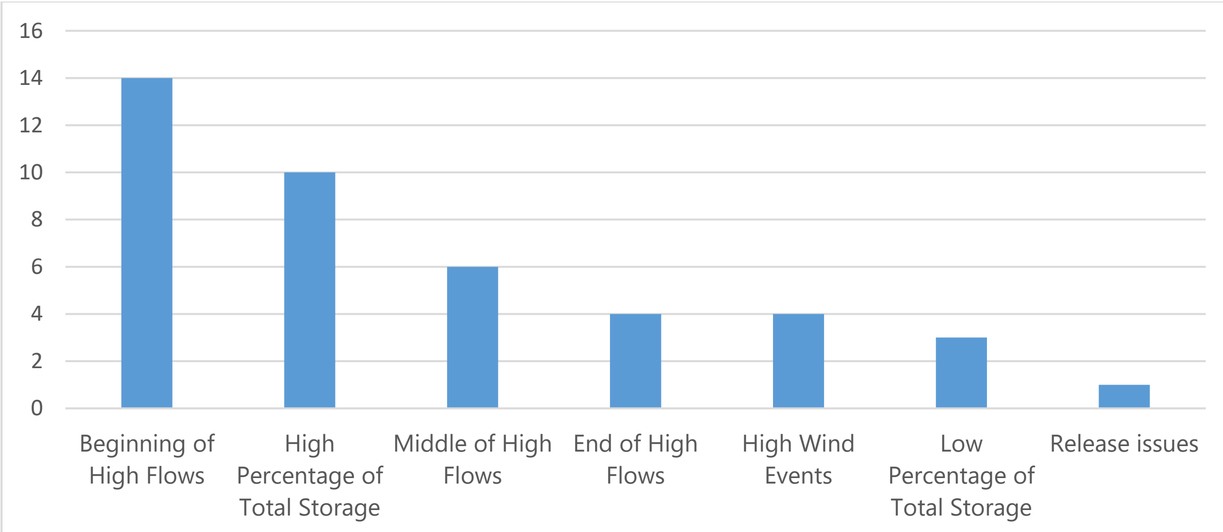

Figure 2. Response to the question "What reservoir conditions exist during debris events?". Multiple choices could be selected by the respondent.

Steep slopes (70%), heavily wooded terrain (63%) and erodible soils (56%) were the primary characteristics of the surveyed drainages basins. Peak months for debris loading were April, May, and June. At partner facilities east of Reclamation's boundaries, this trend was shifted earlier in the year by about a month.

3.2 Debris Type and Size

At almost every Reclamation facility surveyed (88%) dead fall trees make up a portion of the debris load. The second most common type of debris was vegetative debris at (65%).

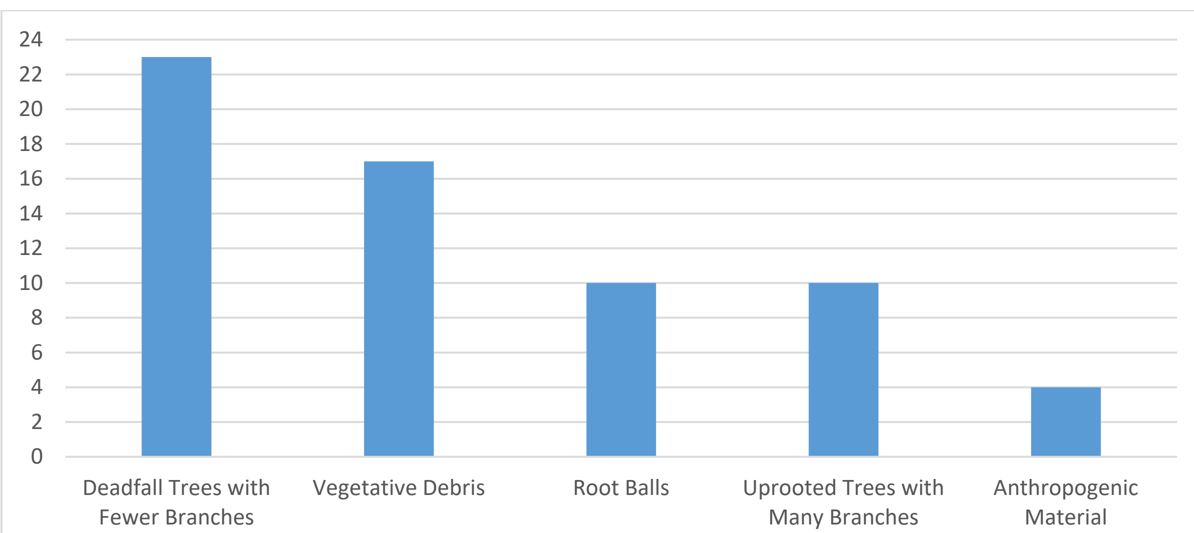

Figure 3. Response to the question "What type of debris material enters the reservoir?". Multiple choices could be selected by the respondent.

Larger woody debris and smaller vegetative debris can both be problematic depending on the structure geometry and operation of the facility. Respondents indicated that the size of most of the debris received was medium (could potentially pass through feature) or small (passes through on its own but plugs when arriving in mats or recruits other material). Combined these responses made up 78% of the total.

Even though the vast majority of responses mentioned deadfall trees as being a portion of the debris that enters the facility, most of the Reclamation facilities surveyed were able to pass logs through the spillway without creating a problematic clog depending on the size of the spillway. One quote from the Grand Coulee office stated, "Grand Coulee can receive large, full size trees, but the spillway openings are about four times larger in length and can easily pass one of these trees if necessary."

Figure 4. Small- to medium-sized floating woody debris and vegetative debris against Keswick Dam, California.

Figure 5. Manual removal of large log from Morrow Point Dam, Colorado.

3.3 Fate of Debris

Several questions focused on the eventual fate of the debris including the location of the jams, the buoyancy of the debris, and if it is eventually removed or sinks to the bottom of the reservoir. Reclamation results show that surface debris typically accumulates at a spillway or the dam crest and submerged debris typically accumulates at outlet works or power intakes (Figure 6). Debris accumulation downstream of the dam on baffle blocks or in the stilling basin was less likely. Other features selected in the survey may not be present at every facility and respondents could select more than one option.

Responses indicated that debris can be located at the surface, submerged, or, in many cases, both locations (Figure 7). If debris is not physically removed, the debris may become waterlogged and sink to the bottom of the reservoir. Several respondents indicated that the reservoir bed is not typically surveyed due to its deep depth. Once the debris is no longer floating, its eventual fate is largely unknown. When a clog/jam was discovered, it was generally found at an outflow point of the facility with the outlet works being the most common location. In these situations, flow releases can be restricted or power generation can be limited.

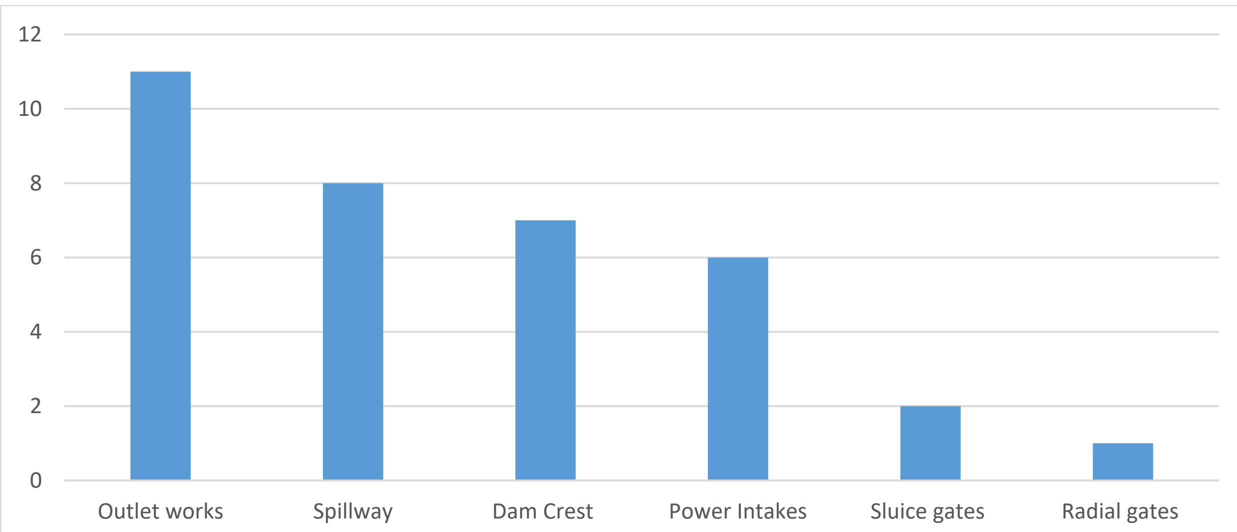

Figure 6. Response to the question "Where do clogs/jams occur?". Multiple choices could be selected by the respondent.

