# Invasive Aquatic Plant Control for Noxon Rapids and Cabinet Gorge Reservoirs, Montana: An Adaptive Management Plan

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## Preface

Using a systematic and organized effort, a dedicated task force rallied the stakeholder community to accept the challenge of protecting local waterways from the damage associated with an aggressive invasive plant, Eurasian watermilfoil (EWM). Linking sound science with site-specific management practices, EWM was reduced in Noxon Rapids Reservoir from a peak of 364 acres in 2009 to a treatable infestation of ~ 8 acres in 2014 - representing a decline of 98%. This level of removal of invasive EWM was accomplished over a 5-year period through carefully planned and prudent applications of environmentally compatible aquatic herbicides. The success of this chemical control strategy was predicated on a comprehensive applied research and development process involving many groups over several decades. By any measure, this ecological restoration achievement has been a success for managing a submersed invasive plant in a large and complex water body. As an added benefit, the valuable native plant community is thriving in the littoral zone of the reservoir, once heavily infested with EWM.

In spite of this achievement, an unexpected recovery of EWM populations in Noxon Rapids Reservoir occurred in 2015, and ultimately some 150 acres required additional treatments. Widespread growth of EWM was also reported in other water bodies in the region, indicating that natural events provided optimal growth conditions for the plant in 2015 – a factor, among others, that must be considered when developing long-term management strategies.

The vast experiences and lessons gained after seven years of management efforts (2009-2015) has led to a need for development of long term management strategies and goals for Noxon Rapids and Cabinet Gorge reservoirs. This will be accomplished by using data and information from the 7-year period of treatments and plant assessment records, and other pertinent information. The following document will help guide those future management strategies.

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**Executive Summary**

By 2008, the invasive plants Eurasian watermilfoil (EWM), curlyleaf pondweed, and flowering rush were spreading in Noxon Rapids and Cabinet Gorge reservoirs, with EWM being the most problematic species. A series of herbicide demonstrations to control EWM were conducted in Noxon Rapids Reservoir from 2009 to 2011, linking bulk water exchange processes with performance of the herbicides triclopyr, endothall, and diquat. Based on these successful demonstrations, operational programs to control EWM were implemented in Noxon Rapids Reservoir (2010, 2012-2015 and Cabinet Gorge Reservoir (2014-15). As a result, dense EWM populations were reduced by 98% in Noxon Rapids Reservoir, and 77% in several Cabinet Gorge Reservoir sites through 2014. Moreover, the reservoirs continued to support a healthy and diverse community of native plants, providing valuable fish and wildlife habitat and other ecosystem services during this time.

However, surveys conducted prior to 2015 treatments indicated an unexpected resurgence of EWM growth in Noxon Rapids Reservoir (a natural event that occurred in water bodies region-wide), and ~ 150 acres required treatment in July and August 2015. Since management resources were limited, only 20 acres were treated on Cabinet Gorge during that period. Six-week and 12-month post treatments injury rankings (September 2015, August 2016) showed control ranging from 75-98% in most of the treated plots in Noxon Rapids Reservoir and 85-88% in the Cabinet Gorge Reservoir plots.

The primary objective of this document is the development of an adaptive management plan for long term management of invasive species in Noxon Rapids and Cabinet Gorge reservoirs. Conducting problem assessments, project management, management goals, vegetation monitoring, management actions, science-based management, education outreach, and program evaluation.

Problem assessments should be conducted for all invasive plant species established in the reservoirs (e.g., EWM, curlyleaf pondweed, hybrid watermilfoil, and flowering rush). Conducting problem assessments led to a successful operational control program against EWM and is a key component in developing a maintenance control plan to keep invasive plant populations at low levels. Using this approach, a maintenance control plan can be developed to keep invasive plant populations at low levels thereby sustaining the uses and functions of the reservoirs and reducing environmental and economic impacts. Specific management goals included in the adaptive management plan will support selection of specific strategies, which is critical when controlling invasive plants with herbicides in complex and dynamic reservoirs.

The current herbicide control program has shown that EWM levels could be maintained at < 5% of the littoral zone, and at < 50% density in local sites (i.e. no dense EWM beds), while maintaining native plant populations in the reservoirs. Over time, maintenance level control

program goals will be the most cost-effective strategy, will keep EWM populations at acceptable levels, and will minimize the use of herbicides.  Reliable plant surveys that quantify infestation levels of problem plants, combined with accurate identification and prioritization of treatment areas, will be the key to ensure the success of an adaptive management-maintenance control approach.

Successful control programs link research results to management practices. Therefore, continued selection of science-based management options will greatly increase the chances of successful and cost-effective control of invasive plants in the reservoirs. It is also important to address stakeholder satisfaction with the management program via a variety of education and outreach activities such as public information meetings or workshops. These events inform the public about the extent of the problem, status of the management program, and future management actions. When using herbicides in public waters it is imperative to consult with the regulatory community to ensure that best management practices are applied, human health is protected, and threatened and endangered species are addressed.  Evaluations of control techniques and treatment results are critical for understanding the status of the program, and for adopting more effective management strategies if required. These evaluations will provide justifications for maintaining and securing annual resources to implement a management program.

The key factors of using science-based control technologies, quantifying treatment efficacy, and ensuring public transparency of management activities, have been the foundation of the program's success to date.  To build on that success, a 5-year adaptive management plan for selectively suppressing EWM to prescribed maintenance control levels in both reservoirs should be developed.  This plan and operational program should be based on a prioritized chemical control strategy, using the best science available, supplemented with non-chemical control methods where appropriate.  In addition, a preliminary plan to control hybrid watermilfoil, curlyleaf pondweed and flowering rush in the reservoirs should be developed.

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# 1 INTRODUCTION

## Background

Noxon Rapids and Cabinet Gorge reservoirs are run-of-the river impoundments along the Lower Clark Fork River System in northwestern Montana. The dams that create these water bodies are owned and operated by Avista Utilities. The primary function of these reservoirs is for hydroelectric power generation, with flood control being a secondary purpose. To achieve the prescribed level of electrical output, daily dam operations and water discharge schedules are fairly consistent, but are dependent upon daily and/or seasonal demands on the regional power grid. In addition to power generation and flood control, these reservoirs provide an important regional source of outdoor recreational activities, including boating and angling. The shallow-water littoral zones have traditionally supported diverse stands of native aquatic plants, which provide considerable fish and wildlife habitat, and other beneficial ecological services. A brief overview of key physical properties of the reservoirs and status of the aquatic plant communities is provided below.

Noxon Rapids Reservoir. Noxon Rapids Dam was completed in 1959. The reservoir it created stretches for over 35 linear miles, with its upstream boundary at the base of Thompson Falls Dam (completed in 1915; owned and operated by NorthWestern Energy). The reservoir has a surface area of 7,852 acres at full pool, averaging < 1 mile in width, with its widest fetch at 2.5 miles across, and an average depth of 65 feet. Noxon Rapids Reservoir is presently used as a storage facility and the dam is used for base load and peaking power production, drafting approximately 1-2 feet daily. Maximum drawdown allowable under the operating license is 10 feet from October 1 through May 14, and 4 feet from May 15 through September 30, though typically does not exceed 8 feet.

Cabinet Gorge Reservoir. Cabinet Gorge Dam was completed in 1952 and is located in the Idaho panhandle, just west of the Montana border. The reservoir it created stretches for over 18 linear miles into Montana, with its upstream boundary at the base of Noxon Rapids Dam. The reservoir has a surface area of 2,879 acres at full pool, averaging one-third of a mile in width, with its widest fetch ~ 0.8 miles across, with an average depth of 67 feet. Since completion of Noxon Rapids Dam immediately upstream, Cabinet Gorge Reservoir has been primarily used as a base-load re-regulating impoundment for fluctuating flows from Noxon Rapids Dam. The maximum drawdown allowable under the operating license is 7 feet all year, though water level fluctuations in the reservoir rarely exceed 5 feet.

Aquatic Plant Communities in the Reservoirs. Based on the 2008 survey results, the maximum extent of the littoral zone (and thus the maximum potential for EWM infestation) was set at a depth of 25 feet for both Noxon Rapids and Cabinet Gorge reservoirs – based on deepest extent of plants observed. Using these data, a littoral zone of 2,200 acres for Noxon Rapids Reservoir

(30% of surface area at full pool), and 1,200 acres for Cabinet Gorge Reservoir (40% of the lake surface area at full pool) were calculated, which represents the total acreage where aquatic plants are likely to occur. Of this amount, it was estimated that 83% of the littoral zone in Noxon Rapids Reservoir (1830 acres) and 90% in Cabinet Gorge Reservoir (1080 acres) could support problematic levels of EWM. These estimates were based on presence of native plants occurring up to 25-feet deep, and the fact that EWM can grow at depths near 20 feet. If management activities selectively removed all EWM in the reservoirs, native plant communities would continue to grow in the littoral zones – where they have historically occurred – providing fish and wildlife habitat. This level of native vegetation would also support healthy fisheries (Dibble 2014).

In 2008, quantitative whole lake surveys (Madsen and Cheshier 2009) showed the reservoirs to be infested at varying levels with EWM (*Myriophylum spicatum* L), curlyleaf pondweed (*Potamogeton crispus* L), and flowering rush (*Butomus umbellatus* L), all of which are problematic invasive plant species of Eurasian origin (Figures 1 through 3). Many of the beds survey contained dense stands of EWM and curlyleaf pondweed. Some 250 acres (11 % of littoral zone) of EWM, 400 acres (18% of littoral zone) of curlyleaf pondweed, and 45 acres (2% of littoral zone) of flowering rush were reported for Noxon Rapids Reservoir, while approximately 120 acres (10 % of littoral zone) of EWM, 195 acres (16% of littoral zone) of curlyleaf pondweed, and 0 acres of flowering rush were reported for Cabinet Gorge Reservoir (Table 1).

Since EWM is considered the most problematic plant in the reservoirs, this report will concentrate on management of that plant. Management issues for curlyleaf pondweed, flowering rush, and hybrid watermilfoil will be addressed in a separate section of the report.

The 2008 survey also indicated that both reservoirs supported a healthy and diverse community of native submersed plants (> 10 species), with prolific and extensive growth occurring in most areas of the littoral zone at depths of up to 25 feet. Common native plants occurring in varying abundance in the reservoirs include elodea (*Elodea canadensis* Michx.), sago pondweed (*Stukenia pectinatus* (L) Boerner), leafy pondweed (*P. foliosus* Raf.), Richardson's pondweed (*P. richardsonii* (Benn.) Rydb.), Illinois pondweed (*P. illinoensis* Morong.), flatstem pondweed (*P. zosteriformis* Fernald), slender pondweed (*P. gramineus* L), coontail (*Ceratophyllum demersum* L), northern watermilfoil (*M. sibiricum* Komarov), whitewater crowfoot (*Ranunculus aquatilis* L), and muskgrass (*Chara* spp.). These desirable plants are valuable for fish and wildlife habitat and other ecosystem services.

At a minimum, the infestation of invasive plants found at the time of the survey posed a serious threat to the diversity of the native submersed plant communities established in the littoral zones of the reservoirs. Additional potential negative impacts included degradation of fish and wildlife habitat (including that of the endangered bull trout), interference with recreational boating and swimming, increased sedimentation rates, and suppression of bulk water exchange processes that can alter water quality (e.g., diurnal and seasonal water temperatures, and dissolved oxygen and pH levels).

## Aquatic Plant Management Efforts: 2009-2015

The infestation levels of EWM reported in 2008 motivated the Sanders County Aquatic Invasive Plants Task Force (hereafter, Task Force) to develop and execute selective control measures against that plant in Noxon Rapids Reservoir. An attempt to control curlyleaf pondweed, where interspersed with EWM, was also evaluated in those treatments. Herbicides approved for use in aquatic sites by the US Environmental Protection Agency and the Montana Department of Agriculture became the focus of the management effort. These products comprised the systemic herbicide, triclopyr, and the contact herbicides, endothall and diquat.

Reliance on herbicides for the initial and subsequent management activities was based on a technical review by the Task Force of all options that might be available for effective and selective control of EWM on the reservoirs. This review process established the lack of viable biocontrol organisms available for suppression of the targeted plants in run of the river reservoirs, like Noxon Rapids and Cabinet Gorge. Likewise, mechanical harvesting techniques were not appropriate due to likelihood of spread of viable EWM fragments into un-infested areas of the reservoirs during harvesting operations. The extent of the plant infestations precluded the costly and labor intensive use of physical control methods, such as benthic barriers over large areas, within the scope of the planned operational program. To achieve a high level of control, it was determined that aquatic herbicides should be evaluated. Chemicals used and annual acres treated are shown in Tables 2 and 3. A thorough technical review of all aquatic plant control methods can be found in Gettys et al. (2014).

Selection of chemical products and application rates used on the reservoirs were based on numerous herbicide concentration and exposure time studies, and results of successful field trials against the target plants (Getsinger et al. 1996, 1997, 2000; Getsinger and Netherland 1997; Poovey et al. 2002, 2004; Skogerboe and Getsinger 2006). Prior to initiation of an operational control program, a series of treatment demonstrations, and 1-year post treatment evaluations, were conducted in Noxon Rapids Reservoir (2009 – 2011). These demonstrations linked bulk water exchange processes with performance of the herbicides triclopyr, endothall, and diquat using a variable depth application technique (Getsinger et al. 2013; Getsinger et al. 2014). These trials were followed by the execution of an operational control program in Noxon Rapids Reservoir (2010, 2012 - 2015) and in Cabinet Gorge Reservoir (2014 - 2015), using herbicides and application techniques developed in the field demonstrations. Due to high summer flows in the system, no herbicides were used in the growing season of 2011. A summary of the herbicide program results, both demonstrations and operational phases, are provided in a following section (Management Actions with Herbicides).

It should be noted that the use of small-scale benthic barrier and diver-assisted control technologies were also employed in the operational program. In addition, an educational outreach program was conducted which included several public workshops and ongoing public education. While important to the overall scope of the operational program, results from the benthic barrier and diver-dredge treatments, or from the public workshops and education outreach, will not be addressed in this report.

### Objectives

The primary objective of this document is to develop an adaptive management plan, using vegetation and chemical control data collected in the reservoir system over a 7-year period. In addition, management recommendations will focus on the use of herbicides for selectively controlling EWM in Noxon Rapids and Cabinet Gorge reservoirs to acceptably low population levels, a widely accepted and environmentally sound management technique known as maintenance control.

## 2 DEVELOPMENT OF AN ADAPTIVE MANAGEMENT PLAN

### Overview

Proactive management is the most successful and cost-effective strategy to eliminate pioneer infestations of invasive aquatic plants. The linchpin of this management practice involves early detection and rapid response efforts. An early detection and rapid response program should be employed in conjunction with prevention efforts to control new infestations at an early stage. Proactively controlling new infestations before they develop into large populations is both technically easier and less expensive, which results in major cost savings in the long run. In addition, the eradication of small populations is much more likely than eradication of large established populations. Early detection and rapid response is a critical component of an exotic species prevention program and is emphasized by federal agencies involved in invasive species management.

However, once an aggressive invasive plant, such as EWM, becomes firmly established in a water body an adaptive management plan should be developed. This comprehensive plan requires the inclusion of several key components: a) problem assessment; b) project management; c) management goals; d) vegetation monitoring; e) management actions; f) science-based management; g) education and outreach; and h) program evaluation (Madsen 2014). An effective plan will allow managers to successfully communicate the need for controlling invasive species – and provide the rationale for management. This communication is critical for building broad stakeholder support, and acquiring adequate and consistent resources to achieve management goals. While components of the plan serve specific functions, they can overlap and are necessarily linked to support the overall plan.