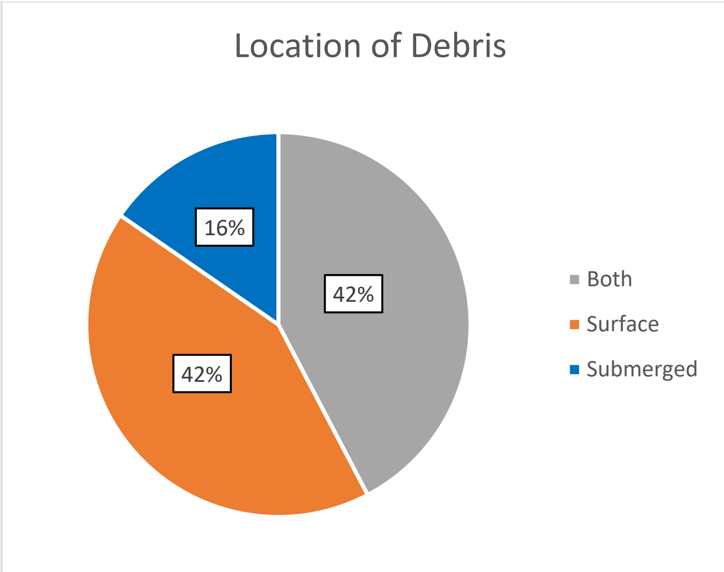

Figure 7. Response to the question "Is debris primarily submerged or on the surface?"

Reclamation's Underwater Inspection Team stated that most submerged intakes have some debris covering the trashracks, typically at the base of the trashrack (Figure 8-9). Locations with deadfall trees seem to have the most problems with debris accumulating on the trashracks.

Figure 8. Photograph from Reclamation's Columbia-Pacific Northwest Underwater Inspection Team of Keechelus Dam, Yakima Project, Washington on October 27, 2005 showing woody debris and sediment build up at the base of a trashrack.


Figure 9. Photograph from Reclamation's Columbia-Pacific Northwest Underwater Inspection Team of Twin Lakes Dam, Fryingpan-Arkansas Project, Colorado on October 12, 2010 showing a two-foot high mat of twigs, sticks, and branches on the vertical trashracks of the outlet works intake structure.

Of the 27 responses from Reclamation, 6 indicated that their facility has notable issues with sediment impacting outlet structures and 4 indicated minor issues with sediment. Reservoir sediment that accumulates at or near a dam can clog outlet works which can lead to a restricted ability to make flow releases. Submerged woody debris that racks against grated submerged outlet works and/or intakes can exacerbate problems with sediment accumulation. In some cases, sediment erodes during low water levels and then sediment-laden wood is transported to submerged outlet works. This can lead to eventual burying of the intake due to difficulties in removing the sediment and woody debris by dredge (Ubing et al. 2016).

Reclamation results indicate that sediment is either a big problem at a facility or it is not currently known to be a problem. Generally, not much is known about the bed of the reservoir and only about 35% of Reclamation reservoirs have been re-surveyed since dam construction (Kent Collins, Reclamation's Technical Service Center, personal communication). It is likely that some facilities not currently experiencing sediment-related issues may be subject to sediment deposition that impacts future facility operations.

When sediment clogging becomes an issue, an urgent and/or costly response may be required. When Paonia Reservoir was drained in 2014 to inspect the reservoir outlet works, waterlogged submerged woody debris was racked against the trashracks.

Figure 10. Photograph from Paonia Dam in Colorado showing sediment deposition in the reservoir (left) and at the intake structure (right). Small debris is not too big to fit through the trashrack openings if oriented lengthwise, but debris that impinges on the trashrack allows sediment to back up behind it.

3.4 Debris Management and Removal Techniques

From this survey, most Reclamation facilities with larger debris report physical removal with a crane by land or by boat, or saw-cutting and removing by hand if debris is located on rip rap or banks. Occasionally, divers are required to remove submerged debris. Debris is removed annually or as needed. Operational techniques such as flushing are used to pass larger debris in some locations. For smaller woody and vegetative debris, trash racks with rakes provide much of the debris removal. Sediment removal is typically conducted by dredging as needed. Several respondents indicated that taking advantage of favorable wind conditions can assist with debris loads by collecting debris at a certain location for removal or pushing debris over the spillway. Unfavorable wind events, however, can accumulate debris in undesirable locations or create debris back-ups at trashracks.

At most facilities, monitoring is conducted through visual inspections. Probing of intakes can detect the amount of sediment build up. Divers or sonar mapping are used to monitor debris and sediment when problems arise. If required flow rates cannot be obtained, gates can be adjusted and then operators are notified of the need for debris removal. Reduced performance of power generating units can also indicate debris build up.

Figure 11. Sediment dredging has occurred twice in the reservoir at Belle Fourche Dam around the South Canal intake. Woody debris collected along the dam embankment rip rap is saw cut and hand removed.

Figure 12. Medium-sized deadfall trees accumulated at Buffalo Bill Dam, Wyoming. Surface debris piled against the face of the dam is removed annually depending on resource availability (typical removal effort is 1 - 2 weeks). A large rake attached to a front end loader is used to remove wood debris on the reservoir bed.

Figure 13. Removed debris at Buffalo Bill Dam, Wyoming, is hauled by truck.

Figure 14. Medium-sized woody debris caught in dentates at drop structure on Marble Bluff Dam, Nevada.

Figure 15. Removal of deadfall by crane at Marble Bluff Dam, Nevada.

3.5 Cost of Debris Management

The direct and indirect cost of debris management at most facilities was unknown by respondents. For those facilities with estimated costs, the average percentage of O&M budget spent on debris-related impacts was about 5-10% for Reclamation facilities. Respondents from TVA and FERC indicated similar budgets for most facilities, but some facilities reported up to 40% of the annual budget can be spent on debris management. Typical annual maintenance costs are primarily labor with some associated equipment costs. Indirect costs such as lost revenue from reductions in power production or water delivery can be substantial when intakes are completed clogged or if the reservoir must be drained for debris mitigation. Indirect costs were not quantified in the survey responses by respondents.

High costs are reported for management of specific debris-related incidents such as debris clogging due to high-flow events, fires, and avalanches where heavy machinery or lengthy removal processes are required. Removal of debris intermixed with sediment also notably increases reported cost. In one example, release flows decreased during normal operations at Caballo Dam in New Mexico without any changes to gate settings due to debris and sediment clogging. Multiple methods were pursued to increase release flows, but procurement of crane services was the most effective at clearing the intake. The respondent at Caballo Dam suggested that having a viable plan for episodic debris removal can improve response time to incidents which may reduce associated direct and indirect costs.

Figure 16. Caballo Dam, New Mexico before (left) and after (right) debris removal with crane and clamshell bucket. Although annual O&M costs related to debris removal are typically low, a debris clogging incident at the intake created a unique maintenance cost for contracted dredging services.

4. Conclusions and Recommendations

The purpose of this scoping level project was to collect information on debris clogging of either spillway or outlet works structures at various Reclamation facilities. Information from TVA and FERC facilities was also obtained to develop a broader understanding of debris clogging issues.

Key Takeaways:

- Excessive debris occurs during flood events at 70% of reported facilities and only during normal operations at 22% of reported facilities.
- Debris arrives during the beginning of high flows events such as spring runoff or heavy rain events and typically during spring months - April, May, June.
- Burn events and extreme hydrological events often contribute to excessive debris.
- Debris load consists most frequently of deadfall trees (88%) and vegetative debris (65%).
- Debris size was medium (could potentially pass through feature) or small (passes through on its own but plugs when arriving in mats or recruits other material) in 78% of the responses.
- Surface and submerged debris can both be problematic for operators.
- Submerged debris typically starts as surface debris and then sinks at the dam rather than moving through the reservoir along the bed.
- Sediment accumulation was currently impacting outlet structures in 22% of responses.
- Large woody debris removal is typically conducted physically by crane for debris near the dam or saw-cutting and hand removal for debris deposited on rip rap or banks.
- Small woody debris and vegetative debris are typically removed by trash racks with rakes.
- Operational techniques such as flushing are used to pass debris and sediment in some locations.
- Divers are occasionally required to remove submerged debris.

- Direct costs of debris management are generally low (5-10% of operating and maintenance budget), but direct and indirect costs can become very high when an urgent issue is detected.

Recommendations:

- More rapid removal of surface debris is needed to minimize amount of debris that becomes waterlogged and sinks.
- Underwater sonar surveys and imaging should be conducted more frequently to determine the fate of submerged debris. This will help detect potential blockages before outlet works or intakes become clogged. Remote surveys and imaging can increase human safety by minimizing the need for diving around clogged infrastructure. Early detection of submerged debris may help avoid urgent situations where outlet works and intakes are restricted.
- More focus should be placed on prevention as a submerged debris management option because of the difficulty in removing submerged debris, particularly when it is mixed with accumulated sediment.
- Best practices for existing mitigation strategies (operations, retrofits, removal techniques) should be developed for facilities experiencing different types of debris size, type, and loading.
- New mitigation strategies should be developed, particularly for submerged intakes where options are currently limited.
- Predictive tools can be developed to better understand when debris clogging may be problematic based on land type; debris size, type, and loading; associated spillway feature design and geometry (e.g. gate count, gate size, pier details, approach channel details, trashrack spacing); and operational history.
- Development of an annual debris mitigation program and creating a plan for episodic debris removal during urgent incidents can improve facility O&M.

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Appendix A – Survey Questions

The following survey questions were asked to Reclamation offices and other agencies:

1. What is the name and location of your facility?
2. What are the authorized purposes of the facility?
3. What events (if any) have occurred in the drainage basin in recent history that might cause excessive debris to come downstream? (Select multiple if applicable.)
    a. Burn Events
    b. Deforestation
    c. Mudslides
    d. Beetle Kill
    e. Extreme Hydrological Events (floods or Droughts)
    f. Other
4. If excessive debris enters your facility, when does it occur?
    a. Flood events
    b. Normal Operations
    c. Other
5. What reservoir conditions exist during debris events? (Select multiple if applicable.)
    a. Higher percentage of total storage
    b. Low Percentage of total storage
    c. High wind events
    d. Beginning of high flows
    e. Middle of high flows
    f. End of high flows
    g. Other
6. What land type is characteristic of your drainage basin? (Select multiple if applicable.)
    a. Heavily wooded
    b. Steep slopes
    c. Erodible soils
    d. Plains
    e. Grasslands
    f. Rolling hills
    g. Desert
    h. Other
7. What type of debris material enters the reservoir? (Select multiple if applicable)
    a. Anthropogenic material
    b. Uprooted trees with many branches
    c. Deadfall tress with fewer branches
    d. Root balls
    e. Vegetative debris, leaves, small woody material
    f. Other
8. What size of debris material enters the reservoir? (Select multiple if applicable.)
    a. Large (spans spillway or outlet works)
    b. Medium (could potentially pass though feature)
    c. Small (passes through on its own, but plugs when arriving in mats or recruits other material)

9. Where do debris clogs/jams occur? (Select multiple if applicable.)
    a. Outlet works
    b. Power intakes
    c. Spillway
    d. Sluice gates
    e. Dam crest
    f. Baffle Blocks
    g. Stilling basin
    h. Other
10. Is debris primarily submerged or on the surface?
    a. Submerged
    b. Surface
    c. Both
11. If there is submerged debris, does it start off as surface debris and then sink, or is the debris moving along the reservoir bed? Is the submerged debris buried in sediment or sitting on top of sediment?
12. How is debris currently being managed at your facility and is it effective? (e.g. physical removal or operational techniques)
13. Is sediment loading a problem at your facility?
14. What percentage of the total O&M budget is being used on debris management? What is an estimate of direct (contract equipment) and indirect (labor) costs?
15. How long has debris been a concern at the facility and how is it being monitored?
16. What months are you having problems with debris? (Select multiple if applicable)
    a. January
    b. February
    c. March
    d. April
    e. May
    f. June
    g. July
    h. August
    i. September
    j. October
    k. November
    l. December
17. Are there other comments regarding debris that you would like to add?
18. Name and Contact Information
19. If you have relevant photos that you would like to share with the Reclamation Technical Service Center please email them to jcartergibb@usbr.gov

Appendix B - Detailed Survey Responses for Reclamation Facilities

Facility Name	Agency/Office	Facility Location	Authorized Purposes of Facility	Events in the Drainage Basin Producing Excessive Debris	Occurrence of Excessive Debris	Reservoir Conditions During Debris Events
Caballo Dam	Bureau of Reclamation – Upper Colorado Basin	New Mexico	Irrigation	Burn events; extreme hydrologic events (floods or droughts)	Low reservoir elevation; flood events	Keeping reservoir low; low percentage of total storage
Crystal Dam & Powerplant	Bureau of Reclamation – Upper Colorado Basin	Colorado	Flood control, storage, irrigation, recreation and hydroelectric	Above normal snowpack from prior year	During spring runoff and fulfilling Record of Decision based on May snowpack; normal operations	Beginning of high flows
Four Corners Construction Office – Multiple Facilities	Bureau of Reclamation – Upper Colorado Basin		Navajo Indian Irrigation Project-irrigation and Navajo Gallup Water Supply Project-potable water transmission	Windy conditions	Windy conditions	High wind events
Morrow Point Dam	Bureau of Reclamation – Upper Colorado Basin	Colorado	Store water, deliver water, power generation	Avalanche. heavy snow	Spring melt	High percentage of total storage; beginning of high flows; middle of high flows; end of high flows
Nambe Falls Dam	Bureau of Reclamation – Upper Colorado Basin	New Mexico	Irrigation	Burn events	Flood events	Release issues
Paonia Dam	Bureau of Reclamation – Upper Colorado Basin	Colorado	Irrigation, flood control, recreation		Normal operations	Problem debris is primarily submerged in sediment
Angostura Dam and Reservoir	Bureau of Reclamation – Missouri Basin and Arkansas-Rio Grande-Texas Gulf	South Dakota	Irrigation, recreation	Burn events; deforestation; mudslides; beetle kill; extreme hydrologic events (floods or droughts)	Flood events	High percentage of total storage; beginning of high flows
Belle Fourche Reservoir	Bureau of Reclamation – Missouri Basin and Arkansas-Rio Grande-Texas Gulf	South Dakota	Irrigation	Burn events; deforestation; mudslides; beetle kill; extreme hydrologic events (floods or droughts)	Flood events	High percentage of total storage; beginning of high flows
Bretch Diversion Dam	Bureau of Reclamation – Missouri Basin and Arkansas-Rio Grande-Texas Gulf	Oklahoma	Supplemental water supply for Tom Steed Reservoir. Tom Steed Reservoir provides municipal water, flood control, fish & wildlife, and environmental quality benefits.	Extreme hydrologic events (floods or droughts)	Flood events	High percentage of total storage

Facility Name	Land Type of Drainage Basin	Months with Debris Problems	Debris Type	Debris Size	Debris Clogging Location
Caballo Dam	Heavily wooded; steep slopes; erodible soils; rolling hills	September – October	Burn scar material; uprooted trees with many branches; deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Large (spans spillway or outlet works)	Intake rack; outlet works
Crystal Dam & Powerplant	Heavily wooded; steep slopes; erodible soils	April – June	Anthropogenic material; uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Large (spans spillway or outlet works)	Left abutment at boat ramp and dock; dam crest
Four Corners Construction Office – Multiple Facilities	Steep slopes; erodible soils; desert	February – June; September – October	Tumble weeds; vegetative debris, leaves, small woody material	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	Canal radial gates and trashracks
Morrow Point Dam	Heavily wooded; steep slopes; erodible soils	April – June	Uprooted trees with many branches; deadfall trees with fewer branches; root balls	Medium (could potentially pass through feature)	Outlet works; power intakes; spillway
Nambe Falls Dam	Heavily wooded upstream; erodible soils		Deadfall trees with fewer branches	Large (spans spillway or outlet works)	Possible at outlet works
Paonia Dam	Steep slopes; erodible soils		Deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	Outlet works intake structure; outlet works
Angostura Dam and Reservoir	Heavily wooded; steep slopes; rolling hills	March – June	Sediment; uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	No debris clogs or jams. Debris collects along the riprap.
Belle Fourche Reservoir	Heavily wooded; steep slopes; plains; grasslands; rolling hills	April – June	Uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Large (spans spillway or outlet works)	Outlet works
Bretch Diversion Dam	Erodible soils; plains	April – June	Deadfall trees with fewer branches	Medium (could potentially pass through feature)	Spillway

Facility Name	Submerged Debris or Surface Debris?	Does submerged debris start as surface debris and then sink, or is the debris moving along the reservoir bed?	Sediment Loading	Current Debris Management at Facility
Caballo Dam	Both	Debris starts off at the surface and then sinks to base. The debris was mixed in with the sediment.	There is some sediment loading but was cleaned out in 2016 when the crane was there. Sediment is monitored around the intake structure.	Physical removal when present. Use of crane when the intake was clogged with debris.
Crystal Dam & Powerplant	Both	Starts on surface and sinks when saturated. Most debris settles on rock at left abutment.	Not problematic, but does add to normal work load at the facility.	Occasional physical removal in order to place boats in the reservoir, but now with the Record of Decision, most of the debris usually goes over the spillway if the winds are favorable.
Four Corners Construction Office – Multiple Facilities	Both	Mostly on top	Sediment is an issue and it is physically removed	Trash rake, but with a wind event, the trash rake cannot keep up.
Morrow Point Dam	Surface	Starts off as surface debris and then sinks.	No	Physical removal with boat and crane
Nambe Falls Dam	Submerged	Submerged and collected by the outlet works, due to forest fires upstream of the dam.	Yes, on the upstream side	No work has been done on the outlet works. Some work was done on the upstream to remove sediment.
Paonia Dam	Submerged	Buried in sediment	Yes	When the reservoir has been drained a couple of times, the submerged debris is pushed through the trashracks. It is usually less than 3 feet long and less than 1 inch diameter.
Angostura Dam and Reservoir	Both	Angostura Reservoir is relatively shallow and has a lot of sediment. The reservoir is slowly losing storage capacity due to sediment. Flows can be very high every 20 years or so and high flow flushing seems to have kept sediment levels in the reservoir manageable. During the mechanical Comprehensive Review several years ago, the river outlet gate was operated for the first time in years releasing a great deal of dark earthy material before running clean water. All the gates are operated regularly now reducing the likelihood of sediment build up against a gate.	Sediment loading is not currently an issue	Debris collecting along the rip rap is collected saw cut and hand removed to be trucked off or burned later.
Belle Fourche Reservoir	Submerged	Reservoir has been dredged twice to keep the south inlet canal from being clogged by primarily sediment but also woody debris. Intentionally sinking recycled Christmas trees for fish habitat as well as other sunken woody debris has had the effect of putting a large amount of woody debris up against the south canal inlet intake grates increasing the likelihood of clogging releases.	Sediment has threatened to clog South Canal intake and had to be dredged for a significant amount of money. Last dredging cost about $1 million.	Sediment has been removed via dredging twice in the 100+ year history of the reservoir, both times around South Canal intake. Woody debris collected along the dam embankment rip rap is saw cut and hand removed.
Bretch Diversion Dam	Surface		Sediment is not a problem for the diversion dam, but can be problematic when it deposits along the diversion canal.	Operational techniques - flushing