Most of the components required for a successful aquatic plant management plan have been adopted in some fashion by the Task Force, and are working well. Components of an adaptive management plan specific to EWM control on Noxon Rapids and Cabinet Gorge reservoirs are presented below. The general principles for each of the plan's components are presented and compared with actions by the Task Force. In addition, recommendations are provided for each component that can be used by the Task Force to refine and improve their management plan so that it is reflective of current conditions. Refinement will strengthen the plan and lead to more cost-effective control of this invasive plant. In addition, these alterations will enhance opportunities to consistently acquire adequate resources for continuation of management activities. This plan can be used as a model to address infestations of other invasive aquatic plants in the reservoirs.

## Problem Assessment

Problem assessment is the process of both acquiring objective information about the problem, such as maps and data on plant distribution, and identifying groups or stakeholders that should have input into formulating the concerns of users and the nature of the nuisance problem. Shortly after the discovery of EWM was reported in Noxon Rapids Reservoir, and prior to initiation of management actions, a series of events occurred: a) stakeholders were identified and a Task Force was formed; b) quantitative information was gathered on the extent of the infestation; c) problems associated with submersed invasive plant infestations on Noxon Rapids and Cabinet Gorge reservoirs were recognized and defined; and d) potential control techniques were reviewed, and viable options were selected.

Recommendations:

- The success of the current EWM control program is directly related to the timely and methodical problem assessment phase used by the Task Force for developing the current management plan. Therefore, problem assessments should be conducted for other problematic invasive aquatic plants established in the reservoirs (e.g., curlyleaf pondweed, flowering rush, and hybrid watermilfoil).
- The problem assessment should be reviewed and refined for the invasive plant, curlyleaf pondweed, on the reservoirs.
- A problem assessment should be initiated for the invasive plant, flowering rush, on the reservoirs.

- A problem assessment should be initiated for the hybrid milfoil (M. spicatum x M. sibiricum) recently reported in Noxon Rapids Reservoir.

## Project Management

Productive and successful programs are the result of good planning and careful management of assets, which include financial resources, record keeping, partnerships, volunteers and other personnel.  All of these elements have been successfully implemented and maintained by the Task Force.  This process has been a positive feature for the program, and has undoubtedly resulted in the program's operational success to date.

Recommendations:

- The Task Force should continue its planning and asset management process, and strive to refine and improve the process utilizing input from a diverse cross-section of local stakeholders, experts, and professionals in the field of aquatic invasive species management and treatment.
- The Task Force should continue to evaluate the success of the program (including expenditures of both time and labor) on a regular basis, as part of planning and management procedures.

## Management Goals

Specific management goals that are reasonable and measureable are a key component of any management plan. This set of goals provides the milestones that can be used to determine whether the management program is successful. If specific goals are not established, stakeholders may lack a clear understanding of program expectations and may dispute the progress and success of the management efforts. Goals should be as specific as possible and focused on areas that have a higher management priority.  Providing stakeholders with a specific set of goals will allow them to evaluate quantitative data to determine whether management goals have been met (i.e., the success of the management program can be measured, tested and compared to the specific goal).

Adaptive Management:  Selection of site-specific management techniques provides the most likely scenario for successful control of invasive plants and achieving a maintenance level of control.  However, specific management techniques will vary based on conditions within the water body and may change over time.  Therefore, management approaches must be able to adapt based on these variable conditions.  An adaptive approach allows for flexibility in management strategies, as variances in ambient conditions and target plant populations will occur on a seasonal and annual basis. This flexibility is particularly important when managing invasive plants with herbicides in dynamic water bodies, such as Noxon Rapids and Cabinet Gorge reservoirs. Site-specific management utilizes techniques that are selected for their technical merits and are suited to the needs of a particular location at a particular point in time. In addition, site-specific techniques should be selected based on management priorities, environmental and regulatory constraints, and potential efficacy to control plants under the site's particular conditions. The Task Force has utilized flexibility in its annual control program, but this situation should be codified through the adoption of an adaptive management plan for future operational activities. It must be noted that adaptive management requires on-going monitoring of aquatic nuisance species on a system-wide basis, and a regular evaluation of management techniques.

Concept of Maintenance Control: The strategy of maintenance control is widely and successfully used in many areas of the country to selectively manage invasive aquatic plants. The use of aquatic herbicides plays a central role in this management strategy. Within the greater aquatic plant management community, maintenance control is defined as a routine and recurring effort to suppress a problem aquatic plant population to an acceptable level (Netherland and Schardt 2009). As such, "acceptable level" is specifically linked to the water body or aquatic system under a management program. In other words, one size does not fit all.

The process of maintenance control indicates a conscious decision to actively control an aquatic plant problem, linked with a long-term commitment to management, rather than eradication, as a goal. For highly invasive plants (e.g., EWM, hydrilla, water hyacinth), one approach is to reduce and sustain a population at the lowest feasible level that technology, finances and circumstances will allow (Netherland and Schardt 2009). Clearly, this maintenance control approach is in stark contrast to a "crisis management" strategy, where plants are allowed to reach problem levels before control actions are undertaken. The logarithmic growth of populations is a universal principle in invasive plant biology and evidence suggests that general patterns of invasion exist in nature (Laroche and Ferriter 1992; Hobbs and Humphries 1995). One aim of maintenance control is to keep invasive plant populations below the exponential growth component of the curve, where populations are doubling in a year or less. Furthermore, implementation of a maintenance control strategy will frequently lead to a reduced requirement of resources in the long-term to keep the problem in check. For example, using less herbicides each year to maintain plants at low levels, rather than waiting for a major problem to occur (Langeland 1987; Getsinger 1993; Arim et al. 2005; Netherland and Schardt 2009; Smith et al. 2012).

Several states implement maintenance control based programs for managing EWM including Idaho, Michigan, New York, and Washington (Hart et al. 2000; Idaho Invasive Species Council and Idaho State Department of Agriculture 2007; Menninger 2011; Washington Department of Ecology 2015). Perhaps the ultimate example of a maintenance control policy is practiced by the State of Florida, where Florida Statute 369.22(3) mandates that non-indigenous aquatic plants be managed at the lowest feasible levels for the purpose of achieving more effective control at a lower long-range cost. As a consequence, that state's maintenance control program results in a plethora of benefits including the reduction of sedimentation, native plant damage, management costs, navigation problems, flood control problems, loss of fish and wildlife habitat, loss of recreation, loss of property values, and the use of herbicides. However, inadequate funding in early stages of the program was the greatest barrier to sustaining maintenance control of invasive aquatic plants (Langeland 1996). In addition, past funding lapses and the resulting inability to effectively treat infestations allowed plants to quickly colonize new areas and persist for years from accumulated seed banks (Adams and Lee 2007).

By actively managing the problem plant to some prescribed low level (i.e., maintenance control), the uses and functions of the water body are sustained and environmental and economic impacts are reduced (Adams and Lee 2007). This management level threshold is inherently determined by the nature of the aquatic plant and specific conditions related to its intersection with the water body, such as its ability to grow, reproduce and spread, the size and proportion of the littoral zone with respect to the entire water body, and the negative impacts imposed on the water body if the threshold growth level is exceeded (e.g., reduced species diversity, limited fish and wildlife habitat, poor water quality, increased sedimentation rates, interference with water storage capacity). Successful maintenance control programs have limited aquatic plant infestations to approximately 5% of potential areal coverage in many situations (Schardt 1997). It is well known that once introduced, EWM can exhibit rapid expansion in water bodies (Steenis 1967; Adams and McKraken 1974.), and its growth characteristics fit the exponential growth rate model of other aggressive invasive plants.

To reach its full and intended potential, maintenance control should be applied on a lake-wide scale, and treatment areas must be identified, prioritized, and routinely surveyed. Plant populations can shift due to natural events and/or successful control efforts. In addition, resources for control programs can vary as budget cycles tend to fluctuate on an annual basis. Therefore, management efforts must be able to adapt to achieve overall success. Regular and reliable plant surveys that quantify infestation levels of problem plants and accurate identification and prioritization of treatment areas based on those surveys, become the keystones of an adaptive management plan. The centerpiece of the adaptive management plan will involve a long-term commitment to a maintenance control strategy for each target species in each water body. By keeping problem plant populations at a low level, it is possible to schedule management efforts around fish spawning seasons, waterfowl or wildlife migrations and nesting patterns (including those of listed species), special recreational events such as fishing tournaments, reservoir operation schedules, and even weather patterns.

<u>Maintenance Control as Applied to the Reservoirs:</u> Run of the river reservoirs present a unique set of challenges for controlling submersed plants. Foremost of these challenges are water-level fluctuations linked to daily and seasonal hydropower demands. In addition, bulk water exchange

processes and complex circulation patterns created by reservoir discharges complicate herbicide concentration and exposure time requirements for effective chemical control of target plants. While recognizing the difficulty of invasive plant eradication in run of the river reservoirs, a maintenance control strategy, tailored for the reservoirs, will keep EWM populations at an acceptably low level.

This strategy addresses a number of important factors that aid in maintaining the designed functions and uses of the reservoirs: 1) prevents EWM populations from reaching exponential growth phases resulting in costly "crisis management" situations; 2) protects desirable native plant communities; 3) reduces total herbicide inputs, lowering costs and minimizing potential environmental impacts; and 4) establishes budgetary template and realistic funding levels to support an annual and long-term operational program.

Generally, an acceptable reservoir-wide threshold, or maintenance control level, for EWM infestations would comprise ~ 10% of the EWM-supporting littoral zones of a large water body. This would represent ~ 200 acres for Noxon Rapids Reservoir and ~ 100 acres for Cabinet Gorge Reservoir. The 10% threshold level allows for the suppression of EWM growth below the logarithmic growth patterns typical of aggressive invasive plants. A successful maintenance control program can only be achieved by keeping EWM in the "lag phase" of the population growth model (Figure 4). This threshold could be lowered pending control effectiveness in future years on each reservoir. A maintenance control program to limit areal extent of EWM to ~ 10% of the littoral zone has been successfully employed in Houghton Lake, Michigan, a shallow 22,000 acre water body, since 2002 (Smith et al. 2012).

On Noxon Rapids Reservoir, a more aggressive threshold range of 2-5% of the littoral zone (45-110 acres) might be possible and cost effectively achieved, as demonstrated after several years of successful herbicide applications on that reservoir. In 2014, only 7.6 acres of dense EWM and ~ 16 acres of scattered and intermediate stands were found, and herbicides applications were only necessary on 23.6 acres on Noxon Rapids Reservoir (Tables 1 and 2), which represented < 2% of the littoral zone that can support EWM. A summary of herbicide treatments for both Noxon Rapids and Cabinet Gorge reservoirs is provided in later sections of this report (Management Activities). Once achieved, a low maintenance control threshold (< 5%) should greatly reduce the recovery and spread of the plant, as well as limit annual treatment costs. These annual costs include regular vegetation monitoring, applications of herbicides, and reporting and outreach expenses. Also, small-scale non-chemical management techniques, such as diver-assisted suction dredging and utilization of benthic barriers, become more practical. On a lake-wide basis, a threshold infestation acreage of 5% has been achieved in the long-standing and highly successful maintenance control program in Florida (Joyce 1985; Schardt 1997).

Distinct changes occur in plant communities as EWM density becomes > 50% of the plant bed in a particular site (Madsen et al. 1991). These changes are primarily expressed by the decline of native plant species under dense canopies of EWM. Therefore, in addition to establishment of a reservoir-wide infestation threshold, a secondary threshold level of EWM density in local plant beds of mixed species should be considered. A > 50% density of EWM in a local site (plant bed) would trigger treatment, even if the reservoir-wide threshold level has been met. As a practical advantage for this approach, it is easier to map and prioritize potential treatments with "dense beds" of 50% cover or more, as compared to scattered plants or intermediate stands.

<u>Recommendations:</u>

- By establishing reasonable and achievable management goals, the Task Force has run a successful and credible program to date - one that has been accepted and supported by the stakeholders and the public.
- To ensure long term success of the management program, this adaptive plan establishes specific goals and management strategies, but provides the flexibility needed to manage plant populations in dynamic reservoirs with variable water fluctuation schedules and complex flow and water circulation patterns (which impact herbicide efficacy). In addition, all of these factors must be considered in the context of economic and environmental constraints.
- A well-defined maintenance control strategy – driven by level and density of EWM populations was developed as part of this adaptive management plan.
- It is an aggressive approach to keep Noxon Rapids reservoir EWM levels at < 5% of the littoral zone based on point-intercept surveys of the EWM-susceptible littoral zone regions, and at < 50% density in local sites (i.e. no dense plant beds). While Noxon Rapids Reservoir was at the < 5% EWM level entering the 2015 growing seasons (following 5 rounds of herbicide treatments over 6 years), it will take several years of management to bring Cabinet Gorge Reservoir into the same category. Occasionally, seasonal climate events that enhance EWM growth will challenge the 5% EWM goal as experienced in 2015, when temperatures and water conditions were favorable for explosive growths of EWM populations on a region-wide basis. Over time, such maintenance control programs will be the most cost-effective management strategies, will keep EWM populations at acceptable levels, and will minimize the use of herbicides.
- Once under maintenance control, the use of nonchemical techniques (which will further reduce the use of herbicides) such as benthic barriers and diver-assisted suction dredges – should be implemented where economically practical.
- To achieve management goals, treatment areas should be prioritized on an annual basis. Among other factors, prioritizations should be determined by size/density of plant infestations, location of infestations, the return on investment, environmental

considerations, stakeholder concerns, and overall fit within a maintenance control strategy.

- Management priority should be placed on sites that are:
  - Dense EWM beds (> 50% cover) versus scattered plants, to maximize the effectiveness of herbicide treatments and minimize damage to native plants.
  - Sites of high utilization (heavily human populated shorelines) and boat launches, to reduce spreading by boats and trailers.
  - Upstream areas versus downstream areas, to minimize re-infestation of EWM.
  - Prioritization based on these and other factors as determined by consensus of task force members and stakeholders.
- The selection of site-specific control techniques will enhance the adaptive management plan.
- Regular and reliable plant surveys that quantify infestation levels of problem plants, and accurate identification and prioritization of treatment areas based on those surveys, must become a key factor to ensure the success of the adaptive management plan.

## Vegetation Monitoring

Quantitative assessments (e.g., vegetative monitoring, water quality parameters such as light transparency, temperature, dissolved oxygen, and pH) should be consistently performed on a regular basis to determine the effectiveness of management activities, identify environmental impacts (both positive and negative) of those activities, and provide an economic analysis of the activities.

Quantitative data provides critical advantages for a successful adaptive management strategy (Madsen and Bloomfield 1993), including:

a) hard evidence regarding the distribution and abundance of plants, whereas subjective surveys are based on opinion rather than fact;
b) rigorous statistical evaluation of plant trends in assessment, monitoring and evaluation phases
c) basis to eliminate costly and/or ineffective techniques in a given management approach
d) evaluation by individuals other than the observer/data collector and development of independent conclusions based on assessment, monitoring and evaluation data
e) creation of site-specific maps used to prioritize and conduct treatments

Plant quantification techniques vary in their purpose, scale and intensity (Madsen and Wersal 2012). Cover techniques include both point and line-intercept methods. These techniques yield the most information regarding species diversity and distribution and can reveal small changes in plant community composition. The best method for measuring plant abundance is biomass measurements, but this is time-intensive and costly. Hydroacoustic surveys measure submersed plant canopies while the plants are still underwater and are excellent for assessing the distribution and abundance of submersed plants; however, this technique is unable to discriminate among species. Visual remote sensing techniques, whether from aircraft or satellite, have also been widely used to map topped-out submersed plants, but differentiation among species is difficult at best, unless substantial ground-truthing techniques are employed.