Facility Name	How long has debris been a concern at the facility and how is it being monitored?	Cost of Debris Management (e.g. Percent of O&M Budget, Estimated Direct and/or Indirect Costs)	Other Comments
Caballo Dam	Debris has been a major concern since 2016. Operators are trying to manage the reservoir at a higher elevation so debris does not have a chance to make it to the intake structure. Intake probing occurs each year to see the amount of sediment is building up around the intake.	On an annual basis the facility is spending 0.5%. However in the last major event in 2016 when the intake was 95% clogged, costs were $51,000 on labor and $75,000 on contract equipment.	With the last major debris event in 2016, facility operators learned that removal can cost a lot and impact release ability. Debris should be something that every reservoir should be concerned about and have an idea of how to remove it. Operators had to learn very fast and use many different methods to meet release demand, but it was a steep curve.
Crystal Dam & Powerplant	Debris is not much of a concern. It is monitored when physically on top of dam. There is also monitoring from the control room.		
Four Corners Construction Office – Multiple Facilities	Several years after construction	Unknown	
Morrow Point Dam	Visual inspection. Little concern during normal years. Historic avalanches from previous year increased debris loads.	Typically small percentage, but previous year was probably $100,000 in labor to remove debris because of avalanches.	
Nambe Falls Dam	2010/2011	None, this is a transferred facility.	There was a couple of forest fires upstream in 2010/2011 and then had flushing floods that brought in woody debris and sediment into the reservoir.
Paonia Dam	2014	Unknown	The problem debris is transported in the sediment. There is no longer dead pool storage below the lip of the intake structure, so the debris that gets transported to the intake structure gets hung up on the trashracks. The debris is not too big to fit through the trashrack openings if oriented length wise, but the debris gets pushed up against the trashrack and then backs the sediment up behind it.
Angostura Dam and Reservoir	Debris is monitored continuously by a full-time dam tender. Debris against the rip rap has always been a concern due to wave action and heavy winds in South Dakota.	5% of the dam budget goes to debris removal. Costs are primarily labor.	
Belle Fourche Reservoir	The first time Belle Fourche Reservoir was dredged was in the 1950s. Sediment collecting around the intake is a major concern and is watched closely as the sediment collects to a point where operations are impacted. The dam is inspected and observed at least once a week and woody vegetation along the embankment is removed continuously.	It depends on the year. On a normal year O&M budget for the dam is about 10% of the operational costs. The primary costs are labor. For dredging, cost included contracting for large dredging equipment and divers.	
Bretch Diversion Dam	This facility has to be continuously monitored when diversions are occurring to adjust gates, etc. Debris is periodically flushed during these times as needed.	Very small	

Facility Name	Agency/Office	Facility Location	Authorized Purposes of Facility	Events in the Drainage Basin Producing Excessive Debris	Occurrence of Excessive Debris	Reservoir Conditions During Debris Events
Buffalo Bill Dam	Bureau of Reclamation – Missouri Basin and Arkansas-Rio Grande-Texas Gulf	Wyoming	Flood control, recreation, power generation	Burn events; mudslides; beetle kill; extreme hydrologic events (floods or droughts)	Flood events; normal operations	High percentage of total storage; beginning of high flows; middle of high flows; end of high flows
Deerfield Reservoir	Bureau of Reclamation – Missouri Basin and Arkansas-Rio Grande-Texas Gulf	South Dakota	Municipal water, irrigation, recreation	Burn events; deforestation; beetle kill; extreme hydrologic events (floods or droughts)	Flood events	High percentage of total storage; beginning of high flows
Keyhole Reservoir	Bureau of Reclamation – Missouri Basin and Arkansas-Rio Grande-Texas Gulf	Wyoming	Flood control, irrigation, recreation	Burn events; deforestation; mudslides; beetle kill; extreme hydrologic events (floods or droughts)	Flood events	High percentage of total storage; low percentage of total storage; high wind events; beginning of high flows
Olympus Dam	Bureau of Reclamation – Missouri Basin and Arkansas-Rio Grande-Texas Gulf	Colorado	Power generation, irrigation, no flood control	Extreme hydrologic events (floods or droughts)	Flood events	Middle of high flows
Pactola Dam	Bureau of Reclamation – Missouri Basin and Arkansas-Rio Grande-Texas Gulf	South Dakota	Flood control, municipal water, irrigation water, recreation	Burn events; deforestation; beetle kill; extreme hydrologic events (floods or droughts)	Flood events	High percentage of total storage; beginning of high flows
Shadehill Reservoir	Bureau of Reclamation – Missouri Basin and Arkansas-Rio Grande-Texas Gulf	South Dakota	Flood control, irrigation, recreation	Mudslides; extreme hydrologic events (floods or droughts)	Flood events	High percentage of total storage; high wind events; beginning of high flows
Horse Mesa Dam	Bureau of Reclamation – Lower Colorado Basin	Arizona	Generation and reservoir storage	Heavy rain; burn events	Very infrequent, last year was the first time in many years	Middle of high flows
Mormon Flat Dam	Bureau of Reclamation – Lower Colorado Basin	Arizona	Flood control, water and power delivery	Burn events; extreme hydrologic events (floods or droughts)	Flood events	Beginning of high flows
Parker Dam	Bureau of Reclamation – Lower Colorado Basin	Arizona and California	Irrigation and flood control	Grass growth due to Quagga mussels	Annually when the grass dies off; normal operations	During normal flows but grass dies and Mark Wilmer stops pumping

Facility Name	Land Type of Drainage Basin	Months with Debris Problems	Debris Type	Debris Size	Debris Clogging Location
Buffalo Bill Dam	Heavily wooded; steep slopes; erodible soils	January – December	Material is "beached" as reservoir elevation drops. As reservoir elevation rises, material is floated again; deadfall trees with fewer branches; root balls	Medium (could potentially pass through feature)	Outlet works; power intakes; dam crest
Deerfield Reservoir	Heavily wooded; steep slopes; grasslands; rolling hills	April – July	Uprooted trees with many branches; deadfall trees with fewer branches; root balls	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	It collects along the embankment riprap where it can damage the riprap.
Keyhole Reservoir	Heavily wooded; plains; grasslands; rolling hills	March – June	Sediment; uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	Outlet works
Olympus Dam	Heavily wooded; steep slopes	May – July	Anthropogenic material; vegetative debris, leaves, small woody material	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	Outlet works; spillway
Pactola Dam	Heavily wooded; steep slopes	April – July	Uprooted trees with many branches; deadfall trees with fewer branches; root balls	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	Along the creek debris can cause flooding and also damages the dam embankment riprap
Shadehill Reservoir	Plains; grasslands; rolling hills	March – July	Deadfall trees with fewer branches; root balls	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	No debris clogging. Ice jams can be an issue upstream and downstream.
Horse Mesa Dam	Steep slopes; desert	July	Deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Dam crest
Mormon Flat Dam	Steep slopes; desert	January – March; September – December	Uprooted trees with many branches; deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Outlet works; power intakes; sluice gates
Parker Dam	Desert	August – September	Vegetative debris, leaves, small woody material	Large (spans spillway or outlet works)	Trashrack structure upstream of the forebay

Facility Name	Submerged Debris or Surface Debris?	Does submerged debris start as surface debris and then sink, or is the debris moving along the reservoir bed?	Sediment Loading	Current Debris Management at Facility
Buffalo Bill Dam	Both	Starts as surface debris. Eventually becomes waterlogged and sinks to the bottom.	Yes.	Physical removal when possible.
Deerfield Reservoir	Surface	There is some submerged debris. Most of the submerged debris started off as surface debris. Reservoir bed is not observed closely.	Sediment loading is not a current issue at the facility. Sediment is collecting slowly reducing storage capacity and may someday impact reservoir operations.	Saw cutting debris and then hand removal is the method of handling debris collection against the dam riprap.
Keyhole Reservoir	Submerged	Both surface and submerged debris. Woody debris and sediment.	Sediment loading has not become a problem at this facility yet.	Debris is cut with chainsaws and removed from the rip rap by hand. Debris removal has not been required from the intake yet, but in time it is expected.
Olympus Dam	Both	Debris likely floats to the radial gates, then gets moved down to the bottom of the gates from releases.	No	Physical removal of debris with a crane mounted on the crest of the dam at the canal outlet works intake.
Pactola Dam	Surface	Reservoir bed is over 200 ft deep and is not generally studied. Floating debris that ends up on the riprap is better known. Debris can pile up against the intakes over time. It is assumed most debris is floating and washes up along the embankment where it is removed.	Sediment build up has not affected operation or capacity notably although it surely is accumulating and may be an issue someday.	Physical removal by saw cutting and hand removal.
Shadehill Reservoir	Surface	Subsurface debris not observed beyond reservoir capacity studies.	Sediment loading has not proven to be a problem at Shadehill Dam yet.	Chainsaw cut debris along the riprap and remove it by hand to avoid damage to the revetment coverage.
Horse Mesa Dam	Both	Some debris starts out floating and slowly sinks to below the surface.	Not a problem normally.	Physical removal of debris with boats and equipment.
Mormon Flat Dam	Both	Starts off as surface debris and then sinks. Suspect submerged debris is both buried and sitting on top of sediment.	Unknown	Physical relocation by having divers move debris.
Parker Dam	Surface		No	Trashrack.

Facility Name	How long has debris been a concern at the facility and how is it being monitored?	Cost of Debris Management (e.g. Percent of O&M Budget, Estimated Direct and/or Indirect Costs)	Other Comments
Buffalo Bill Dam	Debris has been a problem since the dam was built with divers working to remove debris back in the 1940's. Divers were also used to remove debris during the Buffalo Bill Dam Modifications (~1985 - 1992). Debris/sedimentation is currently impeding on the intakes for the Lower Level Outlet Works and the Shoshone Power Plant Intake which are both located at the base of Buffalo Bill Dam. Due to flow restrictions, the power generation output of Shoshone has been reduced by approx. 20% (3 MW down to 2.4 MW). The facility has worked with TSC to do a sonar scan and mapping of the debris and sedimentation buildup with plans to remove the debris and sedimentation.	Never calculated. Removal cost ranges from $25,00 to $50,000 / year for Buffalo Bill Dam and Diamond Creek Dike.	Debris is removed in late June or July annually depending on resource availability. Typical removal effort is 1 - 2 weeks. This effort is resource intensive as it takes the entire Buffalo Bill O&M Staff as well as staff from the WYAO. Staff remove surface debris against the face of the dam (which usually accumulates due to wind pushing west to east), but are only able to remove a small amount of what is in the reservoir. Wood is removed at Diamond Creek Dike when the reservoir elevation is low in the fall/winter. A large rake was purchased for a front end loader to scoop up wood debris on the reservoir bed. Wood is placed in large piles and burned when there is snow on theground.
Deerfield Reservoir	Debris is monitored continuously at least once per week as a part of the operations work.	10% of the O&M budget is being used on debris management. Primarily costs are labor costs. Equipment costs are low.	
Keyhole Reservoir	Debris has always been a constant concern especially after flooding. Spring debris deposits are generally cleaned up annually.	5% of the O&M budget is being used on debris management. Primary costs are direct in-house labor.	Debris is not much of a problem at Keyhole presently under existing maintenance. If the intake were to be clogged similar to Belle Fourche Dam, we would need to dredge to continue operations.
Olympus Dam	Debris is not much of a concern at the facility, but rather is a normal O&M activity associated with operating an in-stream dam. Debris is monitored on a daily basis by the Casper Control Center. If the canal intake structure is becoming plugged, the control center can tell this by having to open the radial gates further to achieve the proper flowrate. They then let the dam operators know to clean the trashracks.	Unknown. Debris removal with the trash rake occurs year-round with about 2 persons, 2 hours per week for 10 months (outside of runoff) and 2 person, 4 hours per week for 2 months (during runoff).	There are problems with anthropogenic debris at the river outlet works intake, which is left of the radial gates. Currently, there are fish screens installed upstream of the slide gate. The fish screens clog with plastic grocery bags, chip bags, and leaves. The fish screens will be replaced with trashracks with larger gaps between the metal bars, allowing debris to pass through, so this problem may be mitigated.
Pactola Dam	It is monitored regularly by the full-time dam tender. It is observed a minimum of once a week. Generally once or twice a year debris removal efforts are mobilized but the dam tender watches and manages debris daily.	10% in-house labor costs primarily by the dam tender but also other staff depending on availability and funding.	Generally debris is collected and burned during winter months after snow cover and ice have provided an easy method of fire protection. On a high debris year, it may be trucked off.
Shadehill Reservoir	Debris is a constant concern since construction, but it is a minor one with small impact to the riprap.	5% of the budget is being used on debris management. Most of the cost is in-house direct labor.	Shadehill has a very large drainage basin, but there are very few trees and woody vegetation along it.
Horse Mesa Dam	First time	This was an isolated event that cost was not budgeted for.	There is not a debris issue in a normal year.
Mormon Flat Dam	With recent large inflows, debris concerns increased significantly. During the comprehensive reviews, it is requested to observe the quantity and location of debris using a remote operated vehicle This is often not quantifiable due to ineffective lighting and turbidity of water at depth.	< 1%	
Parker Dam	Since Quagga mussels became an issue around 2009.	Unknown	

Facility Name	Agency/Office	Facility Location	Authorized Purposes of Facility	Events in the Drainage Basin Producing Excessive Debris	Occurrence of Excessive Debris	Reservoir Conditions During Debris Events
Grand Coulee and Hungry Horse Dam	Bureau of Reclamation – Columbia-Pacific Northwest	Washington and Montana	Irrigation, flood control	Burn events; deforestation; beetle kill	Flood events	Beginning of high flows; middle of high flows; end of high flows
Yakima Field Office – Bumping Lake Dam, Clear Creek, Keechelus, Cle Elum	Bureau of Reclamation – Columbia-Pacific Northwest	Washington	Irrigation, flood control			
Buckhorn Dam	Bureau of Reclamation – California Great Basin	California	Sedimentation control	Burn events	Winter run-off	Beginning of high flows
Keswick Dam	Bureau of Reclamation – California Great Basin	California	Flood control, power generation	Burn events	Normal operations	
Klamath Basin Area Office – multiple facilities	Bureau of Reclamation – California Great Basin		Irrigation		Flood events; normal operations	
Marble Bluff Dam	Bureau of Reclamation – California Great Basin	Nevada	Fisheries	Extreme hydrologic events (floods or droughts)	Flood events; normal operations	No specific flow or storage
Northern California Area Office – multiple facilities	Bureau of Reclamation – California Great Basin		Water and power	Burn events; extreme Hydrologic events (floods or droughts)	Normal operations; spring runoff; flood events	High percentage of total storage; high wind events; beginning of high flows; middle of high flows; end of high flows
Trinity Dam	Bureau of Reclamation – California Great Basin	California	Water storage, power generation, flood control, recreation	Burn events	Normal operations	
Whiskeytown Dam	Bureau of Reclamation – California Great Basin	California	Water storage, power generation, recreation	Burn events; mudslides	Normal operations	Beginning of high flows

Facility Name	Land Type of Drainage Basin	Months with Debris Problems	Debris Type	Debris Size	Debris Clogging Location
Grand Coulee and Hungry Horse Dam	Heavily wooded; steep slopes; erodible soils; grasslands; rolling hills	April – June	Deadfall trees with fewer branches	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	Power intakes
Yakima Field Office – Bumping Lake Dam, Clear Creek, Keechelus, Cle Elum			Woody debris		Spillway; trash racks
Buckhorn Dam	Heavily wooded; erodible soils	March – June	Deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Log boom prior to spillway; spillway; da m crest
Keswick Dam	Rolling hills	March – December	Deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes
Klamath Basin Area Office – multiple facilities	Heavily wooded; steep slopes; erodible soils; grasslands	May – September	Anthropogenic material; deadfall trees with fewer branches	Medium (could potentially pass through feature)	Outlet works; spillway
Marble Bluff Dam	Heavily wooded; steep slopes; erodible soils; desert		Uprooted trees with many branches; deadfall trees with fewer branches	Medium (could potentially pass through feature)	Spillway dentates; sluice gates
Northern California Area Office – multiple facilities	Heavily wooded; steep slopes; erodible soils; grasslands; rolling hills	January – December	Anthropogenic material; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Large (spans spillway or outlet works); medium (could potentially pass through feature)	Outlet works; power intakes; spillway; dam crest
Trinity Dam	Heavily wooded; steep slopes; erodible soils	March – June	Deadfall trees with fewer branches s; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Dam crest
Whiskeytown Dam	Heavily wooded; steep slopes; erodible soils	March – June	Deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Boom/temperature curtain; dam crest

Facility Name	Submerged Debris or Surface Debris?	Does submerged debris start as surface debris and then sink, or is the debris moving along the reservoir bed?	Sediment Loading	Current Debris Management at Facility
Grand Coulee and Hungry Horse Dam	Surface	Unknown.	Not at this time due to size in reservoir.	Debris removal contractor removes it before it gets to the dam, and at the dam if necessary.
Yakima Field Office – Bumping Lake Dam, Clear Creek, Keechelus, Cle Elum	Surface		Tieton has silt issues	
Buckhorn Dam	Surface		No	Physical removal on an annual basis.
Keswick Dam	Both	Probably starts as surface debris then sinks at the intake	no	Infrequent clamshelling of the power intakes, surface debris removed from the log boom by excavator.
Klamath Basin Area Office – multiple facilities	Both			Typical debris is aquatic weeds from milfoil to Tulepods and only some woody debris. All debris is removed with machines or by hand.
Marble Bluff Dam	Surface		Yes	Physical removal with a crane.
Northern California Area Office – multiple facilities	Both	Both floating and submerged. Usually sitting on top of sediment.	Only at culverts.	When it accumulates, it is physically removed. Crane and clamshell operation for submerged debris against face of dam and maintenance crew corralling and moving floating debris onto the shore at Keswick is very effective. Debris at Shasta either becomes waterlogged and sinks or it moves by itself away from the dam and doesn't usually present a problem.
Trinity Dam	Surface		No	Physical removal on an annual basis
Whiskeytown Dam	Surface		No	Physical removal from dam crest