Recommendations:

- In order to critically evaluate treatment efficacy, and to effectively plan (and budget) for future treatment events, a repeatable and quantitative vegetation survey must be conducted on a consistent and regular schedule.
- Ideally, an annual reservoir-wide survey should be conducted on each water body in late July or early August at a regular point-intercept grid pattern with sampling intervals of 150 meters (~ 500 ft). All sites indicating presence of EWM should be re-surveyed using a finer resolution of a 50-meter (~ 165-ft) grid pattern. This fine-resolution data should be used to construct bed maps for prioritization and selection of treatments sites for the following year.
- This minimal survey protocol can be supplemented (time and cost permitting) with a pretreatment survey within several weeks of herbicide applications to verify condition of selected treatment sites. And a 6-week post treatment survey to assess initial plant injury. However, the most reliable assessment of control will be at 1-year post treatment.
- The annual reservoir-wide surveys – used to select treatment plots and to compare treatment efficacy from previous years – should be conducted by a qualified third-party person. Supplemental surveys could be conducted by the herbicide applicator, if qualified, and survey assessment verification procedures are employed.
- This survey activity is the foundation for a successful adaptive plant management program. All other activities including evaluating program progress, cost effectiveness, and direction and continuation of the program will depend upon the quality and timeliness of these surveys.
- The results of these surveys are the basis for factual measurement of success, which will build stakeholder and public support and guarantee the future of the program, and to secure the necessary resources to implement the program.

## Management Actions with Herbicides

Prior to initiation of an operational control program for EWM, littoral zone surveys were conducted on Noxon Rapids and Cabinet Gorge reservoirs to locate infestations of EWM (Figures 1 through 3). A series of demonstrations (with 1-year post treatment evaluations) were conducted in Noxon Rapids Reservoir (2009 – 2011), linking bulk water exchange processes with performance of the systemic herbicide triclopyr, and the contact herbicides endothall, and diquat (Getsinger et al. 2013; Getsinger et al. 2014). All products were applied as liquid formulations. These trials were followed by the execution of a limited operational control program in Noxon Rapids Reservoir in 2010, followed by full scale operational programs from 2012 to 2015. An operational control program was conducted in Cabinet Gorge Reservoir in 2014. In 2015, a series of water exchange studies, followed by herbicide applications, were conducted in Cabinet Gorge Reservoir, using herbicides and application techniques developed in earlier field demonstrations.

Water flows remained quite high during the optimal herbicide application window (July – August) in the reservoir system in 2011. Since these high flows persisted through the growing season, herbicide treatments were not conducted in 2011. In all likelihood, adequate aqueous herbicide exposure times could not have been maintained in treatment plots to provide adequate control of EWM.

<u>Demonstrations – Noxon Rapids Reservoir:</u> From 2009 to 2011, a series of demonstrations were conducted to test the efficacy of the aquatic herbicides triclopyr, endothall, and diquat on selected EWM beds in Noxon Rapids Reservoir (Figure 5; Getsinger et al. 2013, 2014; Wersal and Madsen 2011). Results of the demonstrations provided guidance for an operational-scale program to manage EWM in Noxon Rapids and Cabinet Gorge reservoirs. The initial demonstrations linked herbicide application methods with site-specific water exchange patterns to selectively control the target plant. Bulk water exchange patterns were measured in plant stands by using rhodamine WT (RWT), an inert tracer dye. These site-specific water exchange patterns were matched with appropriate herbicide application rates required to selectively control EWM and curlyleaf pondweed. Herbicides were applied using a variable-depth injection system. This system was designed to place herbicides directly into plant stands, providing maximum chemical contact time around the target plants.

In July 2009, two plots, 20 and 28 acres in size (Table 4) were treated using combinations of triclopyr (1.3-1.85 ppm) and endothall (1.89 – 2.5 ppm), along with the application of RWT (10 ppb) for evaluating water exchange and potential herbicide dissipation. Applications were conducted to coincide with the minimum reservoir discharge patterns. Whole plot water exchange half-lives ranged from 16 to 33 hr. Aqueous triclopyr residues ranged from 0.5 to 1.0 ppm, while aqueous endothall residues ranged from 0.4 to 1.5 ppm (19-48 hr posttreatment). Residues were highest around plants growing in the lower half of the water column. Vegetation abundance was assessed using a quantitative point-intercept method. Treatments provided > 85% control of EWM for two years and > 75% control of curlyleaf pondweed for one year. Native plant species richness and dissolved oxygen levels were unchanged in treatment plots during the study period.

In August 2010, endothall was applied to four small, narrow shoreline plots totaling ~ 14 acres at 3 ppm; diquat was applied to four similar plots totaling ~ 8 acres at 0.37ppm; and a combination of both products was applied to four similar plots totaling ~ 12 acres, with endothall at 1.5 ppm and diquat at 0.19 ppm (Table 4). Individual plots ranged from 1 – 5 acres, and averaged ~ 3 acres in size. Herbicides were applied by boat using a variable-depth injection system. Bulk water exchange processes were also measured using RWT dye. Vegetation abundance was assessed using a quantitative point-intercept method. These treatments provided significant reductions in EWM (59-69%) and curlyleaf pondweed (40-60%), through 1-year post treatment. Both of these typically broad-spectrum products provided some degree of selective control against the target plants, with a variety of native plants surviving the treatments.

Based on these successful demonstrations, an operational EWM control program was instituted by the Task Force. These initial efforts were conducted in the upstream reservoir, Noxon Rapids Reservoir (Tables 2 through 4; Figures 5 through 8). Treatments in the downstream reservoir, Cabinet Gorge, were not initiated until much of the EWM had been removed from Noxon Rapids Reservoir to minimized re-introduction of the plant from that upstream site (Tables 2 and 5).

Operational Treatments - Noxon Rapids Reservoir (2012-2015)

In 2012, 2013, 2014, and 2015 multiple plots in Noxon Rapids Reservoir were treated with herbicides tested in the initial 2009 and 2010 demonstrations (Figs 5-7; Aqua Technex 2013; Clean Lakes 2012, 2014). Subsequent surveys (point-intercept methods – as by Turnage and Madsen (2014)) and treatment records have documented a considerable decline in EWM acreage in the water body since these management efforts have been implemented (Tables 1 and 2; Aqua Technex 2013; Wersal et al. 2009, 2011; Turnage and Madsen 2014). Sites of EWM comprising approximately 95 acres found in the 2008 and 2013 surveys have not received an herbicide treatment (Figures 9 and 10). Surveys in 2014 found only 7.6 acres of dense EWM beds (Hanson Environmental 2014b). This represented a reduction of over 350 acres (~ 98%) compared to peak levels of some 360 acres (16% of littoral zone) reported in 2009.

However, when 1-year post treatment surveys were conducted in late spring of 2015, it was discovered that an unexpected resurgence in EWM growth had occurred in Noxon Rapids Reservoir, most likely due to extremely favorable growing conditions. This enhanced EWM population growth was also reported in other water bodies in the region (T. Woolf, Idaho State Department of Agriculture and P. Gilbert US Army Corps of Engineers Fort Peck Project Office, personal communications). Because of this increase in EWM levels, ~ 150 acres were treated with herbicides Noxon Rapids Reservoir in 2015 (Table 1; Figure 14).

While an initial concern expressed by some of the stakeholders was the potential impact on native species due to herbicide applications, native species abundance is still at acceptable levels following several years of treatments (Hanson Environmental 2014a, 2014b; Wersal and Madsen

2011; Turnage and Madsen 2014). The native plant seed bank seems to be re-colonizing habitat used by EWM prior to herbicide treatments.

Another concern is the apparent increased infestation of curlyleaf pondweed, flowering rush, and a recently reported hybrid watermilfoil (a cross between EWM and native northern watermilfoil) in Noxon Rapids Reservoir. Survey data indicates that curlyleaf pondweed and flowering rush abundance are increasing in Noxon Rapids Reservoir, as control efforts have not specifically targeted these species (Table 1). Typically, the spread of flowering rush is moderate and steady, and will most likely not be impacted by EWM control efforts in the reservoirs. For example, flowering rush colonization rate in Flathead Lake, MT, averaged > 45 acres per year from 1964 to 2007 (Rice et al. 2010). It is also well known that curlyleaf pondweed can exhibit large natural changes in annual abundance, due to seasonal weather events. Controlling EWM in the reservoirs may release the growth of curlyleaf pondweed in some years causing an increase in infestations of that plant. The 2013 vegetation survey was conducted during the late summer months after the natural, seasonal senescence of curlyleaf pondweed had occurred on the reservoir. This natural and seasonal decline undoubtedly masked any noticeable treatment effects on curlyleaf pondweed. As EWM continues to decline due to management actions, pre and post treatment quantitative surveys will document the recovery of native plants, as well as alert managers to any major changes in abundance levels of curlyleaf pondweed, flowering rush, and hybrid watermilfoil. A short review of these other invasive plants is presented in a later section of this report.

Operational Treatments - Cabinet Gorge Reservoir (2014-2015)

Surveys have documented an increase in EWM acreage in Cabinet Gorge Reservoir between 2008 and 2014 (Tables 1 and 2; Figures 3, and 11 through13). With the sustained reduction of EWM acreage in Noxon Rapids Reservoir, and the growing infestation of that plant in Cabinet Gorge Reservoir, herbicide control efforts were focused in Cabinet Gorge Reservoir in 2014 (Table 5; Figure 13). Herbicide treatments found to be effective on Noxon Rapids Reservoir were also employed on Cabinet Gorge Reservoir (Tables 3 and 5). However, post treatment assessments indicated that EWM control was less than experienced in Noxon Rapids Reservoir treatments in two of the plots (CAB-2, 50%; CAB-3 70%) as shown in Table 5.

It was thought that this reduced efficacy was most likely related to complex water exchange patterns in the upper reaches of the reservoir. Therefore water exchange studies using RWT dye were conducted prior to herbicide treatments in 2015 in the areas of concern (Cold Water Environmental 2015) to improve understanding of bulk water movement in herbicide-treated plots. Calculated aqueous half-lives for RWT (which simulates a liquid herbicide) within the plots ranged from 2 to 3 hours, much shorter than in Noxon Rapids Reservoir and therefore the probable reason for lower efficacy. Based on these short water retention times, the quick-acting contact herbicide diquat was recommended for treatments rather than the slower-acting endothall + triclopyr herbicide combination.

Because of the unexpected increase in EWM levels in Noxon Rapids Reservoir, and limited operational resources in 2015, targeted plots in Cabinet Gorge Reservoir were assigned a lower priority for control activities and only 20 acres (two, 10-acre plots; CAB-2 and CAB-3) were treated with diquat in late July 2015 (Table 6; Figure 15). As with Noxon Rapids Reservoir, documentation of curlyleaf pondweed, flowering rush, and or hybrid watermilfoil abundance in Cabinet Gorge Reservoir will play an important role in future management decisions.

Overall Assessment of Aquatic Herbicide Treatments

To date, all herbicide treatments in Noxon Rapids and Cabinet Gorge reservoirs have been applied as liquid formulations of either triclopyr, diquat, or endothall as indicated in Tables 3 and 6. Products were applied using a boat-mounted variable-depth injection technique. This method is designed to place the herbicide in direct contact with submersed plant stands to maximize herbicide contact time around the target plants within the treated plots. Water distribution patterns (via RWT tracer dye measurements) and measurements of aqueous herbicide residues have indicated that the variable-depth injection technique placed a major proportion of the products in the lower half of the water column, where target plant biomass was concentrated.

*Triclopyr* – Triclopyr is a selective systemic herbicide that requires a moderate concentration and exposure time (CET) relationship (48-96 hours) around submersed target plants to attain adequate levels of control (> 85%). Because of constant and fluctuating water flows and circulation patterns, the CET required for triclopyr is not easily attainable in run-of-the-river reservoirs. These CET requirements may be enhanced somewhat if the product is used in backwater areas that have low water exchange rates, or if used at times of low water discharge rates (periods of low power demand) in the reservoir. Triclopyr was used alone in Plot 7 (24.5 acres; 1.8 ppm) in 2010 in Noxon Rapids Reservoir (Tables 3 and 4). The EWM control in this plot was 70% (Table 4) – falling short of the 85% level that is commonly accepted as adequate when using herbicides for partial lake treatments of submersed species, particularly in treatment plots > 15 acres in size. Most likely, water exchange processes reduced herbicide retention time in the plot, and optimal CET requirements were not achieved.

*Endothall* – Endothall is generally a non-selective, fast acting contact herbicide that requires a low CET relationship (12-24 hours) to achieve acceptable control (> 85%). This low CET requirement makes endothall a good candidate for some situations in run of the river reservoirs.

Endothall was used alone at 3 ppm to control EWM in 2010 and 2012 – 2014 in small plots (generally 2 to 4 acres in size) in Noxon Rapids Reservoir. In 2010, control was 52% short-term (~ 6 weeks after treatment) and 69% long-term (52 weeks after treatment), as shown in Tables 3 and 4. In 2012, control was only 17% in one plot, but 83% and 87% in the other two plots (Table 4). Data in 2013 showed 0% short term control of EWM in the one plot where endothall was applied alone. However, data collected in 2014 showed that short term control ranged from 55 to 95% across five plots (Table 4). In 2015, an endothall-treated plot provided a 6-week post treatment injury rating of 75%, and by 12-months post treatment a reduction of 93% was reported (Table 6). For the most part, the level of control provided by endothall in these small plots within a run of the river reservoir would be considered as acceptable. Low levels of control were most likely due to elevated water-exchange processes which reduced required CET relationships and can be problematic in small plots in large reservoirs.

*Triclopyr + Endothall* – Mixtures of triclopyr and endothall were used in every year of the management program in Noxon Rapids Reservoir. This combination was designed to take advantage of the short CET requirement of endothall, with the systemic action of triclopyr for more complete control of EWM in the relatively rapid water-exchange situations. Based on treatments of plots 1 and 3 (20-28 acres in size) in 2009, short-term control of EWM was 88% and 80%, while long-term control was 80% and 94%, respectively (Tables 3 and 4). From 2010 – 2014, this mixture was used at a rate of 1 ppm triclopyr + 2 ppm endothall in plots that mainly ranged from 10 – 30 acres in size (Tables 3 and 4). The level of EWM control varied, but was generally higher in plots > 15 acres. Short-term control in 2010 was calculated as 86%, and ranged from 29% to 66% in 2012(Table 4). Short-term control of EWM seen in 2013 ranged from 75% to 100%, and in 2014 ranged from 50 to 85% (Table 4). In 2015, 6-week post treatment injury ratings for EWM ranged from to 80 to 90 % in six of the treated plots, and from 55 to 75 % in four of the plots (Table 6). With the exception of one plot (55% injury), all of the plots provided acceptable control at the 6-week after treatment period. A 1-year after treatment assessment in August 2016 indicated similar or decreasing levels of control ranging from 57 to 95% (Table 6).

To date, this combination of products has been the most widely used treatment in Noxon Rapids Reservoir, consistently providing good EWM control (> 85% in many cases). Best control has been obtained in larger treatment plots, where water-exchange processes that determine CET requirements would not be as great as in smaller plots.

This combination was the only treatment used in Cabinet Gorge Reservoir in 2014 in plots that ranged from 9 to 75 acres in size (Table 5). Data from Cabinet Gorge Reservoir sites showed short-term control ranging from 50% to 95% (Table 5). Efficacy of the triclopyr+endothall combination was boosted by using this treatment against EWM, compared to using triclopyr and endothall alone.

*Diquat* – Diquat is a fast acting, broad spectrum contact herbicide that requires a low CET relationship (6-12 hours) to achieve acceptable control (> 85%). Due to the fast acting nature of diquat it is useful in run of the river systems with elevated water-exchange processes, and where short CET relationships are required to achieve control. Diquat cannot be used effectively in turbid water, as it readily binds to suspended sediment and other particles in the water column - thereby making the herbicide unavailable for plant uptake. Even though it is non-selective, native plants impacted at a treatment site will usually recover due to a viable propagule bank in the sediment available for re-sprouting. Diquat is not translocated through the plant, thus perennial species have an additional avenue (rootcrown tissue) to survive and recover from treatments.

Diquat was used on Noxon Rapids reservoirs in small-plot settings (< 3 acres in size) in 2010, and in plots of approximately 1 to 7 acres in 2012 and 2013, at the maximum label rate of 0.37 ppm (Tables 3 and 4). Because of its low CET requirement against target plants, diquat was selected for these small, high water-exchange plots. In 2010, diquat provided 57% short-term control, and 66% long-term control of EWM, while in 2012 it provided control ranging from 25% to 75%. Based on data from 2013, short-term EWM control ranged between 85% and 100%, although two plots showed no control (Table 4). For the most part, the level of control provided by diquat in these small plots within a run of the river reservoir would be considered as acceptable.

In 2015, two 10-acre plots were treated with diquat at 0.37 ppm in Cabinet Gorge Reservoir (Table 6). Since water-exchange studies had shown potentially short aqueous herbicide retention time in the upper reaches of the reservoir, diquat was selected to mitigate these short herbicide CET requirements. Results at 6 weeks post treatment showed injury ratings of 85 to 88%. Unfortunately, a 1-YAT assessment of these treated plots could not be determined due to timing of herbicide treatments and pretreatment assessments.

*Diquat + Endothall* – Diquat and endothall were only used in combination in the 2010 demonstrations at rates of 0.19 ppm diquat + 1.5 ppm endothall, in plots < 3 acres in size (Table 3). Short-term EWM control was 64%, while long-term control was 59% (Table 4). While these control levels are acceptable for small-plot treatments impacted by water-exchange processes, they did not show appreciably enhanced control compared to using diquat or endothall alone in similar situations.

Recommendations:

- Herbicide selection should be tailored to water-exchange processes in treatment sites.
- Historical patterns of reservoir discharge events, storage level capacities, and regional temperature, rainfall, and snow pack conditions should be compiled and reviewed. This information should be analyzed to determine if short- and/or long-term cyclical patterns can be used to aid in treatment planning and improved implementation of operational programs in future years.
- For the near-term, continue to use the herbicides endothall, triclopyr, and diquat, alone or in combinations, at rates and in sites, known to be effective from past treatments.
- Herbicide treatments of triclopyr + endothall have been used more often than any other treatment and have consistently shown good, and species-selective, levels of EWM control (75%-100%) across most treated plots during the management program (2009-2014). As such, this herbicide treatment should be considered as a primary option for

future EWM management efforts in these reservoirs, except where high water exchange dictates contact herbicides with lower CET requirements (such as in the upper end of Cabinet Gorge Reservoir).

- Diquat and endothall have both been utilized alone and as a mixture for treating in narrow strips along the shorelines, or in small plots with high water exchange conditions. While these herbicides show a moderate level of EWM control, new treatment protocols should be explored for managing the narrow strip plots.
- Triclopyr has been utilized alone as an herbicide treatment once during this study and showed 70% EWM control. Sites on run-of-the-river systems conducive to the use of triclopyr, alone, are limited. This treatment would best be used in back water areas where water exchange process are reduced, or in situations where reservoir discharge operations can limit water exchange processes for the required CET timeframe in selected treatment areas.
- Conduct herbicide applications during low-flow periods in the reservoirs to improve required aqueous herbicide CET relationships against target plants. This strategy should be coordinated in advance with appropriate Avista personnel.
- If herbicide contact time issues are of a concern, water-exchange evaluations (using tracer dye) should be conducted in sites prior to herbicide treatments.
- Consider any new developments in herbicide delivery technologies, formulations, or active ingredients that may improve control of EWM, compared to current levels of control on the reservoirs.
- Consider incorporation of non-chemical methods to "mop-up" small patches or beds of target plants where water-exchange processes could limit herbicide treatment success, or shallow areas with limited accessibility.
- Adequate and stable funding should be secured on an annual basis to implement a successful adaptive management program. As EWM levels decline, reduced funding amounts will be required for maintenance control.
- Prioritize treatment areas, within budgetary and environmental constraints, based on the following concepts:
    - Treatments should start at the upstream end of the reservoir system and move progressively downstream, to reduce potential for spread of plants. While some transport can occur upstream, the downstream transport predominates.
    - All locations with a public boat launch are high priorities to reduce spread both within and between water bodies.
    - All locations that are public use areas, including shore-owner docks, are high priorities.
    - Treatment of dense stands of EWM is a higher priority than treating scattered patches of the plant.
    - Areas that protect water intakes or improve fish and wildlife habitat should be high priorities.

- As EWM continues to decline, site-specific management strategies must be developed to control curlyleaf pondweed, flowering rush, and hybrid milfoil. These efforts will be most successful if linked to the growth cycles of these plants in the reservoirs.

**<u>Management of Other Invasive Plants</u>**

In addition to EWM, there are three other invasive plant species that have become established in the Noxon Rapids/Cabinet Gorge reservoir system: curlyleaf pondweed, flowering rush, and hybrid watermilfoil. All of these invasive species can dominate the littoral zones of the reservoirs and cause a variety of ecological impacts, as well as impacts on human use. Species-specific strategies – differing from EWM control strategies - will be required to successfully manage these plants.

<u>Curlyleaf Pondweed:</u> The annual plant, curlyleaf pondweed, echibits a submersed growth habit that currently infests moderate areas of the littoral zones in the Noxon Rapids/Cabinet Gorge system. In the initial 2008 survey, some 400 acres (18% of littoral zone) of curlyleaf pondweed were reported in Noxon Rapids Reservoir and 195 acres (16% of littoral zone) were reported in Cabinet Gorge Reservoir. Because of its unique life-cycle events, site-specific studies are required to develop successful management techniques for curlyleaf pondweed. Life cycle events of the plant have been well documented in some northern tier states, and understanding the timing and duration of these events has improved control in those locations. In a similar fashion, the phenology of curlyleaf pondweed in the Noxon Rapids/Cabinet Gorge system needs to be determined. Identifying weak points in the plant's life cycle in the reservoir system, and linking that information with treatment strategies, will provide the most effective management approach.

<u>Flowering Rush:</u> The perennial plant, flowering rush, expresses both submersed and emergent life cycle stages. In the initial 2008 survey 45 acres (2% oflittoral zone) of flowering rush were reported in Noxon Rapids Reservoir, but the plant was not reported in Cabinet Gorge Reservoir. However, frequent reports of flowering rush are common over the past few years, and the plant is spreading in several locations regionally. Flowering rush has the potential to out-compete other invasive plants, and has become a major problem in areas upstream of the Noxon Rapids/Cabinet Gorge reservoir system including Thompson Falls Reservoir, the Clark Fork River, and Flathead Lake. Control of flowering rush will also require different and unique management approaches than those being used for other invasive plants in the reservoir system.

<u>Hybrid Watermilfoils:</u> Over the past decade, hybrid watermilfoil genotypes, which are crosses between the invasive EWM (M. spicatum) and the native northern watermilfoil (M. sibiricum), have been reported in northern tier states (Moody and Les 2002, 2006). At present, it is unclear if these wild crosses have been augmented by aggressive EWM removal techniques (primarily using herbicides) in various water bodies, have occurred at a natural pace, or both. From a

management standpoint, initial study results suggest that some hybrid watermilfoils may not respond as well to the standard herbicide treatments that have worked against EWM (Glomski and Netherland 2010; LaRue et al. 2013; Berger et al. 2105; Netherland and Willey 2016). If additional empirical evidence indicates levels of hybrid watermilfoil tolerance to herbicide applications, this situation will impact invasive plant control programs, including those implemented on Noxon Rapids and Cabinet Gorge reservoirs.

In July 2015, hybrid watermilfoils were suspected from plant samples collected in eight sites in Noxon Rapids Reservoir. Hybridity was genetically confirmed in plants from six of the eight collection sites (Laboratory of Dr. Ryan Thum, Montana State University). Two of these sites were not previously treated with herbicides, but the others had been treated (C. Duncan, Weed Management Services, personal communication). These findings indicate that hybrid watermilfoils are present in the Noxon Rapids/Cabinet Gorge system, and if left untreated these populations are likely to expand in areal extent and cause ecological damage comparable to unchecked EWM populations.

Recommendations:

- A rigorous assessment of growth, vegetative spread, and treatment efficacy of hybrid watermilfoils in the Noxon Rapids/Cabinet Gorge reservoir system should be undertaken and compliment the annual EWM population assessment efforts.
- Based upon that quantitative assessment, a hybrid watermilfoil management strategy should be developed and implemented for the reservoir system as soon as possible.
- Based upon quantitative vegetative assessments, management strategies should also be developed for curlyleaf pondweed and flowering rush for the reservoir system.

## Science-based Management

The most successful operational programs link results of scientific research to management practices. While many examples of these science-based management programs exist, several prominent ones include those conducted by the California Division of Boating and Waterways, the Florida Fish and Wildlife Conservation Commission, the Idaho State Department of Agriculture, the Tennessee Valley Authority, and the US Army Corps of Engineers. The longstanding success of these programs has been the strong and consistent linkage between third-party research efforts and development of technology and best management practices designed to solve aquatic plant problems in public waters.

Over the past 25 years, hundreds of millions of dollars have been spent on applied research projects to develop the environmentally compatible techniques routinely used for aquatic plant management. Much of the work has centered on developing species-selective herbicides, lowering pesticide usage, and understanding and mitigating any negative impacts associated with chemical control. Most of the studies have been conducted by third-party research groups, rather than by the chemical industry or product registrants. These independent groups comprise academic and technical institutions with applied science programs, and government research organizations. In addition, the research groups maintain regular interactions with the regulatory community (e.g., USEPA, USFWS, USACE and appropriate state agencies) to provide updates of the current scientific findings. The regulatory community uses the "best available science" to make decisions on the environmentally compatible use of herbicides in water.

To date, the Task Force has been mindful to seek-out and use the best available science to implement the management program on Noxon Rapids/Cabinet Gorge reservoirs. The overall success of the program is directly linked to that process.

Recommendations:

- Vigilance should be maintained to select science-based management options for the reservoirs. This path will greatly increase the chances of successful and cost-effective control of targeted invasive plants.
- The best available science can be obtained by: a) regular review of the current peer-reviewed and technical literature; b) consulting with subject matter experts (SMEs) from academia, government and industry; c) contacting other state programs with similar problems; and d) fund evaluations specific to ambient conditions on the reservoirs by qualified groups (local, regional, or national).
- Since herbicides will continue to play a major role in maintenance control management efforts, the Task Force should seek current information on new chemical products and application techniques that could improve control of EWM in the reservoirs.
- Encourage establishment and funding of applied research groups affiliated with local and/or regional academic institutions. These local groups will be able to perform on a cost-effective basis, and will become key centers of education and training for future SMEs that can work in the local area.
- Involve local and/or regional academic institutions in development of selective control techniques for curlyleaf pondweed and flowering rush in the reservoirs.

## Education and Outreach

It is important to address stakeholder and public satisfaction with the management program via a variety of education/outreach activities. In a prudent fashion, education/outreach activities were initiated by the Task Force in the early stages of program development. Beginning in 2008, public meetings and aquatic plant management workshops (2008 and 2010) were held to familiarize stakeholders and the general public on the problem and possible solutions. Presentations were provided by SMEs concerning plant identification, ecology and biology of invasive aquatic plants, fish and wildlife issues, and reviews of management options and impacts as related to EWM and curlyleaf pondweed. This process advanced a consensus regarding potential solutions to the invasive plant problem on the reservoirs.

Since 2012, an Education Coordinator has acted as liaison between the recreating public and the Task Force. Specifically, the Education Coordinator interacts with the public and conducts a survey to gauge public awareness of aquatic invasive species (AIS) and knowledge of activities to reduce its spread. The Coordinator also provides basic information about EWM and resources for gaining additional information related to AIS. By contacting the public directly through the Education Coordinator, the issue of EWM management in the Lower Clark Fork river system remains current and at the forefront of recreationists utilizing the resource. In addition, the Task Force keeps current on public perceptions related to EWM management, and other AIS issues.

<u>Recommendations:</u>

- A public information meeting should be organized and conducted by the Task Force to coincide with the roll-out of the new adaptive management plan.
- Public meetings or workshops should be held every 2-3 years, which include presentations by SMEs on the problems caused by invasive plants, the current state of control, technologies and associated impacts. These events will familiarize and inform the stakeholders, environmental groups and the public about the extent of the problem, status of the program (benefits, successes, failures, budgetary issues), and what future actions will be required to continue the program. It is important to provide as much information as possible to the public, and to be forthright and open about management activities.
- A public web page devoted to the management program would be a useful tool to disseminate information, but the Task Force should also maintain relationships with local print and broadcast media outlets. Also, the success of the program should continue to be shared with likeminded associations, at regional weed control meetings and county cooperative extension service venues, and with elected officials and decision makers.
- The Task Force must continue to interact with the Federal, state and local regulatory community as well as Native American tribes. When using herbicides in public waters it is imperative to consult with these groups on a regular basis to ensure that the most current best management practices will be applied, that potential listed species concerns are being addressed, and that there have been no revisions to herbicide labels and/or permitting requirements.

**Program Evaluation**

Regular evaluations of control techniques and treatment results are critical for understanding the successes and failures of the program, and for modifying or adopting more effective management strategies if required. These evaluations can also provide necessary justifications for maintaining and securing annual resources required to plan and implement the management program. A quantitative assessment should be made to: a) determine the effectiveness of management activities; b) identify environmental impacts (both positive and negative); c) calculate economic costs; assist with planning and scheduling future management activities; and d) address stakeholder satisfaction. Although the Task Force has conducted annual program evaluations, a few inconsistencies in this phase seem to have complicated and impacted the timeliness of the management planning process.

Recommendations:

- The Task Force should refine the program evaluation phase to create a more methodical and timely planning process for management actions in future years. This might be accomplished by developing a check-list of tasks, identifying responsible individuals for each task, and linking the tasks to a "hard" calendar schedule.
- A refined and improved evaluation phase will aid in securing resources required to operate the program, and ensure that annual management activities are planned and executed in a timely manner.

## 3 GENERAL CONCLUSIONS AND RECOMMENDATIONS

**Conclusions**

- The 7-year herbicide management program presented in this document has been successful in reducing the abundance of EWM in Noxon Rapids Reservoir, keeping nuisance levels of EWM at < 8% of the littoral zones in the last two years.
- During that period, the native plant community remained healthy and abundant, providing adequate fish and wildlife habitat and other beneficial ecological services.
- The key factors of using science-based control technologies, quantifying treatment efficacy, and ensuring public transparency of management activities, have been the foundation of the program's success.
- The hydraulic complexity of this dynamic reservoir system, primarily flow regimes and impacts of water exchange processes, can impact decisions for herbicide applications, including products selected, application rates, and timing of treatments. These flow regimes can vary on a diurnal and seasonal basis.