Facility Name	How long has debris been a concern at the facility and how is it being monitored?	Cost of Debris Management (e.g. Percent of O&M Budget, Estimated Direct and/or Indirect Costs)	Other Comments
Grand Coulee and Hungry Horse Dam	Since construction. Debris removal has been in place since the 1960s at Grand Coulee.	1/81 of total O&M budget	In terms of debris size, the size options are all relative. Grand Coulee can receive large, full size trees, but the spillway openings are about 4 times larger in length and can easily pass one of these trees if necessary.
Yakima Field Office – Bumping Lake Dam, Clear Creek, Keechelus, Cle Elum			At Tieton Dam, debris at the spillway "intake" causes the gates to be weighted down.
Buckhorn Dam	Ongoing. Monitored during ongoing visual inspections	Unknown	
Keswick Dam	Ongoing. Performance of power generating units is an indicator of debris build-up.	Unknown	
Klamath Basin Area Office – multiple facilities	Debris has been there since the facilities were installed. In the past, debris removal was done by hand. Currently, equipment does the work. In the future, automated systems will be used.	Biggest debris areas are pumping plans EE and FF where about 800 manhours is budgeted per year at each facility.	Most of our issues are aquatic weeds like milfoil and Tulepods. Tumble weeds are an issue as well. Systems are treated with Cascade to reduce the milfoil. We chain the systems to remove the milfoil and break up tulepods. In the three big reservoirs; Gerber, Clear Lake and Link Dam (upper klamath lake), not much woody vegetation is seen at the structures.
Marble Bluff Dam	Since 1975. You can see the debris on the dentates.	Direct - 10%; indirect - 2%	Marble Bluff Dam is a fish passage facility and debris on the dentates can alter the location of flow on the spillway, affecting attraction flows for fish. Logs and debris can also affect the ability to operate the sluiceway and fish exit channel.
Northern California Area Office – multiple facilities	Since the facilities were constructed. It is monitored by visual inspection or when cooling water alarms come in or efficiency drops.	5%	None
Trinity Dam	Ongoing	Unknown	
Whiskeytown Dam	Ongoing. Monitored during visual inspections.	Unknown	

Appendix C - Detailed Survey Responses for Non-Reclamation Facilities

Facility Name	Agency/Office	Facility Location	Authorized Purposes of Facility	Events in the Drainage Basin Producing Excessive Debris	Occurrence of Excessive Debris	Reservoir Conditions During Debris Events
Ninety-Nine Islands Hydro	FERC		Power generation	Extreme hydrologic events (floods or droughts)	Flood events	Middle of high flows
Anson and Abenaki Stations P2364 and P2365	FERC		Power generation		High flows with spring run off, fall leaves	Spring, building storage; low percentage of total storage
Riley, Jay, Otis and Livermore Hydro	FERC		Power generation	Leaves, trees and debris in river	Spring and fall; normal operations	Beginning of high flows; middle of high flows; end of high flows
Eagle Creek Sartell Hydro	FERC	Sartell, Minnesota	Power generation	Extreme hydrologic events (floods or droughts)	Flood events; normal operations	High wind events; beginning of high flows; middle of high flows
Worumbo Hydro Station	FERC	Lisbon Falls, Maine	Power generation	Spring run off	Flood events	Middle of high flows
Menominee and Park-Mill Dams	FERC		Power generation	High river flows	Spring run off	High wind events; middle of high flows; end of high flows
Littleq	FERC	Niagara, Wisconsin	Peaking hydro plant	Extreme hydrologic events (floods or droughts)	Flood events; normal operations	Beginning of high flows; middle of high flows
Woronoco Hydro	FERC	Russell, Massachusetts	Power generation	Extreme hydrologic events (floods or droughts)	Flood events; normal operations	High percentage of total storage; high wind events; middle of high flows; end of high flows

Facility Name	Land Type of Drainage Basin	Months with Debris Problems	Debris Type	Debris Size	Debris Clogging Location
Ninety-Nine Islands Hydro	Heavily wooded; rolling hills	January – December	Anthropogenic material; uprooted trees with many branches; deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes; spillway
Anson and Abenaki Stations P2364 and P2365	Heavily wooded; rolling hills	March – April; September – November	Anthropogenic material; uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes; spillway; dam crest
Riley, Jay, Otis and Livermore Hydros.	Heavily wooded	March – June; October – December	Uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Large (spans spillway or outlet works)	Power intakes
Eagle Creek Sartell Hydro	Heavily wooded; rolling hills	April – October	Deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Large (spans spillway or outlet works)	Power intakes; sluice gates
Worumbo Hydro Station	Heavily wooded; steep slopes	April – May; October – November	Anthropogenic material; uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes
Menominee and Park-Mill Dams	Heavily wooded; grasslands	April – November	Deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes; sluice gates
Littleq	Heavily wooded	April; July – October	Deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	Power intakes
Woronoco Hydro	Heavily wooded; steep slopes	March – May October – November	Deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes

Facility Name	Submerged Debris or Surface Debris?	Does submerged debris start as surface debris and then sink, or is the debris moving along the reservoir bed?	Sediment Loading	Current Debris Management at Facility
Ninety-Nine Islands Hydro	Both	It starts out as surface debris	Yes	Physically removed by dragrake at powerhouse intake
Anson and Abenaki Stations P2364 and P2365	Surface		No	Some passes the stations and other is physically removed. Rack rakes and other.
Riley, Jay, Otis and Livermore Hydros.	Both	Leaves, trees and anything that is in the river.	Yes, spring and fall are 24 hr a day operation to remove	Raking intake racks with hydro rack rakers
Eagle Creek Sartell Hydro	Both	Most debris is surface debris. If it has been in the water a long time, it will become waterlogged and sink just below the surface. Occasionally a deadhead log that had been buried in sediment will come in to the intakes. Submergent vegetation seasonally lets loose from the stream bed and annual leaf drop in the fall are problematic.	No	Hand rake the intake trash racks. Large debris is lifted out with a mini excavator with a custom grapple.
Worumbo Hydro Station	Both	Both, moves along bed	No	Physical
Menominee and Park-Mill Dams	Both	Submerged debris starts as surface debris and then sinks; debris also moves along the reservoir bed	At times in the Menominee intake during very high flows (15,000 cfs range and above)	By hand rakes and large machines.
Littleq	Surface	Some logs cleaned out of forebay when dewatered	No	Physical removal for trees and mechanical removal for grass, leaves and small sticks.
Woronoco Hydro	Both	Submerged debris is generally debris that has been in the river for a while. It generally sits on top of the river sediment, but not always. It may be disturbed by high water events.	Sometimes	Physical removal (trash rake)

Facility Name	How long has debris been a concern at the facility and how is it being monitored?	Cost of Debris Management (e.g. Percent of O&M Budget, Estimated Direct and/or Indirect Costs)	Other Comments
Ninety-Nine Islands Hydro	Has been an ongoing issue for years		
Anson and Abenaki Stations P2364 and P2365	Facility plans for debris each spring and fall season. Operators track and manage the amount, always looking for more efficient ways to deal with it.	Unknown	Any leaves, trees, non anthropogenic biodegradable items that come out of the river do not go back in. Biomass facilities will not or can not take it. We end up hauling it away to licensed landfill sites, it can be expensive.
Riley, Jay, Otis and Livermore Hydros.	40 years	$100,000	Intake racks are raked 24hrs a day, 7 days a week every spring and fall. Facility removeshundreds of yards weekly.
Eagle Creek Sartell Hydro	It has always been there. The quantity is pretty similar from year to year depending on how long it is between high flow events.	Approximately $20-25,000 per year in manhours and equipment lease for debris removal.	
Worumbo Hydro Station	30 years, not a major concern	Minimal, $1,000/year	
Menominee and Park-Mill Dams	Since the dam was built 1800s	Unknown	Spring run-off and the fall die-off is worst for debris. High rain events and high flows bring high debris as well.
Littleq	Every year there are weeds and leaves in the fall, but not very often are trees.	1 to 2 hours per day from August until November	
Woronoco Hydro	Debris has always been a concern at this facility.	Unknown	

Facility Name	Agency/Office	Facility Location	Authorized Purposes of Facility	Events in the Drainage Basin Producing Excessive Debris	Occurrence of Excessive Debris	Reservoir Conditions During Debris Events
Indian River Power Supply	FERC	Russell, MA	Electrical generation	Extreme hydrologic events (floods or droughts)	Flood events; normal operations	High percentage of total storage; high wind events; beginning of high flows; middle of high flows
Pepperell Hydro	FERC	Pepperell, MA	Electrical generation	Extreme hydrologic events (floods or droughts)	Flood events; normal operations	High percentage of total storage; high wind events; beginning of high flows; middle of high flows
Turner's Falls Hydro	FERC	Turner's Falls, MA	Electrical generation	Extreme hydrologic events (floods or droughts)	Flood events	High percentage of total storage; high wind events; beginning of high flows; middle of high flows
Chicopee Hydro	FERC	Chicopee, MA	Electrical generation	Extreme hydrologic events (floods or droughts)	Flood events; normal operations	High percentage of total storage; high wind events; beginning of high flows; middle of high flows
Eagle Creek Renewable Energy's Oconto Falls WI Hydro Projects	FERC	Oconto Falls, WI	Hydropower generation	Extreme hydrologic events (floods or droughts)	Flood events	Beginning of high flows; middle of high flows; end of high flows
Ball Mountain Dam and Hydro, Jamaica Vermont	FERC		Flood control and hydroelectric generation	Extreme hydrologic events (floods or droughts)	Flood events	End of high flows