- Extended climatic events (particularly low flows and warm temperatures) can impact the efficacy and/or recovery of EWM following treatments. The amplitude of such events is somewhat unpredictable and will require timely flexibility in annual operational management efforts.
- As EWM populations decline, other invasive plants already in the system, could spread and require development and implementation of additional plant-specific management strategies. Such strategies will likely differ from those currently used to control EWM.
- A maintenance-level infestation goal of <5% (<110 acres) of the EWM-susceptible littoral zone, and <50% density in EWM stands, is anticipated to reduce annual treatment requirements and maintain a low rate of spread of EWM. This is a flexible goal that may not be achievable every year due to environmental and other conditions, but serves as a realistic target for the management program.

## Recommendations

- An aggressive, prioritized, and flexible chemical control strategy for selectively controlling EWM should be continued in the reservoirs. This strategy should include management of hybrid watermilfoils if warranted.
- This 5-year adaptive management plan, based on recent experiences and the best science available, should be implemented for suppressing EWM to maintenance control levels in both reservoirs. The plan should be reviewed, and revised if needed, on a regular basis.
- Development of a summary spreadsheet that updates historical monitoring and treatment information should be undertaken. Such an exercise would clearly document both short term and long term accomplishments of the operational program, and could be used for funding and resource justification over time.
- Annual herbicide treatment strategies should initially be developed in the fall, prior to summer treatments, and refined based on EWM growth as the summer application period approaches. Forecasts and real-time information of reservoir discharge patterns and flow regimes will be critical for flexibility in treatment implementation to maximize control of EWM.
- Proven, non-chemical strategies should be implemented to control EWM in appropriate sites. Such sites would include areas where water-exchange processes would limit herbicide contact time and efficacy, and where native vegetation predominates.
- A preliminary plan to control curlyleaf pondweed, flowering rush, and hybrid watermilfoils in the reservoirs should be developed.
- A vigorous education and outreach program targeted to all stakeholders, decision makers and the general public should be maintained.

- To maintain science-based management programs, applied research groups affiliated with local and/or regional academic institutions should be established and adequately supported.

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## Tables and Figures

**Table 1.** Aquatic invasive plant acreage in Noxon Rapids and Cabinet Gorge reservoirs, MT, 2008-2015. Data based on quantitative littoral zone surveys and mapping. A blank cell indicates no survey was conducted that year.

| Water body | Species | 2008 acres | 2009 acres | 2010 acres | 2011 acres | 2012 acres | 2013 [A] acres | 2014 acres | 2015 acres |
|---|---|---|---|---|---|---|---|---|---|
| Noxon | Eurasian watermilfoil | 223 | 364 | 117 | | | 96.6 | 7.6 | |
| | Curlyleaf pondweed | 401 | 246.4* | 368.5* | | | 15.4* | | |
| | Flowering rush | 46 | 30.8* | 6.6* | | | 300* | | |
| | Hybrid watermilfoils | | | | | | | | + |
| Cabinet | Eurasian watermilfoil | 78.1 | | 327.9 | | | 205.2 | 205 | |
| | Curlyleaf pondweed | 195 | | 197.3* | | | 239* | | |
| | Flowering rush | | | 4.4* | | | 22.9* | + | + |

[A] In 2013 survey was conducted after curlyleaf pondweed had senesced which is indicated by low acreages.

* Indicates acreage estimate from littoral survey rather than mapping.

+ Indicates species was present based on observations in a reservoir even though no surveys were conducted that year

**Table 2.** Eurasian watermilfoil acres treated in Noxon Rapids and Cabinet Gorge reservoirs, MT, 2008 - 2015. To our knowledge, surveys only depict dense Eurasian watermilfoil acreages. 'NA' indicates that no survey was done that year.

| Waterbody | 2008 acres | 2009 acres | 2010 acres | 2011 acres | 2012 acres | 2013 acres | 2014 acres | 2015 acres |
|---|---|---|---|---|---|---|---|---|
| Noxon Treated Acres | 0 | 88.5 | 74.0 | 0 | 172.4 | 106.2 | 23.6 | 148.8 |
| Noxon Surveyed Acres | 223 | 364 | 117 | NA | NA | 96.6 | 7.6 | 148.8 |
| Cabinet Treated Acres | 0 | 0 | 0 | 0 | 0 | 0 | 183.3 | 20 |
| Cabinet Surveyed Acres | 78.1 | NA | 327.9 | NA | NA | 205.2 | 205 | 183.1 |

**Table 3.** Herbicide treatments and rates used on aquatic invasive plants in Noxon Rapids Reservoir, 2009-2015. No treatments were made in 2011. Rates in treatments utilizing two herbicides follow the order of the herbicide names in the treatment column (e.g. 2010 diquat + endothall treatment is 0.19 ppm diquat + 1.5 ppm endothall). 'NA' indicates that no herbicide treatments were conducted that year.

| Treatments | 2009 | 2010 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|
| Triclopyr | NA | 1.8 ppm | NA | NA | NA | NA |
| Endothall | NA | 3 ppm | 3 ppm | 3 ppm | 3 ppm | 3ppm |
| Diquat | NA | 0.37 ppm | 0.37 ppm | 0.37 ppm | NA | NA |
| Triclopyr + Endothall | 1.85 ppm + 2.5 ppm<br>1.3 ppm + 1.89 ppm | 1 ppm + 2 ppm | 1 ppm + 2 ppm | 1 ppm + 2 ppm | 1 ppm + 2 ppm | 1 ppm + 2 ppm |
| Diquat + Endothall | NA | 0.19 ppm + 1.5 ppm | NA | NA | NA | NA |

**Table 4.** Plot designations and herbicide treatments in Noxon Rapids Reservoir, MT, 2009-2014. No treatments were made in 2011. Colors indicate herbicide treatment and rate from Table 3. Numbers in parentheses are percent change in Eurasian watermilfoil (EWM) following herbicide treatment. If two numbers are given, first number is designated as short-term control (5 – 7 Weeks After Treatment – WAT), and second number as long-term control (52 WAT). A negative symbol (-) indicates a decline in EWM, a positive symbol (+) indicates an increase in EWM. Eastern part of Plot 7 treated as part of plot T-13-32 in 2013. Acreage reported is from time of initial survey or treatment, whichever was later. Multiple acreages are different treatment years listed in chronological order.

| 2015 Name | 2009 Name | 2010 Name | 2012 Name | 2013 Name | 2014 Name | Acreage | |
|---|---|---|---|---|---|---|---|
| NOX-1 | **Plot 1 (-88, -80)** | Plot 1 | Plot 1 | Plot 1 | Plot 1 | 20.00 | |
| NOX-2 | Plot 2 | Plot 2 | **Plot 2 (-58)** | Plot 2 | Plot 2 | 24.00 | |
| NOX-3 | **Plot 3 (-80, -94)** | Plot 3 | Plot 3 | Plot 3 | Plot 3 | 29.50 | |
| NOX-4 | Plot 4 | Plot 4 | **Plot 4 (-66)** | Plot 4 | Plot 4 | 28.10 | |
| NOX-5 | Plot 5 | Plot 5 | **Plot 5 (-32)** | Plot 5 | Plot 5 | 15.70 | |
| NOX-6 | Plot 6 | Plot 6 | **Plot 6 (-47)** | Plot 6 | Plot 6 | 14.30 | |
| NOX-7 | Plot 7 | **Plot 7 (-70)** | Plot 7 | Plot 7 | Plot 7 | 24.44 | |
| NOX-8 | Plot 8 | **Plot 8 (-86)** | **Plot 8 (-29)** | Plot 8 | **N-12-14 (-85)** | 15.88, 11.40, 9.40 | |
| NOX-9 | Plot 9 | Plot 9 | **Plot 9 (-42)** | Plot 9 | Plot 9 | 22.10 | |
| NOX-10 | Plot 10 | Plot 10 | **Plot 10 (-33)** | Plot 10 | Plot 10 | 15.30 | |
| NOX-11 | Plot 11 | Plot 11 | **Plot 11 (-65)** | Plot 11 | Plot 11 | 19.30 | |
| NOX-12 | Plot 12 | Plot 12 | **Plot 12 (-33)** | Plot 12 | Plot 12 | 2.90 | |
| NOX-13 | | Strip 1 | **Strip 1 (-25)** | Strip 1 | Strip 1 | 2.40 | |
| NOX-14 | | **Strip 2 (-64, -59)** | Strip 2 | Strip 2 | Strip 2 | 2.10 | |
| NOX-15 | | Strip 3 | **Strip 3 (-100)** | Strip 3 | Strip 3 | 1.99 | |
| NOX-16 | | **Strip 4 (-64, -59)** | Strip 4 | Strip 4 | **N-10-14 (-90)** | 3.45, 0.60 | |
| NOX-17 | | Strip 5 | **Strip 5 (-75)** | Strip 5 | Strip 5 | 2.43 | |
| NOX-18 | | **Strip 6 (-52, -69)** | Strip 6 | Strip 6 | **N-9-14 (-65)** | 1.85, 2.50 | |
| NOX-19 | | **Strip 7 (-64, -59)** | Strip 7 | Strip 7 | Strip 7 | 3.16 | |
| NOX-20 | | **Strip 8 (-64, -59)** | Strip 8 | Strip 8 | **N-8-14 (-50)** | 2.98, 0.50 | |
| NOX-21 | | **Strip 9 (-52, -69)** | Strip 9 | Strip 9 | Strip 9 | 4.80 | |
| NOX-22 | | Strip 10 | **Strip 10 (-25)** | Strip 10 | Strip 10 | 2.41 | |
| NOX-23 | | **Strip 11 (-52, -69)** | Strip 11 | Strip 11 | Strip 11 | 2.40 | |
| NOX-24 | | Strip 12 | **Strip 12 (-87)** | Strip 12 | Strip 12 | 3.64 | |
| NOX-25 | | Strip 13 | **Strip 13 (-50)** | Strip 13 | Strip 13 | 2.29 | |
| NOX-26 | | Strip 14 | **Strip 14 (-17)** | Strip 14 | Strip 14 | 2.72 | |
| NOX-27 | | Strip 15 | Strip 15 | Strip 15 | Strip 15 | 3.32 | |
| NOX-28 | | Strip 16 | **Strip 16 (-83)** | Strip 16 | Strip 16 | 3.47 | |
| NOX-29 | | Strip 17 | **Strip 17 (-75)** | **T-13-32 (-90)** | T-13-32 | 1.69 | 18.60 |
| NOX-30 | | Strip 18 | Strip 18 | | | 2.19 | |
| NOX-31 | | **Strip 19 (-52, -69)** | Strip 19 | **T-13-25 (-75)** | **N-6-14 (-70)** | 4.68, 5.10, 2.30 | |
| NOX-32 | | **Strip 20 (-57, -66)** | Strip 20 | **T-13-26 (-100)** | T-13-26 | 2.36, 6.70 | |
| NOX-33 | | **Strip 21 (-57, -66)** | Strip 21 | **T-13-27 (-100)** | T-13-27 | 3.06, 5.10 | |
| NOX-34 | | **Strip 22 (-57, -66)** | Strip 22 | Strip 22 | Strip 22 | 1.61 | |
| NOX-35 | | Strip 23 | Strip 23 | Strip 23 | Strip 23 | 0.24 | |
| NOX-36 | | **Strip 24 (-57, -66)** | Strip 24 | Strip 24 | Strip 24 | 1.23 | |
| NOX-37 | | | | **T-13-0903 (-85)** | T-13-0903 | 9.40 | |
| NOX-38 | | | | **T-13-10 (0)** | T-13-10 | 1.20 | |
| NOX-39 | | | | **T-13-11 (0)** | T-13-11 | 1.40 | |
| NOX-40 | | | | **T-13-14 (0)** | T-13-14 | 1.90 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| NOX-41 | | | | **T-13-17 (-95)** | T-13-17 | 4.10 |
| NOX-42 | | | | **T-13-21 (-85)** | T-13-21 | 1.60 |
| NOX-43 | | | | **T-13-28a (-100)** | T-13-28a | 21.40 |
| NOX-44 | | | | **T-13-28b (-100)** | T-13-28b | 20.90 |
| NOX-45 | | | | **T-13-30 (-100)** | T-13-30 | 74.40 |
| NOX-46 | | | | **T-13-31a (-90)** | T-13-31a | 9.10 |
| NOX-47 | | | | **T-13-31b (-80)** | T-13-31b | 2.10 |
| NOX-48 | | | | Bed 1 | Bed 1 | 74.80 |
| NOX-49 | | | | Bed 2 | Bed 2 | 1.80 |
| NOX-50 | | | | Bed 3 | Bed 3 | 12.10 |
| NOX-51 | | | | Bed 4 | Bed 4 | 2.00 |
| NOX-52 | | | | Bed 11 | Bed 11 | 0.10 |
| NOX-53 | | | | | **N-4-14 (-50)** | 2.00 |
| NOX-54 | | | | | **N-5-14 (-55)** | 0.16 |
| NOX-55 | | | | | **N-7-14 (-95)** | 1.10 |

**Table 5. P**lot designations and herbicide treatments in Cabinet Gorge Reservoir, MT, 2014. Colors indicate herbicide treatment and rate from Table 2. Numbers in parentheses are percent change in Eurasian watermilfoil (EWM) due to herbicide treatment. A negative symbol (-) indicates a decline in EWM, a positive symbol (+) indicates an increase in EWM. Acreage is reported from time of initial survey or treatment, whichever was later.

| 2015 Name | 2013 Name | 2014 Name | Acreage |
|---|---|---|---|
| CAB-1 | Bed 1 | **C-1-14 (-75)** | 72.57 |
| CAB-2 | Bed 2 | **C-2-14 (-50)** | 60.62 |
| CAB-3 | Bed 3 | **C-3-14 (-70)** | 21.73 |
| CAB-4 | Bed 4 | **C-4-14 (-95)** | 19.47 |
| CAB-5 | Bed 5 | **C-5-14 (-95)** | 8.97 |
| CAB-6 | Bed 6 | Bed 6 | 11.47 |
| CAB-7 | Bed 7 | Bed 7 | 10.70 |

**Table 6.** Eurasian watermilfoil (EWM) injury rankings at six weeks and 12 months after treatment in herbicide-treated plots on Noxon Rapids (Nox) and Cabinet Gorge (Cab) reservoirs, September 10, 2015.

| Plot Number | Plot Size (acres) | Mean Depth (ft) | Herbicide Rate (ppm) | EWM Injury (%) 6 weeks Posttreatment | EWM injury (%) 12 months Posttreatment |
|---|---|---|---|---|---|
| Nox-4 | 28.2 | 7.0 | endothall 2<br>triclopyr 1 | 70 | 73 |
| Nox-5 | 11,8 | 7.0 | endothall 2<br>triclopyr 1 | 90 | 69 |
| Nox-6 | 23.1 | 6.1 | endothall 2<br>triclopyr 1 | 80 | 70 |
| Nox-8 | 0.5 | 7.0 | endothall 2<br>triclopyr 1 | 55 | na |
| Nox-10 | 2.6 | 7.4 | endothall 2<br>triclopyr 1 | 98 | 86 |
| Nox-25 | 13.1 | 7.0 | endothall 3 | 75 | 93 |
| Nox-56 | 2.6 | 4.0 | endothall 2<br>triclopyr 1 | 85 | 68 |
| Nox-57 | 6.6 | 4.0 | endothall 2<br>triclopyr 1 | 98 | 95 |
| Nox-58 | 2.3 | 7.5 | endothall 2<br>triclopyr 1 | 75 | 57 |
| Nox-59 | 58.0 | 7.2 | endothall 2<br>triclopyr 1 | 90 | 89 |
| | 148.8 | | | | |
| | | | | | |
| Cab-2 | 10.0 | 6.0 | diquat 0.37 | 88 | na |
| Cab-3 | 10.0 | 6.0 | diquat 0.37 | 85 | na |
| | 20.0 | | | | |

The 6-week posttreatment data from Clean Lakes Inc. October 2015, In “Cabinet Gorge & Noxon Rapids Reservoirs, Sanders County, Montana, 2015 AIS Aquatic Pesticide Application Report (APAR). 12-month posttreatment data from Hanson (2016); na = data not available, plots were selected and treated before pretreat data could be collected by Hanson.

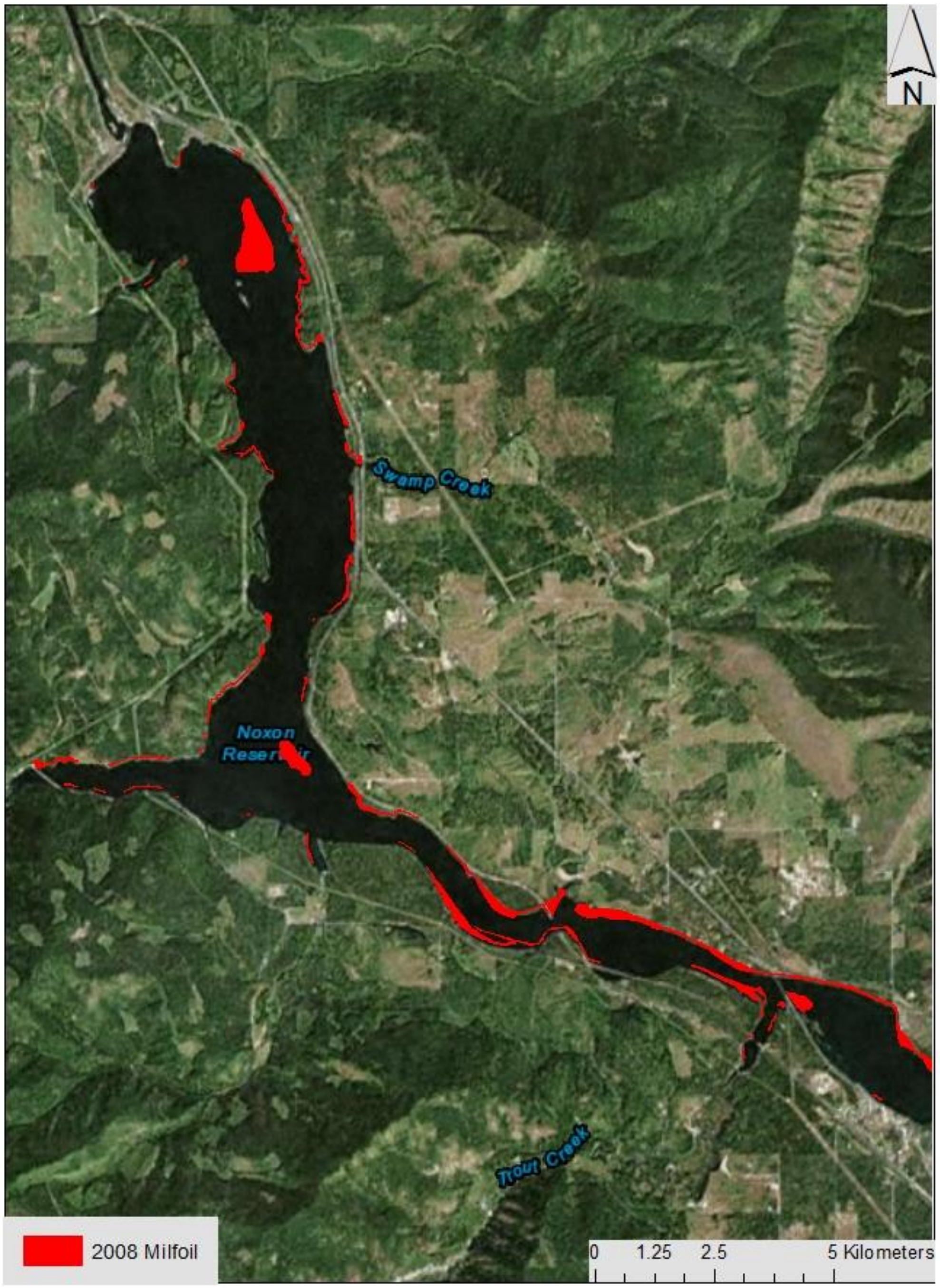


**Figure 1.** Location of Eurasian watermilfoil presence in the lower portion of Noxon Rapids Reservoir in 2008.

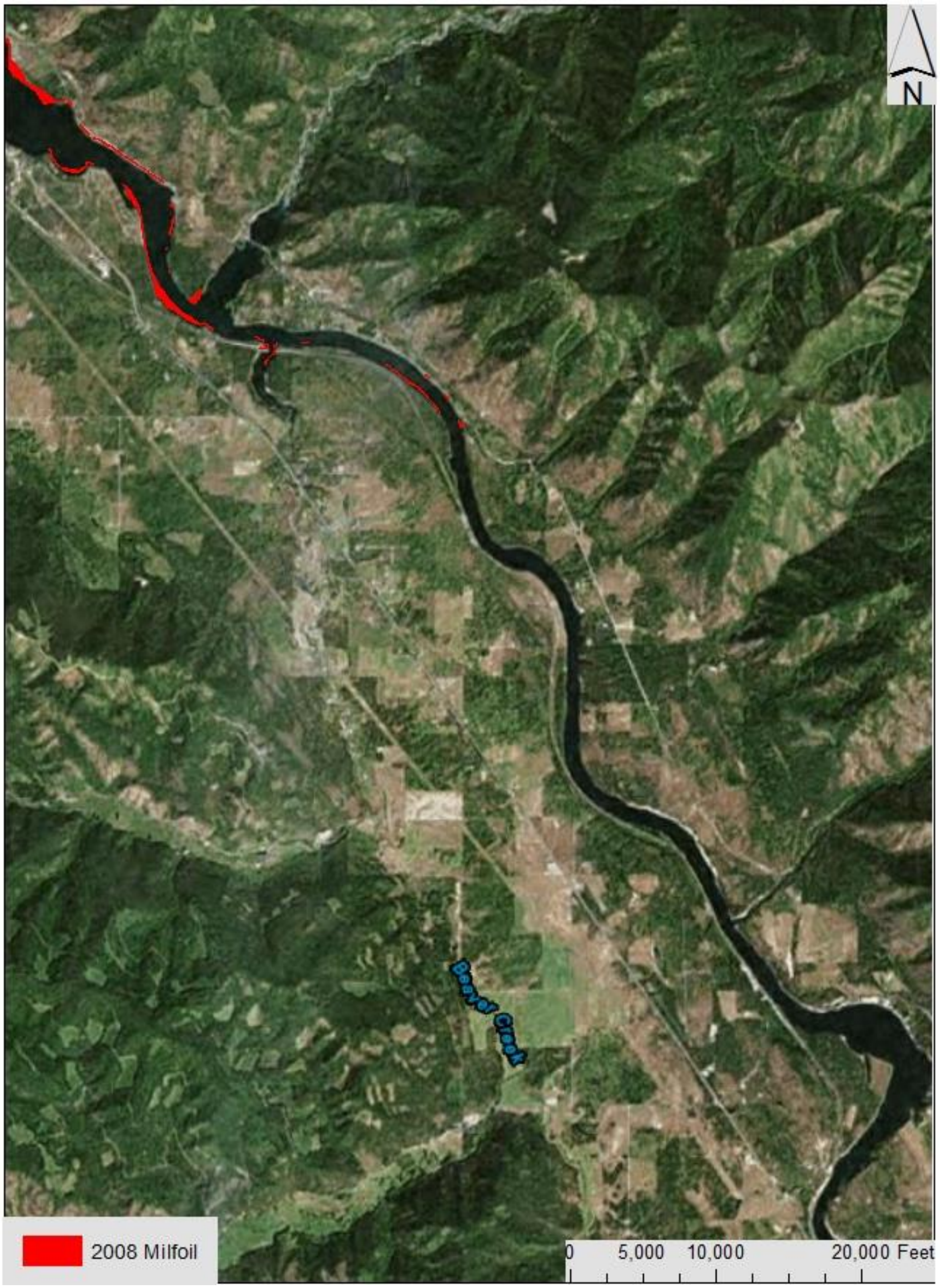


**Figure 2.** Location of Eurasian watermilfoil presence in the upper portion of Noxon Rapids Reservoir in 2008.

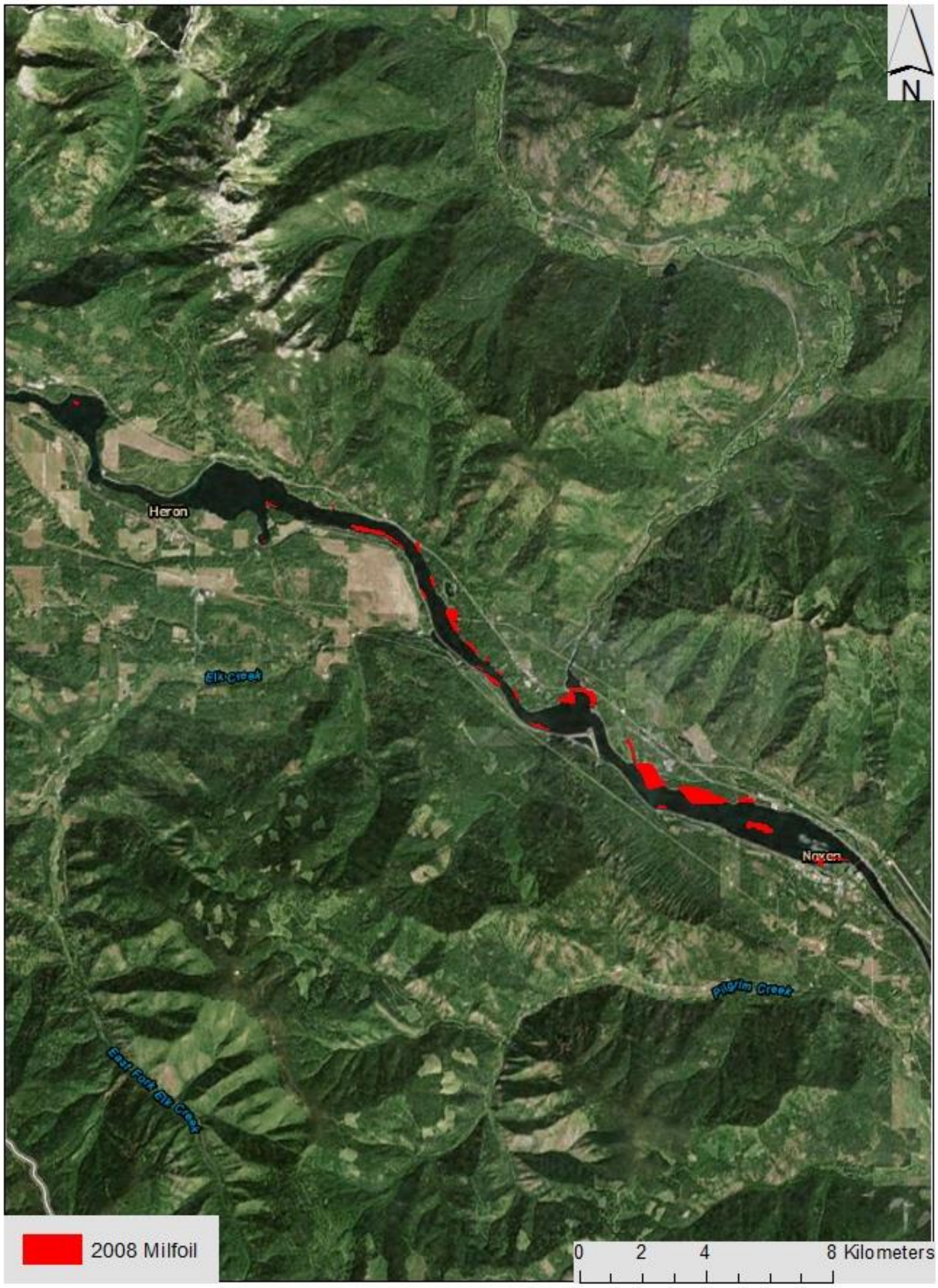


**Figure 3.** Location of Eurasian watermilfoil presence in Cabinet Gorge Reservoir in 2008.

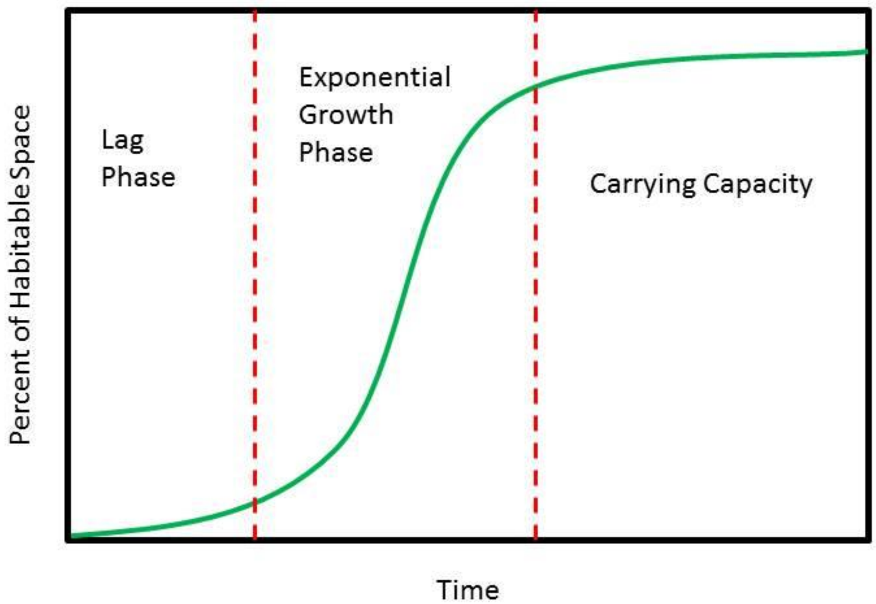


**Figure 4.** Typical exponential growth pattern of an aggressive invasive plant species, such as Eurasian watermilfoil.

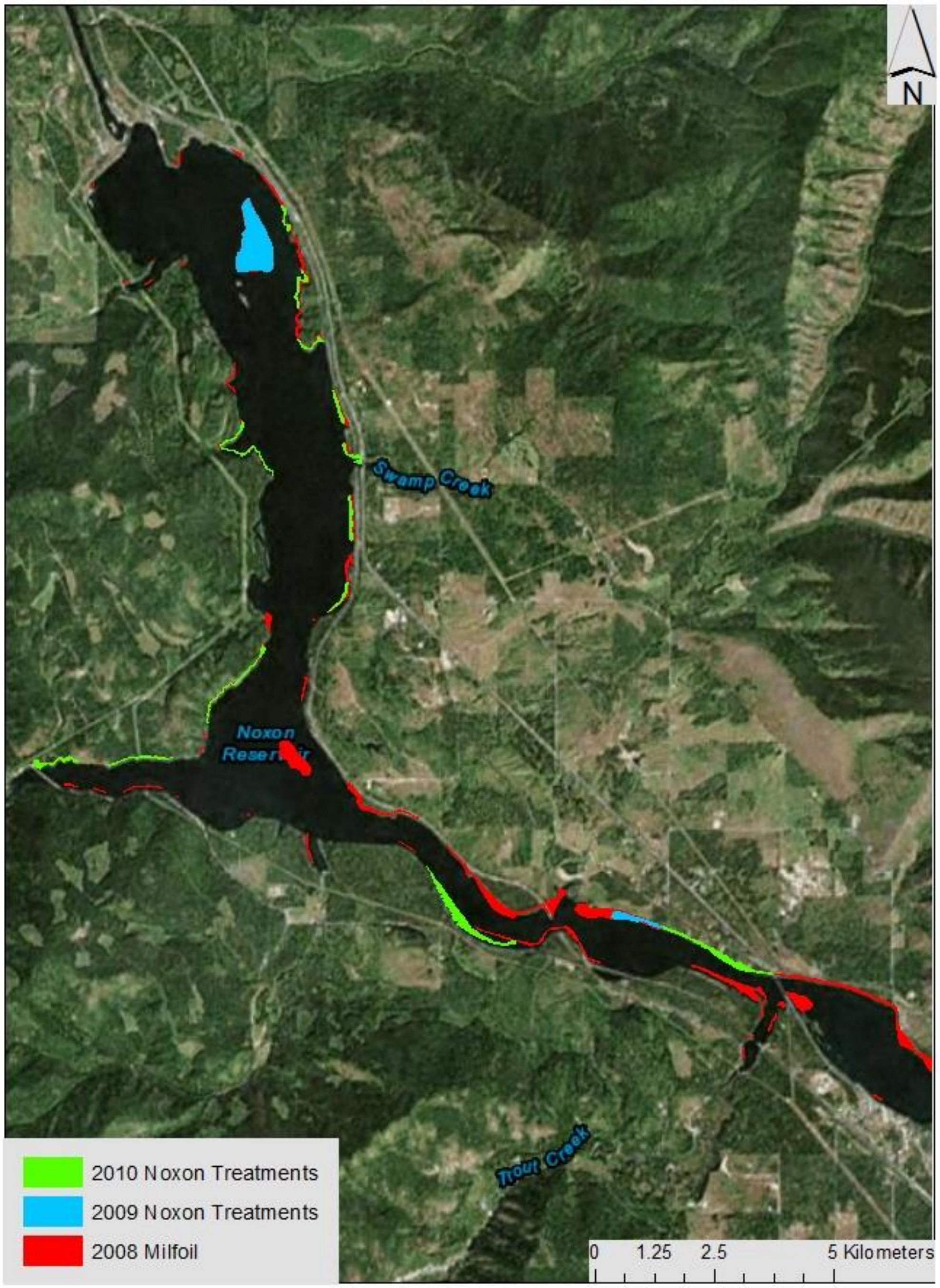


**Figure 5.** Eurasian watermilfoil herbicide demonstration treatments in the lower portion of Noxon Rapids Reservoir in 2009 and 2010.

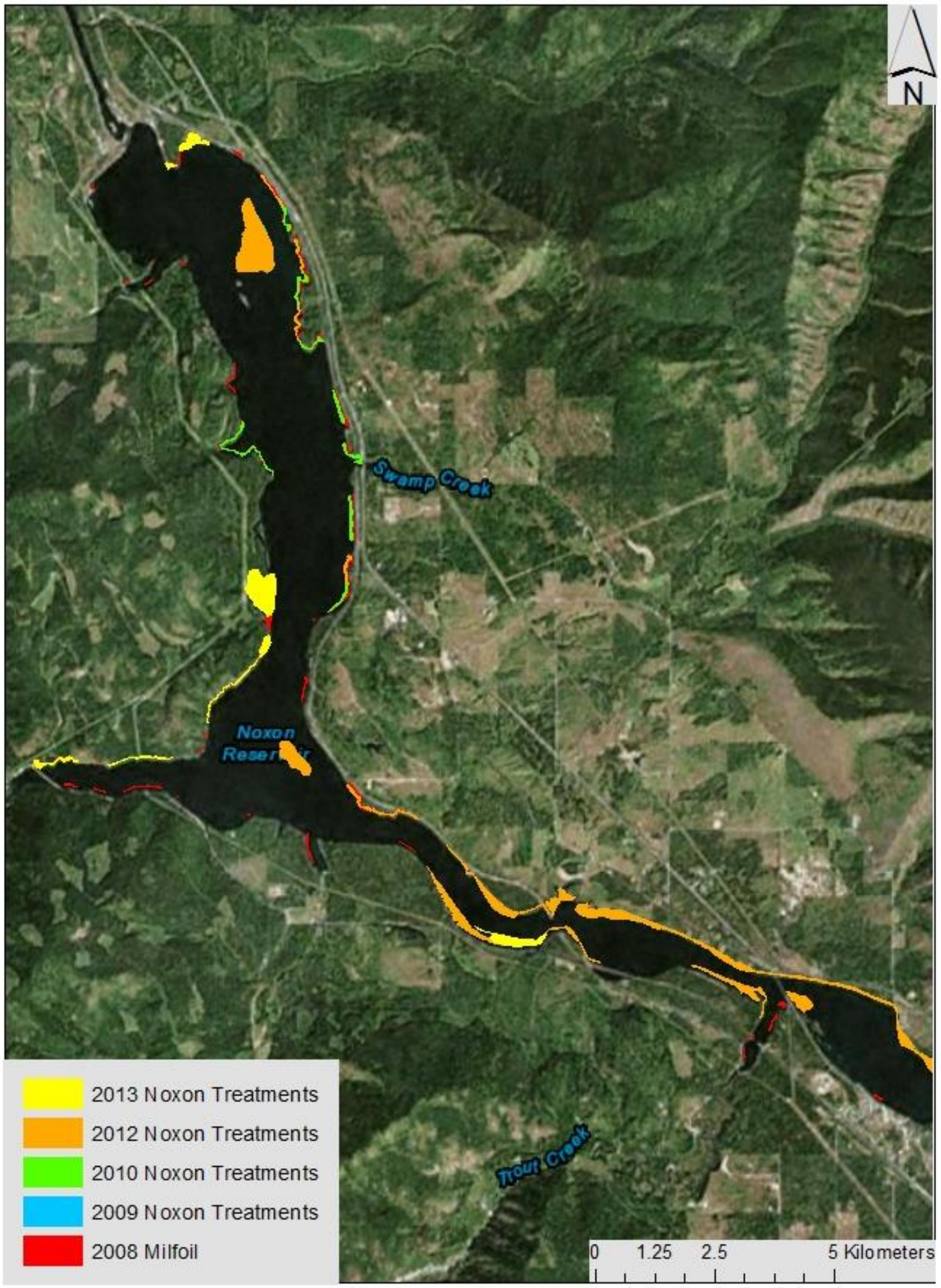