Facility Name	Land Type of Drainage Basin	Months with Debris Problems	Debris Type	Debris Size	Debris Clogging Location
Indian River Power Supply	Heavily wooded; steep slopes	March – May; September – November	Deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes
Pepperell Hydro	Heavily wooded; rolling hills	March – May; September – November	Deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes
Turner's Falls Hydro	Heavily wooded; rolling hills		Vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes
Chicopee Hydro	Heavily wooded; rolling hills	March – May; September – November	Deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes
Eagle Creek Renewable Energy's Oconto Falls WI Hydro Projects	Heavily wooded; grasslands	March – May	Deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	Power intakes; spillway
Ball Mountain Dam and Hydro, Jamaica Vermont	Heavily wooded; steep slopes	March – April; October	Deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Large (spans spillway or outlet works)	Log boom upstream of dam

Facility Name	Submerged Debris or Surface Debris?	Does submerged debris start as surface debris and then sink, or is the debris moving along the reservoir bed?	Sediment Loading	Current Debris Management at Facility
Indian River Power Supply	Both	Submerged debris is generally debris that has been in the river for a while. It is usually sitting on top of the river sediment.	Sometimes	Physical removal (trash rake)
Pepperell Hydro	Both	Submerged debris is generally debris that has been in the river for a while. It is usually sitting on top of the river sediment.	Not very often	Physical removal (trash rake)
Turner's Falls Hydro	Both	Submerged debris is generally debris that has been in the river for a while. It is usually sitting on top of the river sediment.	Not generally	Physical (hand trash raking)
Chicopee Hydro	Both	Submerged debris is generally debris that has been in the river for a while, starting out as surface debris. It is usually sitting on top of the river sediment.	Sometimes	Physical (trash rake)
Eagle Creek Renewable Energy's Oconto Falls WI Hydro Projects	Surface	NA	No	Physical removal
Ball Mountain Dam and Hydro, Jamaica Vermont	Surface	NA	No	Physical (trash rake)

Facility Name	How long has debris been a concern at the facility and how is it being monitored?	Cost of Debris Management (e.g. Percent of O&M Budget, Estimated Direct and/or Indirect Costs)	Other Comments
Indian River Power Supply	Debris has always been a problem at this facility. Debris loading at the trash racks is monitored by water level transducers, before and after the trash racks.	Not available.	
Pepperell Hydro	Debris has always been a concern at this facility, though not as much as at some other hydro sites.	Not available.	
Turner's Falls Hydro	Debris loading at this site is not very problematic.	Not very much, possibly 5%	Debris at this site is not a particular problem. The power station is located on a canal. Generally, trashracks need to be cleaned only a few times a year.
Chicopee Hydro		Not available.	
Eagle Creek Renewable Energy's Oconto Falls WI Hydro Projects	Debris has always been a concern and is monitored and removed daily.	Not available.	Spring runoff or heavy rainfall cause higher debris flows. Dam safety concerns are minimal during excess debris events at the Oconto Falls Projects because of the project layout. The biggest concern during these times is the loss of power production.
Ball Mountain Dam and Hydro, Jamaica Vermont	5 years. Monitored by visual observation.	5%	Cooperative effort between US Army Corp of Engineers (flood control) and Eagle Creek Renewable Energy (hydro).

Facility Name	Agency/Office	Facility Location	Authorized Purposes of Facility	Events in the Drainage Basin Producing Excessive Debris	Occurrence of Excessive Debris	Reservoir Conditions During Debris Events
Townshend Dam and Hydro Facility	FERC		Flood control and hydroelectric generation	Extreme hydrological events (floods or droughts)	Flood events	Beginning of high flows; middle of high flows
Rapidan Hydroelectric Project	FERC	Mankato, Minnesota	Power production	Mudslide; extreme hydrological events (floods or droughts)	Flood events; normal operations	High percentage of total storage; beginning of high flows; middle of high flows
Dayton FERC P-287-IL	FERC		Hydroelectric Production	Extreme hydrological events (floods or droughts)	Flood events	Beginning of high flows; middle of high flows; end of high flows
Thunder Bay Power Projects	FERC		Hydro generation	Extreme hydrological events (floods or droughts)	Normal operations	Beginning of high flows; middle of high flows; end of high flows
York Haven	FERC		Electrical Generation	Extreme hydrological events (floods or droughts)	Flood events; normal operations	Middle of high flows; end of high flows
Southern Maine	FERC	Kezar Falls, Maine	Hydropower	Heavy rain	Flood events; normal operations	Beginning of high flows

Facility Name	Land Type of Drainage Basin	Months with Debris Problems	Debris Type	Debris Size	Debris Clogging Location
Townshend Dam and Hydro Facility	Heavily wooded; erodible soils; plains; rolling hills	March – April; October	Silt; deadfall trees with fewer branches	Large (spans spillway or outlet works)	Power intakes
Rapidan Hydroelectric Project	Heavily wooded; steep slopes; erodible soils	March – October	Uprooted trees with many branches; deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Large (spans spillway or outlet works)	Power intakes; sluice gates; dam crest
Dayton FERC P-287-IL	Erodible soils; plains	March – June	Uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Large (spans spillway or outlet works)	Power intakes; spillway; sluice gates; dam crest
Thunder Bay Power Projects	Heavily wooded; erodible soils	March – May; October – November	Anthropogenic material; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes
York Haven	Heavily wooded; rolling hills	January – May; September – November	Anthropogenic material; uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Large (spans spillway or outlet works)	Power intakes; sluice gates
Southern Maine	Rolling hills	January – June; October – December	Deadfall trees with fewer branches	Medium (could potentially pass through feature)	Power intakes

Facility Name	Submerged Debris or Surface Debris?	Does submerged debris start as surface debris and then sink, or is the debris moving along the reservoir bed?	Sediment Loading	Current Debris Management at Facility
Townshend Dam and Hydro Facility	Both	Silt deposited on submerged hydro modules during high flow conditions	Yes	Physical removal as well as air blast system on trash rack to address leaves and small debris
Rapidan Hydroelectric Project	Both	Starts as surface debris, then sinks. There is evidence of debris buried in sediment as well.	Yes	Debris is manually raked from the intake trash racks. Trees caught in the gates sometimes can be cleared from the top using pole saws. Extreme cases require an excavator to assist with removal.
Dayton FERC P-287-IL	Both	Both	Yes	Divers and excavating machinery
Thunder Bay Power Projects	Both	It mostly starts off as surface debris, then sinks to enter the trash rack area (intake)	Not normally	Physical removal
York Haven	Both	Starts on the surface and submerges as it approaches the intakes	No	Passed through the sluice gate
Southern Maine	Surface		No	Physical removal

Facility Name	How long has debris been a concern at the facility and how is it being monitored?	Cost of Debris Management (e.g. Percent of O&M Budget, Estimated Direct and/or Indirect Costs)	Other Comments
Townshend Dam and Hydro Facility	5 years. Visually monitored as well as pressure across trash screen monitored and trips turbines as clogging occurs	5%	Debris managed collectively between US Army Corp of Engineers (flood control) and Eagle Creek Renewable Energy (hydroelectric).
Rapidan Hydroelectric Project	Debris has always been a problem and is monitored daily.		
Dayton FERC P-287-IL	50+ years	10%	
Thunder Bay Power Projects	It occurs every year during high flows.	Maybe 30%	All sizes of debris are present. Also weeds tend to plug up the intakes (trashracks) normally every fall.
York Haven	Since construction.	8%	Ice is also a large concern
Southern Maine	Since 1920. Not being monitored.	Not available	

Facility Name	Agency/Office	Facility Location	Authorized Purposes of Facility	Events in the Drainage Basin Producing Excessive Debris	Occurrence of Excessive Debris	Reservoir Conditions During Debris Events
Eric Hamby Ft. Loudoun	TVA		Flood control, power generation		Flood events	High wind events; beginning of high flows
Melton Hill Hydro	TVA		Flood control, power generation		Flood events	High percentage of total storage; high wind events; beginning of high flows
Fontana Dam	TVA		Flood control, power generation		Flood events	High wind events; beginning of high flows
Chickamauga Hydro	TVA		Flood control, power generation	Extreme hydrological events (floods or droughts)	Flood events	High percentage of total storage; end of high flows
Nickajack Hydro Plant	TVA		Flood control, power generation	Extreme hydrological events (floods or droughts)	Flood events	High percentage of total storage; end of high flows
Watts Bar Hydro Plant	TVA		Navigation, flood control, hydrothermal flows, and power generation.	Extreme hydrological events (floods or droughts)	Flood events	High percentage of total storage; high wind events; beginning of high flows
Guntersville Dam	TVA		Flood control, navigation, power generation, recreation, water quality	Extreme hydrological events (floods or droughts)	Flood events, normal operations	Beginning of high flows; middle of high flows; end of high flows
Tims Ford Hydro Plant	TVA		Flood control, power generation	Extreme hydrological events (floods or droughts)	Flood events	High percentage of total storage