**Figure 6.** Eurasian watermilfoil herbicide treatments in the lower portion of Noxon Rapids Reservoir in 2009, 2010, 2012, and 2013. There were no herbicide treatments in Noxon Rapids Reservoir in 2011.

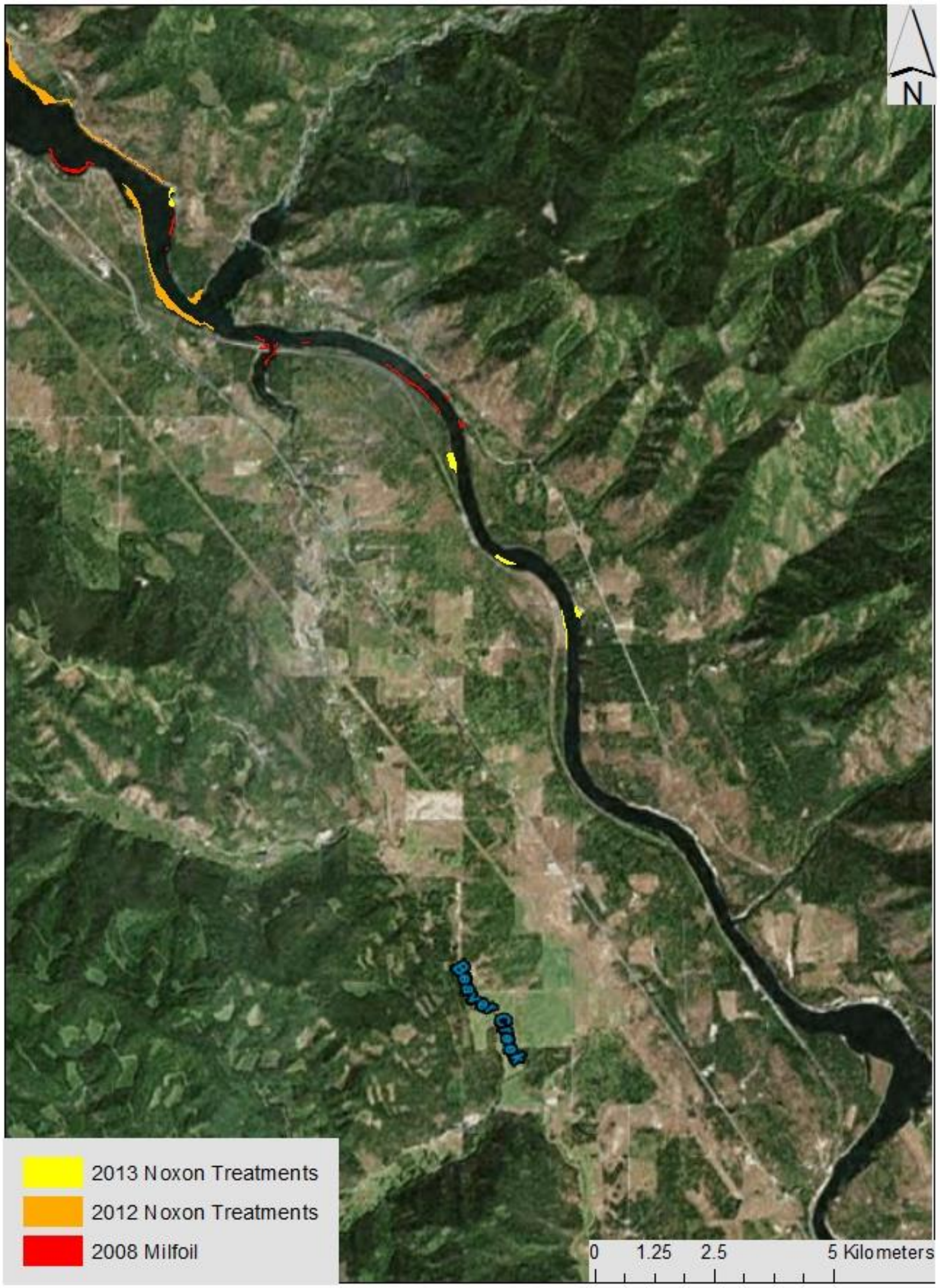


**Figure 7.** Eurasian watermilfoil herbicide treatments in the upper portion of Noxon Rapids Reservoir in 2012, and 2013. There were no herbicide treatments in this area in 2009 or 2010. There were no herbicide treatments in Noxon Rapids Reservoir in 2011.

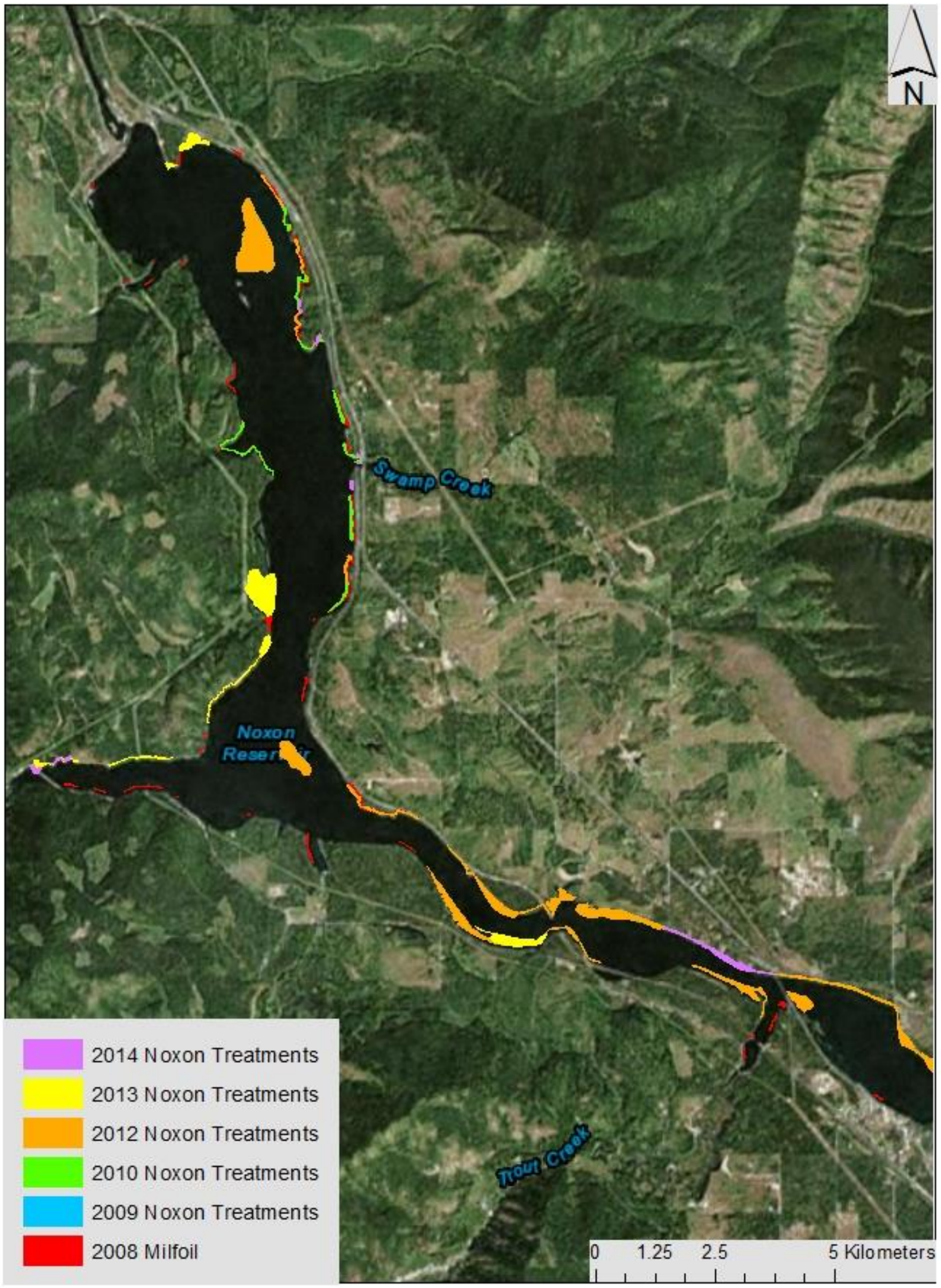


**Figure 8.** Eurasian watermilfoil herbicide treatments in the lower portion of Noxon Rapids Reservoir in 2009, 2010, 2012, 2013, and 2014. There were no herbicide treatments in Noxon Rapids Reservoir 2011.


**Figure 9.** Location of Eurasian watermilfoil presence in the lower portion of Noxon Rapids Reservoir found in 2008 that remain untreated.

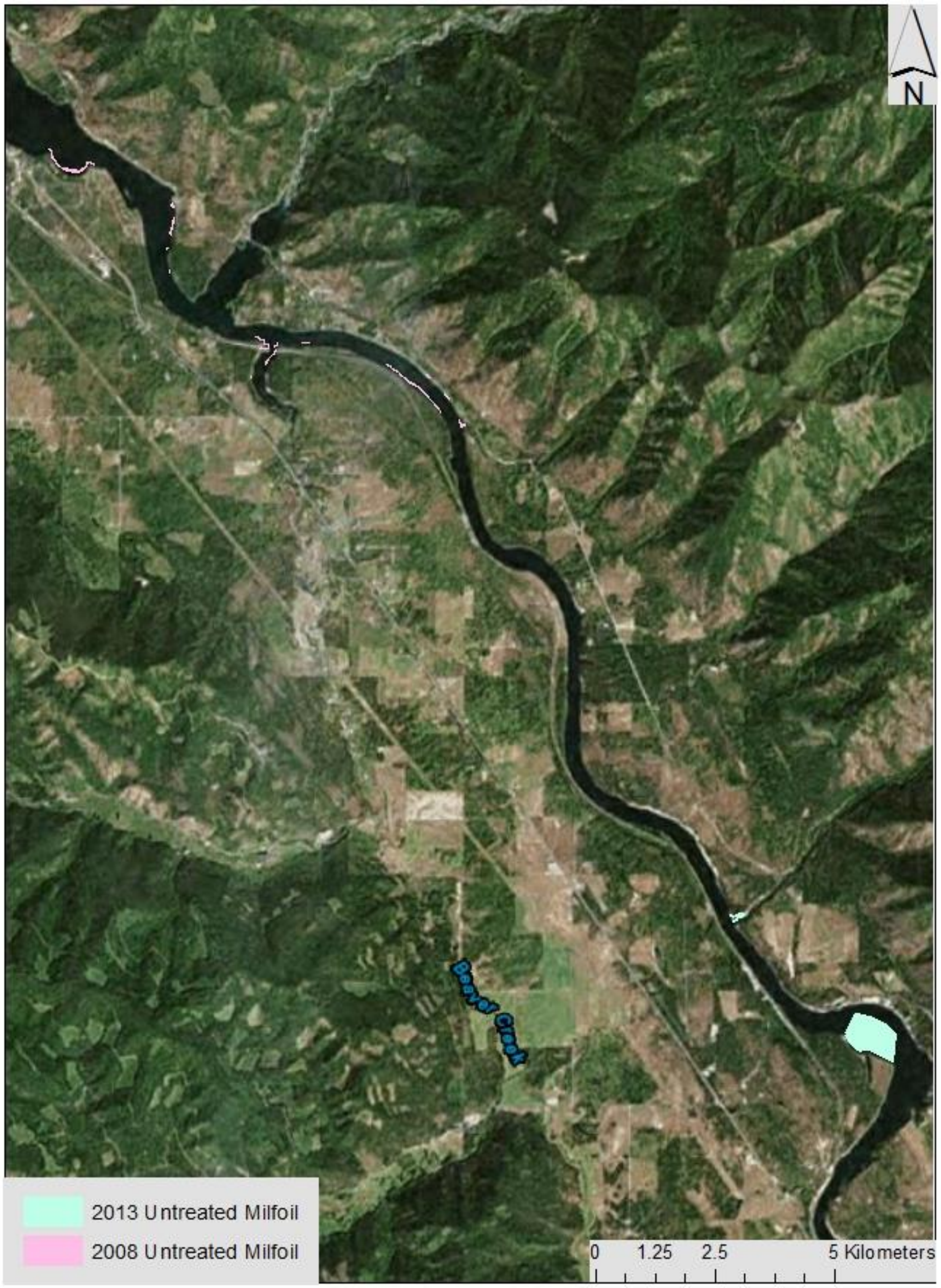


**Figure 10.** Location of Eurasian watermilfoil presence in the upper portion of Noxon Rapids Reservoir found in 2008 and 2013 that remain untreated.

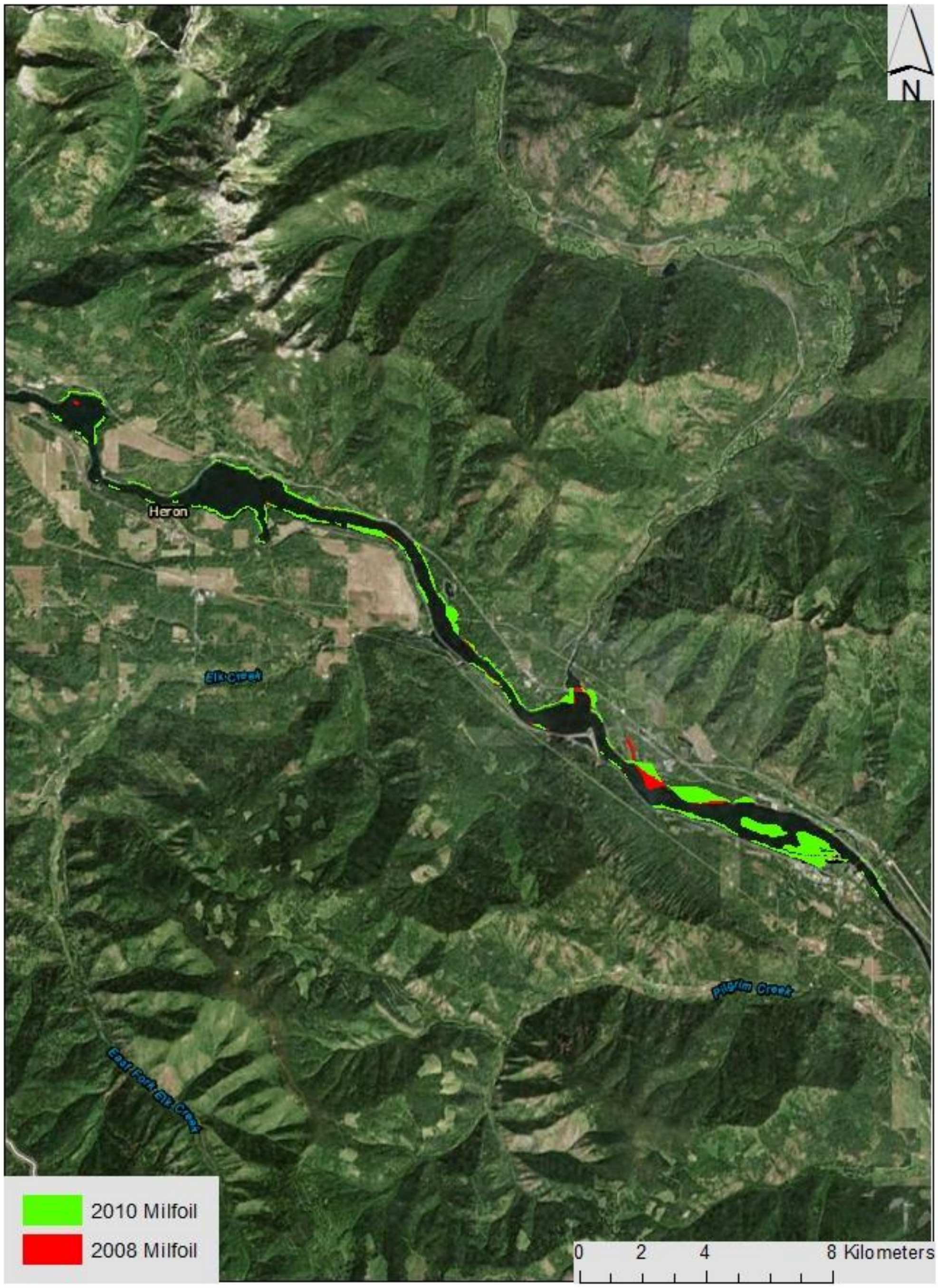


**Figure 11.** Location of Eurasian watermilfoil presence in Cabinet Gorge Reservoir in 2008 and 2010.

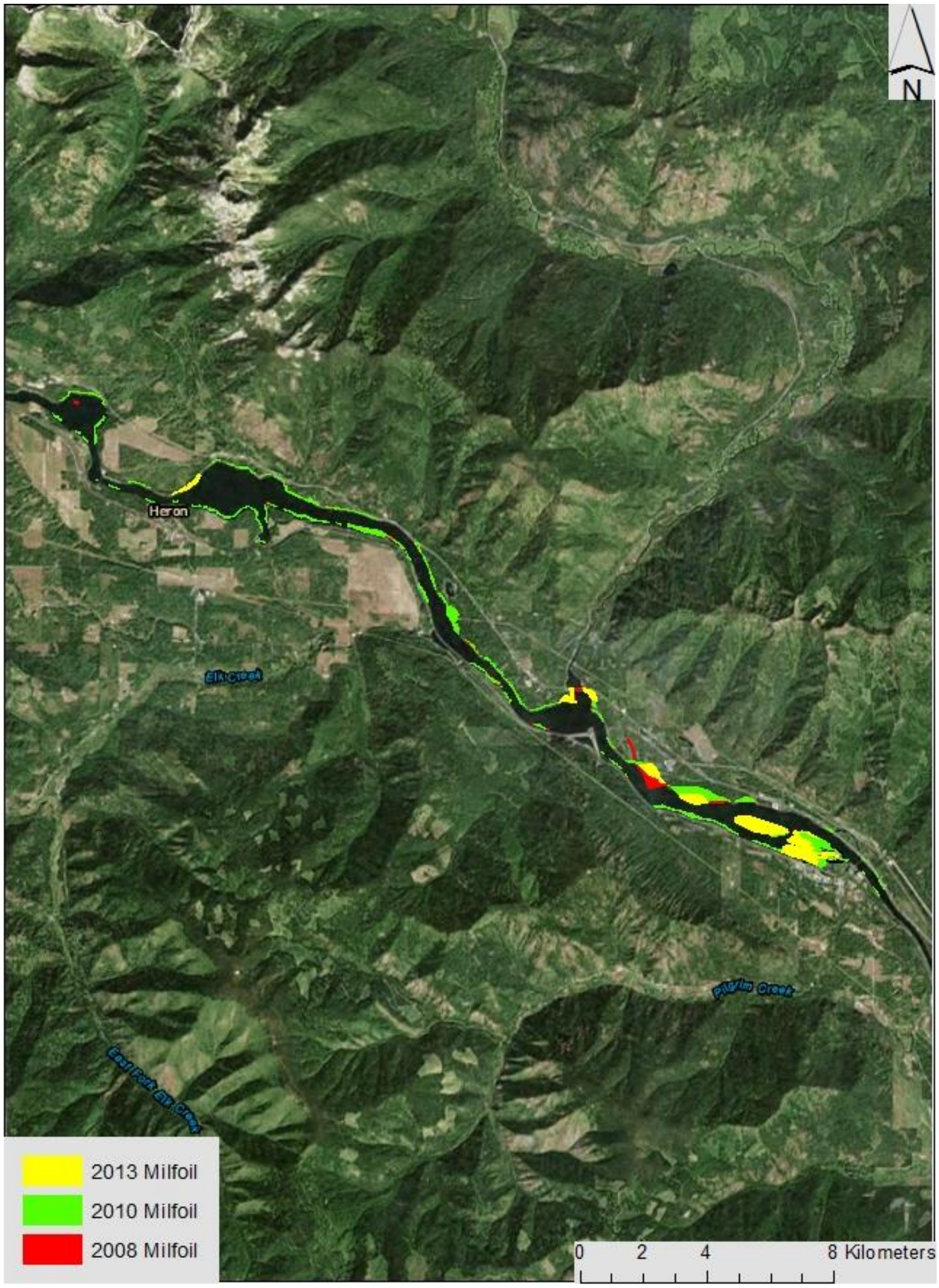


**Figure 12.** Location of Eurasian watermilfoil presence in Cabinet Gorge Reservoir in 2008, 2010, and 2013.

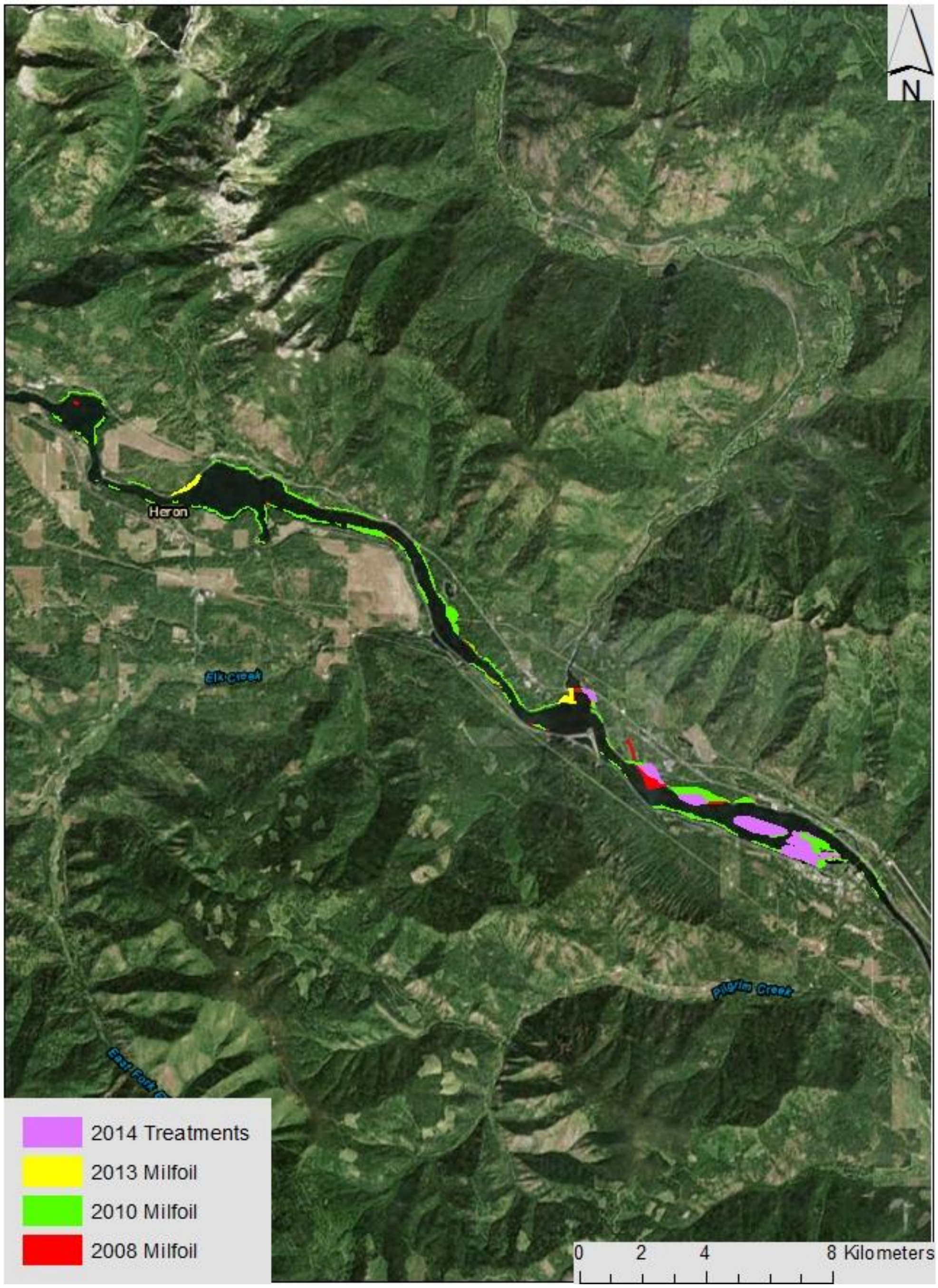


**Figure 13.** Location of Eurasian watermilfoil presence in Cabinet Gorge Reservoir in 2008, 2010, and 2013 and herbicide treatments in 2014.


**Figure 14.** Eurasian watermilfoil herbicide treatment sites in Noxon Rapids Reservoir in 2015.


**Figure 15.** Eurasian watermilfoil herbicide treatment sites in Cabinet Gorge Reservoir in 2015.