Facility Name	Land Type of Drainage Basin	Months with Debris Problems	Debris Type	Debris Size	Debris Clogging Location
Eric Hamby Ft. Loudoun	Heavily wooded; erodible soils; grasslands; rolling hills	February – April	Anthropogenic material; deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	Power intakes; spillway
Melton Hill Hydro	Heavily wooded; grasslands; rolling hills	January – April	Anthropogenic material; deadfall trees with fewer branches;	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	Power intakes; spillway
Fontana Dam	Heavily wooded; steep slopes; erodible soils; grasslands	January – April	Anthropogenic material; deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	Power intakes; spillway
Chickamauga Hydro	Erodible soils	February – April	Anthropogenic material; uprooted trees with many branches; deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes; spillway sluice gates
Nickajack Hydro Plant	Erodible soils; rolling hills	February – May	Anthropogenic material; uprooted trees with many branches; deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes; spillway sluice gates
Watts Bar Hydro Plant	Heavily wooded	January – February; October – December	Anthropogenic material; deadfall trees with fewer branches;	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	Screen house intakes for WBN; power intakes
Guntersville Dam	Heavily wooded; steep slopes; erodible soils; plains; grasslands	January – April; September – December	Anthropogenic material; uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Small (passes through on its own, but plugs when arriving in mats or recruits other material)	Outlet works; power intakes
Tims Ford Hydro Plant	Erodible soils; rolling hills	February – May	Anthropogenic material; uprooted trees with many branches; deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes; spillway

Facility Name	Submerged Debris or Surface Debris?	Does submerged debris start as surface debris and then sink, or is the debris moving along the reservoir bed?	Sediment Loading	Current Debris Management at Facility
Eric Hamby Ft. Loudoun	Surface		No	Spill activities
Melton Hill Hydro	Surface		No	Normal spillway operations to remove
Fontana Dam	Surface		No	Normal spillway operations. Yes
Chickamauga Hydro	Both	Usually starts off as surface debris and sinks	No	spill trash
Nickajack Hydro Plant	Both	Surface debris then sinks	No	operational techniques -spill trash
Watts Bar Hydro Plant	Both	Debris is on the surface and sinks. There are some debris that that are already submerged, but not as much.	No	Open spillway gate 1 open out of the water to flush trash while shutting down the units to pull the debris. Also dredge the main river every 10 years to get sunken debris.
Guntersville Dam	Both	Both. We have the greater issue with various types of grasses and various sizes of tree debris.		Operational techniques. On some occasions, a barge is called in and/or divers to mitigate.
Tims Ford Hydro Plant	Surface	Surface debris then sinks	No	Operational techniques

Facility Name	How long has debris been a concern at the facility and how is it being monitored?	Cost of Debris Management (e.g. Percent of O&M Budget, Estimated Direct and/or Indirect Costs)	Other Comments
Eric Hamby Ft. Loudoun	Since the dam inception. Daily observation via walkdown.	$15,000	
Melton Hill Hydro	Since dam inception. Visual rounds.	$10,000	
Fontana Dam	Since inception of dam. Visually monitored.	$5,000	
Chickamauga Hydro	M&D center monitoring.	Less than 2% No contract equipment cost. Labor cost less than $10,000 a year	
Nickajack Hydro Plant	M&D center monitoring.	No contract equipment. Labor cost less than 2%, less than $10,000 per year.	
Watts Bar Hydro Plant	Debris is not as much of a concern since located at the start of the TN River basin. It is monitored by visual inspections by both WBH and WBN personnel.	Less than 2 to 5%	
Guntersville Dam	Years	10-20%	
Tims Ford Hydro Plant	M&D monitoring center.	Less than 2% of budget, no contract equipment, labor less than $5,000 a year.	

Facility Name	Agency/Office	Facility Location	Authorized Purposes of Facility	Events in the Drainage Basin Producing Excessive Debris	Occurrence of Excessive Debris	Reservoir Conditions During Debris Events
Great Falls Hydro Plant	TVA		Flood control, recreation, and power generation.	Extreme hydrological events (floods or droughts)	Flood events; normal operations	High percentage of total storage; low percentage of total storage; high wind events; beginning of high flows; middle of high flows; end of high flows
Boone Hydro	TVA		Power operations and river management	Boone Stabilization Project, lower levels will cause debris once level is brought back up.	It will occur once lake level is brought up.	Raising level conditions
Fort Patrick Henry Hydro	TVA		Power operations and river management	Wooded debris	Over time	Beginning of high flows
Hiwassee/MURPHY NC	TVA		Tributary and reservoir management	Burn events; deforestation; mudslides, extreme hydrological events (floods or droughts)	Flood events	Manageable through significant rain and weather events.
Wilbur Hydro	TVA		Power operations and river management	Underwater grass	Normal operations	Beginning of high flows
CRH/DGH/NOH	TVA		Hydro generation	Extreme hydrological events (floods or droughts)	Flood Events	Middle of high flows
Picwick Hydro	TVA		Manage river system and generate electricity	Extreme hydrological events (floods or droughts)	Excessive rainfall; flood Events	Middle of high flows; end of high flows
Wilson Hydro	TVA		Floor control and power generation	Extreme hydrological events (floods or droughts)	Flood events	Middle of high flows

Facility Name	Land Type of Drainage Basin	Months with Debris Problems	Debris Type	Debris Size	Debris Clogging Location
Great Falls Hydro Plant	Heavily wooded; steep slopes	January – May; October – December	Anthropogenic material; uprooted trees with many branches; deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Large (spans spillway or outlet works)	Power intakes; spillway; dam crest
Boone Hydro	Heavily wooded; steep slopes; erodible soils; grasslands; rolling hills	January – February	Uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Large (spans spillway or outlet works)	Power intakes; spillway; sluice gates; dam crest
Fort Patrick Henry Hydro	Heavily wooded; steep slopes; erodible soils	January – February	Anthropogenic material; uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Power intakes; spillway
Hiwassee/MURPHY NC	Heavily wooded; steep slopes	January – March; October – December	Anthropogenic material; uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Large (spans spillway or outlet works)	Power intakes; spillway; sluice gates; dam crest
Wilbur Hydro	Heavily wooded; steep slopes; erodible soils; grasslands	January – March	Lake grass	Medium (could potentially pass through feature)	Power intakes
CRH/DGH/NOH	Heavily wooded; steep slopes; rolling hills	February – March	Anthropogenic material; deadfall trees with fewer branches; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Spillway; dam crest
Picwick Hydro	Heavily wooded; erodible soils	January – April November – December	Anthropogenic material; uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Medium (could potentially pass through feature)	Head and tailwaters around powerhouse; power intakes
Wilson Hydro	Heavily wooded; erodible soils; rolling hills	January – April; November – December	Anthropogenic material; uprooted trees with many branches; deadfall trees with fewer branches; root balls; vegetative debris, leaves, small woody material	Large (spans spillway or outlet works)	Power intakes; spillway

Facility Name	Submerged Debris or Surface Debris?	Does submerged debris start as surface debris and then sink, or is the debris moving along the reservoir bed?	Sediment Loading	Current Debris Management at Facility
Great Falls Hydro Plant	Both	There is an issue with both submerged and surface debris. Great Falls Hydro Plant is built where 4 rivers meet so the entire river shed drains through the generators or spillway when spilling. This causes all the debris from the river to travel to this site.	No	Trash at the intake is physically removed via trash racks and burned via propane burners. This is very labor intensive. Also dredging is done every 5 years.
Boone Hydro	Both	It will be both once levels are raised.	Not applicable	Physical
Fort Patrick Henry Hydro	Both	Typically just surface	Not applicable	Physical
Hiwassee/MURPHY NC	Both	Mostly surface debris	No	Operational techniques. Open the gates and flush it out.
Wilbur Hydro	Submerged			Trashrack
CRH/DGH/NOH	Surface		No	If water is high enough to utilize the spillway gates, we will spill the debris. If it is not, then we have to wait until it is high enough.
Picwick Hydro	Both	Debris moves along the reservoir bed	Yes. Facility keeps one dumpster on site which has a rental fee and has budget impacts. When big dumpsters are needed, it could take a couple of days to get to the facility.	Physical removal and operational techniques (crane with claw)
Wilson Hydro	Both	The debris is both types.	Yes	Operational techniques

Facility Name	How long has debris been a concern at the facility and how is it being monitored?	Cost of Debris Management (e.g. Percent of O&M Budget, Estimated Direct and/or Indirect Costs)	Other Comments
Great Falls Hydro Plant	Debris has been an issue since the inception of the site in 1916. This is monitored via trash rack differential alarms on the units as well as annual sonar scanning of the debris field in front of the intake structures.	40%	Debris management is a very labor intensive issue at Great Falls due to the nature of the river makeup and dam being 2 miles downstream. This makes it difficult for the dam to open a spillway gate to pull enough to make the trash move from the intakes. Because of this, trash that is pulled out is burned and ash is disposed of accordingly. This process is labor intensive and takes a large portion of the crew to perform for over 6 months out of the year.
Boone Hydro	Minimal every year. Continuous.	Typically $20,000-$25,000annually, but could be more once levels start raising.	Not much problem right now but typically have to clean once annually. This is predicted to be an issue once levels come up from the stabilization project.
Fort Patrick Henry Hydro	Ongoing/continuous	Typically $20,000-$25,000 annually.	
Hiwassee/MURPHY NC	Visually monitored and it has not been a concern.	2-3% but could be more or less depending how many significant events occur. Too many variables to budget out separately to track.	
Wilbur Hydro	Ongoing/continuous	$10,000 annually	
CRH/DGH/NOH	It is very rare that we have debris issues at any of the plants listed.	Almost $0.	
Picwick Hydro	Ever since facility has been in service. Monitored by differential gauges.	Monthly dumpster rental. Six units at the plant. One unit a month to clean debris and other maintenance. One unit twice a year.	
Wilson Hydro	Since the facility was built. It is currently monitored by trashrack differential and also visual inspection.		